Trends in Wadden Sea Fish Fauna

Part II: Dutch Demersal Fish Survey (DFS)

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Summary

Shallow waters along the North Sea coast provide nursery areas for juveniles of several fish species, including commercially exploited species, and natural habitat for resident species and seasonal visitors. These areas have gone through major changes in the last decades due to climate change and human activities, which will likely result in changes in the abundance and species composition of the fish fauna in coastal waters.

Using data from the Demersal Fish Survey (DFS), we present trends from 1970 to 2006 in 34 fish species in three coastal areas in the Netherlands. By comparing trends in the Dutch Wadden Sea to those in the shallow part of the Dutch coastal zone and the Westerschelde, we attempt to identify similar patterns among species and species groups that could give rise to hypotheses on the causes of observed trends. Total fish biomass showed a dome shape pattern with an increase from 1970 to 1985 and a subsequent decline until the early 2000s. The patterns varied widely among individual species as well as between the three areas.

Based on multivariate and time series analyses we explore possible correlations of fish density with a predefined set of three categories of environmental variables: abiotic, biotic and fisheries related variables. Dynamic factor analysis (DFA) identified one common trend for every area: for the Wadden Sea and Westerschelde increasing from the 1970s to the early 1980s followed by a steep decrease until the mid 1990s, a temporary period (until 2002) of increase for the Wadden Sea, and a continuing increase for the Westerschelde. The common trend in the Dutch coastal zone showed a similar increase but with a time lag compared to the inshore areas, while the distinct decline was absent here. The species that showed the strongest correlation with this common trend differed between the areas, and this explains the difference between the common trend in the coastal zone and those in the inshore areas. Common trends were best described by models containing variables from all categories of environmental variables.

The analyses presented in this report provide a description of the major changes in the fish community in inshore and coastal areas in the Netherlands and a first attempt to identify possible causal processes. However, at this stage the causes for the observed changes remain highly speculative. Our study clearly showed that no single or simple set of environmental variables can be found to explain the observed patterns. Correlative research alone is not sufficient to obtain a good understanding of the causal factors underlying the observed trends in fish fauna. More detailed research is required focussing on mechanisms and processes for specific (groups of) species.

1 Introduction

Shallow coastal areas in the Netherlands such as the Wadden Sea and Westerschelde have long been regarded important nursery areas for the juveniles of many North Sea fishes (Zijlstra 1976, Bergman et al. 1989, van Beek et al. 1989). Nurseries are areas where juveniles aggregate and where survival and growth are enhanced through better feeding conditions, refuge opportunities and high connectivity with other habitats. After they have reached a certain size or age, they leave the nursery area and recruit to the (sub)adult populations (Pihl et al. 2002). Other species visit these shallow areas only seasonally. In addition to marine juveniles and seasonal migrants there are also several resident species that inhabit the Wadden Sea and Westerschelde year round. Most non-resident species leave in autumn and migrate to the deeper waters of the North Sea and return again in spring.

In addition to its natural dynamics, environmental characteristics in the coastal areas have changed considerably in the past decades. Long-term data series have shown that water temperature has increased (van Aken 2003), a phenomenon that has been observed at North Sea scale as well (Becker & Pauly 1996). Nutrient loads showed a peak in the seventies of the last century and decreased subsequently (van Raaphorst & de Jonge 2004). Especially in shallow areas such strong changes in environmental factors are expected to impact the ecosystem. Changes in primary production and bivalve recruitment (Cadee & Hegeman 2002, Philippart et al. 2003, Philippart et al. 2007) and a change in the composition of the benthic community has been shown (Ens et al. 2004). Fish are in the middle of the food web, feeding on zooplankton and benthos and are eaten by predatory fish, birds and sea mammals. Depending on whether abundance of fish is controlled top-down or bottom-up, they are likely to respond to changes in either food availability or predator abundance.

On top of changes in environmental conditions, also human activities such as shellfish fishing have impacted coastal waters (Piersma et al. 2001, van Gils et al. 2006). Until 1990 the cockle *Cerastoderma edule* fisheries was not limited by quota, between 1990 and 2003 it was more or less regulated and by 2005 it was expelled from the Wadden Sea. Mussel fisheries take place on mussel cultivation lots in the Wadden Sea. Shrimp fisheries have traditionally been an important fisheries in the Wadden Sea and adjacent coastal waters. Although brown shrimp *Crangon crangon* is the target species of these fisheries, young fish are caught as well and discarded. Due to the fact that brown shrimp is a non-quota species, there is very little information on the magnitude and variations in shrimp fisheries. The impact of this type of fisheries on the ecosystem is poorly known, but bycatch is substantial (van Marlen et al. 1998, Polet 2003, Doeksen 2006, Catchpole et al. 2008). Offshore fisheries will also directly and indirectly impact the coastal fish assemblage through the offshore species that utilize coastal waters as nurseries or seasonal feeding areas (Zijlstra 1976, van Beek et al. 1989).

The above described changes in physical and biological factors will likely result in changes in the abundance and species composition of the fish fauna in coastal waters. Long-term trends in the fish assemblages of the Wadden Sea, Westerschelde and the shallow part of the Dutch coastal zone were explored using data of the Demersal Fish Survey (DFS). By comparing trends in the Wadden Sea to those in the shallow part of the Dutch coastal zone and the Westerschelde, we attempt to identify similar patterns among species and species groups that could give rise to hypotheses on the causes of observed trends.

1.1 Assignment

The overall objective of this project, and of the future research requirements as identified within this project, is to obtain a better understanding of the processes and causal factors underlying trends observed in Wadden Sea fish fauna.

The work plan consisted of 3 components:
(1) collate an inventory of long-term/ongoing fish monitoring programmes in the Wadden Sea
(2) analyse trends in fish fauna based on data collected during the Dutch Demersal Fish Survey
(3) identify future research needs

Part of the work was carried out in cooperation with international colleagues through the TMAP ad hoc Working Group Fish. This covered the inventory of fish monitoring programmes (component 1), elaborate quality controls of the basic data (pre-requisite for component 2), and trend analyses for 14 selected fish species and species composition (part of component 2). Hence, component 2 was elaborated in comparison to the original plan as German monitoring data were included in this part of the trend analyses. Furthermore a list of fish species presently occurring in the Wadden Sea and an overview of environmental data available for the Wadden Sea and adjacent waters were compiled. The previous report (Trends in Wadden Sea Fish Fauna – Part I: Trilateral Cooperation, Bolle et al. 2009) presented the results of the work carried out in international cooperation. A large part of these results have also been used in the Quality Status Report 2009 (Jager et al. 2009).

The rest of the work was based on Dutch data only and is presented in the current report (Trends in Wadden Sea Fish Fauna – Part II: Dutch Demersal Fish Survey). This comprised an elaboration of the trend analyses (component 2): the number of individual species included in the analyses was increased to 34, correlations between trends in fish fauna and environmental variables were explored, and trends were compared with other coastal waters and between groups of species to identify similar patterns that could give rise to hypotheses on the causes of the observed trends. The results of the trend analyses presented in this report have been published in the peer-reviewed literature (Tulp et al. 2009).

Future research requirements (component 3) were identified based on the results presented in both reports. The 2 reports are stand-alone documents which can be read independently of each other.

2 Methods

2.1 Fish data

The Dutch Demersal Fish Survey (DFS) is part of an international inshore survey carried out by the Netherlands, England, Belgium and Germany (van Beek et al. 1989, ICES 2006, ICES 2007). The Dutch survey covers the coastal waters from the southern border of the Netherlands to Esbjerg, including the Wadden Sea, the outer part of the Eems-Dollard estuary, the Westerschelde and the Oosterschelde. This survey has been carried out in September–October since 1970. For the purpose of this report, data from three distinct areas were analysed: the Dutch Wadden Sea (including the outer part of the Eems-Dollard estuary), the Dutch coastal zone and the Westerschelde (Figure 2.1.1). Each year approximately 120, 65, and 40 hauls are taken in the three areas respectively. Sampling effort has been constant over the years, although in a few years not all sampling points were sampled due to adverse weather (e.g. 1976 Dutch coastal area). For each haul, the position, date, time of day, depth and surface water temperature were recorded. The Westerschelde and Wadden Sea are sampled with a 3 m beam trawl, while along the Dutch coast a 6 m beam is used. The beam trawls were rigged with one tickler chain, a bobbin rope, and a fine-meshed cod-end (20 mm). Fishing is restricted to the tidal channels and gullies deeper than 2 m because of the draught of the research vessel. 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. Sample locations are stratified by depth. Fish are sorted and measured to the cm below. The mean abundance per area was calculated for 34 species in the period 1970–2006 weighed by surface area for each depth stratum (see Bolle et al. 2009). Species were classified according to food types: planktivore, shrimp/fish-eating, benthivore and parasitic; and biogeographical guilds: Lusitanian (preferring warm water), boreal (preferring coldwater) and Atlantic (Table 2.1.1). Only species caught in at least one third of all years were analysed. This means that the selection of species may differ slightly between the three areas.

