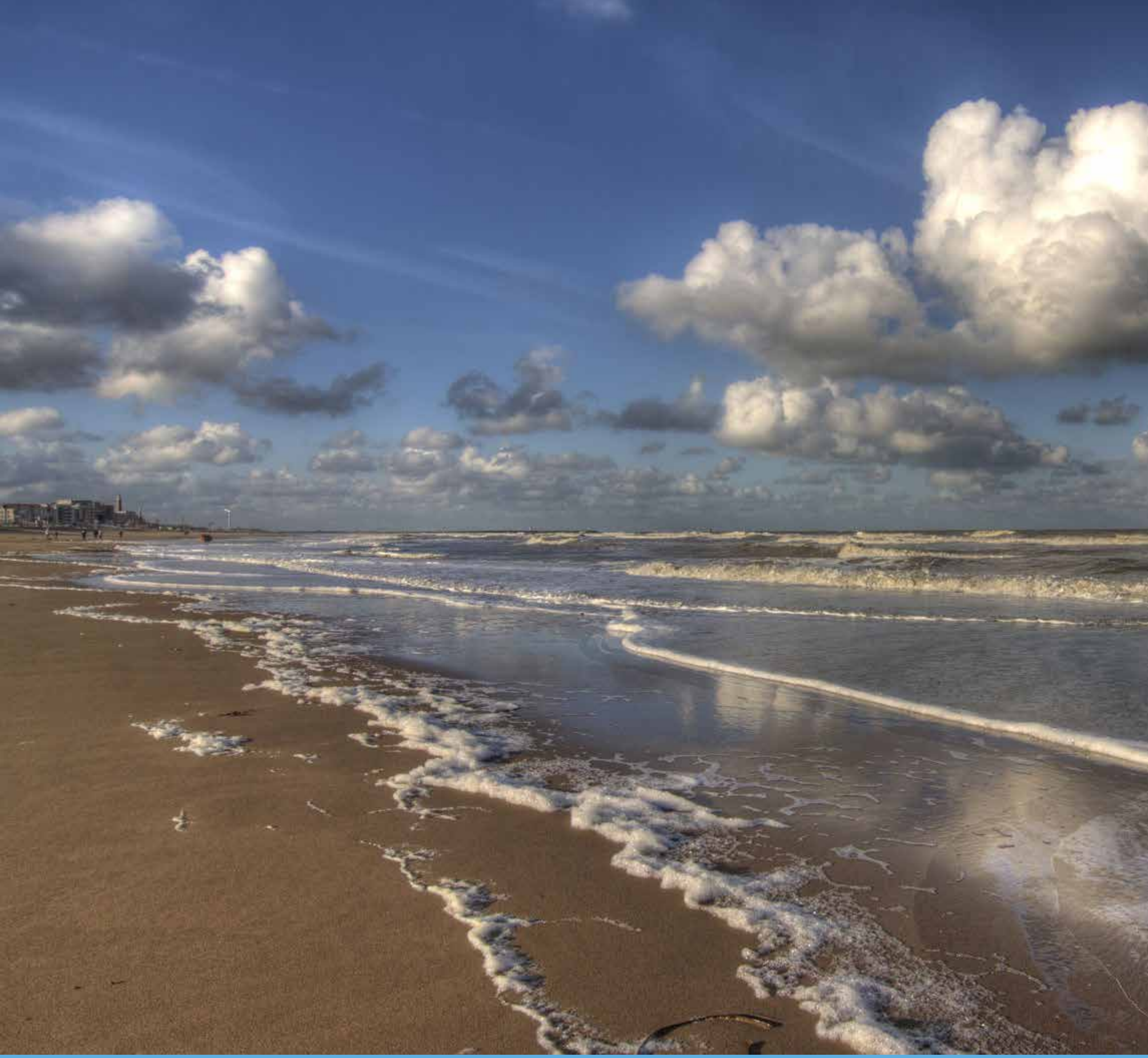

Effects of seabed protection on the Frisian Front and Central Oyster Grounds

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LEI
WAGENINGEN UR

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Hans van Oostenbrugge[1], Diana Slijkerman[2], Katell Hamon[1], Oscar Bos[2], Marcel Machiels[2], Olga van de Valk[1], Niels Hintzen[2], Ernst Bos[1], Jan Tjalling van der Wal[2] and Joop Coolen[2]

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This report provides an overview of the important benefits and costs for six variant closures for the protection of the benthic ecosystem on the Frisian Front and the Central Oyster Grounds. The proposed closures lead to a range of ecological benefits and economic costs. The current study facilitates an informed discussion about an optimal allocation of the closures.

Dit rapport geeft een overzicht van de belangrijke kosten en baten voor zes varianten voor gebiedssluitingen voor de bescherming van het benthische ecosysteem op het Friese Front en de Centrale Oestergronden. De voorgestelde afsluitingen leiden tot een reeks ecologische baten en economische kosten. De huidige studie faciliteert daarmee een geïnformeerde discussie over een optimale allocatie van deze afsluitingen.

Key words: Cost Benefit Analysis, Fisheries

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Contents

Preface

This report gives an overview of the potential benefits and costs of six variants for fishery closures on the Frisian Front and the Central Oyster Grounds within the framework of a Cost Benefit Analysis. The effects of fisheries closures on both the ecology and the fishing sector have been widely discussed but a lot remains unknown, especially when comparing specific closures as is done here. The authors have been working on the cutting edge of science, combining scientific knowledge with new analyses and assumptions made on expert knowledge and stakeholder information. The results do not provide a clear choice for policy makers, but facilitate the discussion on preferences and possible compromises between stakeholders and managers. In this discussion the present study shows the most recent knowhow on the costs and benefits of the different variants. The methods and outcomes have been intensely discussed during the process and many persons and institutions have given valuable contributions. Most importantly the authors want to thank the representatives of the Dutch fisheries and the NGOs for their comments, discussions and time spent during the various stakeholder events. Moreover we want to thank the NVWA and the Ministry of I&M for their information on control and monitoring costs. The colleagues from sister fisheries institutes in Denmark (DTU-aqua), Germany (Von Thünen), Belgium (ILVO) and the UK (CEFAS) are thanked for their contribution on the effort estimates for the foreign fleets.

Prof.dr.ir. Jack G.A.J. van der Vorst
General Director Social Sciences Group - Wageningen UR

Summary

S.1 Key findings

The various proposed closures for protection of the benthic communities of the Frisian Front and the Central Oyster grounds (Figure S.1) lead to a range of ecological benefits and economic costs (Table S.1). The current study provides an overview of benefits and costs and therewith facilitates an informed discussion about an optimal allocation of the closures.

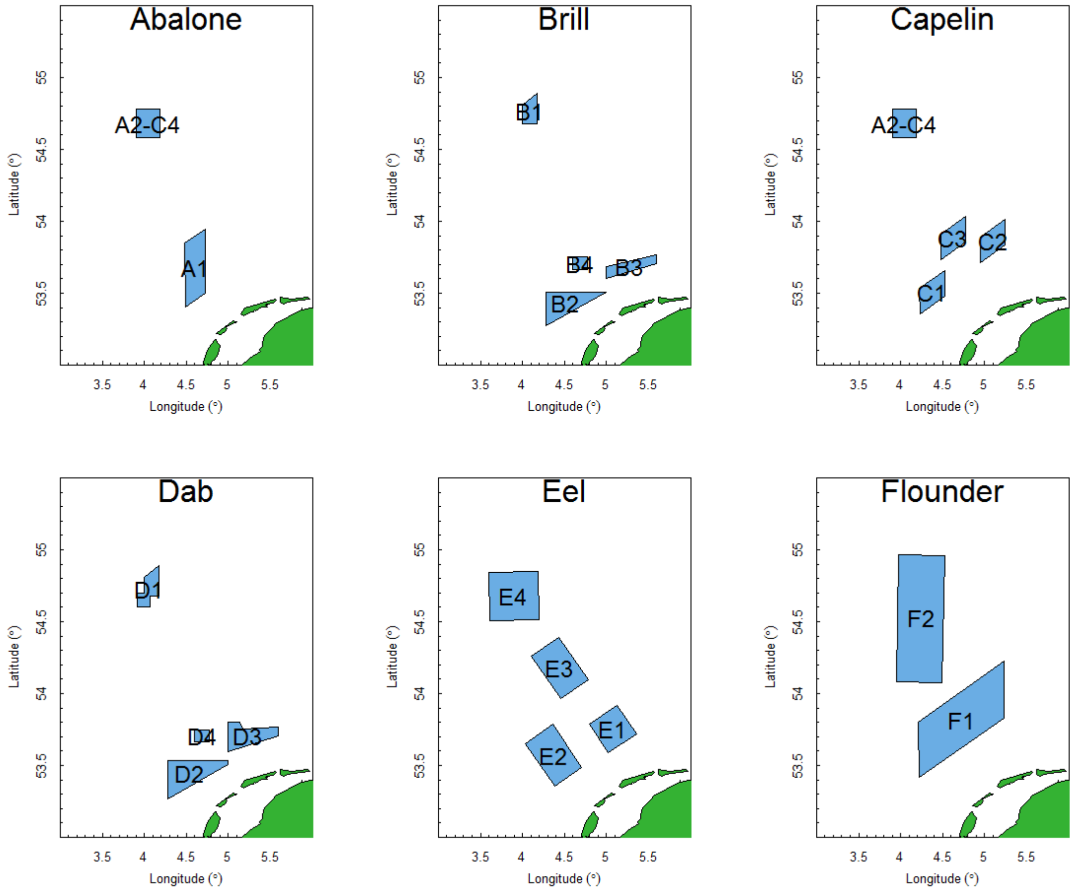

Figure S.1 *Maps of different variants taken into consideration*
Source: Ministry of I&M, processed by LEI.

Table S.1

Overview of costs and benefits of variant closures. NPV, Net Present Value (future discounted costs over 30 years period); GVA, Gross Value Added

Type of costs/benefits	Unit	Abalone			Brill			Capelin			Dab			Eel			Flounder		
	Displacement scenario	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ecologic benefits	Quality		4.87			3.74			4.96			3.92			4.64			5.08	
	Weight factors		0.2-1			0.05-1			0.12-1			0.06-1			0.31-1			0.28-1	
	Ecopoints/km2		0.97-4.87			0.19-3.74			0.62-4.69			0.24-3.92			1.45-4.64			1.44-5.08	
	Ecopoints total		12-59			2-47			10-79			4-66			61-195			91-322	
Costs (m euro)																			
Dutch fisheries (NPV, m euro)	PEI-Scenario 0	1.4	3.4	0.0	0.8	1.4	0.0	1.8	4.3	0.0	1.1	2.2	0.0	3.7	10.0	0.0	10.9	33.4	0.0
	PEI-Scenario 1	1.6	4.6	0.0	0.9	1.9	0.0	2.2	6.1	0.0	1.3	2.9	0.0	4.6	14.7	0.0	14.4	49.6	0.0
	PEI-Scenario 2	1.4	3.0	0.0	0.8	1.3	0.0	1.8	3.9	0.0	1.1	1.9	0.0	3.6	9.0	0.0	10.3	30.1	0.0
	PEI-Scenario 3	1.6	4.1	0.0	0.9	1.7	0.0	2.2	5.5	0.0	1.2	2.6	0.0	4.4	13.2	0.0	13.5	44.5	0.0
Monitoring	NPV (m euro)		0.6-0.9			0.7-1.1			0.6-0.8			0.7-1.1			0.6-0.9			0.6-1.1	
Control	NPV (m euro)		1.3			0.9			1.6			1.2			2.7			4.2	
Total	PEI-Scenario 0	3.3-3.6	5.3-5.6	1.9-2.2	2.4-2.8	3-3.4	1.6-2	4-4.2	6.5-6.7	2.2-2.4	3-3.4	4.1-4.5	1.9-2.3	7-7.3	13.3-13.6	3.3-3.6	15.7-16.2	38.2-38.7	4.8-5.3
	PEI-Scenario 1	3.5-3.8	6.5-6.8	1.9-2.2	2.5-2.9	3.5-3.9	1.6-2	4.4-4.6	8.3-8.5	2.2-2.4	3.2-3.6	4.8-5.2	1.9-2.3	7.9-8.2	18-18.3	3.3-3.6	19.2-19.7	54.4-54.9	4.8-5.3
	PEI-Scenario 2	3.3-3.6	4.9-5.2	1.9-2.2	2.4-2.8	2.9-3.3	1.6-2	4-4.2	6.1-6.3	2.2-2.4	3-3.4	3.8-4.2	1.9-2.3	6.9-7.2	12.3-12.6	3.3-3.6	15.1-15.6	34.9-35.4	4.8-5.3
	PEI-Scenario 3	3.5-3.8	6-6.3	1.9-2.2	2.5-2.9	3.3-3.7	1.6-2	4.4-4.6	7.7-7.9	2.2-2.4	3.1-3.5	4.5-4.9	1.9-2.3	7.7-8	16.5-16.8	3.3-3.6	18.3-18.8	49.3-49.8	4.8-5.3
Fishing activities in the area																			
Dutch fleet	Annual GVA (m euro)		0.4			0.2			0.5			0.3			0.9			1.6	
Foreign fleets total	Annual GVA (m euro)		0.4			0.3			0.5			0.5			1.5			3.3	
Belgian and German flag vessels	Annual GVA (k euro)		45			19			62			29			143			429	

From the compiled overview of costs and benefits (Table S.1) the variants (named after fish) can be characterised as follows:

Abalone
The total area is 1,204 km^2 and comprises two subareas. Together with Brill this is the smallest variant, and represents the lower boundary of the government objective for the closing of areas for seabed protection. The costs for the Dutch fishery related to this variant are low to intermediate and the costs for control are relatively low. The ecologic benefits depend on the expression of ecopoints and the weighting factors applied. Abalone results in the upper range when ecopoints are expressed per km^2, which depends on the weighting factor applied. Using the weighting factor 'hard substrate' results in a lowest score among all variants; applying weighting factors related to front and gradient results in relatively high scores. Ecopoints expressed at the total area fit in the upper range of the four smaller variants compared to Eel and Flounder. The impact of the weighting factors are the same as in the results of ecopoints/km^2.

Brill
The total area is 1,263 km^2 and comprises four subareas. Together with Abalone this is the smallest variant. The two larger subareas are located on sandy substrate, below the Frisian Front. The two smaller subareas are located within the Frisian Front and the Central Oyster Grounds. This variant results in relatively low costs for both the Dutch fishing sector and for control. The ecological benefits are in the lower range, compared to the other variants, except when using the weighting factor 'hard substrate' (highest score in ecpopoints/km2, mid range when expressed as total ecopoints).

Capelin
The total area is 1,597 km^2 and comprises four subareas. The four subareas are of similar size: three are located in the Frisian Front and one at the Central Oyster Grounds. The gradients in the Frisian Front are covered over the three subareas, but not as a continuous area. The Central Oyster Grounds area is approximately of comparable size, location and quality value to the variants Abalone, Brill and Dab, scoring high for long-living species and species richness. This variant results in intermediate costs for both the Dutch fisheries and for control. The number of ecopoints per km^2 is in the mid-range, for most of the weighting factors applied. Ecopoints expressed at the total area fit in the upper range of the four smaller variants. Weighting factors vary for this variant and they have similar impacts on the results of ecopoints/km^2 and total ecopoints.

Dab
The total area is 1,683 km^2 and comprises four subareas. This variant is an extended version of Brill and consists of two large subareas that are partly situated in the sandy sediment, below the Frisian Front, and two smaller subareas within the Frisian Front and the Central Oyster Grounds. This variant results in low to intermediate costs for the Dutch fisheries and intermediate control costs. The ecologic benefits are in a mid to lower range when ecopoints are expressed per km^2, depending on the weighting factor applied. However, using the weighting factor 'hard substrate' results in highest scores when expressed in ecopoints/km2. Also 'number of habitats' results in relatively higher scores. Depending on the weighting factors it is in the mid to low range but higher than Brill. The impact of the weighting factors is the same as in the results of ecopoints/km^2.

Eel
The total area is 4,206 km^2 and comprises four subareas. The four large subareas vary in size from 700 to 1,400 km2, and are distributed throughout the search area, from the sandy substrate to the Central Oyster Grounds. In this way, a suite of habitat types is protected, while allowing for fishing in between the areas. The size of the Central Oyster Grounds subarea is considerably larger than that within the variants Abalone to Dab. This variant results in intermediate to high costs for both the Dutch fisheries and for control, and it scores in an overall higher range in terms of both ecopoints/km^2 and total ecopoints. The actual value depends on the weighting factor applied. Using the weighting factor 'hard substrate', and % in the parallolgram results in lower ecopoints/km^2, applying weighting factors related to gradient, results in relatively mid-range to high scores for both ecopoints/km^2 and total ecopoints.

Flounder

The total area is 6,339 km_2 and comprises of two subareas. This is the largest variant. The two subareas, cover fully the Frisian Front and Central Oyster Grounds. Therefore it fully protects all (a)biotic gradients on the Frisian Front and scores highest for species richness. This variant results in both highest costs for both the Dutch fisheries and for control, and highest scores for ecopoints/km_2, except when hard substrates are taken into account (in terms of ecopoints/km2). When ecopoints are expressed on the total area, Flounder has the overall highest scores.
In case no long-term costs of fisheries displacement are assumed to be 0 (displacement scenario C) the relative ranking of the various variants remains similar with low costs for Brill and Dab, intermediate costs for Abalone and Capelin and high costs for Eel and Flounder. The reason for this is the assumption that control costs are related to the amount of fishing activities in the areas.

This study does not provide a clear answer to the question on the optimal management choice. Having said that, the outcomes have a value as a characterisation of the aspects of the areas under study that will be affected by a closure. As such, the present study can provide useful information in a discussion on preferences and possible compromises between stakeholders and mangers. In these discussions, the present study shows the most recent knowhow on the different variants and distinguishes between facts and fiction for the topics under study.

S.2 Complementary results

The ecopoint method has been applied to assess the ecological benefits of the closures. The ecopoints are based on the current status of the benthic ecosystem. The weighting factors applied resemble various management priorities that are taken from the current management. The choice of used weighting factors is of prime importance for the results, together with the size of the closed area. See Chapter 4.

The economic effects of closures on the Dutch fishing sector using four Policy, Economy and Innovation scenarios (PEI scenarios) and three displacement scenarios. The PEI scenarios include effects of external developments such as fish prices, stock developments and other area closures. The displacement scenarios are based on scientific insights into displacement effects (A), the fishing sectors' point of view (B), and the assumption that because of alternative fishing opportunities the long-term costs of displacement will be negligible (C). The scenarios result in a wide range of costs with substantial overlap between the various variants. The displacement scenario based on the fishing sectors view results in significantly higher costs than the two other scenarios. See Chapter 6.

The total importance of the areas for foreign fleets is in four variants comparable and in two variants larger than for the Dutch fleet. Landings value and GVA are similar in case of variants Abalone, Brill, Capelin and Dab and in case of Eel and Flounder foreign values are higher. Because part of the foreign vessels is owned by Dutch enterprises the effects on foreign fleets will also affect the Dutch economy but is not taken into account in the costs in this study. See Chapter 5.

The closures will have an effect on social aspects in fisheries and their communities. Most of these aspects cannot be attributed to one of the variants but have been described. See Chapter 7.
Costs for monitoring and control are non-distinctive for most of the variants as the uncertainty in the costs is high. See Chapter 8.

Although the current study provides an overview of the benefits and costs of protecting the seabed in the different variants, many of the costs and benefits are not comparable and the outcomes are quite uncertain See Chapter 9.

The main reason for this is:
- Uncertainty in the data and assumptions underlying the scenarios
- The scope of the study that result in the fact that e.g. the effects on flag vessels have not been fully assessed.

- The absence of clear and measurable management objectives to which the costs and benefits can be compared with
- The inability to assess potential future changes in the importance of these areas for ecology and the economy.

S.3 Method

The Frisian Front and Central Oyster Grounds have been selected for area protection measures under the Marine Strategy Framework Directive (MSFD, EU, 2008) because of their high benthic biodiversity scores (Bos *et al.*, 2011) relative to the rest of the Dutch North Sea. The aim of the Dutch government for the Dutch part of the North Sea is to protect 10-15% of the Dutch Continental Shelf against appreciably disrupting by human activities, with a minimum impact for the fishermen (Ministry of I&M, Ministry of EZ, 2012). The fishery measures in Natura 2000 areas (North Sea Coastal Zone, Vlakte van de Raan, Voordelta, Dogger Bank and Cleaver Bank) contribute to this aim partly. The closures on the Frisian Front and Central Oyster Grounds should help to reach the 10-15% and contribute to the targets as defined in the Dutch Marine Strategy Part 1 (Table 1.1, Ministry of I&M, Ministry of EZ, 2012). During a stakeholder process 6 possible variants for closed areas have been developed (Figure S1.1). The question of the ministry is what the costs and benefits are for each of these six variants. See Chapter 1.

An MKBA provides a thorough method to compare costs and benefits of interventions. As such this method has been used to compare the costs and benefits of the closures. See Chapter 2.

For all direct consequences of the closures on the ecosystem, fisheries and monitoring and control the consequences for all variants were assessed using a range of methods. The ecologic benefits were assessed using the ecopoint method, focusing on the current status of the benthic ecosystem and possible focus areas in the management. The effects of closures on the fisheries were assessed by an analysis of the historic fishing activities in the areas combined with scenario analysis. Social effects have been assessed through interviews with fishermen and the costs for monitoring and control have been estimated. See Chapter 4-8.

Samenvatting

S.1 Belangrijkste uitkomsten

De diverse voorgestelde afsluitingen voor bescherming van de benthische gemeenschappen van het Friese Front en de Centrale Oestergronden (figuur S.1) leiden tot een reeks ecologische baten en economische kosten (tabel S.1). De huidige studie geeft een overzicht van de baten en kosten en faciliteert daarmee een geïnformeerde discussie over een optimale allocatie van deze afsluitingen.

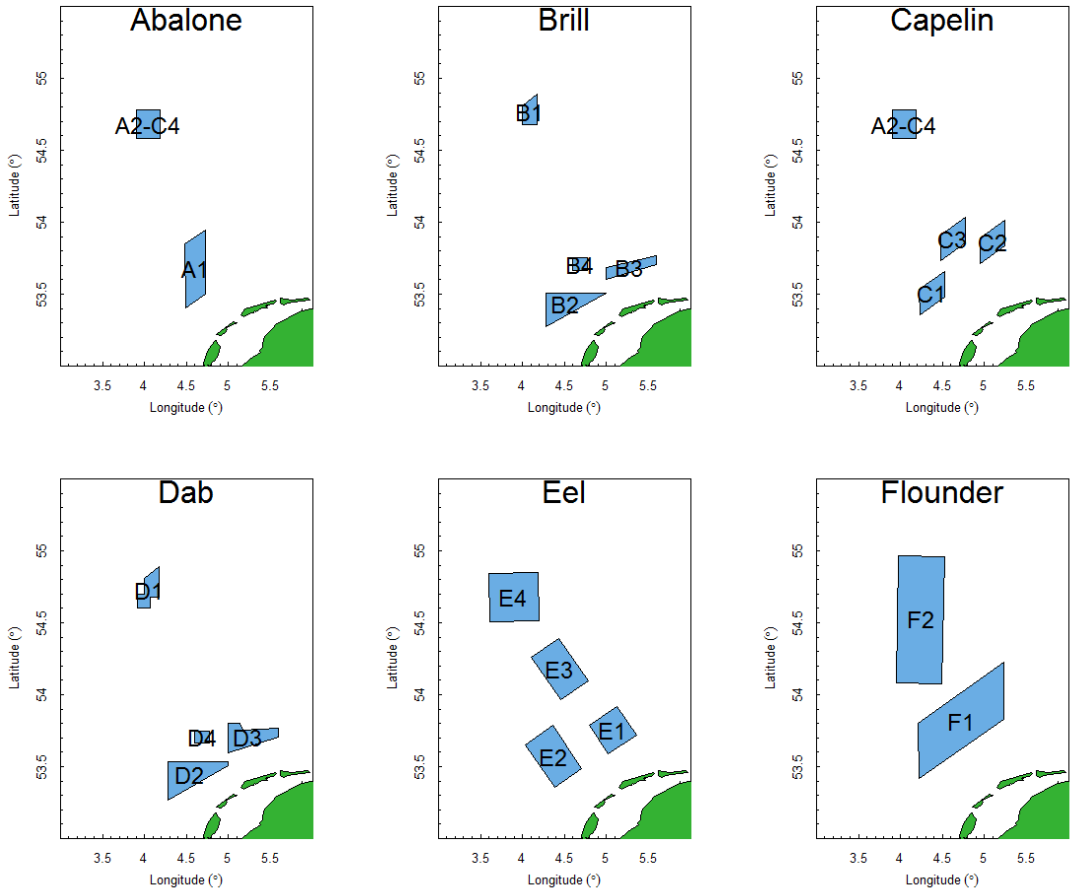

Figure S.1 *Kaarten van de verschillende overwogen varianten*
Bron: Ministerie van Infrastructuur en Milieu, bewerkt door het LEI.

Tabel S.1

Overzicht van de baten en kosten van afsluitingsvarianten. NPV, Netto Contante Waarde (toekomstige contant gemaakte kosten over een periode van 30 jaar); BTW, Bruto Toegevoegde Waarde

Type kosten/baten	Eenheid	Abalone			Brill			Capelin			Dab			Eel			Flounder		
	Verplaatsingscenario	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ecologische baten	Kwaliteit		4.87			3.74			4.96			3.92			4.64			5.08	
	Weeg factoren		0.2-1			0.05-1			0.12-1			0.06-1			0.31-1			0.28-1	
	Ecopunten/km2		0.97-4.87			0.19-3.74			0.62-4.69			0.24-3.92			1.45-4.64			1.44-5.08	
	Ecopunten totaal		12-59			2-47			10-79			4-66			61-195			91-322	
Kosten (m euro)																			
Nederlandse visserij (NPV BTW*, m euro)	PEI-Scenario 0	1.4	3.4	0.0	0.8	1.4	0.0	1.8	4.3	0.0	1.1	2.2	0.0	3.7	10.0	0.0	10.9	33.4	0.0
	PEI-Scenario 1	1.6	4.6	0.0	0.9	1.9	0.0	2.2	6.1	0.0	1.3	2.9	0.0	4.6	14.7	0.0	14.4	49.6	0.0
	PEI-Scenario 2	1.4	3.0	0.0	0.8	1.3	0.0	1.8	3.9	0.0	1.1	1.9	0.0	3.6	9.0	0.0	10.3	30.1	0.0
	PEI-Scenario 3	1.6	4.1	0.0	0.9	1.7	0.0	2.2	5.5	0.0	1.2	2.6	0.0	4.4	13.2	0.0	13.5	44.5	0.0
Monitoring	NPV (m euro)		0.6-0.9			0.7-1.1			0.6-0.8			0.7-1.1			0.6-0.9			0.6-1.1	
Controle	NPV (m euro)		1.3			0.9			1.6			1.2			2.7			4.2	
Totaal	PEI-Scenario 0	3.3-3.6	5.3-5.6	1.9-2.2	2.4-2.8	3-3.4	1.6-2	4-4.2	6.5-6.7	2.2-2.4	3-3.4	4.1-4.5	1.9-2.3	7-7.3	13.3-13.6	3.3-3.6	15.7-16.2	38.2-38.7	4.8-5.3
	PEI-Scenario 1	3.5-3.8	6.5-6.8	1.9-2.2	2.5-2.9	3.5-3.9	1.6-2	4.4-4.6	8.3-8.5	2.2-2.4	3.2-3.6	4.8-5.2	1.9-2.3	7.9-8.2	18-18.3	3.3-3.6	19.2-19.7	54.4-54.9	4.8-5.3
	PEI-Scenario 2	3.3-3.6	4.9-5.2	1.9-2.2	2.4-2.8	2.9-3.3	1.6-2	4-4.2	6.1-6.3	2.2-2.4	3-3.4	3.8-4.2	1.9-2.3	6.9-7.2	12.3-12.6	3.3-3.6	15.1-15.6	34.9-35.4	4.8-5.3
	PEI-Scenario 3	3.5-3.8	6-6.3	1.9-2.2	2.5-2.9	3.3-3.7	1.6-2	4.4-4.6	7.7-7.9	2.2-2.4	3.1-3.5	4.5-4.9	1.9-2.3	7.7-8	16.5-16.8	3.3-3.6	18.3-18.8	49.3-49.8	4.8-5.3
Visserij activiteiten in gebied																			
Dutch fleet	BTW* (m euro)		0.4			0.2			0.5			0.3			0.9			1.6	
Nederlandse vloot	BTW* totaal (m euro)		0.4			0.3			0.5			0.5			1.5			3.3	
Buitenlandse vloot	BTW* BEL en DUI vlagschepen (k euro)		45			19			62			29			143			429	

Op basis van het samengestelde overzicht van kosten en baten (Tabel S.1) zijn de varianten als volgt te karakteriseren:

Abalone
Het totale gebied heeft een oppervlak van 1.204 km^2 en omvat twee subgebieden. Abalone is samen met Bril de kleinste variant en vertegenwoordigt de ondergrens van de overheidsdoelstelling voor het afsluiten van gebieden ter bescherming van de zeebodem. Deze variant leidt tot lage tot gemiddelde kosten voor de Nederlandse visserij en lage kosten voor controle. De ecologische voordelen zijn afhankelijk van de uitdrukking van ecopunten per km^2 of voor het hele gebied en van de toegepaste wegingsfactoren. Abalone scoort bovengemiddeld wanneer ecopunten worden uitgedrukt per km^2, maar dit is afhankelijk van de toegepaste wegingsfactor. Het gebruik van de wegingsfactor 'hard substraat' resulteert in de laagste score van alle varianten, terwijl toepassing van wegingsfactoren met betrekking tot front en gradiënt resulteert in relatief hoge scores. Ecopunten uitgedrukt voor het totale gebied zijn voor Abalone bovengemiddeld ten opzichte van de vier kleinere varianten. De impact van de wegingsfactoren is hetzelfde als bij de resultaten van ecopunten/km^2.

Brill
Het totale gebied heeft een oppervlak van 1.263 km^2 en omvat vier subgebieden. Samen met abalone is dit de kleinste variant. De twee grotere subgebieden bevinden zich op zandsubstraat, ten zuiden van het Friese Front. De twee kleinere subgebieden liggen binnen het Friese Front en de Centrale Oestergronden. Deze variant leidt tot relatief lage kosten voor zowel de visserij als voor controle. Vergeleken met de andere varianten liggen de ecologische voordelen hier in het onderste bereik, behalve wanneer de wegingsfactor 'hard substraat' wordt toegepast (hoogste score voor de ecopunten per km^2, gemiddeld voor het totale aantal ecopunten).

Capelin
Het totale gebied heeft een oppervlak van 1.597 km^2 en omvat vier subgebieden. De vier subgebieden zijn van vergelijkbare omvang: drie ervan bevinden zich in het Friese Front en één in de Centrale Oestergronden. De gradiënten in het Friese Front beslaan de drie subgebieden, echter niet als een aaneengesloten gebied. Het gebied in de Centrale Oestergronden is ongeveer van vergelijkbare omvang, locatie en kwaliteitswaarde als voor de varianten Abalone, Brill en Dab, en scoort hoog voor langlevende soorten en biodiversiteit. Deze variant leidt tot middelhoge kosten voor zowel de Nederlandse visserij als ook voor controle. Het aantal ecopunten per km^2 bevindt zich voor de meeste toegepaste wegingsfactoren in het middenbereik. Ecopunten uitgedrukt voor het totale gebied vallen in het bovenste bereik van de vier kleinere varianten. De wegingsfactoren variëren voor deze variant en hun impact op de resultaten van ecopunten/km^2 en het totale aantal ecopunten is vergelijkbaar.

Dab
Het totale gebied heeft een oppervlak van 1.683 km^2 en omvat vier subgebieden. Deze variant is een uitgebreide versie van Brill (griet) en bestaat uit twee grote subgebieden die zich deels in het zandfundament bevinden, onder het Friese Front, en twee kleinere subgebieden binnen het Friese Front en de Centrale Oestergronden. Deze variant leidt tot lage tot middelhoge kosten voor de Nederlandse visserij en gemiddelde kosten voor controle. De ecologische baten liggen in een gemiddeld tot laag bereik wanneer ecopunten worden uitgedrukt per km^2, afhankelijk van de toegepaste wegingsfactor. Gebruik van de wegingsfactor 'hard substraat' resulteert echter in de hoogste score wanneer ecopunten worden uitgedrukt per km^2. Ook 'aantal habitats' resulteert in relatief hoge scores. Afhankelijk van de wegingsfactoren ligt dit in het middelhoge tot lage bereik, maar hoger dan griet. De impact van de wegingsfactoren is hetzelfde als bij de resultaten van ecopunten/km^2.

Eel
Het totale gebied heeft een oppervlak van 4.206 km^2 en omvat vier subgebieden. De vier grote subgebieden variëren in grootte van 700 tot 1.400 km^2 en liggen verspreid over het gehele zoekgebied, van het zandige gronden in het zuiden tot de Centrale Oestergronden. Op deze manier wordt een suite van habitatsoorten beschermd, terwijl vissen tussen deze gebieden in is toegestaan.

De omvang van het subgebied in de Centrale Oestergronden is aanzienlijk groter dan het betreffende subgebied binnen de varianten Abalone tot Dab. Deze variant leidt tot middelhoge tot hoge kosten voor zowel de Nederlandse visserij als de controle, en scoort ook in het algeheel hoger, zowel wat betreft ecopunten/km^2 als wat betreft het totale aantal ecopunten. De daadwerkelijke waarde is afhankelijk van de toegepaste wegingsfactor. Gebruik van de wegingsfactor 'hard substraat' en '% in het parallellogram' resulteert in minder ecopunten/km^2, terwijl gebruik van gradiëntgerelateerde wegingsfactoren resulteert in relatief middelhoge tot hoge scores, zowel voor ecopunten/km^2 als voor het totale aantal ecopunten.

Flounder
Het totale gebied heeft een oppervlak van 6.339 km^2 en omvat twee subgebieden. Dit is de grootste variant. De twee subgebieden dekken het Friese Front en de Centrale Oestergronden in hun geheel. Daarom beschermt deze variant alle (a)biotische gradiënten op het Friese Front en scoort hij het hoogste voor biodiversiteit. Deze variant leidt zowel tot de hoogste kosten voor zowel de Nederlandse visserij als de controle, als ook tot de hoogste scores voor ecopunten/km^2, behalve wanneer harde substraten worden meegerekend (in termen van ecopunten/km^2). Wanneer ecopunten worden uitgedrukt voor het totale gebied, heeft Flounder de hoogste totaalscores.

Ook als ervan uit wordt gegaan de lange termijn kosten voor de verplaatsing van visserijactiviteiten 0 is (Verplaatsingsscenario C) verandert dat de rangschikking van de varianten niet. De kosten van Brill en Dab zijn laag, de kosten van Abalone en Capelin gemiddeld en de kosten voor Eel en Flounder hoog. De reden hiervoor is de aangenomen afhankelijkheid van de controle kosten van de mate van visserijactiviteiten in de gebieden.

Deze studie karakteriseert de gebieden die voor sluiting in aanmerking komen en de effecten die afsluiting op die gebieden zal hebben op basis van de meest recente kennis over de kosten en baten van de diverse varianten. Het onderzoek biedt daarmee geen eenduidig antwoord op de vraag wat de optimale managementkeuze is maar kan wel een goede basis vormen voor discussie over voorkeuren en mogelijke compromissen tussen stakeholders en managers.

S.2 Overige uitkomsten

Het ecopuntensysteem is toegepast om de ecologische baten van de afsluitingen te beoordelen. De ecopunten zijn gebaseerd op de huidige status van het benthische ecosysteem. De toegepaste wegingsfactoren komen overeen met diverse beheersprioriteiten die zijn afgeleid van het huidige beheer. De keuze welke wegingsfactoren worden gebruikt, speelt een cruciale rol in de resulterende voordelen, samen met de grootte van het afgesloten gebied. Zie hoofdstuk 4.

De economische effecten van afsluitingen op zowel de Nederlandse visserij zijn beraamd met behulp van vier beleids-, economische en innovatiescenario's (PEI-scenario's) en drie verplaatsingsscenario's. De PEI-scenario's houden rekening met effecten van externe ontwikkelingen zoals visprijzen, ontwikkeling van voorraden en afsluitingen van andere gebieden. De verplaatsingsscenario's zijn gebaseerd op wetenschappelijke inzichten in de effecten van verplaatsing (A), en het standpunt van de visserijsector (B) en de aanname dat door alternatieve visserijmogelijkheden de lange termijn kosten voor verplaatsing verwaarloosbaar zijn (C). De scenario's resulteren in een brede bandbreedte van kosten met substantiële overlap tussen de diverse varianten. Het verplaatsingsscenario dat is gebaseerd op het standpunt van de visserijsector leidt tot aanzienlijk hogere kosten dan de twee andere scenario's. Zie hoofdstuk 6.

Het totale belang van de gebieden voor buitenlands vloten is vergelijkbaar/groter dan voor de Nederlandse vloot. Aanvoerwaarde en de Bruto Toegevoegde waarde zijn vergelijkbaar voor de varianten Abalone, Brill, Capelin en Dab en in het geval van Eel en Flounder liggen deze parameters voor de buitenlandse vloten hoger. Omdat een deel van de buitenlandse schepen eigendom is van Nederlandse ondernemingen zullen effecten op buitenlandse vloten ook hun weerslag vinden in de Nederlandse economie. Dit effect is niet meegenomen in de huidige studie. Zie hoofdstuk 5.

De afsluitingen zullen gevolgen hebben voor maatschappelijke aspecten van de visserij en hun gemeenschappen. De meeste van deze aspecten kunnen niet worden toegeschreven aan een van de varianten, maar zijn beschreven. Zie hoofdstuk 7.
Kosten voor het monitoren en controleren zijn niet-onderscheidend voor de meeste varianten omdat de onzekerheid van de kosten hoog is. Zie hoofdstuk 8.

Hoewel het huidige onderzoek een overzicht biedt van de kosten voor en baten van de verschillende varianten voor het beschermen van de zeebodem, zijn veel van deze kosten en baten niet vergelijkbaar en zijn de uitkomsten vrij onzeker. Zie hoofdstuk 9.

De voornaamste reden hiervoor is:
- onzekerheid van de gegevens en aannames die ten grondslag liggen aan de scenario's
- de scope van het onderzoek, wat tot gevolg heeft dat bijvoorbeeld de effecten op vlagschepen niet volledig zijn meegenomen
- het ontbreken van duidelijke en meetbare managementdoelstellingen om de kosten en baten mee te vergelijken
- het onvermogen om potentiële toekomstige veranderingen van het belang van deze gebieden voor ecologie en economie te beoordelen.

S.3 Methode

Het Friese Front en de Centrale Oestergronden zijn geselecteerd voor gebiedsbeschermingsmaatregelen onder de Europese Kaderrichtlijn Mariene Strategie (KRM, 2008) vanwege hun hoge scores op het gebied van benthische biodiversiteit (Bos *et al.*, 2011) ten opzichte van de rest van de Nederlandse Noordzee. De doelstelling van de Nederlandse regering voor het Nederlandse deel van de Noordzee is om 10 tot 15% van het Nederlandse continentale plat te beschermen tegen merkbare verstoring door menselijke activiteiten, met een minimale impact voor de vissers (Ministerie van I&M, Ministerie van EZ, 2012). De visserijmaatregelen in Natura 2000-gebieden (Noordzeekustzone, Vlakte van de Raan, Voordelta, Doggersbank en Klaverbank) dragen deels bij aan deze doelstelling. De afsluitingen van het Friese Front en de Centrale Oestergronden moeten helpen deze 10-15% te bereiken en leveren een bijdrage aan deze doelstellingen zoals gedefinieerd in de Nederlandse Mariene Strategie Deel 1 (tabel 1.1, Ministerie van I&M, Ministerie van EZ, 2012). Gedurende een stakeholderproces zijn zes mogelijke varianten ontwikkeld voor afgesloten gebieden (figuur S1.1). De vraag van het ministerie is wat de kosten en baten zijn voor elk van deze zes varianten. Zie hoofdstuk 1.

Een MKBA vormt een systematisch methode om kosten en baten van interventies te vergelijken. Als zodanig is deze methode gebruikt om de kosten en baten van de afsluitingen te vergelijken. Zie hoofdstuk 2.

Voor alle directe gevolgen van de afsluitingen op het ecosysteem, visserij en monitoring en controle werden de gevolgen voor alle varianten beoordeeld met behulp van een reeks methoden. De ecologische voordelen werden beoordeeld met behulp van de ecopuntenmethode, uitgaande van de huidige status van het benthische ecosysteem en mogelijke focusgebieden in het management. De effecten van afsluitingen voor de visserij werden beoordeeld door een analyse van de historische visactiviteiten in het gebied in combinatie met een scenarioanalyse. Van de beoordeelde effecten op de aanvoerwaarde is ook een schatting gemaakt van de effecten voor visafslagen en de visverwerkende sector. Maatschappelijke effecten zijn beoordeeld aan de hand van interviews met vissers, de kosten voor monitoring en controle zijn geschat. Zie hoofdstuk 4-8.

1 Introduction

Hans van Oostenbrugge and Diana Slijkerman

Protection of the Frisian Front and Central Oyster Grounds area
The Frisian Front and Central Oyster Grounds have been selected for area protection measures under the Marine Strategy Framework Directive (MSFD, EU, 2008). This directive requires EU member states to come forward with a national Marine Strategy. In the Netherlands, the Marine Strategy Part 1 (Ministry of I&M, Ministry of EZ, 2012) describes the current status of the Dutch North Sea (initial assessment), the good ecological status to be reached in 2020 (GES), and the indicators to measure the change from the current status to the good ecological status. Part 2 (Ministry of I&M, Ministry of EZ, 2014) describes the monitoring plan to obtain data for the indicators. In part 3 (due end of 2015), the operational measures will be described that are needed to reach GES. One of the measures in the Dutch North Sea will be the closure of (a part of) the Frisian Front and Central Oyster Grounds area for seabed disturbing fisheries, in order to protect the benthic community.

The Frisian Front and Central Oyster Grounds (Figure 1.1) have been selected for area protection measures under the MSFD because of high benthic biodiversity scores (Bos *et al.*, 2011) relative to the rest of the Dutch North Sea (see maps in Appendix 2). The deep silty benthic habitat and the front system present in the central North Sea (Frisian Front, Central Oyster Grounds) is characterised by a high species richness, high biomass, high density, the presence of vulnerable species and large growing species, but is not listed in the Habitat Directive Annex I and is therefore excluded from Natura 2000 protection measures.

The overall aim of the Dutch government for the Dutch part of the North Sea is to protect 10-15% of the Dutch Continental Shelf against appreciably disrupting by human activities, with a minimum impact for the fishermen (Ministry of I&M, Ministry of EZ, 2012). The fishery measures in Natura 2000 areas (North Sea Coastal Zone, Vlakte van de Raan, Voordelta, Dogger Bank and Cleaver Bank) partly contribute to this aim. The closures on the Frisian Front and Central Oyster Grounds should help to reach the 10-15% and contribute to the targets as defined in the Dutch Marine Strategy Part 1 (Table 1.1, Ministry of I&M, Ministry of EZ, 2012).

Table 1.1
The overall objective of area closures on the Frisian Front and Central Oyster Grounds as defined in the Dutch Marine Strategy Part 1 (Ministry of I&M, Ministry of EZ, 2012)

Main target: structure of the ecosystem: The interim target for 2020 is to reverse the trend of degradation of the marine ecosystem due to damage to seabed habitat and to biodiversity towards a development of recovery. This constitutes a first step towards a situation in which the marine ecosystem in the Dutch part of the North Sea can (in part) recover in the long term. This implies a structure in which the relative proportions of the ecosystem components (habitats and species) are in line with prevailing physiographic, geographic and climatic conditions. **Subtargets:** *Benthos* a) Improvement of the size, quality and distribution of populations of long-living and/or vulnerable (i.e. sensitive to physical disturbance) benthic species. *Habitats* l) Supplementary improvement of the quality of the deeper, silty parts and deeper, non-dynamic sandy seabeds in the Netherlands part of the North Sea. The quality of the habitats applies to the physical structure, ecological function and diversity and structure of the associated species communities. m) 10-15% of the seabed of the Netherlands part of the North Sea is not appreciably disrupted by human activities.

Source: Ministry of I&M.

To determine which areas would contain the highest biodiversity at minimal costs for the fishermen, a number of preparatory studies has been conducted. First an overview was made of available ecological and fishery knowledge for the Frisian Front and Central Oyster Grounds (Slijkerman *et al.*, 2013). Next, studies to explore area closure measures using Marxan (Slijkerman *et al.*, 2014) and an expert judgement workshop on the potential for recovery of the area after closure (Jongbloed *et al.*, 2013) were conducted. In addition, recent trends and possible future developments in the Dutch fishing sector were described (Kuhlman and Van Oostenbrugge, 2014).

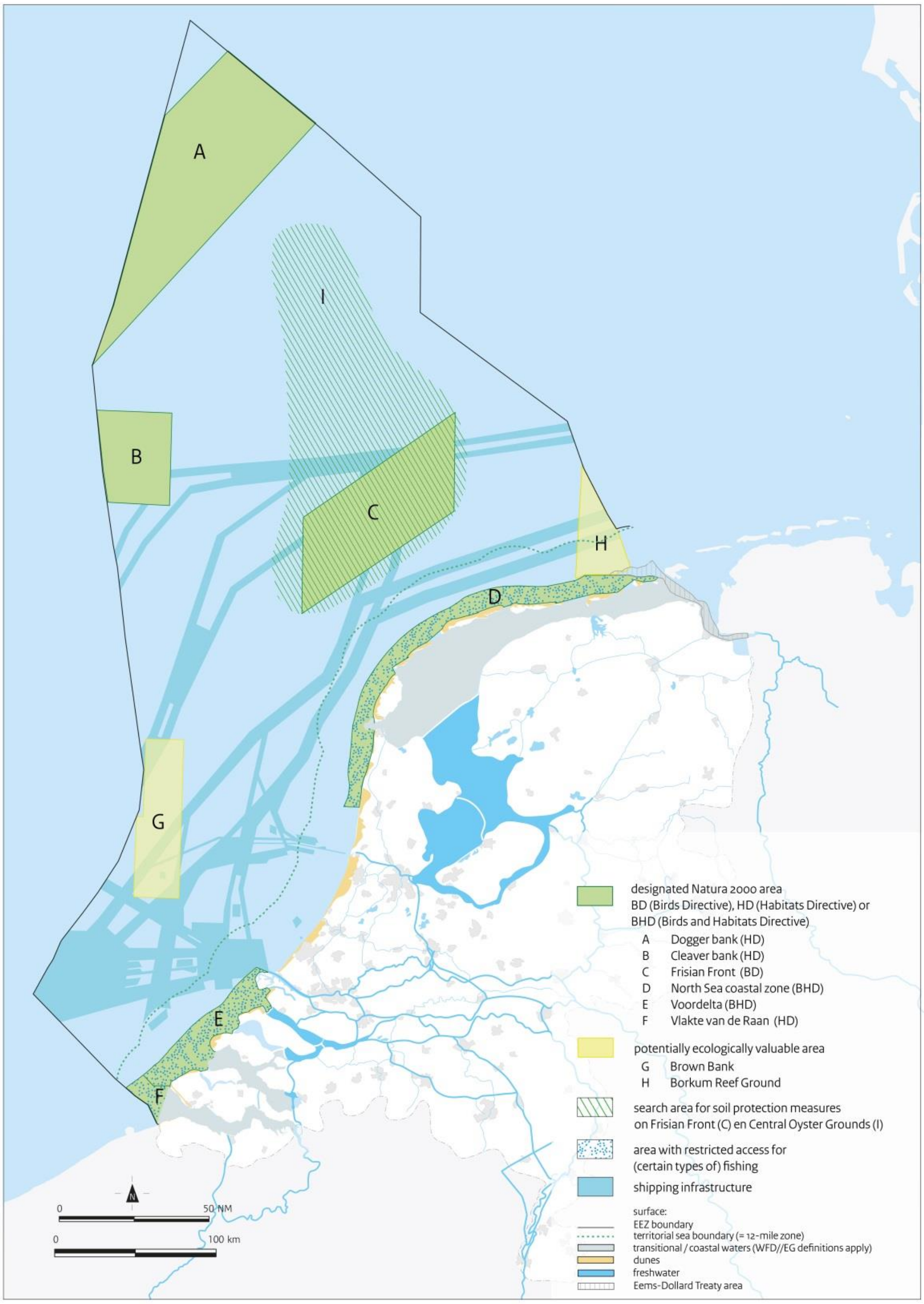

Figure 1.1 *Area use in the Dutch part of the North sea, showing optional locations for fisheries restricting measures in the Central Oyster Grounds and the Frisian Front*
Source: adapted from Ministry of I&M, Ministry of EZ (2014b).

In 2014 a stakeholder process was started by the Dutch Ministry of I&M involving the fishery sector, NGOs and scientists. This led to additional studies: a study on the effects of closures on fisheries and exploited stocks (Van Kooten *et al.*, 2014), one on the effects of fisheries on benthic traits (Van Kooten *et al.*, 2015), a study on the effects of displacement of fisheries after closures (De Vries *et al.*, 2015), a study on the ecological importance of the Frisian Front (Lindeboom *et al.*, 2015), and an evaluation of flyshoot fisheries (Rijnsdorp *et al.*, 2015). In June 2015, after a number of stakeholder meetings, six different variants for area closures to bottom fisheries were put forward by the ministry of Infrastructure & Environment, three of them based on propositions by the stakeholders (see Chapter 2).

To facilitate the decision-making process on the choice of a variant for implementation of protection measures for the sea bottom substrate and to comply with the MSFD, the present study aims to quantify the benefits and costs of each of the six proposed variants. This is done using the Dutch guidance on Cost Benefit Analyses (CBA)(Romijn and Renes, 2013) (See Chapter 2).

The product of this project will facilitate the discussions on the choice of the closures with stakeholders in 2016.

The project has been carried out by LEI and IMARES for the Ministry of I&M from February 2015 to December 2015.

Chapter 2 describes the general application of the CBA guidelines and selection of costs and benefits that have been taken into account in the study. Chapter 3 shows the main characteristics of the variants. In Chapter 4-9 the main effects of the proposed closures are analysed. Each of the chapters include a section on the specific methodology used, the results and a discussion of the results. Chapter 10 integrates all findings and discussed these in the context of the general aims of the study.

2 Application of Cost Benefit Analysis to closed areas

Hans van Oostenbrugge and Ernst Bos

General methodology Cost Benefit Analysis

The analyses are done in accordance with the Dutch guidance on CBA (Romijn and Renes, 2013). The guidance specifies various steps in the CBA (Figure 2.1) in order to come to a complete and comparable overview of all costs and benefits. After a problem analysis (see Chapter 1), a description of the autonomous developments in ecology and in fisheries (Step 2) in the area have already been carried out in preparation of this study (Slijkerman *et al.*, 2013, Kuhlman and Van Oostenbrugge, 2014). For the fisheries, the data have been updated as described in Chapter 5). A description of the variants (Step 3) is given in Chapter 3. In the following chapters (Chapter 4 – 8) the effects of the alternative measures are described in more detail and quantified (Step 4 and 5). While most of the costs are relatively easy to quantify and value, the monetarisation of ecological effects requires indirect valuation techniques (Buisman and de Vos, 2010). An example of such methodology applied to marine ecosystems can be found in Borger et al 2014. Although application of such valuation methodology would enable to get a rough idea about social benefits from assumed ecological changes, this technique was not applied as the resolution of the variants is too low and furthermore, the technique itself is yet to be found to be too uncertain and not suitable to diversify among the variants. Ecological benefits have been quantified as the *current* ecological values of the different variants, and not the *future* ecological benefits. Moreover, some additional effects have been analysed that are complementary to the valuable costs and benefits (e.g. social effects).

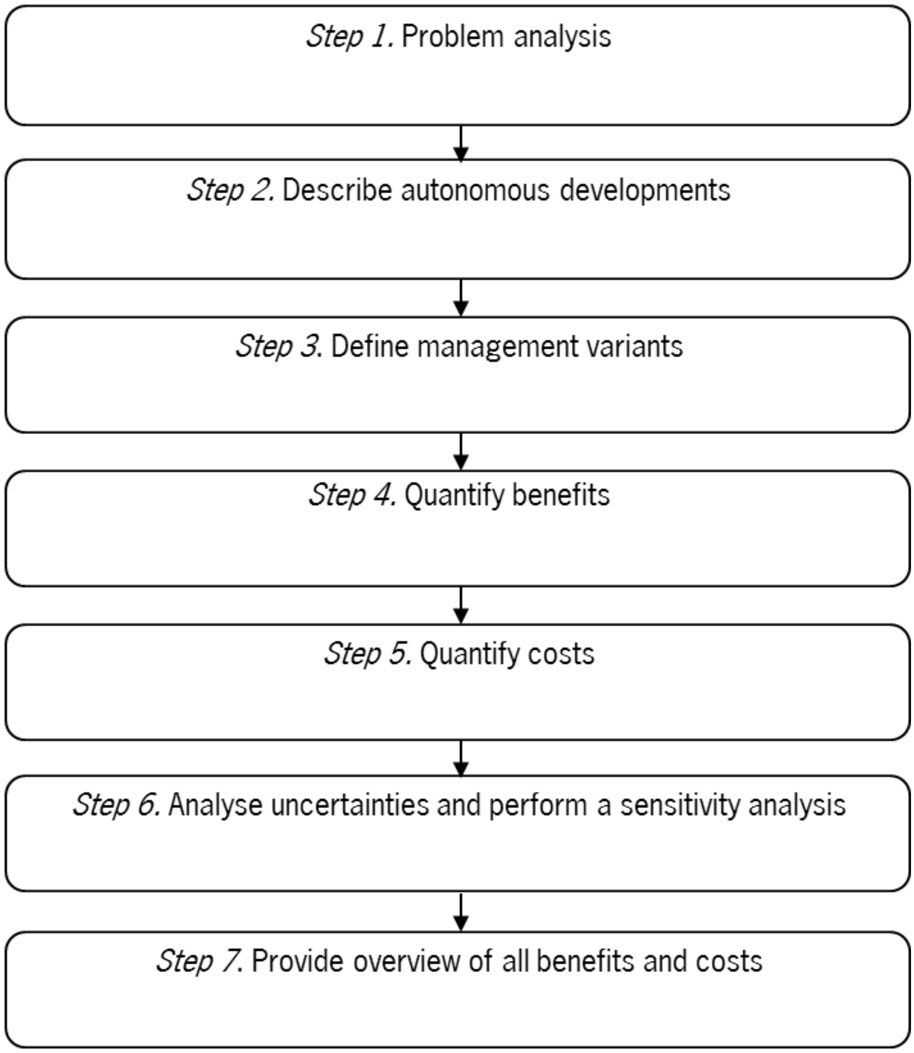

Figure 2.1 *Overview of the steps in the Cost Benefit Analysis*
Source: Dutch guidance on Cost Benefit Analyses (Romijn and Renes, 2013).

For most effects, an analysis of the uncertainty (Step 6) is carried out and included in the Chapter on the quantification. Chapter 10 provides an overview of the benefits and costs (Step 7) and draws conclusions.

Identification of possible effects of management measures
The overall aim of the management measures under study is to protect the continental shelf against appreciably disruption by human activities. In order to do so, management will reduce the the bottom-contact fisheries in the areas. As a consequence, the measures will directly affect the fish cluster and the ecology of the area. Other activities (e.g. shipping, tourism, navy) will not be affected directly by the management action, but might benefit indirectly as a consequence of changes in ecology in the areas. In addition ecological changes in the area might also affects fishing opportunities (Van Denderen, 2015). However, these indirect effects are highly uncertain and as such are not the subject of this study.

This study focusses on the direct effects of management measures in the areas in accordance with the guidance on Cost Benefit Analyses (Romijn and Renes, 2013). Figure 2.2 summarises of the various effects of the closures. The direct effects of the closures include effects on the protected benthic ecosystem, the affected fishing sector and the costs for monitoring the ecological developments and the costs for control.

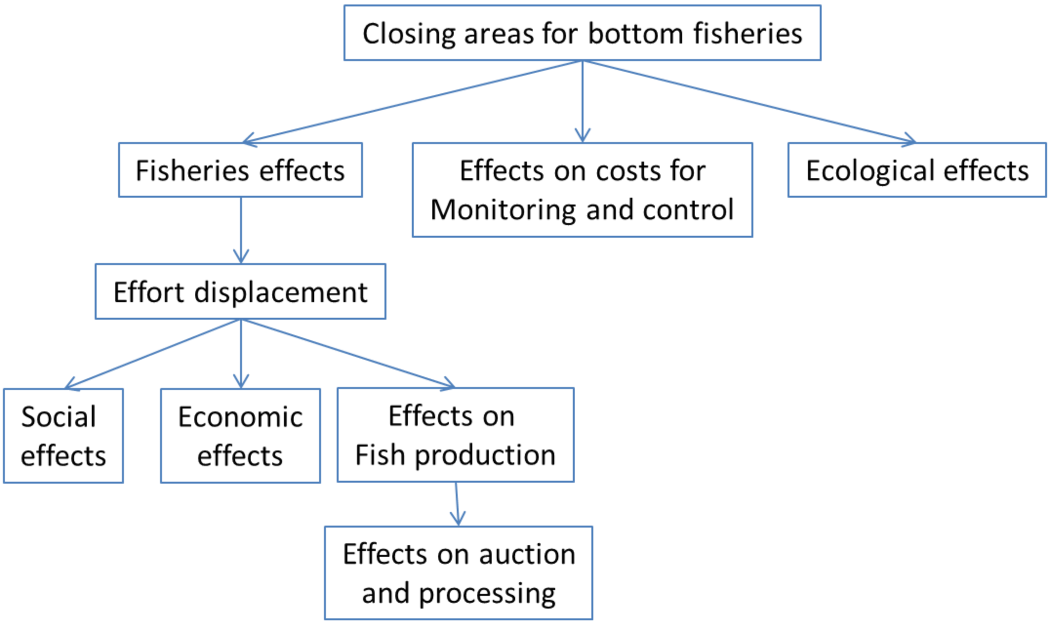

Figure 2.2 *Main effects of area closures and the way in which these effects were taken into account in this study.*

The closures aim is to protect the benthic ecosystem from the effects of bottom fisheries. The absence of fishing pressure is assumed to have a positive effect on the development of the benthic community (see Chapter 4). The ecological benefits are studied taking into account the value of the areas and possible management aims using the ecopoint method. The analysis has been limited to the current status of the ecology in the area. The main reason for this is the fact that the effects of the closures on the ecology in the area are highly uncertain and the valuation of such ecological developments by means of indirect valuation techniques also adds uncertainty to the estimates, which makes a comparative analysis of the variants of little added value.

As fishing using bottom gears is forbidden in the closed areas, the affected fishermen need to reallocate their fishing activities to other locations. This reallocation may affect their economic performance, social welfare and the amount of fish produced. This applies both to Dutch fishing vessels as well as to foreign vessels. The effects on the economic performance of the Dutch fleet are studied most extensively (Chapter 6); the value of the areas to the fisheries are quantified and the effects of closures are estimated under various scenarios and assumptions for the costs of displacement. The scenarios assess the effects of possible external developments on the consequences of the closures. Furthermore, the future costs are discounted and a sensitivity analysis is carried out for all major effects. Additionally, effects for the employment in the fishing sector are quantified. For the foreign fleets, the analysis is restricted to the quantification of the current value of the areas to the fisheries. The effects of external factors and possibilities for displacement depend on the national contexts of each of the foreign fleets and the analyses of those contexts are outside the scope of the study. The displacement of fishing activities to other (and possibly new) fishing grounds also might result in social consequences such as longer trips, other landing harbours etc. The social effects of closures for the fishing sector have been mapped using interviews (Chapter 7).

In order to monitor the developments in the benthic community and to enforce the closures extra monitoring and control costs need to be made (Chapter 8). The costs for monitoring and enforcement have been valued and discounted, but because of the simplicity of the estimation method no sensitivity analysis has been included.

In the first inventory of the possible effects, also the effects on the Dutch auctions and the fish processing sector were identified as effects of closures. The vast majority of the fish caught in the areas is sold to the Dutch processing sector through Dutch auctions. According to the Dutch guidelines for Cost Benefit Analyses, these effects should not be considered in an formal Cost Benefit Analysis. The reasons for this are (Romijn and Renes, 2013):

- The auction and processing sector are indirectly affected by the closure of the areas
- Potential effects on the sector are small. Based on previous studies on the value of the areas for the Dutch fishing sector it was concluded that the value of the total area of the Frisian Front and the Central Oyster Grounds 2% of the total value of the fish landed by the Dutch demersal fisheries. Moreover Beukers, (2015) stated that the dependency of the Dutch processing sector on the Dutch fisheries was around 50% (based on the value of landings of sole and plaice). Taking this into account, the potential effect on the raw material for the processing industry would be 1% at max which can be regarded as a small effect. The dependency of the auctions on foreign vessels is not known, but also for the auctions it can be concluded that the maximal effect on auctions will be small.
- The sector functions in a well-functioning market. The markets for the raw material for both the auctions and the processing industry are open markets that are very transparent. Fishermen are free to choose the auction where to land there fish and a considerable proportion of the fish is transported by truck to fish auctions other than the auction of the harbour where the fish is landed to be sold at a (presumably) better price. Most auctions publish price and landings data daily in order to inform their customers on the fish landings and there are multiple sellers and buyers. Based on this information it can be concluded that the market for raw fish are well functioning markets.

