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CHAPTER 6 - ADDENDUM APPLICATION OF THE WESTERSCHELDE RESPONSE MODELS TO FISH AND MACRO-CRUSTACEAN DATA FROM THE OOSTERSCHELDE

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Abstract. The aim of this study is to test the applicability of the statistical models, which were developed to predict fish and macro-crustacean responses to the environmental conditions in the Westerschelde estuary (Chapter 6). For this, a data set from the Oosterschelde was used. The probability of occurrence and the prediction of abundance of several dermersal fish and macro-crustaceans in reponse to four environmental variables (salinity, temperature, dissolved oxygen concentration and turbidity) are investigated. The present study can only be seen as a preliminary attempt to validate the robustness of the models that were established for another system. The diagnostics (% correctly predicted, sensitivity and specificity) for the 15 presence/absence models based on the Oosterschelde data were comparable to the diagnostics based on the Westerschelde data. Only the models that explained >45 % of the variance in density for six species in the Westerschelde, were applied to the density data from the Oosterschelde. These were largely successful when temperature was the main forcing variable (e.g. for Sprattus sprattus and Pomatoschistus microps). The constant high salinity in the Oosterschelde is a favorable condition for Carcinus maenas and Liocarcinus holsatus, partially masking the effect of the other environmental variables in these models. Limanda limanda and Pomatoschistus minutus have different seasonal distribution patterns in both systems. In the Westerschelde both species only occurred during a relatively short period, while in the Oosterschelde they were present throughout the year. This shows the difficulty of applying statistical models from a real estuary to a different type of ecosystem, namely a marine bay like the Oosterschelde.

6.1 Introduction

Changes in the environment can affect the distribution of several organisms (*e.g* Kröncke 1990, Pihl & van der Veer 1992). For example, alteration of the Oosterschelde estuary (NL) into a marine bay, lead to an increase in the biomass of flatfish and gadoids, but shrimp biomass was found to have decreased shortly after the engineering works were completed (Chapter 3). On the other hand, ten years after the closure of the former Grevelingen estuary (NL), the density and biomass of O-group plaice were reduced with more than 50 % (Doornbos 1982). Next to the fact that postlarvae could hardly enter the Grevelingen system anymore, this reduction was probably related to the continuous oligo-mesotrophic conditions in the saline lake.

Estuarine environments are important nurseries for juvenile fish and macro-crustaceans (see Elliott & Hemingway 2002). To be able to manage these systems from an ecological point of view, it is necessary to understand the relationship between the biota and the environment. The demersal fish and macro-crustacean assemblages in shallow estuaries and coastal areas are mainly structured by salinity, temperature and exposure/habitat type (*e.g.* Chapter 2-Add.2). It may be desirable to be able to predict the responses of fish and macro-crustaceans to (changes in) these environmental variables, in order to predict the effects of human interventions.

Up till now a number of studies developed predictive models for different taxonomic groups in single systems (*e.g.* Attrill *et al.* 1999, Ysebaert *et al.* 2002), but none of these tried (or were able) to validate their models with data from other ecosystems. However, validation of the robustness of statistical models is a prerequisite for them to be useful.