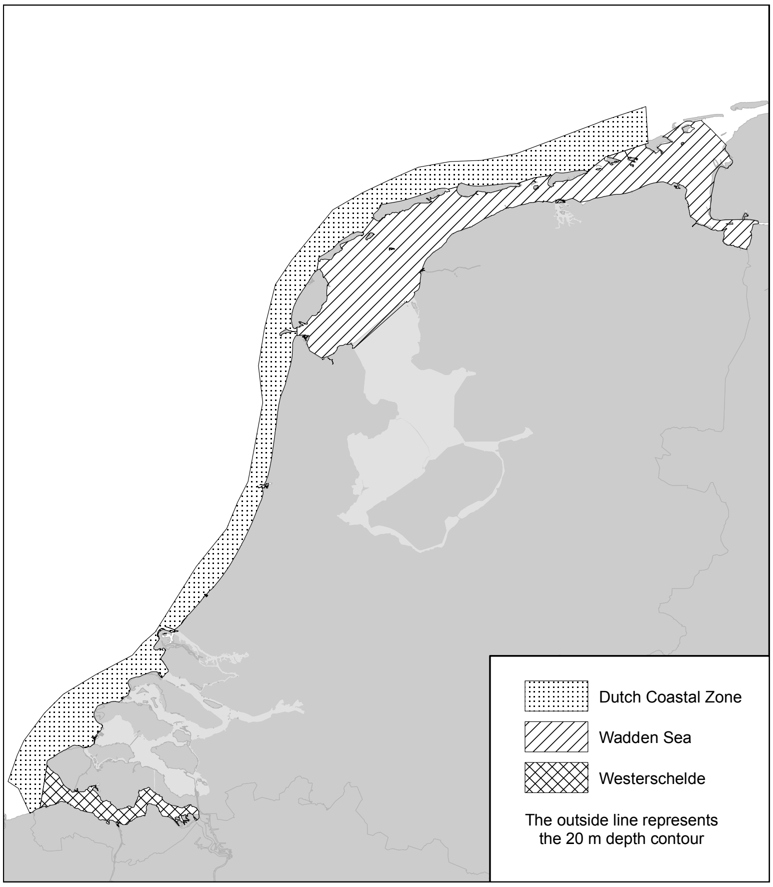


Figure 2.1.1. The three coastal areas in the Netherlands used in this study.

Table 2.1.1. List of species for which trend data are presented and their classification in food groups and biogeographic guild. The classifications are derived from www.fishbase.org for food types and Yang (1982) for biogeographic guild.

Species	Scientific name	Food	Biogeographic guild
river lamprey	*Lampetra fluviatilis*	parastitic	Boreal
eel	*Anguilla anguilla*	benthivore	Atlantic
twaite shad	*Allosa fallax*	planktivore	Lusitanian
herring	*Clupea harengus*	planktivore	Boreal
sprat	*Sprattus sprattus*	planktivore	Lusitanian
smelt	*Osmerus eperlanus*	planktivore	Boreal
cod	*Gadus morhua*	shrimp/fish	Boreal
poor cod	*Trisopterus minutus*	benthivore	Lusitanian
bib	*Trisopterus luscus*	shrimp/fish	Lusitanian
whiting	*Merlangius merlangus*	shrimp/fish	Lusitanian
fivebearded rockling	*Ciliata mustela*	shrimp/fish	Boreal
eelpout	*Zoarces viviparus*	benthivore	Boreal
pipefishes	*Syngnathus sp.*	planktivore	Lusitanian
tub gurnard	*Trigla lucerna*	shrimp/fish	Lusitanian
grey gurnard	*Eutrigla gurnardus*	shrimp/fish	Lusitanian
bull rout	*Myoxocephalus scorpius*	shrimp/fish	Boreal
hooknose	*Agonus cataphractus*	shrimp/fish	Boreal
sea snail	*Liparis liparis*	shrimp/fish	Boreal
lumpfish	*Cyclopterus lumpus*	jellyfish	Boreal
sea bass	*Dicentrarchus labrax*	shrimp/fish	Lusitanian
lesser weever	*Echiichthys vipera*	benthivore	Lusitanian
butterfish	*Pholis gunnellus*	benthivore	Boreal
sandeel	*Ammodytes sp.*	planktivore	Boreal
greater sandeel	*Hyperoplus lanceolatus*	planktivore	Boreal
dragonet	*Callionymus lyra*	benthivore	Lusitanian
gobies	*Pomatoschistus sp*	shrimp/fish	Lusitanian
turbot	*Psetta maxima*	benthivore	Lusitanian
brill	*Scophthalmus rhombus*	benthivore	Lusitanian
scaldfish	*Arnoglossus laterna*	benthivore	Lusitanian
dab	*Limanda limanda*	benthivore	Boreal
flounder	*Platichthys flesus*	benthivore	Lusitanian
plaice	*Pleuronectes platessa*	benthivore	Boreal
sole	*Solea solea*	benthivore	Lusitanian
solenette	*Buglossidium luteum*	benthivore	Lusitanian

2.2 Environmental variables

We used several time series of explanatory variables comprising abiotic variables, biotic variables and variables related to fisheries. Naturally any choice of parameters is arbitrary and partly driven by the availability of the data. That is also the reason why we sometimes used different datasets for different areas (Table 2.2.1). In this exploratory phase we focused on variables potentially impacting fish densities directly, but did not consider indicators of water quality such as pollutants. We did include nutrients given the recent discussions on the effect of these on the carrying capacity of coastal systems, even though we are aware that nutritional links between nutrients and fish are still not well understood and only partly proven (Philippart et al. 2007, Kuipers & van Noort 2008). So besides the direct links in the food web, be it as predator or prey, we included the NAO winter index, temperature, river runoff, salinity, total phosphate and nitrate.

Table 2.2.1. *Environmental variables used in the time series analyses of the three different areas*

explanatory variable	Wadden Sea	Dutch coastal area	Westerschelde
abiotic parameters			
temperature (°C)	DFS	DFS	DFS
salinity (1)	NIOZ: Texel, 't Horntje	www.waterbase.nl: average 2 stations (3)	www.waterbase.nl: average 2 stations (4)
river runoff (m^3/s)	www.waterbase.nl: Kornwerderzand	www.waterbase.nl: IJmuiden	www.waterbase.nl: Schaar van ouden Doel
total phosphate (mg/l)	www.waterbase.nl: Noordwijk	www.waterbase.nl: Noordwijk	www.waterbase.nl: average 2 stations (5)
total nitrate (mg/l)	www.waterbase.nl: Noordwijk	www.waterbase.nl: Noordwijk	www.waterbase.nl: average 2 stations (5)
biotic parameters			
piscivorous fish North Sea coast (kg/ha)	SNS: gadoids>20cm, within 30 m depth	SNS: gadoids>20cm within 30 m depth	SNS: gadoids>20cm within 30 m depth
cormorants (n or n breeding pairs)	SOVON nonbreeding birds	SOVON breeding birds	SOVON nonbreeding birds
seals (n)	IMARES common and grey seals	IMARES common and grey seals	DELTARES: common and grey seals
brown shrimp densities (kg/ha)	DFS: Wadden Sea	DFS: Dutch coast	DFS: Westerschelde
fishing pressure			
brown shrimp effort (see text)	ICES WGCRAN: total Dutch landings (2)	ICES WGCRAN: total Dutch landings (2)	ICES WGCRAN: total Dutch landings (2)
cockle landings (million kg meat)	Ministry LNV: Wadden Sea	Ministry LNV: North sea coast	Ministry LNV: Westerschelde
beam trawl effort North Sea (hp days)	Rijnsdorp et al. 2008	Rijnsdorp et al. 2008	Rijnsdorp et al. 2008

(1) Texel: practical salinity scale of 1978, other areas:‰

(2) corrected for brown shrimp densities

(3) North of Terschelling and off Goeree mean for september

(4) Hansweert geul and Vlissingen boei SSVH

(5) Vlissingen boei SSVH and Terneuzen boei 20

2.2.1 Abiotic parameters

The NAO winter index (December–March) was taken from the Internet http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index.html. During the DFS sea surface temperature is recorded at haul level. For the Wadden Sea we used salinity data collected by NIOZ on Texel; for the other areas, series were taken from www.waterbase.nl (mean for September/October). River runoff was also taken from the same source. It was measured at all major outflows, we used the annual mean of the series at Kornwerderzand for the Wadden Sea, at IJmuiden for the North Sea coast and at the Schaar van Ouden Doel for the Westerschelde. These runoff series are all highly correlated. Total phosphate and nitrate was taken from www.waterbase.nl (annual means). Missing values were interpolated based on correlations between local values and concentrations in the Rhine discharge (van Raaphorst & de Jonge 2004).

