COEXIST

Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries

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Report on economic analysis in coastal fisheries on the basis of revenue for individual profession and fishing trips

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1. Introduction

1.1. General background

For decision makers the knowledge of the outcome of a changed future management regime on the specific sector of interest (e.g. economic wellbeing of industry), society (e.g. number of jobs), or abiotic environment (toxins, minerals) and ecosystem (e.g. number of species, diversity) is crucial for a successful management. However, the exact outcome is difficult, if at all, to determine. But some techniques exist to estimate the outcome of different management scenarios. Models like FISHRENT (see D3.3) give the possibility to test different scenarios against each other and aim at forecasting the overall resulting economic parameters of the fisheries and the status of biological compounds. In contrast, the approach of an individual stress level analyses (ISLA) used here presents a method at a much higher spatial resolution, which allows for comparing fishing effort and revenues depending on management scenarios, thereby estimating the potential impact of spatial closures on the fisheries sector.

1.2. Aims and objectives

Deliverable 3.2 aims at analysing the impact of future (~20 years) spatial management on coastal fisheries, i.e. individual fishermen (vessels) and fishermen's communities. In this approach logbook, landing and vessel monitoring system (VMS) data of commercial fisheries are used in a multiple step method to calculate the "stress level" (SL) of the fishing sector. SL is defined as percentage of effort/landings/revenues of total effort/landings/revenues which will be "lost" in due to a closure of an area for a specific industry. So SL reflects the maximum negative effect on fisheries, since displacement of fishing effort is not considered.
To achieve this task the information on fishing effort per individual trip and landings of individual trips are in a first step combined to allocate landings and with that revenues to a fine spatial grid. In a second step, this earlier effort/landings/revenues of each individual fisherman in an area which is considered to be closed for a specific fishery in the future is compared to the overall effort/landings/revenues of this fisherman at a certain time (reference time span). Then, in a third step, this calculated "individual stress level" (ISL) can be aggregated at different levels: producer organisation, harbour community, segments or fishery with a specific gear used or a total national fleet. This aggregation (e.g. $ISL_{revenues}$ profiles) is often obligatory not only to simplify the results but also to take account of confidentiality issues of individual data. In the present study data from the commercial fishery of the Netherlands and Germany were used to evaluate the management plans for the Dutch, German and Danish waters. Five different management scenarios were tested for the differences in their impact on fishery.

To test the outcome of future management excluding certain fisheries five scenarios (S1 to S5) were investigated (Fig. 1). Please note that these scenarios do not necessarily reflect actual plans or legaly authorized decision but are based on the ongoing political discussion in the countries, e.g. the political process around Nature 2000 regulations and wind farm approval. Please note that no specific management proposals were available on the management in the coastal waters of Germany and in the Danish waters.

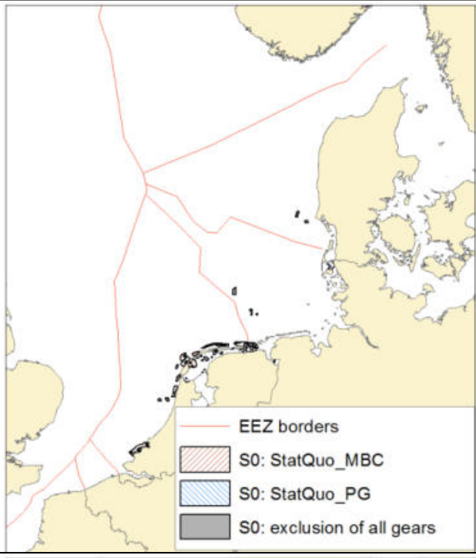
Status Quo

At the moment (2011/12) exclusion in nature conservation areas and existing wind farms or construction sites of Germany, Netherlands and Denmark.

Area (km²):

PG	1945.40
MBC	663.48

From that covered by wind: 189.43 km²



S1: NatCon (Nature Conservation)

Exclusion of fishing activities (MBC, PG) as suggested in one of several alternative proposals for fisheries management in the designated Natura 2000 areas of Germany and the Netherlands. No management in Danish Natura 2000 areas included, as comparative proposals were not available.

Closed areas (km²):

PG	7198.20
MBC	10891.98

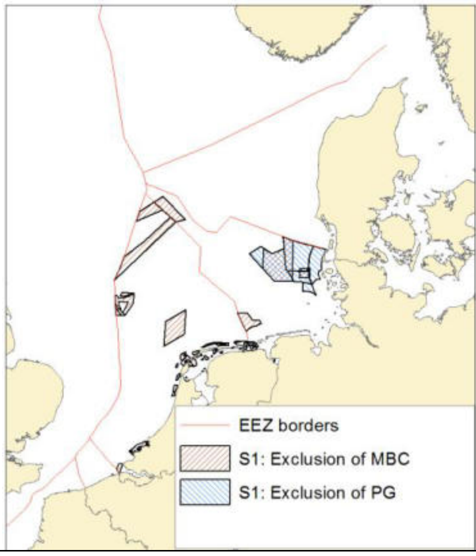
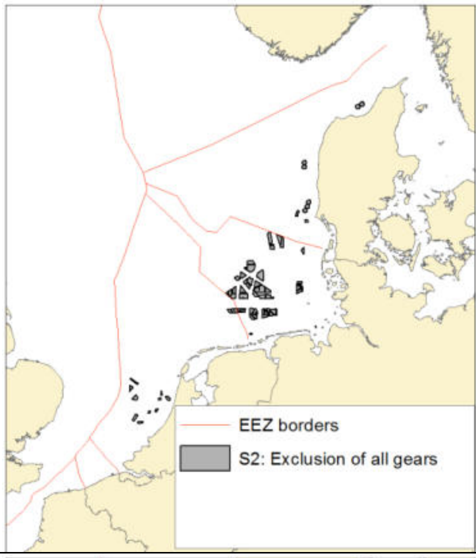


Figure 1: Status quo and five scenarios (S1 – S5) of future fisheries management measures excluding certain fisheries used in the analyses of individual stress levels. MBC: mobile bottom contact gears. PG: passive gears. Striped areas: areas where either MBC or PG are excluded. Please note that in wind farms (S2) all fishing activities are banned.

<table>
<tr>
<td>S2: Wind50 (50% of wind farms)

Exclusion in 50% of currently (status 2012) planned wind farm areas in Germany, the Netherlands and Denmark. For these areas, exclusion of all types of fishing activities is assumed.