In a previous study, predictive models of the occurrence and density for a number of demersal fish and macro-crustaceans in response to a limited set of environmental variables in the Westerschelde estuary were established (Chapter 6). In the present study a first attempt is made to externally validate these response surfaces with data from the adjacent Oosterschelde marine bay.
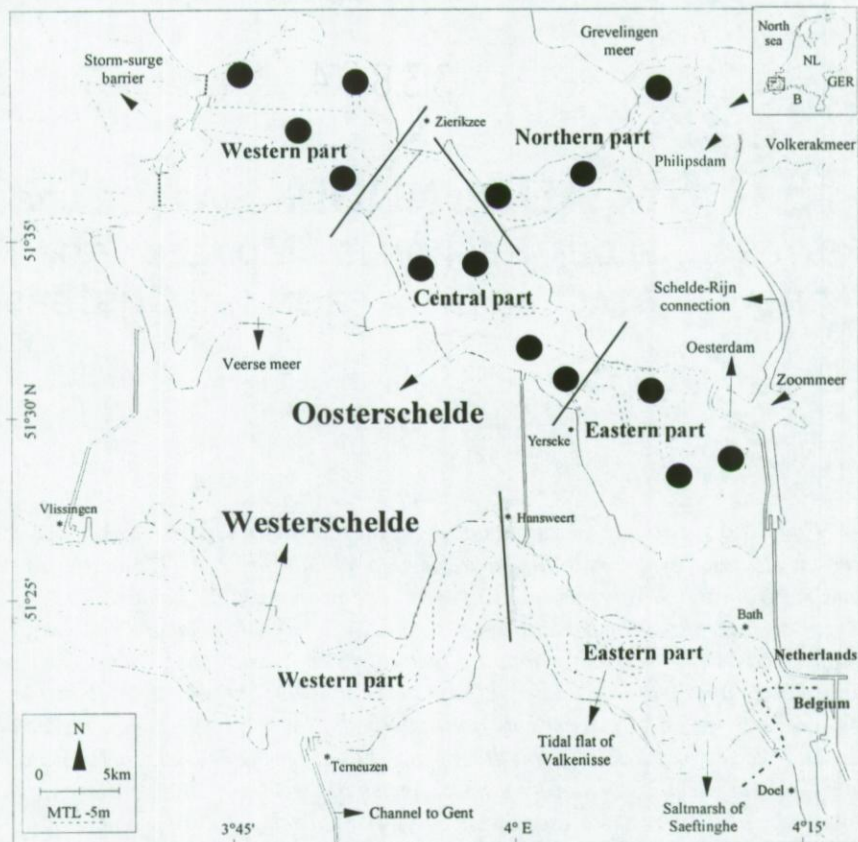
Fig. 6.6 Map of the Oosterschelde and Westerschelde with indication of the 14 stations sampled in the Oosterschelde

6.2 Material and methods

The Oosterschelde is located north of the Westerschelde estuary and is connected with it indirectly through sluices and canals (Fig. 6.6). Through major engineering works in the period 1960-'87, the Oosterschelde was altered from a true estuary into a marine bay. As a consequence, the major estuarine gradients in salinity, turbidity and oxygen concentration have disappeared. Details on the geomorphology, hydrodynamics and ecology are given in Nienhuis & Smaal (1994a).

Only for a limited part of the large Oosterschelde data set on demersal fish and macro-invertebrates, the environmental variables were recorded simultaneously (see Chapter 1). Data were taken from 8 surveys conducted at 14 subtidal stations in the Oosterschelde (Fig. 6.6). The demersal fish and macro-invertebrate fauna was sampled with a 3-m beam trawl on a quarterly basis between September 1999 and May 2001. A total of 112 sampling points could be used. See Chapter 4 and Chapter 5 for details on the sampling and data processing.

Based on a large data set from the Westerschelde, presence/absence and density models for 12 fish and 3 macro-crustacean species were developed (Chapter 6). For a description of the methodology,

the selection of the species, and the model diagnostics and parameters, the reader is referred to that paper. The environmental variables used were salinity (psu), temperature (°C), dissolved oxygen concentration (mg l^{-1}) and turbidity (as the reciprocal of secchi depth, m^{-1}). See Chapter 5 and Chavatte (2001), for the patterns in these environmental variables.

The final model equations (based on multiple logistic regressions), which predict the occurrence of fish and macro-crustaceans in the Westerschelde, were applied to the Oosterschelde data. The predictive success, sensitivity (% presence predicted as being present) and specificity (% absent predicted as being absent) were calculated.