Mean temperature during the survey period has increased in all three areas, but stronger in the Wadden Sea and Westerschelde than along the Dutch coast (Figure 2.2.1). Besides a slow increase in salinity along the Dutch coast, no long-term trend seems apparent in salinity in the other areas. River runoff has shown great annual fluctuations and an increase in all three areas, but steepest in the Wadden Sea. Total phosphate showed a maximum in the period 1975–1985, and declined subsequently. Nitrate showed a similar pattern in the Westerschelde and Dutch coastal zone, while concentrations in the Wadden Sea were more stable after an initial decline.

2.2.2 Biotic parameters

For biotic series we used data on predators and prey. The most common (non-fish) predators are cormorant *Phalacrocorax carbo*, common *Phoca vitulina* and grey seals *Halichoerus grypus*. For cormorants in the Wadden Sea we used the number of non-breeding birds, because these numbers are usually larger than the breeding numbers and the period corresponds better with the fish sampling period. For the Dutch coastal zone only breeding numbers were available and compiled from different sources (M. Leopold pers. comm.). Seals are counted several times per year by airplane and total populations are estimated (monitoring program IMARES). Because of their larger numbers, the harbour porpoise *Phocoena phocoena* has probably been a more important fish predator in recent times than seals in the Dutch coastal zone. However, the time series has the same signal as that for seals with a steep increase from the early 1990s onwards (Camphuysen 2005) and therefore we used seal time series for all three areas. As a measure of predation pressure by fish we have included gadoid densities (in kg/ha within the 30 m depth contour, between 52°N and 55°30'N and east of 3°E from the Sole Net Survey (SNS)) as explanatory variable for the three areas. Gadoids are piscivorous already from lengths of 4 cm onwards (Bromley et al. 1997), but since they generally eat prey about 4 times smaller than their own size we used a lower size limit of 20 cm (Daan 1973).

In the Wadden Sea the number of non-fish predators has shown a steep increase since 1980 (Figure 2.2.1). Populations of both common and grey seals have increased. Grey seals only appeared in 1979 for the first time in this period. Although common seals still outnumber grey seals, by 2006 the ratio common to grey seals has decreased to approximately 2:1. In the Westerschelde the numbers of seals have shown a similar increase although total numbers are generally lower than in the Wadden Sea. For the Dutch coast no separate line is presented as the seals from both Wadden Sea and Westerschelde visit the North Sea to feed and the Dutch coast does not provide haul out sites. Cormorants increased both in the Wadden Sea and Westerschelde, but stabilized recently in the Westerschelde. Piscivorous fish in the North Sea have shown variable densities over the years, with an overall decrease from the early 1990s onwards.

Fish feed on zooplankton, buried benthic and epibenthic prey. The only food source for which information is available (for all areas and the full time series) is brown shrimp abundance. However the role of brown shrimp is complicated as brown shrimp can also predate on juvenile fish (van der Veer & Bergman 1987, Amara & Paul 2003). No time series on other benthic prey or zooplankton are available for the study period and study area. Brown shrimp densities are overall highest in the Wadden Sea and show strong annual variation and a long-term decline in the Westerschelde but no clear trend in the Wadden Sea or Dutch coastal zone (Figure 2.2.1).

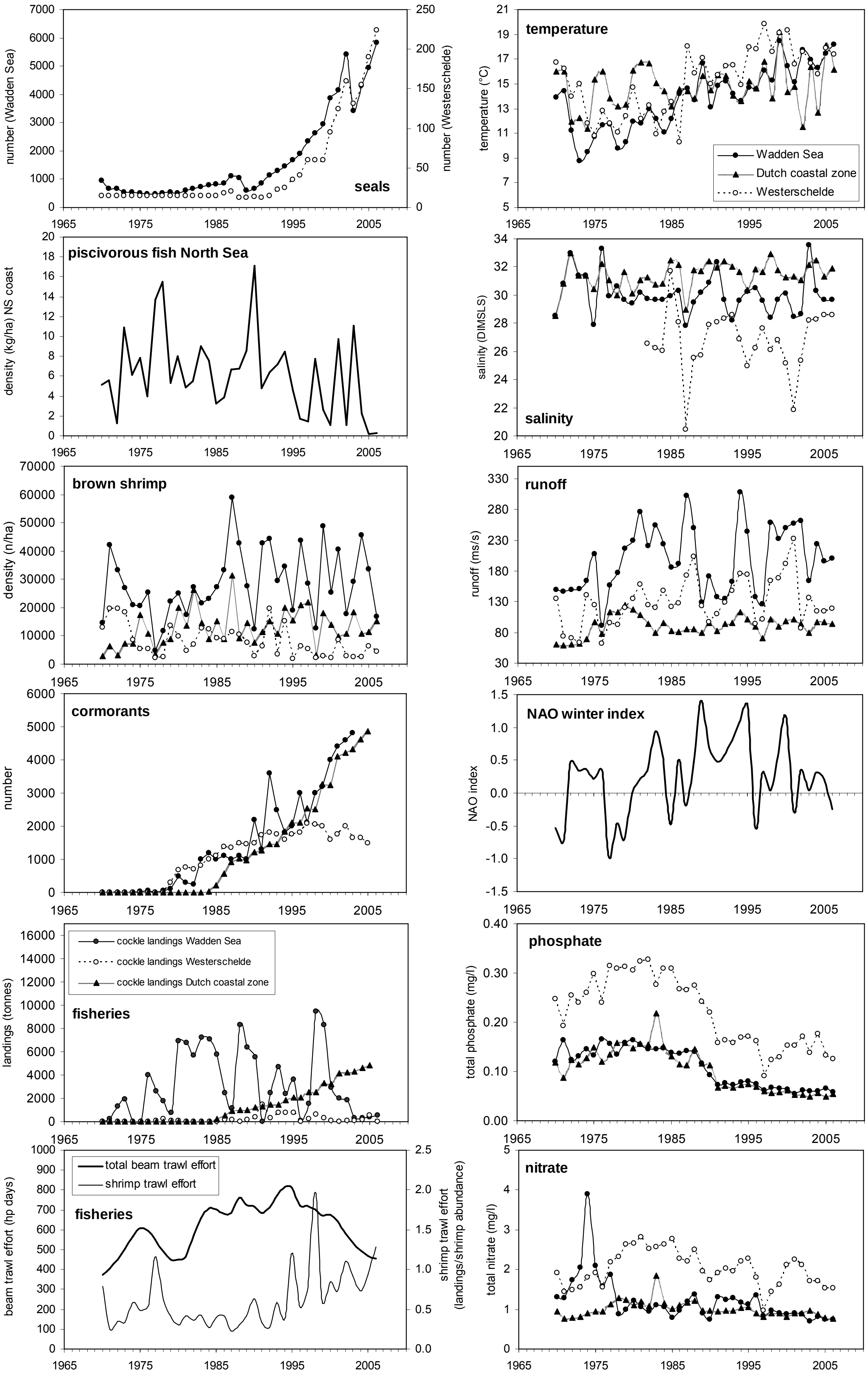


Figure 2.2.1. Time series of environmental variables. See Table 2.2.1 for further explanation.