Stakeholder involvement

During the project several stakeholder meetings were organised. The meetings provided in discussions on the methodology and possible additions to the study.

Separate meetings with both fisheries representatives and NGO representatives took place at the IMARES office on respectively July 28th and August 25th. Topics discussed with fisheries representatives were to include additional weighting factors (wrecks, fisheries pressure- see chapter 4) and to clarify the need to include weighting factors for frontal area and connected gradients. Topics discussed with NGO representatives were related to the scope of the benthic ecosystem, which was discussed to be a limited scope. Furthermore the need was expressed and discussed to evaluate additional aspects representing the ecosystem based approach and ecosystem services and how these could be included in the methodology.

For the costs, meetings were held to discuss the PEI scenario's (16th June), methods for estimating the economic value of fishing activities in the areas (2nd July) and a workshop on the effects of displacement (27th August). These meetings resulted in the addition of a special analysis for the value of the areas for foreign fleets and adaptations in the scenarios for the costs of effort displacement in case of closure. After the presentation of the concept results, the stakeholders had the opportunity to provided additional comments, which have been taken into account in this version.

3 Variants

Hans van Oostenbrugge and Diana Slijkerman

This study compares the effects of six variants of closures of (parts of) the Central Oyster Grounds and the Frisian Front. Boundaries of the Frisian Front and the Central Oyster Grounds have been defined differently in various contexts. In the management context the Frisian Front has been defined as in Figure 3.1 (Flounder) as a protection zone for birds. These boundaries and the boundaries of the Central Oyster Grounds as shown in Figure 3.1 (Flounder) have also been used in previous studies on the ecological and economic value of the areas (e.g. Kuhlman and Van Oostenbrugge, 2014; Slijkerman *et al.*, 2014). In the context of the MSFD the boundaries of the optional locations for fisheries restricting measures in the Central Oyster Grounds and the Frisian Front have been combined into one organically shaped area (Ministry of I&M, Ministry of EZ, 2014b, Figure 1.1).

In the spring of 2015 a stakeholder process was set up by the Ministry of I&M to develop variants for the closures. This was done based on insights of previous studies about the ecology in the area and the fishing patterns and developments (Slijkerman *et al.*, 2013, Kuhlman and Van Oostenbrugge, 2014) and these insights were discussed during so called 'Knowledge meetings'. This process culminated in a maptable session on the 17th of April. The stakeholders were asked to provide their preferences and IMARES and LEI facilitated the discussion by providing maps on ecological patterns and fishing activities. After the meeting the variants were proposed by the ministry (variants Abalone, Capelin and Eel), the fisheries sector (variants Brill and Dab) and the NGOs (variant Flounder). To increase the readability of the report, the variants were ordered in increasing surface area and named after fish species from A (Abalone) to F (Flounder). The proposed variants all consist of several subareas in both the Central Oyster Grounds and the Frisian Front as well as outside these areas. They vary in the positioning of the subareas, the total size and the total perimeter. Table 3.1 and Figure 3.1 summarise the main characteristics of the variants and subareas.

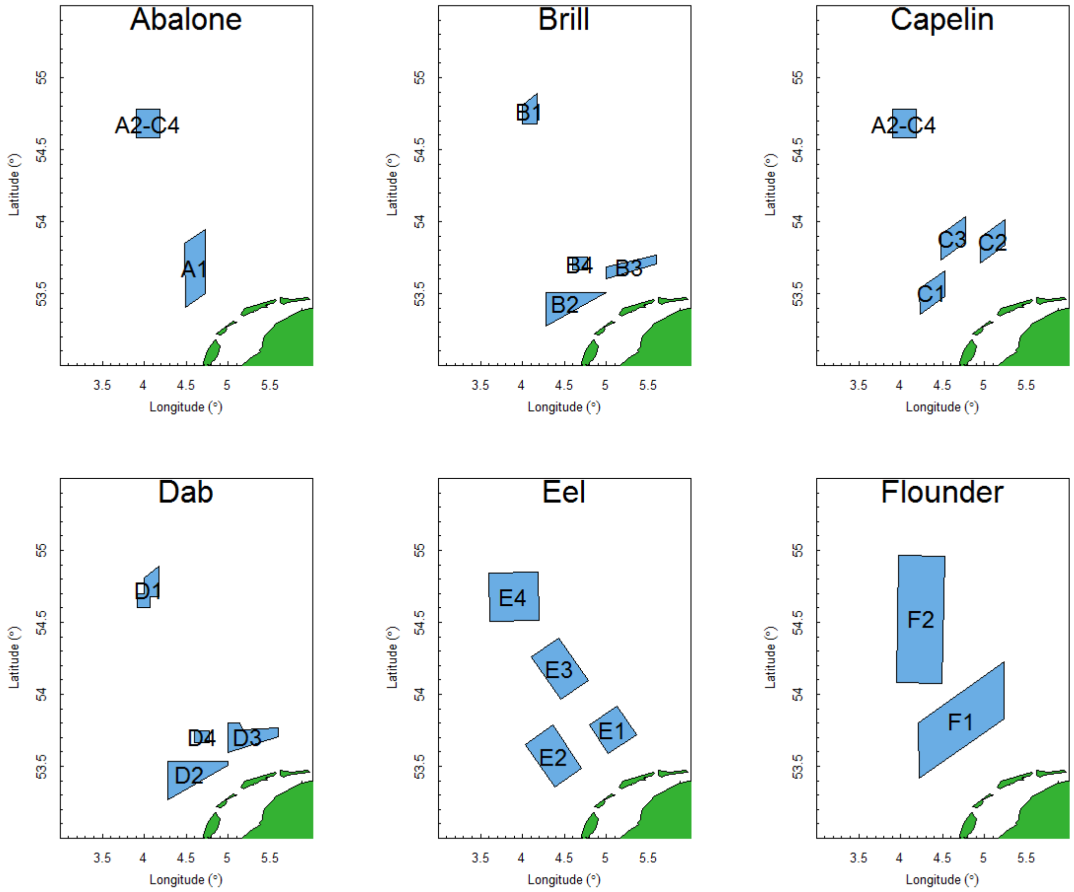

Figure 3.1 *Maps of different variants taken into consideration*
Source: Ministry of I&M, processed by LEI.

Table 3.1

Main characteristics of the variants under study in the CBA

Variant [1]	No. in Figure 3.1	Subarea coding	Surface area (km^2)	Perimeter area (km)
Abalone	A1	FF	800	138
Abalone	A2	CO	404	81
Total			1,204	219
Brill	B1	CO	207	63
Brill	B2	FFSW	632	129
Brill	B3	FFSE	319	97
Brill	B4	FFC	105	41
Total			1,263	330
Capelin	C1	FFSW	398	88
Capelin	C2	FFSE	398	88
Capelin	C3	FFNO	398	88
Capelin	C4	CO	404	81
Total			1,597	345
Dab	D1	CO	304	91
Dab	D2	FFSW	772	135
Dab	D3	FFSE	501	112
Dab	D4	FFC	105	41
Total			1,683	380
Eel	E1	FFSE	700	106
Eel	E2	FFSW	1,050	133
Eel	E3	COS	1,050	133
Eel	E4	CON	1,406	150
Total			4,206	521
Flounder	F1	FF	2,882	249
Flounder	F2	CO	3,457	267
Total			6,339	516

[1] Dutch translations of variant names: Abalone, zeeoor; Brill, griet; Capelin, lodde; Dab, schar; Eel, aal; Flounder, bot.

Source: Ministry of I&M.

4 Ecological benefits

Diana Slijkerman, Oscar Bos, Jan Tjalling van der Wal and Joop Coolen

4.1 Methodology

4.1.1 Ecological cost and benefits and the ecosystem approach

As described in Section 1.1.1., the area closure(s) will serve as spatial protection measures in addition to Natura 2000 areas and are needed to move forward to a Good Environmental Status (GES) in 2020. The interim target for 2020 is to reverse the trend of degradation of the marine ecosystem due to damage to seabed habitat and to biodiversity towards a development of recovery, and these closures will contribute to that target. Although the target of the closures in the FF/CO area are to protect vulnerable benthic species, their ecological benefits could be larger, and it would be wise to take these additional benefits into account.

The main question to be answered in this chapter is: what are the ecological benefits of closing one or more areas to bottom fisheries and how do they compare between the 6 variants? First of all, ecological benefits are difficult to express in terms of euros, although monetary values have been assigned to ocean services such as 'lifecycle maintenance', 'gene pool protection', 'food', 'climate regulation' within ecosystem services project (e.g. the TEEB project, Van der Ploeg and De Groot, 2010). The general assumption is that area closures are beneficial for the environment. From an ecosystem approach point of view, the benefits of area closures could therefore be expressed in terms of an increase in biodiversity (biomass, density, or species numbers of benthic fauna, commercial and non-commercial fish, birds, marine mammals, etc.). In general, this seems to be the case. Fox *et al.* (2011) report that no-take protection typically results in increases of organism sizes, higher densities, higher biomass, and higher species richness. They further report that such effects vary by taxa and are most dramatic for species targeted by fisheries. However, the effects of (partial) closures may also be different from the expected results. The Plaice Box for example does not protect young plaice, because the plaice left the area. This is probably because of a rise of water temperatures and of lowered eutrophication, rather than a change in fishing regime (Beare *et al.*, 2013). Effects on food webs may take longer - sometimes decades - because top predators are long-lived and slow growing (Fox *et al.*, 2011). Also benefits of area closures for ecosystem functions (spawning grounds, feeding grounds, etc.) should be considered. The benefits of area closures for the ecosystem will probably largely depend on the size of the closure: the larger the size, the better. To get a grip on the supposed benefits, the ministries of I&M, EZ and WWF have funded a number of studies that provide insight into this matter:

- Comparison of the ecology of the Frisian Front with Oyster Grounds, now and in the future. Read this study if you would like to compare expected developments in both areas. Jongbloed *et al.* (2013) (http://edepot.wur.nl/288777)
- Proposed Marine Protected Areas in the Dutch North Sea: An exploration of potential effects on fisheries and exploited stocks. Read this study if you want to know more about the potential effects of the closures on the fisheries. Report for WWF: Van Kooten *et al.* (2014)
- An exploratory analysis of environmental conditions and trawling on species richness and benthic ecosystem structure in the Frisian Front and Central Oyster Grounds. Read this study to understand how fisheries affects biodiversity: Van Kooten *et al.* (2015).

In Section 4.5 and further these costs and benefits are discussed in more detail.

In this report the focus is not on the entire area, but on 6 different variants. General ideas on how the larger area could profit ecologically cannot be expressed quantitatively on the scale of the proposed closures and they cannot be compared among the 6 variants. For example, it is not known what

minimum size the area should have to serve as a spawning ground, and it is not known either where exactly spawning grounds are located. To answer the question how the 6 variants will differ in their potential to serve as spawning grounds is therefore impossible. In the discussion section, we elaborate on this.
Data that can be compared among the different variants are those on the current status of the biodiversity (biomass, density, species numbers, etc.), for which Bos *et al.* (2011) have provided an overview, in combination with data on the variants' sizes (km^2) and other characteristics (e.g. habitat diversity) (see also Appendix 3). Therefore, the ecological part of the cost-benefit analysis is in this report just a comparison of *current* biodiversity values among the variants, because future biodiversity values, as well as contributions of the closures to the rest of the ecosystem (ecosystem approach) unfortunately cannot be predicted on the level of the variants.

In the following sections, we will therefore only compare the current benthic biodiversity values of the different variants. Strictly speaking this is therefore not an analysis of ecological benefits, but of existing and already heavily fisheries influenced benthic ecological values.

4.1.2 Introduction to the ecopoint valuation method

To analyse the costs and benefits, a quantitative method was needed and proposed. One way to express biodiversity values per variant, is the ecopoint valuation method (Sijtsma *et al.*, 2009).

The ecopoint valuation method (Sijtsma *et al.*, 2009) is used to calculate ecological values or gain in values of a certain area before and after implementation of measures. It is an extension of the Natural Capital Index (Ten Brink *et al.*, 2002), which is defined as the product of nature quantity (%) and quality (%). The ecopoint method takes into account the same formula, but adds a weighting factor, based on the fraction of the total biodiversity that is represented by the specific ecosystem or habitat (Sijtsma *et al.*, 2009). The weighting factor is often a calculated value representing habitat rarity which in turn represents the importance of the specific habitat for maintaining overall biodiversity (Liefveld *et al.*, 2011). The method has been applied in previous cost-benefit studies and evaluated to be feasible to quantify ecological features such as biodiversity and the impact of measures (Sijtsma *et al.*, 2009; Liefveld *et al.*, 2011). Ecological values per measure are expressed as dimensionless values, based on available biodiversity data and habitat information, instead of using qualitative data (e.g. plusses and minuses).

The principle of the ecopoint method is that the amount of biodiversity within an area with multiple habitats is evaluated by three factors: 1) quantity of the habitat (area), 2) quality of the habitat (i.e. number of species) and 3) a weighting factor per habitat. Ecopoints are calculated as:

$$\text{Ecopoint total} = \sum_{\text{all habitats}}(\text{Area} * \text{Quality} * \text{Weighting factor})_{\text{per habitat}}$$

Ecopoints versus quality gain
The concept of ecopoints can be visualised as the volume of a box (Figure 4.1), where the axes consist of area quantity, area quality and a weighting factor. The larger the volume, the higher the value. In general, ecopoints are calculated before and after a measure, providing a value for quality gain. The calculation of the gain requires knowledge on the effect of the measure and requires a thorough set of model equations to calculate the effect of the measure compared to a baseline variant. However, such knowledge and the model equations are often lacking, resulting in expert opinion or best guesses. Also, in the execution of this study, model equations are lacking for a proper calculation of the gain of ecological quality in quantitative terms. Therefore, the gain is not calculated in terms of ecopoints. Instead the ecological gain of measures is qualitatively described on higher abstraction level in the discussion section. The calculated ecopoints reflect the baseline values of each variant.

The gain of measures on the North Sea level was not part of this study.

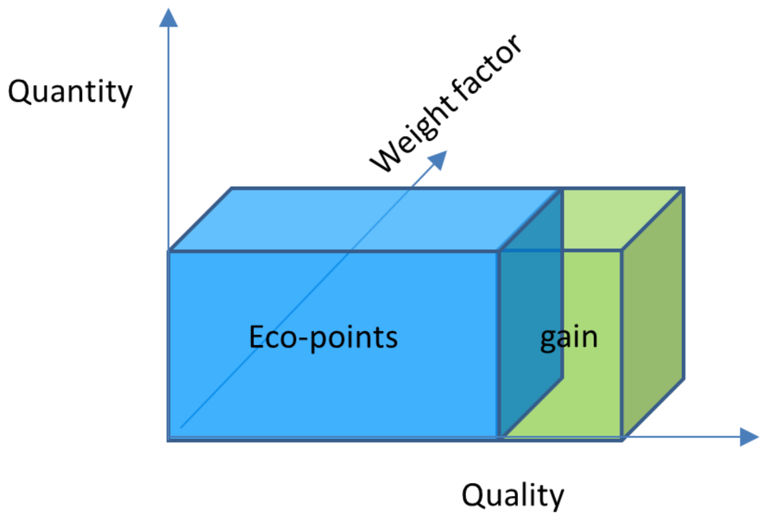

Figure 4.1 *Visualisation of ecopoints (blue) before measure and gain in ecopoints (green) after measure (after Liefveld et al., 2011)*
Source: after Liefveld et al. (2011).

A weighting factor is applied to express the importance, threat or rarity of different habitats (Liefveld *et al.*, 2011). The basic methodology can be retrieved in Sijtsma *et al.* (2009) and Liefveld *et al.* (2011).

4.1.3 Adapted ecopoint valuation for the Frisian Front and Central Oyster Grounds

In the current study, the ecopoint method of Sijtsma *et al.* (2009) was adapted to the specific purpose of this study, i.e. to select for closed areas (variants) that contribute most to the targets of the Dutch Marine Strategy. In the ecopoint calculation formula shown above, the first factor, the area, is the size of each of the 6 proposed closures (variants), expressed in km^2. The second factor in the equation, habitat quality, is expressed as a biodiversity value, calculated on the basis of benthic biodiversity maps as published in Bos *et al.* (2011), which are based on the MSFD criteria for biodiversity indicators (EU, 2010). The weighting factor is generically used to express the importance of the specific habitat for maintaining overall biodiversity. In this study a number of weighting factors are defined to differentiate the benthic ecological values of the variants resulting from various ecological viewpoints. The following aspects were taken into account:

1. The weighting factor should contribute to the aims of the closure with respect to the improvement of the quality of deeper, silty seabeds and deeper, non-dynamic sandy seabeds.
2. The weighting factor should select for habitat rarity (rare habitats are more in need of protection than common habitats).
3. The weighting factor should reflect the general MSFD ecosystem approach (favour all species groups and important ecosystem characteristics where possible).
4. The weighting factor should favour one larger single area over a combination of many smaller areas (rationale in Section 4.2.3.2)

Since it is not very clear how to create one weighting factor that encompasses all of these aspects, we have constructed different weighting factors that each address one or more of these points. We thus provide results for a number of different weighting factors and compare their effects on the ecopoint score for the variants. We also provide data per subarea to be able to compare results within a variant and between subareas.

To highlight the rarity or importance of certain habitats over others within the search area, the characteristics of the local ecosystems need to be compared. Such a comparison between the Frisian Front and Central Oyster Grounds has been made by Jongbloed *et al.* (2013) during an expert workshop. Both areas are characterised by deep muddy habitats and are highly biodiverse (Bos *et al.*, 2011). The Frisian Front, however, is a front system, is more productive, has a higher biodiversity, higher heterogeneity, has depth gradients resulting in hydrographical and sedimentological gradients, has little stratification and has a large variation in angle of inclination (Lindeboom *et al.*, 2015). In the Central Oyster Grounds there is little variation in depth, there is a longer and more gradual gradient of sediment, less variation in depth and stability of stratification and there is little energy input in the system (Jongbloed *et al.*, 2013).

4.2 Methodology

In this project, 6 different variants for combinations of closed areas in the Frisian Front/Central Oyster Grounds area are compared in terms of ecopoints. Ecopoints are calculated for the 'baseline' situation only, as explained in the introduction (Section 4.1.1), according to the following formula:

Ecopoint total = Area * Quality* Weighting factor

In the subsequent sections, each of these factors are discussed in more detail. Based on the commonly applied methodology of ecopoint derivation (e.g. Sijtsma *et al.*, 2009; Liefveld *et al.*, 2014; Van Gaalen *et al.*, 2011), area describes the total surface area, quality describes the quality of an habitat in terms of species or biodiversity, and weighting factors describe the areas' relative importance or uniqueness to maintain overall biodiversity.

In this study, several options to derive ecopoints are presented. In these options, the area (km^2) per variant and quality factors are kept constant, while a number of weighting factors are defined which can be used to differentiate the ecological score of the variants. The list of weighting factors comprise different alternatives of which it can be debated which one is most relevant for the final assessment. This latter depends e.g. on policy ambition.

The following steps were taken to obtain information that allows for calculation of the ecopoints:

Step 1: Area quantity calculation
Step 2: Area quality calculation
- 2a: Selection of relevant quality indicators
- 2b: Calculation quality indicator values
- 2c: Scaling of quality indicators to values between 0 and 1

Step 3: Weighting factor
- 3a: Selection of weighting factors
- 3b: Calculation of weighting factors

Step 4: Calculation of ecopoints
Step 5: Evaluation of data robustness and effect on outcome

4.2.1 Step 1: Area quantity

The area (km^2) per variant is calculated as the sum of the subareas (see Table 4.1 and Figure 4.1).

4.2.2 Step 2: Area quality indicators

4.2.2.1 Step 2a: Selection of area quality indicators

Quality indicators in the ecopoint methodology refer to species lists or biodiversity values, expressed as abundance of typical species listed on a national species list (e.g. at N2000 qualifying species lists, combined with a goal per species) (Sijtsma *et al.*, 2009; Liefveld *et al.*, 2011). In the context of the MSFD and this study, the area closures to bottom impact by fisheries should contribute to the recovery of habitats and biodiversity, and improve the size, quality and distribution of long-lived and or vulnerable benthic species.

The area quality indicators should therefore inform on biodiversity values, with emphasis on benthos, and in particular long-lived and/or vulnerable benthic species. The search area (Frisian Front and Central Oyster Grounds) was selected for benthic protection measures based on high benthic biodiversity values, as presented in Bos *et al.* (2011). In this study we therefore use the same data (see Appendix 2) to calculate the area quality.

The indicators calculated by Bos *et al.* (2011) represent different aspects of biodiversity, including density of species, biomass and condition, corresponding to the requirements for MSFD indicators (EU, 2010). These maps have been constructed with the best possible data available (see discussion). The methodology of kriging (interpolating) to obtain the coloured areas between sampling points is described in Bos *et al.* (2011). The following maps and data are used for this study (see maps in Appendix 2):

Macrobenthos (BIOMON)[1]
- Species richness
- Species biomass
- Species density
- Species evenness
- Long-lived benthic species
- Large growing species

Megabenthos (triple D)[2]
- Species richness
- Species biomass
- Species density

Since quality indicators should be independent of one another to avoid a 'double counting' of indicators, the quality indicator 'rare species' (see map in Appendix 2) was excluded, since this is a subset of the data on 'species richness' and therefore strongly correlates with 'species richness'. The other quality indicators represent different aspects of biodiversity that are independent of one another.

To avoid double counting of aspects within the overall equation, a clear distinction is made between quality aspects and weighting factor aspects. Abiotic habitat characteristics are used to derive weighting factors, whereas species information is used to calculate quality indicators.

4.2.2.2 Step 2b. Calculation of quality indicator values

Biodiversity data were obtained from maps in Bos *et al.* (2011) which consist of scaled data, with each class containing more or less the same number of data on a Dutch Continental Shelf (DCS) scale. In Bos *et al.* (2011) these values per sampling station were kriged (extrapolated over space) in GIS so that colours represent classes, (see maps in Appendix 2). In this study, these maps are used to obtain biodiversity values for each of the 6 variants, by calculating the average value of an indicator within a variant, using GIS. Basically, this follows Liefveld *et al.* (2011), except, in this study, we concentrate only on benthos and do not calculate the gain (rationale see Section 4.1.2). As such this is a Limited Benthos Approach (LBA) and not an overall ecosystem approach.

For example, if a variant would consist of 2 subareas (Figure 4.2), subarea 1 of 400 km^2 and subarea 2 of 800 km^2, the following calculation is made:

If the first subarea consisted for 100% of a biodiversity quality value 3 (orange colour) the quality value for the first subarea would be 3*400=1,200. The second subarea of 800 km^2 would have a value of 70% of value 3 and 30% of value 2, with a total biodiversity value of (0.7*3+0.3*2)*800=2,160. Then the average biodiversity value would be (1,200+2,160)/(400+800)=2.8.

---

[1] BIOMON is the biological monitoring program (BIOMON) of Rijkswaterstaat, in which data on macrobenthos are collected at the Dutch Continental Shelf. Macrobenthos consists of the organisms that live at the bottom and are larger than ~0.5 mm.

[2] Triple D is the monitoring device of NIOZ, applied in benthic monitoring on the North Sea in several research programmes. Provides complementary benthic data to BIOMON because another part of the seafloor is sampled. Sampling focuses on larger benthos species than in BIOMON, such as larger infauna and the epifauna.

Next, these values are scaled to a value between 0 and 1, using the minimum and maximum values of the specific indicator within all variants together (see glossary and Figure 4.3). For example: if the minimum biodiversity value would be 2 and the maximum would be 5 within the search area, the quality indicator value would become (2.8-min)/(max-min)=(2.8-2)/(5-2)=0.27. This method applies to all benthic data for each individual indicator. Alternatively, one could use the min and max from the entire Dutch Continental Shelf (DCS), for example with a min of 1 and a max of 5, resulting in a value of (2.8-1)/(5-1)=0.45. However, in this process we are looking for differences between variants for closed areas within the search area and not within the DSC. By comparing within the variants, the differences between the variants will be more pronounced than comparing on a DSC scale.

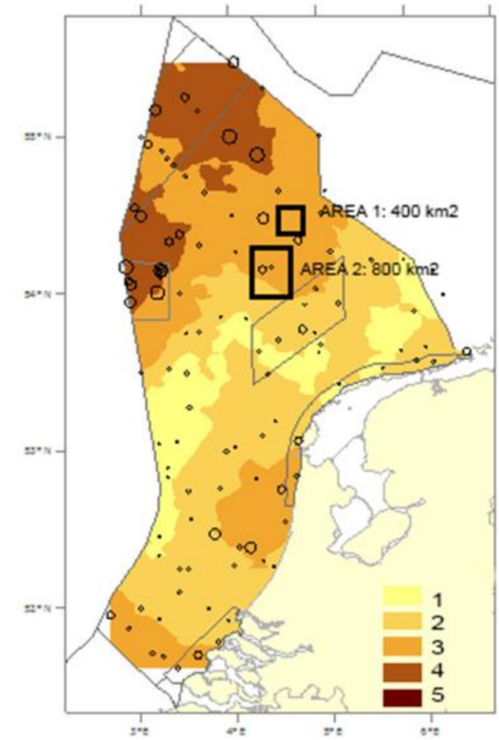

Figure 4.2 *Example of biodiversity value calculation*
Source: IMARES.

4.2.3 Step 3 Weighting factors

Within the ecopoint calculation, weighting factors are applied to express the relative importance of a habitat related to the preservation of national biodiversity (Van Gaalen *et al.*, 2014). The way to express weighting factors is however different among various studies.

The expression of rarity of a habitat is commonly used as a weighting factor. Within the application of this type of weighting factor, the biodiversity of rare habitats is considered more important than that of common habitats. In the studies of Sijtsma *et al.* (2009) and Liefveld *et al.* (2011), rarity of habitats was used as a weighting factor. They scaled rarity of a habitat level of the Dutch Continental Shelf (DCS), resulting in higher weighting factor for the rare habitat type ‘gravel’ compared to habitat fine sand which is much more common.

In our study we propose several other weighting factors that each express different aspects of relative importance of habitats and ecosystems, based on the characteristics stated in Section 4.1.3.

To express the relative importance of the different benthic ecosystems and habitats, the different subareas had to be evaluated on their significance in this respect. All variants comprise subareas that relate to one or two distinct subareas, the Frisian Front, and the Central Oyster Grounds.

Within the North Sea, the Frisian Front area has been judged to be ecologically more valuable than the Central Oyster Grounds (Jongbloed *et al.*, 2013; Lindeboom *et al.*, 2015), because of its relative higher production, higher bioturbation, greater connectivity due to the presence of a frontal area, as well as a higher potential for recovery after closure for fisheries compared to the Central Oyster Grounds (Jongbloed *et al.*, 2013). Definition of additional weighting factors to reflect the ecosystem of the Central Oyster Grounds was debated but found not relevant. The Central Oyster Grounds in itself is a relevant benthic ecosystem, but compared to the Frisian front ecosystem less unique in the North Sea (Lindeboom *et al.*, 2015).

Some weighting factors emphasise more or less the same aspects, and differ only in detail. This seems redundant, but is not the case. As each weighting factor is applied individually, no redundancy exists: it is either factor A or B, not both. The choice for a certain weighting factor will depend on the policy ambition. For example, if the ambition is to close a large single area versus several smaller areas, then the decision maker should look at the results of the corresponding weighting factor. Furthermore, no combinations of weighting factors are applied in this study to be able to compare them independently, except for factor 5 which includes gradient and front together (see Figure 4.3). Also, multiplying different factors would result in redundancy.

The different weighting factors express not only the overall score of a variant, but can be used to evaluate the importance of one subarea over another.

4.2.3.1 Step 3a Selection of weighting factors

The weighting factors are grouped into the following categories (additional details and calculation are explained in 4.2.3.2 and Figure 4.3):

- Generic weighting factors including weighting factors based on habitat rarity (following Sijtsma *et al.*, 2010 and Liefveld *et al.*, 2011) and habitat diversity in general. Weighting factors 1 and 2 highlight the variants with a lot of rare or diverse habitats and are explained in more detail below
- In addition, weighting factors are included that take the ‘border effect’ into account (see Section 4.2.3.2, weighting factor 3, following Lindeboom *et al.*, 2015). Decision makers can choose to use these weighting factors if they want to be able to compare e.g. the value of one larger area versus several smaller areas.
- Weighting factors emphasising the frontal area and gradients within this area. The emphasise on the frontal area follows from the arguments by Lindeboom *et al.* (2015) in which it is described how and why the frontal area could be evaluated as ecological more significant than other regions in the North Sea. The weighting factors from this category apply to all subareas but will favour those subareas positioned within the Frisian Front region.
- Weighting factor reflecting the density of artificial hard substrate within variants. This weighting factor is proposed in the stakeholder process, and is assumed to be a proxy for biodiversity. This weighting factor benefits the variants with higher density of artificial substrates. A rationale regarding this weighting factor is included in section 4.4.3.2.
- Weighting factor in which fisheries pressure within a variant is used as a proxy for benthic habitat damage due to fisheries and potential habitat recovery when fisheries would be excluded. Based on the rationale that fishing pressure negatively relates to benthic biodiversity (see section 4.4.1). This weighting factor benefits variants with high fisheries pressure over variants with lower fisheries pressure based on the assumption that the higher the current pressure, the larger the recovery can be.

The weighting factors are summarised below and described in more detail in the following section (Section 4.2.3.2).

Generic weighting factors:

- Weighting factor 1: rarity of habitats (average rarity of habitats within area)
   - *This basic method (Liefveld et al., 2011) allows to select for variants that have more rare habitats than others and thus better contribute to the maintenance of the overall biodiversity.*
- Weighting factor 2: diversity of habitats (N habitats/ area)
   - *This factor selects for the variants with the highest habitat diversity (all habitats count evenly)*

Weighting factors emphasising the net effective area (larger over smaller and border effects):

- Weighting factor 3a: border effect (border/area of an area relative to that of a circle)
  - *This factor selects for fewer larger areas over more smaller areas, in order to compensate for ineffective protection: A single large area will have less a border length than multiple small areas of the same size (for details see below) and is more effective in its net protection compared to smaller areas (Lindeboom et al., 2015).*
- Weighting factor 3b: effective area (effective area relative to that within a buffer of 1 km around
  - *Similar to 3a, with the additional ecological motivation that benthic fauna may migrate to outside the area, so that a buffer zone is needed to protect them efficiently.*

- Weighting factor 3c: effective area (effective area relative to that within a buffer of 2,5 km around)
  - *Similar to 3a, with an additional ecological motivation (larger buffer zone)*

Weighting factors emphasising frontal area and gradients:

- Weighting factor 4a: importance of central front within the FF expressed by the central front system (% of 20% silt area within subarea) (rationale in Lindeboom *et al.*, 2015).
  - *This factor selects for variants that are located in the centre of the Frisian Front, the central and most silty part.*
- Weighting factor 4b: importance of FF expressed as influenced ecosystem around the central front system (% Frisian Front parallelogram within closed area) (rationale in Lindeboom *et al.*, 2015)
  - *This factor selects for variants that are influenced by the central front in the Frisian Front, i.e. located in the Frisian Front area as defined in Lindeboom et al. (2005)*
- Weighting factor 5a: importance of abiotic gradients (max N habitats within highest scoring subarea within parallelogram Frisian Front)
  - *This factors selects for variants that are within the Frisian Front and contain a gradient (nature types)*
- Weighting factor 5b: importance of benthic gradients (max N connected benthic zones within Frisian Front)
  - *Similar to 5a. This weighting factor selects for variants that cover a gradient in silt content, corresponding to benthic zones (see below)*
- Weighting factor 5c: importance of benthic gradients including the front (max N connected benthic zones within Frisian Front- including the front)
  - *Similar to 5b. This weighting factor selects for variants that are located in the central part of the Frisian Front, and that cover a gradient.*

Weighting factor emphasising the presence of artificial hard substrates

- Weighting factor 6:
  - *This factor reflects the relative abundance of artificial hard substrate located based on the number of wrecks and oil and gas facilities providing substrate for organisms to settle on.*

Weighting factor reflecting fisheries pressure and potential recovery

- Weighting factor 7:
  - *This factor reflects the potential recovery of the benthic ecosystem within a variant based on the fisheries pressure (in fishing days- see Table 5.5)*

4.2.3.2 Step 3b. Calculation of weighting factors

Figure 4.3 presents each of the weighting factors and their differences. Thereafter, for each weighting factor the calculation method is described.

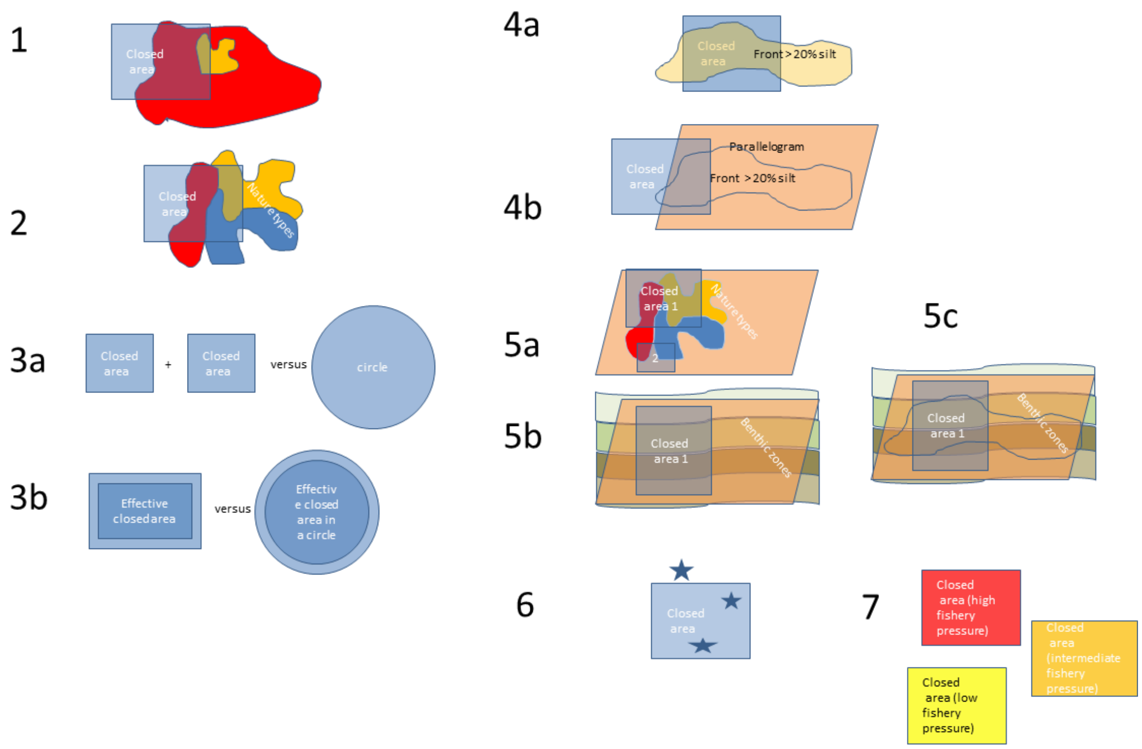

Figure 4.3 *Graphic representations of the weighting factors. Left: generic weighting factors, right: weighting factors emphasising the frontal area and gradients and hard substrate*
Source: IMARES.

Generic weighting factors

Weighting factor 1: Habitat rarity

This weighting factor takes into account the rarity of the habitats on the DCS, where the protection of rare habitats is considered more important than the protection of common habitats (according to Sytsma *et al.*, 2009 and Liefveld *et al.*, 2011). The rationale is that rare habitats contain a different biodiversity than more generic habitats and should be included in protected areas. The habitat types used in this weighting factor are the 'nature types' (Bos *et al.*, 2011), consisting of combinations of depth classes (0-10 m, 10-20, 20-30, 30-40, >40), sediment size classes (<150 um, 150-210; 210-420; >420), absence/presence of silt (>15%), absence/presence of stratification. This weight indicator 'Presence of rare habitats' is expressed as the average rarity based on the nature type map published in Bos *et al.* (2011) where rarity is defined as (1-occurence) (see Appendix 2). In this way, a rare habitat type will be given a greater importance than a common habitat type. For example, if a habitat type covers 5% of the DCS, the rarity is (1-0.05)=0.95. The data were thereafter scaled based on the minimum and maximum values related to this indicator. The most common habitat type in the Dutch North Sea is sandy sediment, which covers 28% of the seafloor (rarity = 1-0.28=0.72). In this example rarity is scaled on a scale ranging from 0.72 (which is the min) to 1 (which is the max).

For example, a closed area consists of 20% of habitat type A and 80% of habitat type B. The coverage of habitat type A at the DCS-scale is 5% (or 0.05) (rarity value: 1-0.05=0.95) and of habitat B is 25% (rarity value of 0.75). The rarity values are first rescaled between the minimum (0.72) and the maximum (1). Thus the rarity of habitat type A becomes (0.95-0.72)/(1-0.72))=0.89. Of type B: (0.75-0.72)/(1-0.72))=0.11. Then the weighting factor becomes 20%*0.89+80%*0.11=0.73.

Weighting factor 2: Habitat diversity

Weighting factor 3 takes into account the diversity of habitats within a closed area, where multiple habitats ('nature types' based on Bos *et al.*, 2011. See Appendix 2) are preferred over a single one. The assumption is that a combination of different habitats potentially results in higher biodiversity than a single habitat. It is expressed as the number of nature_types (combinations of depth, sediment size, absence/presence of silty, absence/presence of stratification) to express the importance of protecting a range of different habitats. For example, if a closure contains 3 different nature types, and the maximum number of nature types present within the searching area (see map) is 15, then the weighting factor is 3/15=0.2.

Weighting factors emphasising the net effective area (larger over smaller and border effects)

Weighting factor 3: Border effect

Weighting factors 3a and 3b stress the importance of creating a single marine protected area rather than a number of smaller ones with the same area. The rationale is that benthic species are mobile to a certain extent and could therefore crawl or swim out of the closed area (Lindeboom *et al.*, 2015). A single large area will have less a border length than multiple small areas of the same size, and animals are less affected by the border in larger areas than in smaller areas. To calculate this weighting factor, three approaches are provided (3a, 3b, 3c).

Weighting factor 3a: Border effect: relative ratio of circumference (km) and area (km^2)

One possibility is to compare the total circumference (km) of the subareas with the smallest circumference possible for that same area, i.e. with the perimeter of a circle (see Figure 4.3). The circumference of the subareas is obtained from the GIS maps. The circumference of a circle with the same area (km^2) is derived from: area circle = $\pi * r^2$ = area of closed area. Hence, r= √(closed area (km^2)/π) and the smallest possible circumference becomes 2*π*r=2*π*√(closed area (km^2)/π). The ratio then becomes: (circumference circle)/(circumference area). The higher the ratio, the better.

For example, if a closed area of 1,200 km^2 consists of 3 square subareas of each 20x20=400 km^2, the total length of the border is 3x4x20=240 km. A circle with a surface of 1,200 km^2 would have a radius of 19.5 km and a border of 2*19.5*pi=122.8 km. The ratio would be 122.8 km/240km=0.51. A similar exercise using 2 subareas of 20x30=600 km^2 instead, would yield 2x(20+20+30+30)=200 km of border, leading to a ratio of 122.8/200=0.61. A single square area of 30x40 km would yield a ratio of 122.8/(30+30+40+40)=0.88. This weighting factor is not rescaled. For each variant and subarea this ratio is calculated based on its actual size and dimensions. The higher the ratio, the less border (km) per unit surface (km^2), thus the more effective the variant is.

Weighting factor 3b: Relative effective protected area (km^2) (1 km buffer zone)

Another relatively simple way to express the importance of a single area over multiple areas is to compare the variants in terms of effectively closed area (km^2) (see Figure 4.3). The rationale is that the smaller the protected area, the larger the chance that mobile benthic species can move out of the area. The effective closed area would then be the closed area minus a buffer zone of a certain distance, above which benthic species are not likely to crawl out of the protected area. For this weighting factor, we used a buffer zone of 1 km (based on the rational in Lindeboom *et al.*, 2015).

For example, if benthic fauna would travel a maximum distance of 1 km, then the effective area for a single area having an area of 30x40 =1,200 km^2, is (30-2*1)*(40-(2*1))= 28*38=1,064 km^2. This area loss (1,200-1,064= 136 km^2) is then compared to the area loss if the area were a circle. This number can then be compared to the circle of 1,200 km^2, with a radius of sqrt (1,200/pi)=19.54 km, with an effective area of (19.54-1)^2 *pi=18.54^2*pi=1,080 km^2. The ratio would then be 1,064/1,080 = 0.985, which means that 98.5 % is protected in comparison with a circle with the same surface. However, if 3 areas of each 20x20=400 km^2 are compared, using the same buffer zone of 1 km, the effective closed area becomes much smaller: 3*(20-2*1)*(20-2*1)=3*18*18=972 km^2. The ratio then becomes 972/1080=0.90, meaning that 90% is protected, in comparison to a circle.

Weighting factor 3c: Relative effective protected area (km^2) (2.5 km buffer zone)

Same as previous weighting factor, but then with a buffer zone of 2.5 instead of 1 km. If the zone is increased to 2.5 km, the maths for the example with the 3 subareas of each 20x20 km becomes: 3*(20(2*2.5)*20*(2*2.5))=3*15*15=675 km^2 for the closed areas versus (19.54-2.5)^2*pi=17.04^2*pi=912 km^2 for the circle. The ratio then becomes 675/912=74%.

Weighting factors emphasising frontal area and gradients:
Within the search area for FF and CO, the presence of a front is a unique feature, which ensures high biodiversity. On an international North Sea scale, the habitat type EUNIS A5.35 (circalittoral sandy mud) is special, and more unique than e.g. A5.25 (circalittoral fine sand). On a DCS scale, the differences within the area become apparent. This diversity of habitat types is addressed in weighting factors 1 and 2. However, an additional unique feature within the search area is the presence of a front. The following weighting factors therefore concentrate on the presence of fronts.

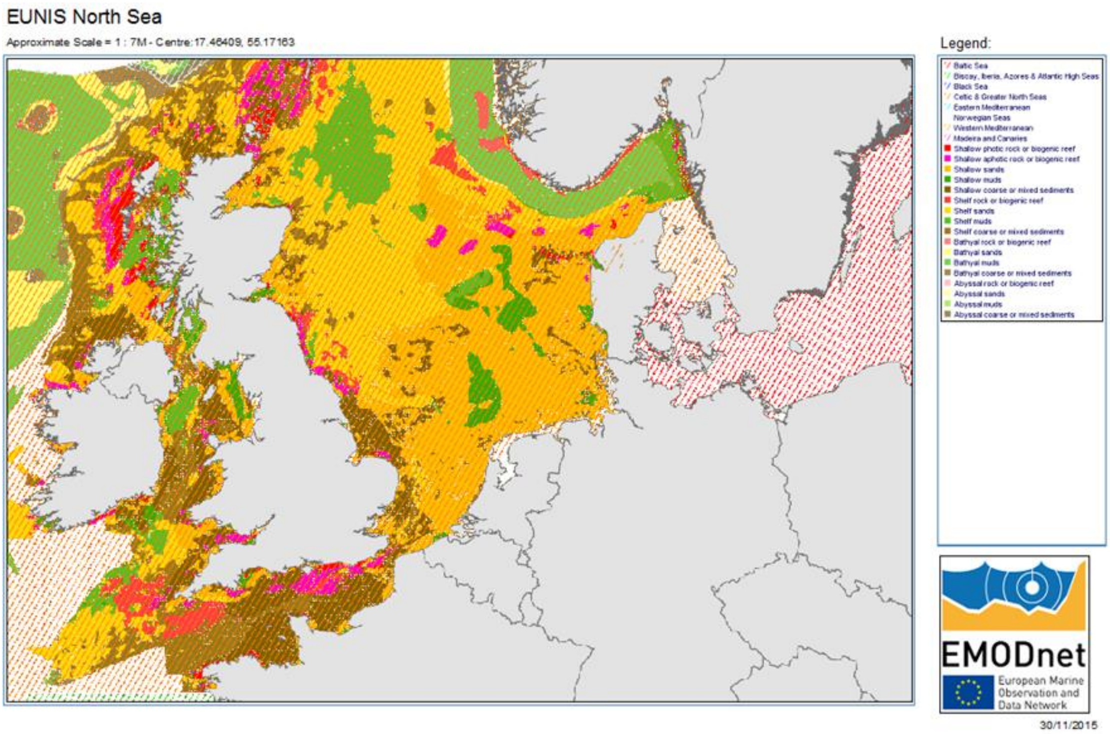

Figure 4.4 *EUNIS habitat types, with 'shelf muds' indicated in green*
Source: EMODnet.

Weighting factor 4a: Importance of Frisian Front (inclusion of core area of 20% mud)
The first weighting factor considers the extent to which a variant includes part of the front system- being the core area of the Frisian Front. The rationale is that from an ecosystem point of view, the front is an important area and should be included in the protected area. This 'presence of front system' can be expressed as percentage of the area covered by the front system defined by the presence of >20% silt, according to the map published by De Bree *et al.* (1991) (Appendix 2). The maximum area containing >20% silt is 748.42 km^2. For example, if 55% of the silty area is covered by the closed area, the weighting factor is 0.55. If a the silty area is not covered, the weighting factor is 0.

Weighting factor 4b: Importance of Frisian Front (inclusion of FF ecosystem delineated by parallelogram)
The rationale for this weighting factor is that from an ecosystem point of view, the front and its surrounding area is an important area and should be included in the protected area. The area of the FF (the parallelogram) represents the larger ecosystem influenced by the front area (factor 1). The weighting factor can be calculated by expressing how much of the Frisian Front (parallelogram) is included in the variant. For example: if 80% of the closed area is covered by the parallelogram, the weighting factor is 0.8. If 100 % is covered, the factor is 1. Connectivity within the Frisian Front is *not* included in this weighting factor (see factors 5).

Weighting factor 5a. Importance of abiotic gradients
The rationale for this weighting factor is that the front is the most important ecosystem within the search area, and that within the front it ecologically assumed to be of importance to protect a continues gradient, based on Lindeboom *et al.* (2015).

First, the number of nature types within the Frisian Front parallelogram within a subarea are counted. Next, the score of the subarea containing most nature types is taken to calculate a weighting factor. We have calculated the maximum number of connected nature types and not the average number of nature types, since the weighting factor should express the maximum gradient, in terms of the number of connected nature types. Averaging would results in less interpretable results. The score is scaled by using the minimum (0) and maximum number of nature types (14) that can be enclosed within the parallelogram.

For example, if subarea number 1 is located within the parallelogram, and contains 4 nature types, and if subarea number 2 is half located in the parallelogram, and contains 2 nature types, the score of 4 is taken for further calculations, because this is the maximum number of connected nature types Next, the weighting factor is calculated as: (4-min)/(max-min)=4/(14-0)=0.29. The maximum of the weighting factor is 1, the minimum is 0 (see Figure 4.3)

Weighting factor 5b. Importance of benthos gradients
This weighting factor is calculated by counting the number of zones (Creutzberg *et al.*, 1984) within a subarea within the parallelogram (see Appendix 2). The zones have been found by Creutzberg *et al.* (1984) to represent distinct benthic zones and are situated in parallel. The difference with the previous factor is that these zones are based on mud content, while the nature types include more abiotic characteristics (see glossary). The rationale is that the front is the most important ecosystem within the search area, and that within the front it is important to protect a continues gradient. These zones reflect the change in mud content and each zone more or less coincides with peaks of certain species. The weighting factor is based on the maximum number of connected zones within the Frisian Front parallelogram. The rationale for including a continuous gradient is provided in Appendix 13. The score is obtained by counting the zones from the map. The weighting factor is calculated by scaling the score between the minimum (0) and maximum (8) number of benthos zones, yielding a number between 0 and 1.

For example, if a closed area consists of 2 subareas, and subarea number 1 covers 2 benthos zones, while subarea number 2 covers 4 zones, then the score is 4. The weighting factor becomes 4/(max-min)=4/(8-0)=0.5.

Weighting factor 5c. Importance of benthos gradients
Same as 5b, but in this case it is obligatory to include the core of the front (20% mud) as the centre of the gradient.

Weighting factor emphasising the presence of artificial hard substrates
Weighting factor 6. Artificial hard substrate
This weighting factor is suggested by stakeholders. The rationale is that artificial hard substrate provides substrate for organisms to settle on. It is assumed that the more artificial hard substrate a variant has, the higher the biodiversity can be. The factor is calculated by counting all artificial hard substrata objects (wrecks and oil/gas facilities) within the variants.

Wreck positions are retrieved from the website http://www.wrecksite.eu. The retrieved dataset includes a total of 16,726 wrecks in the North Sea, of which 180 lay within the various variants. Based on NLOG datasets[3] which provide positions of oil and gas facilities in the North Sea, the number of facilities is counted per variant. A total of 38 facilities are positioned within all variants together. The sum of number of wrecks and oil and gas facilities per variant is taken as the total number of

[3] http://www.nlog.nl/nl/mappingDatasets/mappingDatasets.html retrieved on November 17 2015

artificial hard substrata. The number is then divided by the total surface of the variant to obtain the density. Next, the weighting factor is scaled between 0-1 based on the density range that was theoretically possible (min = 0, max = highest density within search area (max total number of hard substrate items (218)/lowest possible surface (1,204 km^2)).

Maps of both wreck and oil and gas facilities are presented in Appendix 2.

Weighting factor reflecting fisheries pressure and potential recovery

- Weighting factor 7: Fisheries pressure
  This factor reflects the fact that the present ecosystem is already heavily influenced by fisheries. Duineveld et al. showed that the impact of bottom trawl fisheries depends on the fishing intensity. This is different for the different scenario's and therefor a weighing factor taking this into account was introduced. At the same time if a heavily influenced area is closed to fisheries the potential recovery of the benthic ecosystem is higher. Both effects were taken into account within a variant based on the fisheries pressure (in fishing effort in days- see Table 5.5). The weighting factor is calculated as the proportion of the maximum pressure: the maximum fishing pressure of 0.12 gives a weighting factor of 1, the fishing pressure of 0.8, being 67% becomes 0.67, etc.

4.2.4 Step 4 Calculation of ecopoints

Ecopoints are expressed in two ways:

- per km^2 (quality x weighting factor) per (total) variant and subareas to obtain a weighted ecopoint value /km^2 (since size difference largely and steers outcome). Total score is calculated on the whole/total area, following the methodology as described above. It is not a sum nor an average of the subareas.
- per area (area/100* quality* weighting factor) per variant and subareas to obtain the total amount of ecopoints, according to the formula shown in Section 4.2. This method follows descriptions in Liefveld *et al.* (2011). By dividing the area (km^2) per variant by 100, the multiplication factor is in the same order of magnitude as the sum of the quality indicators, which range from 3.72 to 5.08 (see Table 4.2). For example, if a variant would have a total area of 1,200 km^2, the multiplication factor becomes 1,200/1,00=12. This number is in the same order of magnitude as the total sum of the quality factors. The total score is calculated on the whole/total area, following the methodology as described above. It is not a sum nor an average of the subareas.

4.2.5 Step 5 Test of the robustness/sensitivity of the analysis

To test the influence of each contributing element to the outcome, a sensitivity analysis can be performed. In this study, a sensitivity analysis is not done by means of statistical analysis, but based on minimum and maximum ranges. Of each quality factor, weighting factor, and area factor the range between minimum and maximum ecopoint value across the different variants is presented, including the factor describing the effect of this range. For example, Abalone has a surface of 1,204 km^2, while Flounder has a surface of 6,339 km^2 (see Table 3.1). This means that, based on surface area alone, the smallest variant already scores (6,339/1,204=) 5.26 times lower than the largest variant. In the same way, the quality factor and the weighting factor are evaluated. The set of quality indicators accumulate into one quality value, which all add to the final quality indicator. Also these individual contributions are evaluated. An overview of these ranges and factors is presented in the results section.

In addition, the scores of each subarea provide insights on how the weighted score of the overall variant is a result of similar scores of the subareas, or that large differences between the subareas are present. That is why all subarea values are presented as well to be transparent on the subvalues, resulting in a weighted average total score for each variant.

4.3 Results Ecopoints

In this section, the results per calculation step of the ecopoint calculations are presented in tables and figures. In Chapter 4.5 the meaning of the results is discussed. In Appendix 4, the scores for the subareas are presented.

4.3.1 Step 1. Area quantity

In Table 4.1, the area quantity per variant and per subarea is presented. This information is used for the ecopoint calculation (step 4). The total surfaces are divided by 100 (see Liefveld *et al.*, 2011) in order to obtain values in the same order of magnitude.

Table 4.1
Area quantity per variant and per subarea (km^2)

Variant [1]	Variant code	Subarea coding	Surface area (km^2)
Abalone	A	FF	800
Abalone	A	CO	404
Total			1,204
Brill	B	CO	207
Brill	B	FFSW	632
Brill	B	FFSE	319
Brill	B	FFC	105
Total			1,263
Capelin		FFSW	398
Capelin	C	FFSE	398
Capelin	C	FFNO	398
Capelin	C	CO	404
Total			1,597
Dab	D	CO	304
Dab	D	FFSW	772
Dab	D	FFSE	501
Dab	D	FFC	105
Total			1,683
Eel	E	FFSE	700
Eel	E	FFSW	1,050
Eel	E	COS	1,050
Eel	E	CON	1,406
Total			4,206
Flounder	F	FF	2,882
Flounder	F	CO	3,457
Total			6,339

Source: Ministry of I&M.

4.3.2 Step 2. Area quality indicators

In Table 4.2 the biodiversity quality indicator are shown for the 6 variants, per subarea and for the total area. These values are calculated on the basis of maps, as explained in Section 4.2.2. and represent different aspects of species biodiversity. Rarity' is set at 0 for the indicators because rarity is strongly correlated with species richness.

Table 4.3 shows the rescaled values to a value between 0 and 1 for the quality indicators. Figure 4.5 presents an overview of the summed quality for each variant. The highest possible score was 9. The overall quality score for these variants ranges from 3.74-5.08. Overall, Flounder represents the highest quality score, and Brill lowest.

Table 4.2
Area quality indicators

Variant	Macrobenthos							Megabenthos			
	biomass	evenness	large_species	long-lived species	species richness	rarity	density	biomass	density	rarity	richness
Abalone	5.33	4.31	5.43	5.16	7.01	2.18	5.62	5.88	6.62	4.99	6.54
Brill	5.72	4.10	4.66	3.56	5.25	1.98	5.75	5.24	5.41	3.57	5.20
Capelin	5.30	4.35	5.55	4.99	6.77	2.23	5.78	5.46	6.80	5.28	7.25
Dab	5.71	4.04	4.75	3.73	5.43	2.00	5.90	5.41	5.60	3.74	5.41
Eel	5.11	4.33	5.62	5.88	7.06	2.53	5.72	4.58	5.50	5.07	6.51
Flounder	5.00	4.40	5.86	6.09	7.69	2.60	5.45	4.62	6.57	5.81	7.63
Min	4.00	3.00	4.00	2.00	2.00	1.00	4.00	2.00	1.00	2.00	3.00
Max	7.00	6.00	7.00	9.00	9.00	4.00	8.00	8.00	9.00	9.00	9.00

Table 4.3
Re-scaled values of quality indicators

Variant	Macrobenthos							Megabenthos				
	biomass	evenness	large_species	long-lived species	species richness	rarity	density	biomass	density	rarity	richness	sum area quality
Abalone	0.44	0.44	0.48	0.45	0.72	0	0.40	0.65	0.70	0	0.59	4.87
Brill	0.57	0.37	0.22	0.22	0.46	0	0.44	0.54	0.55	0	0.37	3.74
Capelin	0.43	0.45	0.52	0.43	0.68	0	0.44	0.58	0.73	0	0.71	4.96
Dab	0.57	0.35	0.25	0.25	0.49	0	0.47	0.57	0.57	0	0.40	3.92
Eel	0.37	0.44	0.54	0.55	0.72	0	0.43	0.43	0.56	0	0.59	4.64
Flounder	0.33	0.47	0.62	0.58	0.81	0	0.36	0.44	0.70	0	0.77	5.08

Table 4.3 shows the rescaled values for the quality indicators (see Section 4.2.2). The final quality is the sum of the 9 different biodiversity indicators.

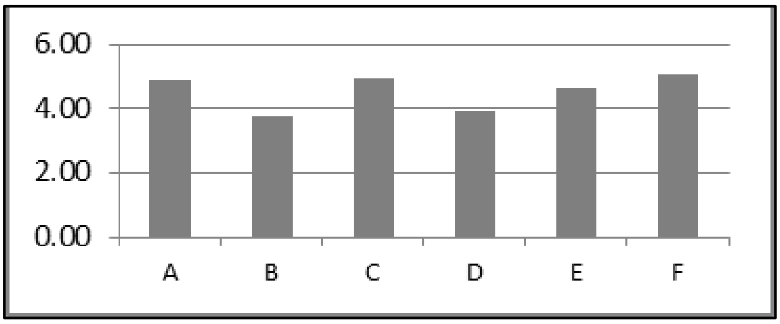

Figure 4.5 *Quality of each variant (sum of 9 scaled biodiversity indicators)*

4.3.3 Step 3. Weighting factors

In Table 4.4 the weighting factors are presented as original - not scaled values. The factors are scaled to a value between 0 and 1 (see methodology in Section 4.2.2.2). The scaled values are presented in Table 4.5 and Figure 4.6.

Remarks regarding the total scores corresponding to each of the weighting factors:

- 1. habitat rarity: rarity of the total area (not average of subareas, nor sum of subarea)
- 2. N habitat: total per area = number unique habitat types in total area
- 3a. relative border: total is compared to circle. NB subareas are compared to subcircles
- 3b. Effective protect.-1 km: total is compared to circle with same area (km^2) minus 1 km buffer zone
- 3c. Effective protect.-2.5km: total is compared to circle with same area (km^2) minus 2.5 km buffer zone
- 4a. 20%FFmud: total per area = sum of subareas
- 4b. %FFparallelogram: total per area = sum of subareas
- 5a. Abiotic gradients: Total is max within subareas
- 5b. Benthic gradients: Total is max within subareas
- 5c. Gradients including centre: Total is max within subareas
- 6. Artificial hard substrate: total number of artificial hard substrate/km^2
- 7: fisheries pressure: fishing effort in days/km^2

Overall, the highest weighting factors are related to the factors representing the ecological significance of the Frisian Front (4 and 5). Flounder, Eel and Abalone qualify for the highest weighting factors (factor of 1), whereas Brill and Dab qualify for the lowest factors.

Taking into account the generic weighting factors (1-3), it depends largely on the specific weighting factor which variant qualifies for highest or lowest factor.

Table 4.4

Weighting factors, original values (see Section 4.2.2.2 for method)

Variant	1. habitat rarity	2. N habitats	3a. relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Artificial hard substrate	7. Fishery pressure
Abalone	89.91	9	56%	92%	78%	25%	20%	8	8	8	0.02	0.12
Brill	81.57	9	38%	84%	58%	13%	5%	4	3	3	0.06	0.08
Capelin	91.63	11	41%	87%	67%	12%	35%	6	5	4	0.03	0.12
Dab	82.86	15	38%	86%	63%	13%	6%	4	3	3	0.05	0.08
Eel	92.13	15	44%	93%	82%	35%	31%	8	8	8	0.02	0.09
Flounder	94.41	14	55%	96%	90%	100%	100%	14	8	8	0.02	0.12

Table 4.5 shows the rescaled values of Table 4.4, according to the methods described in Section 3.2.3.2. The minimum and maximum values of the weighting factors shown in Table 4.5 are used to scale the weighting factors between 0 and 1.

