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Abundance patterns of six fish species in the shallow coastal zone in The Netherlands

Abundance patterns of six fish species in the shallow coastal zone in The Netherlands

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Contents

1. Introduction

Sand nourishment is an essential part of the long term flood defense strategy of the Dutch coast. A distinction can be made between beach nourishments and underwater nourishments. This report concerns underwater nourishments. Nourishments have ecological consequences that differ between species living in the shallow coastal zone (here defined as in between 0.5 and 10 m water depth). In addition, different nourishment strategies, such as mega-nourishments (concentrated nourishment with large volume) or shoreface nourishments (nourishments that create an extra berm at water depths of 5 to 8 m), will have different ecological impacts in space and time and depending on species present. The trade-off of the ecological consequences for the different species for the different nourishment strategies, positive - negative - neutral, is difficult to assess. The objective of the study is to derive abundance patterns based on habitat suitability models for a number of selected fish species that live in the shallow coastal zone. Abundance patterns form the basis for an assessment of the effects of nourishments.

Habitat suitability models

In general, habitat suitability models are a tool that aid understanding of the habitat requirements of species and species groups. Moreover, these models allow for extrapolation in space and time to predict the suitability in other areas or to predict changes in suitability due to environmental changes or management measures. At the core of these models are functions of habitat suitability and (a-)biotic variables (Figure 1), which are combined with spatially explicit input maps of these (a-)biotic variables. With a GIS application (R, PCRaster, ArcGIS, Erdas etc.) the habitat suitability functions combined with input maps yield output maps that provide spatial information on suitability. By comparing results of different input maps on the habitat suitability, the ecological effects of different nourishment strategies can be assessed.

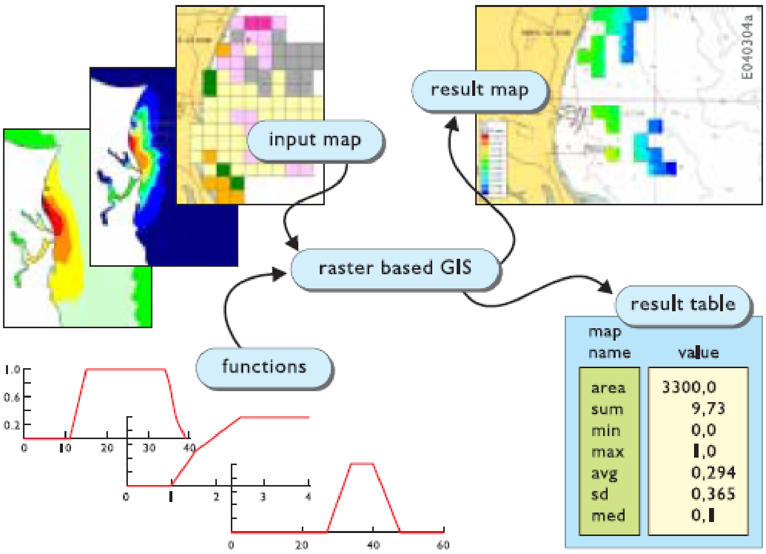

Figure 1. Scheme of a habitat suitability assessment (source: Deltares)

2. Data and Methods

Demersal Fish Survey

A complication for this study is that the ecosystem in the shallow coastal zone is not well studied because it is too shallow to use a ship, and too deep to walk. Hence, knowledge on abiotic and biotic conditions in which species live is scarce. One of the aims of the Building with Nature HK3.8 Smart Nourishments project was to gain knowledge on the habitat use of juvenile fish. Field surveys were conducted (Teal & van Keeken 2011), sampling the shallow area. Unfortunately, these surveys did not result in the aimed habitat suitability knowledge due to sampling difficulties. In Building with Nature EDD2 – Habitat suitability of the shallow coastal zone (Van de Wolfshaar et al. 2012) fish habitat suitability rules were developed based on data from the Demersal Fish Survey. These suitability rules are presented here as alternative to the fish surveys that did not yield the expected result.