2.2.3 Fishing pressure

The most important fisheries within the three areas include brown shrimp fisheries and shellfish fisheries (Verver et al. 2005). These fisheries are likely to have the biggest impact on small fish, because of the bycatch, bottom disturbance and removal of possible prey. Because no detailed information on fishing pressure per area is available, we estimated brown shrimp trawl effort by dividing total shrimp landings in the Netherlands by mean brown shrimp densities in the autumn DFS survey. Cockle fisheries pressure was estimated as the cockle landings per area. Fishing effort in the offshore waters bordering our study area was estimated from the Dutch beam trawl effort which dominates the fishing effort in this area (Jennings & Cotter 1999).

Brown shrimp trawl effort has been constant throughout the 1970s and 1980s, but has shown a steep increase since the early 1990s. Cockle fishing started in the Wadden Sea in the mid 1980s and lasted until 2005, after which mechanical dredging was prohibited, but hand raking is still permitted on a smaller scale. Currently there still is a cockle fisheries in the Westerschelde, but not as large as the Wadden Sea fisheries used to be. Beam trawl effort increased until the mid 1990s where after it showed a steep decrease.

2.3 Data analysis

Species that were observed in less than 1/3 of the years were omitted from any of the analyses. The reason why we did not put a stronger constraint is to include newcomers among species that may provide valuable information. After adding 0.01 to zero observations data were log-transformed to stabilise the variance. This term was very close to the lowest densities in the dataset. Occasionally measured values fall below this line, but for reasons of consistency we used the same transformation of $^{e}\log(x+0.01)$ for all species and areas. In the graphs the same scale was used per species for all areas to facilitate comparison among areas.

Time series were analysed for the individual species in the three different areas separately. First, time series of individual species were analysed using Trendspotter, a program that is based on structural time series analysis (Harvey 1989) in combination with the Kalman filter. The program identifies periods with significant increases or decreases from annual fluctuations, by estimating smoothed population numbers for a time series with N equidistant measurements over time. Trendspotter also estimates the standard deviations of the smoothed population numbers. Finally, it estimates the standard deviations of the differences between consecutive timepoints. The estimation of confidence intervals is based on the deviations of time point values from the smoothed line. A more detailed description of the method can be found in Visser (2004) and Soldaat et al. (2007). The advantage is that this method takes account of serial correlation and provides confidence limits that enable to test changes in abundance.

Second, dynamic factor analysis (DFA) was used to estimate underlying common patterns within each of the three regions (Harvey 1989, Zuur et al. 2003, Zuur et al. 2007). DFA is a multivariate extension of structural time series analysis. The 34 time series were modelled as a function of a linear combination of common trends, an intercept, one or more explanatory variables and noise (Zuur et al. 2007). DFA can indicate whether there are any underlying common patterns in different time series, whether there are interactions between the response variables, and identify the effects of explanatory variables. The aim of DFA is to set the number of common trends as small as possible but still have a reasonable model fit. The magnitude and sign of the factor loadings determine how these trends are related to the original time series.

One problem with this analysis is that we model fish density as a function of biotic variables. This approach assumes that the number of fish is a function of the explanatory variables used. But for some of the biotic variables (e.g. number of seals) the relationship might also be reversed, that is the biotic variable (e.g. number of seals) is a function of fish densities. This endogeneity is of course a difficult problem and we cannot assume that it does not occur in this set.

Only DFA models with a symmetric, non-diagonal error covariance matrix could be used, fitted for 1 and 2 common trends and with no, 1 or 2 explanatory variables (with 12 possible explanatory variables this results in 92 models to be tested for every number of common trends and area). Analyses were performed on log-transformed and standardized time series. Explanatory variables were standardized if they contained large values (in order to arrive at interpretable regression estimates). Model selection was based on Akaike's information criterion (AIC). Canonical correlations are presented to illustrate correlations between common trends and original series. Model validation was carried out by comparing the time trends of the individual species with the original data. Results were obtained with the software package Brodgar (http://www.brodgar.com).

In summary, in DFA, the trends are the common signal in the 34 time series that are not related to the explanatory variables. The common trend can be interpreted as a partial, common effect. The trends calculated by Trendspotter are real trends that capture the pattern of the data, without taking the effect of explanatory variables into account.

Data exploration indicated strong collinearity (correlation of >0.80) between the variables cormorants and seals, cormorants and phosphate, and phosphate and nitrate in the Dutch coastal zone; between seals and cormorants, and cormorants and phosphate in the Wadden Sea; and between seals and phosphate, phosphate and nitrate, and seals and beam trawl effort in the Westerschelde. Because of the almost similar pattern in the seal and cormorant population for Wadden Sea and Dutch coastal zone and the fact that the cormorant series had one missing value, we excluded cormorants from the analyses for these areas. The choice to exclude any other variables would be very arbitrary. Instead we included all variables in the analyses to see which ones resulted in the best model, keeping the collinearity in mind and not selecting models that contained two collinear variables.

3 Results

3.1 Trends total fish numbers and biomass

Mean total fish biomass per haul shows a dome-shaped pattern in all three areas with an increase from 1970 to 1985 and a subsequent fivefold decline (Figure 3.1.1). However this dome shape seems most pronounced in the Wadden Sea. The decline in the Westerschelde sets in a few years later and the decline levels off since 2000. For the Wadden Sea and the Westerschelde the pattern in densities reflects the same patterns as found in total biomass. Along the Dutch coast there is no clear trend in densities. Overall the Westerschelde has the lowest densities of these three areas.

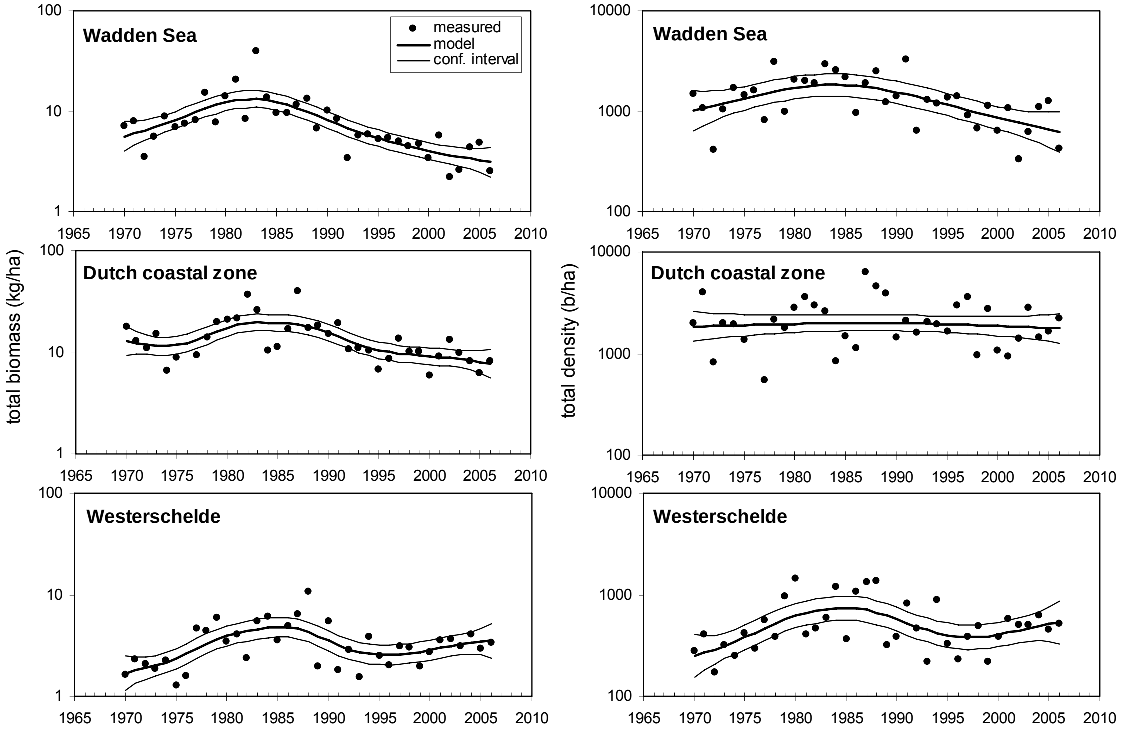


Figure 3.1.1. Time series of total biomass (left, kg/ha) and total density (right, n/ha) of fish in the three sub-areas. The dots indicate the means per year. The middle black line is the smoothed trend as estimated by Trendspotter. The other 2 lines indicate the upper and lower limits of the 95% confidence interval.