Table 4.5
Scaled weighting factors (see Section 4.2.2.2 for method)

Variant	1. habitat rarity	2. N habitats	3a. relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Artificial hard substrate	7. Fishery pressure
Abalone	0.61	0.57	0.63	0.83	0.55	0.25	0.20	0.57	1.00	1.00	0.28	1.00
Brill	0.29	0.57	0.43	0.67	0.15	0.13	0.05	0.29	0.38	0.38	1.00	0.67
Capelin	0.68	0.71	0.46	0.74	0.35	0.12	0.35	0.43	0.63	0.50	0.43	1.00
Dab	0.34	1.00	0.43	0.71	0.26	0.13	0.06	0.29	0.38	0.38	0.81	0.67
Eel	0.70	1.00	0.50	0.86	0.65	0.35	0.31	0.57	1.00	1.00	0.35	0.75
Flounder	0.79	0.93	0.61	0.92	0.81	1.00	1.00	1.00	1.00	1.00	0.28	1.00

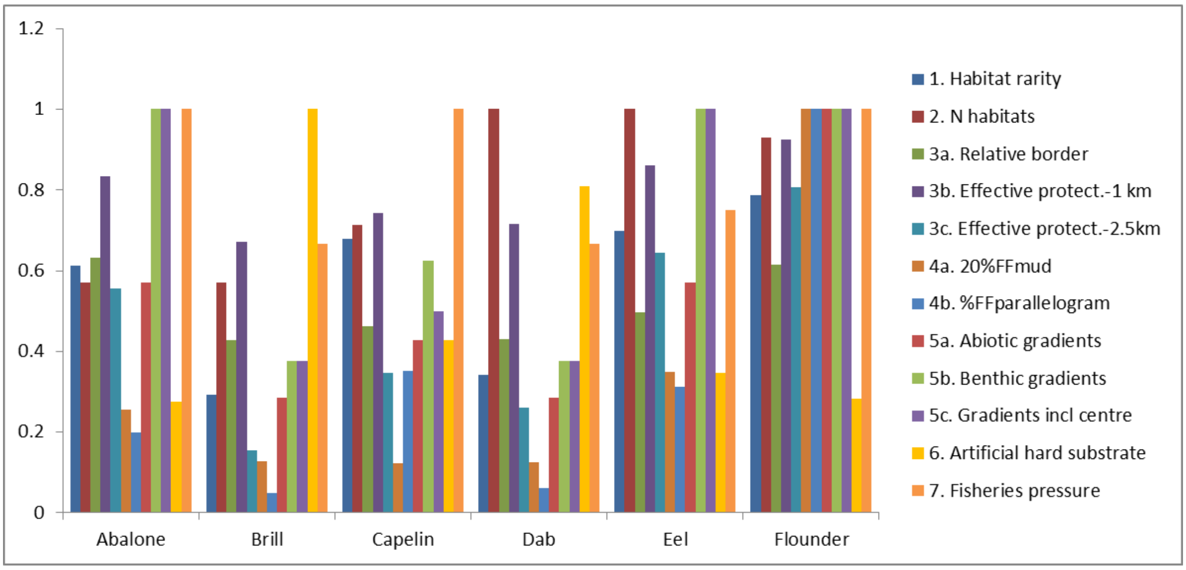

Figure 4.6 *Visual presentation of the scaled weighting factors for each variant*

4.3.4 Step 4. Ecopoints

First the ecopoints per km^2 are shown in Table 4.6. These numbers are obtained by multiplying the quality factors with the weighting factors as explained in Section 3.2.4, resulting in ecopoints per km^2.

In the next table, these numbers are multiplied with the area.

Overall, Brill and Dab score lowest in ecopoints, and Flounder scores highest. The way of expression (per km^2, of per variant) does not influence this result (see overview in Table 4.7B).

Table 4.6
Calculated ecopoints per km^2 for each variant, depending on the applied weighting factor

Variant	0. no weighting factor	1. habitat rarity	2. N habitats	3a. relative border	3b. Effective protect.-1 km	3c. Effective protect.- 2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery pressure
Abalone	4.87	2.98	2.78	3.07	4.06	2.70	1.24	0.97	2.78	4.87	4.87	1.34	4.87
Brill	3.74	1.10	2.14	1.61	2.51	0.58	0.48	0.19	1.07	1.40	1.40	3.74	2.50
Capelin	4.96	3.37	3.55	2.29	3.69	1.73	0.62	1.74	2.13	3.10	2.48	2.12	4.96
Dab	3.92	1.34	3.92	1.69	2.80	1.02	0.49	0.24	1.12	1.47	1.47	3.18	2.61
Eel	4.64	3.24	4.64	2.30	3.99	2.99	1.62	1.45	2.65	4.64	4.64	1.61	3.48
Flounder	5.08	4.00	4.72	3.12	4.70	4.09	5.08	5.08	5.08	5.08	5.08	1.44	5.08

In Table 4.7A, the ecopoints are calculated, according the formula (area/100) x quality x weighting factor (see Section 4.3.4). In Table 4.7B the ranking of the ecopoints is shown (1=lowest, 6=highest)

Table 4.7A
Calculated ecopoints for each variant, depending on the applied weighting factor

Variant	0. no weighting factor	1. habitat rarity	2. N habitats	3a. relative border	3b. Effective protect.- 1 km	3c. Effective protect.- 2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery pressure
Abalone	59	36	33	37	49	32	15	12	33	59	59	16	59
Brill	47	14	27	20	32	7	6	2	14	18	18	47	32
Capelin	79	54	57	37	59	28	10	28	34	50	40	34	79
Dab	66	23	66	28	47	17	8	4	19	25	25	53	44
Eel	195	136	195	97	168	126	68	61	111	195	195	68	146
Flounder	322	253	299	198	298	260	322	322	322	322	322	91	322

Table 4.7B

Ranking of calculated ecopoints for each variant, depending on the applied weighting factor

Variant	0. no weighting factor	1. habitat rarity	2. N habitats	3a. relative border	3b. Effective protect.- 1 km	3c. Effective protect.- 2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery pressure
Abalone	2	3	2	4	3	4	4	3	3	4	4	1	3
Brill	1	1	1	1	1	1	1	1	1	1	1	3	1
Capelin	4	4	3	3	4	3	3	4	4	3	3	2	4
Dab	3	2	4	2	2	2	2	2	2	2	2	4	2
Eel	5	5	5	5	5	5	5	5	5	5	5	5	5
Flounder	6	6	6	6	6	6	6	6	6	6	6	6	6

In Figures 4.7 and 4.8, the ecopoints values are presented in figures. The Y-axes represent the ecopoint value. For each variant the values of each of the 10 different calculations of ecopoints are given in bars. Figure 4.6 represents the ecopoint score per km^2, whereas Figure 4.7A represents the ecopoints per variant (including total surface). The difference between the two figures emphasises the effect of surface within the ecopoint derivation.

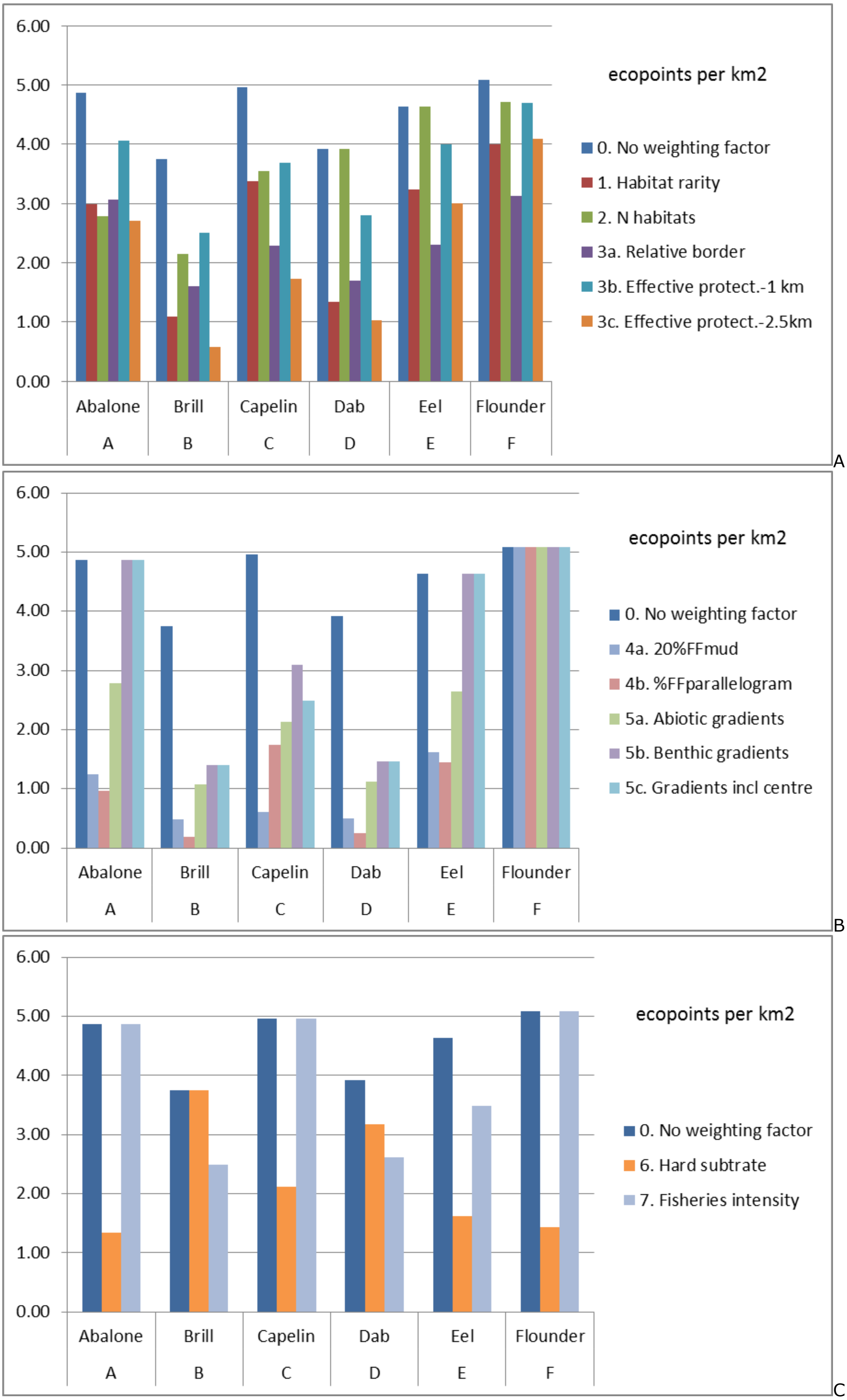

Figure 4.7 *Graphs of ecopoints per km² for each variant for the different weighting factors. A: generic factors (habitat rarity and number of habitats) and factors related to correction of border effects. B: weighting factors related to gradient and front. C: weighting factor related to artificial hard substrate and fishery pressure. Y-axis: ecopoints/km², X-axis: variants*

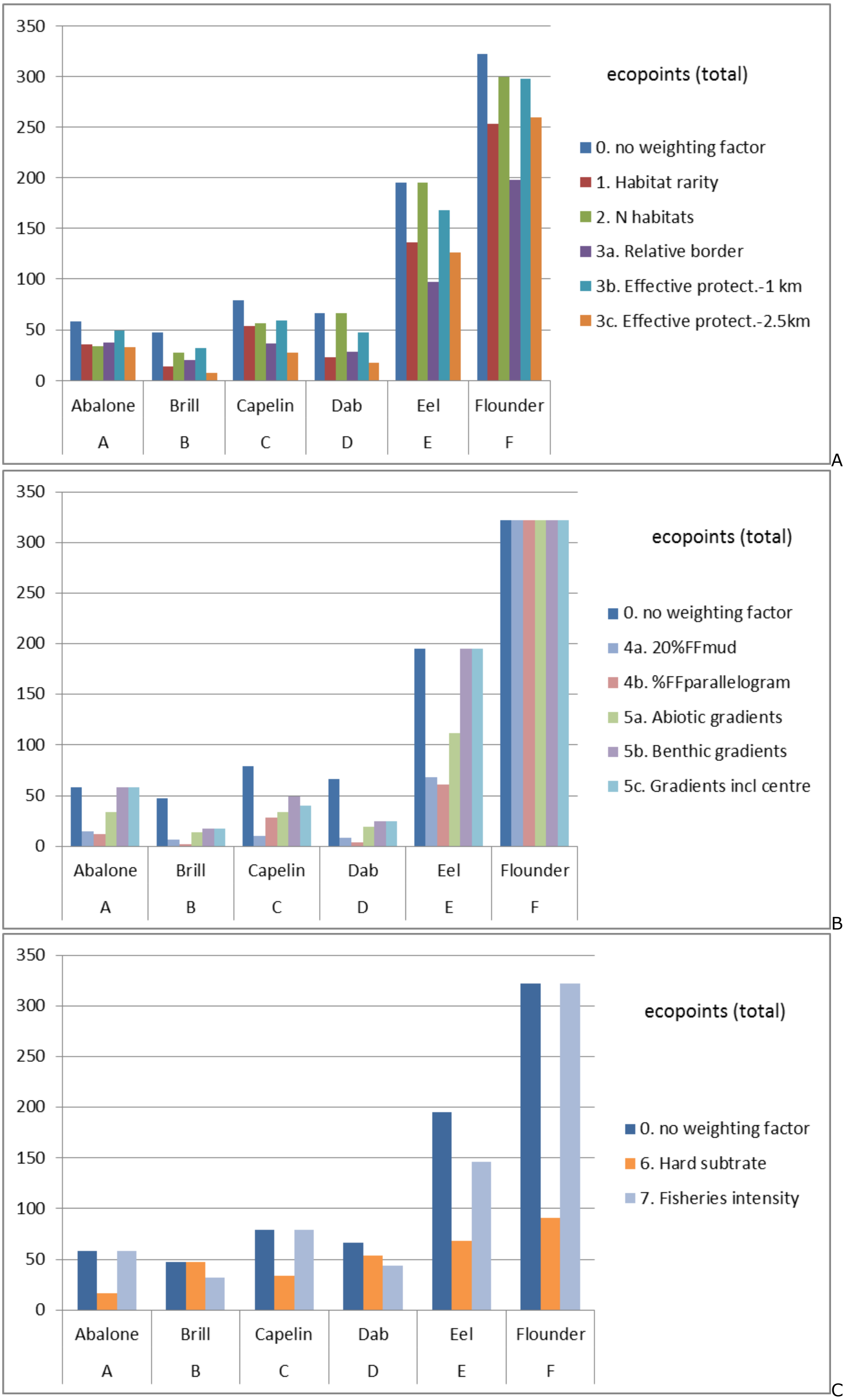

Figure 4.8 *Graphs of total Ecopoints per variant for each weighting factor. Y-axis: ecopoints, X-axis: variants. A: generic factors (habitat rarity and number of habitats) and factors related to correction of border effects. B: weighting factors related to gradient and front. C: weighting factor related to artificial hard substrate and weighting factor Fisheries pressure*

4.3.5 Step 5. Test of robustness/sensitivity

Table 4.8 provides an overview of the contribution of each quality indicator and weighting factor to the ecopoint score. From this table it becomes clear that the outcome of the ecopoint equation is largely determined by surface area (km^2) and some weighting factors. Surface area determines the score largely because it is relatively large compared to the sum of the quality indicators. The total sum of quality indicators can theoretically add up to 9 (based upon 9 indicators). In this study however, the maximum 'quality' for the subareas is 5.89 (Table 3.1). Compared to the range of values of surface area (12-63) the outcome of the equation will always be steered by area size and not by quality.

Within the selection of weighting factors, '% parallelogram' (factor 20), '% mud' (factor 8.3), and 'effective area (2.5 km border)' (factor 6.3) have the largest contribution in discriminating between variants.

Looking into detail within the quality indicators, species richness, long-lived species and large species have the largest contribution in discriminating the score.

Table 4.8
Range of scaled values (min - max) for each element in the equation (individual quality indicators, surface area and weighting factors) including the difference, and the factor min/max as an indication for contribution of each element in the equation

		Min value	Max value	Difference	Factor min/max
surface area	area size	12	63.00	51.00	5.3
Quality indicators	biomass	0.37	0.57	0.20	1.5
	eveness	0.35	0.47	0.12	1.3
	large_species	0.22	0.62	0.40	2.8
	long-lived species	0.25	0.58	0.33	2.3
	species richness	0.46	0.81	0.35	1.8
	density	0.36	0.47	0.11	1.3
	biomass	0.43	0.65	0.22	1.5
	density	0.55	0.73	0.18	1.3
	richness	0.37	0.77	0.40	2.1
	sum of quality indicators	3.36	5.67	2.31	1.7
Weighting factor	1. habitat rarity	0.29	0.93	0.64	3.2
	2. N habitats	0.57	1.00	0.43	1.8
	3a. relative border	0.43	1.00	0.57	2.3
	3b. Effective protect.-1 km	0.67	0.97	0.30	1.5
	3c. Effective protect.-2.5km	0.15	0.93	0.78	6.2
	4a. 20%FFmud	0.12	1.00	0.88	8.3
	4b. %FFparallelogram	0.05	1.00	0.95	20.0
	5a. Abiotic gradients	0.29	1.00	0.71	3.4
	5b. Benthic gradients	0.38	1.00	0.62	2.6
	5c. Gradients incl centre	0.38	1.00	0.62	2.6
	6. Artificial hard substrate	0.28	1.00	0.72	3.6
	7. Fisheries pressure	0.67	1.00	0.33	1.5

4.4 Ecosystem development: Qualitative description

4.4.1 Quality indicators: limited benthos approach

The MSFD follows the ecosystem approach and therefore it can be discussed whether the applied selection of benthic quality indicators is broad enough to assess the overall ecological benefit of the area closures. Various ecosystem components (species groups other than benthos) and ecosystem services were considered whether they could be part of the assessment (Appendix 3). These other

ecosystem aspects include the function of the area in terms of e.g. connectivity, breeding area, foraging area, or export of larvae. Connectivity within ecosystems and between ecosystems are very relevant aspects to consider.
Jongbloed *et al.* (2013) reported that the Frisian Front ecosystem is relatively more connected to other regions compared to Central Oyster Grounds due to its geographical position in combination with local currents. In general, import and export of larvae are assumed to be larger from and to the Frisian Front than to and from the Central Oyster Grounds (Jongbloed *et al.*, 2013). The studies listed in Appendix 3 did however not contain spatial biodiversity data on the level of the variants.

Since the area closures should contribute to the protection of vulnerable benthic species it would have been useful to include data on vulnerable species for both mega benthos (Triple D data), and macro benthos (box core data). However, Bos *et al.* (2011) and other studies could not provide such maps for mega benthos, making this only a Limited Benthos Approach (LBA). On the other hand, adding 1 more quality indicator to a suit of 9 indicators will probably not result in large changes in the final ecopoint calculations between the variants (see Section 4.4.3).

Closure of areas will most probably not only be beneficial to benthic species, but also to other species groups, ecological functions and ecosystem services (see Section 4.4.5). This depends on the size and position of the area. Variants habitat characteristics, and connectivity to the region are important aspects for additional benefits for e.g. fish. Data on fish were however not included, because fish are very mobile, and closed areas of relatively small sizes will in general not contribute to restoring fish populations of vulnerable species such as sharks or rays. Closed areas of > 3,600 km^2 (60 x 60 km^2) are mentioned by Bergman *et al.* (1991) to provide protection for fish. This is approximately the size of an ICES rectangle. Although included quality indicators did not contain the fish component of the ecosystem, the larger variants (Eel and Flounder, covering > 3,600 km^2) are expected to contribute to recovery or protection of some less mobile or homing fish species (maybe including rays).

4.4.2 Artificial hard substrata as proxy for biodiversity

Artificial hard substrata such as shipwrecks and oil & gas facilities contribute to the total biodiversity of a predominantly muddy or sandy area, since they provide hard substrate which attracts a different group of species. Up to 90% of the species present on shipwrecks in the Belgian part of the North Sea was found to be absent in the surrounding sandy bottom (Zintzen, 2007). Van Moorsel (2014) reviewed the species present on artificial and natural hard substrata in the international North Sea. He reports 417 species that are specific for hard substrata and concluded that these form an important part of the benthic life in the North Sea. Of these species, 113 were found exclusively on artificial hard substrata.

A relevant function of artificial hard substrata in the context of seabed protection could be that it serves as a single-point refugium, since species in the immediate surroundings are probably less affected by bottom trawling fisheries. The distance of trawling to wrecks however depends largely on the type of fisheries. Cod and seabass fisheries using trawled nets fish as close to wrecks as possible to catch fish. Fishing in the 500 m exclusion zone around oil and gas installations is prohibited and it is likely to be of low intensity around shipwrecks. Without detailed knowledge on their biodiversity, the estimated number of shipwrecks and oil and gas facilities could therefore either be used as a proxy of hard substrate biodiversity and as a proxy of the number of refugia and serve as an additional quality indicator.

A wreck's potential for contributing to biodiversity depends on many additional factors: Size, age and level of decay, vertical position (%under of above sediment, type of habitat), material (steel, wood, iron). Biodiversity data or data on the ecological function of shipwrecks in the area of interest are lacking to present better estimations. Although in 2013 the biodiversity of 10 shipwrecks was investigated (Lengkeek *et al.*, 2013) and scuba divers collected data on the biodiversity of ~100 wrecks in the North Sea in 2010-2015 (see e.g. Gittenberger *et al.*, 2013; Lengkeek *et al.*, 2013; Schrieken *et al.*, 2013; Coolen *et al.*, 2015), data in the search area are too limited for specific shipwreck biodiversity values per variant. Finally, the wrecks' status and size, which vary a great deal, are not known in detail, making it difficult to give any insight in their contribution to total biodiversity values.

The species community on various oil and gas installations is currently under study (Van der Stap *et al.*, 2016; Coolen *et al.*, 2016) and appears to be similar to that on shipwrecks (Coolen, unpublished data). However, many O&G installations also introduce hard substrata at the water surface, facilitating shallow water species such as mussels and their associated fauna. It is likely that these species would be extremely rare at offshore locations in the absence of these artificial intertidal zones.

Furthermore, although wrecks could partly be considered an artificial substitute for formerly present hard substrata such as oyster reefs, shipwrecks are currently not protected by any nature protection regulation in the Netherlands.

4.4.3 Baseline descriptions and ecosystem development after measures are implemented

As explained in the introduction (Chapter 1), appropriate model calculations to evaluate the ecological gain of measures were not available, and therefore not included in the ecopoint assessment. Autonomous developments of ecology (e.g. due to climate change, but without fishery closure measures) are furthermore difficult to assess on the level of variants, and are therefore described in a more general way. The study of Jongbloed *et al.*, 2013 and the references therein are used for the descriptions in the following section.

4.4.3.1 Ecosystem development i.r.t. continued fisheries

The North Sea ecosystem is affected by the impact of more than 100 years of bottom trawling. Limited scientific information is available to describe the 'pre-fisheries' North Sea ecosystem. Herewith, our knowledge of the North Sea status is shifting, which refers to the 'shiftig baseline' concept of Pauly, 1995).
Our reference on how the ecosystem would look like is shifted because most recent data are used in assessments, like in the derivation of ecopoints. Hence, these data reflect an already disturbed/shifted ecosystem.

The direct effects of trawl fishing is fish death (sensitivity depending on species), change in food availability and changes in habitat conditions on the benthos which ultimately results in effects on abundance and diversity of the benthic community, total biomass, secondary production and local extinction of species (Deerenberg & Heinis, 2011).
More specifically, some of the aspects are described in the following two sections on removal and impact (species) and substrate and abiotic factors.

<u>Removal and impact</u>
Benthic organisms can be caught or damaged by fishing gear. This effect is particularly affecting long-lived species, leading to a shift in the age structure to younger animals or even the complete disappearance of species that have an irregular or absent spat fall. The very long-lived species quahog (*Arctica islandica*), for example, in the period from 1902 to 1912 was found at 45% of the sampling stations in the southern North Sea, while in 1986 at only ~20% of the stations the species was observed (Rumohr & Kujawski 2000). Along the southern edge of the Frisian Front were at the end of the 80s of the last century still found reasonable numbers Arctica (Lindeboom *et al.* 2008). More recent surveys (2006-2007) in the area suggest that densities in the area have since fallen sharply (Lindeboom *et al.* 2008). Also in the central part of the Oyster Grounds the population has declined. This decline is most likely caused by increased mortality due to increased beam trawl fisheries as in the Frisian Front is the case (Lindeboom *et al.* 2008).
Sessile epifauna is generally seen as vulnerable for trawl fishing which to a large extent is a result of the dislocation of the colonized substrate by fisheries. This can lead to suffocation or suboptimal conditions because orientation to its food source or water is changed negatively. Dislocation of hard substrate in the situation without fisheries is limited to the effects of natural causes such as flow resulting from major storms.

In addition, smaller species are less impacted by fisheries than larger species which is explained by the generally slower recovery of larger species (Hiddink *et al.* 2006). The study indicates that a reduction in species diversity is primarily caused by the loss of large species. Regarding the succession and age structure of species, fisheries will result in a reset of the succession sequence to an earlier stage. The consequences can be seen in the age structure and the presence of species that are indicative of soil disturbance, ie that benefit from it (e.g. Van Kooten *et al.*, 2015).

<u>Alteration of substrate and abiotic factors</u>
The structure of the bottom substrate can be affected by the trawled gears. There are two effects to distinguish (Heinis & Deerenberg, 2011) :
• The removal of abiotic and biotic structures, such as sand ribs and biogenic reefs, so that also the related biota is affected.
• The homogenization of the soil structure.
The structure of the substrate for the slopes to the deep silty areas more important than for shallow sandy soils (references in Jak *et al.*, 2009).

Trawl fishing causes a re-suspension of fine sediments (see van der Molen *et al.*, 2013)). Via direct and indirect effects decomposition processes result in increased oxygen consumption. In combination with the reduced oxygen tension by the summer stratification, this may lead to additional oxygen stress and increased mortality. The model study of Van der Molen *et al.* (2013) suggests that the effects of bottom fisheries and climate change are additive but that the effects on nutrient fluxes in the Central Oyster Grounds are relatively small.

In conclusion, fishing leads to set backs of the succession of ecosystem development to an earlier stage. The consequences are observed in the age structure and the presence of species that are indicative of soil disturbance, or benefiting from them. Continued fisheries will result in sustained setbacks of ecosystem succession, preventing the ecosystem to recover and develop into a state with long-lived and vulnerable species.

4.4.3.2 Ecosystem development after exclusion of fisheries

<u>Generic development</u>
In an expert workshop in 2013, various researchers discussed the possible ecological development of the Frisian Front and the Central Oyster Grounds given the hypotheses that fisheries would be excluded. The results are described by Jongbloed *et al.* (2013) and the included literature (e.g. Duineveld *et al.*, (2007)) and summarised in this section.

After exclusion of trawl fishing in an area, it is expected that seabed structure will change towards natural intrinsic conditions, resulting in an increase in natural bioturbation[4] combined with the increased influence of occasional storms on the one hand and increased stabilisation of the sediment on the other hand. A benthic community can develop in which epifauna has a larger role and share. Biodiversity may increase and this may be a recovery towards a natural situation. The prevalence of worms will decrease, and bivalves and burrowing sea urchins can increase. The biomass of epi- and infauna will potentially increase, but a prediction on actual numbers is hard as it depends on various uncontrolled factors. It is expected that the age distribution and densities of the species will change. Which specific species this will be, and how they will affect the soil is speculation. Some experts expect that biodiversity will increase if top predators also have more opportunities in the North Sea. Biogenic structures and their associated soil fauna can recover. Habitats associated with these structures are more heterogeneous. An increase in the density of shellfish and species diversity of soil fauna is expected. The period over which a benthic community recovers cannot be exactly determined. On the basis of various studies, it is expected that this may be in the order of 5 to 25 years. The presence of a source population outside the area (connectivity) is one of the important factors for recovery. This is however regarded by experts as an unpredictable factor. A restored seabed is of ecological value to the region as well (Jongbloed *et al.*, 2013).

[4] Bioturbation is the reworking of sediments by animals or plants. Its effects include e.g. changing texture of sediments

Development on the Central Oyster Grounds and Frisian Front

In the study of Jongbloed *et al.* (2013), the Frisian Front and the Central Oyster Grounds are similar in *assumed* development with regard to the following developments after stopping trawl fishing- assuming the whole area is closed:

Assumed biodiversity increase of benthos, development of biogenic structures, decrease of scavengers, equal in worms, increase of crustaceans and bivalves, increase of sensitive fish species and predatory fish and large specimens of certain species.

The Frisian Front and the Central Oyster Grounds differ with respect to the following assumed developments:

Frisian Front ecosystem has a faster recovery of benthic fauna (for a start situation which is a result of a greater impact of fisheries and dynamism, heterogeneity and dynamics of the landscape), higher potential for growth of long-lived benthic (individuals and species), higher potential for growth of biomass, higher potential for increasing biodiversity, higher potential for several types of big fish.

In addition, return of the historical ecosystem of the Central Oyster Grounds (where oyster beds were key elements) is not expected in the foreseeable future due to the absence of hard structures. However, reintroduction of native flat oysters may lead to a partial restoration. It is also noted by Jongbloed *et al.*, (2013) that this is not an end in itself, the viewing direction should be recovery from the current situation, and not historic. It was noted that the potential natural oyster beds may develop again, provided there is hard substrate present when the oyster larvae settle. There are shell remnants (which can serve as a hard substrate) present. There may, in principle, only few hard structure to be present in order to allow formation of oyster- beds and other biogenic structures.

The supply of oyster larvae will also determine whether oysters can return to the area. There is no record of where potential source populations are located. In future, the quahog can spread in the northern part of the Central Oyster Grounds, potentially making a major contribution to the status of local biomass and long lived species.

Next to the assumptions from the experts as summarised above, a technical evaluation study was performed on the effect of a partial fisheries closure in an area close by the FF and CO - the Plaice Box (PB). Beare *et al.* (2013) evaluated whether the PB has been an effective management measure. The changes in the ecosystem (plaice, demersal fish, benthos) and fisheries were analysed to test whether the observed changes are due to changes in the environment unrelated to the PB or to the PB closure. Data showed that juvenile growth rate of plaice decreased and juveniles moved to deeper waters outside the PB. Demersal fish biomass decreased, whereas the abundance of epibenthic predators (seastars and brown crab) increased in the PB. Polychaetes and small bivalves, the main food items of plaice, remained stable or decreased both inside and outside the PB. Beare *et al.* (2013) concluded that the observed changes were most likely related to changes in the North Sea ecosystem, which may be related to changes in eutrophication and temperature. It is less likely that observed changes are related to the change in fishing.

4.4.4 Generic effects of displacement on ecology

Slijkerman and Tamis (2015) provided an overview of recent literature on ecological effects of displacement. Displacement of fishing effort to other areas could lead to effects on habitats and/or species, depending on:

- fishing effort prior and after closure
- amount of effort displaced, as well as the gear type
- homogeneity of trawling effort after closure
- protected species within the closed area, i.e. fish- or benthic species
- additional management measures

4.4.4.1 Displacement- generic ecological effects

Understanding the spatial-temporal patterns of fishing-effort allocation around closed areas is essential for assessing their effectiveness (Forcada *et al.*, 2010). As described by Slijkerman and Tamis (2015) there are many factors influencing fisheries distribution after area closure. Also the effect of fisheries displacement depends on many different factors. Increased effort in lightly or unfished areas would cause substantial additional mortality (Greenstreet *et al.*, 2009), whereas increased effort to an already heavily fished area causes relatively little additional mortality of benthic invertebrates. This would also be the case for the North Sea (Dinmore *et al.*, 2003). It has been concluded that closed areas alone appear inefficient at reducing fishing impact on the overall North Sea benthic invertebrate community (Greenstreet *et al.*, 2009). Measures concerning the closure of areas should therefore be combined with additional management measures, such as TAC in order to compensate for the additional fishing pressure in the remaining areas. In addition, fisheries on larger fish within the best fishing grounds could shift to catch of smaller fish in less fishing grounds. This effect of displacement on the (by) catch of smaller fish could also affect fish stocks.

The consequences of displacement (after closing areas), both in ecological as in economic terms, depend largely on the level of specialisation of the fisheries. The level of specialisation results in choices on where and when to fish elsewhere. On the North Sea level, it is yet uncertain where which fisheries will exactly displace to and with what effort. Ecological impact of displaced fisheries depends on the type of habitat, the historic fishing pressure, the additional fishing pressure, and the gear type of displaced fisheries. However, in recent years the fishing pressure already went down with approx. 30% (see also Table 5.4) and it is not expected that even with displacement the mean fishing level in the open areas will increase to former levels (e.g. as they were in 2008).

Slijkerman and Tamis (2015) emphasise the need for gear specific high resolution VMS data for use in spatial planning when managing both fisheries and seabed habitats for e.g. biodiversity conservation. The lack of gear type specific (and flag specific) spatial and temporal maps was put forward as essential input for proper discussions. The effort to produce these high resolution maps was not available in this first attempt to outline spatial and temporal displacement expectations. Hence, it is hard to make high resolution estimates on consequences at this moment as well.

4.4.4.2 Displacement effects resulting from the different variants

Based on results of the displacement workshop as described in Slijkerman and Tamis (2015) it was concluded that displacement patterns in the search area and resulting from the different variants is hard to predict. Displacement depends largely on the type of fisheries.

Displacement in time and space depends highly on the importance of the closed fishing grounds for fisheries (size and location), the expertise and character of the skipper, distance to the fishing harbours, and the quota for the different fish stocks. These factors all result in a certain level of specialisation of the fisherman/fisheries. The more specialised, the harder it is to displace or to predict where displaced effort will be allocated.

The extent of displacement in terms of location and effort is hard to forecast because of uncertainties in this phase of the process of implementing the closed areas. Moreover, factors which may be relevant in 5 years will determine displacement in future as well. These are however unknown, in definition and extent.

In general, a few rough estimates on displacement were drafted during the workshop by a small selection of fishermen and representatives (see Slijkerman and Tamis (2015) for details). The displacement assumptions showed that displacement cannot be generalised for near future, as well as on the longer term, nor it can be predicted for the whole fleet. Due to the large uncertainties of where the displacement will occur in time and space, in combination with the gear and habitat specific influence, it is highly speculative what the ecological effects in the surrounding of the variants will be. Based on findings of Greenstreet *et al.*, 2009 and Dinmore *et al.*, 2003 (see above section) and the findings of the workshop described by Slijkerman and Tamis (2015), the following effects resulting from displacement can be assumed:
In the context of the MSFD potential closures, local additional effects on ecology are possible on the borders of some of variants *if* all fisheries would concentrate along the border of the MPA. Although a (long term and structural) concentration of fisheries along the borders is unlikely to happen, this might temporally be possible for MSFD measure variants Abalone, Capelin, Eel and Flounder - related to flyshoot and twinrig fisheries. For pulse fisheries, additional effects are expected along the 30 m line

or along the borders of the Frisian Front. The extent of the additional impact is however hard to quantify due to limited information in this phase of the study. Flyshoot fisheries exploring e.g. the Skagerrak will most probably display a heterogeneous distribution, resulting in a low or negligibly additional ecological impact on the benthic community.

Economically, the consequences are drafted in the following chapters. Yet, we can state, that fishermen without experience in the open remaining areas will be affected more compared to fishermen with experience and more generalised way of fishing (exploring and adapting).

4.4.5 Ecosystem services and ecosystem valuation

During the stakeholder process various ecological factors were suggested to include in the assessment. These aspects are discussed in this section.

The use of environmental valuation and cost-benefit analysis is done more and more by policymakers (Borger *et al.*, 2014). This means that policy-makers, regulators and stakeholders are placing increasing demands on economists and ecologists to supply such values for use in policy analysis and management (Hanley *et al.*, 2014). There is also a growing emphasis on basing environmental analysis and management on the ecosystem services (ES) approach (e.g. Fisher *et al.*, 2008, Keeler *et al.*, 2012).

Ecosystem services are the benefits people obtain from ecosystems. These services include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain other services. A clear example of a provisioning ecosystem service is the value of fisheries. Examples of other services are resilience to climate change, mining sources for all kind of compounds (e.g. medical, industrial or spiritual) and tourism.

There is still a lack of recognition and quantification of uncertainty in valuation of ecosystem services, and furthermore, techniques for assessing and monetising non-use values are still widely criticised (e.g. Parks and Gowdy, 2013; Bateman and Mawby, 2004; Gómez-Baggethun *et al.*, 2014). Quantification of ecosystem services (except for fisheries value which is quantified in Chapter 5) is an upcoming science in which various techniques are being developed and tested. Some case studies show interesting examples on the application of e.g. choice experiments, or so-called 'willingness to pay' methods in which the total economic value of non-marketable goods are assessed. For the Doggersbank valuation scenarios have been assessed using these methods (Borger *et al.*, 2014).

The scientific knowledge on how to express ecosystem services using *ecological data* is also relatively new. Hussain *et al.* (2010) demonstrated that the benefit estimation of ecosystem services is complicated by scientific uncertainty and data gaps that hinder the development of a bottom-up valuation of the ecosystem services. Overall, there are many issues related to economic valuation of ecosystem services that require further research and discussion. Unfortunately, the lack to account for the ecosystem services because of the difficulty associated with their valuation (Chan *et al.*, 2012), both economically as ecologically, exclude these important issues from the cost-benefit analysis in this project so far.

4.5 Discussion and conclusions

4.5.1 Summary of ecopoint scores

Table 4.9 and Table 4.10 present a summary of the previous tables for each variant. For each weighting factor, the range of values is supported with a shading. The shading intensity categories are applied within each column, in order to provide a quick overview of highest and lowest scores per weighting factor. The intensity follows a gradual relation. The intensity of the grey colour indicates the ranking of the ecopoints: the more intense the shading, the higher the ecopoint value and thus ecological benefit. It becomes clear that when the ecopoints per km2 are multiplied by 'area (km2/100)', that variant Flounder has most ecopoints, independent of the applied weighting factor. Variant Brill has the lowest ecopoint total- except for ecopoints/km2 when hard substrates are included. Averages and variation on the totals are not provided as the total scores are calculated as weighted scores. To obtain some sense of variation we refer to Appendix 4 in which the scores of the subareas are presented.

Table 4.9

Summary of ecopoints per km^2 for each variant. Shading intensity indicates the order of the values within columns

Variant	0. No weighting factor	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard subtrate	7. Fisheries intensity
Abalone	4.87	2.98	2.78	3.07	4.06	2.70	1.24	0.97	2.78	4.87	4.87	1.34	4.87
Brill	3.74	1.10	2.14	1.61	2.51	0.58	0.48	0.19	1.07	1.40	1.40	3.74	2.50
Capelin	4.96	3.37	3.55	2.29	3.69	1.73	0.62	1.74	2.13	3.10	2.48	2.12	4.96
Dab	3.92	1.34	3.92	1.69	2.80	1.02	0.49	0.24	1.12	1.47	1.47	3.18	2.61
Eel	4.64	3.24	4.64	2.30	3.99	2.99	1.62	1.45	2.65	4.64	4.64	1.61	3.48
Flounder	5.08	4.00	4.72	3.12	4.70	4.09	5.08	5.08	5.08	5.08	5.08	1.44	5.08

Table 4.10A

Summary of ecopoints per variant. Shading intensity indicates the relative values within columns

Variant	0. no weighting factor	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard subtrate	7. Fisheries intensity
Abalone	59	36	33	37	49	32	15	12	33	59	59	16	59
Brill	47	14	27	20	32	7	6	2	14	18	18	47	32
Capelin	79	54	57	37	59	28	10	28	34	50	40	34	79
Dab	66	23	66	28	47	17	8	4	19	25	25	53	44
Eel	195	136	195	97	168	126	68	61	111	195	195	68	146
Flounder	322	253	299	198	298	260	322	322	322	322	322	91	322

Table 4.10B

Ranking of ecopoints per variant. Shading intensity indicates the relative values. 11= lowest rank, 6 = highest rank

Variant	0. no weighting factor	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard subtrate	7. Fisheries intensity
Abalone	2	3	2	4	3	4	4	3	3	4	4	1	3
Brill	1	1	1	1	1	1	1	1	1	1	1	3	1
Capelin	4	4	3	3	4	3	3	4	4	3	3	2	4
Dab	3	2	4	2	2	2	2	2	2	2	2	4	2
Eel	5	5	5	5	5	5	5	5	5	5	5	5	5
Flounder	6	6	6	6	6	6	6	6	6	6	6	6	6

4.5.2 Ranking the variants on ecopoint scores

Independent of the method of expressing the ecopoints - average per km2 or total for the area - variant Flounder yields the most ecopoints, and thus highest ecological benefit compared to the other variants (Tables 4.9 and 4.10). The subsequent ranking of the other variants depends on the way of expressing the ecopoints, and the weighting factor applied. In the section below each contributing factor to the ecopoint score is discussed. In Chapter 9 a synthesis of the highlights per variant is presented.

4.5.2.1 Ecopoints per km^2

Variant Flounder has the highest score- except of the ecopoints related to weighting factor 'hard substrate'. The high score on ecopoints is due to its large size- all factors are co-related with the larger size- even if total area is not taken into account in the calculation. The larger areas contain more habitats, species and score relatively good on weighting factors and consequently have more ecopoints per km2.

The second best scoring variant depends on the applied weighting factor: most times it is either variant Abalone or Eel. In general, variants Brill and Dab score lowest on ecopoints, except for weighting factors hard substrate and number of habitats. The overall quality score of these variants was lowest.

4.5.2.2 Ecopoints per area

When multiplying the values (quality * weighting factor) with the area (km^2/100), variant Flounder has the highest score (Table 4.9). Variant Eel ranks second. Comparing the ranking of variants of approximately equal size shows that variant Abalone has a much higher score than Brill (both ~1200 km^2), and variant Capelin has a higher rank than variant Dab (both ~1,600 km^2).

4.5.2.3 Effect of weighting factors on ecopoints

In contrast to the quality indicators, the weighting factors can, to some extent, be used to select for a variant that contributes more to the protection of the ecosystem as a whole than others. However, different lines of thinking can be followed. If artificial hard substrate is considered an important part of the ecosystem (see section on hard substrate), then weighting factor 6 should be considered in the decision making process. If the aim is to protect a diverse and unique area with numerous functions on a North Sea wide scale, then weighting factors considering the inclusion of the frontal area should be given importance. If the aim is to emphasise benthic biodiversity values, then it would make sense to look at the quality alone, and not use a weighting factor. When fisheries pressures is set as a proxy for relative recovery, weight factor 7 should be considered. And if it is considered important that a single large area is chosen, to avoid benthic animals to leave the protected area, or to make sure that certain ecosystem functions have a higher change to be restored, then weighting factor 3 could be important. Of course the size of the closed areas themselves is of large importance, but they are not a weighting factor as this is expressed by the ecopoints for the total area. The average or sum of all separate ecopoints combined can be sued to evaluate the overall score for a variant.

The *generic* weighting factors differentiate the scores of ecopoints as follows (score/km^2). Flounder has highest ecopoint scores, and Brill has lowest ecopoint scores. The ranking in between depends on the weighting factor of interest. Weighting factors 'habitat rarity' and 'habitat diversity' rank Abalone, Dab, Capelin, and Eel differently than weighting factors expressing the effective area. Effective area rank Dab and Brill lowest, whereas Dab scores relatively high when applying the number of habitats as a weighting factor.

When looking at the total score- in which area is taken into account as well, the highest and lowest score are attributed to Flounder and Brill as well. Variant Eel is always second in rank, independent of the weighting factor.

The weighting factors *emphasising the frontal area and gradients* rank the variants differently than the generic factors. Although Flounder still scores highest and Brill lowest, the ranking in between differs significantly, as well the relative scores. Taking into account the score per km^2, variant Abalone benefits from the weighting factors in which gradients are taken into account. Its overall score increases compared to the other variants. The way of expressing the gradient - with or without the frontal area as an obligatory aspect - does not influence its rank. Overall it is clear that variant Abalone scores relatively higher and thus reflect more ecological benefit when taking into account the ecological significance of gradients and the frontal area. Variant Capelin scores relatively lower compared to Abalone.

The weighting factor reflecting the density of artificial hard substrate rank the variants totally different compared to the other factors. When expressed as ecopoint/km^2 Brill scores highest, followed by Dab and Capelin. Abalone and Flounder score lowest.
The weighting factor reflecting fisheries pressure rank the variant more or less the same as the generic weighting factor 0 (no weighting factor), 1 (habitat rarity) and factor 3 (effective protection). Brill scores lowest, and Flounder highest when fisheries pressure- as a proxy for habitat recovery- is taken into account.

4.5.2.4 Sum of quality at the subarea level

Ecopoints are a sum of the equation to which habitat quantity (area), habitat quality (biodiversity) and weighting factors contribute. In this section, the influence of the quality per subarea is discussed. These values are presented in Appendix 4. Values for hard substrate and fisheries pressure were not included on the subarea level.

Overall, the *sum of the quality* (see Table 4.2 and 4.3 and Figure 4.4) is highest for variant Flounder, followed by Capelin. Lowest quality score have variants Brill and Dab. The overall quality score ranges from 3.74-5.08. The highest possible score was 9. The highest quality of a subarea is obtained by the Frisian Front subarea.

Taking into account the scores of subareas it is obvious that the quality score per subarea is determined by different indicators. In general, subareas covering the Central Oyster Grounds score relatively high on 'large species', 'long-lived species' and species richness of the macrobenthos compared to Frisian Front subareas, while Frisian Front subareas in general score relatively high on quality indicators 'biomass' and 'density'. Furthermore, the megabenthos values for species richness, density and biomass are relatively higher for Frisian Front areas compared to Central Oyster Ground subareas.

Long-lived species scores are highest for Eel and Abalone, and Eel scores highest for large species as well. These scores are all related to the Central Oyster Ground subareas. Species richness of the macrobenthos is highest for Flounder and Brill CO subareas. Capelin Frisian Front subareas scores relatively high on megabenthos density and richness, followed in rank by Flounder Frisian Front subarea and Brill and Dab Frisian Front subareas.

4.5.3 Scaling of quality indicators

All values originate from DCS scale monitoring. The question is how to properly scale the values in order to obtain scaled values that can be summed up in the ecopoint equation.

During the stakeholder meeting it was asked why the original values for area quality (step 2) as obtained from the maps shown in Appendix 2 were scaled between the lowest and highest value encountered within the search area and why not on the level of the entire map. Although the explanation is given in Section 4.2.2, we have tested this and performed the calculations for ecopoints, but then scaled between 1 (min) and 10 (max), being the min and max values for the quality indicator on the DCS scale. The result is that there is no difference the ranking of scores of variants. The absolute values of ecopoints are different of course, but the ranking remains the same. As explained earlier, the ecopoint values themselves do not have a meaning on their own, only in relation to others.

4.5.4 Sensitivity and robustness

4.5.4.1 Data origin and kriging

The values originate from monitoring data and are mapped as described and illustrated in Bos *et al.* (2011). Data robustness of the available data is not tested. The data from monitoring such as from BIOMON and Triple-D (see Bos *et al.*, 2011) are the best available given the monitoring effort of the both programs. These data result in a temporal- spatial resolution that is valid to get some sense of spatial distribution of benthic species. Robustness also depends on the resolution used. Based on data density and kriging choices, the best resolution of underlying maps possible is 5 x 5 km (Bos *et al.*, 2011). Kriging is a method of interpolating data for which the interpolated values are modelled by a Gaussian process governed by prior selected covariates. These covariates - such as sediment type in the study of Bos *et al.* (2011) - are chosen to optimise smoothness of the fitted values. Kriging gives the best linear unbiased prediction of the intermediate values within a larger area.

The kriged data resulted in data-categories (see Bos *et al.*, 2011) and the values of these categories are used to obtain scores per km^2 for each variant (see material section). This elaboration within GIS did not allow a statistical variance derivation.

The overall score per variant depends on 2-4 subareas, and the variance of scores of subareas can be used as a proxy of the variance of the overall score of a variant.

4.5.4.2 Effect of area size

In this study, the ecopoint scores were expressed in two ways: score per km^2 and score per area. As illustrated in the results section, the area size determines the outcome of the ecopoint score, and quality of the area is of relatively minor importance.

In this study, a total of 9 quality indicators were scaled to values between 0 and 1, providing a highest possible quality value of 9. The minimum total area value was 12 (i.e. 1,200 km^2/100). This means that differences between variants are determined more by size than by quality.

Therefore, we suggest to evaluate the ecopoints in score/km^2 instead when one wants to evaluate quality of the variant in itself. In this way the differences between variants are corrected for the area size. However, the comparisons between variants in terms of ecopoint/km^2 are still influenced by the area size in some way. The larger a closed area, the larger the chance of containing more habitats and species diversity. This is reflected by some of the weighting factors. On average, variant Flounder has highest scores since it covers all habitat types and accompanied species variation. The relationship between size and the ecopoint score is however non-linear. The explanation is that the variants are all different in shape and positioned in other areas within the search area.

This does not mean that the ecopoint method is not suitable to calculate ecological benefits - the basic data and methodology are still valid - the results are based on quantitative data, representing the present quality of an area.

5 Fishing activities in the areas

Hans van Oostenbrugge, Katell Hamon Niels Hintzen and Marcel Machiels

The first step in order to assess the effects of the closures on the fishing sector is the quantification of the historic fishing activities in the areas. This is important for the estimation of the costs of closures as historic data provide the basis for any analysis of effects of closures and the effect of closures depend on the extent of fishing activities, the type of fisheries in the area and the dependency of these fisheries on the area. This was done for the period from 2008-2014 for the Dutch fishing vessels and from 2011-2014 for foreign vessels. Fishing activities in the areas were quantified in terms of effort, landings volume, landings value and contribution to the Gross Value Added (GVA). The GVA is especially important as this metric indicates the value of the fishing activities to society: the returns on the invested capital (fishing vessel) and labour by the crew. For the Dutch fishing vessels also the dependency on the areas was estimated per vessel as this is important for the effects of closures on the fishing practices and herewith on the potential costs (see also Chapter 6).

5.1 Methodology

5.1.1 Fishing activities of Dutch vessels

5.1.1.1 Total fishing activities

The methods applied and the data used to assess the fishing activities in the areas were similar to those used for the previous studies (e.g. Van Oostenbrugge *et al.*, 2010). In addition some extra data checks were included and another data processing platform was used for part of the analysis. Because of the large similarity in the method, this report contains a limited description focusing on small adjustments that have been made. A complete description can be found in Van Oostenbrugge *et al.*, 2010.

Several steps were needed to process the Dutch data for the analysis. First of all, the Vessel Monitoring Data (VMS data) were processed and the patterns in fishing efforts were determined. To clean up the VMS data set, the R package VMStools was used (Hinzen *et al.*, 2011). Duplicated points, points in harbour, points on land and points with impossible speed/location (<1% of total) were removed.

Next, the fishing efforts were used to distribute the catches between the various points. The method used is illustrated by the example included in Table 5.1. The fishing vessel carries out a fishing trip from 14:00 to 19:00 hours on 21 August. First, the vessel speed was used to determine whether the vessel was fishing or steaming at each VMS point based on speed thresholds derived from South *et al.* (2009) and an analysis of frequency distribution of VMS-speed data by vessel and year.

Table 5.1

Example of a calculation of the catch at the VMS positions during one trip of a vessel of 300 hp using Otter board Trawl (OTB)

DH1	time	Speed	Time since last position	catch
21-aug	14:00	0.2		
21-aug	15:00	5.6	1:00	0
21-aug	17:00	3.4	2:00	1,200
21-aug	18:00	3.2	1:00	600
21-aug	19:00	0	1:00	0
Total catch				1.800

In Table 5.1 the speed of VMS point at time 14:00 is too low to be fishing. At the second VMS point (15:00) the speed is too high to be fishing. Therefore neither of these points get catch attributed. The next two VMS points (17:00 and 18:00) have a speed that falls within speed range for which we assume the vessel to be fishing. Next, the duration was determined for each position (the time interval between the current and previous position). The catch (kg) was distributed on the basis of the duration at the various positions at which the vessel was fishing.

Table 5.2 shows the thresholds per gear determining fishing and steaming activities. Any gears missing in this table were assigned the activity Unknown.

Table 5.2

Determination fishing and steaming activity

Gear	Fishing	Steaming
Gill nets, Danish seines	speed<0.3	speed>=0.3
Scottish seine	speed<7	speed>=7
Beam trawl, shrimp trawl	Speed within 3 to 6	Speed<3 or speed>6
Otter board trawl 0-300hp	Speed within 3 to 5	Speed<3 or speed>5
Otter board trawl >300hp	Speed within 3 to 4	Speed<3 or speed>4
Twin trawl 0-300hp	Speed within 3 to 5	Speed<3 or speed>5
Twin trawl >300hp	Speed within 3 to 4	Speed<3 or speed>4

Source: South *et al.* (2009).

The example in Table 5.1 illustrates the ideal situation where a trip is comprised of a number of fishing and/or steaming VMS points and the day catch is available. This was not always the case. Several factors could complicate the distribution of catch over the VMS points. For example in a number of cases a vessel was sailing at all the available VMS positions on a day or data were lacking, for example on the fishing gear, HP and speed, which made it not possible to allocate an activity to a VMS point. To still be able to allocate catch to VMS locations a number of assumptions needed to be made in the case of missing data. The distribution methods used in these cases are summarised in Table 5.3.

Table 5.3

Distribution catch in several situations (see text for further explanation

Day catch recorded for trip	Day catch recorded on day	Type of Activity	Distribution
Yes	Yes	Fishing and other	Fishing time/fishing time on fishing day
Yes	Yes	Only steaming	Catch not distributed
Yes	Yes	Only unknown	Time unknown/time on fishing day unknown
Yes	Yes	Steaming and Unknown	Catch not distributed
Yes	No	All combinations	Catch not distributed
No	No	Fishing and other	Fishing time/fishing time on fishing day
No	No	Only steaming	Catch not distributed
No	No	Only unknown	Time unknown/time on trip unknown
No	No	Steaming an unknown	Catch not distributed

The VMS data do not provide full coverage. This is, in particular, due to vessels with a length less than 12 meters and which consequently do not have on-board VMS as well as an inability to fully distribute all the catches between VMS points. Moreover some landings cannot be distributed because of the specifics of the VMS data of a trip (see Table 5.3). This was corrected by increasing the landings at each location by a factor based on coverage percentages per gear and type of vessel. So for example if for a certain gear type the coverage was 95%, the total catches with this gear type were multiplied by a factor (1/0.95). This approach facilitated the distribution of all catches found in the VIRIS logbook data.

The catches and average auction prices were used to determine the value of the catches at the various VMS points. Finally, the contribution to the gross value added was calculated on the basis of the average cost structure for each year, type of vessel and type of fishery, as known in LEI's Farm Accountancy Data Network.

This described method is in agreement with the methods used in earlier LEI reports on the estimation of the value of fishing areas (such as Van Oostenbrugge *et al.*, 2010).

5.1.1.2 Dependency analysis

For each vessel and year combination the level of dependency on the closed areas was calculated as the percentage of the annual revenue coming from each of the proposed closed areas in the various variants. Average dependencies over the time period were calculated for each vessel. The individual dependency levels were aggregated in so called stress profiles, showing the distribution of vessels over the various dependency levels. Dependency levels have been calculated on both annual and quarterly level.

5.1.2 Fishing activities of foreign vessels

Recent trends in the fishing intensity in the areas has been assessed for the Danish, German, Belgian and UK fishing fleets. This was done by analysing the Vessel Monitoring System datasets available at the national fisheries institutes and estimating the effort in each of the variants. Because the VMS data are available in a uniform data format (EFLALO), this could be done by using a uniform analysis script written in R.[5] To estimate the effort in the areas, the same methodology was used as for the Dutch fishing fleet. For the German and Belgian fleet it was possible to distinguish between vessels owned by foreign companies and those owned by Dutch companies (flag vessels). This was done based on a list of these vessels provided by the fisheries sector. For the UK fleet merging the list of

[5] R is an open-source statistical software package that is widely used in fisheries science.

flag vessels was not possible. These analyses resulted in the amount of effort (sea days) per gear, vessel length class and nationality in each of the variants. In order to assess the landings, landings value and the GVA of the foreign fleets, the effort data were combined with information on catch composition and economic information from the database of the Annual Economic Report of 2015 (STECF 2015). In this database, catch information (landing volume and value) is only available at the level of gear and ICES subarea (e.g. Central North Sea). Because of this, the landings and landings value was estimated by combining the effort information with average landings and landings values for each gear type in the Central North Sea. The GVA was estimated using the proportion of landing and GVA for the fishing fleet in question.

5.2 Data

5.2.1 Fishing activities of Dutch vessels

Several data sources were used in the evaluation. The data sources used were Vessel Monitoring System (VMS) data, catch data from VIRIS (Fish Registration and Information System), Fleet data from the Netherlands Register of Fishing Vessels (NRV), average monthly price data per species collected by the Productschap Vis (Netherlands Fish Product Board) and economic data (The LEI panel). The datasets used and the data coverage are described in more detail in Appendix 5.

5.2.2 Fishing activities of Foreign vessels

Effort data on foreign fleets were used from the EFLALO datasets of the sister institutes in Denmark, Germany, Belgium and the UK. Data on landings volume, value and economic performance of foreign fleets were taken from the database of the Annual Economic Report of the EU fishing fleets (AER 2015).

5.3 Results

5.3.1 Value for Dutch fishing vessels

5.3.1.1 Recent fishing activities

Over the last seven years the amount of fishing activities has been quite different in the various variants and from year to year (Table 5.4). Variant Flounder shows by far the highest level of fishing activities; on average the Dutch fleet spent around 730 days fishing in these areas creating a total Gross Added Value (GVA) of around 1.6m euros. The amount of fishing activities in variant Brill was the lowest (100 fishing days and a total GVA of around 0.2m euros), less than 15% of the fishing activity in Flounder. The other variants show intermediate levels of activity. Variant Abalone and Dab show comparable levels of effort and landings (around 140 fishing days and 320 tonnes of fish annually). However, the value of landings and GVA for Abalone were around 20% higher (1m euros and 0.35m euros, respectively) than for Dab (0.77m euros and 0.28m euros, respectively). The number of fishing activities of Capelin is approximately twice the number of activities for Brill (190 fishing days and a total GVA of around 0.5m euros) and the fishing activities in Eel are approx. four times the activities for Brill (360 fishing days and a total GVA of around 0.9m euros). The average total value of the landings by the Dutch demersal fishing sector amounted approximately 250m euros per year in the same period (www.visserijincijfers.nl). The values for the various subareas can be found in Appendix 7.

Table 5.4

Overview of effort, landings and values and gross value added of the Dutch fishing sector in the areas of the different variants

Variant	2008	2009	2010	2011	2012	2013	2014	Average
Effort (fishing days)								
Abalone	165	194	160	118	168	106	91	143
Brill	156	143	124	63	113	75	34	101
Capelin	221	261	241	193	155	156	124	193
Dab	230	217	156	78	135	94	46	136
Eel	505	481	428	268	344	292	214	362
Flounder	835	871	809	762	723	600	524	732
Landings (tonnes)								
Abalone	295	345	328	166	640	209	321	329
Brill	184	223	182	67	616	236	82	227
Capelin	411	406	441	282	643	375	336	413
Dab	291	321	237	98	799	346	123	316
Eel	876	866	864	695	1,568	886	519	896
Flounder	1,535	1,459	1,618	1,686	2,372	1,359	1,377	1,630
Value (1000 euros)								
Abalone	1,229	1,287	1,093	663	1,453	700	572	1,000
Brill	824	619	581	237	961	354	169	535
Capelin	1,681	1,523	1,451	1,095	1,398	1,017	816	1,283
Dab	1,337	996	744	307	1,259	506	243	770
Eel	3,467	2,970	2,741	1,796	3,296	2,201	1,436	2,558
Flounder	5,714	5,250	5,147	5,108	5,663	3,966	3,358	4,887
Gross Value Added (1,000 euros)								
Abalone	403	548	400	225	412	274	199	352
Brill	300	268	216	74	290	139	62	193
Capelin	564	657	532	364	371	392	281	452
Dab	472	430	277	98	382	196	90	278
Eel	1183	1,279	1,000	510	922	772	516	883
Flounder	2015	2,270	1,883	1,572	1,418	1,428	1,199	1,684

a) preliminary estimates;

Source: Logbook data and VMS data, processed by LEI

Table 5.5

Average fishing intensity per km^2 of the Dutch fishing sector in the variants over the period of 2008-2014. Stdev is the standard deviation of the average over the years

	Effort (fishing days/km^2)		Landings (kg/km^2)		Value (euros/km^2)		Gross Value Added (euros/km^2)	
	average	stdev	average	stdev	average	stdev	average	stdev
Abalone	0.12	0.03	273	127	830	291	292	103
Brill	0.08	0.04	180	145	423	235	153	80
Capelin	0.12	0.03	259	71	803	195	283	84
Dab	0.08	0.04	188	139	458	263	165	93
Eel	0.09	0.03	213	77	608	183	210	72
Flounder	0.12	0.02	257	55	771	140	266	60

Source: Logbook data and VMS data, processed by LEI.

Although the size of the areas in the variants is a major determinant of the total level of fishing activities, the fishing intensity per km^2 also varies substantially (Table 5.5). Variants Abalone, Capelin and Flounder show similar, relatively high fishing intensities; around 0.12 fishing days/km^2 and a GVA between 260-300 euros/km^2. Fishing intensities for Brill and Dab are 30-50% lower; around 0.08 fishing days/km^2 and a GVA between 150- 170 euros/km^2. Eel shows intermediate fishing intensity (around 0.09 fishing days/km^2 and a GVA of 210 euros/km^2.