Closed areas (km²):
PG 3535.97
MBC 3535.97</td>
<td>
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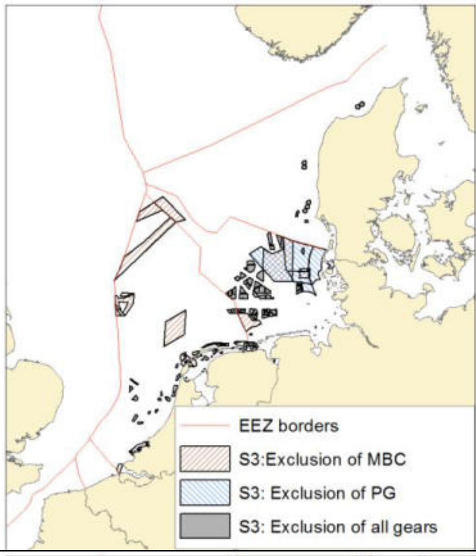
<tr>
<td>S3: NatConWind50

Exclusion of PG and MBG from Nature 2000 areas as well as of all gears from 50% of planned wind farm areas in Germany, Netherlands and Denmark (i.e. S1 + S2).

Closed areas (km²):
PG 10822.97
MBC 14558.25

From that covered by wind farms: 3535.97 km²</td>
<td>
</td>
</tr>
<tr>
<td>S4: NatConWind100

S1 + Exclusion of all gears from 100% of planned wind farms in Germany, Netherlands and Denmark

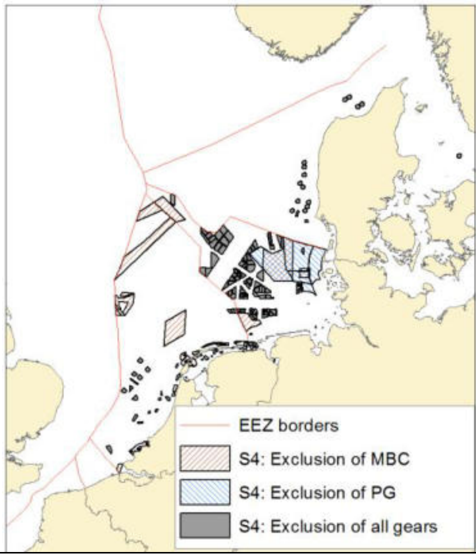
Closed areas (km²):
PG 14018.91
MBC 17736.41
From that covered by wind: 6844.44km²</td>
<td>
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Figure 1 continued.

<table>
<tr>
<td>S5: NatConWind100DK

S4 + Exclusion of MBC and PG from all designated Nature 2000 areas in Denmark (DK)

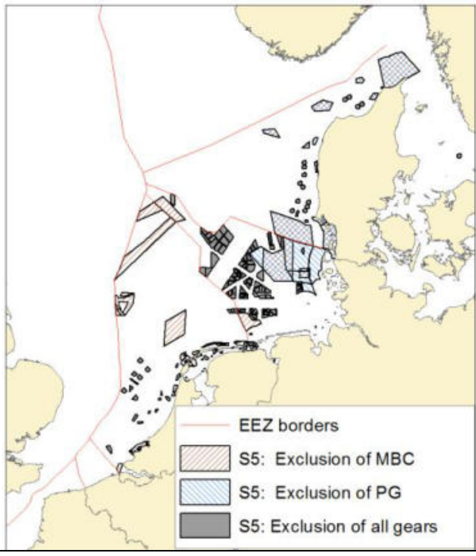
Closed areas (km²):
PG 21919.05
MBC 25660.64
From that covered by wind: 6844.44km²</td>
<td>
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Figure 1 continued.

2. Material and methods

2.1. Data

Data of the year 2010 from the Netherlands and Germany were available for this analysis and used to analyse the scenarios S1 to s5. Information of the logbooks, landings and fisheries vessel register was aggregated to EFLALO2 format (see Hintzen et al 2012). Vessel Monitoring System (VMS) data were formatted according to TACSAT specification (Hintzen et al 2012). In Europe, all fishing vessels over 15m length are required to have VMS, but smaller vessels are exempted, resulting in only a partial coverage of the fleet. VMS provides position and speed of a vessel with a 2 hour interval between the “pings”.

In this study 328 Dutch vessels (covering 56% of the Dutch fleet and about 94% of its revenue) and 243 German vessels operating in the North Sea (covering 19% of the German fleet and about 86% of its revenue) were included. The majority of German vessels are shorter than 15 m, many of them operating in the Baltic Sea. For those vessels no VMS data exist which leads to a low coverage of the German fleet. About 40 vessels longer than 15 m were excluded as they were not operating in the North Sea. However, within the North Sea, the coverage of the German vessels and revenues in present analyses is much higher than 19% and 86%, respectively, since most German vessels operating in the North Sea are longer than 15 m and are tracked by VMS. Therefore, VMS analysis allows for investigating the majority of national landings, effort and revenue in the North Sea.

2.2. Analysis steps & software

In ArcMap 10 (ESRI 2010) c-squares (CSIRO 2012) (about 3 x 1.5 nautical miles; 0.05 degree) overlapping with the scenarios activities were indicated by means of a binary coding (1 for closure, 0 if fishing was possible). Effort was then calculated and results were transformed to maps again using ArcMap.

Most of the existing methods used to handle VMS data and run analysis to link VMS and logbook data have been compiled in an R package (R development team, 2012) called "vmstools" (for documentation see Hintzen et al., 2012 and http://code.google.com/p/vmstools/wiki/Introduction). The analyses conducted in this study used extensively the available tools and methods that have been peer reviewed and published. The steps used to link the datasets EFLALO and TACSAT were:

- Cleaning-up of raw data EFLALO and TACSAT using vmstools guidelines (http://code.google.com/p/vmstools/wiki/Practicals2) to correct for wrong data (e.g. positions on land, high speeds, headings above 360 degrees)
- Identifying trips in both datasets using vessel identifiers and dates with method "mergeEflalo2Tacsat" to combine logbook (e.g. information on gear used, fish caught) and VMS data (geographic position, speed, heading) via vessel identification code and time stamp in both data.
- The method "interpolateTacsat" (Hintzen et al. 2010) was used to interpolate between two VMS recordings (pings, two hour interval) using cubic Hermite splines and to ad 20-min intervals. By that the spatial conflict between spatial closures and fishing was possible on the applied c-square level.
- Identifying the vessel state as "fishing" or "steaming" depending on the speed of the vessel retrieved from VMS data. For each vessel, the method "segmentedTacsatSpeed" (modified in vmstools from Bastardie and others 2010) is used to identify speed boundaries and identify the state of each vessel when sending a VMS ping. With that, the area where a vessel was fishing can be identified. Please note that the use of the speed profile of the vessels works relatively well for active gears but the performances of the method are quite low for passive gears where vessel movements are less strictly correlated to fishing effort.
- Allocating the catch and revenue of the trip to the position of the pings using method "splitAmongPings" and the effort using "effort" function. With that, based on the effort of each trip, the catch of each trip can be allocated to the area which was fished during the trip.