The Demersal Fish Survey (DFS) is a survey carried out by IMARES aiming at monitoring young plaice and sole in their nursery grounds in the North Sea coastal zone. The survey is carried out annually in autumn and samples the shallows of 5 metres depth and more. The DFS is primarily used to provide area specific depth stratified abundance indices for juvenile (0- group and 1-group) flatfish to be used in stock assessments. The DFS never was designed for the assessment of habitat suitability. This beam trawl survey aims at demersal species, hence, pelagic species that inhabit the shallow zone are not sampled adequately. A 6 meter beam trawl is used that is rigged with one tickler chain, a bobbin rope, and a fine-meshed net (mesh size is 40 mm and 20 mm in the cod-end). The combination of low fishing speed (2–3 knots) and fine mesh size results in selection of mainly the smaller species and younger year classes (Tulp & Bolle 2009).

Habitat suitability rules

DFS data were used from the period 2006-2011. The data availability of the six most abundant species (plaice (*Pleuronectes platessa*), sole (*Solea solea*), dab (*Limanda limanda*), flounder (*Platichthys flesus*), whiting (*Merlangius merlangus*) and gobies (*Gobiidae* sp.)) was sufficient to create habitat suitability rules for the Dutch coastal zone. Analysis was done using all ages and the density data was log transformed. The variables water depth and region (Figure 2) were taken into account in the final linear regression (LM) models of species density, assuming a normal distribution. Region is included as discrete class.

Other studies based on the Demersal Fish Survey reported 45 to 73 different fish species (Welleman 1999, Bolle et al. 2009), so the majority of species inhabiting the area is not taken into account. Tulp & Bolle (2009) examined long term trends in the abundance of 34 fish species and found that no single or simple set of environmental variables could explain the observed trends. The rules presented here are therefore rather simple and they lack a solid scientific explanation. In addition, they are not validated with an independent dataset. These restrictions limit the use of the information presented, which should be taken into consideration in further use. The results give only an impression of the spatial distribution of the 6 species taken into account.

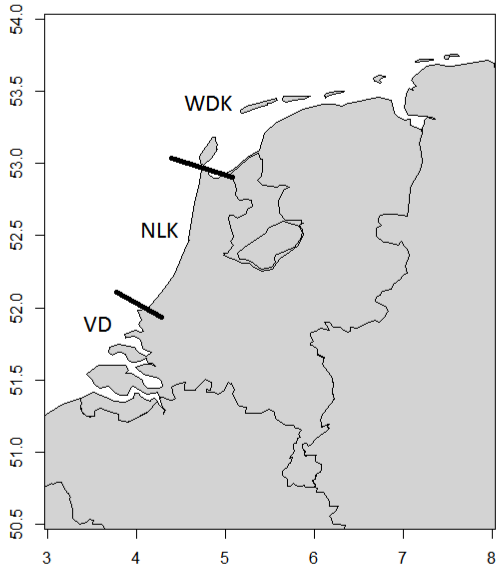

Figure 2. Regions used for the linear regression models. WDK = Wadden coast, NLK = Holland coast, VD = Voordelta.

3. Results

Using linear regression on the explanatory variables water depth (depth) and region (either WDK or VD) the explained R^2-variance ranged from 0.026 to 0.111 (Table 1).

Table 1. Models and explained variance of species density. ': 'denotes a bilinear interaction.

Species	**Model**	R^2
Plaice	WDK + VD + depth + WDK:depth + VD:depth	0.059
Sole	WDK + VD	0.063
Dab	WDK +VD + depth + WDK:depth + VD:depth	0.111
Flounder	WDK + VD + depth	0.070
Whiting	WDK + VD	0.026
Gobies	WDK +VD + depth + WDK:depth + VD:depth	0.065

The models for each species differ slightly, and only the one with the highest R^2 was used to obtain the results (Table 2).

Table 2. Linear regression models per species. ':' denotes a bilinear interaction, *** p<0.001, ** p<0.01 and * p<0.05.