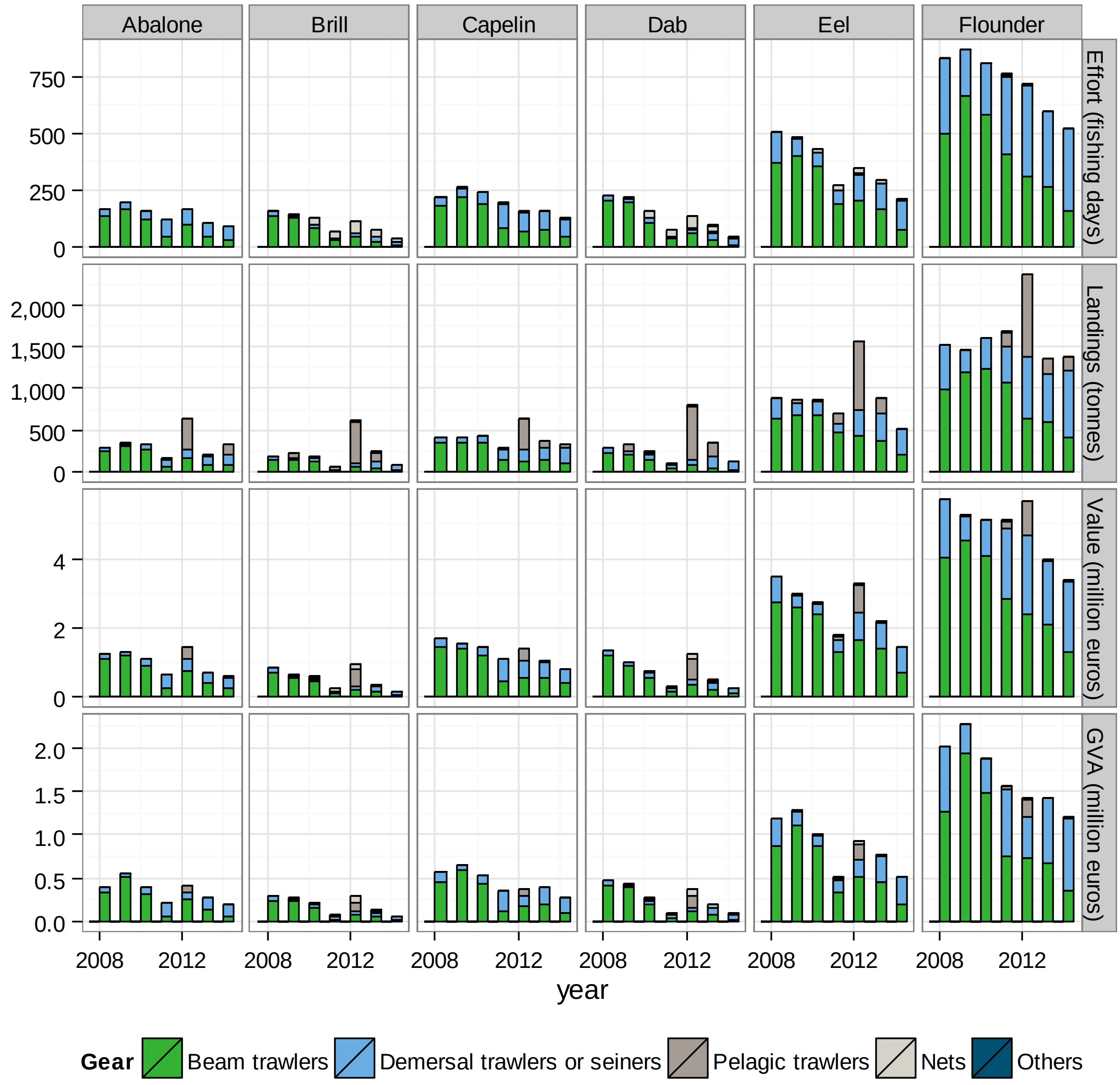

Figure 5.1 *Historical trends of the fishing activities by the Dutch fleet in the areas of the variants. Effort, landings, value of landings and GVA are given by gear groups as specified in the European DCF. Source: Logbook data and VMS data, processed by LEI.*

For all variants the fishing activities have decreased substantially during the seven years taken into consideration (Figure 5.1). On average, the effort, landings value and the GVA decrease around 50-60%. The reductions in landings volume are considerably less; around 30% for all variants. This is mainly due to the general increase in fishing opportunity in the North Sea and decreasing prices. Variants Brill and Dab show the highest reduction in activities: effort, landings value and GVA are reduced by around 75% and landings volume by around 60%. The reduction in fishing activity in Flounder is lowest; around 40% in effort, landings value and GVA and less than 10% in landings volume.

The main gear types used in the area are bottom gears such as beam trawl and its innovative successors (puls trawl, pulswing and SumWing) and other types of bottom trawls. Over the period 2008-2014 beam trawls (including puls gears) accounted for 62% of the total effort and 64% of the GVA. Other bottom trawls and seines were on average less important, accounting for 34% of the total effort and 30% of the GVA. However, whereas the fishing activity of the beam trawls has decreased, the fishing activities of other bottom trawls and seines such as otter trawl and twin trawl have been stable or even increased. Because of this as from 2013 onwards beam trawls were no longer the dominant gear used in the areas, but other bottom trawls and seines became more important. In 2012 considerable catches of pelagic fish have been caught in the areas, but these catches were incidental and they represent a low value because of the low prices of pelagic fish. Nets and other gears (dredges or shrimp trawls) are hardly used in the areas.

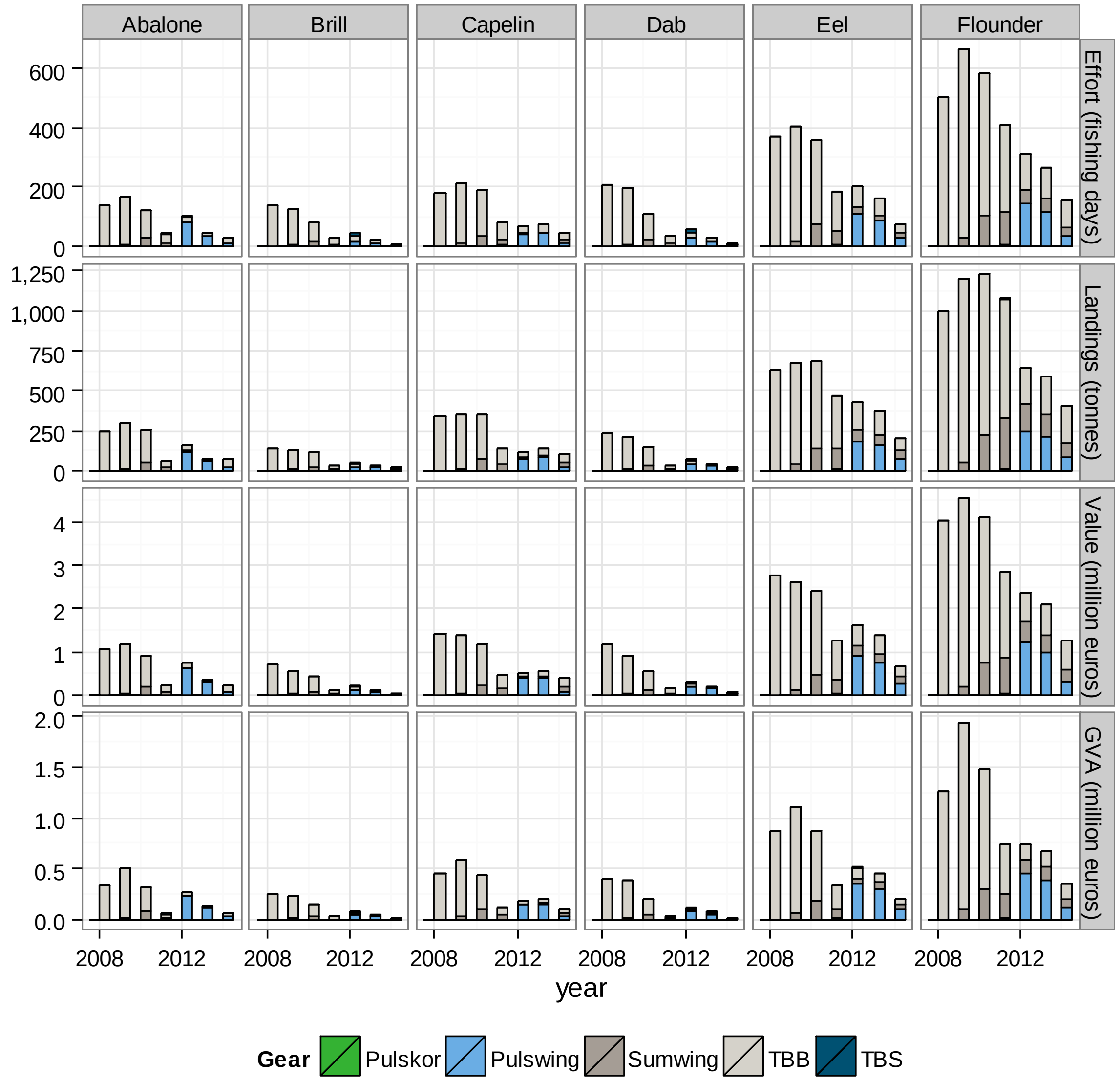

Figure 5.2 *Historical trends of the fishing activities by the Dutch beam trawl fleet (including traditional and pulse trawls gears) in the areas of variants. Effort, landings, value of landings and GVA are given by gear type; TBB, traditional beam trawl; TBS, shrimp trawl.*
Source: Logbook data and VMS data, processed by LEI.

Activity levels of beam trawl fisheries (including puls gears) in the areas of the variants show similar patterns as the total Dutch fisheries in the North Sea (Figure 5.2). The level of fishing activities are lowest for variant Brill (average 62 fishing days and GVA of 0.13m euros), Abalone and Dab show comparable levels of activity (around 90 fishing days and GVA of 0.18-0.24m euros) and Capelin, Eel and Flounder show higher levels of fishing activity (resp. 120, 250 and 410 fishing days and GVA of 0.30m, 0.62m and 1.0m euros). In all variants the total fishing activity level of beam trawls has decreased substantially but especially for Brill and Dab, the decrease has been very large (more than 90% for both fishing days and GVA). For other variants the decrease in fishing activity level was around 70-80%. Within the beam trawls a partial shift has taken place from the traditional beam trawl to the pulse wing gear. Was in 2008 100% of the fishing activity still carried out by traditional beam trawl, in 2012 and 2013 this gear only contributed around one third of the effort and GVA in the areas.

In 2014 however, the relative importance of the traditional beam trawl increased again for some of the variants; for Abalone Capelin and Flounder the importance of the traditional beam trawl increased this year to around 60%. Good fishing opportunities for plaice and relatively low fuel prices might have contributed to this development. For Dab and Eel, the pulse gears have become the most important gears used with a relative importance of around 60% but total fishing intensity decreased substantially in these variants from 2013 and 2014.

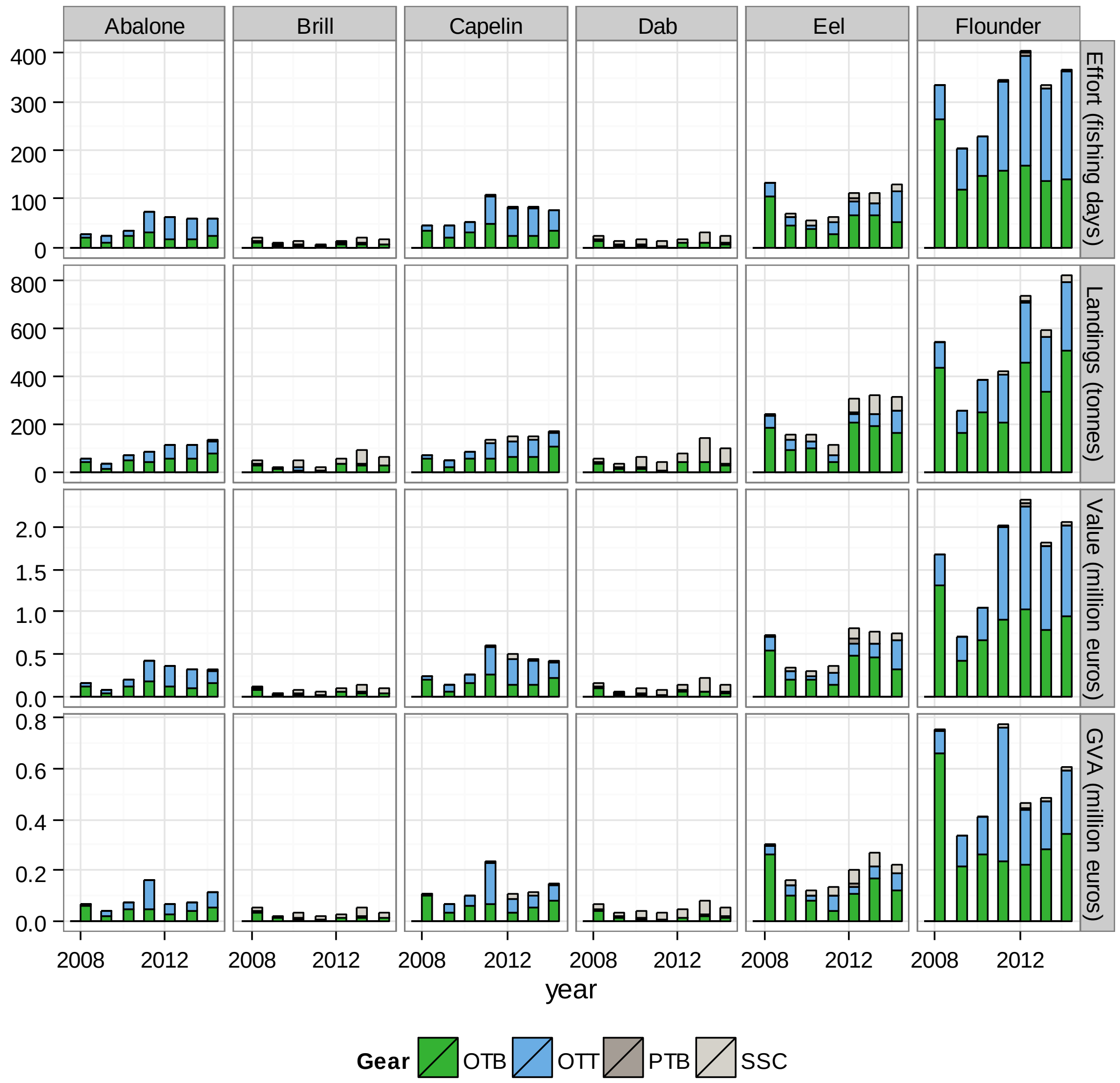

Figure 5.3 *Historical trends of the fishing activities by the Dutch demersal trawlers in the areas of the different variants. Effort, landings, value of landings and GVA are given by gear type: OTB, otter trawl bottom; OTT, twin trawl; PTB, pair trawl bottom; SSC, Scottish seine (fly shoot fishery) (see also Appendix 6).*
Source: Logbook data and VMS data, processed by LEI.

Activity levels of 'other trawls and seiners' have been relatively high in all variants during the last years and have become the most important gear type used in the area (Figure 5.3). Average fishing activity level lowest in Brill and Dab. In these variants, the effort was around 15 and 20 fishing days and the contribution of the areas to the GVA was 36 and 52 kEur. In the other variants fishing activities ranged from 50 fishing days for Abalone, 70 fishing days for Capelin, 100 fishing days for Eel to 310 fishing days for Flounder. The patterns in GVA resembled those in effort and relative differences between variants are similar. Only for 2012 GVA was lower than expected, because of high costs.

The most important gears used were otter board trawl (OTB) and twin trawl (OTT). The importance of twin trawls (including the quadrig fishery) has increased and in recent years these gears are more important than the otter board trawl fishery. This has mainly been the result of changes in the relative availability of quota of the target species for these gears. The relative importance of the twin trawl and otter trawl fisheries was similar in most variants: In Abalone, Capelin and Founder the importance of these gears was around 50% of the total. In Eel, Brill and Dab, the otter board trawls were more important. The flyshoot fishery has been of relatively minor importance in most of the variants. Only in Brill and Dab the flyshoot fishery was relatively important: 47% and 56% of total effort and 52% and 61% of GVA. In the other variants, the relative importance of the flyshoot fishery was less than 15%. The values for the various subareas can be found in Appendix 7

5.3.1.2 Dependency on the areas

The relative contribution of all variants to the total economy of the Dutch demersal fishing sector (the cutter fleet as specified in Taal *et al.*, 2010) was less than 2.1 % over the period 2008-2014, (Table 5.6). The contribution ranged from 0.16% (landings in Brill) to 2.1% (value in Flounder). The importance in value of landings was highest, which is mainly due to the fact that the areas are used for the fisheries of expensive species like nephrops and sole. The importance in terms of GVA and value of landings was similar. As for the total fishing activities, the dependency on the area has decreased over the last years. For Brill and Dab, the decrease was highest (70%). For the other variants the dependency decreased by around 50%-60% from 2008-2014.

Table 5.6

Relative contribution (%) of the fishing activities in each of the variants to the fishing activities of the Dutch fishing sector over the period 2008-2014

	Effort (sea days)		Landings (kg)		Value (euros)		Gross Value Added (euros)	
	average	stdev	average	stdev	average	stdev	average	stdev
Abalone	0.36	0.07	0.31	0.10	0.42	0.16	0.42	0.15
Brill	0.25	0.10	0.16	0.07	0.22	0.12	0.23	0.11
Capelin	0.49	0.10	0.42	0.12	0.54	0.15	0.55	0.17
Dab	0.34	0.15	0.23	0.11	0.32	0.19	0.34	0.18
Eel	0.92	0.25	0.90	0.23	1.07	0.34	1.07	0.34
Flounder	1.89	0.29	1.76	0.32	2.05	0.46	2.03	0.57

Source: Logbook data and VMS data, processed by LEI.

Although the overall contribution of the areas to the whole fishery is low, dependency can be high for individual vessels for specific seasons. Figure 5.4 shows the relative contribution of the fishing activities in the various variants to the total revenue of individual vessels per quarter and averaged over the period 2008-2014. This means that the vessels that are in the class between 10-20% dependency obtained between 10-20% of their total income of that quarter from the area over the period 2008-2014. The total number of vessels operating in the areas in a quarter ranges from around 25 to 45.

Most of the vessels that use the areas are less than 10% dependent on these areas for their total revenue of that quarter. In Abalone, Brill, Capelin and Dab, more than 90% of the vessels that fish in the areas were less dependent than 10%, and only for one quarter, one vessel obtained more than 20% of his revenue in the Area; Capelin in quarter 3. For variant Eel and Flounder the number of vessels that is more dependent on the area is larger. Six to eleven vessels obtain more than 10% of their quarterly revenue from the areas in Eel and one to three vessels obtain more than 20% of their revenue. For Flounder the number of vessels that obtain more than 10% of their quarterly revenues in the area is between 10 and 21 and two to five of these vessels obtain more than 40% of their quarterly revenues in the area.

The relative importance of the areas vary depending on the season and variant. Relative importance depends especially on the number of highly dependent vessels. For Abalone and Capelin it is highest in the second and third quarter. For Brill and Dab relative importance is highest in the second quarter and for Eel and Flounder relative importance is highest in the third quarter (Figure 5.4 and 5.5). For all areas, dependency is lowest for the fourth quarter. The main reason behind this dependency is the seasonal distribution patterns of the target species of the fisheries.

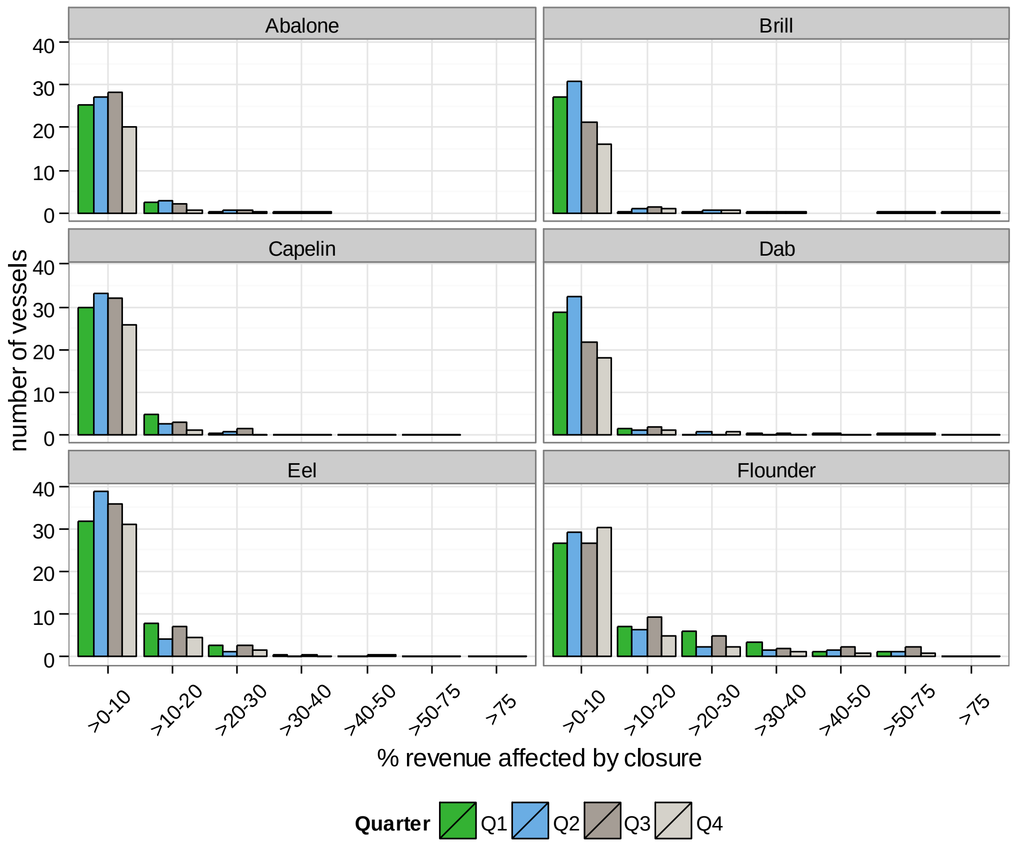

Figure 5.4 *Quarterly stress profiles of the Dutch fishing fleet for the various variants, based on average dependency of the areas in the period 2008-2014. Dependency is measured by the percentage of the revenue that is taken from the areas.*
Source: Logbook data and VMS data, processed by LEI.

Figure 5.5 shows the contribution of the revenues from vessels in each of the dependency classes to the total revenue in each of the variants and quarters. In Abalone, Brill Capelin and Dab, the majority of the revenue is obtained by vessels that show low dependency on these areas (< 10%), and the seasonal differences are caused by changes in the revenue of these vessels. For Eel and Flounder seasonal differences in landings are caused by vessels that are more dependent on these areas. For Eel these are vessels that obtain 10-30% of their revenue in the area and for Flounder these are vessels that obtain 10 to more than 80% of their revenue in the area.

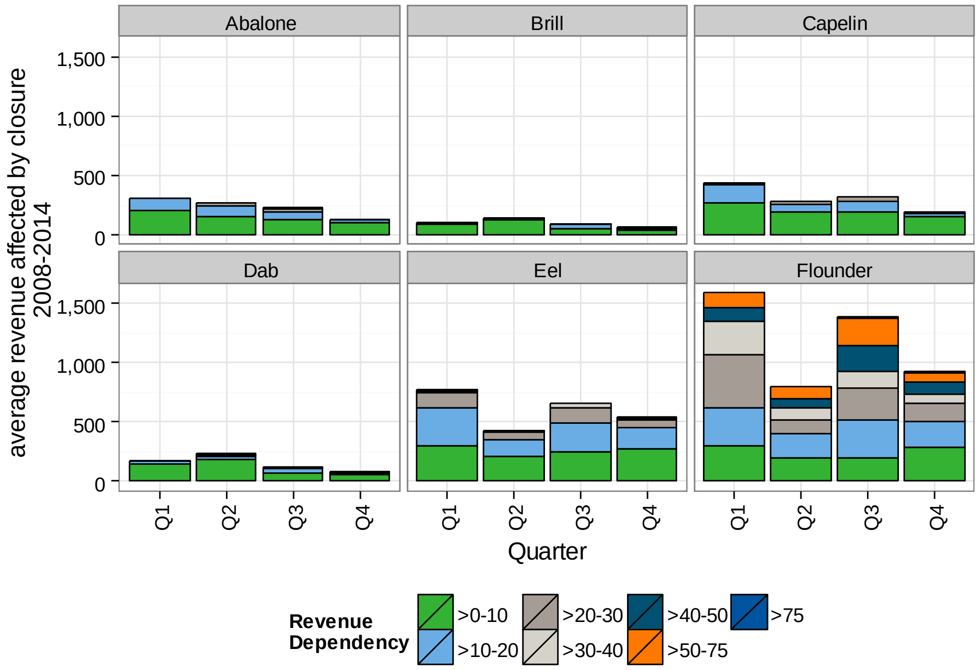

Figure 5.5 *Average revenue (*1,000 euros) per quarter over the period 2008-2014 in each of the variants a)*
a) The various colours show the level to which the vessel depend on the areas. E.g. almost the complete revenue in quarter 2 for variant Brill is obtained by vessels that are less than 10% dependent on these areas.
Source: Logbook data and VMS data, processed by LEI.

Seasonal patterns in utilisation of the area vary among gear types. Appendix 8 shows the patterns for the most important gear types.

On an annual basis the dependency is lower than on an quarterly basis. Figure 5.6 shows that for the first four variants, almost none of the vessels obtain more than 10% of their income from the area. Only in case of Eel and Flounder, the number of vessels that obtain more than 10% is larger: 7 for Eel and 19 for Flounder. This means that the vessels utilising the areas vary between seasons and that although fishermen perceive dependency on the area at the quarterly level, the average dependency on an annual level is limited. On the other hand it shows that low a low level of dependency at the annual level, may still be an indication of seasonal dependency on the area. This information has been used in the assumptions for the estimation of the possible displacement effects.

Most of the vessels that fish in the areas are registered in Wieringen and Urk (Figure 5.6). Some other vessels come from the province of Friesland and Groningen, but their dependency is lower than 10%. Nearly all vessels with high dependency levels (>20%) come from the previously mentioned two fishing communities. Although the dependency levels vary among the various variants, the regional distribution is similar in all variants. As the vessels utilising the area mostly originate from the communities of Urk and Wieringen, these communities will also be most affected by possible consequences of fisheries measures in the areas. This is discussed in Chapter 8 and 10.

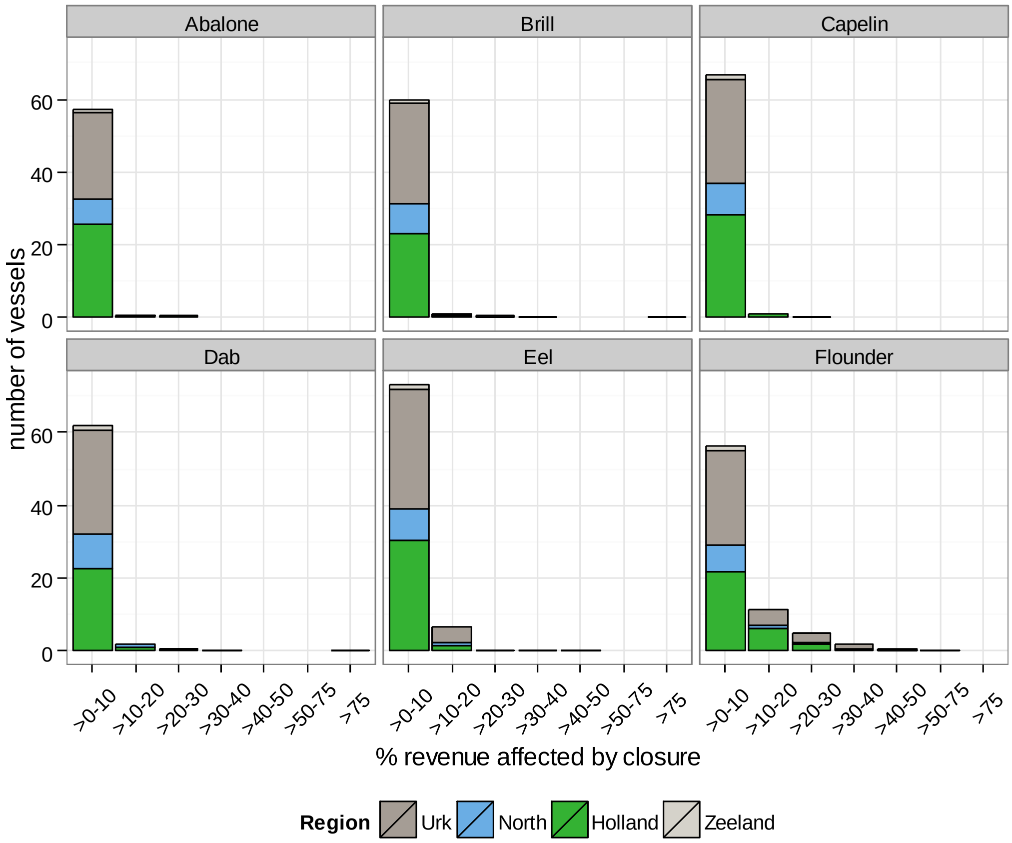

Figure 5.6 *Stress profile of the Dutch fishing fleet for the various variants, based on average annual dependency of the areas in the period 2008-2014, aggregated by region of registration of the vessel (e.g. UK220 is registered in Urk). North, harbours in Groningen and Friesland; Holland, harbours in Noord- and Zuid-Holland. A specification of the classification of fishing harbours is presented in Appendix 9. Dependency is measured by the percentage of the revenue that is taken from the areas. Source: Logbook data and VMS data, processed by LEI.*

5.3.2 Fishing activities foreign vessels

For the foreign fishing fleets, the areas under study also have provided considerable fishing opportunities over the last 5 years (Table 5.7). In variant Brill fishing intensity is lowest with around 60 fishing days and an average GVA of around 0.25m euros. In Abalone fishing intensity is approx. 50% higher resulting in an average GVA of around 0.37m euros. Capelin and Dab show comparable levels of fisheries activities resulting in GVAs around 0.5m euros and as for the Dutch fleet fishing activity is highest for Eel and Flounder (GVAs 1.5 and 3.3m euros, respectively).

Table 5.7

Overview of the average fishing activities by foreign fishing fleets in the areas of the variants, distinguishing between vessels owned by foreign owners and by Dutch owners (so called flag vessels)

	Abalone	Brill	Capelin	Dab	Eel	Flounder
Foreign owned vessels (including all UK vessels)						
Fishing days	75	48	100	86	344	716
Landings (tonnes)	790	616	1,052	1,452	3,188	6,567
Landings value (kEuro)	712	455	987	890	3,264	6,695
GVA (kEuro)	329	234	430	497	1,379	2,831
Dutch owned vessels						
Fishing days	20	10	31	14	66	194
Landings (tonnes)	39	19	55	30	126	366
Landings value (kEuro)	92	44	134	65	393	863
GVA (kEuro)	45	19	62	29	143	429
Total						
Fishing days	95	58	131	100	410	910
Landings (tonnes)	829	636	1,107	1,483	3,314	6,934
Landings value (kEuro)	804	499	1,121	956	3,557	7,558
GVA (kEuro)	374	252	492	526	1,523	3,260

Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2015), processed by LEI, CEFAS, ILVO, Von Thünen and DTU. *All UK vessels are assumed to be foreign owned.

The majority of the fishing activities in the areas are carried out by the UK fleet which contributes to more than 50% of the effort in all variants (Figure 5.7). The landings volume of the Danish fleet is relatively high, but these are predominantly low price species, caught in large quantities. As a result the contribution of the Danish fleet to the total effort and landings value is relatively low, between 8-17% in effort. The effort levels of the German fleet and Belgian fleet are generally comparable to the Danish ones, but differences exist for specific years and variants. E.g. the Belgian fleet spend only 5 days fishing in Dab, whereas the Danish fleet spend 30 days.

The time series of the foreign fleets do not show a clear trend. In Eel and Flounder fishing activities seem to be stable over time and for the other variants, fishing activities are highly variable among years.

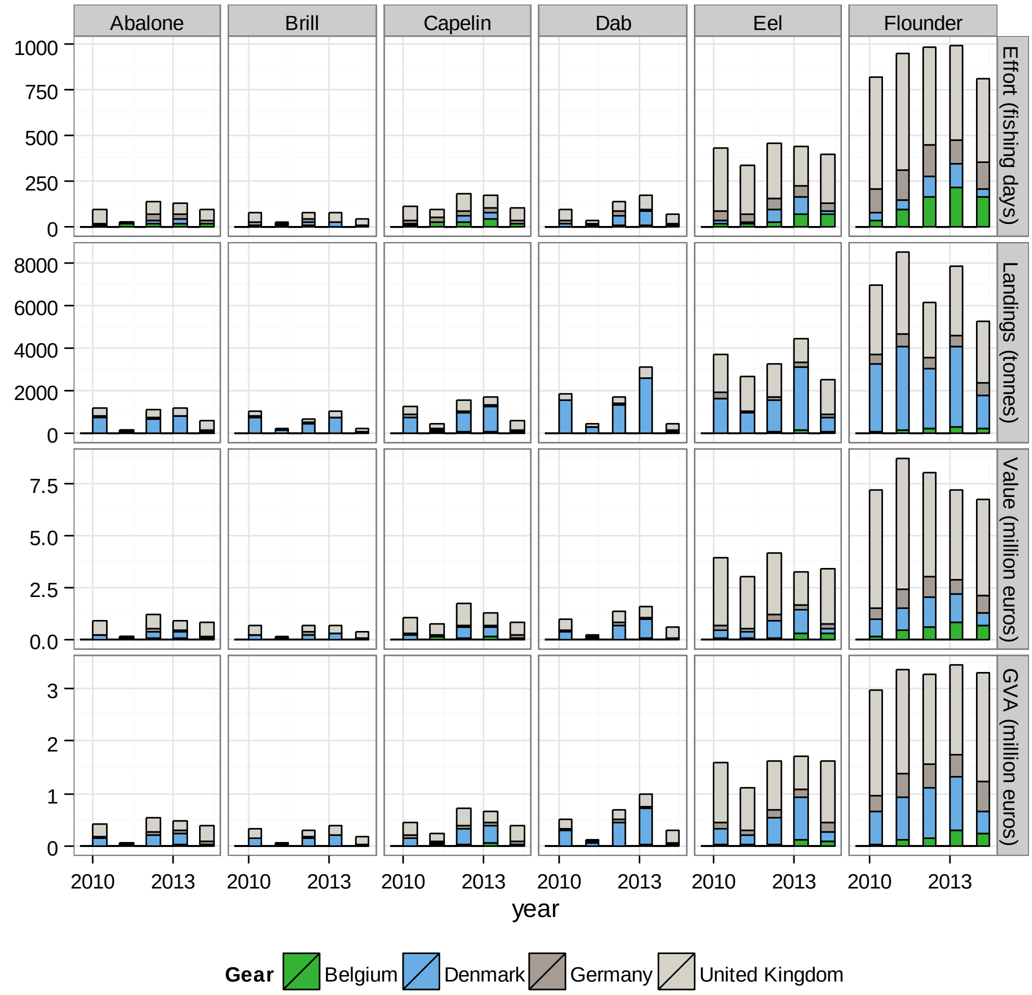

Figure 5.7 *Historical trends of the fishing activities by the foreign fishing fleets (including foreign owned and Dutch owned vessels) in the areas of the variants. Effort, landings, value of landings and GVA are given by country of origin*
Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2015), processed by LEI, CEFAS, ILVO, VTI and DTU.

The relative importance of the fishing activities of flag vessels (Dutch owned vessels) in the area in the foreign fleets seems limited (Table 5.7). However, the values presented here are underestimating the contribution of flag values to the total fishing activities of foreign fleets as the data for UK flag vessels is missing. This is due to the fact that for the UK the information on fishing activity could be matched only partly with the vessel information from the Dutch sector. For other countries the information could be matched completely. Dutch flag vessels under Belgian and German flag operating in the areas contribute minimal 20% to the total effort and 4% to the GVA of foreign fleets over the period 2010-2014. The total effort of all flag vessels ranges from 10 fishing days for Brill to 194 fishing days for Flounder. Large differences exist from one to another country, (Figure 5.8): whereas no Danish flag vessel (Dutch owned Danish vessel) is operating in any of the areas, 80% of the effort from German vessels and 60% of the effort of Belgian vessels is made by flag vessels.

Based on the current data, the German flag fleet in the area is more important than the Belgian flag fleet in all of the variants. The contribution of these vessels to the total effort of flag vessels ranges from 56% in Flounder to 85% in Brill. Belgian flag vessels are found in all variants as well but their relative importance is much lower: from 15% in Brill to 44% in Capelin.

For Eel and Flounder fishing activities of Belgian and German flag vessels have been increasing over the period 2010-2014. Efforts nearly doubled in the areas and value of landings and GVA more than doubled. This might be due to the fact that in the last years it has become easier for owners of flag vessels to use their Dutch quota on foreign vessels. In other variants 2014 figures are also higher than 2010 figures, but the trend is not clear.

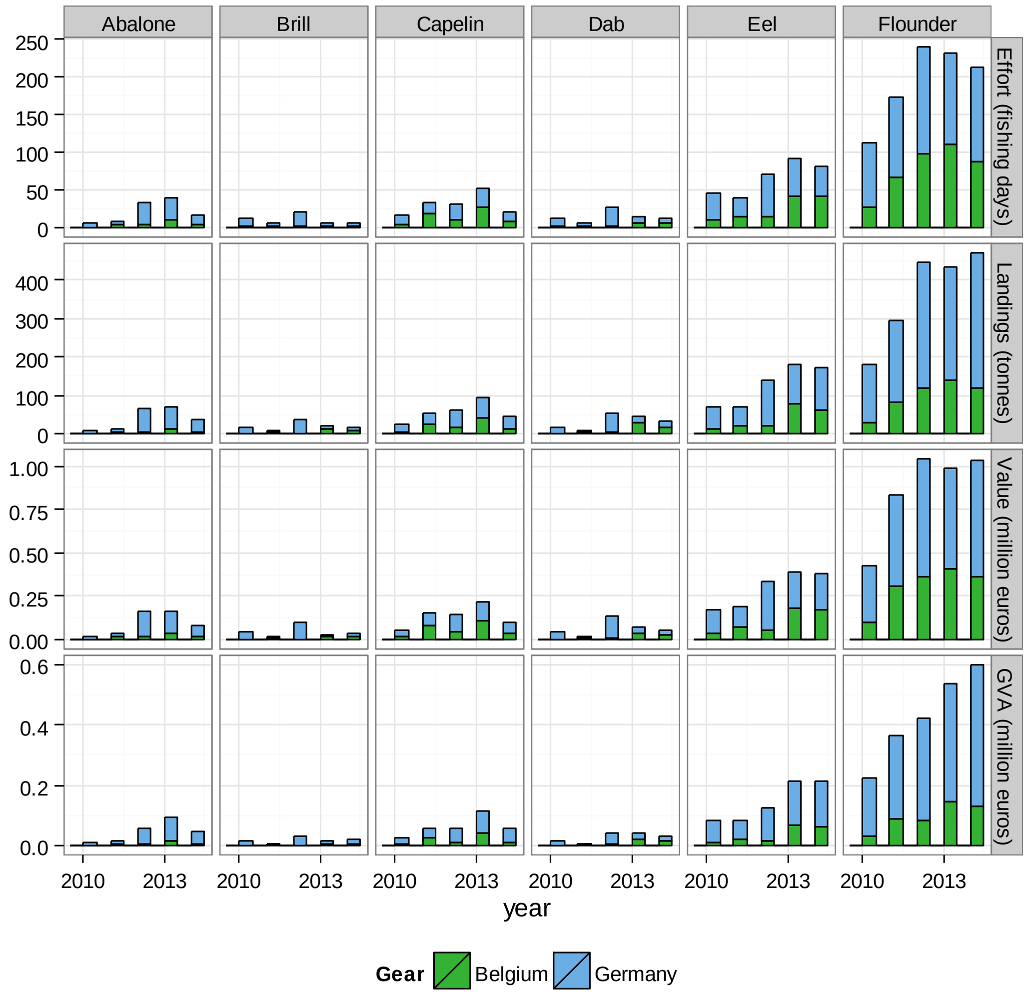

Figure 5.8 *Historical trends of the fishing activities by Belgian and German vessels with Dutch ownership (flag vessels) in the areas of the variants. Effort, landings, value of landings and GVA are given by country of origin (see text for explanation)*
Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2015), processed by LEI, CEFAS, ILVO, VTI and DTU.

5.4 Discussion

5.4.1 Fishing activities Dutch vessels

The analyses of economic effects of closures is completely dependent on the analyses of spatial fishing patterns using combined VMS and logbook data. The methodology to create maps of fishing efforts and landings is complex and has undergone rapid developments over the past decades. In recent years a number of publications has clarified issues and sub-issues such as methods for improved estimations of vessel trajectories (such as Hintzen *et al.*, 2010; Lee *et al.*, 2010; Pedersen *et al.*, 2009). New sources of data such as e-logbooks and more precise location data may offer an opportunity for the further development of the distribution analyses.

Analyses of distribution data published in available literature have given very little attention (virtually none) to analyses of the uncertainty of the results. However, in view of the large number of assumptions made during the processing of the data, it is certainly necessary to quantify the uncertainties to avoid giving the impression that the results from these studies constitute the only truth. Van Oostenbrugge (2010) took a first step in quantification of uncertainty and estimated the standard error of fishing activities indicators catch, catch value and GVA of the complete area of the Frisian Front (as in variant Flounder) to range from 10 to 20%. Since then, the level of detail of the analyses have progressed; daily logbook data instead of trip totals are used for distribution of catches and the distinction between fishing and non-fishing for each VMS ping is made on an analysis of vessel speeds per vessel and year. Therefore, it is reasonable to assume that the quality of the estimates of the indicators of fishing intensity in the areas have increased, and that the standard error of the estimates of large areas is lower than 10%. However, for smaller areas, and areas with low fishing intensity, the estimates are less accurate. Moreover, as the method used by Van Oostenbrugge was a first attempt to quantify uncertainty in this kind of data, using these data should be done with some caution.

5.4.2 Fishing activities foreign vessels

The fishing intensity of foreign vessels in the area have been analysed in cooperation with other national fisheries institutions. This was possible due to harmonisation of VMS databases and has led to a considerable increase of the quality of the estimates of fishing effort. A comparison between the estimated fishing activities in Flounder and the fishing activities from previous studies that estimated the fishing activities in the same area (Van Oostenbrugge *et al.*, 2013; Hamon *et al.*, 2013) shows that the new method led to a fourfold increase in the estimated effort of the foreign fleets (Table 5.8). As the current analysis is based on full coverage and detailed data on vessels positions, the estimate should be regarded as much more accurate than the previous estimate. The difference is also due to the inclusion of the Danish fishery which contributes to around 20% of the total effort in the area. The estimation of landings, landings value and GVA has been based on data on high aggregation levels; landings and effort data per fleet and gear from the complete central North Sea and cost structure data by fleet segments (from STECF, 2015). As such, it is assumed that landings per seaday are the same all over the central North Sea and throughout the year. This makes the estimates of the landings value and GVA highly uncertain and these figures should therefore only be used as indicative for the scale of operation in the area. The large increase in landings volume can be fully explained by the inclusion of the Danish fleet, that catches much higher volumes of low value fish per seaday than the other fleets.

Table 5.8
Overview of the average fishing activities by foreign fishing fleets in the areas of variant flounder in this study and the results found in previous studies (Van Oostenbrugge et al., 2013 and Hamon et al., 2013) and the relative difference (current/previous)

	2010			2011		
	Current study	Previous study	Factor	Current study	Previous study	Factor
Fishing days	816	239	3.4	951	218	4.4
Landings (tonnes)	6,931	806	8.6	8,503	878	9.7
Landings value (kEuro)	7,181	2,079	3.5	8,692	2,255	3.9

Source: Current study: Logbook data and VMS data and data from the Annual Economic report (STECF 2015), processed by LEI, CEFAS, ILVO, VTI and DTU. Previous study: Van Oostenbrugge *et al.* (2013) and Hamon *et al.* (2013).

The fishing activities of so-called flag vessels could be estimated for the German and Belgian fleets by using a list of flag vessels names presented to the researchers by the fishing industry in 2015. From the results it is clear that for the fleets concerned, the flag vessels contribute considerably to the fishing activities in the areas. For the UK fleet, this conclusion cannot be tested, but the significant number of UK flag vessels (33) suggests that the proportion of the UK fishing activities in the areas carried out by Dutch vessels can be substantial. In case 50% of the fishing activities of the UK vessel would be carried out by Dutch owned vessels, the economic value of the Flag vessels would be around 75% of the value for the Dutch fleet. From the trends it seems that the fishing intensity by flag vessels in the area has been increasing over the last years. This is most probably a true trend, but it could also be partly due to the inaccuracy of the list for the previous years.

6 Costs for Dutch fisheries

Hans van Oostenbrugge and Katell Hamon

6.1 Methodology

The costs of the closures for the Dutch fisheries depend both on the future value of the designated areas to the fishery and the possibilities for the fisheries to displace their activities to other locations in case of closures. Because both the future value of the areas and the possibilities for displacement are highly uncertain, scenarios have been designed for both aspects to get some idea of potential costs. First Policy, Economy and Innovation scenarios were developed to show the effects of externalities on the fishing activities in the areas. Subsequently the effects of reallocation of the fishing activities in case of closures were estimated, by developing displacement scenarios.

6.1.1 Scenarios for policy, economy and innovation

6.1.1.1 Defining Policy, Economy and Innovation scenarios

The fisheries sector in Europe is currently in a very dynamic period because of all kinds of internal and external developments. The most important ones are:

- Price changes (fish prices and fuel price)
- Changes in fish abundance (MSY targets of management)
- Implementation of the landing obligation
- Technical innovations
- Restriction of the fishing area by nature conservation, wind parks etc.

In the previous study on developments in the Dutch demersal fishing sector (Kuhlman and van Oostenbrugge, 2014) an inventory of these developments and their potential economic effects on the fisheries sector was made. These developments are used and combined into four Policy, Economy and Innovation scenarios (PEI scenarios). These PEI scenarios are used to evaluate the value of the potentially closed areas under different external developments. The developments were combined in the PEI-scenarios in such a way that the PEI scenarios would resemble extreme outcomes: PEI scenario one and two combine all developments that will have either positive (PEI scenario 1) or negative (PEI scenario 2) consequences for the overall economic performance of the Dutch fishing sector. PEI scenario 0 resembles the situation as it was during the reference period (business as usual). In PEI scenario 3, all developments have been combined.

The specifics of the four scenarios are given in Table 6.1 and the background and implementation of each of the factors is described below.

Table 6.1
Overview of the combination of external developments used in each of the Policy, Economy and Innovation scenarios. See text for explanation

Factors taken into account	Scenarios			
	0	1	2	3
Fish stocks		X		X
Fish prices a)		1	2	1+2
Fuel prices			X	X
Technical innovation		X		X
Landing obligation			X	X
Area closures			X	X

a) 1, positive price scenario (see text); 2, negative price scenario. See text for more explanation.

Fish Stocks
Recently, the key fish stocks in the North Sea (especially sole and plaice) have been growing. The fishing effort (mortality) is for sole and plaice at the level of MSY (Maximum Sustainable Yield), and the stock size increases for both species (ICES, 2013). For plaice, this has also led to increased fishing opportunities in recent years and the prospects are that this trend will continue. If fishing pressure will stay at a sustainable levels (MSY), the stock size will potentially grow to over 1m tonnes. This would mean that the catches could increase approximately by a factor two compared to the level of 2012, which is close to the average of the seven years. For sole, the situation is different (ICES, 2013). Due to the large recruitment to the stock in recent years, it is expected that the current stock size is larger than usual. Because of this, future catches will not be able to increase in order to sustainably use the stock, but will remain constant or even decline slightly compared with the 2012 level. Based on this, it is assumed that in PEI scenario 1 and 3 catch levels will increase for plaice catches by 100% and will stay constant for sole. For other species catch levels are assumed to increase by 25%. This can be either read as the development in the complete stocks, but also as the development of the stocks in the area. In PEI scenario 2 catches of all species are assumed equal to the level in the base year.

Fish prices
Two possible price developments have been implemented in the scenarios. Price development one originates from the so-called Delta-Groei scenario (Bruggeman and Dammers, 2013). The Delta Scenarios have been developed as possible directions for the future (2050 with a view through to 2100) based on future (WLO) scenarios of CPB and PBL (Janssen *et al.*, 2006) and show four possible development directions, based on two dimensions: from moderate to rapid climate change and socio-economic contraction to growth. For this study it is particularly important what bandwidth these scenarios provide for the most relevant external variables of the fishing sector. For example, the Delta Scenarios for 2050 indicate a population of Netherlands ranging from 15 to 20m, and an average growth of the gross domestic product of 1-2.5%. In comparison, the WLO scenarios were based on a population of 16-20m in 2040 and economic growth of 0.7 to 2.6% per year. In 2012 CPB performed an update of the WLO scenarios from 2006, and the conclusion is that the ranges are still realistic (Huizinga, 2012). Using the assumed growth in the domestic product of 2.5% and an income elasticity on demand for fish of 0.27 (Lechene, 2000), and constant imports of fish from outside the EU, the Delta-Groei scenario results in price increases for sole (+4%) plaice (+1%) and others (+2%).

The second price development is based on EU information on population growth and economic growth. The total EU population is expected to grow between 2013 and 2050 by 3.6% (Eurostat). This corresponds to 0.1% per year. Economic growth is the most important for the growth in the demand for fish. Assuming a somewhat conservative estimate of the per capita income growth of 1.5% per year and the same demand elasticity as for the previous scenario, this amounts to an increase in demand for fish from about 0.5% per year. Undoubtedly, competition from farmed fish will increase rather than decrease. It is therefore likely that the EU demand for wild fish the next 15 years will stagnate at best, and likely fall slightly. This also means pressure on prices. Therefore, it is assumed that the sale price of fish for the fishing sector will decrease by 10% for all species.

The two possible price developments are implemented in PEI scenario 1 and 2. In PEI scenario 3 the two price effects are combined. This results in a (hypothetic) price reduction.

Technical innovation
In the past decade a series of new fishing gears were developed as replacement for the traditional beam trawl. It is assumed that these new fishing techniques such as pulse trawl and pulswing will find further passage and will further replace the beam trawling in the coming years. It is also possible that the landing obligation will provide an incentive for changes in fishing techniques and shifts in the targeted species. Together with further fuel savings it will reduce the impact of higher fuel prices and tighter emission restrictions. The simplest calculation of the effects of this development is an increase in the cost of maintenance of fishing gear and a decrease in fuel consumption. Based on recent studies (Marlen *et al.*, 2014) it is assumed that technical innovation will increase gear costs by 50% and decrease fuel consumption by 25% in the beam trawl fleet. As the innovative pulse gears are not allowed above 55 degrees latitude, all beam trawl effort above this border is assumed to reallocate to more southern areas. This effort is distributed proportionally to the existing effort south of 55 degrees latitude. The effects of technical innovation are expected to have a positive effect on the economic performance of the sector and as such are included in PEI scenario 2 and 3.

Landing obligation
The effects of the landing obligation (discard ban) in the longer term are still very unclear. The landing obligation might lead to an increase in the cost, but how high this increase is depends on a number of factors:
- the type and size of adjustment of the (bycatch) quota
- the possible exemptions of certain species/fisheries
- the options for discard reduction by means of technical measures and changes in fishing patterns
- the price that can be obtained for bycatch
- the additional costs to be incurred for processing and landing of catches
- reduced fishing because of the extra catches and limits in storage capacity on board
- the extra labour needed on board to sort out the catches.

Buisman *et al.* (2013) estimated that in case fishing behaviour will not change and quota are not increased, the net cost to the Dutch cutter sector will be about 22-26m euros per year. This is mainly caused by the fact that some of the bycatch quota will limit the fishing activities of the fleet. With an adjustment of quotas (in which current discards would be added to the future quota) costs are estimated to be much lower; 6-12m euros (Buisman *et al.*, 2013.). In this study the effects of the landing obligation are assumed to be similar to those in Buisman *et al.*, 2013 (Table 6.2) with an adjustment of the quota.

Table 6.2
Overview of constants used in estimating the effects of the landings obligation (from Buisman et al., 2013)

Variable	Value
Discard rate (% of the total catch):	
Euro cutters (engine power <300 hp)	95%
Large cutters (engine power >= 300 hp)	80%
Price discards (Euro/kg)	0.2
Landings costs discards (Euro/kg)	0.3
Extra labour costs (%):	
Euro cutters (engine power <300 hp)	20
Large cutters (engine power >= 300 hp)	25
Extra steaming costs for Euro cutters (%)	6

The effects of the discard ban are included in PEI scenario 2 and 3. The inclusion of this effect in the scenarios can also be explained as the effect of different levels of discards in the area, with 0 discards for PEI scenario 1 and average discard levels in PEI scenario 2 and 3 while the discard ban applies to all scenarios.

Area closures

Competition for space on the North Sea with other space users, particularly wind farms and protected areas has increased and will further increase. This will potentially lead to lower fishing efficiency because fishermen need to reallocate fishing activities. To what extent the loss of fishing grounds also leads to lower catches is uncertain: on the one hand the displacement effect leads to greater pressures elsewhere, and thus possibly to lower catch per unit effort (see also Rijnsdorp *et al.*, 2000). On the other hand, there are potential (but uncertain) benefits of the closed areas in the development of resources (van Denderen, 2015). Because of this uncertainty, only the direct effects of effort displacement on the effort in the areas of the closures are taken into account. An inventory of all closures in the North Sea with their specific conditions is outside the scope of this study. Therefore, the inventory of possible closures carried out in the North Sea in the EU project Vectors is used to estimate the total effort in all possible closure areas (Marchal *et al.*, 2014). In the overview (Figure 6.1) potential MPA's but especially potential areas for wind farm development are depicted. However, in the UK and Denmark these so called wind farm search areas are very large and when taking into account that only in smaller sub-areas actual wind farms will be developed fisheries displacement will be much less than indicated by the areas shown in Figure 6.1. Furthermore, in the UK the government is considering the possibilities to allow fishing within wind farms resulting in less displacement.
To calculate the effects of displacement by future MPA's and wind farms we assumed that on the German shelf in the coming decades 50 % of the indicated search areas will actually be developed, while in Denmark and the UK about 10% of these areas will be developed such that this leads to fisheries displacement. The effects of closures have been included in PEI scenario 2 and 3 and can be read as the potential effects of effort allocation due to area closures.

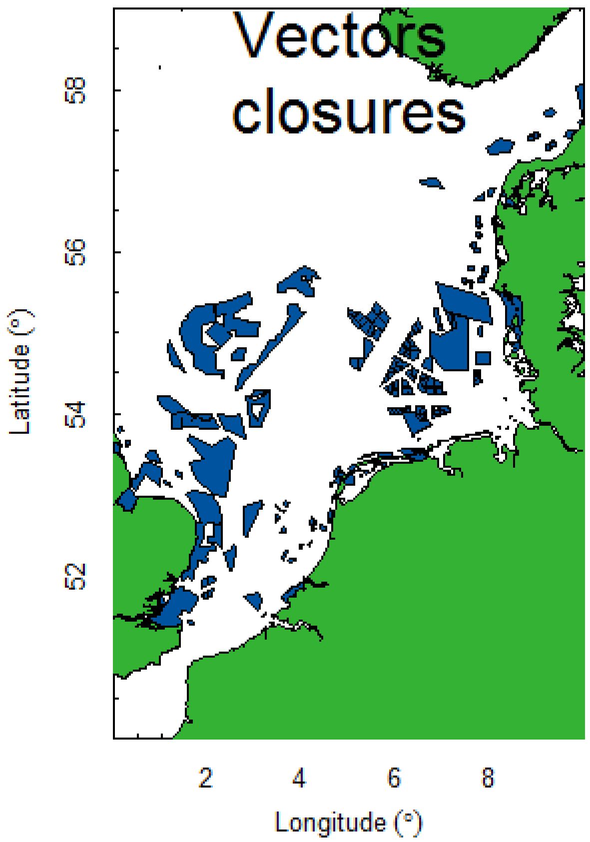

Figure 6.1 *Potential area closures in the North Sea from Marchal et al., 2014. These area closures were used as a proxy for all area closures (see also text).*
Source: Logbook data and VMS data, processed by LEI.

6.1.1.2 Implementation of PEI scenarios

The effects of the scenarios were estimated for each vessel and each year in the time series individually. In case of effort displacement (in technical developments and area closures) the proportion of effort from these areas is estimated for each vessel and this proportion is redistributed in the remaining fishing grounds proportional to the existing effort pattern. This means that in case a vessel fishes 20% in potential closed areas, the effort of this vessel on all other fishing grounds, including the Frisian Front and the Central Oyster Grounds will increase by 20%. In this way the variations in effort distribution, gear use, fish prices, species composition etc. of each vessel and year were taken into account in the estimation of the value of the variants in each of the PEI scenarios. After the estimation at the individual level the results were aggregated. All of the scenarios analyses implemented in R.

6.1.2 Displacement scenarios

Effort displacement is a complex issue and effects are hard to quantify. Yet these effects are crucial for the economic consequences of closures for fisheries and essential for assessing the effectiveness of closures (Forcada *et al.*, 2010). In order to get an idea about possible displacement mechanisms and the resulting effects for the closure of these areas, another project about effort displacement was carried out in parallel with the current project. The parallel project included a desk study on the general aspects of displacement, a case study on the displacement effects of closures in the North Sea and a workshop with fishermen to discuss the results of the desk study and consequences for the effects of closures (Slijkerman and Tanis, 2015, De Vries *et al.*, 2015).

Displacement effects resulting from the different variants

Based on results of the displacement workshop as described in Slijkerman and Tamis (2015) it was concluded that displacement patterns resulting from the different variants are hard to predict and that displacement depends largely on the type of fisheries. Moreover, displacement depends highly on the importance of the closed fishing grounds (size and place), the expertise and character of the skipper, distance to the fishing harbours, and the quota for the different fish stocks. These factors all result in a certain level of dependency of the fisherman/fisheries. The more dependent the fishermen are, the harder it is to displace or to predict where displaced effort will be allocated.

The extent of displacement in terms of location and effort is hard to forecast because of uncertainties in this phase of the process of implementing the closed areas. Moreover, factors which may be relevant in 5 years will determine displacement in future as well. These are however unknown, in definition and extent.

Nevertheless, a few rough estimates on displacement were drafted during the workshop by a small selection of fishermen and representatives. It should be emphasised that these conclusions have not been widely discussed and confirmed within the fisheries sector, and reflect only a first attempt to qualify displacement (more information in Slijkerman and Tamis, 2015).

- Twinrig nephrops fishermen might first explore near/at the borders of the closed area, in case this is nearby their original grounds. Displacement will probably be explorative and heterogeneous in the remaining open areas when fishing grounds are all closed. After exploring, fisheries will concentrate in areas when proper fishing grounds are found.
- Flyshoot fishermen may follow the fish on their route and displaced fisheries depend on these routes. As a result, the Frisian Front is an important area for these fisheries in the period May - July. Displacement probably focuses on the open areas, nearby the optimum concentration of fish stocks. Displacement also depends on the amount of quotas. In case of enough plaice quota fishermen might be able to displace to the Dogger Bank although fishing opportunities are also limited there because of closures. With sufficient cod quota they might be able to displace to areas like Skagerrak.
- Pulse fisheries may displace to the remaining open areas of 30 m depth. This depth line goes right through the Frisian front and is the border between harder and softer grounds. Fishermen that are highly dependent on the area probably have little idea where to displace to.

Based on the outcomes of the workshop a methodology for the estimation of economic effects of displacement was developed. Elements that were taken from the results of the workshop were:

There are three different situations with respect to use of the areas:
- *Use by dependent fishermen*
  Use by fishermen that depend on the area for a large proportion of their fishing activities. This can also be seasonal, because of distribution patterns of target species.
- *Use by independent fishermen*
  Use by fishermen that are fishing in different areas and fish in the area once in a while.
- *Fishing through the area*
  Use by fishermen that are on their way to other fishing areas and fish through the area. This was only mentioned as a problem in case the whole Frisian Front was closed (variant Flounder).

The options for reallocation of the fishing activities and their effects on the economic performance of the fisheries depend on the type of use and the fishery that is conducted in the area. The main gear types differ in respect to the use of the area (see Chapter 5) and alternative fishing possibilities as explained below.