Also, the final multiple (lognormal) regressions, which predict the abundance of the fish and macro-crustaceans in the Westerschelde, were externally validated with the same data from the Oosterschelde. Only the models that explained >45 % of the variance in the Westerschelde (6 models, *Platichthys flesus* was excluded as this species is almost absent from the Oosterschelde), were used. For these models it was shown that the combined interaction between the four environmental variables was the main forcing factor behind the temporal and spatial distribution of the seven species, rather than the proper appearance of suitable food resources (Chapter 6). The predicted values were graphically compared with the real density data, but not statistically tested.

Table 6.5 Validation of the 15 final presence/absence models, established for the Westerschelde, with the Oosterschelde data: predictive success (% correct), specificity (% absent predicted as absent) and sensitivity (% present predicted as present)

Species	Oosterschelde		
	%corr	%AasA	%PasP
Clupea harengus	69	80	28
Sprattus sprattus	76	82	63
Merlangius merlangus	42	49	32
Trisopterus luscus	66	70	61
Syngnathus rostellatus	49	64	17
Pomatoschistus microps	72	80	55
Pomatoschistus minutus	86	11	92
Pomatoschistus lozanoi	66	76	41
Pleuronectes platessa	83	29	91
Limanda limanda	76	46	85
Platichthys flesus	55	72	28
Solea solea	74	79	67
Liocarcinus holsatus	69	58	76
Carcinus maenas	88	-	92
Crangon crangon	96	-	98

6.3 Results

The coefficients for the different presence/absence and density models are given in Chapter 6.

The final logistic models from the Westerschelde were able to predict the presence of the most common species in the Oosterschelde (Table 6.5). For 9 out of 15 species >70 % of the occurrences were correctly predicted. Only the prediction for *Merlangius merlangus* and *Syngnathus rostellatus* failed in >50 %. Sensitivity was <40 % for four species, with the least successful prediction of presences for *S. rostellatus* and *Platichthys flesus*. Specificity was relatively high, although the absence of six spe-

cies could not be predicted very well. For *Pomatoschistus minutus* and *Pleuronectes platessa* <30 % of the absences were predicted to be absent, and for the most common macro-crustaceans *Crangon crangon* and *Carcinus maenas* in the Oosterschelde the prediction of absence failed.

The prediction of the density for six species in the Oosterschelde based on the final density models from the Westerschelde was less successful. The models were able to predict the major pattern for *Sprattus sprattus* and *Pomatoschistus microps*, and to a lesser extent for *Liocarcinus holsatus* and *Carcinus maenas* (Fig. 6.7). For *Limanda limanda* the autumn and winter densities could be predicted fairly well (at least the major patterns), but the model failed to predict spring and summer densities. The opposite holds for the density model for *Pomatoschistus minutus*, where autumn and winter densities were not predicted very well.

6.4 Discussion

Fish and macro-crustaceans belong to the higher trophic levels and are present in a variety of trophic chains. They can be indicators of the changes occurring in other components of the ecosystem such as plankton and benthos (Marchand *et al.* 2002). As fish and macro-crustaceans (like crabs and shrimps) may be commercially exploited, the general public may be more attentive to information about these components. As such, they can be important indicator species and it may be interesting to know how species respond to changes in the environment, and if these responses can be predicted.