Once effort, catch, and revenue are allocated to the individual pings, data is aggregated at the grid of 0.05 degree c-squares and compared to the area closures. Indicators were calculated at different levels of aggregation. First the "revenue stress levels" were calculated for the national fleets as the percentage of the 2010 revenue in areas that would be closed in the future following the scenarios described in Fig. 1 ("revenue stress level" = max. % of revenues lost if no compensation in other areas occurs; relative to the revenues of the year analysed). Then, individual revenue stress levels ($ISL_{revenues}$) were calculated for every vessel in the analysis using the same method as for the national fleets. ISL were categorised into 11 classes (0%, >0 to 10%, >10 to 20%; ...) used to visualize the stress profile of national fleets and harbour communities.

To investigate whether some fishing activities were more likely to be impacted by closures than others, the main gear used by a vessel within the year (for at least 50% of its effort) was used to classify vessels into fleets (see Tab. 1). Vessels for which no main gear could be identified were classified as "others", OTH. Vessels were assigned to a port depending on where they had the highest number of landing events. The harbour is used to explore the potential impact of area closures on coastal communities.

Table 1: Gear definitions and aggregations used. Numbers of vessels for the Netherlands (NLD) and Germany (GER) in italics.

MBC	**Mobile bottom contact gears**				
		TBB	*NLD: 108* *GER: 7*		Beam trawl targeting mostly flatfish
		TBS	*NLD: 37* *GER:174*		Beam trawl targeting brown shrimp
		DTS	*NLD: 53* *GER:44*		Demersal trawlers and seiners
				OTB	Otter trawls targeting mostly flatfish
				SSC	Fly shooting seines
				SDN	Danish seines
				PTB	Bottom pair trawl
				SB	Beach seines
PG	**Passive gear**		*NLD: 204* *GER:5*		
		GNS			Gill nets
		GTN			Trammel nets
PEL	**Pelagic gears**				
		PTS	*NLD: 37* *GER:6*		Pelagic trawl and seine
OTH	**Other gear**		*NLD: 20* *GER:7*		

3. Results

3.1. Effort distribution

In the effort maps some overlap between the potential closure areas and the fishing activity of the fleets is evident (Fig. 2). Overall, both the Dutch and the German fleets would be impacted by the closing of nature conservation areas more than by the closing of wind farms.