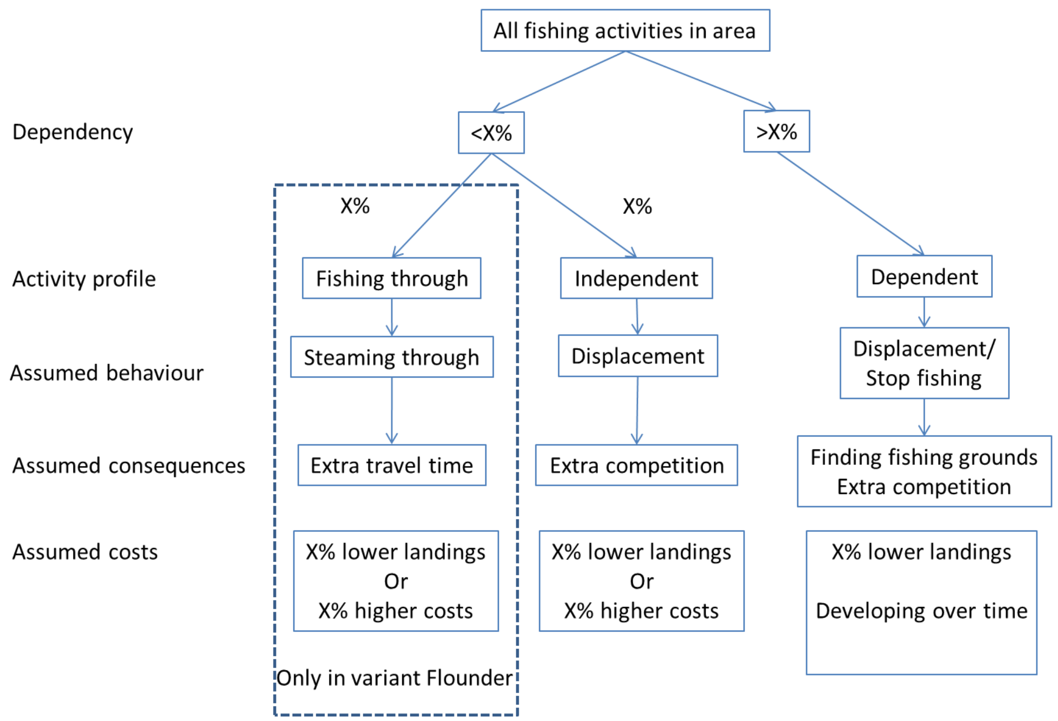

Figure 6.2 *Schematic approach to assess the effects of displacement of fishing activities. The value for the various percentages are given in Table 6.3*

Figure 6.2 shows the approach taken to estimate the effects of the closures.
Distinction is made between the three types of use mentioned during the workshop; specific use of the areas by dependents and independents, and fishing through. The last type of use (fishing through) was only mentioned to become a problem in variant Flounder for the fishing activities in the Frisian Front, because in this variant large area is closed for fishing without corridors that fishermen can use to fish through the area from north to south and vice versa.

For the estimation of the effects of displacement the following assumptions are made:
- If a fisherman spends more than 10% of his annual fishing time using a specific gear in the area, he is *dependent on the area.* This percentage is based on the observation that considerable seasonal dependency occurs and translates into lower dependency on an annual basis.
- If a fisherman spends less than 10% of his annual fishing time using a specific gear in the area, he is *not dependent on the area.*

- In case of variant Flounder and the gears twin trawl, pulse trawl and beam trawl, part of the effort of the *independent fishing vessels* in the area is spent fishing through the area and the rest is spent fishing in the area.
- If an area is closed, *dependent fishing vessels* will move to other areas in search of new fishing opportunities. During the first year their catch rates (catches per day) will be lower as a result of inexperience and more competition. After some years it is assumed that the fishermen attain the experience and catch rates gradually increase. However, catch rates will stay lower because of competition and less optimal fishing opportunities. It is also assumed that the decrease in efficiency is resulting in lower landings as most fishermen do not have the opportunity to extend the effort considerably.
- If an area is closed, *independent fishing vessels* will move to other areas known to them. Because they have experience in these areas their fishing opportunities will only be affected by the fact that there are other fishermen active in the area (more competition) and that fishing opportunities are less optimal.
- The costs of not being able to fish through the area are estimated using the following assumptions:
  - The distance travelled by fishing vessels fishing through the closed area on the Frisian Front is approximately 20 miles.
  - Average steaming speeds is around 10 miles per hour
  - Average fishing speed is around 3, 4.8 and 6 miles per hour for twin trawl, pulse trawl and beam trawl respectively
  - Fishermen will steam through the area losing fishing time. The fishing time that will be lost is then the fishing speed divided by the steaming speed multiplied by current time spend in the area.
  - In addition the fishermen will need some time to store the gears before steaming.

To estimate the parameters two approaches were used, resulting in two sets of assumptions:
- One set was based on the available scientific literature on displacement effects of beam trawl fisheries in the North Sea (displacement scenario A).
- One set was developed by the fishermen’s representatives (displacement scenario B).

Besides these two scenario’s an alternative scenario was developed in which the main assumption was that the fisheries sector would manage to adapt quickly to the closures by displacement of the effort to alternative fishing grounds without any significant long term costs. Because of the relative small size of the closures and the large uncertainty in the assumptions on displacement this theoretical scenario was included.

Table 6.3 summarises the parameters used in the three displacement scenarios.

Table 6.3
Overview of parameters used in estimating the effects of displacement

	Scenario A Literature	Scenario B Fishing sector	Scenario C Zero costs
Dependency level for distinction dependent vs independent	10%	10%	NA
% fishing through in case of independent fishermen in variant Flounder (not for flyshoot)	20%	50%	NA
lower landings for specialists in other areas			
year 1	20%	75%	NA
year 2-4	10%	50%	NA
after year 4	5%	40%	NA
lower efficiency for generalists in other areas	5%	25%	NA
Effect of crowding	See text	NA	NA
Factor that will change due to lower efficiency of independent fishermen			
Twin trawl	revenues	revenues	NA
Flyshoot	revenues	revenues	NA
Pulse trawl	effort	revenues	NA
Beam trawl	revenues	revenues	NA
Assumed fishing speed for gears fishing through the area in case of Flounder (knots)			
Twin trawl	3	3	NA
Pulse trawl	4.8	4.8	NA
Beam trawl	6	6	NA
Assumed average distance fished through the area (miles)	20	20	NA
Assumed steaming speed	10	10	NA
Assumed extra time for storing and unravelling gears (hours)	1.5	2.0	NA
% time lost due to steaming through the area			
Twin trawl	42	54	NA
Pulse trawl	67	86	NA
Beam trawl	84	108	NA

The rationale behind displacement scenario A is that fishermen that reallocate their fishing activities will experience lower catch efficiency because they (1) will move to less favourable fishing grounds, (2) will have less knowledge in case they need to explore new fishing grounds and (3) experience more inference competition from other fishermen. The first two effects are specific for the area and for the fishing vessels that operate in the area. The crowding effect is not specific for the area other than through the amount of effort that is displaced, and also affects vessels that are fishing outside the area.
The effects of moving to less favourable fishing grounds is based on the assumption that the proposed closures have added value to the fisheries, because they provide better fishing opportunities than other areas (more fish per sea day), so fishing there is more efficient. A comparative analysis of the value of fish caught per sea day in the area of the Frisian Front shows that the fishery in this area yields specific species compositions with relative high landings values per sea day for some (non-quota) species (see also Appendix 10). Most noticeably, relative landings of turbot are high for most fisheries, whereas landings of plaice and sole are relatively low. Moreover, landings of nephrops are relatively high for otter board trawls and twin trawls and landings of gurnard are relatively high for Scottish seine. As the landings per sea day are compared to landings from other areas with the same gear and type of fishing vessel it can be concluded that the differences in landings value are not coming from changes in gears, but are intrinsic to the area. As such, the areas provide additional fishing opportunities for fishermen that target these species. Moreover, as most of the higher landings concern species that are not allocated to individual fishermen, the landings may also not be compensated by other fishermen. Because the contribution of these species to the total value of

landings in the areas is relatively small (10-20% for Turbot and gurnard combined), the effect of the overall lower catch efficiency will also be small, but it will continue to exists in time in case it is assumed that fish distribution patterns in space will not change. As such it is assumed that the closures will lead to a permanent reduction in VPUE of 5%.

The effects of crowding have been studied for beam trawl fisheries in the North Sea by Rijnsdorp et al 2000. They found that a reduction in fishing intensity led to higher catch rates during the week of prayer in Urk (10% higher catch rates in week with 75% reduction in fishing effort) and concluded that increased fishing intensity in a fishing area will have an negative effect on catch efficiency through crowding. As the effort of the fishing vessels is displaced from the closed areas to alternative areas with other vessels operating, fishing intensity in other areas will increase affecting the catch efficiency of all vessels. As such the effect of crowding can only be estimated on a fleet level. The overall effect on catch efficiency is estimated using the relationship between effort and catch efficiency by Rijnsdorp et al and the relative amounts of effort in the closures (See Table 5.6)(see also Appendix 10). The reductions in catch efficiency are assumed to result in lower landings and higher costs and resulting reductions in GVA in the same way as for the affected fishing vessels (e.g. higher costs for sole fisheries and lower landings for other fisheries).

Rijnsdorp *et al.* (2007) assessed the effects of a temporal large area closure in the North Sea for the beam trawl fishery and included a comparison of the landings of resident fishermen and newcomers. The study concluded that in the northern part of the North Sea the newcomers had lower catch rates: on average 20% lower with a maximum of 40% in one week.

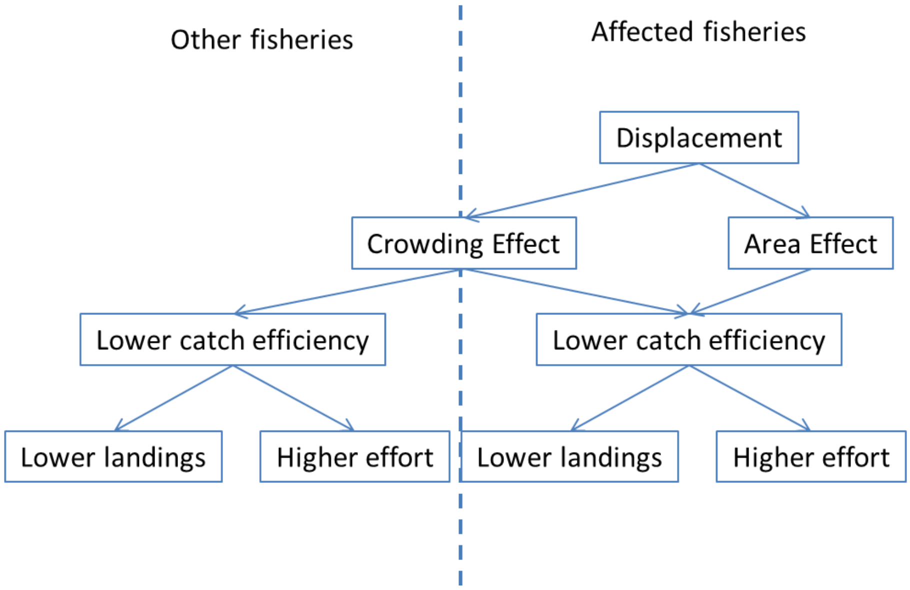

Figure 6.3 *Effects of reallocation effort for the fishing vessels operating inside the closures and the vessels operating outside the closures as assumed in displacement scenario A.*

For fishermen that depend on the closed area the reduction in catch efficiency is assumed to be higher as they also have less knowledge on the local fishing circumstances in the alternative areas. As the reduction in catch efficiency applies to a whole year, and the reduction in Poos and Rijnsdorp was only for a number of weeks, the extra reduction in catch efficiency was assumed to be smaller than in Poos and Rijnsdorp (15%) as fishermen will probably increase their catch efficiency over the time period by getting more experience on the new fishing grounds. This results in a total reduction in catch efficiency of 20% in the first year for the fishing activities that fishermen would need reallocate. During the years after the closure it is assumed that the dependent displaced fishermen will become as efficient as the independent displaced fishermen and the reduction in catch efficiency will decrease to 5%. Moreover it is assumed that depending on the most limiting factor for the fisheries, fishermen will compensate lost fishing opportunities (lower efficiency or lost fishing time) either by making more sea days or landing less fish:

- For pulse trawl (targeting sole) it is assumed that the amount of sole quota is limiting (as is has been during the last years), so that the number of fishing days and costs will increase.
- For other gears it is assumed that the amount of fishing days will be limiting, so the catches and revenues will decrease.

The calculation of the time lost due to fishing through the area results in the maximum fishing time lost. Moreover, currently fishermen that fish through the area will not always take the shortest route as there is no reason to do so. Because of this a conservative estimate of the percentage of fishing days that were spend fishing through the area has been used (20%)

The rationale behind displacement scenario B has been based on expert opinion from the fishermen. A complete rationale can be found in Appendix 11. The reductions in catch efficiency are much higher than the ones in scenario A, based on the conviction that the fishermen will not only lose fish because of lack of knowledge and more competition, but that the catch efficiency on these fishing grounds is much higher than on alternative grounds that could be utilised by the affected fishermen. It is stated that the 75% reduction in catch efficiency for specialists in the first year is an proxy for the fact that a limited number of fishermen will stop completely because of the closures. Further, the effect of steaming through the area is larger than for displacement scenario A. Another difference is that in displacement scenario B it is assumed that the resulting lower catch efficiency by the closures will not be compensated by making longer trips.

6.1.3 Calculation of net present value

Calculating a net present value concerns discounting future costs and benefits. Costs and benefit may occur at various moments in time. Examples are yearly income, continuing maintenance costs and 'once only' costs such as investment costs. In order to evaluate various plan alternatives - such as scenarios for protecting areas - by means of a CBA, costs and benefits that occur at different moments in time are being converted into a single metric, namely a net present value (NPV). The NPV concerns a weighted aggregation of all relevant costs and benefits. Thereby, costs/benefits that occur later in time have a smaller weight in the summation. This weighting of costs and benefits is also referred to as discounting costs and benefits.

In this study the following parameters have been used:

- a discount rate of 5.5 %
- a time horizon of 30 years.

The discount rate is based on the recommendations of the Werkgroep Actualisatie Discontovoet. The time horizon is chosen to be 30 years as an indication of the closed period.

Then the formula for calculating the net present value is:

$$NPV = \sum_{t=0}^{T} \left\{ \frac{(B_t - C_t)}{(1 + r)^t} \right\},$$

where:

T = time horizon
B_t = benefits in year t
C_t = costs in year t
r = discount rate

6.1.4 Sensitivity analysis

A sensitivity analysis was carried out for all main effects taken into account in the scenario analyses. Table 6.4 provides the original value and the adjusted values for all parameters that were adjusted in the sensitivity analysis. The sensitivity analysis was not carried out for each of the parameters separately, but the parameters of each type of development were tested in combination.

Table 6.4

Overview of the factors that were tested in the sensitivity analysis and the relative changes

Factors tested	Original value for Scenario 3	Changed value (10% increase)
Value in the areas:		
Extra effort in each of the areas	variable	+10%
Technical innovation:		
Relative fuel decrease (%)	25	27.5
Relative gear costs increase (%)	50	55
Area closures due to nature conservation and wind farms:		
Effort increase in the areas		10% extra closures
Relative increase fish density (%)		
Plaice	100	110
Sole	0	10%
Other fish	25	27.5
Landing obligation		
Discard rate:		
Euro cutters (<300 hp)	95	104.5
large cutters (>300 hp)	80	88
Discard price (euro per kg discards)	0.2	0.22
Landings costs discards (per kg discards)	0.3	0.33
Relative increase in labour costs (%)		
Euro cutters (<300 hp)	20	22
large cutters (>300 hp)	25	27,5
Relative increase steaming costs for Euro cutters	6	6,6
Relative change in fish prices (%)		
Plaice price	-9.1	-10.0
Sole price	-6.4	-7.0
Price other fish	-8.2	-9.0
Economic results in the area		
Relative increase fuel price (%)	20	22

6.2 Results

In the results section first the effects of the PEI scenarios on the fishing intensity in the areas and the resulting value are presented. Second the effects of the displacement scenarios are presented in combination with the PEI scenarios.

6.2.1 Fishing activities in Policy, Economy and Innovation scenarios

The outcomes of the PEI scenarios illustrate the uncertain future for the Dutch fishing fleet. Dependening on the developments taken into account the fishing activities in the areas and their resulting economic performance can vary significantly.

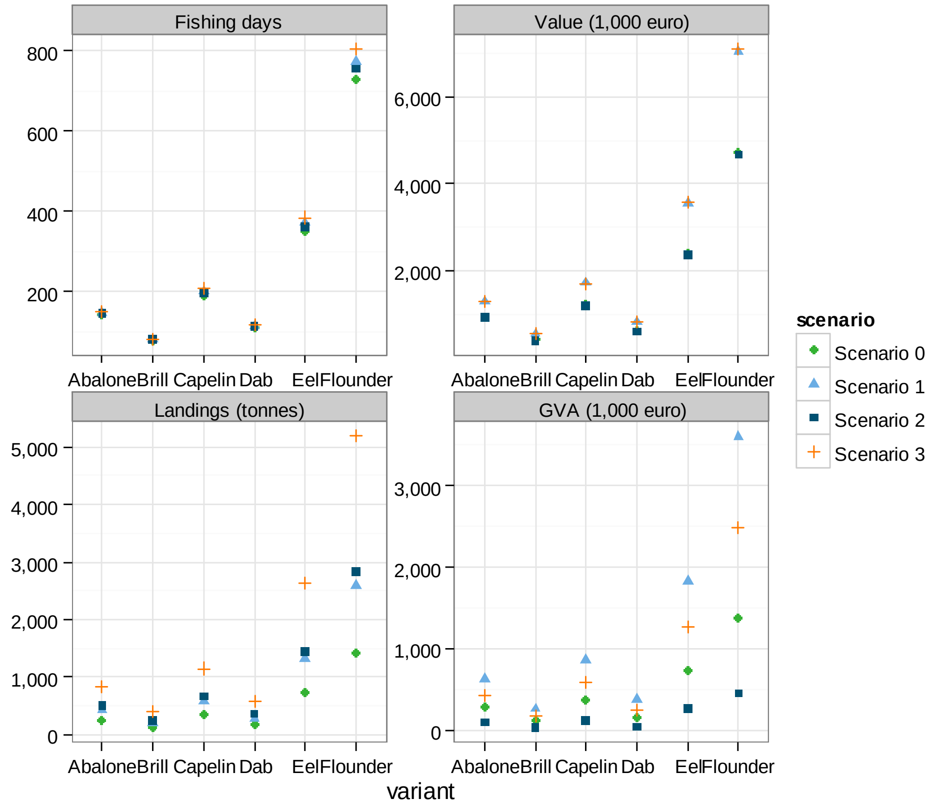

Figure 6.4 *Consequences of the Policy, Economy and Innovation scenarios for the fishing activities of the Dutch fleet in the areas of various variants (annual totals) in case the areas are not closed*
Source: Logbook data and VMS data, processed by LEI.

All scenarios indicate that fishing activities in the areas increase and that the value and volume of landings will be larger than in the current situation (scenario 0, Figure 6.4). This is realistic, based on the fact that the fishing area will get smaller and the fish stocks and thereby the possible landings will increase. Effort increases due to area closures and the change to pulse gears that are not allowed north of 55 degrees latitude. This causes an effort increase of 4 to 7% in scenario 3, depending on the variant. The increase is highest for Flounder and Eel (7% for both in scenario 3) and lowest for Brill and Dab (4% for both in scenario 3). Abalone and Capelin show intermediate increases (5 and 6% in scenario 3). For scenario 1 and 2 the increases are lower, but the ranking of the variants stays the same. The difference between relative increases in effort for the variants indicate that the vessels active in the variants differ in their spatial fishing patterns. Apparently, vessels that are fishing in variant Flounder are more active in other areas that have been identified as closures in the PEI scenarios than vessels that are active in variant Brill.

Landings increase significantly in all PEI scenarios ranging from 60% to 270%. This leads to total landings that range from 400 tonnes for Brill to 5,200 tonnes for Flounder in PEI scenario 3. The main reasons for this increase are the increase of fish biomass in PEI scenario 1 and the inclusion of discards that have to be landed in PEI scenario 2. Also the increase in effort contributes to the increased landings. The differences between the PEI scenarios are large, but despite the large changes, the ranking of the variants is stable. In case of Flounder and Eel the relative changes are largest (around 370% in scenario 3). For the other variants the increases are quite similar, around 310% for Brill and Dab and 330% for Abalone and Capelin.

Landings value also increases in al PEI scenarios and variants, but the change is much smaller than for landings volume. This is mainly due to the low price of discards and the fact that the biomass of sole is assumed to be stable. Because of this the vast majority of extra fish that is caught has a relative low value, especially in PEI scenario 2. As for the landings volume the effects are largest for the largest variants (Eel and Flounder) and the ranking does not change.

GVA is influenced most by all the assumed changes in the PEI scenarios and shows that depending on external developments, economic performance in the variants might vary considerably. In PEI scenario 1 the GVA increases by 130-160% of the original value and in PEI-scenario 2 the GVA decreases of 61-71%. In PEI scenario 3 these opposite effects partly mitigate each other, and the overall effects of all developments result in an increase of the GVA in all variants of 50-80%.

In addition to the overall effects on the fishing activities in the area and the resulting economic performance, the PEI scenarios hardly affect the dependency of individual fishermen on the areas for their fisheries. Figures 6.5 to 6.8 show that although the average landings value affected by the closures of the main fisheries changes considerably, the patterns in dependency are highly consistent. This is mainly due to the fact that the maximum increase in the fishing intensity due to other closed areas is around 6%. In PEI scenario 2 and 3 the dependency increase for all variants, due to area closures elsewhere. In most variants, the effect is however negligible because of the general low level of dependency. In case of Flounder, one would expect that the dependency change is largest as the basic dependency is highest, but the effects are too small to see in the graphs. However, the amounts of fish caught by dependent fishermen do increase substantially in scenario 2 and 3.

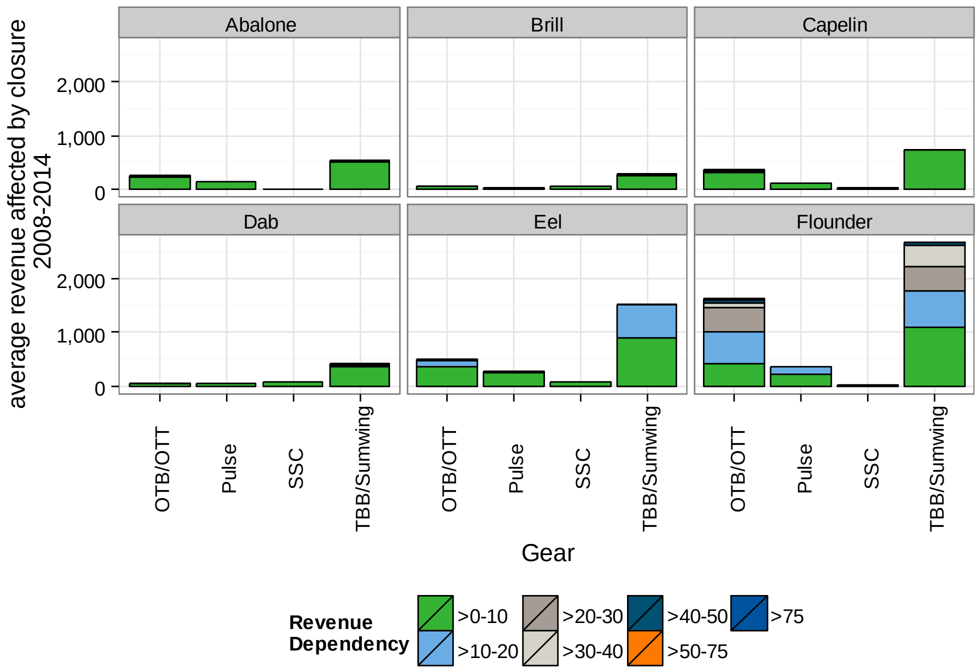

Figure 6.5 *Average revenue of the Dutch fleet (kEuro per year) affected by the closure of the main fisheries in scenario 0 (no change) in each of the variants The various colours show the level to which the vessels generating the revenues depend on the areas on an annual basis. E.g. almost the complete revenue for TBB/sumwing in variant Abalone is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI

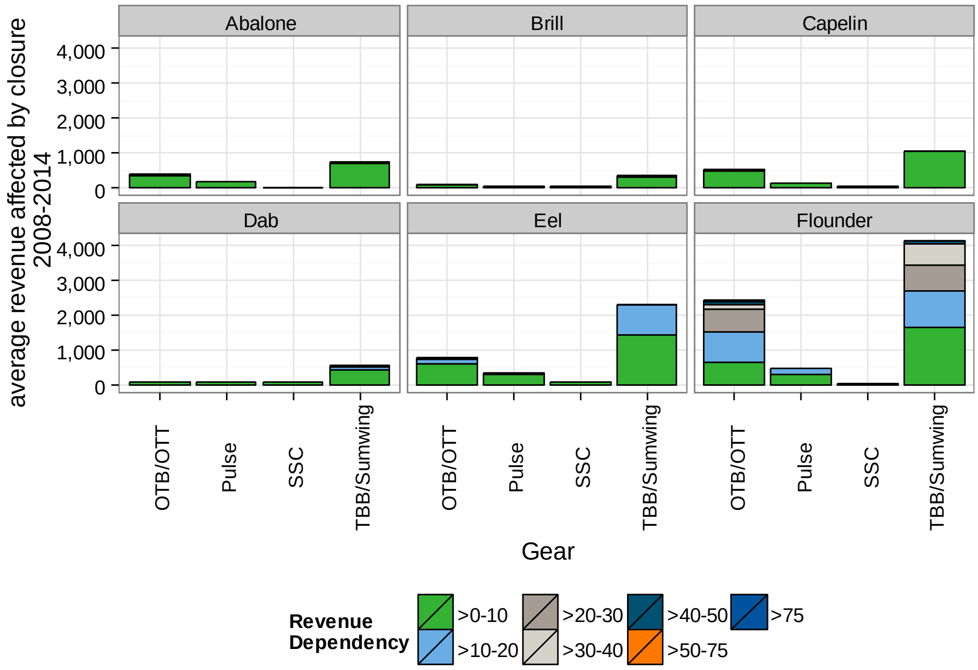

Figure 6.6 *Average revenue of the Dutch fleet (kEuro per year) affected by the closure of the main fisheries in scenario 1 in each of the variants. The various colours show the level to which the vessels generating the revenues depend on the areas on an annual basis. E.g. the complete revenue for TBB/sumwing in variant Abalone is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI.

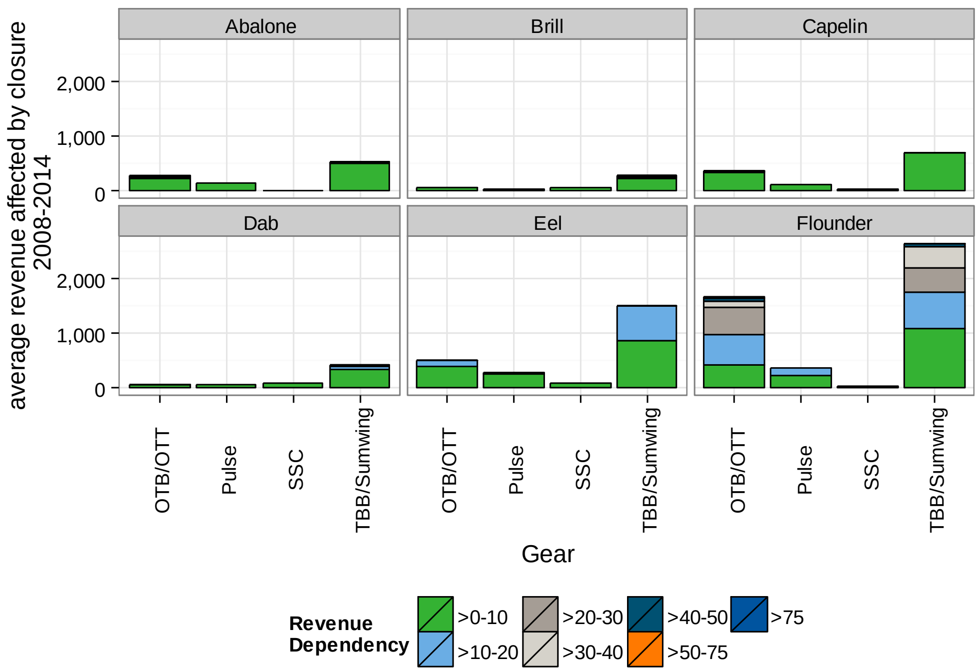

Figure 6.7 *Average revenue of the Dutch fleet (kEuro per year) affected by the closure of the main fisheries in scenario 2 in each of the variants. The various colours show the level to which the vessels generating the revenues depend on the areas on an annual basis. E.g. the complete revenue for TBB/sumwing in variant Abalone is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI.

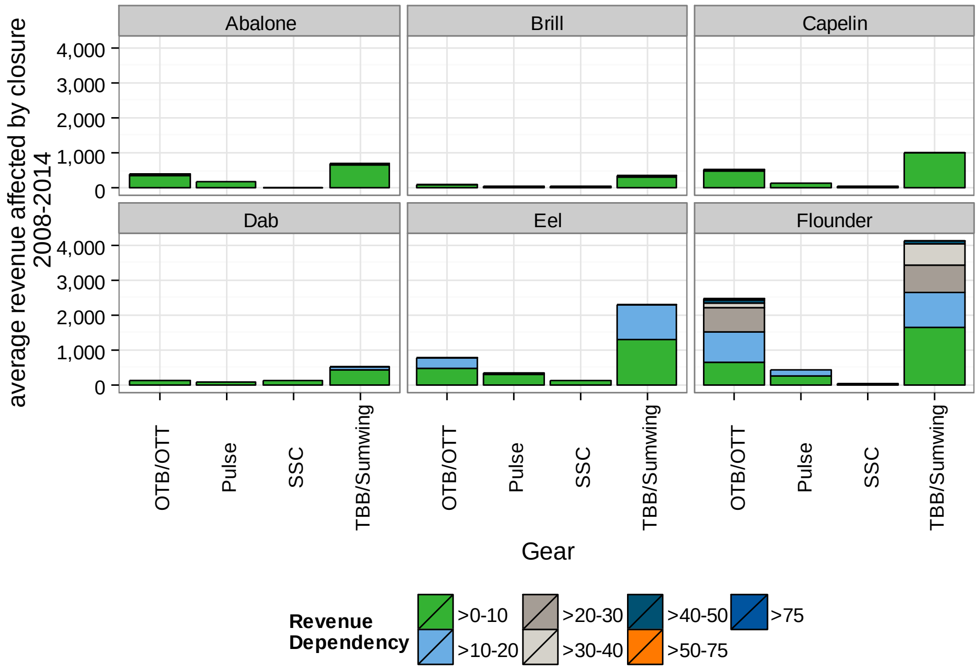

__Figure 6.8__ Average revenue of the Dutch fleet (kEuro per year) affected by the closure of the main fisheries in scenario 3 in each of the variants. The various colours show the level to which the vessels generating the revenues depend on the areas on an annual basis. E.g. the complete revenue for TBB/sumwing in variant Abalone is obtained by vessels that are less than 10% dependent on these areas.
Source: Logbook data and VMS data, processed by LEI.

6.2.2 Displacement costs

As a consequence of area closures a vessel can either increase its effort and costs or decrease its landings and income. Which option is chosen depends on the dependency of the vessels, the variant and the gear used. Because these characteristics vary among vessels, the two effects can occur simultaneously within the fleet; for some vessels income will be lower, while for others costs will increase.

Table 6.5 and Figures 6.9-6.14 show the effects of displacement of the fishing activities from the closed areas. For displacement scenario A only the effects on the vessels affected by the closures are shown. As displacement scenario C results in 0 costs for the fisheries, these have not been presented in the graphs, but have been mentioned in the graphs and tables headers.

Table 6.5
Net effects of effort displacement in case of area closures for the Dutch fleet in the first, second and fifth year after the closure for PEI scenario 0 and displacement scenario A and B. ***For displacement scenario A only the costs for affected vessels are shown. For displacement scenario C the changes in effort, landings, value and Gross Value Added are 0***

	Effort (sea days)		Landings (tonnes)		Value (1,000 euros)		Gross Value Added (1,000 euros)	
Displacement scenario	A	B	A	B	A	B	A	B
Abalone								
Year 1	0.9	0.0	-11	-64	-40	-237	-42	-220
Year 2	0.9	0.0	-11	-63	-40	-236	-42	-219
Year 5	0.9	0.0	-11	-63	-40	-236	-42	-219
Brill								
Year 1	0.2	0.0	-6	-31	-19	-102	-18	-94
Year 2	0.2	0.0	-6	-31	-19	-101	-18	-94
Year 5	0.2	0.0	-6	-31	-19	-101	-18	-94
Capelin								
Year 1	0.7	0.0	-16	-84	-55	-306	-54	-284
Year 2	0.7	0.0	-16	-84	-55	-306	-54	-283
Year 5	0.7	0.0	-16	-84	-55	-306	-54	-283
Dab								
Year 1	0.3	0.0	-9	-46	-29	-155	-28	-144
Year 2	0.3	0.0	-9	-46	-28	-154	-28	-143
Year 5	0.3	0.0	-9	-45	-28	-153	-27	-142
Eel								
Year 1	1.6	0.0	-57	-260	-188	-874	-183	-810
Year 2	1.6	0.0	-41	-220	-133	-736	-132	-682
Year 5	1.6	0.0	-33	-205	-106	-681	-106	-631
Flounder								
Year 1	6.5	0.0	-251	-919	-832	-3108	-805	-2882
Year 2	6.5	0.0	-179	-740	-588	-2498	-579	-2316
Year 5	6.5	0.0	-143	-668	-466	-2254	-465	-2090

Source: Logbook data and VMS data, processed by LEI

Table 6.5 shows that the overall pattern in the effects of effort displacement for scenarios A and B is comparable to that of the PEI scenarios. The consequences of displacement are lowest for variant Brill and Dab. Variant Abalone and Capelin show intermediate values and the values of Eel and Flounder are by far the highest. For nearly all variants, the effects of displacement in scenario B are around 5 to 6 times higher than those in displacement scenario A. This accounts for the landings volume, landings value and the resulting GVA. Only in case of variant Flounder, displacement scenario B results are 3.5-5 times higher than displacement scenario A. This is because in case of variant Flounder, a considerable part of the effect is due to costs of steaming through the area. The difference in this effect between the two displacement scenarios is much smaller than the difference in costs of displacement of fishing in the area (see also Table 6.3). Another difference between the scenarios is the assumption in displacement scenario B that the closures will not lead to extra effort. This effect is however small because the extra effort is limited. In case of displacement scenario C there is no difference in the resulting costs of the variants as for all variants, the costs are 0.

In both displacement scenario A and B the effect of displacement is largest in the first year after the closure as the vessels that are dependent on the closed areas experience the greatest reduction in fishing efficiency. Only in case of variant Eel and Flounder the results show a considerable decrease over the years, because only for these two variants a considerable proportion of the fishing activities is carried out by vessels that are categorised as dependent on the areas. In case of displacement scenario C there is no reduction in the effects of displacement over time.

Next figures show effects of displacement for independent and dependent vessels for the various PEI scenarios and displacement scenarios A and B.

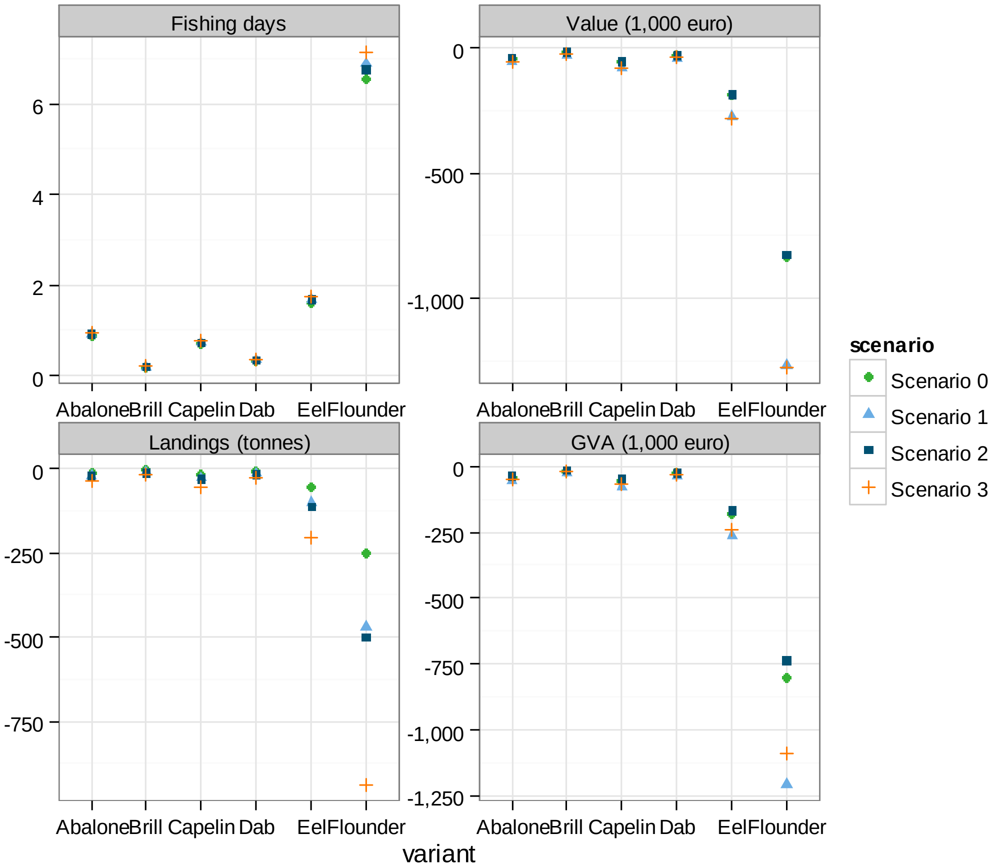

Figure 6.9 *Effects of effort displacement on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario A. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI.

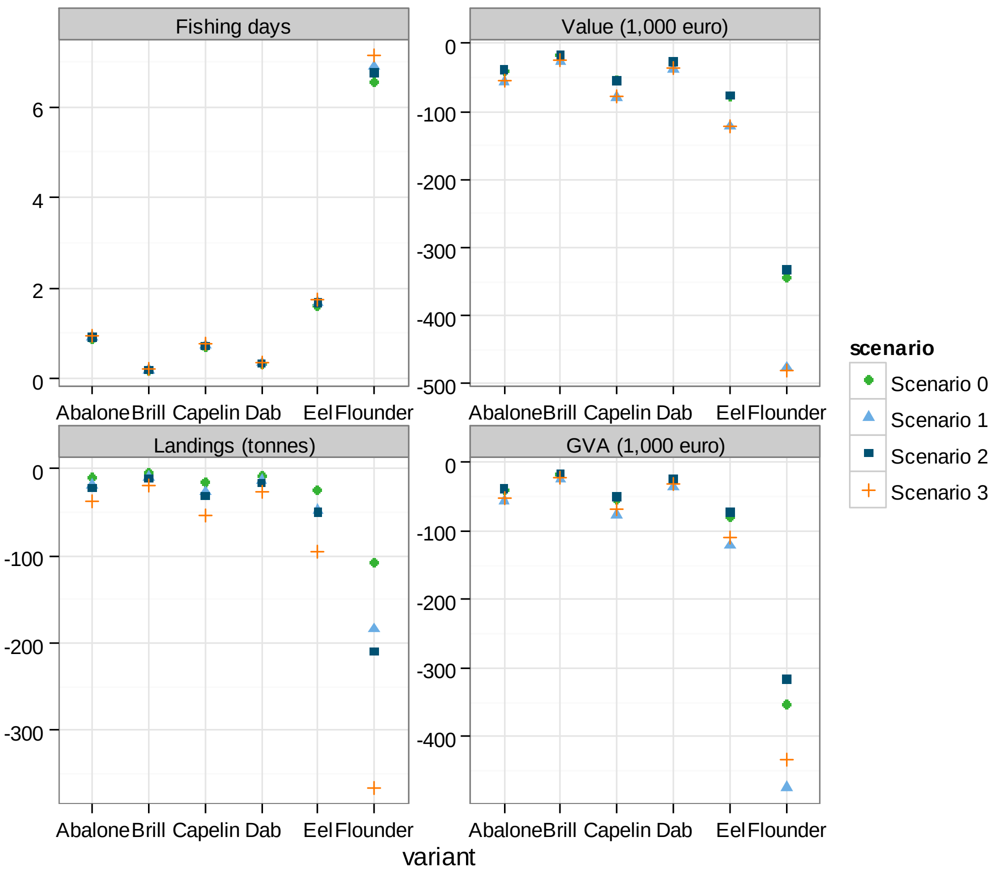

Figure 6.10 *Effects of effort displacement for independent vessels on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario A. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI

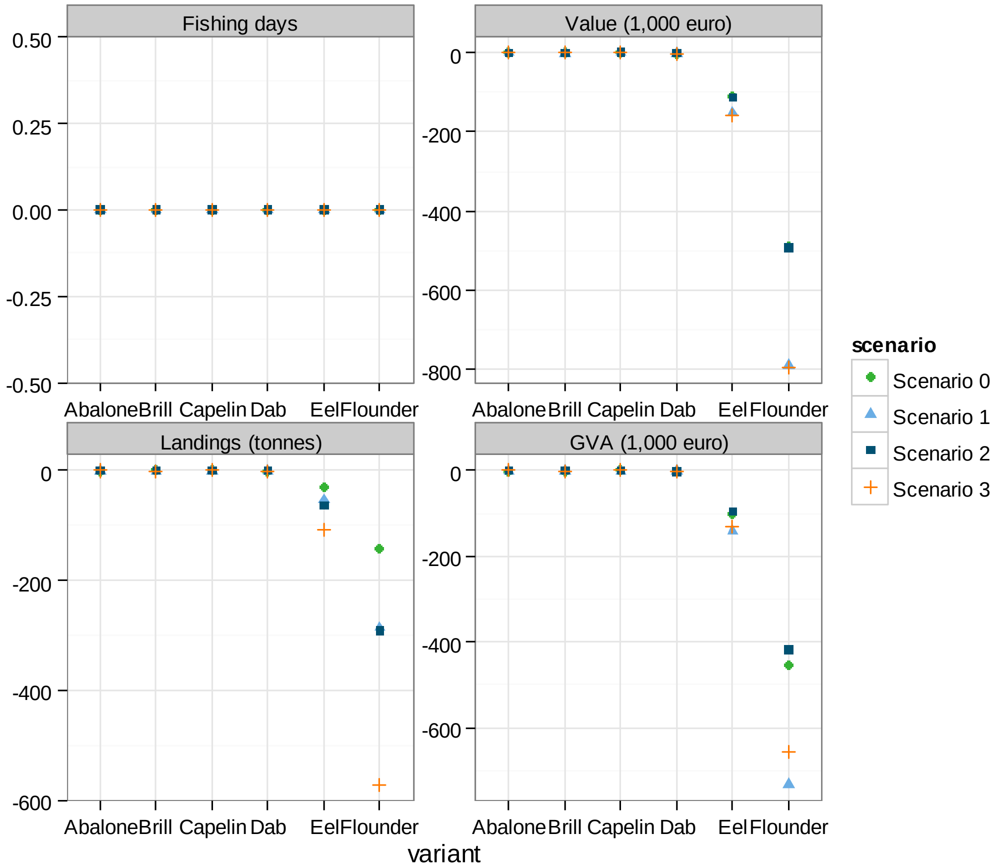

Figure 6.11 *Effects of effort displacement for dependent vessels on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario A. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI.

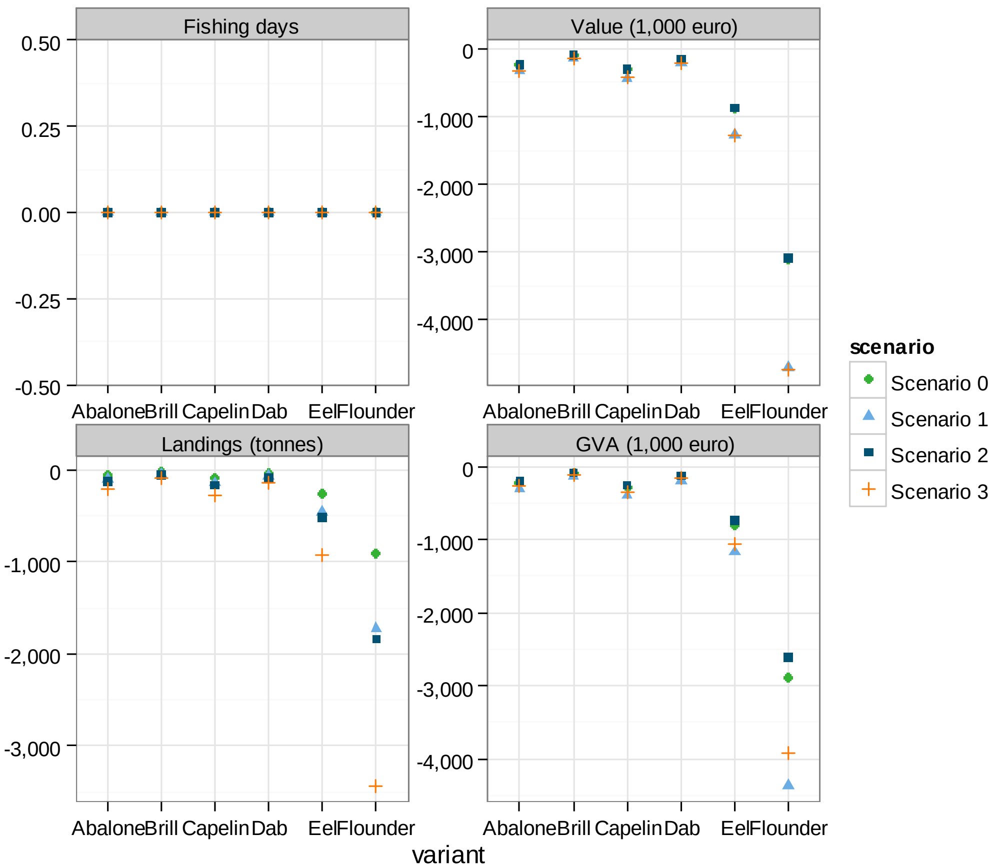

Figure 6.12 *Effects of effort displacement on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario B. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI.

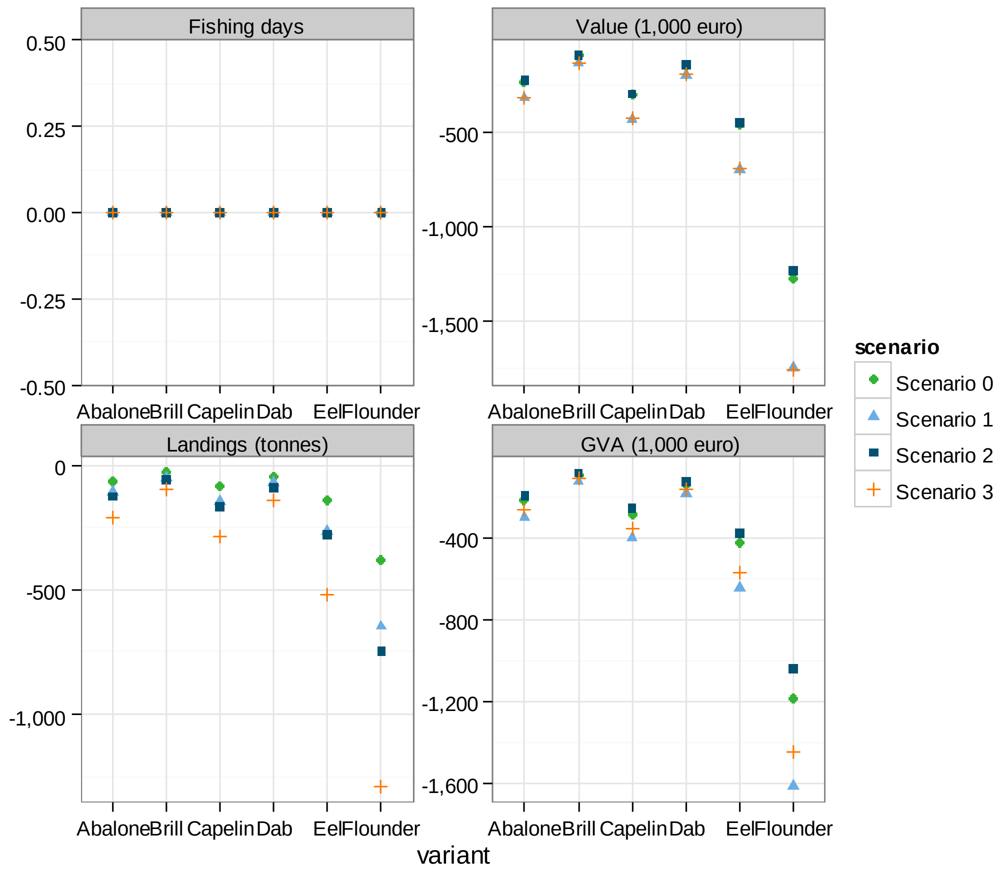

Figure 6.13 *Effects of effort displacement for independent vessels on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario B. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI

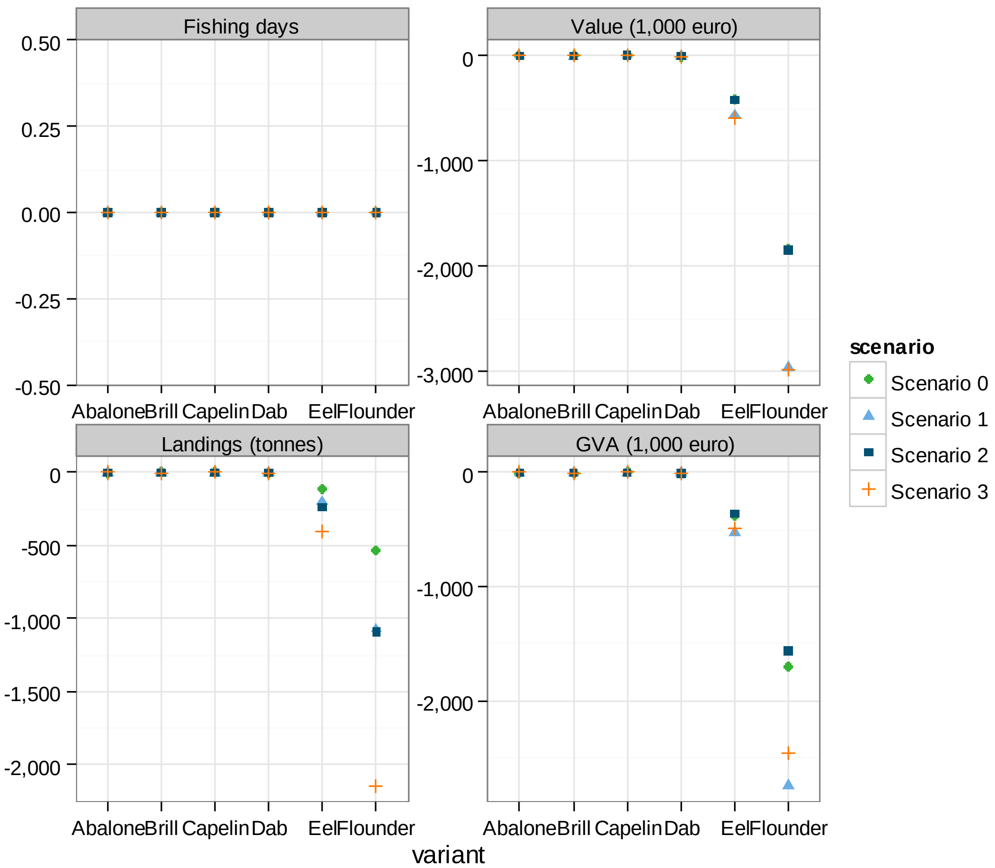

Figure 6.14 *Effects of effort displacement for dependent vessels on the effort, landings volume, landings value and GVA in the first year after the closure for displacement scenario B. Series show the effects of the PEI scenarios (see text for further explanation).*
Source: Logbook data and VMS data, processed by LEI

The graphs show the differences in impact of the closures to vessels that have been classified as dependent and independent for displacement scenario A and B. For the variants Abalone, Brill, Capelin and Dap hardly any of the vessels are dependent and their contribution to the total costs is negligible. On the contrary, for Eel and Flounder, the dependent vessels cause much higher costs of displacement. The displacement costs of dependent vessels contribute approximately half of the total costs for variant Eel and Flounder in case of displacement scenario A. In displacement scenario B the costs for the dependent vessels are more important and dominate the total costs. The graphs only show the effects of the first year after closure in which the costs made by dependent vessels are highest. In later years, the differences between dependent and independent vessels are smaller and disappear completely after four years in case of displacement scenario A. For displacement scenario C the distinction between dependent and independent vessels is not relevant as neither of the two categories has costs.

The differences between outcomes of the PEI scenarios are largest for variant Flounder and Eel. The relative difference between the maximum and minimum reduction in GVA are for these variants more than twice the difference for other variants. This is mainly due to effects on the dependent vessels. In PEI-scenario 2 and 3, the reduction in landings are relatively high, but this is mainly due to landed discards.
In case of displacement scenario A additional costs are estimated for the whole fleet, based on the crowding effect. Table 6.6 summarises the effects of crowding for the whole Dutch fleet, based on the effort increase in the remaining open area for each of the PEI scenarios. The effect of increased crowding ranges from 0.5 m euros in variant Brill in PEI-scenario 0 to 3.4 m euros in variant Flounder in PEI-scenario 3 and is almost proportional to the amount of effort displaced. For Abalone, Brill and Dab the effect of displacement is relatively small. For Capelin the effect is intermediate and for Eel and

Flounder the effect is relatively high. The impact of the PEI scenarios is at maximum 25% of the total effect.

Table 6.6
Overview of the resulting effect of crowding for the various variants and PEI-scenarios. See text for explanation

	PEI Scenarios			
	0	1	2	3
Effort displaced (% of total effort of Dutch fleet				
Abalone	0.36	0.37	0.38	0.39
Brill	0.25	0.26	0.26	0.27
Capelin	0.49	0.51	0.51	0.53
Dab	0.34	0.35	0.35	0.36
Eel	0.92	0.97	0.96	1.01
Flounder	1.53	1.60	1.60	1.68
Relative effect on VPUE of Dutch fleet (%)				
Abalone	0.02	0.03	0.03	0.03
Brill	0.02	0.02	0.02	0.02
Capelin	0.03	0.03	0.03	0.04
Dab	0.02	0.02	0.02	0.02
Eel	0.06	0.07	0.07	0.07
Flounder	0.10	0.11	0.11	0.11
Effect on NPV of GVA of Dutch fleet (m euro)				
Abalone	0.7	0.8	0.8	0.8
Brill	0.5	0.5	0.5	0.5
Capelin	1.0	1.0	1.0	1.1
Dab	0.7	0.7	0.7	0.7
Eel	1.9	2.0	2.0	2.1
Flounder	3.1	3.3	3.3	3.4

Table 6.7 summarises the effects of both PEI scenarios and displacement scenarios on the net present value of the GVA. The Net Present Value indicates all future costs for the closures, discounting costs for a period of 30 years (See also Chapter 6) Changes in the NPV of GVA ranges from -0.m euros for displacement scenario C to -50m euros for variant Flounder in PEI scenario 1 and displacement scenario B. The costs of Brill and Dab are in general lowest, but outcomes of the scenarios overlap with variants Abalone and Capelin. In displacement scenario A and B, the costs of Eel and especially Flounder are much larger. The contribution of dependent vessels to the total costs is lower than in the graphs above, because the costs of displacement become lower over time, as specialists find other fishing areas.

Table 6.7
Net effects of effort displacement on the net present value of the GVA (million euros) in the various scenarios and displacement scenarios

	PEI scenario 0			PEI scenario 1			PEI scenario 2			PEI scenario 3		
Displacement scenario	A	B	C	A	B	C	A	B	C	A	B	C
Abalone	-1.4	-3.4	0	-1.6	-4.6	0	-1.4	-3.0	0	-1.6	-4.1	0
Brill	-0.8	-1.4	0	-0.9	-1.9	0	-0.8	-1.3	0	-0.9	-1.7	0
Capelin	-1.8	-4.3	0	-2.2	-6.1	0	-1.8	-3.9	0	-2.2	-5.5	0
Dab	-1.1	-2.2	0	-1.3	-2.9	0	-1.1	-1.9	0	-1.2	-2.6	0
Eel	-3.7	-10.0	0	-4.6	-14.7	0	-3.6	-9.0	0	-4.4	-13.2	0
Flounder	-10.9	-33.4	0	-14.4	-49.6	0	-10.3	-30.1	0	-13.5	-44.5	0

Source: Logbook data and VMS data, processed by LEI

6.2.3 Sensitivity analysis

Fishing activity in areas
The level of fishing activity in the areas provides the basic data for all analysis. As such all effects and scenario outcomes are highly dependent on changes in these basic data. A 10% increase in the estimated effort in the variants causes in some scenarios and variants even a more than proportional increase in the outcomes (see Figure 6.15 and 6.16, panel 10% extra area use) e.g. the effect for variant Brill in displacement scenario B is 13%. This is mainly due to the fact that an increase in the effort in the area also increases the dependency on the area and thereby the costs of displacement. In case of Flounder a large part of the costs of displacement are already from dependent fishing vessels, so here the effect of increased dependence is smaller.

Scenario parameters
The sensitivity analyses carried out on the parameters as mentioned in Table 6.4 for the main effects in the scenarios show that the results are relative robust to many of the parameters in the scenarios. Moreover the analyses show that changing the overall values of most parameters affect the scenario outcomes similarly. Changes in fuel price and technical innovation hardly have any effect on the outcomes of the scenarios. Fuel costs are only part of the total costs and technical innovation decreases fuel costs, but increases gear costs. A 10% extra decrease if the fish price results in a 1% lower NPV of the GVA for PEI scenario 2 and 3 and a 10% increase of the effects of the landings obligation has a comparable effect. Extra closures and extra fish density lead to increases in the value for all the variants. A 10% increase in the other area closures as assumed in the PEI scenarios leads to increased effort in each of the variants, thereby enhancing the value, but the effect is small. A 10% increase in the fish density has a large effect on the outcomes and causes changes in outcome (NPV of GVA) between 5 and 7%. The effect is largest for Brill and Dab and smallest for Abalone, Capelin and Flounder. The effects of parameter changes are hardly influenced by the differences in the two displacement scenarios.

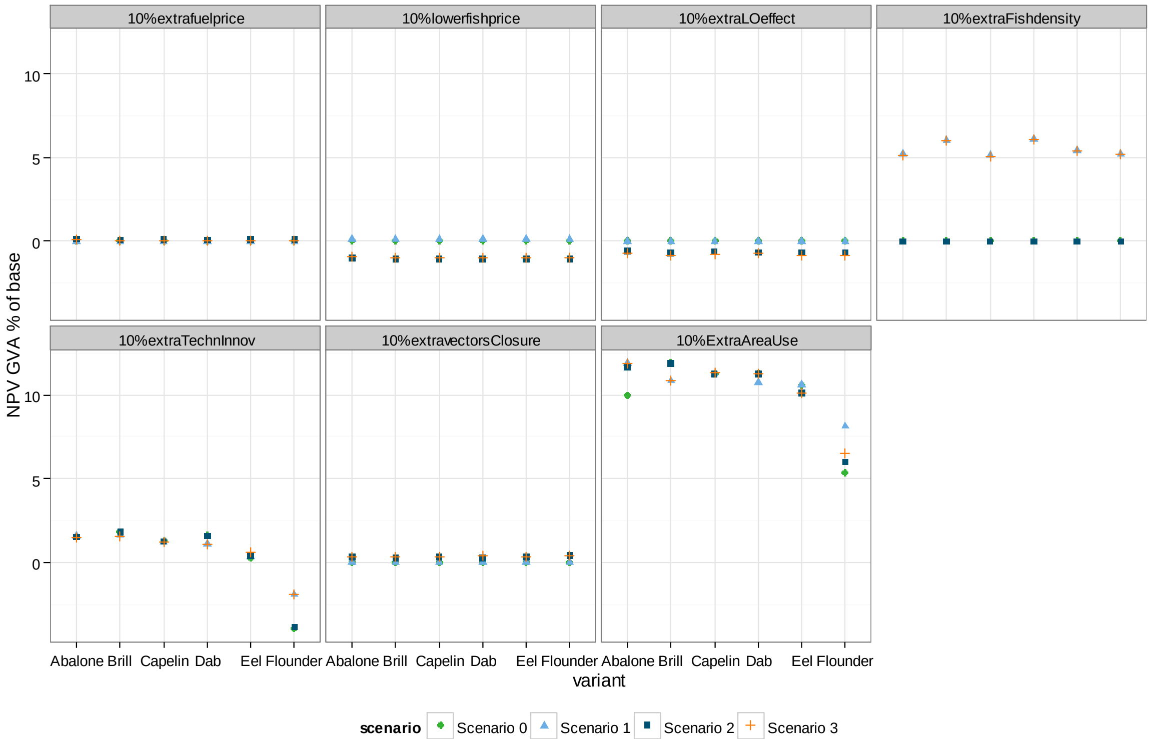

Figure 6.15 *Relative effects of 10% changes in selected parameters (see 6.4) on the net present value of GVA for displacement scenario A. Series show the effects in each of the PEI scenarios. 10%extraLOeffect, 10% extra costs due to the landing obligation (see text for further explanation). Source: Logbook data and VMS data, processed by LEI*

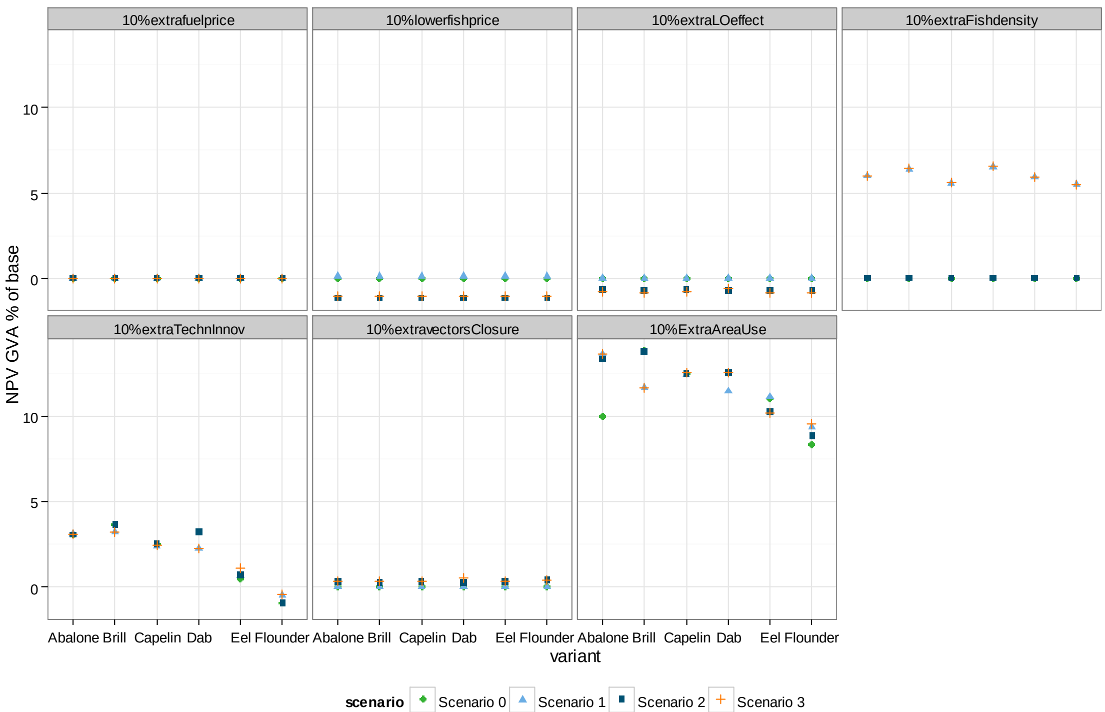

Figure 6.16 *Relative effects of 10% changes in selected parameters (see Table 6.4) on the net present value of GVA for displacement scenario B. Series show the effects in each of the PEI scenarios. 10%extraLOeffect, 10% extra costs due to the landing obligation (see text for further explanation). Source: Logbook data and VMS data, processed by LEI.*

Reference period

As mentioned above, the outcomes of the analyses are highly sensitive to changes in fishing activity in the variants. Because of this historic changes in spatial patterns in effort and landings might have an important effect on the costs of closures for the fishing sector. In order of quantify the effects of the definition of the reference period on the study results the time trends for the fishing activities in the ICES rectangles containing the possible closures were analysed. Figure 6.17 shows the trends in effort, landings and landings value and shows that over the last decades, total effort, landings and value of landings have been decreasing. Moreover, the area including the Frisian Front and the Central Oyster ground has become less important to the Dutch fishing sector than before. The relative importance of the landings value from this area decreased from around 10% in 1999 to around 7% in 2014. However, the averages of the period up to 2014 show a much lower decrease than the values of individual years. This is because the relative importance of individual years that are added to the average decreases as the time series grow larger; e.g. the weight of 2013 data in the average of 2013 -2014 is half of the total value, but the weight of 2005 data in the average of 2005-2014 is only 10%. Never the less, extending the time series backwards increases the average landings volume by 2% and the landings value by 3% for each year that is included. It is unclear whether this trend is indicative for the fishing activities in all variants and whether this would lead to higher estimated costs for the closures. The effects on GVA might be lower than expected, because the overall profitability of the fleet was low during the period from 2003 - 2007 (Taal *et al.*, 2010).