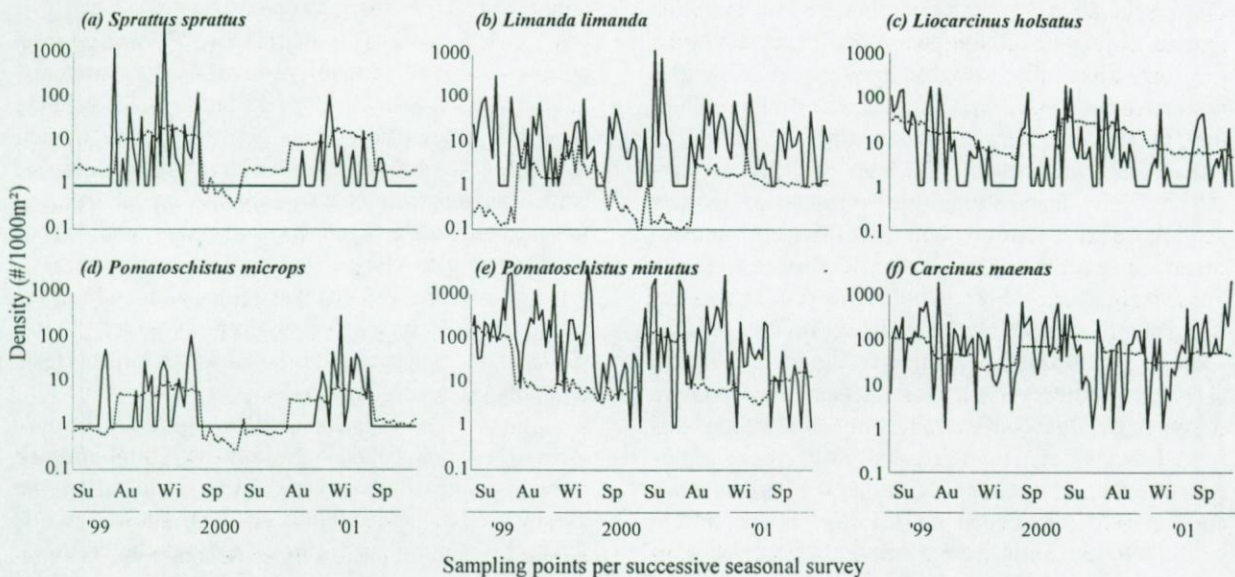Statistical models are best validated with data from other ecosystems. For the fish and macro-

Fig. 6.7 Predicted (broken line) versus actual (solid line) density values in the Oosterschelde, based on the final density models from the Westerschelde for 4 fish species (a-b, d-e) and 2 crustacean species (c, f). Sampling points were ordered from west to east (12 stations) for 8 successive seasons from summer 1999 to spring 2001

crustaceans large data sets exist for both the Wester-schelde and the Oosterschelde, sampled in a uniform way (see Chapter 1). Although, the Oosterschelde is an estuary *s.l.* according to Day *et al.* (1989), it is hardly recognized as such according to the definition *s.s.* given by Pritchard (1967). Important estuarine gradients (salinity, oxygen, turbidity) in the Ooster-schelde have disappeared (Nienhuis & Smaal 1994b). However, as for now, this is the best external data set from an adjacent system available. Another problem is the fact that only for a limited part of the Ooster-schelde data set, environmental variables were simul-taneously measured. Furtheron, almost no data exist on sediment characteristics from the sampling points. A discussion on the importance of food, prey-availability and predation as structuring factors, and the reasons why these factors were not included in the models, were given in Chapter 6.

Salinity, temperature, oxygen and turbidity are important structuring factors in the fish assem-blage (Chapter 2-Add.2). Still, it was shown that most species have a broad tolerance towards changes in the environment, as they are able to thrive under typical estuarine conditions (Chapter 6). However, the average density of macro-crustaceans was at least twice as high in the Westerschelde as in the Ooster-schelde, and the average density of all fish species together was highest in the brackish reaches of the Westerschelde (Chapter 2-Add.2). On the other hand, there is a clear seasonal pattern with a succession of species and life-stages, clearly correlated with changes in the four environmental variables that were used in the models (Hostens *et al.* 1996, Chapter 4, Chapter 5).