Species		**estimate**	**Se**	**t value**	**Pr(>|t|)**
Plaice	(Intercept)	1.725971	0.125005	13.807	<2e-16 ***
	region Wadden coast	0.260509	0.16867	1.544	0.1234
	region Voordelta	-0.55931	0.237004	-2.36	0.0189 *
	water depth	0.007158	0.00908	0.788	0.4311
	region Wadden coast:water depth	-0.02588	0.012049	-2.148	0.0325 *
	region Voordelta:water depth	0.027348	0.019383	1.411	0.1592
Sole	(Intercept)	0.73049	0.05587	13.075	< 2e-16 ***
	region Wadden coast	-0.30603	0.07709	-3.97	8.81e-05 ***
	region Voordelta	0.04215	0.08912	0.473	0.637
Dab	(Intercept)	0.922098	0.159479	5.782	1.71e-08 ***
	region Wadden coast	0.541754	0.215186	2.518	0.01229 *
	region Voordelta	0.091372	0.302366	0.302	0.7627
	water depth	0.062084	0.011584	5.359	1.57e-07 ***
	region Wadden coast:water depth	-0.04333	0.015372	-2.819	0.00511 **
	region Voordelta:water depth	0.003222	0.024728	0.13	0.89641
Flounder	(Intercept)	0.367173	0.043873	8.369	1.64e-15 ***
	region Wadden coast	-0.08677	0.035733	-2.428	0.0157 *
	region Voordelta	-0.0831	0.041481	-2.003	0.0460 *
	water depth	-0.01201	0.002825	-4.25	2.78e-05 ***
Whiting	(Intercept)	0.94739	0.06241	15.179	< 2e-16 ***
	region Wadden coast	0.25434	0.08612	2.954	0.00337 **
	region Voordelta	0.16293	0.09956	1.637	0.10266
Goby	(Intercept)	2.92109	0.20605	14.176	<2e-16 ***
	region Wadden coast	-0.64107	0.27803	-2.306	0.0217 *

Species		estimate	Se	t value	Pr(>|t|)
	region Voordelta	0.44528	0.39067	1.14	0.2552
	water depth	-0.0382	0.01497	-2.552	0.0112 *
	region Wadden coast:water depth	0.02917	0.01986	1.469	0.1428
	region Voordelta:water depth	-0.04876	0.03195	-1.526	0.1279

A map of water depth provided by Deltares was used as input for the habitat suitability models and limited to a habitat suitability map of the shallow coastal zone, i.e. water depths no more than 10 metres.

The spatially explicit results show that species have regional preferences (Figure 3). Plaice and dab are most common in the Wadden Coast area, while sole and gobies inhabit mainly the Voordelta coast. Gobies have the highest densities, especially in the more brackish waters in the Voordelta coast. Whiting densities are lowest in the Holland coast, whereas flounder has highest densities in this region. Flounder generally has the lowest densities. These results corroborate with general expectations (Beek et al. 1989, Tulp et al. 2008).