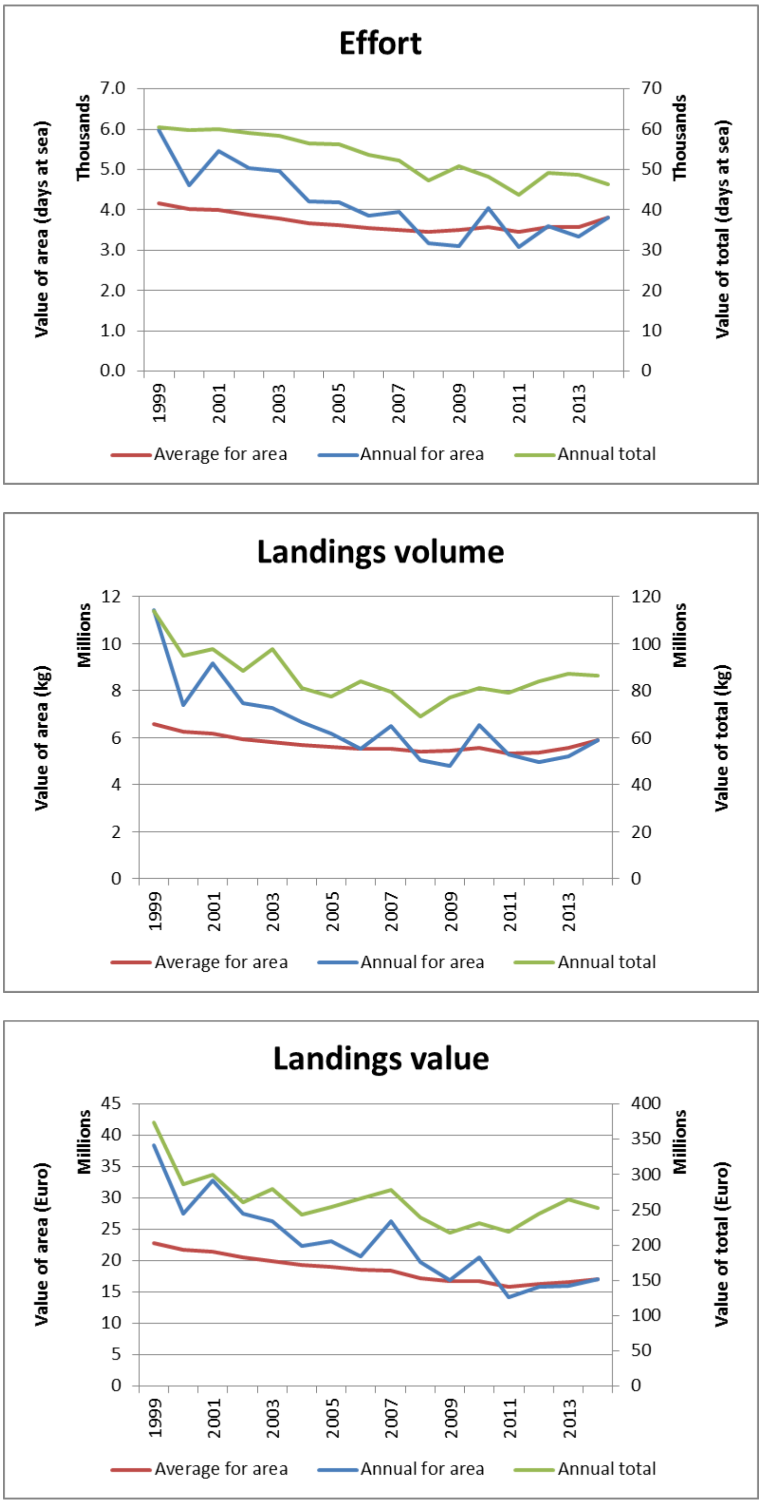

Figure 6.17 *Annual values of the total effort, landings and landings value for the Dutch cutter fleet and from the ICES rectangles containing the closures, and the average values of the ICES rectangles taking into account the total period from the particular year to 2014.*
Source: Logbook data, processed by LEI.

On the other hand, recent changes in the management and economic context of the Dutch fisheries also had consequences for the fishing practices and Figure 6.18 shows that effort and landings for all major gear types have increased during spring 2015 relative to the year before. Although it would be speculation to draw any predictions on these short term trends, the longer term trends show the dynamic behaviour of the fishing sector and the relativeness of results based on any period.

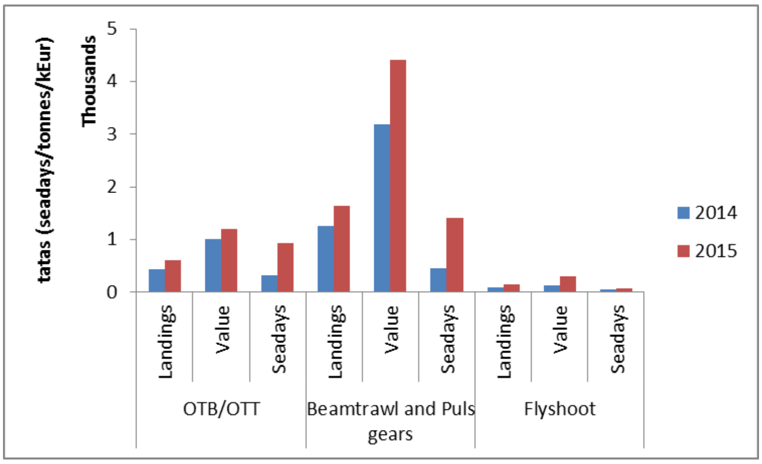

Figure 6.18 *Effort, landings and landings value for the major gear types of the Dutch fleet from the ICES rectangles containing the closures in the first half year of 2014and 2015.*
Source: Logbook data, processed by LEI.

6.3 Discussion

The analysis for the costs of closures for the fishing sector is based on simple scenarios including policy, innovation and economic developments and effects of displacement. In the synthesis the general consequences of making these assumptions is discussed.

The sensitivity analyses carried out show that individual factors taken into account in the scenario analysis do not have a large effect on the outcome of the scenarios and do not change the relative differences between areas. One should be aware that this is mainly due to the simplicity of the scenarios, that assume similar effects of future developments in all areas:
- Fish distribution patterns are assumed constant
- Discard rates are assumed equal in all areas
- Effort distribution patterns are assumed constant
- Relative prices of fish species other than place and sole are assumed constant
- No behavioural changes to the implementation of the discard ban.

The PEI scenarios 1 and 2 provide a range of extreme outcomes that include direct effects of changes in these assumptions: e.g. PEI scenario one assumes that there is no effect of the discard ban on the fishery in the area which can be explained that discard rates in the areas are negligible. In this way the scenarios seem to provide some kind of range of possible outcomes. However, the scenarios only take into account direct effects of the developments, which limit the value of these scenarios. E.g. the fact that discard rates in the area are low (as suggested by some of the fishermen) could attract more fishermen to the area when the landing obligation is implemented. This could potentially increase the value of areas considerably.

As for the effects of displacement, these are mostly based on expert opinion and stakeholder consultation. Although these results provide some indication of possible effects, they do not take into account the complexity of the fishing practice. As a result the actual outcomes could be higher or lower than shown here. This also applies to the PEI scenarios.

Despite the above mentioned uncertainties it can be concluded from the ranges in outcomes of the various PEI and displacement scenarios that variants Brill and Dab will most probably result in relative low costs for the fishing sector, Abalone and Capelin in intermediate costs and Eel and Flounder in relative high costs.

7 Social effects on fisheries and their communities

Olga van der Valk and Hans van Oostenbrugge

7.1 Methodology

A list of vessels was composed that in the last 7 years (2008-2014) had the highest score of sea days spent in the proposed closure areas (all variations) was composed. The list was ranked according to the average of effort since 2008, with yearly average above 10% including at least the last four years (2011-2014). (See Table 7.1). Of the 10 cutters that are most dependent on the proposed areas, most are registered in Urk (6) and Wieringen (2). Also for the top 20, Urk prevails: 9 cutters against 6 from Wieringen. All vessels are most affected (e.g. have the highest dependency score) for variant Flounder, with one exception. From this list, crew was approached for an interview. In total 4 interviews were conducted (highlighted in Table 8.1). In addition to information from the interviews information on safety aspects has been incorporated as stated during the workshop on displacement effects (Slijkerman and Tamis, 2015).

Table 7.1
Ranking of vessels with the highest dependency on the areas, from which the respondents for the interviews were selected (highlighted)

Ranking	Provenance	Average annual dependency	Time period	Highest annual dependency	Year	Variant
1	Wieringen	32%	'08-'14	75%	2008	f
2	Urk	32%	'08-'14	45%	2009	f
3	Urk	32%	'08-'14	39%	2009	f
4	Goedereede	25%	'08-'14	59%	2011	f
5	Texel	24%	'08-'09	38%	2009	e,f
6	Urk	22%	'11-'14	27%	2011	f
7	Urk	22%	'08-'11	26%	'08-'09	f
8	Urk	20%	2013	20%	2013	f
9	Wieringen	18%	'08-'14	27%	2010	f
10	Urk	17%	'08-'14	32%	2009	f
11	Wieringen	17%	'08-'14	27%	2011	f
12	Lemmer	17%	'08-'11	19%	2011	f
13	Wieringen	15%	'08-'14	30%	2011	b,d
14	Tholen	15%	08-'09-'10-'14	23%	2010	f
15	Urk	13%	'08-'14	22%	2013	f
16	Wieringen	13%	'08-'14	22%	2011	f
17	Urk	12%	'08-'14	24%	2008	f
18	Wieringen	11%	'08-'14	25%	2011	f
19	Urk	11%	'08-'14	22%	2009	f
20	Lemmer	17%	'08-'11	19%	2011	f

Source: Logbook data and VMS data, processed by LEI

Research results are based on qualitative interviews, which are not necessarily representative of the entire sector, but give a good indication of what is happening within the fishing communities. One interview was a double interview: two crewmembers of one cutter. The interviewees were all male, in different stages of their lives: young men (25-35 yrs.) with and without (young) family and working as

crew on a vessel of father / uncle; a skipper-owner (40-50 yrs.) whose children are young teenagers; and retired skippers- owners (45-55 yrs.), on shore, still regularly sailing. Used fishing gear was twinrig and beam trawl; the targeted species were langoustine, prawns and plaice / sole / turbot. During the interviews the fishermen were shown the six variants in proposed area closures, but no specific attention was given to how these variations differ. Interview questions focused on the social impact of area closure in general (e.g. their experiences with earlier closures) and on the areas they fish the most.
To assess social costs and benefits because of area closure, a list of topics was used, distinguishing impact / relevance at company and at community level.

Table 7.2
Social consequences of variants discussed during the interviews

Company level	Community level
Company succession	Changes in landing port
Knowledge transfer / loss of experience	Competition with other fishing communities
Working conditions / job satisfaction	Social cohesion at community / national level
	Employment
Previous / expected public policy	

7.2 Results

Company level
Working conditions / job satisfaction
In the case of plaice / sole vessels from, respondents from Urk indicated a direct negative effect of area closure on their working conditions and daily operations insomuch it reduces their options to fish near their hometown. Fishing in areas further away signifies a different working schedule, that is, not returning home for the weekend. Landing the fish further away means having to realise a higher volume to cover transportation cost of bringing the fish to the auction, so the bottom line is that crew members have to work harder for the same income, while time to spend with the family is reduced. Thus, area closure limits the options to choose fishing areas, including those that allow the vessel to return weekly. Nevertheless, the Urker respondents did not give area closure as main criteria for displacement, but available quota, fishing price and expected gross turnover (quantity and quality of fish based on information from other vessels).

The preference for regular working hours depends on the profile of the entrepreneur: how he values family life, family tradition of fishing at the same spot for generations; and religiosity as basis for daily activities. These entrepreneurs are most area-dependent and less prone to diversification of target species.
Well, if we would lose the Frisian Front that is a disaster, that would really be a disaster. Because we fish there for a 100%, we always fish there. I grew up there, in turn I got the knowledge from my father. So I am making myself acquainted with that area, that is familiar, one knows how to fish there. So I mean, as long as I have been at sea, that's how I sail, and my knowledge of other fishing areas is, to be very frank, not that great. [..]Most dart out on Sunday night, but both of us, my cousin and I are the only ones left in the harbour on Monday morning. [..] One has the responsibility for the family, the children, you can only raise them once.

Deteriorated working conditions are seen to be important for crewmembers that have no personal connection with the vessels more than for those who belong to the upcoming generation, prospective successors in family business. The level of commitment and loyalty of the latter is high.
Respondents indicated that imbalance between working hours and earnings may cause crewmembers to giving up the fishing profession if job alternatives are more attractive. Nevertheless, respondents indicate that mutual loyalty between skipper and crew is high and well looked upon by society; even to the point that having to let go of a crewmember / co-skipper for financial reasons burdens both

parties emotionally, creating tension in family relationships. As a result, there is little turnover of crew among vessels.

When you've worked for 10 years under the same captain, you do not easily say 'I quit', because you've experienced the good years. Though it is difficult when you have a large family. You still remain true to your skipper and your company where you work. If the crew is suffering, then the skipper is even suffering more. It's not because of the skipper filling his pockets that crew members quit.

<u>Operational decision making, succession and knowledge transfer</u>

Respondents indicate that there are two levels of decision making: operational and strategic. The skipper on board consults with the crew and decides on the fishing tracks and daily operations, as well as the areas the vessel will go to fish. The 'skippers-on-shore', vessel owners and mostly retired, decide when to change target species, switch fishing gear and leave to a different area to fish. They also have a major say in succession. As for selling the vessel, in the interviews the old generation's (lack of) motivation (because of 'fickle' public policy) was recurrently mentioned as a criteria in strategic decision making. Nonetheless, comments and previous research shows that main reasons for quitting are economic. No direct link with area closure is apparent. One respondent noted that for fishing on the Doggerbank, area-specific knowledge will make a difference in volume of fish caught, where this is less so for other areas (coastal range, Cleaverbank).

In knowledge transfer, the older respondents view the importance of experience and knowledge transfer in a different light than the new generation:

'That is all of their knowledge of the past, and the fish is moving again, so basically there is no telling what will happen. Every year is different. Skagerrak is a good example. There always used to be small fish, always small sorting, always plaice 4. This year, they were big, that's never happened since I have started fishing. Fisheries is really changeable.'

'The disappearance of knowledge has an effect on the employment of the community. A father transferred his company to his son, the son had to take over, but the father was not motivated because of all the regulations coming… I have transferred my knowledge fanatically to my skipper. And he takes it up fanatically. If I transfer my knowledge in a 'la-la-la' way, they also grasp it in a 'la-la-la' way. And I have seen it happening with the younger generation as they take over: nothing comes out of it, and the company is sold or goes bankrupt. I can recall more than 10 cases when these things have happened.'

Respondents indicate that knowledge transfer is not one-sided, it is practice based (the active younger skipper handling the new technologies) versus experience based (knowledge on weather, fish migration, seasonal cycle by the older skipper). The skipper with a young teenager son worried about the fact that he would not be able to support his son with his advice, that the son would have to find out all by himself through trial and error.

Community level

<u>Changes in landing port</u>

Respondents indicated that changes in landing ports will occur, as a result of area closure. One respondent stated that he would probably need to land fish in Danish harbours with higher costs because of changes in fishing grounds, but also at national level the fishermen indicated they might go to other Dutch ports. This is mainly the case for plaice/sole (beam, pulse), not for langoustine (twinrig).

Taking a historical longer term perspective on the importance of knowledge for the local economy, one respondent mentioned that the decimated fleet and disappearance of fisheries related knowledge has led to weakened industry (providers, processing) and innovative capacity of Urk. With the decreasing fleet, supplying industries are diversifying activities (offshore; inland shipping); and specialized expertise on fisheries technologies are sought elsewhere where fishing is economically dominant, like in Denmark and Spain.

<u>Employment and social cohesion at community level</u>

The changes in community life have been different for Wieringen or Urk. In Urk the respondents note the carpet industry and offshore activities offers employment opportunities and retain the youth. Wieringen on the other hand is a noticeably ageing community, and young people move to Amsterdam for study and a job. Surprisingly, respondents comment that the fleet crew is not ageing in neither locality. There are start-ups by young fisherman in both communities, mainly with smaller vessels for shrimps. And while the respondents from Urk mark the decreasing local fishing economy (decreased turnover by the auction; fleet shrinking from 300 to 37 vessels); those from Wieringen conclude that their way of doing business (not going along with past trends of bigger and larger vessels) has made the difference to maintain a stable fleet. Respondents foresee that closure of fishing grounds will lead to a loss of employment.

We will have a very small area, if they close the Frisian Front and the Dogger Bank. I have the image that again cutters will fall out, while this year… no, there was no ship building, but cutters, as good as new, did join.

In both communities the fleet has used foreign workers; in Wieringen only from Poland, in Urk also from the Philippines. Also with regard to previous comments on the desirability of a steady crew, seasonal employment occurs in prosperous times for the fisheries. Foreign people are employed as crewmember; but skipper, boatswain and engineer are preferably Dutch. Mainly the larger companies employ foreigners.

Social cohesion is very high among fishermen. This is not different for the young or the old. Social life hardly involves people from other professions, and the topic of conversation is fishing. They acknowledge the difficulties that their prolonged absence cause for the families on shore. This in turn gives strong networking and cohesion amongst fishermen girlfriends and wives. Strong social bonding makes it easier for fishermen to go to sea. Social cohesion determines the choice for the fisheries sector, besides the earlier mentioned balance. As said before, the priorities in the balance between earnings, working conditions and family life are decided by the individual fisherman. Area closure may force him towards a different balance in order to survive as business.

'If we were the only fishermen amongst our friends, they would say 'you're crazy' Fishermen draw to each other, you can see that amongst the young people as well. We have a separate team that isolates us a bit from the rest. Because during the weekend, yeah that sounds a bit boring, but we also talk about fishing, others do not understand. [..] But at Urk the women are used to it, they know how it is like. But most of the women's father was also a fisherman so they know'

<u>Unfair competition</u>

Fishermen feel that area closure has the opposite effect of what the measure aims at, as it will increase the density of cutters in a certain area, and with it the risk of local resource depletion. While they do not believe that this will create less collegiality amongst fishermen from the different communities, they do foresee more tension among individual vessels, even internationally. Furthermore, respondents express worry and indignation about the increasing amount of areas that are closed for fisheries activities, whether because of fast shipping lanes, windmill parks, oilrigs or 'the placing of rocks'.

'Areas that are taken away from us, we just never get them back, and it causes a considerable impact. At a certain moment we will sail with less vessels but we are forced to bring them to the same fishing grounds. Pulse and beam trawls will move to the areas of twin rig fishing and the two cannot interact, because twin rig fishing occurs at 3 knot, and beam trawling at 6 knots. So the latter chases the fish away for the twinrigger. You are driving others away from their fishing grounds. If we go further south with the Urker flag vessels, the people in Arnemuiden will not appreciate our coming to their fishing grounds, I think.' [..]
Do you think that the Danish are happy with the presence of the Dutch? The same thing you can see with the French. Not so much the Belgian as they practise the same kind of fisheries. With the French we have rows already; tires are being punched and all.. You will see that happening next, when we move more to English and German territory, that they [authorities] will start extra rigorous inspections to check the amount of discards.'

Society level

<u>Legitimacy of public policy is low and decreasing</u>

First and utmost the respondents were keen on ventilating their position towards policy and the regulation of closed areas, recurrently remarking on its demotivating effect, which they consider an important 'social effect' of the regulation. The interviews show that policymaking procedures cause incomprehension, unbelief and cynicism amongst stakeholders.

Low legitimacy of public policy negatively influences the willingness to change behaviour and will increase the cost of policy enforcement. Fishermen are not always negative towards restrictive policy interventions, e.g. all respondents speak positively about the introduction of quotas, which was described by a skipper as 'acquired rights to the sea.' Nevertheless, support for area closure is very low. Regarding the quota as legitimate regulating system, they question the need for area closures. Fishermen give several reasons for the limited support for closed areas, which is also influenced by their view on public policy formulation in general:

1. Doubts about the effectiveness of measures decreases credibility of policy. Fishermen question the 'usefulness' of area closure (increased fish stocks, biodiversity); because they do not see compliance with policy objectives at sea, - rather the contrary -, while scientific proof that fish stock or biodiversity is increasing, is missing. (Plaice Box, being a recurrent example in all interviews).

2. Discontent regarding the policymaking (governance) process. Fishermen express frustration about always being consulted without it leading to changes. *'We indicate, please move the area a bit. It is received, you may have your say, but it is not used. There is nothing more frustrating than when it goes like this. With the same speed it gets rejected. But it concerns [areas] where we have to make our money.'*

3. Feelings of loss because decisions affect the flexibility and autonomy of the fishing profession which are never reversed. *'The Plaice Box would be a temporary solution, but it is still there. Every area that we surrender, is lost to us.'* Fishermen consider that the 'theoretical' fundament of policies does not correspond to (the need for flexible) practice at sea that is dependent on nature, not on planning procedures. *'One storm does more than 10 times fishing there. You do not know what's going on at the bottom. While we experience it every week.' 'You're dealing with the theory and practice, and they differ a lot. That is the fishing life, you talk about a certain freedom, yes, but you're just very nature dependent. And that is also the challenge.'*
   Fishermen also experience that they do not control their own destiny anymore. *'Too many parties who want to have a say regarding the sea.'* Respondents gave examples of how fishermen have been adapting their vessels and fishing practices throughout the decades, and nevertheless see their options for continuation of fisheries diminishing. '*It is time that they look us straight in the eye and tell us that they want us off the North Sea, instead of slowly strangling us.'*

4. Experienced overload in quantity and unpredictability of regulations, which mainly gives rise to demotivation and stress. 'The frustrating thing is: at the moment we are making money, but everybody has fear in the back of their head about how long will the gasoil price be so cheap, and what will happen next, what more is there in store for us?' 'If only it would stop. But additional regulations keep coming every year. We have nowhere left to go. It must stop. You will hear this everywhere: you will hear it in Urk, Texel, in Stellendam. But it does not stop and at a certain moment it breaks your spirit'.

Safety aspects
During the stakeholder process (e.g. the workshop on effects of effort displacement, Slijkerman and Tamis, 2015) it was repeatedly stated by the fisheries representatives that the choice of a variant also affects the safety on board fishing vessels. Two aspects are mentioned in particular:
- The areas south of the Frisian Front of variants Brill and Dab overlap with shipping corridors, where shipping intensity is high and chance on collision is higher than average. Closing these areas for fishing would help to prevent such accidents
- Closure of the Frisian Front area completely, as in variant Flounder, would urge fishermen to steam through the area on their way to more Northern fishing grounds. During bad weather this could lead to extra safety risks as fishing vessels are less stable in case fishing gears are stored.

7.3 Discussion and conclusions

The comments made by the respondents show that fishermen do not consider the closure of fishing areas as a separate measure, but in the light of a whole package of regulations introduced by the government, in which they fail to see a consistent vision for the fisheries sector. This creates anger, bewilderment and disillusion, particularly as most measures that fishermen have adapted to, do have negative economic effects, only to find that new ones are introduced.

Respondents regard fisheries as a 'hunter's' activity. Fishermen cannot control the conditions that makes fish thrive. The presence of fish in a certain area, as well as the success of fishing practices, are defined by nature, not by man. Conditions are highly variable, such as (increasing) sea temperature, weather and wind conditions, and catches depend on fish migration, soil fertility and -structure. To survive as a food providing company, fishermen ask for flexibility in how they organise their fishing practices. The expanding and increasingly complex legal framework seems to reduce that flexibility to a level that fishermen consider inoperable, and economically unfeasible, not to mention a disregard for the complexity of their profession.

The interviews make clear that changing one aspect in fisheries conditions will generate direct and indirect changes in a complex system, that may be cumulative and totally unforeseen. Most effects are at company level: having to change target species, means reallocation of quota, changing gear, nets, lengths of trips and ultimately may signify a changed family life. Changes in fisheries practices also affect feasibility of other Dutch (and European) fishing companies, as it intervenes in the supply and demand of fishing rights (quota prices) which may be the final blow to an individual vessel elsewhere. Interviewees moreover hint at unexpected (negative) consequences for the ecosystem in and outside protected areas.

That brings us to the conclusion that the effects, social and economic, of area closure are very case specific. Categorising fishing companies is difficult, as fishing practices depend on family tradition, the character and social values of the fisherman, his entrepreneurship, and even his (and his partner's) personal ability to combine profession with family life. More than other measures, area closure directly and indirectly affects customary rights of fishermen who have fished on the same spots, sometimes exclusively, for generations. Individual fishermen are struggling to conserve their way of life and, as sector representatives already had marked upon, the interviews confirm that many a company termination is also a personal tragedy.

8 Effects on enforcement and monitoring

Hans van Oostenbrugge

8.1 Methodology

Besides the effects on the fisheries and the ecological effects, two important effects of implementation of these area closures have been taken into account: effects on costs for control/enforcement and effects on monitoring of ecological development in the areas. The effects on control/enforcement have been assessed by means of telephone interviews with experts from the Netherlands Food and Consumer Product Safety Authority (NVWA) and the concept texts have been reviewed by them.
The effects on monitoring have been assessed by experts from by Rijkswaterstaat and Informatiehuis marien and provided to the team as a memo that is presented in Appendix 12. No additional data sets were used for the analysis of these effects.

8.2 Results

8.2.1 Control

The control and enforcement of closed areas is carried out by the NVWA in cooperation with the Coast Guard and Department of Public Works. NVWA has a Fisheries Monitoring Centre (FMC): from this centre all vessel movements of the fishery are monitored 24/7. Currently, the capacity of this centre is reduced. The control is carried out by means of VMS (Vessel Monitoring System) and AIS (Automatic Identification System). The VMS system will, in principle, receive every 2 hours, the location, speed and direction of the vessel but can also be activated from the FMC to transmit actual data. Since May 2014 also the AIS is mandatory for fishing vessels over 15 meters. This system transmits continuously information about the position of the ship, but the strength of the signal (selection between high and low strength is up to the skipper) is not always large enough to capture the information on land and to monitor vessels in this manner.

Currently fishing vessels are only forbidden to fish in protected areas. Because of this, to prove an offense (fishing in a closed area) there must also be evidence of fishing activities in addition to a location observation. This evidence can only be collected on the spot by means of inspection by a vessel or an aircraft. If there are indications of a breach by VMS and AIS data, the NVWA can decide in consultation with the Coast Guard / Rijkswaterstaat seek additional evidence and carry out spot checks. The decision for this is partly dependent on the position and course of the fishing vessel with respect to the area and the position and plans of the units of the Coast Guard (flight plan, etc.). In case a spot check indicates that there has been a breach (e.g. by Photos from an aircraft) formal report may be made. In that case, there are costs associated with the settlement of the offense. Respondents from the NVWA stated that the total budget for control of closures is hardly dependent on the size of the closures and the fishing activities. From 2015 to 2016 the budget was reduced, whereas additional control tasks were added (Dogger Bank, Cleaver bank). Because of this it is assumed that the total control costs will remain constant and there will be some kind of allocation mechanism by which the budget is divided over the various areas.

In 2014, in the coastal zone a number of areas have been closed to fishing under the N2000 regulations (VIBEG areas). These closures are enforced by the NVWA. In total the enforcement costs for NVWA amounted around 500 kEuro during 2015. Out of 300 suspicions only 20 were acted upon by means of air surveillance. The costs of this were approx. 200 kEuro during 2015.

Table 8.1

Size of different zones as specified in the VIBEG covenant (from VIBEG 2011)

Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total
Type of area	Closed for fisheries	Closed for bottom fisheries	Innovation areas	Fishing area	Research area	
Area (km^2)	145	167	49	407	672	1440

Source: VIBEG, 2011

Based on the specification of the zones in the VIBEG covenant (VIBEG 2011), the total area which was closed for different types of fisheries is assumed to be the total of zone 1, 2 and 3; 361 km^2 (Table 8.1). Van Oostenbrugge et al (2010) provided an estimate of the total effort in the coastal zone. Based on proportional distribution of effort over the coastal zone the total effort in the area of the closures is around 1100 sea days per year. Assuming that the total budget will be allocated proportionality to fishing intensity as an indicator of the number of fish movements in and around the area results in costs for control for the different variants that range from 44 – 352 kEuro annually and from 0.8 mln - 4.8 mln NPV. It is important to note that the costs also depend on a number of other factors:

- The total budget for control is crucial for the costs for all of the areas.
- The extent to which follow up is given to suspicious situations.
- The shape of the area is also determine the possible number of offenses. The ratio between area and perimeter most affects the chance of catching offenders. In a narrow elongated area the chance that enforcement is not the spot in time to capture violation. In a larger square area is this more likely.

Because of this large uncertainty, these costs are classified as pro memorie costs and only the ranking is taken into account in the overview.

Table 8.2

Estimation of control costs for the various variants from the costs in the VIBEG areas, assuming proportionality to fishing effort.

Seadays in VIBEG areas	1113*	
Annual control costs (kEuro)	700	
costs per unit (kEuro)	0.6	
Units per variant (km^2 and seadays)		
Abalone	172	
Brill	120	
Capelin	234	
Dab	163	
Eel	442	
Flounder	902	
Costs per variant	**Annual costs (kEuro)**	**Net Present Value (m euro)**
Abalone	68 (3)	135 (3)
Brill	47(1)	94 (1)
Capelin	92(4)	184 (4)
Dab	64(2)	128(2)
Eel	174(5)	347 (5)
Flounder	355(6)	709 (6)

Source: VIBEG, 2011 * average effort in the area, adapted from van Oostenbrugge *et al.*, 2010)

8.2.2 Monitoring

Rijkswaterstaat is responsible for monitoring of the status of the North sea ecosystem in the context of the Marine Strategy. A detailed description of the assessment of the monitoring costs is provided in Appendix 12. An assessment of the benthic ecosystem in the areas under study is carried out every third year. The design of the monitoring of the Frisian Front and Central Oyster Grounds is based on two separate areas (see Annex 5 of Part 2 of the Marine Strategy, Ministry of I&M, Ministry of EZ, 2014a). The measurement strategy is designed in such a way that a change in spatial distribution of indicator species of the Marine strategy within the area of at least 50% change can be observed between two measurement moments with a confidence level of 95%. The design of the measurement strategy does not take into account the imposition of measures (i.e. closing areas) and because of that additional activities need to be carried out in order to incorporate the areas in the monitoring system and assess the developments inside and outside the closures. These activities are specified below and summarised in Table 9.3.

Variant Flounder corresponds with the areas as defined in the Marine Strategy Part 2. The measurement strategy has been prepared to monitor change in the area without taking into account possible measures. Based on this premise an initial assessment (T0) has been performed in spring 2015. Closing the complete area raises the question of whether the measurement strategy still qualifies or whether it should be adapted to include reference areas outside the closures. This means that there may be additional costs in this variant. These costs will be determined on the basis of expert opinion, but could potentially be as high as the costs for T0, causing a doubling of the monitoring costs.

Variant Eel corresponds significantly to the areas in the Marine Strategy Part 2 (Ministry of I&M, Ministry of EZ, 2014a); approximately half of the Central Oyster Grounds and the Frisian Fronts is closed. For the area between CO and FF a measurement strategy has to be set up and a TO has to be carried out. The regular monitoring costs will be higher than now as the intermediate area must be monitored as well.

Variant Capelin appears to cover with three small areas in the Frisian Front about half of the area. It should be examined whether this coverage is in accordance with the current measurement strategy or that more points should be added. The closed area in the CO is (much) smaller than in the original plan. For this area the measurement strategy has to be adjusted and a T0 must be performed again.

For the Central Oyster Grounds of variant Abalone the same applies as in Variant Capelin. Also for the Frisian Front the measurement strategy has to be adjusted and a T0 has to be performed again. The area is smaller than in the current monitoring plan, and also partly located in a different area.

Variant Brill and Dab differ most from the original monitoring plan. This means that the measurement strategy and T0 should be performed again. The areas in Variant Brill are smaller, which may cost more than Variant Dab because more measurements points will be needed. However, this cannot be concluded based on these data.

For the variants Abalone -Eel and possibly Flounder a new measurement strategy need to be established (cost approximately € 5,000 - € 10,000). For these variants also T0 also needs to be adapted/redone, but the extent differs per variant. Because T0 was already carried out in a specific way in spring 2015, the costs for complementary monitoring to complete T0 are not comparable among the variants. Therefore, the costs of T0 have been left out in the calculation of the monitoring costs.

For each of the variants the Net present value has been estimated using a time period of 30 years and a discount rate of 5.5%.

Table 8.3

Monitoring costs for the various variants (follow up monitoring) and an estimate of the Net Present Value of future follow up monitoring costs (every 3rd year)

Variant	Costs follow up monitoring (kEuro)	NPV (kEuro)
Abalone	130 - 200	570 - 877
Brill	150 - 250	658 - 1,097
Capelin	130 - 180	570 - 790
Dab	150 - 250	658 - 1,097
Eel	130 - 210	570 - 921
Flounder	130 - 250	570 - 1,097

Source: RWS 2015

The NPV of total monitoring costs for the various variants ranges from 0.6 to 1.1m euros (Table 8.3). Monitoring costs seem highest for Brill and Dab and Founder. Abalone and Capelin and Eel show somewhat lower cost levels. For each of the variants, however, the estimate of the monitoring costs is quite uncertain. The relative difference between the upper and lower estimate ranges from 38% for Capelin to 92% for Flounder. As a result there is large overlap between the ranges of monitoring costs for the different variants and it is not clear whether the actual costs of monitoring differ among variants.

8.3 Discussion

Both control and monitoring costs of these closures have been made based on expert knowledge and show high levels of uncertainty. As such it is hard to distinguish between the various variants, especially between Abalone, Brill, Capelin and Dab. In addition costs for monitoring and control may not only depend on the choice of the variant, but also on budget availability within the responsible ministries. If this dependency on budget is high, choosing a variant for which estimated costs are higher might not affect total costs but the intensity of the monitoring and control practices. In both control and monitoring this can have consequences for the effects on (perceived) biodiversity and fisheries practices.

9 Synthesis

Hans van Oostenbrugge and Diana Slijkerman

This study has assessed the major costs and benefits of six variants of closures for the bottom fisheries in the areas of the Central Oyster Grounds and the Frisian Front (Figure 9.1). Table 9.1 presents a summary of the various costs and benefits.

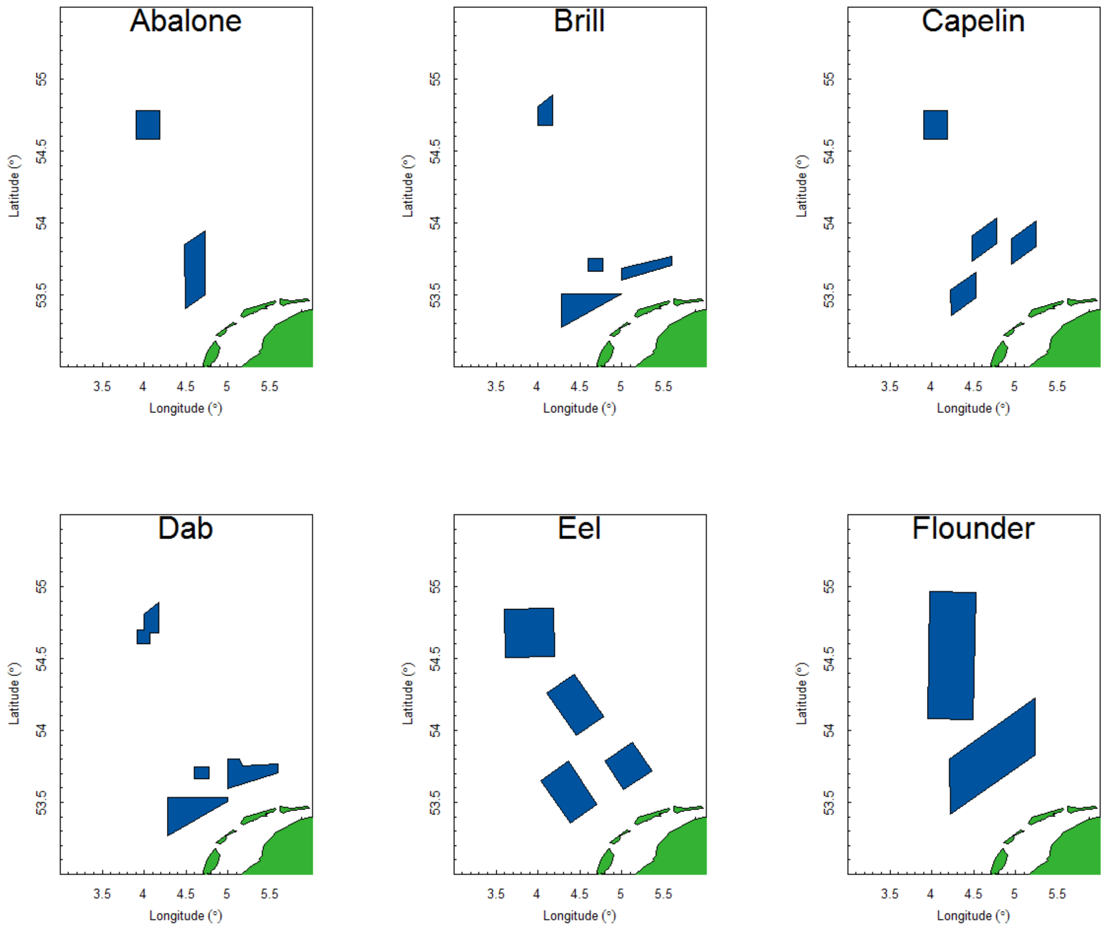

Figure 9.1 *Maps of different variants taken into consideration.*
Source: Ministry of I&M, processed by LEI

Ecopoints per km^2 and total ecopoints for the closures have been used as proxies for the ecological benefits. These numbers resemble the *current* ecological values of the different variants, and not the *future* ecological benefits as an quantitative assessment of the ecological effects is not feasible. Therefore, this is no standard cost-benefit analysis. To compare the six variants, the ecopoint method was used, which calculates Area* Quality* Weighting factor. The quality is the value of the species biodiversity, expressed as the sum of the values of a number of benthic biodiversity indicators, which can be calculated per variant. The weighting factors express the importance of e.g. the rarity of the habitats covered by the closures, the presence of hard substrate, the presence of a front, the ratio between size and circumference, etc. In this way, the results of different ways of thinking and the effects of different preferences and management objectives can be compared. The *future* effects of closures on the ecosystem can only be described in a qualitative way. For example, it is expected that a large closed area could result in restoration of species size distributions (e.g. of benthos or fish), but it is impossible to predict and compare such expected values on the scale of the six variants (see also Chapter 4).

The costs for the Dutch fishing sector have been estimated using historic data on fishing activities in the variants and different PEI scenarios (Policy, Economics and Innovation scenarios)and displacement scenarios. The PEI scenarios have been developed to assess potential effects of external developments on the fishing activities in the areas. The displacement scenarios are used to estimate the costs in case the areas are closed. Each of the three displacement scenarios is based on a specific set of assumptions: Displacement scenario A is based on scientific insights on the specific fishing opportunities in the areas (for non-quota species), the effects of crowding and the effect of fishermen's knowledge. Displacement scenario B is based on the view of fishermen's representatives and also includes costs for some vessels that will stop fishing. Displacement scenario C assumes that the costs of the closures are negligible because fishermen will quickly adapt and find new fishing opportunities. Comparison of the results of the various PEI-scenarios shows that the relative rating of the closures in each of the scenario's is quite stable. However, the sensitivity analyses show that the outcomes are quite sensitive for some of the assumptions made, so some care should be taken into account when focussing on the outcomes per PEI-scenario. The three extreme displacement scenarios exemplify that there is large uncertainty around the possible outcomes of the closures dependent on the assumed behavioural changes by the fishing sector. The results are presented as the Net Present Value (NPV) of the Gross Value Added (GVA) (See also Chapter 6). The Net Present Value indicates all future costs for the closures, discounting costs for a period of 30 years (See also Chapter 6).Because most of the affected vessels are from Urk and Wieringen, the economic impacts of closures will also be highest for these communities.

As the estimation of the effects of the closures are very context specific the effects of closures have not been estimated for the foreign fleets, but the average annual GVA from the variants is presented as an indication of the economic importance of the areas for these fishing fleets (See also Chapter 5). The estimates shown here are much higher than in previous studies that were only based on partial analysis. The economic importance of the areas to foreign fleets is for most of the variants comparable to the importance for the Dutch fleet. For variant Eel and Flounder the importance for the foreign fleets is larger. The annual GVA for Belgian and German flag vessels is also included as these vessels are owned by Dutch entrepreneurs and contribute to the Dutch economy. For the UK vessels the proportion of the fishing activities carried out by Dutch owned vessels could not be estimated. However it is known that a considerable part of the UK fleet is in Dutch hands and this is the most important foreign fleet operating in the area. Assuming a share of 50% of the UK vessels owned by Dutch companies would result in economic returns from the closures which are approximately 75% of the returns from Dutch fishing activities. In case the relative costs of displacement would be similar to those of the Dutch fleet the total costs for Dutch owned vessels could be significantly higher than the costs as stated in Table 10.1. As such, the foreign fleet activities are important and should be taken into account in the discussion between stakeholder and managers. As the GVA of foreign and flag vessels is presented as a number it seems that the uncertainty in the number is small. It should be noted that the numbers presented here are merely indications of the scale of operation of foreign fleets in the variants (see also 5.4.2).

Social aspects of the closures have been mapped using interviews of the most affected fishermen. The interviews show that the effects of closures on the working conditions of fishermen are very context specific and that changing one aspect in fisheries conditions will generate direct and indirect changes in a complex system, that may be cumulative and totally unforeseen. Although social costs have not been specified for each of the variants, safety aspects were mentioned for specific variants during the stakeholder interactions. Safety for fishermen could be enhanced in case of variant Brill and Dab because of smaller risks of collision with cargo vessels. In case of Flounder the practice of steaming through the area could increase safety risks in case of bad weather conditions (See also Chapter 7). The analysis of the dependency of fishing vessels shows that most fishermen affected come from either Wieringen and Urk. Because of this, economic consequences will be concentrated in these two fishing communities. Most of the fish coming from the community fishing fleets of especially Urk is sold via the local auction and Urk also has as considerable fish processing and trade cluster. It is not clear to what extent the closures will affect these sectors, but changes in the availability of fish for the local fish cluster will affect its economy.

For the monitoring costs a range is presented of the net present value comparable to the one for the fishing sector. and for the control costs a point estimate is given. It should be stated that also this estimate is uncertain as it depends on the total budget for NVWA and the need for other control activities (See also Chapter 8).

Comparison of the various types of costs shows that for the larger variants and for displacement scenario B the costs of the fisheries comprise the majority of the costs. Fort the smaller closures, however the costs for control and monitoring are of similar importance as the costs of fisheries.

Table 9.1

Overview of costs and benefits of variant closures

Type of costs/benefits	Unit	Abalone			Brill			Capelin			Dab			Eel			Flounder		
	Displacement scenario	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ecologic benefits	Quality		4.87			3.74			4.96			3.92			4.64			5.08	
	Weight factors		0.2-1			0.05-1			0.12-1			0.06-1			0.31-1			0.28-1	
	Ecopoints/km2		0.97-4.87			0.19-3.74			0.62-4.69			0.24-3.92			1.45-4.64			1.44-5.08	
	Ecopoints total		12-59			2-47			10-79			4-66			61-195			91-322	
Costs (m euro)																			
Dutch fisheries (NPV, m euro)	PEI-Scenario 0	1.4	3.4	0.0	0.8	1.4	0.0	1.8	4.3	0.0	1.1	2.2	0.0	3.7	10.0	0.0	10.9	33.4	0.0
	PEI-Scenario 1	1.6	4.6	0.0	0.9	1.9	0.0	2.2	6.1	0.0	1.3	2.9	0.0	4.6	14.7	0.0	14.4	49.6	0.0
	PEI-Scenario 2	1.4	3.0	0.0	0.8	1.3	0.0	1.8	3.9	0.0	1.1	1.9	0.0	3.6	9.0	0.0	10.3	30.1	0.0
	PEI-Scenario 3	1.6	4.1	0.0	0.9	1.7	0.0	2.2	5.5	0.0	1.2	2.6	0.0	4.4	13.2	0.0	13.5	44.5	0.0
Monitoring	NPV (m euro)		0.6-0.9			0.7-1.1			0.6-0.8			0.7-1.1			0.6-0.9			0.6-1.1	
Control	NPV (m euro)		1.3			0.9			1.6			1.2			2.7			4.2	
Total	PEI-Scenario 0	3.3-3.6	5.3-5.6	1.9-2.2	2.4-2.8	3-3.4	1.6-2	4-4.2	6.5-6.7	2.2-2.4	3-3.4	4.1-4.5	1.9-2.3	7-7.3	13.3-13.6	3.3-3.6	15.7-16.2	38.2-38.7	4.8-5.3
	PEI-Scenario 1	3.5-3.8	6.5-6.8	1.9-2.2	2.5-2.9	3.5-3.9	1.6-2	4.4-4.6	8.3-8.5	2.2-2.4	3.2-3.6	4.8-5.2	1.9-2.3	7.9-8.2	18-18.3	3.3-3.6	19.2-19.7	54.4-54.9	4.8-5.3
	PEI-Scenario 2	3.3-3.6	4.9-5.2	1.9-2.2	2.4-2.8	2.9-3.3	1.6-2	4-4.2	6.1-6.3	2.2-2.4	3-3.4	3.8-4.2	1.9-2.3	6.9-7.2	12.3-12.6	3.3-3.6	15.1-15.6	34.9-35.4	4.8-5.3
	PEI-Scenario 3	3.5-3.8	6-6.3	1.9-2.2	2.5-2.9	3.3-3.7	1.6-2	4.4-4.6	7.7-7.9	2.2-2.4	3.1-3.5	4.5-4.9	1.9-2.3	7.7-8	16.5-16.8	3.3-3.6	18.3-18.8	49.3-49.8	4.8-5.3
Fishing activities in the area																			
Dutch fleet	Annual GVA (m euro)		0.4			0.2			0.5			0.3			0.9			1.6	
Foreign fleets total	Annual GVA (m euro)		0.4			0.3			0.5			0.5			1.5			3.3	
Belgian and German flag vessels	Annual GVA (k euro)		45			19			62			29			143			429	

From the compiled overview of costs and benefits the variants can be characterised as follows:

Abalone

The total area is 1,204 km^2 and comprises of 2 subareas. Together with Brill this is the smallest variant, and represents the lower boundary of the government objective for the closing of areas for sea bed protection.

The subarea on the FF covers an important abiotic south-north gradient, from shallow to deep and from sand to mud, and contributes to the quality specifically in terms of species richness and biomass. The subarea on the CO, is of highest value compared to the other variants because of relative high number of vulnerable species, such as long-lived species. The overall score for the CO subarea is comparable to the CO subareas of the variants Brill, Capelin and Dab. In terms of ecopoints per km^2, this variant scores in the mid-range, and better than Brill which is equal in size. An exception is the ecopoint value with hard substrate as weighting factor where Abalone scores lowest of all variants. When weighting factors for fronts and gradients are applied, this variant scores second highest, next to Flounder. Abalone scores (depending on the weighting factor applied) on average similar as Capelin, which is however larger in size. When ecopoints are expressed on the total area Abalone scores in general higher then Brill and Dab and Capelin, the difference however which depends on the weighting factor of interest. Compared to Eel and Flounder this variant scores lower when ecopoints are expressed on ecopoints/km2 and on the area level.

The fishing intensity of the Dutch fleet and the value of landings per km^2 are relatively high, but because of the small size, the costs of the closure to the Dutch fisheries are low to intermediate in case long-term displacement costs are assumed (displacement scenario A and B). The costs for the fishery are comparable with those for Capelin and the range also overlap with those of variant Brill and Dab. The value for foreign fleets is among the lowest of all variants, together with those for variant Brill. This is caused by the fact that in these variants smaller areas are closed where foreign fishermen are active. Control costs seem to be relatively low for this variant.

In conclusion, the costs for the Dutch fishery related to this variant are low to intermediate. The ecologic benefits depends on the expression of ecopoints and the weighting factors applies. Abalone results in the upper range when ecopoints are expressed per km^2, which depends on the weighting factor applied. Using the weighting factor ‘hard substrate’ results in a lowest score, applying weighting factors related to front and gradient, results in relatively high scores. Ecopoints expressed at the total area fit in the upper range of the four smaller variants compared to Eel and Flounder. Impact of the weighting factors are the same as in the results of ecopoints/km^2.

Brill

The total area is 1,263 km^2 and comprises 4 subareas. Together with Abalone this is the smallest variant. The 2 larger subareas are located on sandy substrate, below the Frisian Front. The 2 smaller subareas are located within the Frisian Front and the Central Oyster Grounds.

The overall value of ecological quality scores is lowest of all variants; the small subarea within the FF however has the highest quality score of all subareas of all variants. The overall score for the CO subarea is comparable to the CO subareas of the variants Abalone, Capelin and Dab. In general, this variant scores lowest in terms of eco-points per km^2, for almost all weighting factors. Only when ‘hard substrate’ is taken into account as a weighting factor, the score per km^2 is highest.

The closure of variant Brill also has a relatively low impact on the Dutch fisheries, together with the closure of variant Dab. The fishing intensity and the value of landings per km^2 are relatively low for the Dutch fleet, and due to the small size, the costs of the closure to the Dutch fisheries are among the lowest of all variants in case long-term displacement costs are assumed (displacement scenario A and B). The costs for Dutch fisheries are comparable with those for Dab and the range also shows some overlap with variant Abalone. The value for foreign fleets is among the lowest of all variants, together with those for variant Abalone. This variant might also result in safety benefits for the fishing sector because it lowers interaction with shipping. Control costs seem to be relatively low for this variant.

In conclusion, this variant results in relatively low costs. The ecological benefits are in the lower range, compared to the other variants, except when using the weighting factor 'hard substrate' (highest in ecopoints/km2).

Capelin
The total area is 1,597 km^2 and comprises 4 subareas. The 4 subareas are of similar size: 3 are located in the FF and 1 at the CO. The gradients in the FF are covered over the 3 subareas, but not as a continuous area. The CO area is approximately of comparable size, location and quality value to the variants Abalone, Brill and Dab, scoring high for long-living species and species richness.

The ecological quality value is the second highest, as a result of relatively high scores for all indicators. In terms of eco-points, this variant scores comparable to variant Abalone, which is smaller. Capelin scores in the mid-range when weighting factors for continuous gradients are taken into account. Compared to Dab, which is equal in size, Capelin has higher ecopoints, except when hard substrate and number of habitats are included as weighting factor.

The costs of closure for this variant to the Dutch fisheries are intermediate. This is mainly due to the fishing intensity and the value of landings per km^2 which are among the highest of all variants, and the intermediate size. The costs for fishery are comparable with those for Abalone and the range also overlap with variant Dab and also Eel for displacement scenario A and B. The value for foreign fleets also has an intermediate level, together with those for variant Dab. Costs for control are intermediate as well for this variant.

In conclusion, this variant results in intermediate costs, and the number of ecopoints per km^2 are in the mid-range, for most of the weighting factors applied. Ecopoints expressed at the total area fit in the upper range of the four smaller variants. Weighting factors vary for this variant and their impact on the results of ecopoints/km^2 and total ecopoints is similar.

Dab
The total area is 1,683 km^2 and comprises 4 subareas. This variant is an extended version of Brill and consists of 2 large subareas that are partly situated in the sandy sediment, below the FF, and 2 smaller subareas within the FF and the CO.

The quality value is one-but-lowest, except for the subarea in the centre of the Frisian Front (see Brill). The overall score for CO subarea is comparable to the CO subareas of the variants Abalone, Capelin and Brill, scoring high for long-lived species and species richness. In general, this variant scores one-but-lowest in terms of ecopoints per km^2, but scores highest when weighting factor "number of habitats" and second highest when hard substrate are applied.

The fishing intensity of the Dutch fisheries and the value of landings per km^2 are similarly low to those of variant Brill, but because this variant is 30% larger the costs of closure are also somewhat higher but somewhat lower than the other variants. Because of the uncertainty in outcomes, the ranges in resulting costs of the two variants overlap substantially for displacement scenario A and B. The range of costs also overlaps with those of Abalone, Brill and Capelin. The value for foreign fleets has an intermediate level, together with that for variant Capelin. This variant might also result in safety benefits for the fishing sector because it lowers interaction with shipping. Costs for control are intermediate.

In conclusion, this variant results in low to intermediate costs. The ecologic benefits are in a mid to lower range when ecopoints are expressed per km^2, depending on the weighting factor applied. Using the weighting factor 'hard substrate' or 'number of habitats' results in higher scores, other weighting factors result in lower scores. Depending on the weighting factors it is in the mid- to low-range but higher than Brill. Impact of the weighting factors are the same as in the results of ecopoints/km^2.

Eel
The total area is 4,206 km^2 and comprises 4 subareas. The 4 large subareas vary in size from 700 to 1,400 km^2, and are distributed throughout the search area, from the sandy substrate to the CO. In

this way, a suite of habitat types is protected, while allowing for fishing in between the areas. The size of the CO subarea is considerably larger than that within the variants Abalone to Dab.

The quality value of Eel is relatively low compared to other variant because a part of the variant covers the sandy substrate with lower biodiversity values. In general the values of the weighting factors are relatively high for this variant, except for hard substrate. However, while the quality factor value is slightly below that of Abalone, Capelin and Founder, this variant scores the second highest number of ecopoints/km2, for most weighting factors - except for hard substrates and fisheries pressure.

The fishing intensity of the Dutch fisheries is relatively low for this variant and the effort per km_2 is almost equal to that of variants Brill and Dab. Because of the large size however, the total costs of the closure of this variant for the Dutch fisheries in scenario A and B are higher than those of the previous variants. This is also because some of the fishermen are classified as being dependent on the area (more than 10% of their annual revenues from the area). Therefore, they are assumed to have higher costs for reallocating their effort to other fishing grounds. The range of costs for the Dutch fishery shows some overlap with the ranges for variant Capelin and with the range for variant Flounder. The value for foreign fleets Is relatively high. Because of the higher value to the fisheries the control costs are also relatively high.

In conclusion, this variant results in intermediate to high costs, and it scores in an overall higher range in terms of both ecopoints/km_2 and total ecopoints. The actual value depends on the weighting factor applied. Using the weighting factor 'hard substrate' results in lower ecopoints/km_2, applying weighting factors related to gradient, results in relatively mid-range to high scores for both ecopoints/km_2 and total ecopoints.

Flounder

The total area is 6,339 km_2 and comprises of 2 subareas. This is the largest variant. The 2 subareas fully cover the FF and CO. Therefore it fully protects all (a)biotic gradients on the FF and scores highest for species richness.

Overall, this variant scores the highest quality value, the highest weighting factors, and therefore also the highest number of ecopoints, for all but one applied weighting factor (hard substrate in terms of ecopoints/km_2). Besides the high scores for quality and weighting factors, the size of the area is very determining for the final result.

The costs of closure for the Dutch fisheries are by far the highest of all variants in case long-term displacement costs are assumed (displacement scenario A and B). This results from both the large size of the area and the high fishing intensity in the area (mainly on the Frisian Front). In addition, the variant has the highest proportion of fishing vessels that are classified as dependent on this area and that are assumed to have extra difficulties in reallocating their activities. Finally, closing the complete Frisian Front also removes the possibility for fishermen to fish through the area on their way to northern fishing grounds or back to the harbour. Fisheries representatives have stated that this can also lead to potential safety risks in case of bad weather. Also for the foreign fleets, the value of the areas is by far the largest for this variant. The costs for control will be highest of all variants.

In conclusion, this variant results in both highest costs, and highest scores for ecopoints/km_2, except when hard substrates are taken into account. When ecopoints are expressed on the total area, Flounder has overall highest scores.

In case no long-term costs of fisheries displacement are assumed to be 0 the relative ranking of the various variants remains similar with low costs for Brill and Dab, intermediate costs for Abalone and Capelin and high costs for Eel and Flounder. The reason for this is the assumption that control costs are related to the amount of fishing activities in the areas.

Although the current study provides a characterisation of the benefits and costs of protecting the seabed in the different variants, many of the costs and benefits are not comparable and the outcomes are quite uncertain. As such this study does not provide clear answers as to which variant is most likely to fulfil the management objective most efficiently. The main reasons for this are described below.

Uncertainty in the data

Part of the high variability in the outcome of the study is due to uncertainty in the basic data that is used for the analysis. Statistical data such as the basic ecological data and the distribution of landings from the fishery is uncertain as it is based on incomplete observations of the reality. As such these estimates are unbiased, but contain some degree of uncertainty. On the other hand stakeholder dependent information is used in the analyses of various effects (e.g. costs of control, displacement effects, social effects). Stakeholders have another perception of the developments. First of all they look at the developments from another point of view (Densen, 2001). The fishermen that were interviewed and were present at the displacement workshop stressed that the consequences of a closure are vessel specific and depend on many aspects such as gear, quota availability, distribution patterns, social background etc. Therefore it is hard to get a good overview of possible effects of closures on fishing operations. Second, the closure studied here is only one of several (policy) developments that affect their position and its consequences might be of little importance in the light of other developments. The large range in outcomes of the PEI scenarios confirm this. This makes it even harder to specify the consequences of this specific management measure. In addition to the fishing sector this might also apply to other stakeholders such as the NVWA, which stated that the costs of enforcement are also driven to by budget limitations. However, the current stakeholder consultation gives stakeholders the opportunity to try and influence the policy by means of strategic behaviour. As such their estimates of effects are uncertain and might also be biased. In this study, the uncertainty is assessed by means of scenario analysis and sensitivity analysis. This enables the reader to get an idea about the uncertainty, but at the same time complicates the choice for an optimal solution solely based on this analysis. A specific discussion on the effects of displacement is provided in the previous chapters. More information on specific uncertainties in the data/assumptions are provided in the discussions of the various chapters. An increased knowledge base about the mechanisms behind fishermen's behaviour and the effects of closures on this would help to create more certainty. The study by de Vries et al (2015) on the effects of the Voordelta closures can be a good starting point for this.