Salinity has long been regarded as the most important structuring factor for estuarine biota that show strong seasonal patterns (Attrill *et al.* 1999). As the Oosterschelde was altered into a marine bay, a number of species (*e.g. Syngnathus rostellatus, Platichthys flesus*) are not common (anymore) in this system (Chapter 4). On the other hand, estuarine resident species like *Crangon crangon* and *Carcinus maenas* are present in the Oosterschelde throughout the year (Chapter 5). This makes it not very useful to model the responses of these species in the Ooster-schelde. The least-fitting presence/absence models were those where salinity and turbidity were the main factors in explaining the response surfaces for the Westerschelde or where temperature played an infe-rior role (*e.g. Merlangius merlangus, Liocarcinus holsatus, Pleuronectes platessa*). Although, typical estuarine gradients in the Oosterschelde environment disappeared, seasonal changes in temperature, dis-solved oxygen concentration and turbity were appar-ent (Chapter 5). It is concluded that the logistic mod-els that were developed for the Westerschelde, are capable of predicting the (temporal) occurrence of several demersal fish and macro-crustaceans in the adjacent Oosterschelde.

The study from the Westerschelde already showed that it is rather difficult to predict abundance of demersal fish and macro-crustaceans. Only for species governed mainly by a combined interaction between the four environmental variables, the models were acceptable. The density models established for eight species from the Westerschelde, which were not used here, had a low explanatory value for the Westerschelde data themselves (see Chapter 6 for a discussion). This makes them less suitable to apply to data from other systems. The models presented by Attrill *et al.* (1999) for *Crangon crangon* and *Car-cinus maenas* from the Thames estuary (UK), in-cluded an instrumental binary variable (indicating presence/absence per month) to capture seasonality. However, by constraining the models with 12 binary variables a huge amount of the variation was elimi-nated, which increased the R^2 values but not neces-sarily made the models fit better to the real data.

Application of the Westerschelde density models to the Oosterschelde ecosystem was only partly successful. The relative success for the crab species (*Carcinus maenas* and *Liocarcinus holsatus*) could be attributed to the fact that the Oosterschelde complied with the higher salinity preference of these species. The seasonal pattern was fine-tuned through temperature (higher densities at higher temperatures) as the second important effect. The appearance of high densities of postlarvae of both crab species in spring (related to an increasing temperature) indi-cated the importance of the system for these species (Chavatte 2001).

The best-fitted models were for those species with a clear seasonal appearance in the system. Both *Sprattus sprattus* and *Pomatoschistus microps* were absent during the spring-summer (warmer) period. Higher densities were indeed predicted during winter and the colder autumn seasons. For those species the effect of the other variables is inferior to the effect of temperature as the main forcing variable.

The density pattern for *Pomatoschistus minutus* was comparable between the two systems, but the autumn and winter peaks in the Oosterschelde were not predicted with the Westerschelde model. Sand gobies were predicted to have higher densities with increasing temperature, slightly higher salinity, lower dissolved oxygen concentrations and higher turbidity in the Westerschelde. The first conditions were fulfilled but oxygen was rather high and turbid-ity in the Oosterschelde seldom exceeded 1 m^{-1} (Chapter 5). The prediction failed as the latter effects probably got too much weight.

In the Westerschelde *Limanda limanda* showed a peculiar density pattern with total absence in spring and summer, which was predicted by the Westerschelde model. However, dab showed a dif-ferent distribution pattern in the Oosterschelde. Also, in the surfzone of Belgian beaches dab was only spo-radically recorded between September and October (Beyst *et al.* 2001), but in the shallow ebb-tidal delta

of the Grevelingen (NL) dab was present thoughout the year (Chapter 4-Add., K. Hostens unpublished data). In the period 1969–'78, before the engineering works in the Oosterschelde, dab showed more or less the same density pattern as in the Westerschelde (De Veen *et al.* 1979). As the Oosterschelde was altered from a real estuary into a marine bay, the density pattern of *L. limanda* resembled the coastal pattern, where small juveniles arrived earlier at higher densities and especially larger individuals (1 and 2 group)

stayed longer in the Oosterschelde ecosystem during springtime (Chapter 4).

If the Oosterschelde were still a real estuary, then probably the models would have fit much better. The present study proved the difficulty of applying density models to different types of ecosystems.