3.2 Individual species trends

Absolute densities of many species differ up to one order of magnitude between areas (Figure 3.2.1, e.g. plaice, flounder, gobies, dragonet). Some species are only common in the Wadden Sea (e.g. bull rout, butterfish) or common along the Dutch coast but rare in the Wadden Sea and Westerschelde (dragonet, scaldfish, solenette). Individual species show great variation in trends. Some species show different trends in the three sub-areas (e.g. plaice, sea snail). Species that have colonized the Dutch coastal waters recently include sea bass, lesser weever and greater sandeel (Westerschelde) (Figure 3.2.1).

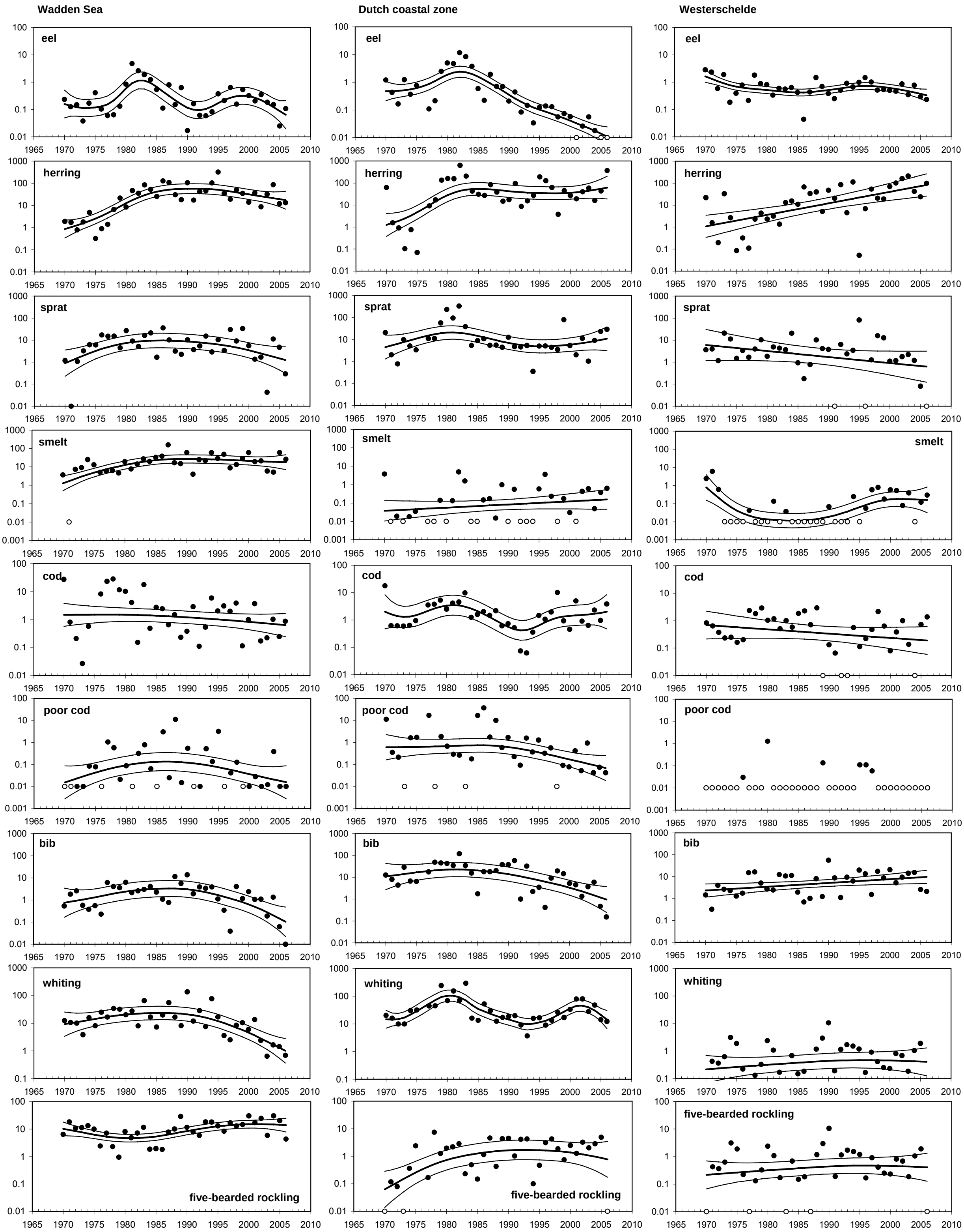


Figure 3.2.1. Time series analysis of the mean density of 32 species in three different areas between 1970 and 2006. The dots indicate the mean densities (n/ha) per year. Twaite shad and river lamprey are not presented because of their absence in the catches in some areas and their very low catch numbers in others. The middle black line is the smoothed trend as estimated by Trendspotter. The other 2 lines indicate the upper and lower limits of the 95% confidence interval. Zero values are indicated with open dots.