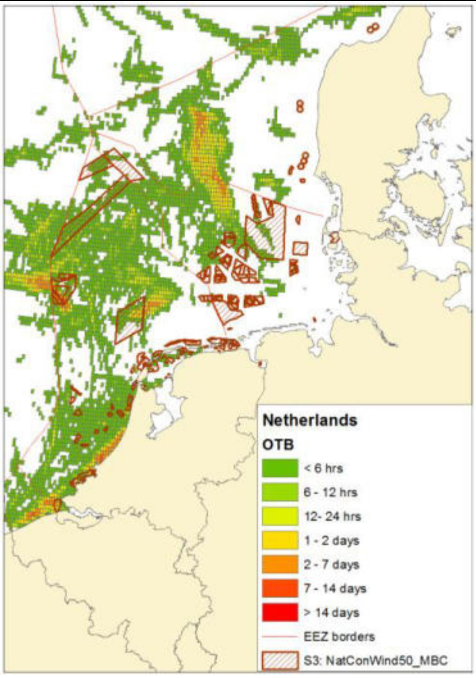
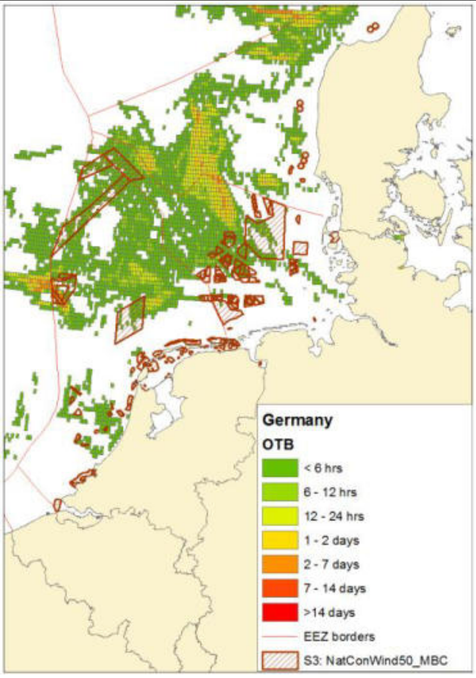
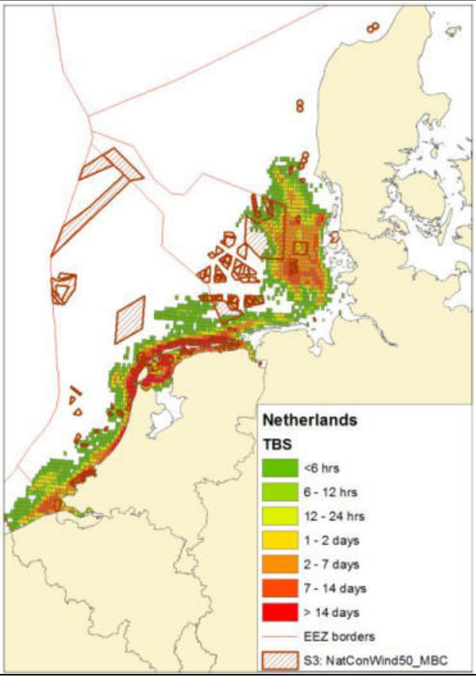
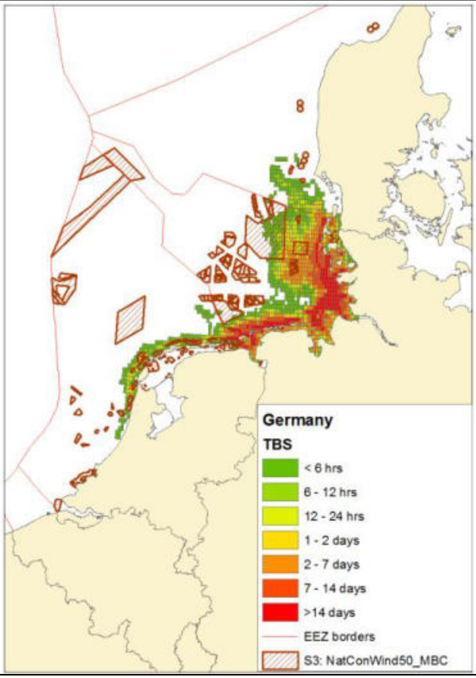
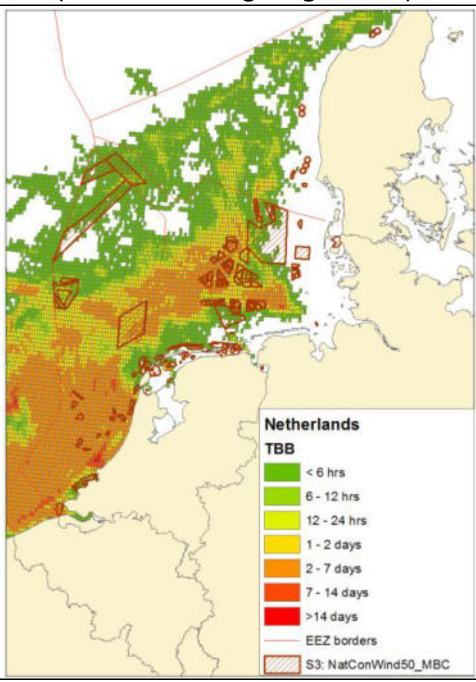
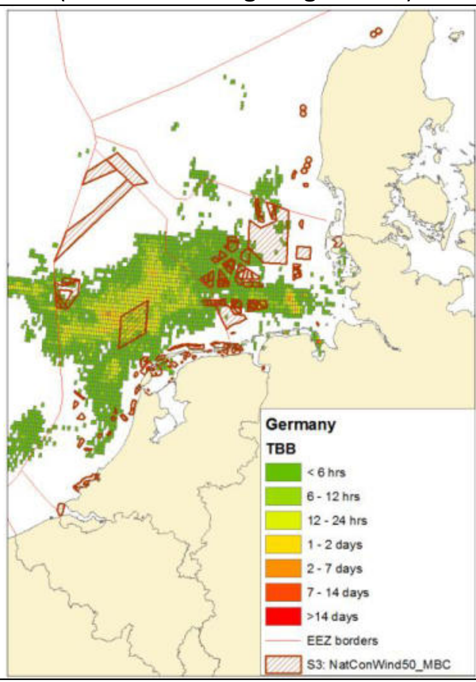
NETHERLANDS	**GERMANY**
OTB (Otter trawls targeting flatfish)	OTB (Otter trawls targeting flatfish.)
	

Figure 2: Effort (time per year per c-square) of main Dutch and German fisheries compared to scenario 3 NatConWind50. Striped areas: areas where mobile bottom contact (MBC) gears are excluded.

<table>
<tr><td>TBS (Beam trawl targeting brown shrimp)</td><td>TBS (Beam trawl targeting brown shrimp)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>NETHERLANDS</td><td>GERMANY</td></tr>
<tr><td>TBB (Beam trawl targeting flatfish)</td><td>TBB (Beam trawl targeting flatfish)</td></tr>
<tr><td>
</td><td>
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</table>

Figure 2 continued.

3.2. Stress levels per country and fishing gear

About 6% of the 2010 revenue of the Dutch fleet and 2% of the German fleet is rendered in potential nature conservation areas compared to 3% and 1% when the 50% of the currently planned wind farms areas are closed (Fig 3).

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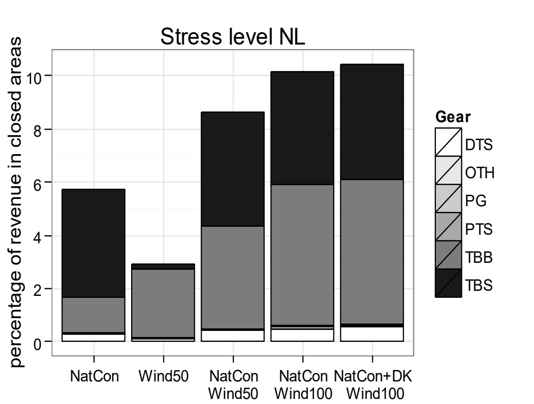
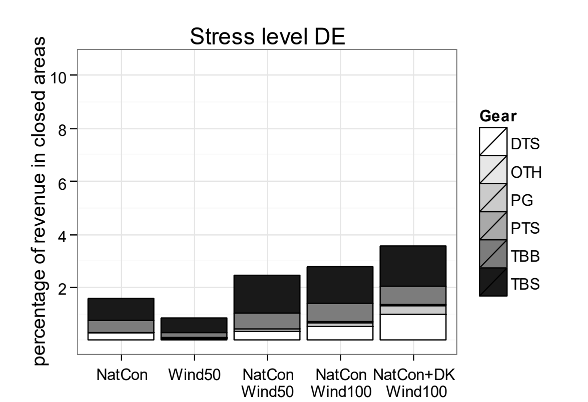
	

Figure 3: Average $SL_{revenue}$ (% loss of revenues if no relocation of fishing effort occurs) for the national fleets for the 5 scenarios. Different gears contribute differently to the national level of stress. DTS: demersal trawl and seine, OTH: other gears, PG: passive gears, PTS: pelagic trawl and seine, TBB: beam trawl targeting mainly flatfish and TBS: beam trawl targeting brown shrimp.