Scope of the study

Limitations in the scope of the study also limits the possibilities to come to a complete evaluation of an optimal solution. These limits can be seen at two levels. First, the different types of effects still have different dimensions (e.g. ecopoints, ecopoints per km^2 and euros) which complicates comparison of costs and benefits between scenarios. In scientific literature various methods exist to monetarise different types of effects (Buisman en Vos, 2010) or to compare effects with different dimensions by means of a multi criteria analysis (Soma *et al.*, 2013). These techniques may provide valuable insights into preferences, but they also add assumptions and thereby uncertainty to the already highly uncertain outcome of the current analysis. Moreover, such studies are only useful in case differences in the ecological effects of the variants could be analysed, which is not possible based on the current knowledge. As such the added value in the application of such techniques in the current context to find 'the best variant' might be questionable.

Besides, the effects of the closures on the foreign fisheries activities have only been partially analysed. This is mainly because the effects on these fleets largely depend on local circumstances and it would be very complex and time consuming (if not impossible) to get reliable (quantitative) results for the effects for all of these fishing vessels. Nevertheless, this study shows that the value of the areas for the foreign fleets is approximately twice the value for the Dutch fisheries. Therefore, the choice of the variant will also have a significant effect on foreign fishing vessels. Because part of these vessels are Dutch owned and part land their catches in Dutch harbours, this will probably also affect the Dutch fish cluster indirectly. The extent of this is, however, highly uncertain.

Complex multiple objectives

The uncertainty in the outcomes of the study is also partly due to the fact that the policy objectives are complex, include multiple sub-objectives which are not (or cannot be) clearly defined in measurable units, e.g. an X% increase in the biomass of these species. In the current study a number of weighting factors are used in case of the ecological benefits, emphasising various characteristics of the closure. The results provide valuable input for a discussion on the pros and cons of each of the variants, but also result in considerable variation in the outcome of the study (see Table 10.1) without clear-cut answers. On the economic side, the choice of the net present value of the GVA as an indicator of economic costs indicates a macroeconomic approach, which assumes that the total returns on invested capital and labour should be optimised. Depending on the policy objectives one could also choose to focus on the effects on employment, income of the crew, or total landings value or volume. All of these variables might show different aspects of the economic effects, while the actual effect on the economy will be a combination of all of them.

Future effects of closures

Last but not least the current study tries to assess potential future effects of closing areas based on current knowledge and historical data. This raises two questions:

- Is the reference period correct?
- Can analysing data from this period tell us something about future potential?

The reference period for ecological data has been based on the most recent available survey data and for fisheries it has been based on data availability of VMS data. These time series have been used to provide a number of years that is representative of recent developments. For the Dutch fishing sector the time series in Chapter 5 show a decreasing trend in both effort, landings and value. A sensitivity analysis on the extension of the time series (Section 6.2.3) suggest that extending the time series to previous years has little effect on the outcomes. Reducing the reference period (e.g. to 2010-2014) would result in lower values. However, it is questionable whether these years are more representative for a normal than the years before. The period between 2010 and 2014 has been a time of transition for the Dutch fisheries to other, more innovative, cost efficient and more eco-friendly ways of fishing (e.g. van Marlen *et al.*, 2014). Moreover, the analysis of the 2015 data (Section 6.2.3) shows that for all gears effort, landings and value increased in the area that includes the potential closures. Because of this, the reference period, including both the transition period and some years before, is regarded as being a proper reference period.

The question whether historical data can tell us something about future effects is not specific for the current study. However, it should be noted that any attempt to provide estimations of future effects will include a great amount of uncertainty, especially in case differences are sought on a detailed level as in this study. The future potential of the areas for both economy and ecology will be highly dependent on the natural and economic context. The ecological analysis in this study focuses on the current situation in the variants and does not assess effects of closing the areas. This is because at the scale of this study, no reliable tools for estimation of ecologic effects of closures are available (see Chapter 4). For the fisheries effects, scenarios do not provide optional future effects but the indicate what possible effects various developments might have on the current situation. From the sensitivity analyses it is clear that the various assumptions made in the analyses have considerable effects on the outcomes. Moreover, the fact that most assumptions are similar for all variants might create an erroneous sense of certainty that the effects of future developments will be similar for all variants. However, this is incorrect because future changes in fish distribution for example are not taken into account in the scenarios, but will have a significant effect on the relative costs for closing one or another area. Changes in relative fish prices or discard rates can have similar effects. As such, the outcomes of the scenarios for the fisheries effects for each of the variants should rather be seen as a measure of uncertainty of the outcomes than of different sets of variant outcomes that can be used to compare variants.

Because of the points mentioned above, this study does not provide a clear answer to the question on the optimal management choice. Having said that, the outcomes have a value as a characterisation of the aspects of the areas under study that will be affected by a closure. As such, the present study can provide useful information in a discussion on preferences and possible compromises between stakeholders and mangers. In these discussions, the present study shows the most recent knowhow on the costs and benefits of the different variants and distinguishes between facts and fiction for the topics under study.

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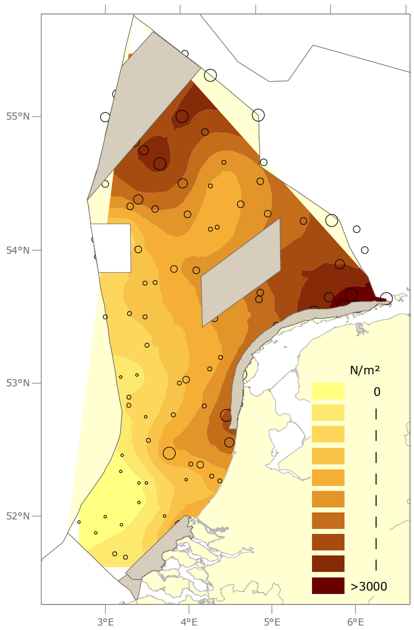
Appendix 1 Glossary

Closed area	Area that is proposed to be closed for fisheries. Can refer to both the whole variant or a subarea
CO	Central Oyster Grounds
Displacement scenario	Scenario used to assess the economic consequences of the closures and the resulting reallocation of fishing activities
FF	Frisian Front
GVA	Gross Value Added; indicator for the economic returns from an activity on investments in labour and capital
MSFD	Marine Strategy Framework Directive
Nature type	A habitat type, defined as a combination of abiotic characteristics: depth, sediment size, stratification and silt content (details in Bos *et al.*, 2011)
NPV	Net Present Value; aggregation of future costs/benefits in which these are discounted (see also Chapter 6)
OTB	Otter board trawls
OTT	Otter Twin Trawls
PEI scenario	Policy, economy and innovation Scenario used to show the possible effects of external developments on the value
Search area	Area including the Frisian Front and Central Oyster Grounds in which the closed area should be situated (see Figure 1.1 on page 12)
SSC	Scottish Seines
Subarea	One of the closed areas within a variant
Variant	Proposal for a closed area to bottom fisheries. Consist of 1 or more subareas
VMS	Vessel Monitoring System (using satellites)

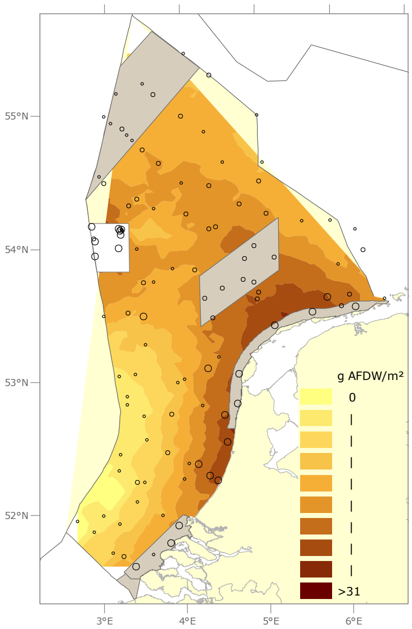
Appendix 2 Biodiversity maps

Biodiversity maps (Bos *et al.*, 2011). Macrobenthos: BIOMON data; Megabenthos = Triple D data. For details on the sampling and mapping methodology, see Bos *et al.* (2011).

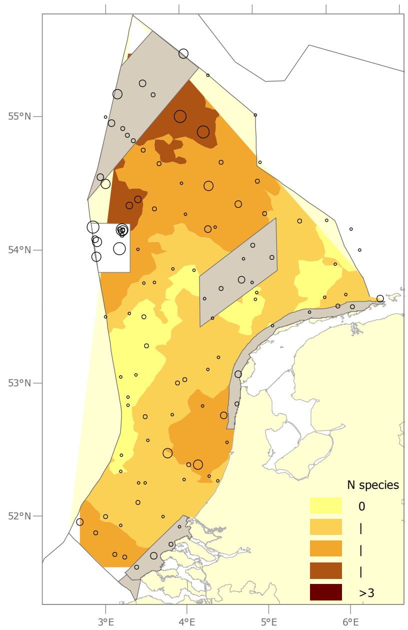
Kriged macrobenthos density



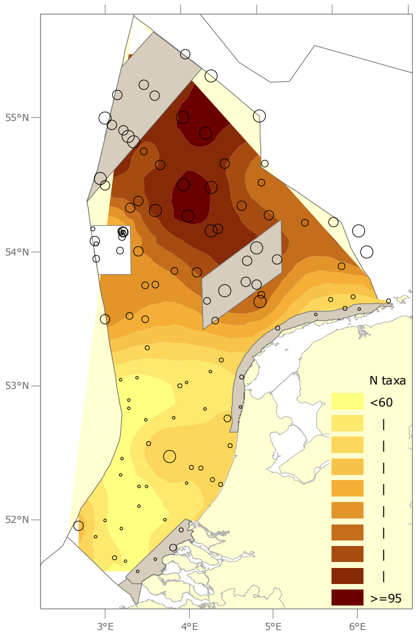
Kriged macrobenthos biomass



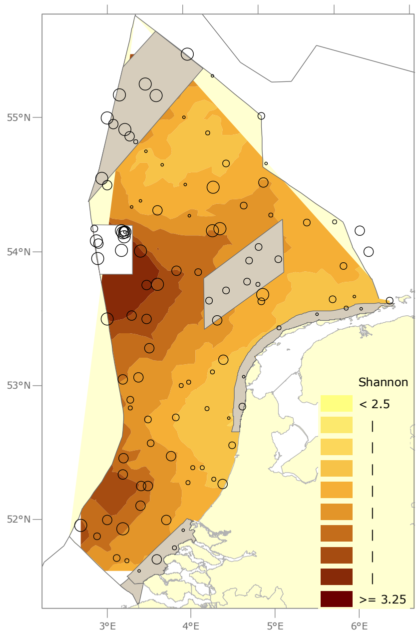
Kriged macrobenthos rarity



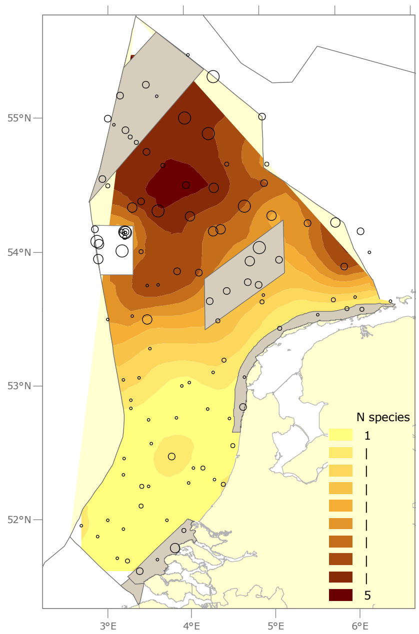
Kriged macrobenthos richness



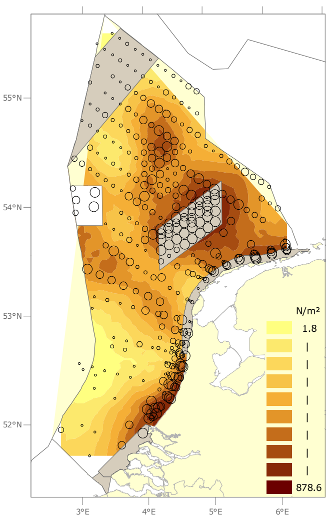
Kriged macrobenthos evenness



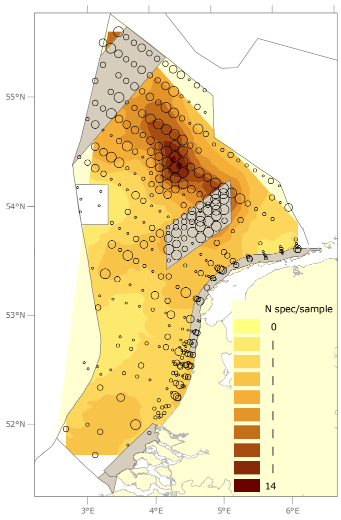
Kriged macrob. large species (ind. AFDW>1g)



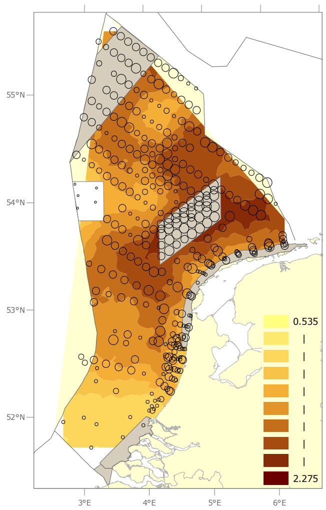
Kriged megabenthos density



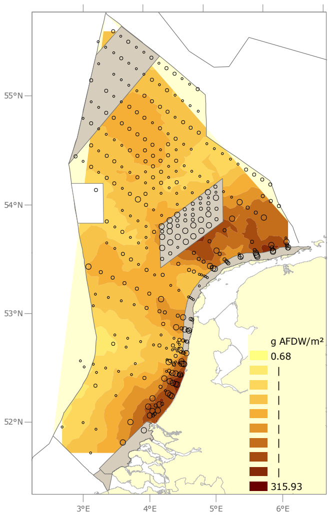
Kriged megabenthos rarity



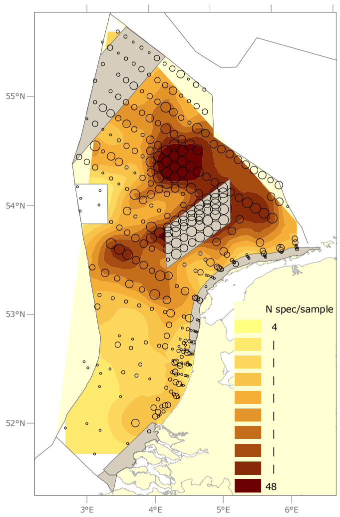
Kriged megabenthos Shannon-Wiener index

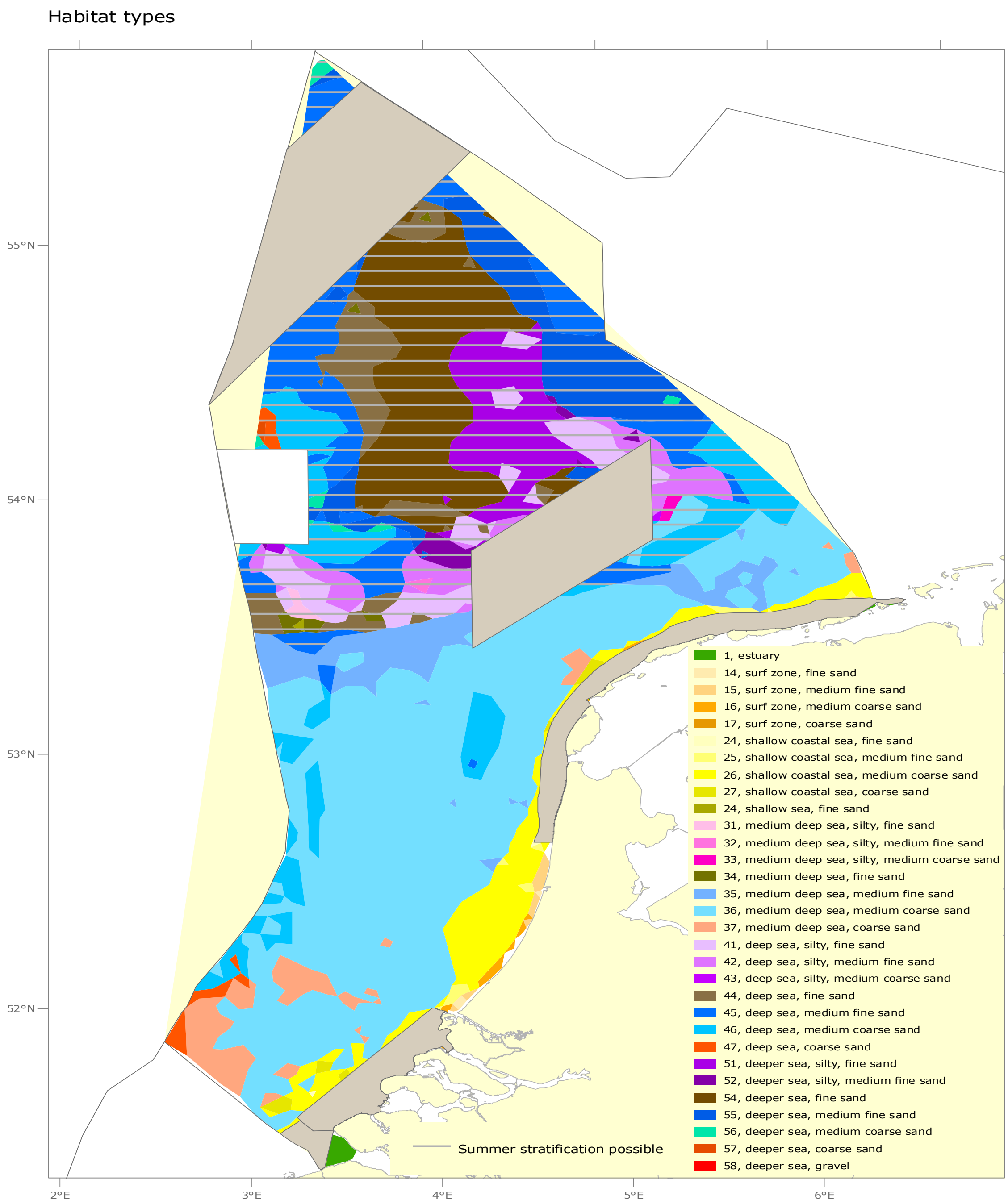


Kriged megabenthos biomass



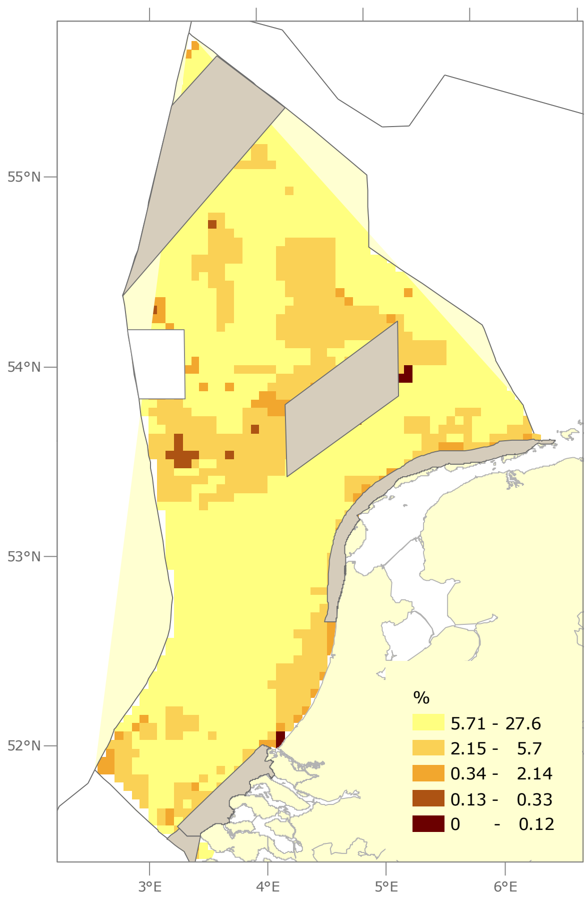
Kriged megabenthos richness

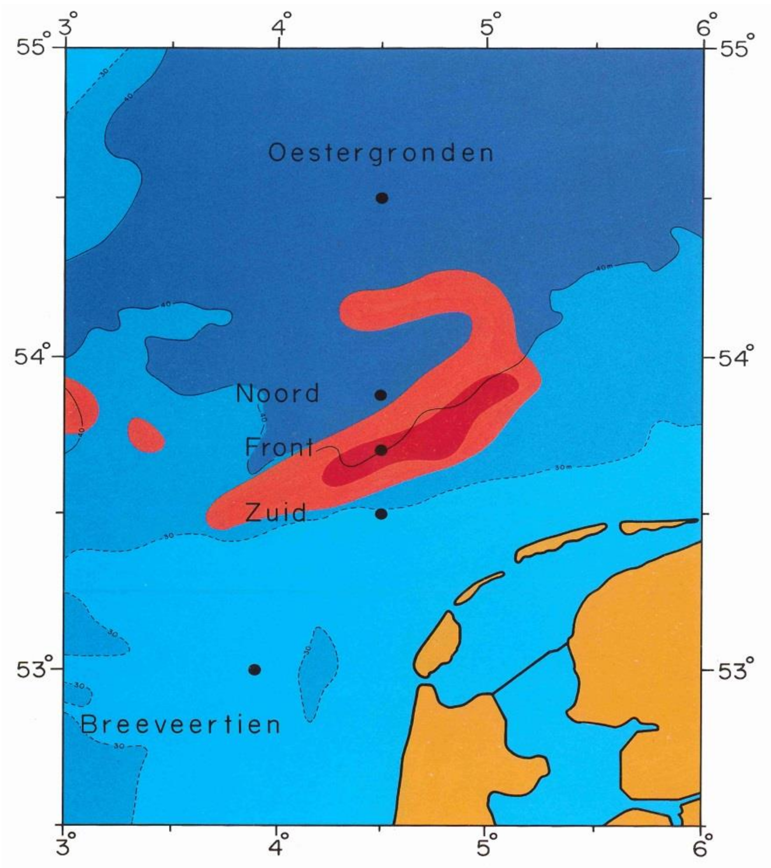




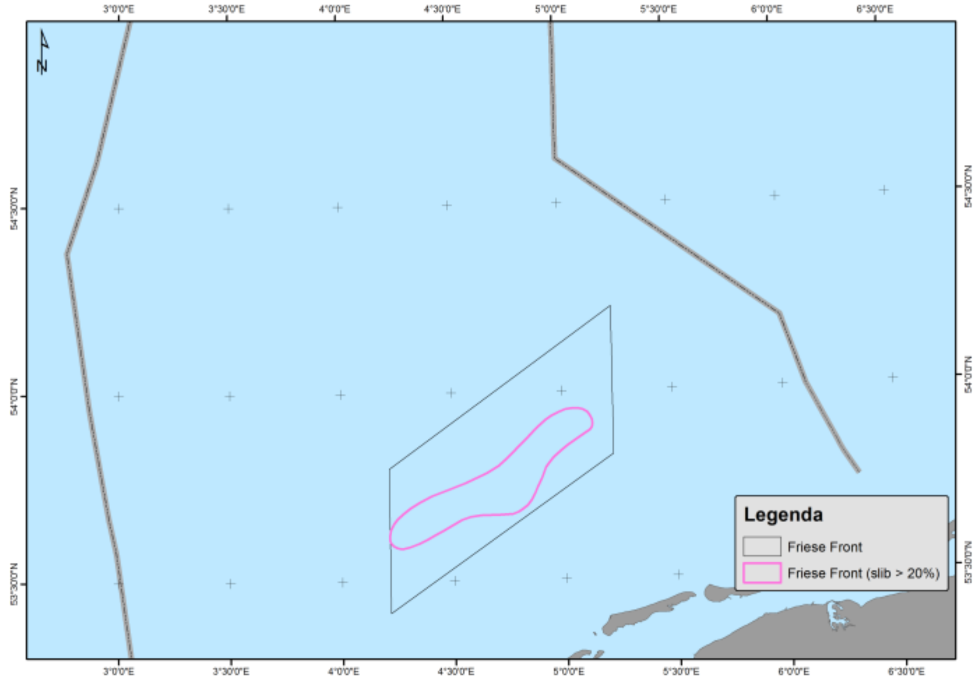
Habitat types (or nature types): combination of abiotic factors depth, sediment type, presence of silt, stratification (see details in Bos et al., 2011)

Habitat rarity %

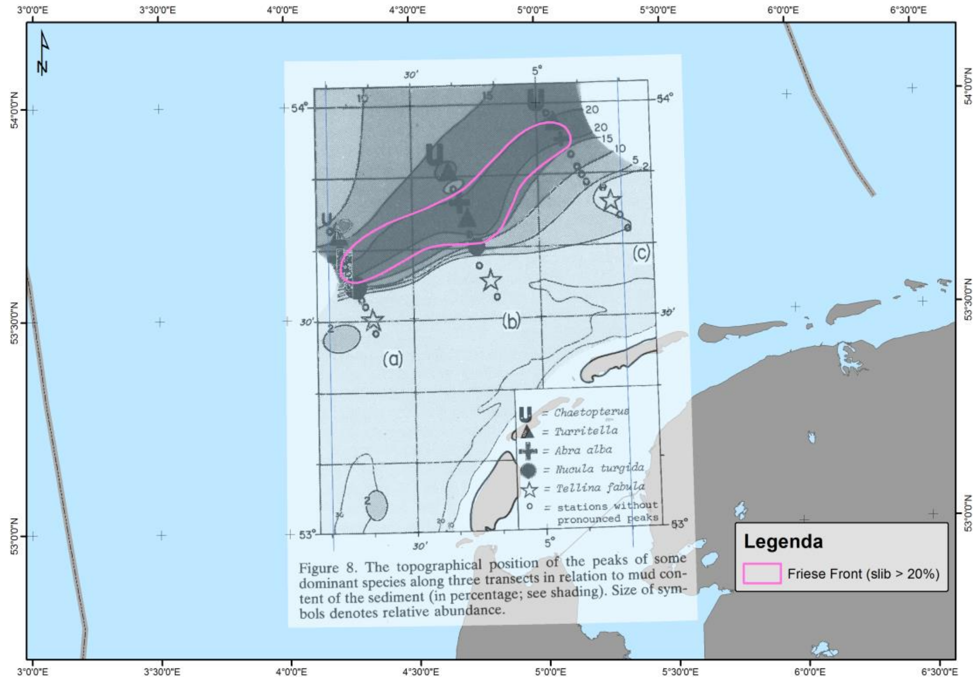




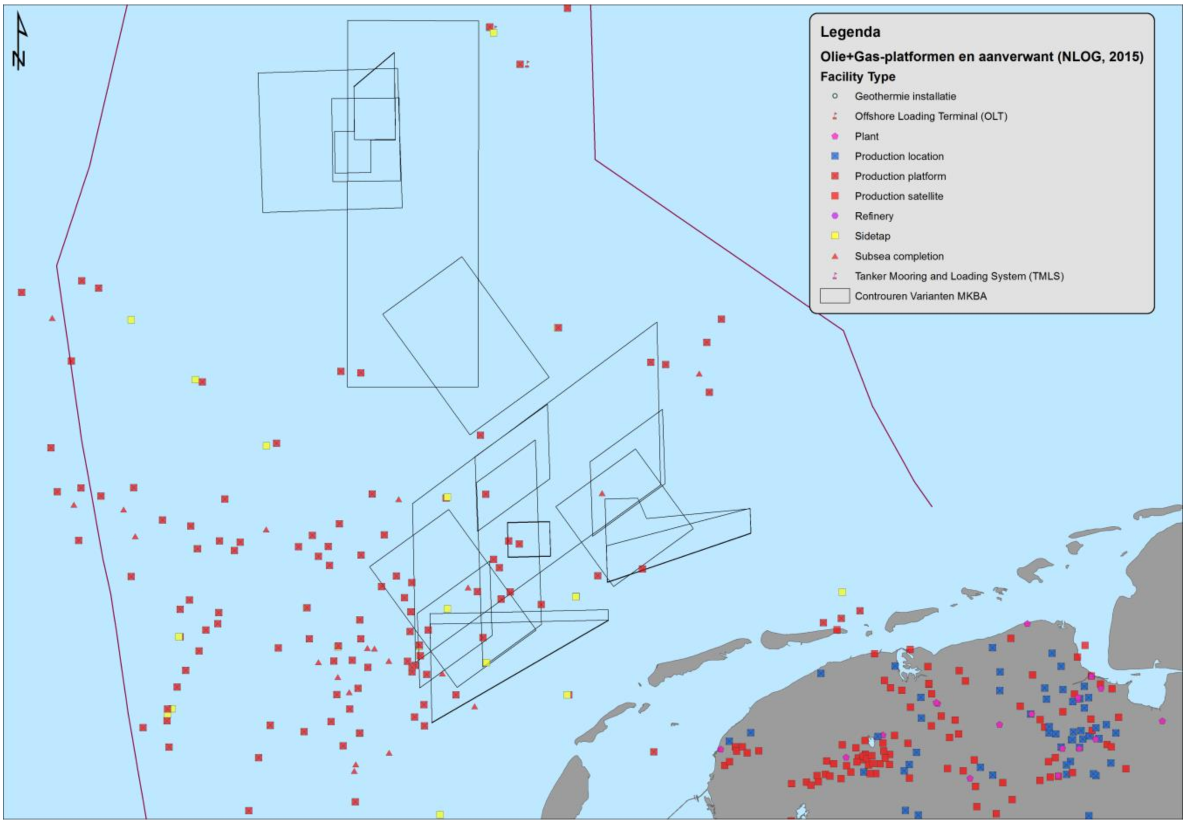
Frisian Front showing the 20% silt (red) and 15% silt (orange red) areas (De Bree et al., 1991)



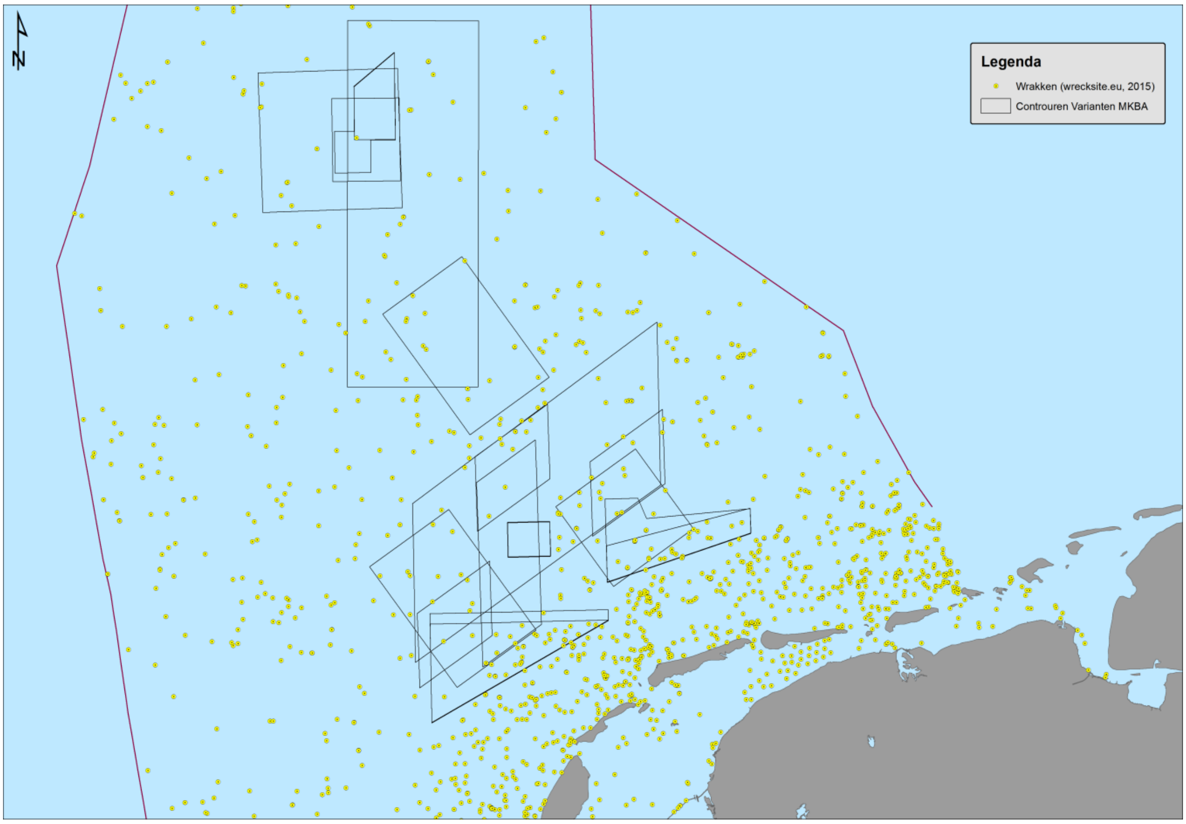
Digitised version of the map presented by De Bree et al. (1991) (see previous figure)



Georeferenced map of Creutzberg et al. (1984), combined with location of front (>20% silt) according to De Bree et al. (1991) (see previous figure)



Map of all oil and gas facilities in the area and within the variants. Retrieved on November 17 2015 from http://www.nlog.nl/nl/mappingDatasets/mappingDatasets.html (dataset dated 2015-03-03)



Map of all known wrecks in the area and within the variants.
Data collected by IMARES (sources: website http://www.wrecksite.eu; http://www.nlog.nl/nl/mappingDatasets/mappingDatasets.htm)

Appendix 3 Availability of ecological data

Availability of data and possible elements to describe the different variants, based on the studies prepared for the stakeholder process.

	Qualitative	Quantitative
Study on biodiversity Dutch Continental Shelf (Bos *et al.*, 2015)		
Macro/megabenthos biomass, density, species richness, evenness, long-lived species, large growing species, etc.		x
Birds, fish, marine mammals		x
Study on Ecological function (report on species traits, Van Kooten *et al.*, 2015)		
Restoration of species richness	X	
Restoration of species size distribution (% population molluscs)	X	
Proportion of benthic species with brood care	X	
Proportion of predatory species (e.g. sea star)	X	
Proportion of deep burrying species (e.g. mud shrimp)	X	
Proportion of bioturbating species	X	
Proportion of mobile benthic species (free living)	X	
Proportion of subsurface deposit feeders (e.g. worms)	X	
Position in sediment (0-5cm, e.g. *Sabellaria*)	X	
Proportion of species with benthic egg development (e.g. whelk or squid)	X	
Study on benefits for fishery (Van Kooten *et al.*, 2014)	X	
Export of larvae (from closed area)	X	
Export of commercial fish (from closed area)	X	
Export of less mobile species (from border of closed area)	X	
Study on potential for recovery of the area after closure (Jongbloed *et al.*, 2013)	X	
Benthos: Increase of bioturbation and biogenic structures	X	
Benthos: Increase biodiversity: shift of biomass, increase bivalves, increase crustaceans, decrease worms	X	
Benthos: Increase of density and age classes, decrease of scavengers (crabs, worms, sea stars), shifts in biomass and abundance	X	
Benthos: increase of whelk	X	
Benthos: increase of long-lived species such as *Artica islandica, Mya truncata, Thracia convexa*	X	
Fish: Increase of rays and sharks	X	
Fish: Increase of larger specimens within fish species	X	
Proportion of species with exoskeleton (e.g. crab, mud shrimp, but not bivalves)	X	

Appendix 4 Ecopoint calculations per subarea

Table A4.1

Area quality indicators

			MACROBENTHOS							MEGABENTHOS			
variant_code	Variant	Subarea	biomass	eveness	large_species	long_lived species	species richness	rarity	density	biomass	density	rarity	richness
A	Abalone	Abalone_CO	4.34	3.03	6.00	8.31	8.06	3.18	6.67	4.02	5.38	6.66	5.78
A	Abalone	Abalone_FF	5.83	4.96	5.14	3.57	6.48	1.67	5.09	6.83	7.24	4.15	6.92
A	Abalone	total	5.33	4.31	5.43	5.16	7.01	2.18	5.62	5.88	6.62	4.99	6.54
B	Brill	Brill_CO	4.00	3.00	6.00	8.00	8.25	3.16	6.84	4.00	5.44	6.70	5.90
B	Brill	Brill_FFSW	5.86	4.58	4.00	2.68	4.20	1.69	4.87	4.67	4.25	2.61	4.11
B	Brill	Brill_FFSE	6.46	3.56	4.99	2.49	4.78	1.77	6.88	6.34	6.83	3.06	5.99
B	Brill	Brill_FFC	6.00	5.03	5.00	3.42	7.00	2.00	5.50	7.82	8.01	4.69	8.00
B	Brill	total	5.72	4.10	4.66	3.56	5.25	1.98	5.75	5.24	5.41	3.57	5.20
C	Capelin	Capelin_CO	4.34	3.03	6.00	8.31	8.06	3.18	6.67	4.02	5.38	6.66	5.78
C	Capelin	Capelin_FFNO	5.51	5.19	6.04	4.65	7.57	2.08	5.10	5.85	8.40	5.19	8.79
C	Capelin	Capelin_FFSE	5.94	4.19	5.72	3.42	6.61	2.00	6.57	6.87	8.43	5.99	8.83
C	Capelin	Capelin_FFSW	5.43	5.00	4.45	3.53	4.81	1.62	4.77	5.12	5.02	3.25	5.60
C	Capelin	total	5.30	4.35	5.55	4.99	6.77	2.23	5.78	5.46	6.80	5.28	7.25
D	Dab	Dab_CO	4.16	3.00	6.00	8.23	8.17	3.25	6.88	4.02	5.28	6.57	5.73
D	Dab	Dab_FFSW	5.90	4.55	4.06	2.70	4.34	1.60	4.94	4.90	4.44	2.64	4.22
D	Dab	Dab_FFSE	6.30	3.67	4.99	2.67	5.10	1.84	6.86	6.55	7.07	3.52	6.50
D	Dab	Dab_FFC	6.00	5.02	5.00	3.40	7.00	2.00	5.49	7.82	8.00	4.67	7.97
D	Dab	total	5.71	4.04	4.75	3.73	5.43	2.00	5.90	5.41	5.60	3.74	5.41
E	Eel	Eel_CON	4.39	3.26	5.89	8.42	8.07	3.28	7.12	3.99	4.02	5.68	5.15
E	Eel	Eel_COS	5.18	5.09	6.48	6.42	8.11	2.94	4.17	2.78	5.64	5.98	7.54
E	Eel	Eel_FFSE	6.09	4.06	5.21	2.97	6.09	1.93	6.54	7.08	7.78	4.87	7.80
E	Eel	Eel_FFSW	5.37	5.20	4.67	3.86	5.28	1.53	4.85	5.49	5.81	3.49	6.45
E	Eel	total	5.11	4.33	5.62	5.88	7.06	2.53	5.72	4.58	5.50	5.07	6.51
F	Flounder	Flounder_CO	4.53	3.88	6.05	7.72	8.44	3.14	5.38	3.39	5.50	6.13	7.04
F	Flounder	Flounder_FF	5.56	5.01	5.63	4.13	6.80	1.95	5.53	6.09	7.86	5.43	8.34
F	Flounder	total	5.00	4.40	5.86	6.09	7.69	2.60	5.45	4.62	6.57	5.81	7.63
		MIN	4.00	3.00	4.00	2.00	2.00	1.00	4.00	2.00	1.00	2.00	3.00
		MAX	7.00	6.00	7.00	9.00	9.00	4.00	8.00	8.00	9.00	9.00	9.00
	opt out	1=in, 0=out	1	1	1	1	1	0	1	1	1	0	1

Table A4.2
Re-scaled values of quality indicators

nt_code Variant	Subarea	biomass	eveness	large_species	long_lived species	species richness	rarity	density	biomass	density	rarity	richness	sum area quality
Abalone	Abalone_CO	0.11	0.01	0.67	0.90	0.87	0	0.67	0.34	0.55	0	0.46	4.57
Abalone	Abalone_FF	0.61	0.65	0.38	0.22	0.64	0	0.27	0.80	0.78	0	0.65	5.01
Abalone	A total	0.44	0.44	0.48	0.45	0.72	0	0.40	0.65	0.70	0	0.59	4.87
Brill	Brill_CO	0.00	0.00	0.67	0.86	0.89	0	0.71	0.33	0.56	0	0.48	4.50
Brill	Brill_FFSW	0.62	0.53	0.00	0.10	0.31	0	0.22	0.45	0.41	0	0.18	2.81
Brill	Brill_FFSE	0.82	0.19	0.33	0.07	0.40	0	0.72	0.72	0.73	0	0.50	4.48
Brill	Brill_FFC	0.67	0.68	0.33	0.20	0.71	0	0.37	0.97	0.88	0	0.83	5.64
Brill	B total	0.57	0.37	0.22	0.22	0.46	0	0.44	0.54	0.55	0	0.37	3.74
Capelin	Capelin_CO	0.11	0.01	0.67	0.90	0.87	0	0.67	0.34	0.55	0	0.46	4.57
Capelin	Capelin_FFNO	0.50	0.73	0.68	0.38	0.80	0	0.28	0.64	0.93	0	0.96	5.89
Capelin	Capelin_FFSE	0.65	0.40	0.57	0.20	0.66	0	0.64	0.81	0.93	0	0.97	5.83
Capelin	Capelin_FFSW	0.48	0.67	0.15	0.22	0.40	0	0.19	0.52	0.50	0	0.43	3.56
Capelin	C total	0.43	0.45	0.52	0.43	0.68	0	0.44	0.58	0.73	0	0.71	4.96
Dab	Dab_CO	0.05	0.00	0.67	0.89	0.88	0	0.72	0.34	0.53	0	0.46	4.54
Dab	Dab_FFSW	0.63	0.52	0.02	0.10	0.33	0	0.23	0.48	0.43	0	0.20	2.96
Dab	Dab_FFSE	0.77	0.22	0.33	0.10	0.44	0	0.71	0.76	0.76	0	0.58	4.68
Dab	Dab_FFC	0.67	0.67	0.33	0.20	0.71	0	0.37	0.97	0.88	0	0.83	5.63
Dab	D total	0.57	0.35	0.25	0.25	0.49	0	0.47	0.57	0.57	0	0.40	3.92
Eel	Eel_CON	0.13	0.09	0.63	0.92	0.87	0	0.78	0.33	0.38	0	0.36	4.48
Eel	Eel_COS	0.39	0.70	0.83	0.63	0.87	0	0.04	0.13	0.58	0	0.76	4.93
Eel	Eel_FFSE	0.70	0.35	0.40	0.14	0.58	0	0.64	0.85	0.85	0	0.80	5.31
Eel	Eel_FFSW	0.46	0.73	0.22	0.27	0.47	0	0.21	0.58	0.60	0	0.58	4.12
Eel	E total	0.37	0.44	0.54	0.55	0.72	0	0.43	0.43	0.56	0	0.59	4.64
Flounder	Flounder_CO	0.18	0.29	0.68	0.82	0.92	0	0.35	0.23	0.56	0	0.67	4.70
Flounder	Flounder_FF	0.52	0.67	0.54	0.30	0.69	0	0.38	0.68	0.86	0	0.89	5.53
Flounder	F total	0.33	0.47	0.62	0.58	0.81	0	0.36	0.44	0.70	0	0.77	5.08
	min value	0.00	0.00	0.00	0.07	0.31	0.00	0.04	0.13	0.38	0.00	0.18	2.81
	max value	0.82	0.73	0.83	0.92	0.92	0.00	0.78	0.97	0.93	0.00	0.97	5.89

Table A4.3
Weighting factors, original values

Variant	Subarea	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery intensity
Abalone	Abalone_CO	91.89	2	88%	97%	92%	0%	0%	0	0	0		
Abalone	Abalone_FF	88.91	8	73%	95%	85%	25%	20%	8	8	8		
Abalone	total	89.91	9	56%	92%	78%	25%	20%	8	8	8	0.02	0.12
Brill	Brill_CO	91.76	1	81%	93%	79%	0%	0%	0	0	0		
Brill	Brill_FFSW	73.97	2	69%	93%	82%	0%	1%	2	1	0		
Brill	Brill_FFSE	84.86	4	65%	87%	57%	0%	0%	0	0	0		
Brill	Brill_FFC	97.27	4	89%	94%	80%	13%	4%	4	3	3		
Brill	total	81.57	9	38%	84%	58%	13%	5%	4	3	3	0.06	0.08
Capelin	Capelin_CO	91.89	2	88%	97%	92%	0%	0%	0	0	0		
Capelin	Capelin_FFNO	97.18	6	80%	95%	86%	0%	14%	6	3	3		
Capelin	Capelin_FFSE	98.24	6	80%	95%	86%	12%	13%	6	4	4		
Capelin	Capelin_FFSW	79.19	4	80%	95%	86%	0%	9%	4	5	0		
Capelin	total	91.63	11	41%	87%	67%	12%	35%	6	5	4	0.03	0.12
Dab	Dab_CO	91.76	1	68%	89%	64%	0%	0%	0	0	0		
Dab	Dab_FFSW	74.09	2	73%	95%	85%	0%	3%	2	1	0		
Dab	Dab_FFSE	87.93	6	71%	92%	76%	0%	0%	0	0	0		
Dab	Dab_FFC	97.27	4	89%	94%	80%	13%	4%	4	3	3		
Dab	total	82.86	15	38%	86%	63%	13%	6%	4	3	3	0.05	0.08
Eel	Eel_CON	93.05	4	89%	99%	97%	0%	0%	0	0	0		
Eel	Eel_COS	95.55	5	87%	98%	95%	0%	0%	0	0	0		
Eel	Eel_FFSE	94.04	9	88%	98%	95%	11%	11%	8	4	4		
Eel	Eel_FFSW	86.18	8	87%	98%	95%	24%	20%	8	8	8		
Eel	total	92.13	15	44%	93%	82%	35%	31%	8	8	8	0.02	0.09
Flounder	Flounder_CO	93.65	5	78%	98%	95%	0%	0%	0	0	0		
Flounder	Flounder_FF	95.32	14	76%	98%	94%	100%	100%	14	8	8		
Flounder	total	94.41	14	55%	96%	90%	100%	100%	14	8	8	0.02	0.12
	MIN	73.97	1	0%	50%	50%	0%	0%	0	0	0	0.00	0.00
	MAX	99.95	15	89%	100%	100%	100%	100%	14	8	8	0.06	0.12

Table A4.4
Weighting factors, scaled values

Variant	Subarea	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery intensity
Abalon	Abalone_CO	0.69	0.07	0.99	0.95	0.85	0.00	0.00	0.00	0.00	0.00		
Abalon	Abalone_FF	0.57	0.50	0.82	0.90	0.71	0.25	0.20	0.57	1.00	1.00		
Abalon	total	0.61	0.57	0.63	0.83	0.55	0.25	0.20	0.57	1.00	1.00	0.28	1.00
Brill	Brill_CO	0.68	0.00	0.91	0.87	0.58	0.00	0.00	0.00	0.00	0.00		
Brill	Brill_FFSW	0.00	0.07	0.78	0.87	0.63	0.00	0.01	0.14	0.13	0.00		
Brill	Brill_FFSE	0.42	0.21	0.73	0.75	0.13	0.00	0.00	0.00	0.00	0.00		
Brill	Brill_FFC	0.90	0.21	1.00	0.89	0.60	0.13	0.04	0.29	0.38	0.38		
Brill	total	0.29	0.57	0.43	0.67	0.15	0.13	0.05	0.29	0.38	0.38	1.00	0.67
Capelir	Capelin_CO	0.69	0.07	0.99	0.95	0.85	0.00	0.00	0.00	0.00	0.00		
Capelir	Capelin_FFNO	0.89	0.36	0.90	0.91	0.73	0.00	0.14	0.43	0.38	0.38		
Capelir	Capelin_FFSE	0.93	0.36	0.90	0.91	0.73	0.12	0.13	0.43	0.50	0.50		
Capelir	Capelin_FFSW	0.20	0.21	0.90	0.91	0.73	0.00	0.09	0.29	0.63	0.00		
Capelir	total	0.68	0.71	0.46	0.74	0.35	0.12	0.35	0.43	0.63	0.50	0.43	1.00
Dab	Dab_CO	0.68	0.00	0.76	0.78	0.28	0.00	0.00	0.00	0.00	0.00		
Dab	Dab_FFSW	0.00	0.07	0.82	0.90	0.70	0.00	0.03	0.14	0.13	0.00		
Dab	Dab_FFSE	0.54	0.36	0.80	0.85	0.53	0.00	0.00	0.00	0.00	0.00		
Dab	Dab_FFC	0.90	0.21	1.00	0.89	0.60	0.13	0.04	0.29	0.38	0.38		
Dab	total	0.34	1.00	0.43	0.71	0.26	0.13	0.06	0.29	0.38	0.38	0.81	0.67
Eel	Eel_CON	0.73	0.21	1.00	0.97	0.93	0.00	0.00	0.00	0.00	0.00		
Eel	Eel_COS	0.83	0.29	0.97	0.96	0.90	0.00	0.00	0.00	0.00	0.00		
Eel	Eel_FFSE	0.77	0.57	0.99	0.96	0.90	0.11	0.11	0.57	0.50	0.50		
Eel	Eel_FFSW	0.47	0.50	0.97	0.96	0.90	0.24	0.20	0.57	1.00	1.00		
Eel	total	0.70	1.00	0.50	0.86	0.65	0.35	0.31	0.57	1.00	1.00	0.35	0.75
Flound	Flounder_CO	0.76	0.29	0.88	0.96	0.90	0.00	0.00	0.00	0.00	0.00		
Flound	Flounder_FF	0.82	0.93	0.86	0.96	0.89	1.00	1.00	1.00	1.00	1.00		
Flound	total	0.79	0.93	0.61	0.92	0.81	1.00	1.00	1.00	1.00	1.00	0.28	1.00
	min value	0.00	0.00	0.43	0.67	0.13	0.00	0.00	0.00	0.00	0.00	0.28	0.67
	max value	0.93	1.00	1.00	0.97	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A4.5

Calculated ecopoints per km^2 for each variant and subareas, depending on the applied weighting factor

5. Ecopoints per km2

ecopoints (per km2) = area quality (per km2)* weight factor

Variant_code	Variant	Subarea	0. No weighting factor	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery intensity
A	Abalone	Abalone_CO	4.57	3.15	0.33	4.52	4.33	3.88	0.00	0.00	0.00	0.00	0.00		
A	Abalone	Abalone_FF	5.01	2.88	2.51	4.09	4.50	3.54	1.28	1.00	2.87	5.01	5.01		
A	Abalone	total	4.87	2.98	2.78	3.07	4.06	2.70	1.24	0.97	2.78	4.87	4.87	1.34	4.87
B	Brill	Brill_CO	4.50	3.08	0.00	4.09	3.91	2.62	0.00	0.00	0.00	0.00	0.00		
B	Brill	Brill_FFSW	2.81	0.00	0.20	2.18	2.44	1.79	0.00	0.04	0.40	0.35	0.00		
B	Brill	Brill_FFSE	4.48	1.88	0.96	3.28	3.34	0.60	0.00	0.00	0.00	0.00	0.00		
B	Brill	Brill_FFC	5.64	5.06	1.21	5.63	5.01	3.39	0.72	0.21	1.61	2.12	2.12		
B	Brill	total	3.74	1.10	2.14	1.61	2.51	0.58	0.48	0.19	1.07	1.40	1.40	3.74	2.50
C	Capelin	Capelin_CO	4.57	3.15	0.33	4.52	4.33	3.88	0.00	0.00	0.00	0.00	0.00		
C	Capelin	Capelin_FFNO	5.89	5.26	2.10	5.32	5.34	4.30	0.02	0.81	2.53	2.21	2.21		
C	Capelin	Capelin_FFSE	5.83	5.45	2.08	5.27	5.28	4.25	0.70	0.74	2.50	2.92	2.92		
C	Capelin	Capelin_FFSW	3.56	0.72	0.76	3.22	3.22	2.60	0.00	0.31	1.02	2.23	0.00		
C	Capelin	total	4.96	3.37	3.55	2.29	3.69	1.73	0.62	1.74	2.13	3.10	2.48	2.12	4.96
D	Dab	Dab_CO	4.54	3.11	0.00	3.46	3.53	1.26	0.00	0.00	0.00	0.00	0.00		
D	Dab	Dab_FFSW	2.96	0.01	0.21	2.42	2.65	2.06	0.00	0.08	0.42	0.37	0.00		
D	Dab	Dab_FFSE	4.68	2.51	1.67	3.72	3.97	2.48	0.00	0.00	0.00	0.00	0.00		
D	Dab	Dab_FFC	5.63	5.05	1.21	5.62	5.00	3.38	0.71	0.21	1.61	2.11	2.11		
D	Dab	total	3.92	1.34	3.92	1.69	2.80	1.02	0.49	0.24	1.12	1.47	1.47	3.18	2.61
E	Eel	Eel_CON	4.48	3.29	0.96	4.46	4.36	4.17	0.00	0.00	0.00	0.00	0.00		
E	Eel	Eel_COS	4.93	4.09	1.41	4.80	4.75	4.44	0.00	0.00	0.00	0.00	0.00		
E	Eel	Eel_FFSE	5.31	4.10	3.03	5.28	5.11	4.77	0.58	0.57	3.03	2.65	2.65		
E	Eel	Eel_FFSW	4.12	1.94	2.06	4.01	3.97	3.71	0.99	0.84	2.35	4.12	4.12		
E	Eel	total	4.64	3.24	4.64	2.30	3.99	2.99	1.62	1.45	2.65	4.64	4.64	1.61	3.48
F	Flounder	Flounder_CO	4.70	3.56	1.34	4.13	4.54	4.26	0.00	0.00	0.00	0.00	0.00		
F	Flounder	Flounder_FF	5.53	4.55	5.14	4.75	5.30	4.91	5.53	5.53	5.53	5.53	5.53		
F	Flounder	total	5.08	4.00	4.72	3.12	4.70	4.09	5.08	5.08	5.08	5.08	5.08	1.44	5.08

Table A4.6

Calculated ecopoints for each variant and subarea, depending on the applied weighting factor

5. Ecopoints per area (km2)

ecopoints = (area(km2)/100)* area quality (per km2)* weight factor

Variant_code	Variant	Subarea	0. No weighting factor	1. Habitat rarity	2. N habitats	3a. Relative border	3b. Effective protect.-1 km	3c. Effective protect.-2.5km	4a. 20%FFmud	4b. %FFparallelogram	5a. Abiotic gradients	5b. Benthic gradients	5c. Gradients incl centre	6. Hard substrate	7. Fishery intensity
A	Abalone	Abalone_C	18	13	1	18	17	16	0	0	0	0	0		
A	Abalone	Abalone_F	40	23	20	33	36	28	10	8	23	40	40		
A	Abalone	total	59	36	33	37	49	32	15	12	33	59	59	16	59
B	Brill	Brill_CO	9	6	0	8	8	5	0	0	0	0	0		
B	Brill	Brill_FFSV	18	0	1	14	15	11	0	0	3	2	0		
B	Brill	Brill_FFSE	14	6	3	10	11	2	0	0	0	0	0		
B	Brill	Brill_FFC	6	5	1	6	5	4	1	0	2	2	2		
B	Brill	total	47	14	27	20	32	7	6	2	14	18	18	47	32
C	Capelin	Capelin_C	18	13	1	18	17	16	0	0	0	0	0		
C	Capelin	Capelin_F	23	21	8	21	21	17	0	3	10	9	9		
C	Capelin	Capelin_F	23	22	8	21	21	17	3	3	10	12	12		
C	Capelin	Capelin_F	14	3	3	13	13	10	0	1	4	9	0		
C	Capelin	total	79	54	57	37	59	28	10	28	34	50	40	34	79
D	Dab	Dab_CO	14	9	0	11	11	4	0	0	0	0	0		
D	Dab	Dab_FFSW	23	0	2	19	20	16	0	1	3	3	0		
D	Dab	Dab_FFSE	23	13	8	19	20	12	0	0	0	0	0		
D	Dab	Dab_FFC	6	5	1	6	5	4	1	0	2	2	2		
D	Dab	total	66	23	66	28	47	17	8	4	19	25	25	53	44
E	Eel	Eel_CON	63	46	13	63	61	59	0	0	0	0	0		
E	Eel	Eel_COS	52	43	15	50	50	47	0	0	0	0	0		
E	Eel	Eel_FFSE	37	29	21	37	36	33	4	4	21	19	19		
E	Eel	Eel_FFSW	43	20	22	42	42	39	10	9	25	43	43		
E	Eel	total	195	136	195	97	168	126	68	61	111	195	195	68	146
F	Flounder	Flounder_	163	123	46	143	157	147	0	0	0	0	0		
F	Flounder	Flounder_	160	131	148	137	153	142	159	160	160	160	160		
F	Flounder	total	322	253	299	198	298	260	322	322	322	322	322	91	322

Appendix 5 Data sources for direct economic effects on fishing sector

VIRIS data
The catch data originates from the VIRIS (Fish Registration and Information System) database that contains records of all landings by vessels sailing under the Dutch flag and all landings by vessels sailing under a non-Dutch flag landing fish at ports in the Netherlands. These records are based on the logbooks kept by the fishermen. The catches of each species controlled by quota must be entered in this logbook per sailing day and ICES quadrant. Records of the catches of species not controlled by quota are kept per trip.

Fleet data
The catch data for the various types of fisheries was calculated using the technical data listed in the NRV (Netherlands Register of Fishing Vessels). The combination of NRV data and VIRIS data yielded information about the technical specifications of the vessel on each trip. Not all the technical specifications of non-Dutch vessels are known.

VMS data
Since 1 January 2000, an increasingly large proportion of fishing vessels are under the obligation to operate an onboard VMS system (Vessel Monitoring System) within the context of the European inspection policy. This VMS system transmits the position of the vessel, vessel identification code and the vessel's sailing speed to a central computer about once every two hours. The computer stores this data (EU Regulation 2244/2003). The vessel's sailing speed can be used to make a distinction between the various activities (fishing, sailing and at anchor). Although this distinction cannot be made completely, the potential error is small relative to the total number of records. Information about the presence of non'Dutch vessels in the Dutch section of the North Sea is also available.

Price data
The value of the catches was determined using the average monthly price data per species collected by the Productschap Vis (Netherlands Fish Product Board). Price data is not collected for all the species listed in VIRIS. When specific price data was not available for fish species then the value of the catches was determined using the average price of less specific market categories (for example, 'other seafish'). In addition, prices from other sources were used for a number of fish species (in particular, sprat and herring, grey mullet and smelt) (requested from fishers and collected from the accounts of the high-sea fisheries) since these species are rarely traded on the fish auctions and the auction prices are not representative of the actual prices paid for the fish. The average auction price of catches by vessels with fixed fishing gear were increased by 15%: an analysis of a limited dataset with price data for the fisheries with fixed fishing gear and discussions with fishermen revealed that these fisheries' catches are, in general, traded at higher auction prices due to a different market grading (in general, larger sole) and quality (fresh fish with less damage as compared to fish caught with beam trawls).

Economic data
The LEI panel has economic data for the various fisheries over the entire period of the study. The data contains the total annual proceeds of the Dutch cutter fisheries in the various fisheries and the relationships between the total proceeds and the gross value added. However, these data are not classified by fishing area. Consequently, the economic data need to be combined with catch data to arrive at an estimate of the contribution each fishing area makes to the economy.