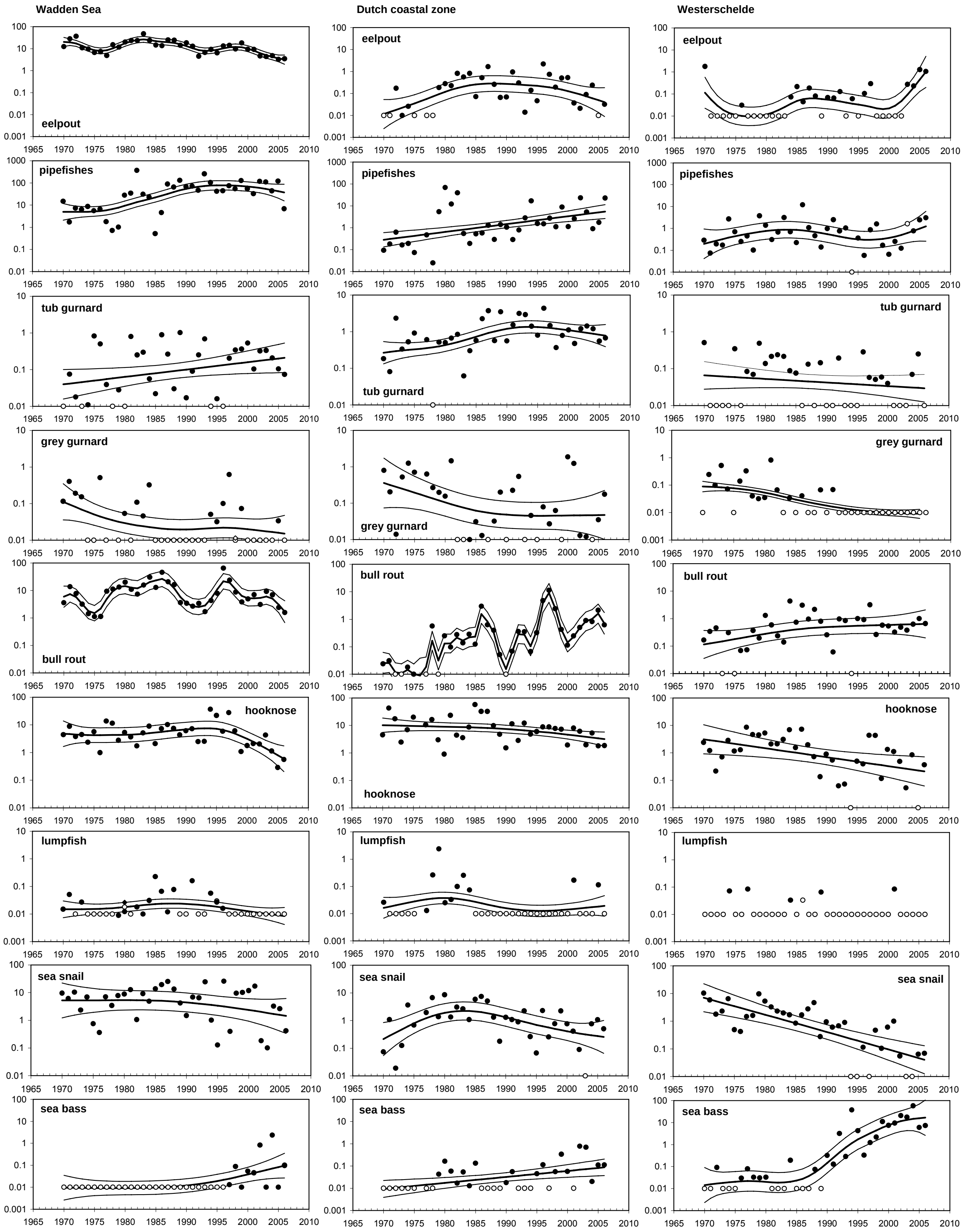
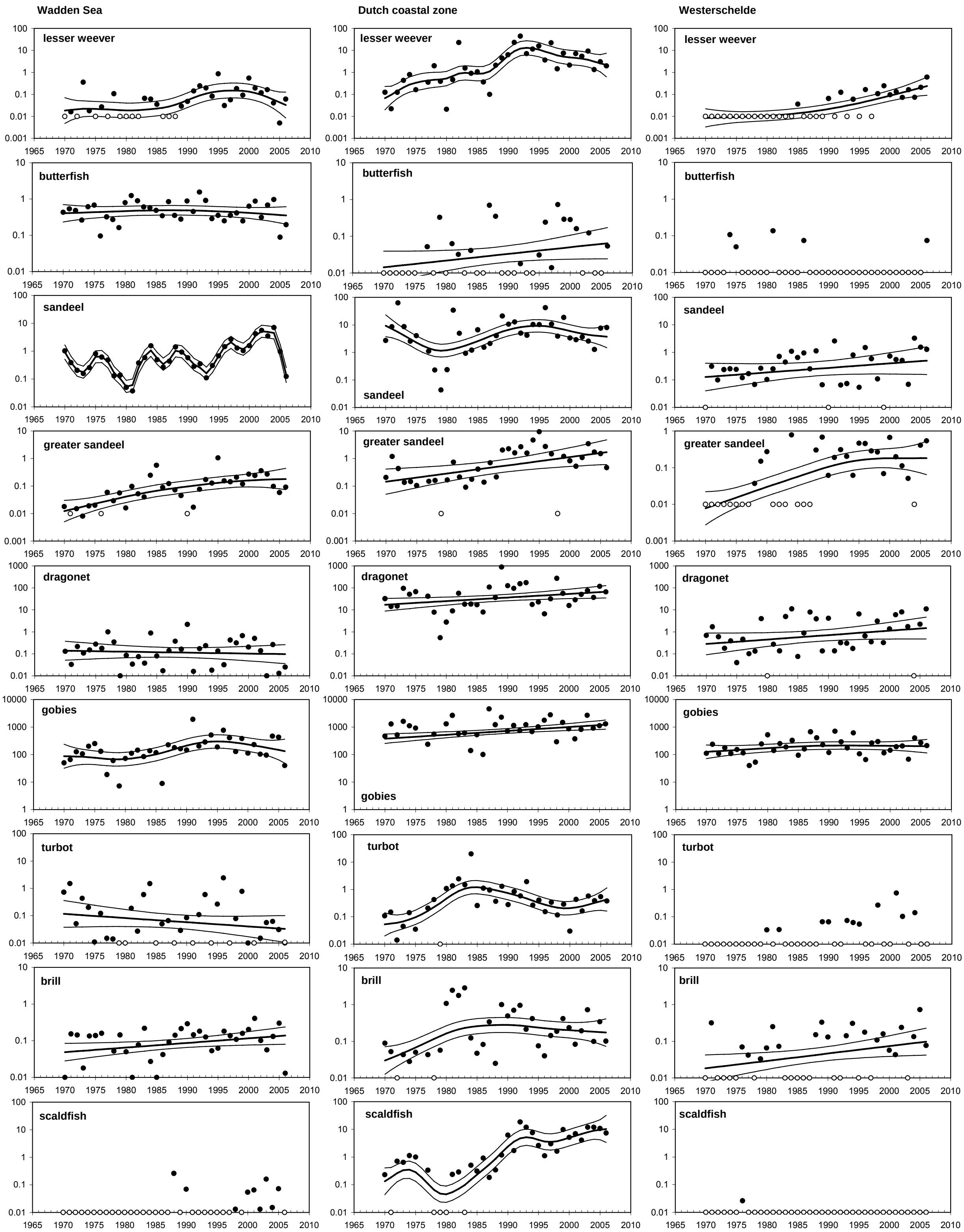


Figure 3.2.1. continued



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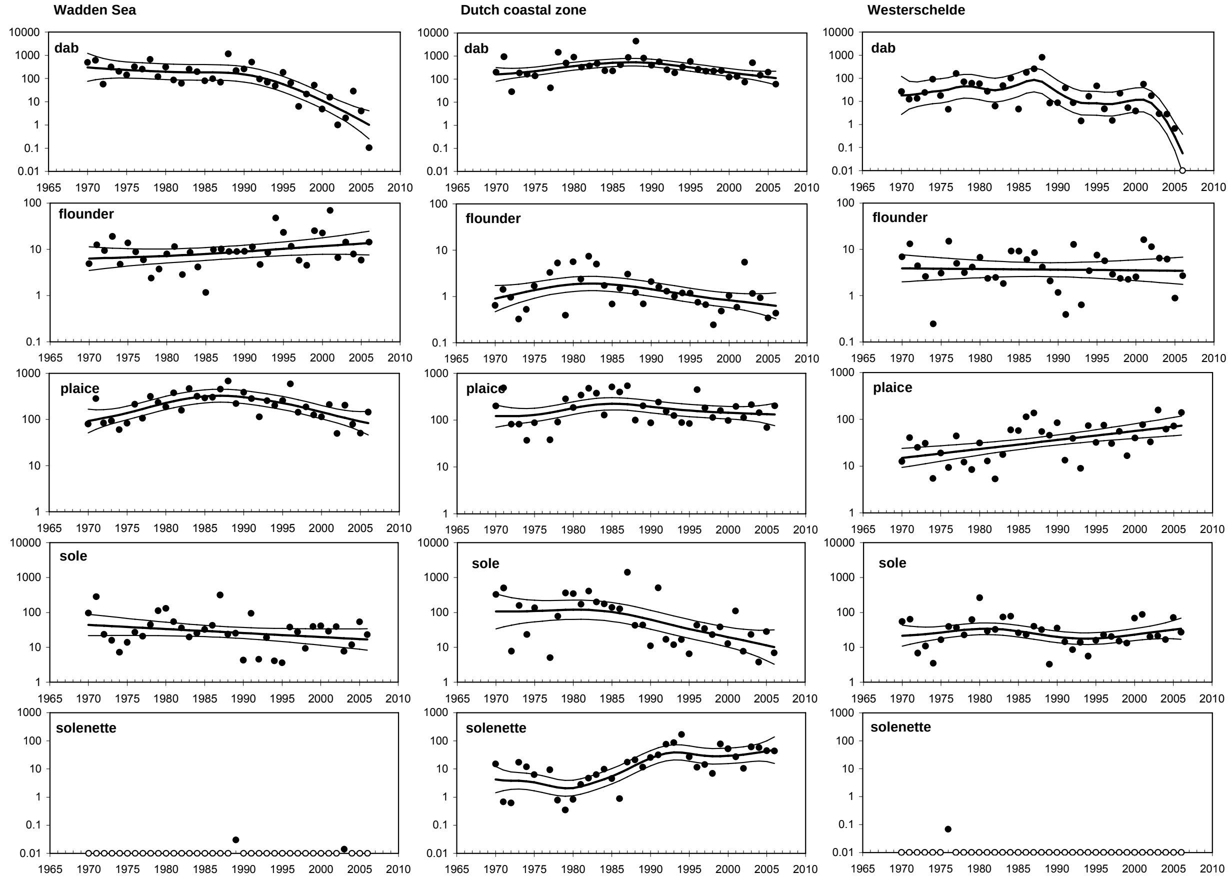