3.3. Stress profiles of national fleets by main gear

In the Dutch fleet different activities (or gears) are affected differently by area closures (Fig. 3). The Dutch shrimpers (TBS) are quite severely affected by the closure of nature conservations areas (S1) as for most shrimpers the stress level is above 20%. In contrast, wind farms (S2) do not affect half of the shrimpers (stress level of 0) and the other half has a stress level below 10% of their revenue since they were more active in areas closer to the coast with less wind farms. The stress levels of flatfish trawlers (TBB) show the opposite, as they are affected by wind farms more than by nature conservation (about twice as much with the 50% wind farms scenario and three times as much with the 100% wind farms scenario).This is according to high efforts off coast where most of the windfarms will be build (see Fig.1 and 2). However, even if a larger proportion of the flatfish trawlers is affected by wind farms than by nature conservation areas, the severity of the stress remains lower than 10% of the 2010 revenue for most of them in case of the 50% wind farms scenario and lower than 20% with the 100% wind farms scenario. Other demersal trawlers (DTS) are affected in the same way as the flatfish trawlers.

In the German fleet about 40% of all vessels will be impacted by the assumed closure of nature conservation areas and about 47% by the closure of 50% of the wind farm areas. If both wind farms and nature conservation areas will be closed, about 55% of the vessels will be affected. The closure of 100% wind farm areas will affect about 57% of vessels. The shrimp fishery commands the majority of the vessels. Therefore, TBS is the most impacted vessel group under that scenario (seeFig.4).

The additional closure of all Danish Nature 2000 areas would not lead to a further increase in ISL for the Dutch fleet (staying at 93% of vessel loosing fishing grounds). In the German fishery about 61% of vessels would be affected. The fleet composition of Dutch harbours lead to a strong gradient of effects of the different scenarios.

NETHERLANDS	GERMANY

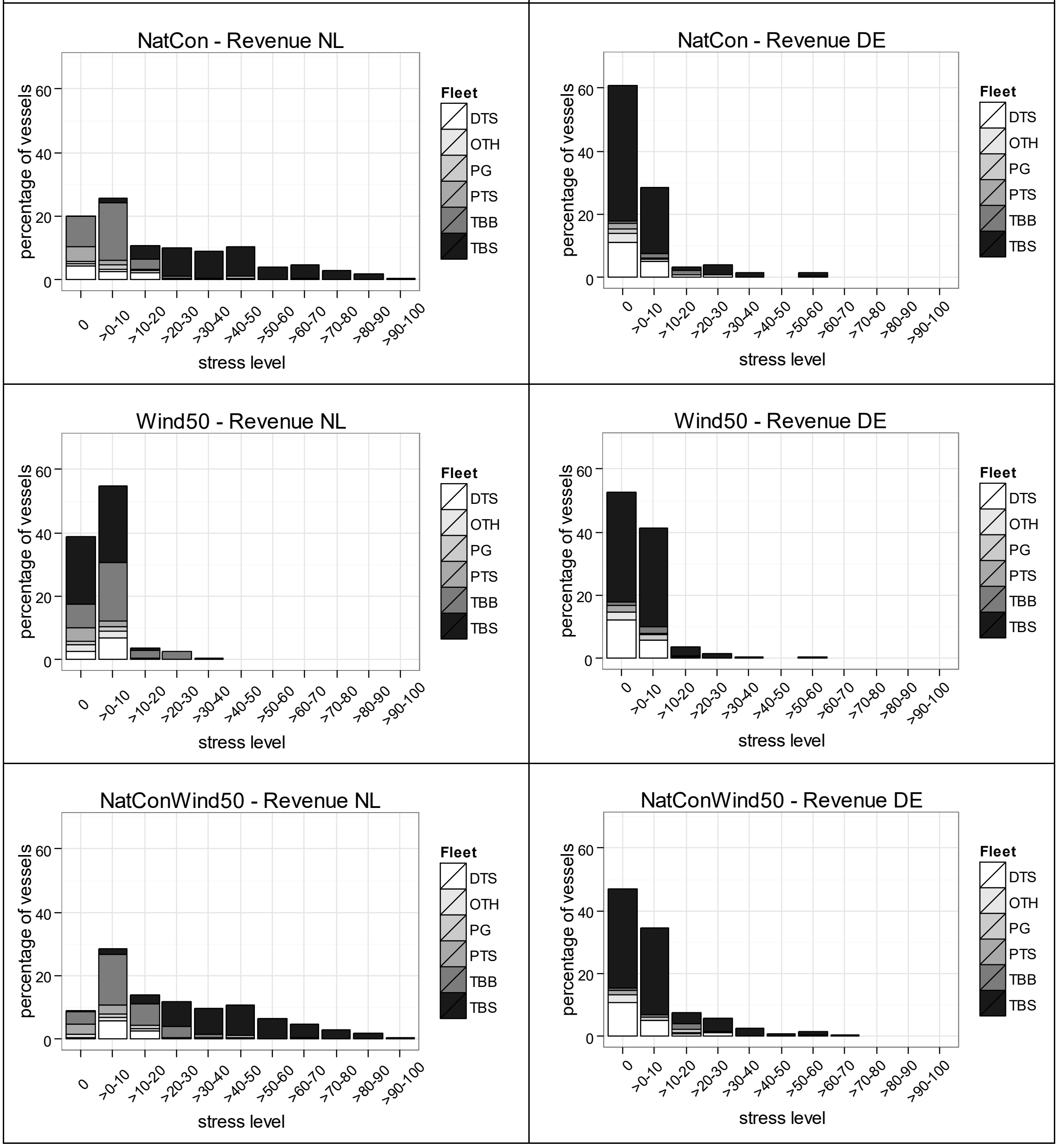
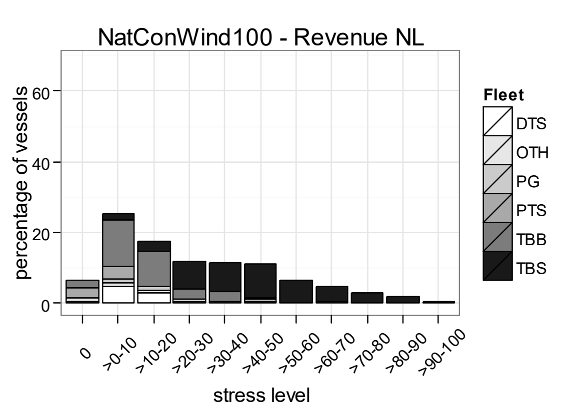
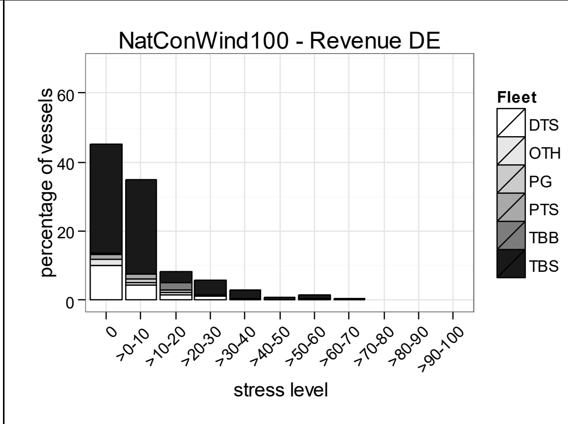