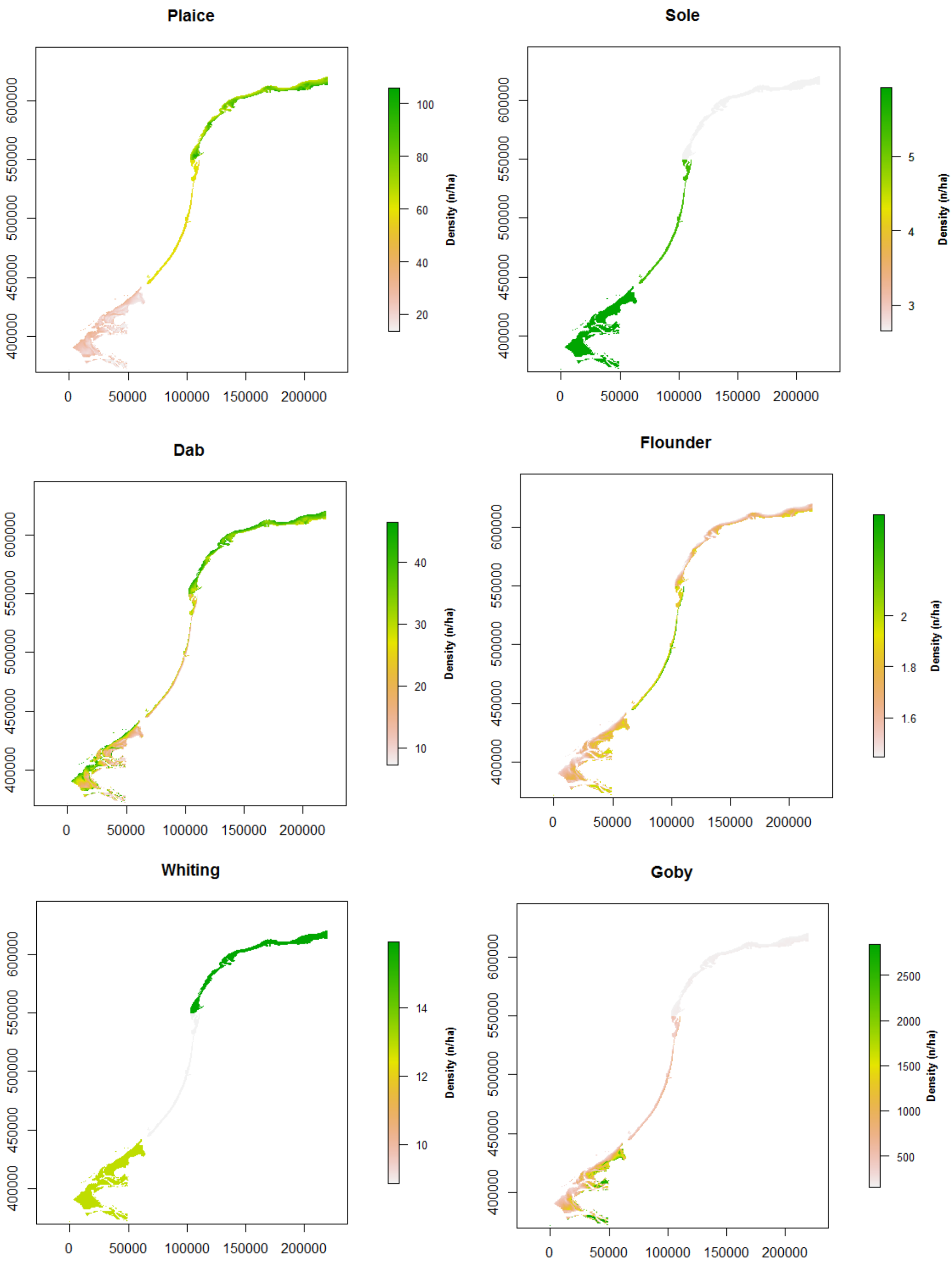

Figure 3. Estimated fish densities (n/ha) for the Dutch North Sea coastal zone down to 10 m water depth.

4. Discussion

Habitat suitability models have a number of limitations. Studies on habitat suitability of benthic organisms show that habitat suitability relationships differ on small local scales, thus their generic application is limited. This is even more the case for mobile species such as fish and sea mammals. Habitat suitability models are static, which means that time-varying processes such as colonisation time or population dynamics are not accounted for. Moreover, behavioural or biotic interactions with other species are not considered. For example, at a certain location the abiotic conditions may be highly suitable, but with a predator or competitor present, or a lack of prey species, the predicted numbers or biomasses by the model are unlikely to be achieved. Furthermore, the abiotic conditions that are measurable or thought to be of importance are included in suitability models, possibly overlooking important conditions. Hence, care must be taken when using suitability models in a forecasting context.

For this study Demersal Fish Survey data were used, a survey not designed for deriving habitat suitability rules. The rules that have been derived were not validated, which should be done if they are to be used in further studies. The explained variance was low, providing little confidence in its predictive power. This is likely due to the DFS study design aiming for stock assessment and the lack of variables measured in the field during the survey. Variables such as sediment grain size, turbidity, temperature or salinity could, when measured and available, improve the model. Regions were used as explanatory variable in the models, and improved the explanatory power. However, the transition from one region to the other, i.e. the transition from one model fit to the other, is very clearly visible in the abrupt changes in density. This highlights the coarseness of the model used. As the DFS does not sample areas with depths less than 5 metres the reliability of the prediction in these very shallow areas is low.

The results presented here give only an impression of the spatial distribution of the 6 species taken into account. The main conclusion is that the species are differently distributed along the coast, but that all of the coast is occupied. Only 6 species were taken into account here, while the DFS registered 45-73 species (depending on the time period and area covered). The Dutch coastal zone is a species rich area and any impact on the region will affect one species or the other. Other metrics such as species diversity could aid decision making on the spatial and temporal planning of sand nourishments.

5. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

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Date: 29 August 2012

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Date: 29 August 2012

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