Appendix 6 Gear Codes

Table A6.1
Gear codes used in the report and the gears

Gear code	Gear type
FPO	Pots
GN	Gillnets (not specified)
GNC	Encircling gillnets
GND	Drift nets
GNS	Set gillnets (anchored)
GTN	Combined gillnets-Trammel nets
GTR	Trammel nets
LHP	Hand-lines and pole-lines (hand operated)
LL	Longlines (not specified)
LLD	Drifting longlines
LLS	Set lines (longlines set)
LN	Lift nets (not specified)
MIS	MISCELLANEOUS GEAR
OTB	Otter trawls bottom
OTM	Otter trawls midwatter
OTT	Otter twin trawls
PTB	Pair trawls bottom
PTM	Pair trawls mid-water
SDN	Danish seines
SSC	Scottish seines
TBB	Beam trawls
TBS	Shrimp trawls

Appendix 7 Characteristics of the Dutch activities in the sub-areas of all variants

Table A7.1

Overview of landings and values of the Dutch fishing sector in the different areas and locations of the possible variants

Variant	Location	2008	2009	2010	2011	2012	2013	2014	Average
Landings volume (tonnes)									
Abalone	FF	256	326	295	160	534	157	281	287
Abalone	CO	39	19	34	6	107	52	40	42
Brill	CO	33	13	17	3	68	31	25	27
Brill	FFSW	96	84	45	18	65	16	9	48
Brill	FFSE	32	79	54	35	338	173	31	106
Brill	FFC	23	48	65	11	146	17	17	47
Capelin	FFSW	90	70	78	28	147	95	20	75
Capelin	FFSE	206	189	168	79	277	148	45	159
Capelin	FFNO	76	129	161	170	112	80	231	137
Capelin	CO	39	19	34	6	107	52	40	42
Dab	CO	37	15	22	4	75	43	30	32
Dab	FFSW	171	149	71	22	79	45	15	79
Dab	FFSE	60	110	81	62	499	242	61	159
Dab	FFC	23	47	63	11	147	16	17	46
Eel	FFSE	229	261	232	102	693	278	90	269
Eel	FFSW	323	274	232	173	392	220	124	248
Eel	COS	221	270	302	384	248	264	190	268
Eel	CON	103	61	98	36	235	124	115	110
Flounder	FF	975	1,182	1,220	956	1,655	934	836	1,108
Flounder	CO	560	277	397	730	717	426	542	521
Landings value (kEuro)									
Abalone	FF	1,136	1,255	1,037	648	1,315	621	511	932
Abalone	CO	93	33	56	15	138	78	61	68
Brill	CO	79	22	31	7	87	48	39	45
Brill	FFSW	489	349	185	93	172	64	25	197
Brill	FFSE	161	71	148	107	494	164	63	171
Brill	FFC	94	185	221	30	208	78	42	123
Capelin	FFSW	399	293	286	99	317	293	81	252
Capelin	FFSE	873	712	584	275	563	338	149	499
Capelin	FFNO	316	485	525	707	381	308	525	464
Capelin	CO	93	33	56	15	138	78	61	68
Dab	CO	88	27	39	8	100	65	45	53
Dab	FFSW	852	607	289	114	256	119	46	326
Dab	FFSE	304	189	210	155	694	247	109	270
Dab	FFC	93	182	215	30	209	74	42	121
Eel	FFSE	1,008	868	739	298	1,179	457	215	679
Eel	FFSW	1,403	1,033	797	365	976	702	394	810
Eel	COS	815	962	1,049	1,046	789	858	626	878
Eel	CON	241	111	164	87	352	185	201	192
Flounder	FF	4,096	4,470	4,179	3,409	4,280	3,107	2,280	3,689
Flounder	CO	1,618	782	967	1,699	1,383	859	1,078	1,198
Effort (fishing days)									
Abalone	FF	152	188	152	116	156	94	82	134
Abalone	CO	13	6	7	2	12	12	9	9
Brill	CO	10	5	4	1	8	7	6	6

Variant	Location	2008	2009	2010	2011	2012	2013	2014	Average
Brill	FFSW	94	95	50	24	38	15	6	46
Brill	FFSE	35	18	42	32	50	44	16	34
Brill	FFC	18	25	28	6	17	10	6	15
Capelin	FFSW	49	45	45	17	27	39	11	33
Capelin	FFSE	116	124	99	51	53	46	22	73
Capelin	FFNO	43	86	90	123	63	59	81	78
Capelin	CO	13	6	7	2	12	12	9	9
Dab	CO	12	5	5	1	10	10	7	7
Dab	FFSW	136	132	66	29	49	21	9	63
Dab	FFSE	64	55	58	42	60	55	25	51
Dab	FFC	17	25	27	6	16	9	5	15
Eel	FFSE	147	153	126	61	99	67	36	98
Eel	FFSW	186	160	121	47	103	90	50	108
Eel	COS	140	149	160	150	105	107	102	130
Eel	CON	33	19	21	10	38	28	26	25
Flounder	FF	577	741	658	556	541	476	374	560
Flounder	CO	258	130	151	206	182	124	150	172

a) preliminary estimates.

Source: Logbook data and VMS data, processed by LEI.

Appendix 8 Seasonal patterns of landings value for various gears

Seasonal patterns in utilisation of the area vary among gear types. For the traditional beam trawl and Sumwing fishery the first quarter is most important in most of the variants and highest dependencies are seen there. Only in case of Brill and Dab the second quarter is slightly more important. Only in case of Flounder vessels are highly dependent (>30% of the quarterly revenue) on the areas. This high dependency occurs mainly during first quarter when some vessels obtain more than 50% of their revenue from the area. For Abalone, Brill and Dab nearly all of the revenue in the area is obtained by vessels that fish occasionally in the area (<10% of the revenue).

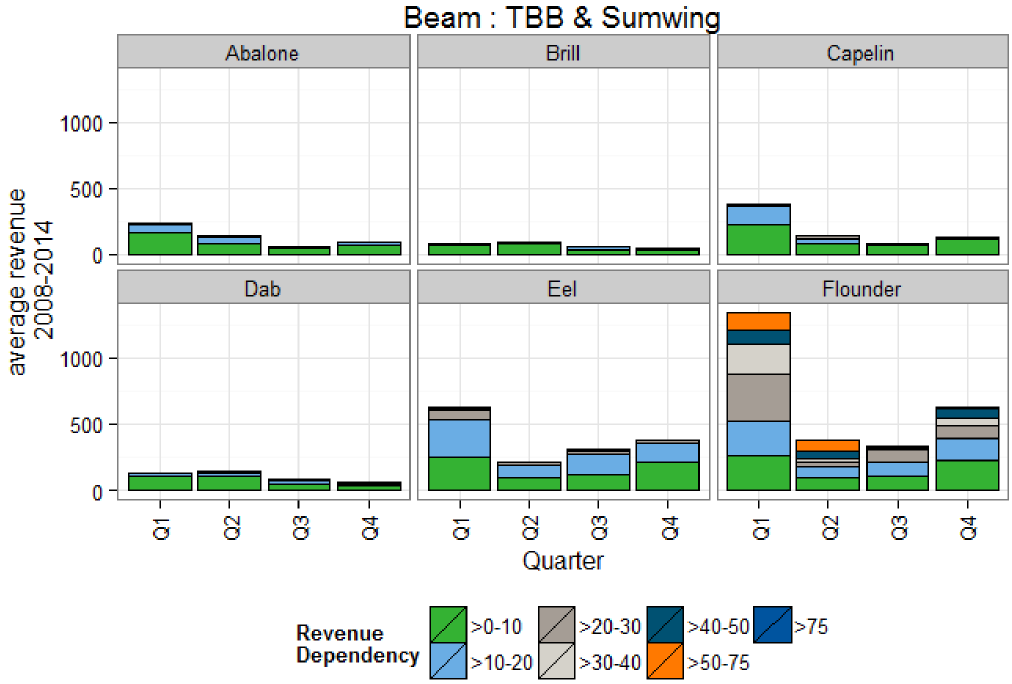


Figure A8.1 *Average revenue (kEuro) of the beam trawl and sumwing fishery per quarter over the period 2008-2014 in each of the variants. The various colours show the level to which the vessel depend on the area's E.g. almost the complete revenue in quarter 2 for variant Brill is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI

The fishing season for twin trawl and otter board trawl fisheries is during the third quarter. In all variants, the revenues from the area are highest for this period and also the highest dependencies occur then. In most of the variants dependency is low, especially in Brill and Dab. In Flounder, however, some vessels depend heavily (>50%) on the revenues from the area. This high dependency also occurs during the fourth quarter, although the total revenue is much lower.

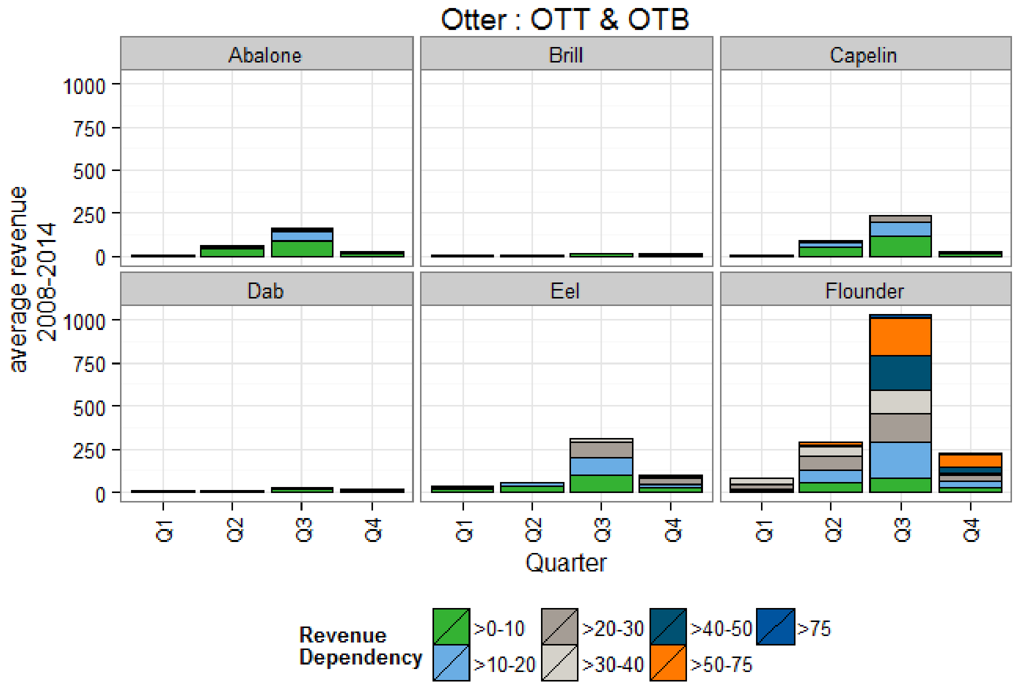


Figure A8.2 *Average revenue (kEuro) of the otter board trawl and twin trawl fishery per quarter over the period 2008-2014 in each of the variants. The various colours show the level to which the vessel depend on the areas E.g. around 200,000 euros revenue in quarter 3 for variant Flounder is obtained by vessels that are 50 - 75% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI.

Pulse gears mainly use the area during the first half of the year (Figure A8.3). It should be noted that because pulse gears have been utilised in the area during the last three years only, the average total revenue is from the areas is relatively low. In theory, this would not change the dependency levels, so it can be concluded that the dependency on this area is lower than for most other gear types. In case of Eel and Flounder, some vessels show dependency levels from 20%-40%. For all other variants the dependency is lower in almost all quarters.

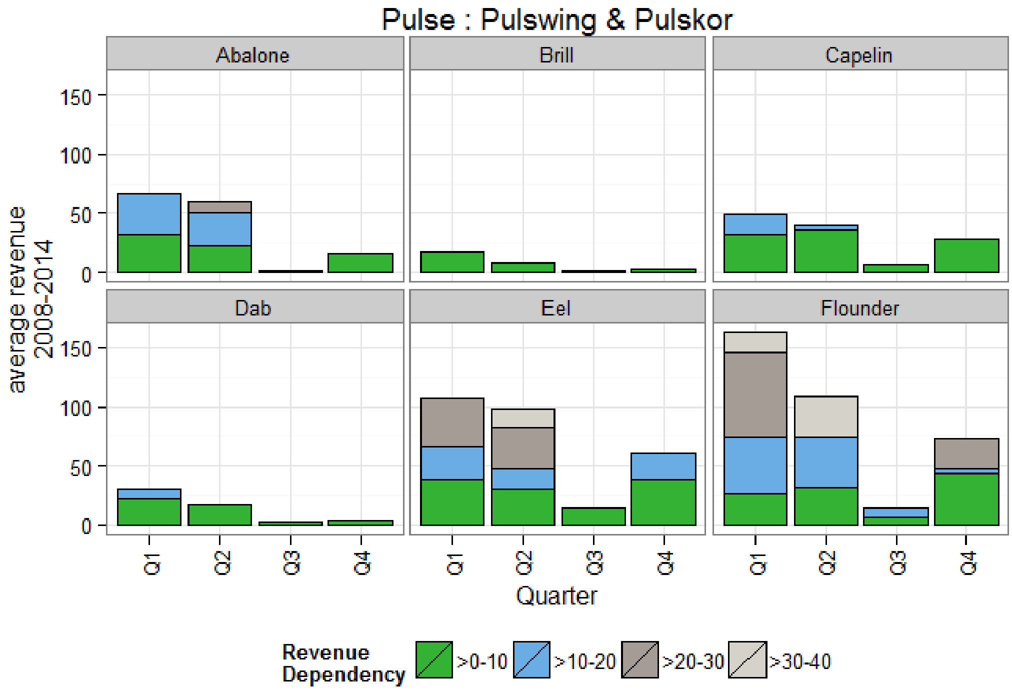


Figure A8.3 *Average revenue (kEuro) of the pulse fisheries per quarter over the period 2008-2014 in each of the variants. The various colours show the level to which the vessel depend on the area's E.g. the complete revenue in quarter 2 for variant Dab is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI.

Flyshoot vessels (SSC) mainly utilise the areas of variant Brill, Dab and Eel during the second quarter (Figure A8.4). Dependency on the areas is low in general, with the exception of Dab and Eel. In these variants around 15% of the revenues are generated by vessels that are more than 20% dependent on these areas (Figure 5.9). The total revenue generated in the variants by this fisheries is however low for all variants; on average less than 70 kEuroper quarter.

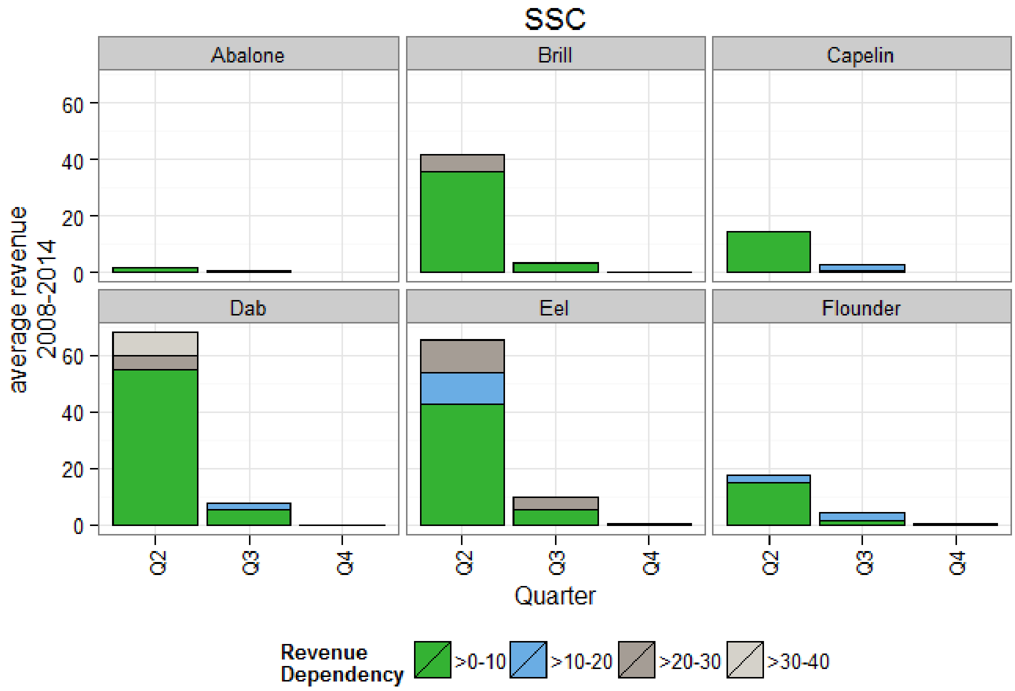


Figure A8.4 *Average revenue (kEuro) of the flyshoot fisheries per quarter over the period 2008-2014 in each of the variants. The various colours show the level to which the vessel depend on the area's E.g. the complete revenue in quarter 2 for variant Dab is obtained by vessels that are less than 10% dependent on these areas.*
Source: Logbook data and VMS data, processed by LEI.

Appendix 9 Classification fishing harbours for stress analysis

Table A9.1

Classification of harbour codes in regions for the stress analysis

Harbour code	Region	Harbour code	Region
ARM	Zeeland	MS	Zeeland
BIW	Holland	NB	Holland
BR	Zeeland	NZ	Zeeland
BRU	Zeeland	OD	Holland
BU	Holland	OH	Holland
BZ	Zeeland	OL	North
DM	Holland	SCH	Holland
DZ	North	SL	Holland
EH	Holland	ST	North
FL	North	TH	Zeeland
GM	North	TM	North
GO	Holland	TS	North
GOE	Zeeland	TX	North
HA	North	UK	Urk
HD	Holland	UQ	North
HI	North	VD	Holland
HK	Holland	VL	Zeeland
HL	North	VLI	Zeeland
HN	Holland	VLL	North
HON	Zeeland	WK	North
IJM	Holland	WL	North
KG	Zeeland	WON	North
KL	Zeeland	WR	Holland
KW	Holland	WSW	Zeeland
LE	North	YE	Zeeland
LO	North	ZK	North
ME	Holland	ZL	Zeeland
MO	Holland	ZZ	Zeeland

Appendix 10 Analyses underlying the assumptions in Displacement scenario A

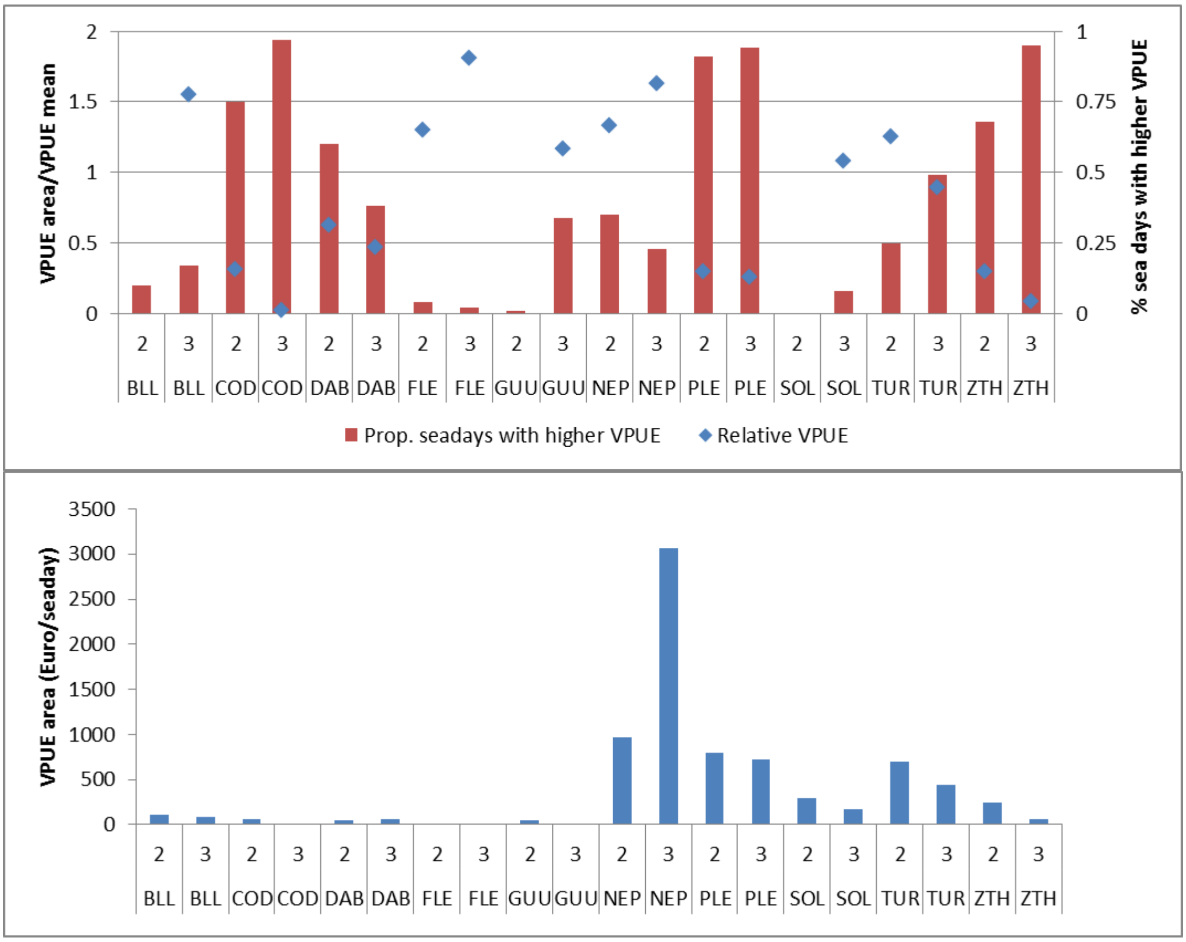


Figure A10.1 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using Otter board trawls (OTB) with engines larger than 300 hp (Big). Upper panel displays the comparison between the average in the area and the overall average, during the quarters (2 and 3) in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species Nephrops VPUE is relative high in the area, turbot is also relative high in quarter 2.

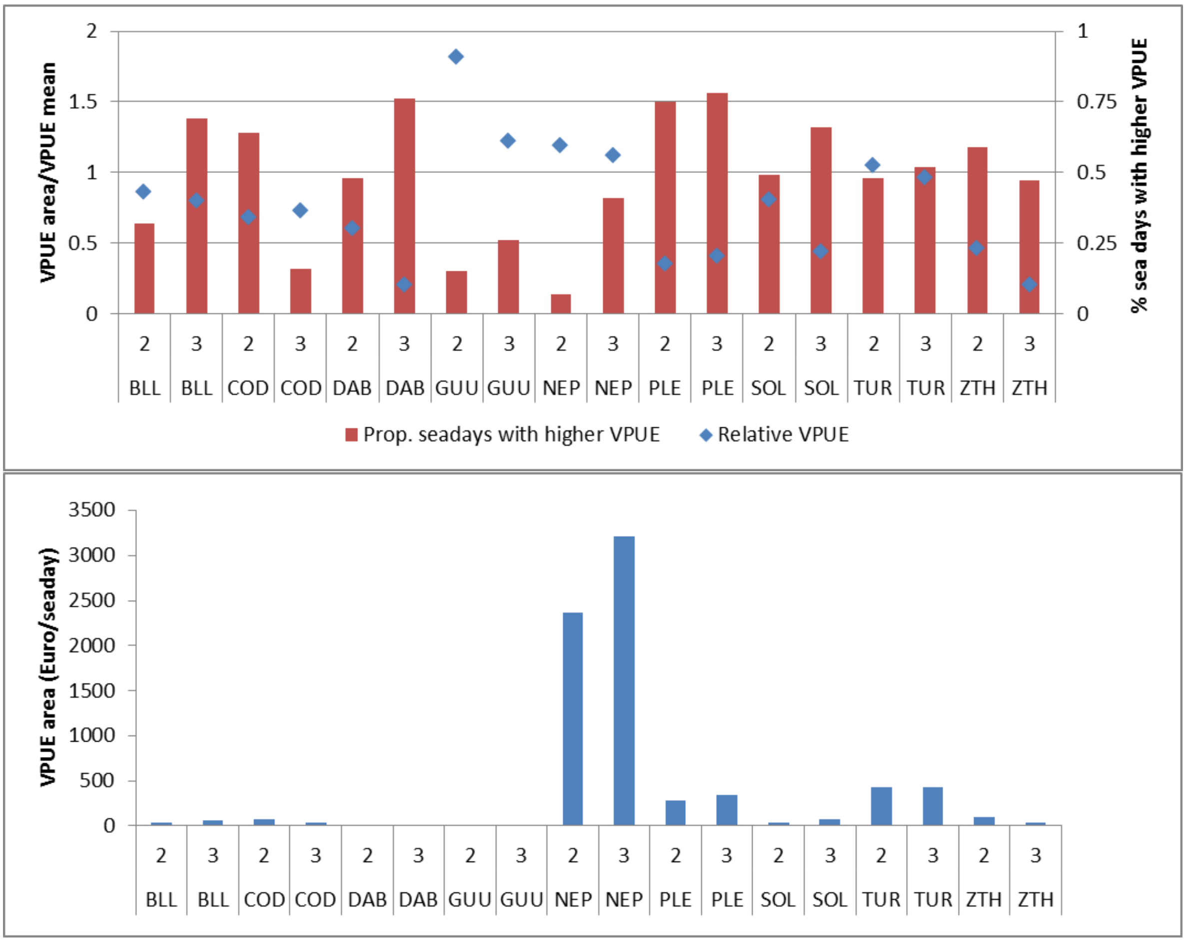


Figure A10.2 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using twin trawls (OTT) with engines larger than 300 hp (Big). Upper panel displays the comparison between the average in the area and the overall average, during the quarter in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species Nephrops VPUE is relative high in the area, turbot is average and plaice relatively low.

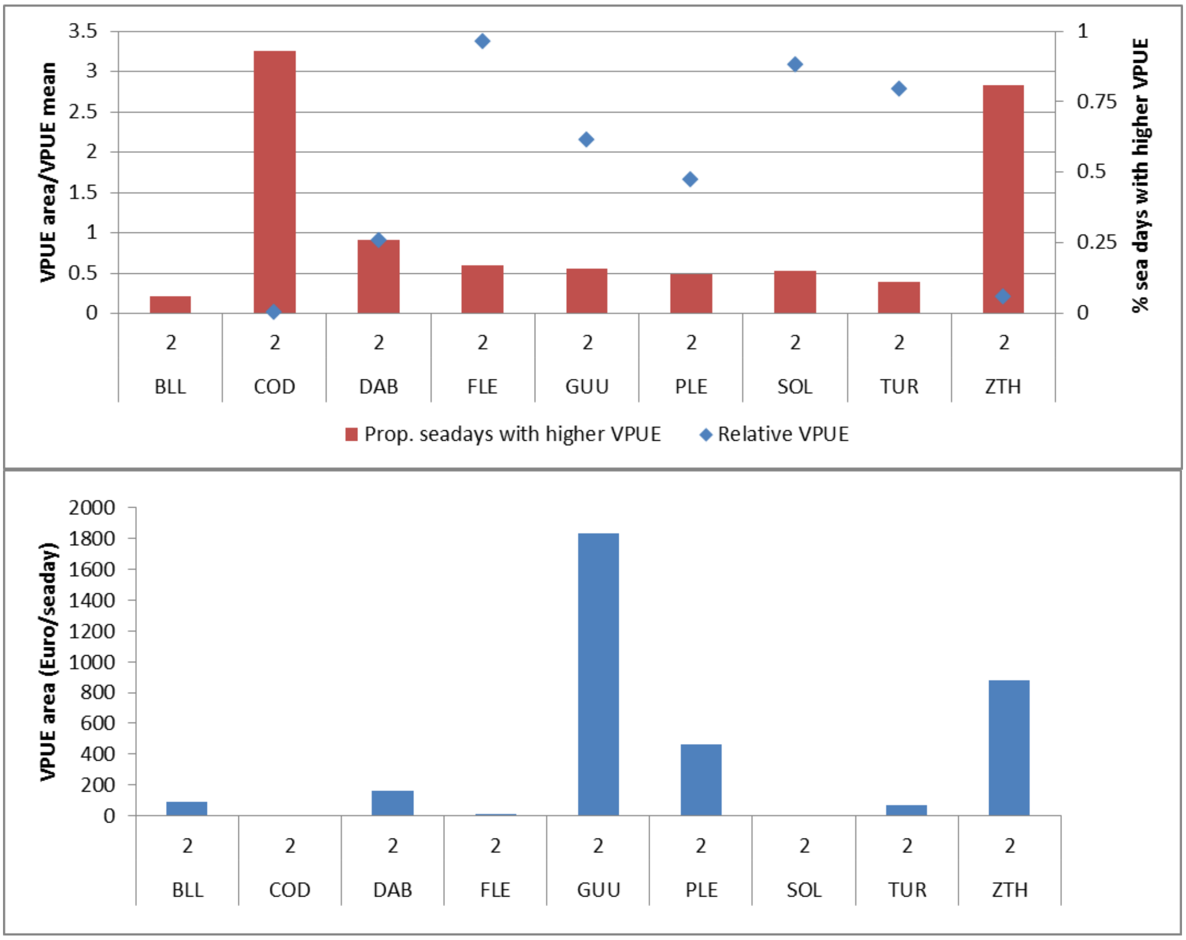


Figure A10.3 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using Scottish seines (SSC) with engines larger than 300 hp (Big). Upper panel displays the comparison between the average in the area and the overall average, during the quarter in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species gurnard VPUE and plaice VPUE are relative high in the area, other species is relatively low.

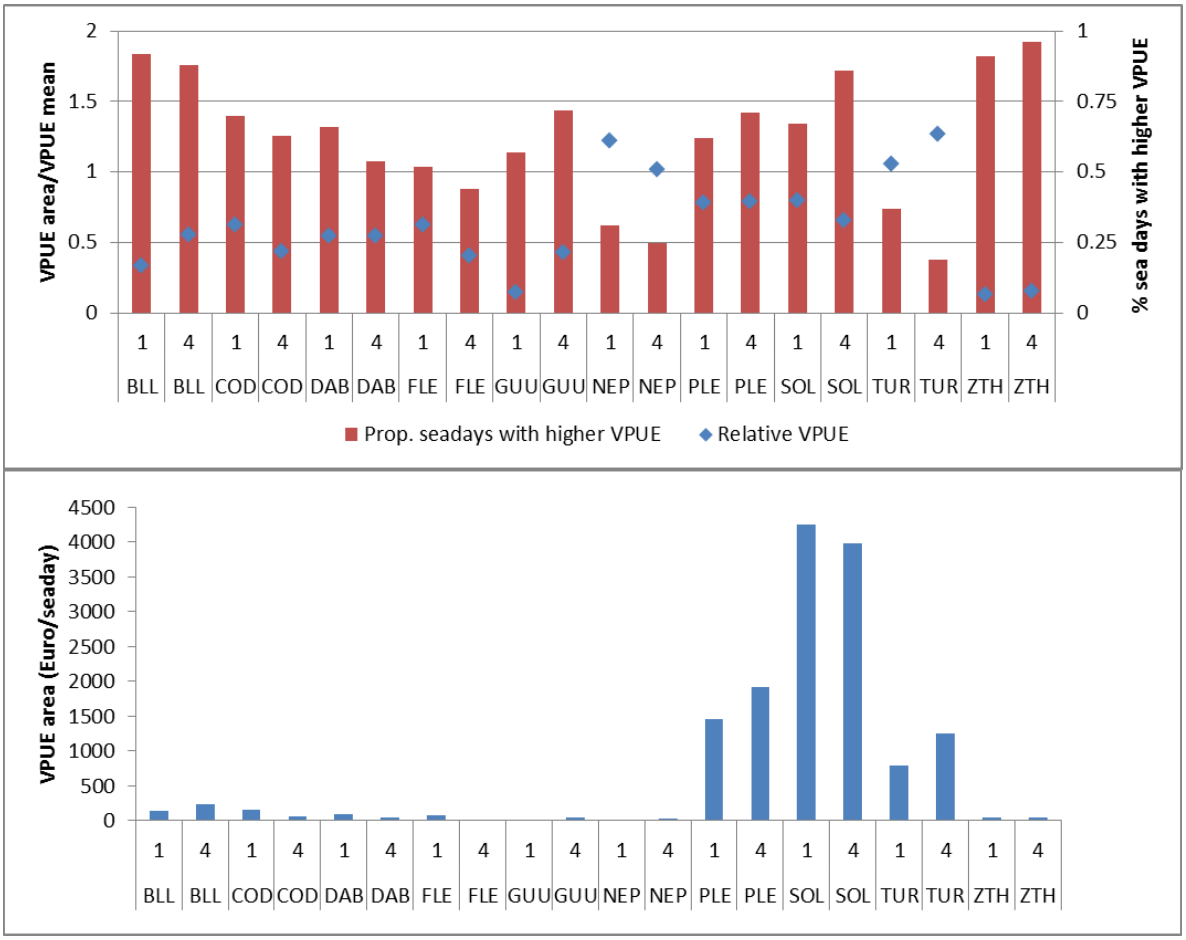


Figure A10.4 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using beam trawls (TBB) with engines larger than 300 hp (Big). Upper panel displays the comparison between the average in the area and the overall average, during the quarter (1 and 4) in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species sole and plaice VPUE are relatively low in the area and turbot VPUE is relative high.

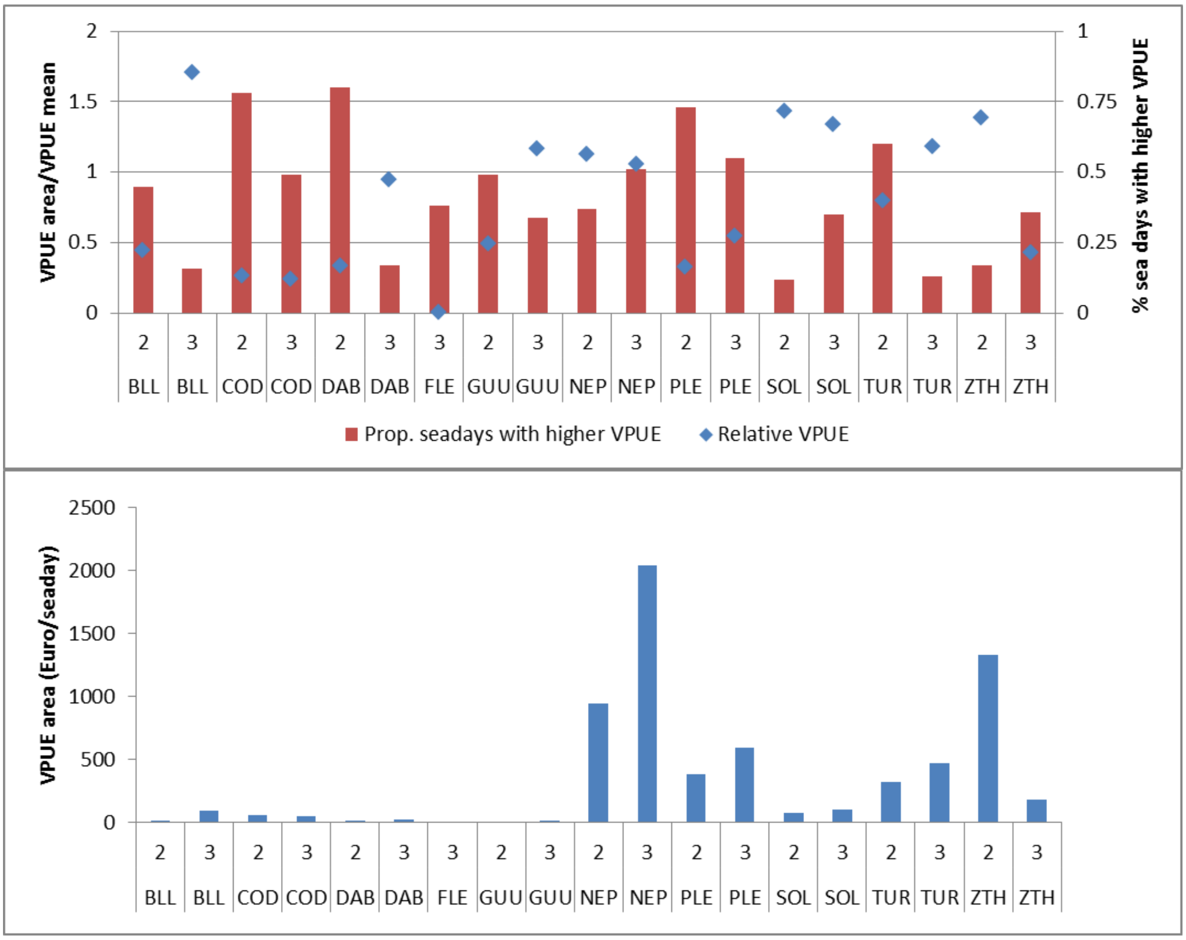


Figure A10.5 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using otter board trawls (OTB) with engines smaller than 300 hp (Euro cutters). Upper panel displays the comparison between the average in the area and the overall average, during the quarter in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: Of the important species nephrops and turbot VPUE are relatively high in the area. Plaice VPUE is relatively low and VPUE of other species is also relatively high in quarter 2 but low in quarter 3.

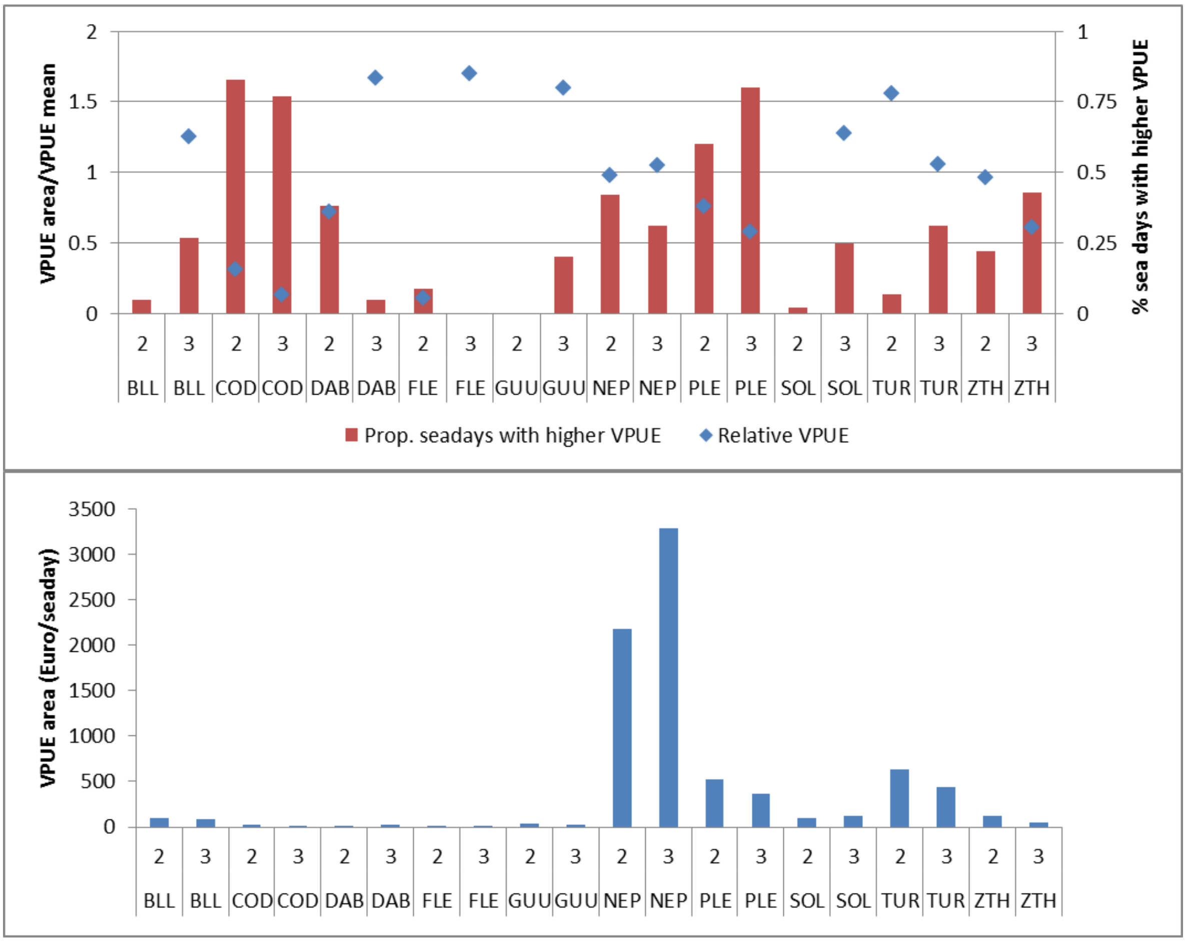


Figure A10.6 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using twin trawls (OTT) with engines smaller than 300 hp (Euro cutters). Upper panel displays the comparison between the average in the area and the overall average, during the quarter in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species Nephrops VPUE is average in the area, and plaice VPUE is relative low. Turbot VPUE is relatively high in quarter 2 and average in quarter 3.

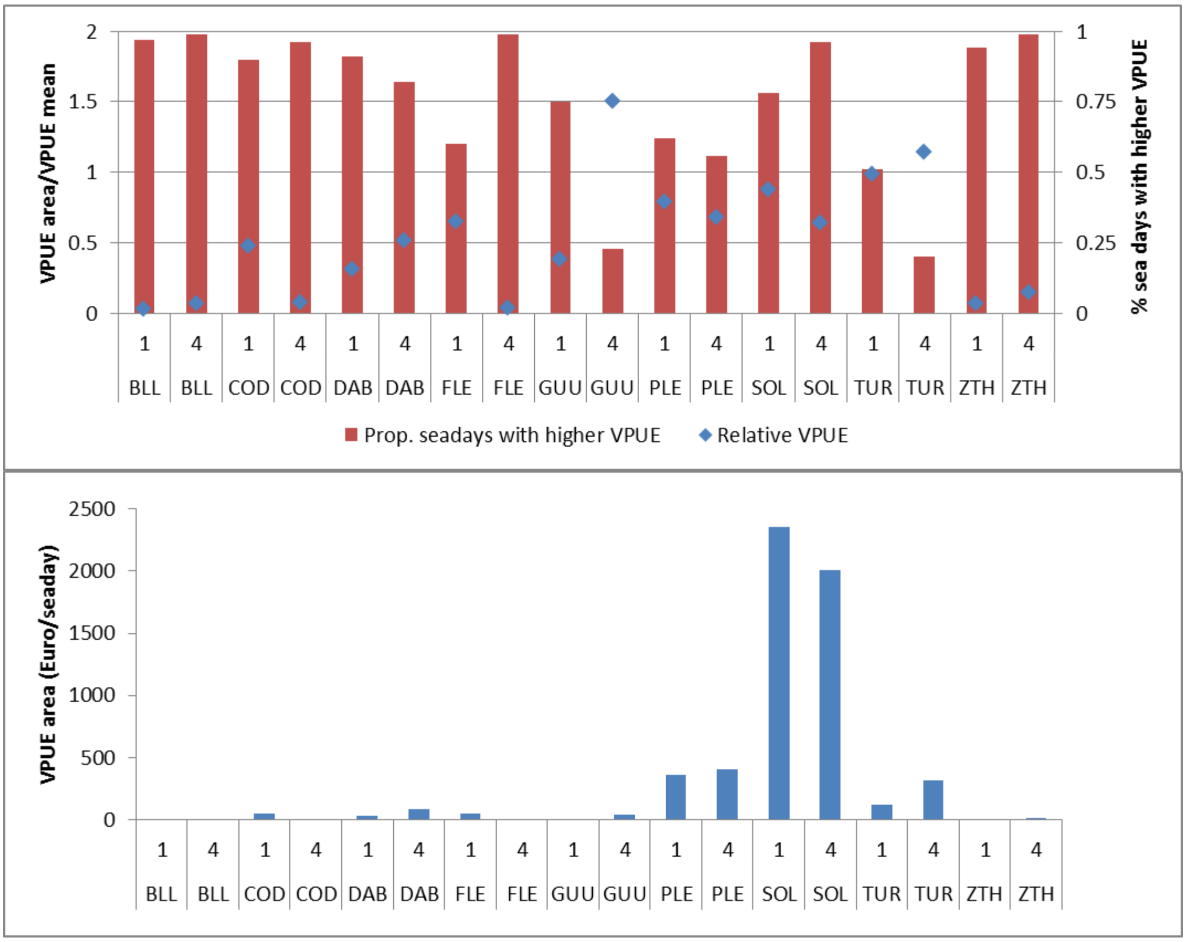


Figure A10.7 *Characterisation of the relative Value per sea day (VPUE) of individual species in the area of the Frisian Front by vessels using Beam trawls (TBB) with engines smaller than 300 hp (Euro cutters). Upper panel displays the comparison between the average in the area and the overall average, during the quarter (1 and 4) in which the landings from the areas are most important (diamonds) and the relative amount of effort in alternative fishing grounds (ICES rectangles) for which the VPUE is higher. Lower panel provides the Average VPUE in the area of the Frisian Front as a means to show the relative importance of the species. FAO species codes are: BLL, brill; COD, cod; DAB, dab; FLE, flounder; GUU, Gurnard; NEP, Nephrops; PLE, plaice; SOL, sole; TUR, turbot, ZTH, Other.*

Conclusion: of the important species sole and plaice VPUE are relatively low in the area and turbot VPUE is average in quarter 1 and relative high in quarter 4.

Effect of crowding

The effect of crowding was estimated as folows:
From Rijnsdorp et al 2000 the conclusion was obtained that decreasing the effort by 75% yields an increase in VPUE of 10%.
If the effect of displacement is assumed to be multiplicative, then the relation between the effort increase the decrease on VPUE = relative effort**-0.0685.
Based on this formula and the total relative effort in the areas from the reference period, the resulting effect on the total revenue of the Dutch fleet can be estimated. This assumes an evenly distribution of the effort from the closures over all other fishing grounds. For Flounder, the effort displaced is 12% lower than the total effort in the area as some of the effort is not shifted because it is used to steam through the area. As the effort increases in the displacement scenario (see Table 6.5) are relatively low (<2%) in comparison to total effort in the areas (Table 5.4), this extra effort has not been taken into account. Assuming costs structure to be constant, the reduction in landings value results in an 7% lower effect on the GVA.
The resultant effect on landings value and GVA was added to the overall effect of landings from the affected vessels.

Table A10.1
Estimation of the effect of crowding based on the results of Rijnsdorp et al 2000 and the relative effort in the areas that will be displaced.

Variant	Effort in the area relative to total effort in the Dutch demersal fleet	Resulting relative effect on total VPUE	Absolute effect on Total Value of landings of Dutch fleet (kEuro/year)	Effect on GVA of Dutch fleet (kEuro/year)	Effect on GVA Dutch fleet (NPV)
Abalone	0.36%	-0.02%	59	55	837
Brill	0.25%	-0.02%	41	38	582
Capelin	0.49%	-0.03%	80	74	1,138
Dab	0.34%	-0.02%	55	52	791
Eel	0.92%	-0.06%	150	139	2,133
Flounder	1.70%	-0.12%	275	256	3,924

Appendix 11 Foundations of the assumptions in Displacement scenario B (partly in Dutch)

Table A11.1

Overview of constants used in estimating the effects of displacement

Dependency level for distinction between dependent and non dependent fishermen	10%
Groep gaat akkoord met 10% als onderscheidingsniveau.	
% fishing through in case of generalists in variant Flounder (not for flyshoot)	50%
Groep vindt 50% een goede aanname en merkt op dat vanwege de ligging zeer veel doorheen wordt gevist op weg naar en van bestekken elders.	
lower landings for specialists in other areas	
year 1	75%
year 2-4	50%
after year 4	40%
lower efficiency for generalists in other areas	25%
Groep acht de getallen zoals door LEI voorgesteld te laag; daarom deze verhoging. *[ingevoegd na reactie LEI] LEI geeft aan de 75% onrealistisch te vinden omdat ze verwacht dat bij meer dan 50% reductie het vissen onrendabel wordt. Dit komt echter wel overeen met het beeld vanuit de sector. Die geeft namelijk aan te verwachten dat voor enkele van de 'specialisten' die er zeer veelvuldig komen, het vissen inderdaad onrendabel gaat worden en dat zij zullen moeten stoppen. De 75% moet dan zo gezien worden dat deze schepen hierin opgenomen zijn: het gemiddelde wordt wat opgetrokken. De schepen welke wel nog kunnen vissen komen ook met een hoog percentage te zitten, maar niet in de verliesgevende cijfers.* *Er is sprake van een leereffect, dus afname van visverlet in periode na sluiting is aannemelijk. Dit is in de getallen behouden. Er zal echter sprake blijven van visverlet omdat de gronden waarheen verplaatst wordt minder gunstig zijn (anders viste men op voorhand op de verkeerde plaats en dat is onaannemelijk) en vanwege de toegenomen druk op deze gronden. Dit is eveneens in de getallen behouden.* *Naast de verwachte verlaging van de vangst tijdens de trek zelf kwam een aanvullend punt ter sprake. Het gebied zal niet alleen effect hebben op trekken uitgevoerd in de tijd die in de uitgangssituatie binnen het te sluiten gebied zou zijn gevist. Een visreis wordt namelijk gepland als serie trekken (visplan) die van elkaar afhankelijk zijn. Er wordt bijvoorbeeld, alvorens naar de visafslag terug te keren op het eind van een week, een serie van vijf trekken doorheen het gebied en de omgeving gepland waarbinnen de verwachte vangst wordt geoptimaliseerd. Een groot gesloten gebied relatief nabij de afslag heeft tot gevolg dat velerlei van dit soort trips geheel anders ingepland zal moeten worden, waarbij ook bij de overige trekken in de serie een lagere vangst mag worden verwacht.* *Eveneens wordt gewezen op het cumulatieve effect van andere gebiedssluitingen, waaronder Natura 2000 en hernieuwbare energieprojecten. Daardoor neemt de druk op de uitwijkgebieden verder toe dan alleen door uitwijk vanuit het voorliggende gebied. Wanneer dit in MKBA's van individuele gebiedssluitingen niet wordt meegerekend, vallen de gevolgen van deze aanvullende druk tussen wal en schip.*	
Factor that will change due to lower efficiency of generalists	
Twin trawl	revenues
Flyshoot	revenues
Pulse trawl	revenues
Beam trawl	revenues
Groep acht de redenering niet reëel dat schepen die met de pulskor vissen zullen compenseren voor de lagere efficiëntie in de uitwijkgebieden door langer door te vissen. De groep verwacht dat schippers en bemanningen dat niet zullen doen omdat ze niet op de schaarse vrije tijd in willen boeten door langer van huis te zijn. Daarom stelt de groep dat voor puls net als voor de andere tuigen de effecten in opbrengst (niet in inspanning) moeten worden uitgedrukt. *Na de bijeenkomst geeft LEI aan de berekening op basis van inspanning te hebben verkozen omdat uitsluitend op vlootniveau wordt gerekend. Dit is één manier van weergave; het is voor de visserijondernemers echter*	

van belang dat eveneens de effecten voor vissers die in dit gebied vissen worden gekwantificeerd. Verder wordt opgemerkt dat voor langoustinevisserij nog een aanvullend effect optreedt. Deze vissers hebben een drietal bestekken waar zij vooral vissen, waarvan de andere twee verder weg liggen. Omdat het kleine scheepjes betreft zijn zij sterk afhankelijk van de weersomstandigheden. Als het slecht weer is of de voorspelling slecht weer aangeeft, dan gaat men niet naar de verder weg gelegen bestekken en is men sterk afhankelijk van de bestekken in het betreffende gebied bij het Friese Front. Dit zou nog ergens tot uitdrukking moeten komen.

Assumed fishing speed for gears fishing through the area in case of Flounder (knots)	
Twin trawl	3
Pulse trawl	4.8
Beam trawl	6
Assumed steaming speed	10
Snelheden worden door de groep als een goede schatting gezien; geen wijzigingen.	
% time lost due to steaming through the area	
Twin trawl	30
Pulse trawl	48
Beam trawl	60

Berekening lijkt correct wanneer puur stoomtijd met vistijd wordt vergeleken. De groep geeft echter aan dat tevens tijd voor handelingen aan de tuigage moet worden meegerekend.
Besproken wordt dat wanneer door het gebied moet worden gestoomd eerst de tuigage moet worden opgeborgen, en na doorvaart weer moet worden uitgepakt. Dat kost bij mooi weer (40% van de dagen) naar schatting 1 uur (opbergen + uitpakken), en bij matig weer (40% van de dagen) naar schatting 1.5 uur. Bij slecht weer (20% van de dagen) kan het voorkomen dat opbergen en uitpakken niet mogelijk is. Er wordt dan zoveel mogelijk met tuig overboord gevaren vanwege de veiligheid: stabiliteit van het schip; zwaaien van loshangende zaken etc. Het is dan te verwachten dat stomen wordt vermeden en er een verlies van zo'n 5 uur gerekend moet worden omdat er om het gebied heen gevaren wordt met tuig overboord.
Bovendien geeft de groep aan dat deze handelingen niet tot de routine behoren tijdens het vissen en dus een risico inhouden. Opgemerkt wordt dat ongelukken bij het vissen over het algemeen tijdens afwijkingen van de routine voorkomen.

Appendix 12 Quantitative assessment of the monitoring costs for the different variants Central Oyster Grounds and Frisian Front

IenM / RWS, November 25, 2015

The design of the monitoring of the Frisian Front (FF) and Central Oyster Grounds (CO) is based on two separate areas (see Annex 5 of Part 2 of the Marine Strategy). The measurement strategy is designed in such a way that on the basis of probability at least 50% change in spatial distribution of indicator species[6] within the area can be observed between two measurement moments (three years in between) with a confidence level of 95%. The design of the measurement strategy does not take into account the imposition of measures (i.e. closing areas).

In 2015, on the basis of this measurement strategy, a baseline monitoring (T0) has taken place on Frisian Front and Central Oyster Grounds as part of the overall baseline for the marine strategy. Subsequently, every three years monitoring will take place. The costs of T0 on Frisian Front and Central Oyster Grounds is budgeted at approximately €130,000, =. In an unmodified implementation of the monitoring program, the monitoring program will cost every three years €130,000,=. The cost of preparing the measurement strategy for the different variants are not distinctive. If the measurement strategy has to be adjusted this can be done with very limited additional non-recurring costs (€5,000 - €10,000, =).

The variants for the measures lead to assumptions other than those made in the measurement strategy for T0: variants have almost all different shapes and sizes and are sometimes (partly) outside the area covered by the T0. That means, that for proper monitoring of each variant the measurement strategy must be adapted to a greater or lesser extent, and possibly the TO has to take place again. This is subject to the following principles:

- The more a variant differs from the defined areas in the Marine Strategy Part 2, the greater the additional T0 is which has to be done again;
- Each area with measures needs to have an equally large area without measures as a reference, with the same EUNIS-3 habitat.
- Monitoring of a large area is more cost effective than monitoring of several small areas with the same surface area. Due to the chosen statistical frameworks, it is not possible to simply add a number of small areas up to a large area. For instance, three small areas probably need more data points than one large area of the same size.

Based on these principles the cost of monitoring of each variant can be estimated.

A comparison of the monitoring costs of the six variants is given below, based upon a cost estimate of the T0 of €130,000. In order to compare the different variants with each other, the costs of the initial T0 has not been taken into account.

6 As defined in Part 2 of the Marine Strategy for Frisian Front and Central Oyster Grounds

Monitoring per variant

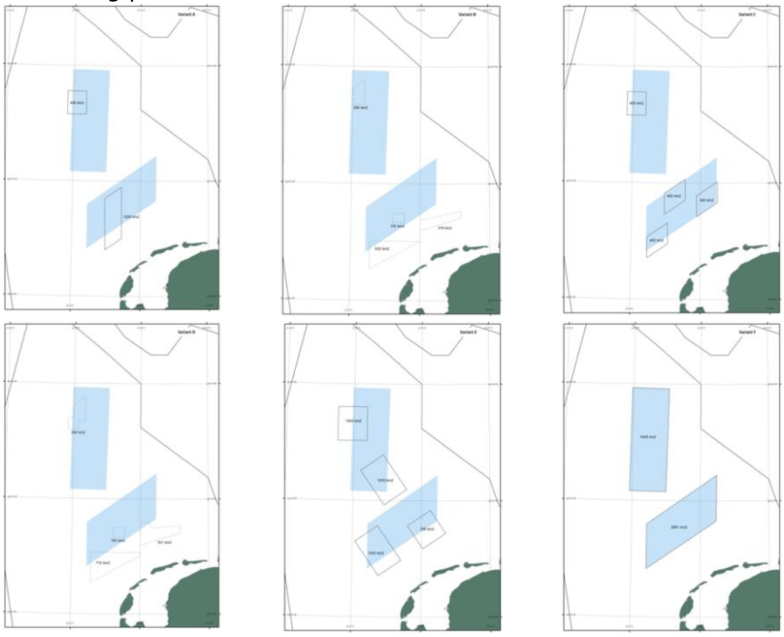


Figure *variants A up to F and in blue the area of the TO (baseline)*

Variant F corresponds with the areas as defined in the Marine Strategy Part 2. The measurement strategy has been prepared to monitor change in the area without taking into account possible measures. Based on this premise a T0 is performed. However, it is also possible that monitoring has to take place in reference areas outside variant F. The costs involved will be determined on the basis of expert opinion. Based on the second criterion, this means in worst case a doubling of the costs.

Variant E corresponds significantly to the areas in the Marine Strategy Part 2; approximately half of the Central Oyster Grounds and the Frisian Fronts has been closed. For the area between CO and FF a measurement strategy has to be set up and a T0 has to be carried out. The regular monitoring costs will be higher than now as the intermediate area must be monitored as well.

Variant C appears to cover with three small areas in the Frisian Front about half of the area. It should be examined whether this coverage is in accordance with the current measurement strategy or that more points should be added. The closed area in the CO is (much) smaller than in the current monitoring plan. For this area the measurement strategy has to be adjusted and a T0 must be performed again.

For CO in variant A the same applies as in Variant C. Also for the FF the measurement strategy has to be adjusted and a T0 has to be performed again. The area is smaller than in the current monitoring plan, and also partly located in a different area.

Variant B and D are most different from the original monitoring plan. This means that the measurement strategy and T0 should be performed again. The areas in Variant B are smaller, which may cost more than Variant D because more measurements points will be needed. However, this cannot be concluded on the basis of these data.

Conclusion estimated monitoring costs

Variant	Estimation of the costs of monitoring (every 3 years)
A	130-200k
B	150-250k
C	130-180k
D	150-250k
E	130-210k
F	130 -250k

Appendix 13 Motivation Weight factor gradients

During sessions with fishermen it has become clear that there are disadvantages related to large closed areas. Large closed areas can be an obstacle for fishermen to arrive to their fishing grounds when they are not allowed to fish while steaming through these closed areas.

There are several ways to design protected/closed areas. The question in this process is whether contiguous areas are important to consider, and as part thereof, whether the aspect of 'gradients' is an essential criterion to distinguish areas regarding effectivity in protection.

Lindeboom *et al*. (2015) reflect on a number of ecological considerations related to this matter in which sub division of areas and effective protection were part of the elaboration. The proposed 'penalty' factor is a practical advise to compensate for these aspects. Weighting factor 3 of the ecopoint calculation, which reflects this penalty, has a generic character, in which the size/perimeter ratio is the steering element. In a further specification of the penalty additional features are included to compensate for ineffectiveness in protection related to total surface to due species mobility. The gradient of the Frisian Front has no role in this weighting factor.

With regard to the Frisian Front, Lindeboom *et al*., (2015) discusses the determining elements for the uniqueness of the Frisian Front. One of the unique aspects is the North-South gradient of sediment types with corresponding ecological characteristics. The question is whether this gradient must be contiguous, or whether it can be disconnected zones, and if there is a preference for one of these based on ecological arguments.

As stated in Lindeboom *et al.* (2015) one of the ways to include the uniqueness and the whole range of niches of the Frisian Front into the ecopoint calculation is to apply a weighting factor that reflects the entire gradient between sand -in the south-, the core area with high silt (15-20%) into the deeper silty areas in the north.

In this viewpoint, it is assumed that the ecological values of the Frisian Front are represented to the maximum (picture A). Studies in which the relationships of each zone on the Frisian Front (in abiotic and biotic terms) are investigated in detail are however lacking. Lindeboom *et al*., 2015 state that the ecological value of the different zones within the gradient on the Frisian Front is more than the sum of its parts. The front and its related area actually covers a wider range of valuable circumstances in which many different species may find their potential niche. The optimum niche for a species is a combination of these factors, and species will associate with the optimum combination of factors in space and time. It depends on the species and its traits how tolerant its population will be and whether it is capable of (long-term) survival within sub-optimal combination of factors.

If one wants to protect areas on the Frisian Front optimally, an area with a continuous gradient is preferred (picture A). If the closed area is split into different parts, the protection will be reduced even if all zones are included (because some are less in surface and not present in each sub-area) (B). Because each zone is characterized by its own benthic community, the border effect will reduce the protection of those zones that lay on the border of the closed area. Subdivision of areas can be compensated for this latter effect by choosing the closed sub areas in such a way that the zones laying at the border are included in both sub –areas (picture C).

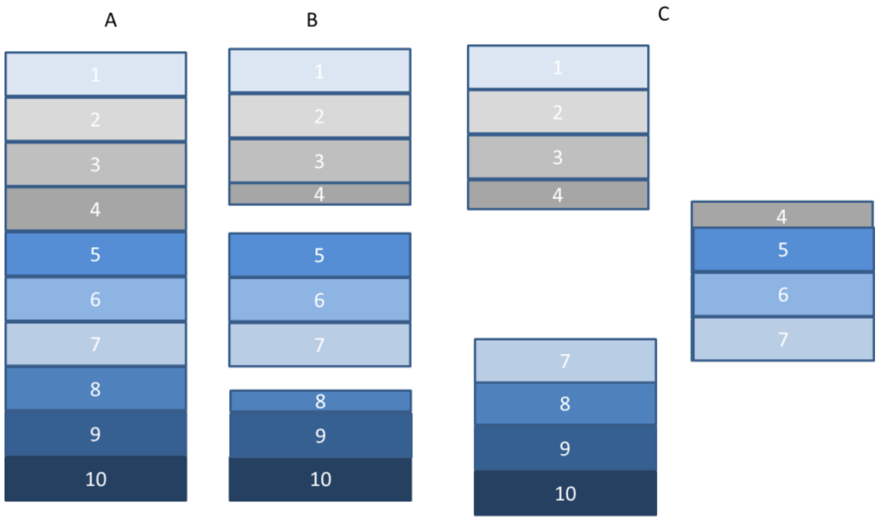


Figure A13.1 *Schematic representation of interpretation of continuous gradients and division into sub-areas. In the text A, B and C are explained*

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