Figure 4: ISL$_{revenues}$ profiles for the Dutch and German national fleets. The vessel percentage is calculated as the percentage of the total national fleet. DTS: demersal trawlers and seiners, OTH: other fleets, PG: passive gears, PTS: pelagic trawlers and seiners, TBB: beam trawlers targeting flatfish and TBS: beam trawlers targeting shrimp.

<table>
<tr><th>NETHERLANDS</th><th>GERMANY</th></tr>
<tr><td>
</td><td>
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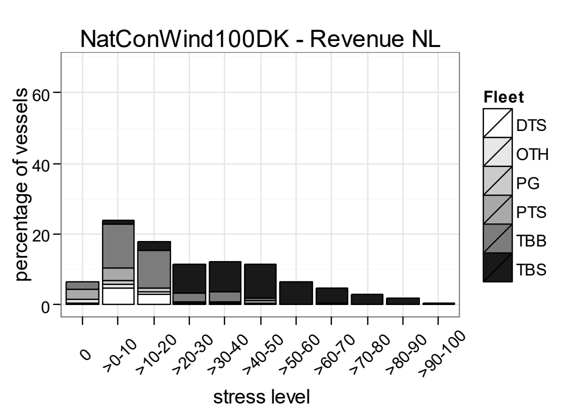
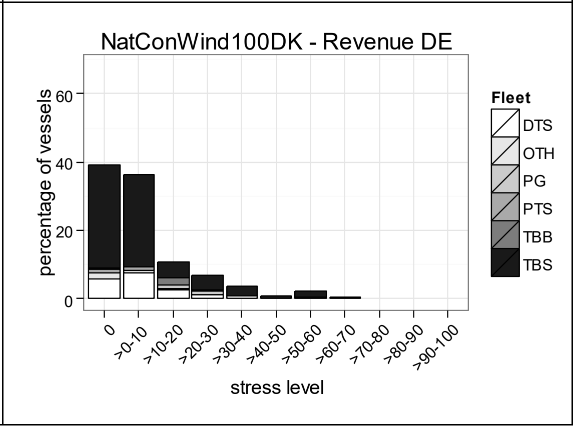
<tr><td>
</td><td>
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Figure 4 continued.

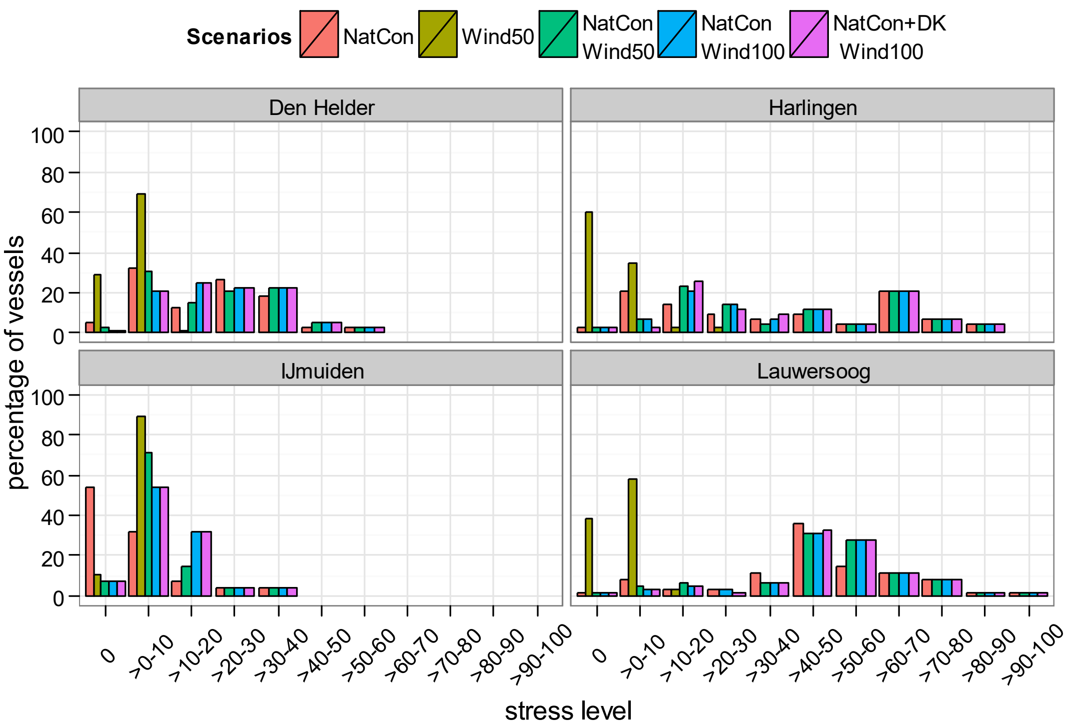
3.4. Stress profiles of harbour communities

Along the Dutch coast from north to south, Lauwersoog, Harlingen, Den Helder and IJmuiden have a different proportion of flatfish trawlers and shrimp trawlers (Fig. 5A & 6). The shrimpers are more present on the Wadden Sea (in the northeast of the Netherlands) where beam trawl used for flatfish is forbidden while flatfish trawlers are dominant in IJmuiden (southern harbour). The stress level for the Dutch fleet increases from south to north for scenarios with closure of nature conservation areas, while wind farms affect the southern harbours (IJmuiden and Den Helder) more.