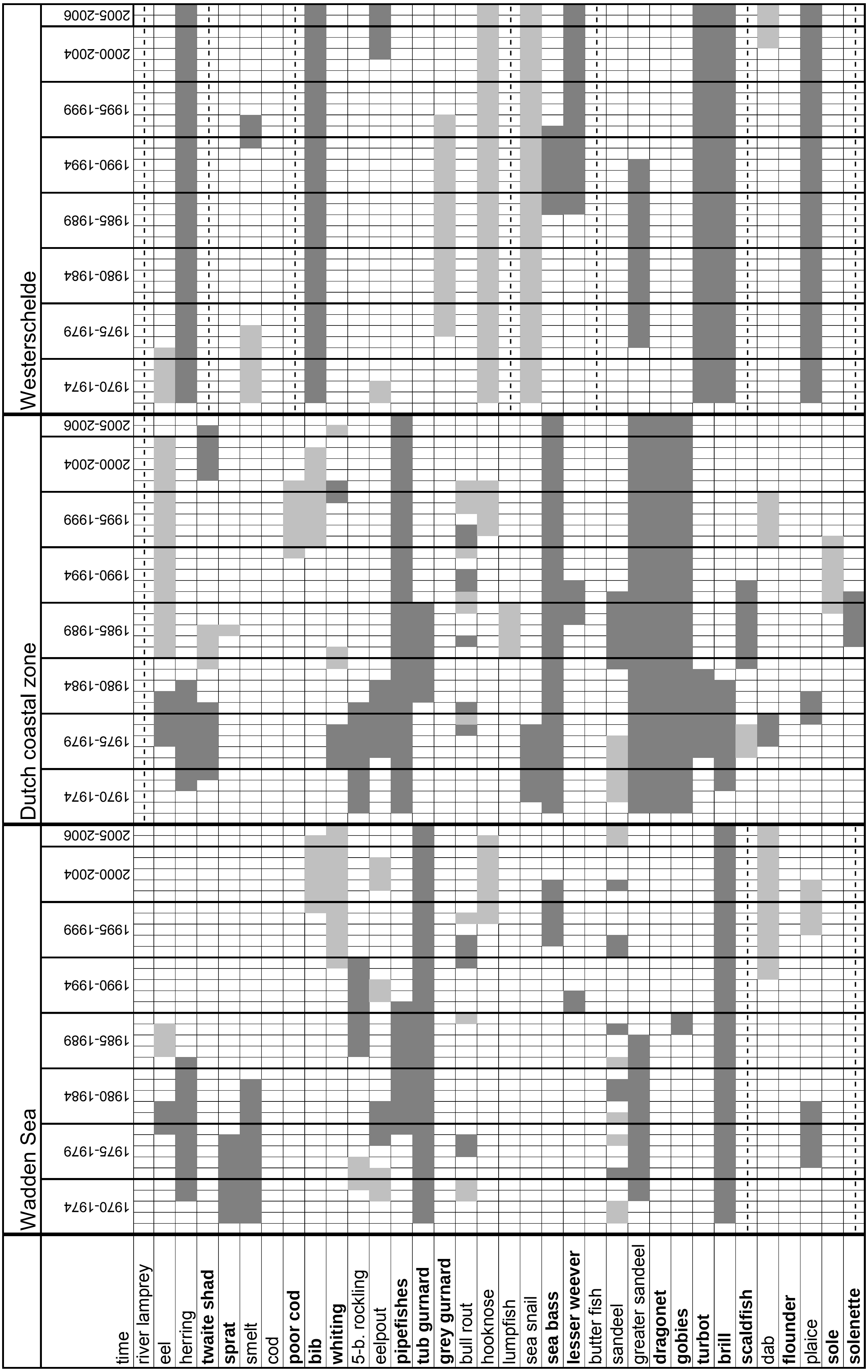
Figure 3.2.1. continued

Species that show significant declines since 1985 in the Wadden Sea include eel, eelpout, bib, whiting, hooknose, dab and plaice (Table 3.2.1), while periods with significant increases occurred in fivebearded rockling, pipefishes, tub gurnard, sea bass, greater sandeel and brill. In general the periods with decreases occurred later than the periods of increases.

Along the Dutch coast eight species (twaite shad, pipefishes, tub gurnard, sea bass, sandeel, greater sandeel, dragonet and gobies) show extensive periods of significant increase since 1985 and seven (eel, poor cod, bib, hooknose, lumpfish, dab and sole) with periods of significant decrease (Table 3.2.1).

In the Westerschelde herring, bib, eelpout, sea bass, lesser weever, greater sandeel, turbot, brill and plaice show long continuous periods of significant increase, while grey gurnard, hooknose, sea snail and dab show recent or long periods of significant decreases (Table 3.2.1).

Table 3.2.1. Summary of trends in 34 species in the Wadden Sea, Dutch coastal zone and Westerschelde. Years with significant increases are indicated with a dark grey panel, years with significant decreases with a light grey panel, years without significant changes with no shading. Species that do not (or very rarely) occur in an area, but do occur in the other two coastal areas, are indicated with –. Lusitanian species are printed bold.


Wadden Sea
Dutch coastal zone
Westerschelde
time
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2006
river lamprey
eel
herring
twaite shad
sprat
smelt
cod
poor cod
bib
whiting
5-b. rockling
eelpout
pipefishes
tub gurnard
grey gurnard
bull rout
hooknose
lumpfish
sea snail
sea bass
lesser weever
butter fish
sandeel
greater sandeel
dragonet
gobies
turbot
brill
scaldfish
dab
flounder
plaice
sole
solenette

3.3 Common trends

The best DFA fit for all three areas was obtained for one common trend (smallest AIC). For every area the five best models are presented (Table 3.3.1). The main common trend for the Wadden Sea and Westerschelde shows an increase from the mid 1970s to the early 1980s followed by a steep decrease in the late 1980s, with a second much smaller peak in the Wadden Sea around 2000 and a subsequent decline (Figure 3.3.1). The pattern for the Dutch coastal zone is different in that the increase started years later, followed by a moderate decline in the mid 1990s and stabilization in the recent decade (Figure 3.3.1).

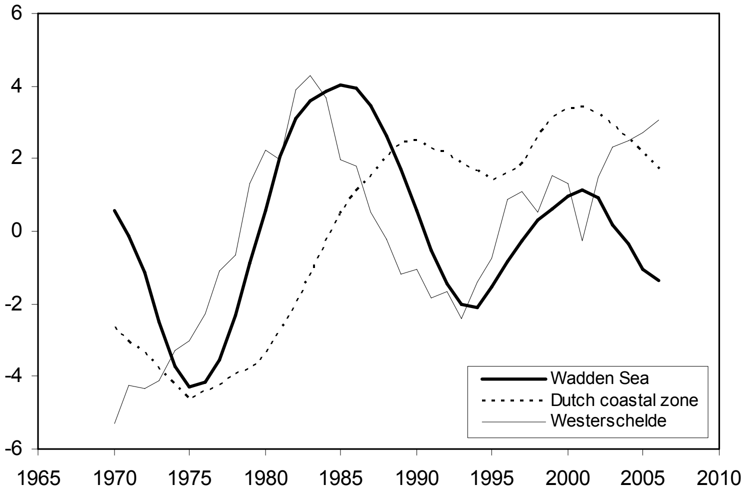


Figure 3.3.1. Common trends in the three areas as estimated by the DFA analyses.

The environmental variables involved in the best five models for the Wadden Sea included seals, beam trawl effort, runoff, brown shrimp densities and total nitrate. The model with the best fit included seals and beam trawl effort (Table 3.3.1). For the Dutch coastal zone the variables in the five best models were brown shrimp density, runoff, seals, cockle landings, temperature, phosphate and shrimp effort with the best model including brown shrimp density and runoff. The common trend for the Westerschelde was best explained by models including beam trawl effort, phosphate, cormorants, beam trawl effort, seals and salinity. The best model included beam trawl effort and phosphate.

Table 3.3.1. Selection of five best models for the common trend in the three areas. All models included one common trend only.

Area	Model no.	Model	AIC
Wadden Sea	1	seals + beam trawl effort	2874.92
	2	runoff + beam trawl effort	2892.73
	3	seals + runoff	2924.66
	4	brown shrimp + beam trawl effort	2930.25
	5	beam trawl effort + nitrate	2932.04
Dutch coastal zone	1	brown shrimp + runoff	2638.79
	2	seals + cockle landings	2667.40
	3	temp + seals	2678.39
	4	runoff + phosphate	2698.37
	5	shrimp effort + phosphate	2702.13
Westerschelde	1	beam trawl effort + phosphate	2683.60
	2	cormorants + beam trawl effort	2695.61
	3	seals + salinity	2710.19
	4	cormorants + phosphate	2710.85
	5	cormorants + seals	2717.53

In the Wadden Sea, river lamprey, sprat, smelt, bull rout, butterfish, greater sandeel, gobies and plaice show strong positive correlations (>0.4) with the common trend (Figure 3.3.2), while no species show strong negative correlations. The remaining species are moderately or poorly correlated to the common trend. The Dutch coastal zone shows strong positive correlations with the common trend for tub gurnard, bull rout, lesser weever, greater sandeel, scaldfish and solenette and strong negative correlations for eel and grey gurnard. All other species show moderate or poor correlation with the common trend (Figure 3.3.2). In the Westerschelde, bull rout, sandeel and sole are the only three species strongly positively correlated to the common trend, while none show strong negative correlations (Figure 3.3.2). The remaining species have weaker correlations. Overall the strongest correlations were found in the Wadden Sea and the Dutch coastal zone.