Most of the German harbours will be affected by the closure of certain areas and the impact cannot simply be concluded from the geographic distance between a harbour and an area that is considered to be closed in the present analysis. For example, the calculated stress levels for Husum and Büsum are rather low in spite of these harbours being in the vicinity of the nature conservation areas (i.e. the Natura 2000 site “Sylt Outer Reef”).

The impact on Greetsiel and Cuxhaven would be the heaviest of the included harbours (Fig. 5B) since their fishermen community had high effort in the areas which were modelled of being closed. Though in Cuxhaven also about 50% of the vessels would be affected, about 20% of the influenced vessels would have a stress above 10%. In Greetsiel even 70% of the vessels would be influenced and 40% of the vessels in Greetsiel would have a stress level higher than 10%.

A)



B)

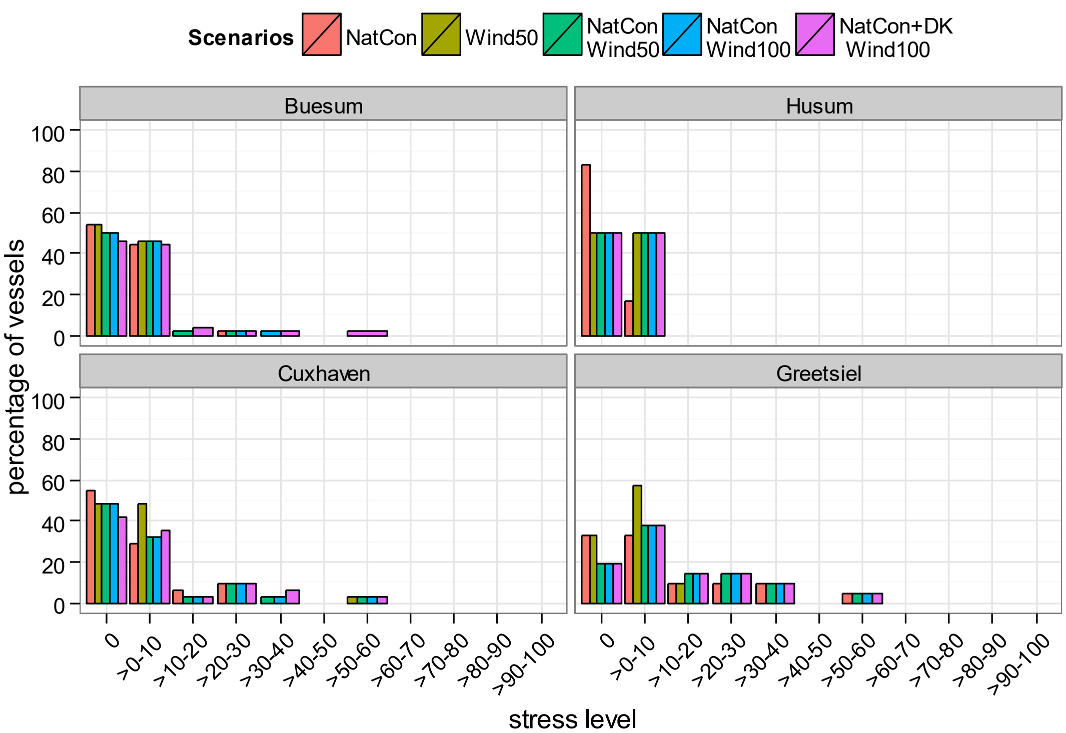


Figure 5: $ISL_{revenues}$ profiles for selected harbours in the Netherlands (A) and Germany (B).

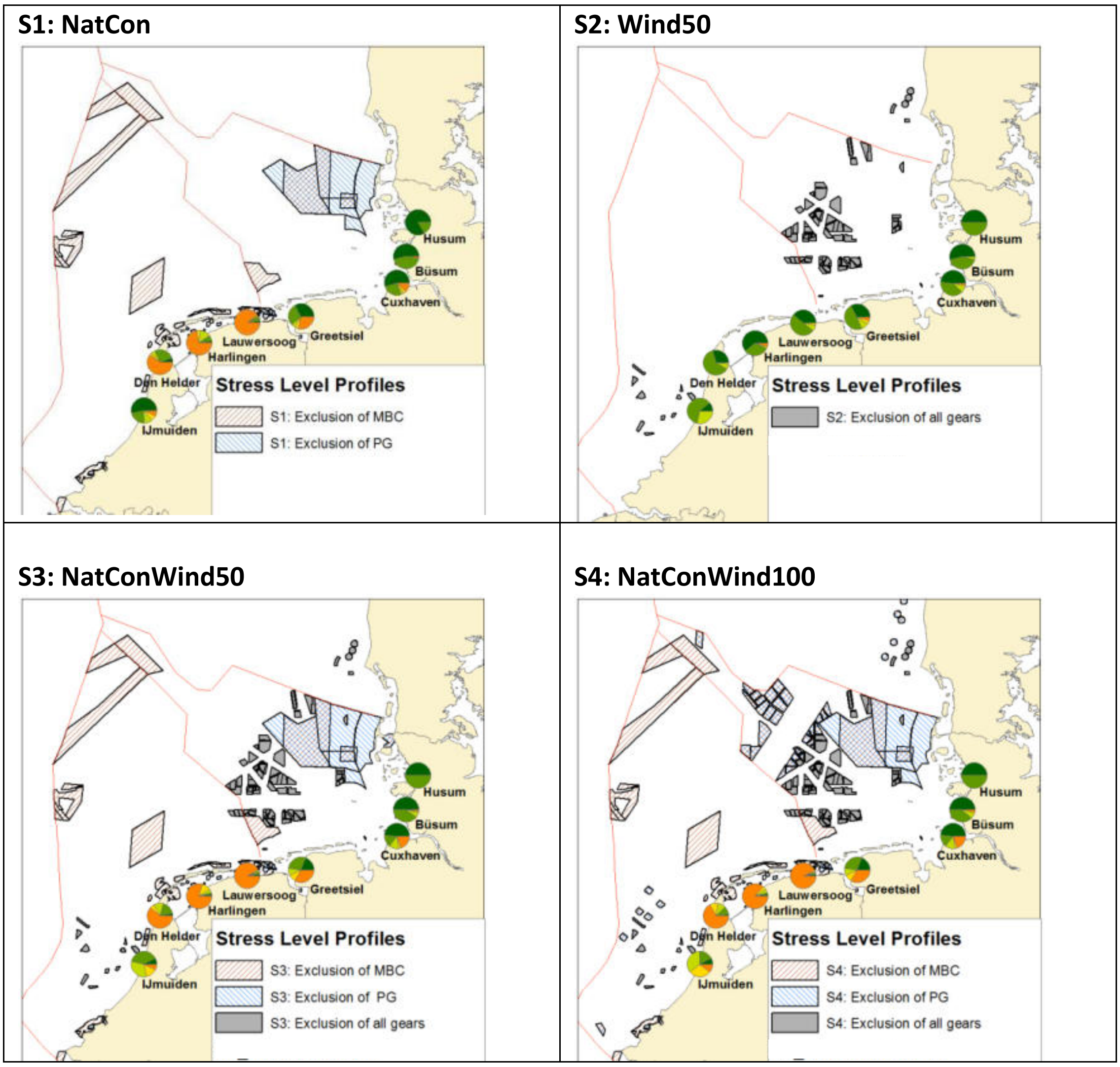


Figure 6: Simplified $ISL_{revenues}$ profiles for selected harbours of the North Sea. Five different scenarios are on display. Harbours displayed (from north to south, clockwise): in Germany Husum, Buesum, Cuxhaven, Greetsiel and in the Netherlands Lauwersoog, Harlingen, Den Helder and IJmuiden.

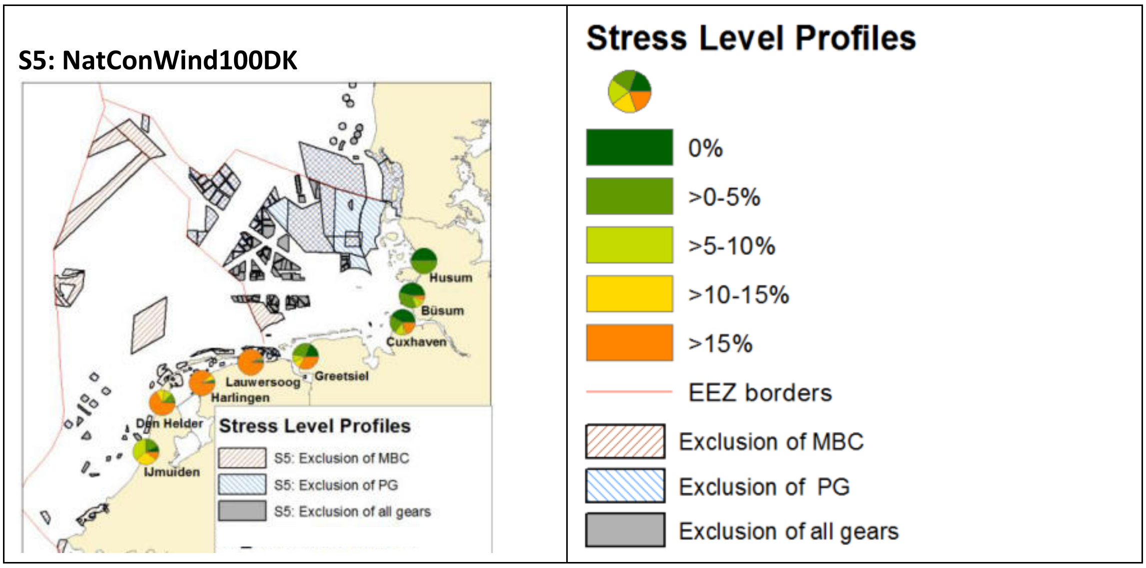


Figure 6 continued.

4. Discussion

The individual stress level analyses (ISLA) revealed that the Dutch and the German fleet will be affected differently by a potential loss of fishing grounds due to wind farms and nature conservation areas. Whereas more than 90% of the Dutch vessel with considered gears will lose at least some fishing ground in the investigated maximum closure scenario (S5), only about 50% of the German vessels will be affected.
The results of the present study suggest that the impact of spatial management on a fishermen community could not be concluded from the geographic distance between a harbour and an area that is considered to be closed. However, this might be due to the fact that the tested Nature 2000 sites in the EEZ are still some miles away from the harbours. This outcome might be different if management would close areas in the German territorial waters, i.e. in very close vicinity to the harbours.
With a coverage of more than 85% in both of the data sets, the major part of the revenues is covered. For the Dutch fleets, area closures will have an effect on the fishing activities and likely lead to the redistribution of effort of shrimp and flatfish trawlers. However, both fleets will not have the same opportunities to reallocate their effort as shrimps are only found in shallow waters and area closure will probably lead to higher competition for space as coastal areas are also used for other activities.
A calculated stress level does not imply that all the earlier revenues of the area are lost in future since it (SL) is defined as percentage of effort/landings/revenues of total effort/landings/revenues which will be "lost" in worst case due to a closure of an area for a specific industry. However, by changing gear or applying innovative lower impact gear (e.g. sum wing, pulse wing) vessels might be allowed in nature conservation areas. Nevertheless, competition for, and increased fishing effort in the remaining areas, will most likely reduce the catch per unit effort and therefore reduce profits for all other gears. Moreover, longer steaming times to circumvent closed areas are likely to increase fuel costs. The described investments and costs to react on the future management are exactly the stress which is

captured by the presented approach. On the other side, increased catches due to the spillover effect of marine protected areas (MPA) may also compensate for the losses and are not covered by the presented approach.

Compared to the bioenergetic model approach (see D.3.3 FISHRENT) the individual stress level analysis (ISLA) cannot account for economic processes and behaviour. However, ISLA enables the analyses of the impact of management on individual companies on a very small spatial scale rather than the analysis of fleet segments and the spatial management according to ICES squares (see D.3.3 FISHRENT).

In conclusion, the stress level calculated in this D3.2 can be used as one element in a set of indicators to estimate the effects of future management on fisheries based on the closure of fishing grounds, but cannot foresee profit or revenue losses of individual fishermen or fishing communities. Subsequently, the stress level calculations can be useful in Marine Spatial Planning exercises.

5. Responsibilities

Deliverable 3.2: Within vTI is responsible for the case study North Sea. vTI and LEI-WUR are in charge of the development of analyses algorithms and provided data from German and Dutch fisheries. LEI-WUR lead the programming in R, vTI provided the spatial analyses and maps using ArcGIS.

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