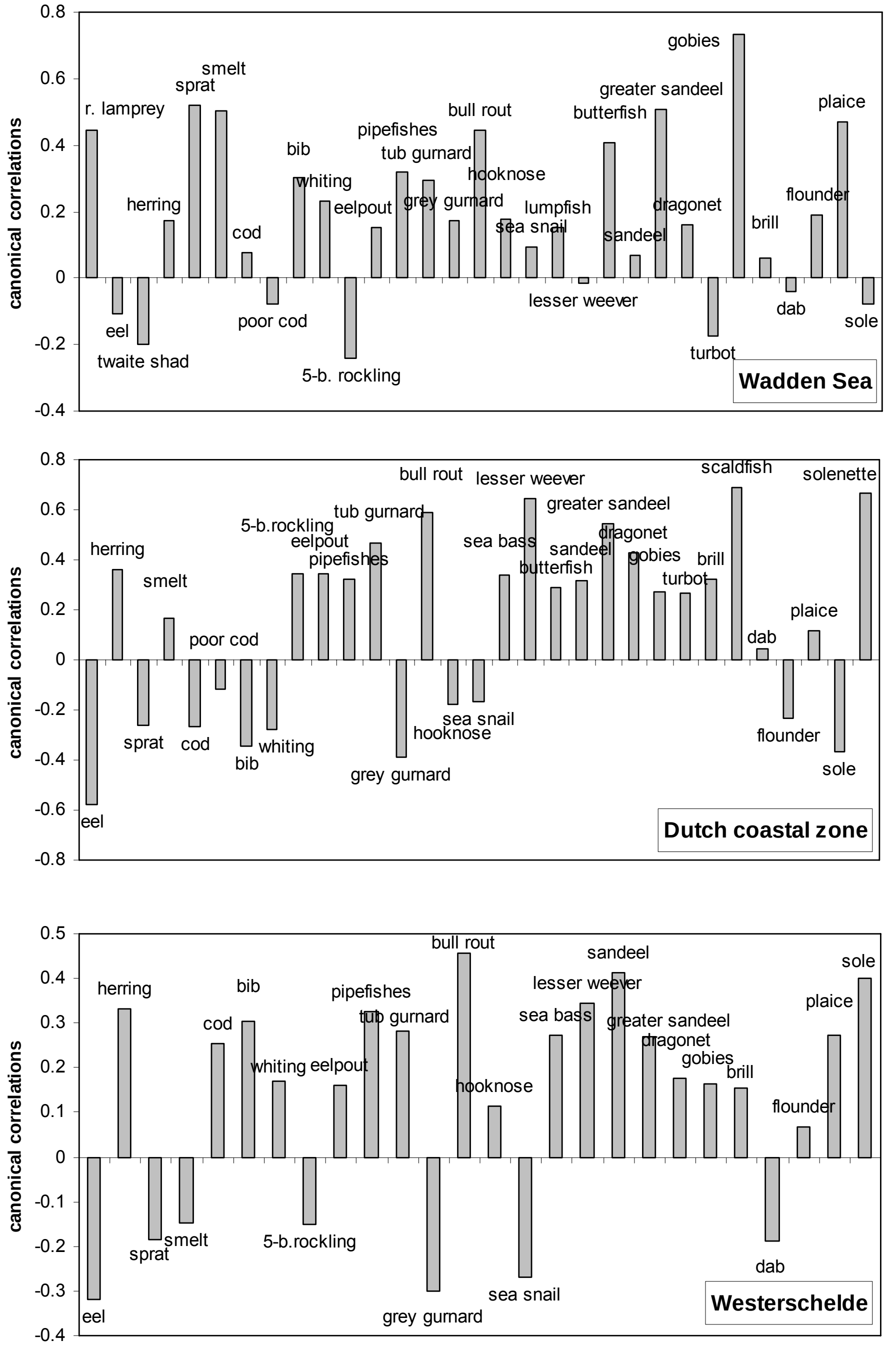


Figure 3.3.2. Canonical correlations between the DFA common trend and the original time series for each species.

The estimated regression parameters for the explanatory variables in the best models are given in Table 3.3.2 for every area. Significant t-values indicate strong relationships with the explanatory variables. For the Wadden Sea, river lamprey, bib, whiting, five-bearded rockling, eelpout, pipefishes, hooknose, lesser weever, greater sandeel, sandeel, dab and plaice had relatively large t-values for the first explanatory variable (seals), of which river lamprey, five-bearded rockling, pipefishes, lesser weever, sandeel and greater sandeel increased with the number of seals and the other species decreased. River lamprey, herring, sprat, smelt, poor cod, pipefishes, hooknose, lesser weever, sandeel, greater sandeel, gobies, brill and sole had relatively large t-values for the second explanatory variable (beam trawl effort). These coefficients were all positive except for sole.

Regression parameters for fish in the Dutch coastal zone were significant and positive for the first explanatory variable (brown shrimp density) for eel, flounder, brill, gobies, herring, eelpout, red gurnard, plaice, smelt, sole and pipefishes indicating an increase in densities with brown shrimp density. Herring, sea snail, five-bearded rockling, whiting and pipefishes showed significant, positive estimates for the regression coefficients of the second explanatory variable (runoff). For gobies, dragonet and sandeel these regression coefficients were negative.

The regression parameters for fish in the Westerschelde showed significant correlations with the first explanatory variable (beam trawl effort) for smelt, dab and sole. These were negative for smelt and sole, pointing at decreasing densities with increasing beam trawl effort. Significant negative coefficients for the second variable (total phosphate) were found for herring, smelt, eelpout, sea bass, lesser weever, greater sandeel and plaice. Whereas sprat, whiting, tub gurnard, grey gurnard, hooknose, sea snail and dab showed increases with total phosphate.

Table 3.3.2. Estimated regression parameters, standard errors (se) and t-values for the explanatory variables in the best model for each area. Significant parameters are in bold.

Wadden Sea

	Seals			Beam trawl effort		
Species	estimate	se	t-value	estimate	se	t-value
river lamprey	0.61	0.12	**4.85**	0.32	0.12	**2.54**
eel	-0.09	0.18	-0.48	-0.16	0.17	-0.96
twaite shad	-0.01	0.17	-0.07	-0.11	0.17	-0.64
herring	0.26	0.14	1.78	0.43	0.14	**3.17**
sprat	-0.20	0.15	-1.37	0.36	0.15	**2.45**
smelt	0.25	0.14	1.85	0.50	0.13	**3.73**
cod	-0.17	0.16	-1.05	-0.14	0.16	-0.88
poor cod	-0.22	0.15	-1.50	0.33	0.15	**2.22**
bib	-0.50	0.14	**-3.57**	0.14	0.14	0.99
whiting	-0.66	0.12	**-5.69**	0.19	0.12	1.61
5-bearded rockling	0.40	0.15	**2.67**	0.27	0.15	1.84
eelpout	-0.55	0.16	**-3.49**	-0.21	0.14	-1.47
pipefishes	0.38	0.14	**2.76**	0.40	0.14	**2.98**
tub gurnard	0.26	0.16	1.63	0.13	0.16	0.81
grey gurnard	-0.22	0.16	-1.37	-0.15	0.16	-0.93
bull rout	-0.15	0.18	-0.81	-0.12	0.17	-0.69
hooknose	-0.49	0.13	**-3.74**	0.35	0.13	**2.72**
sea snail	-0.29	0.16	-1.76	-0.12	0.16	-0.78
lumpfish	-0.25	0.16	-1.56	0.16	0.15	1.04
lesser weever	0.33	0.14	**2.34**	0.55	0.14	**4.00**
butterfish	-0.15	0.17	-0.91	-0.01	0.16	-0.05
sandeel	0.56	0.13	**4.23**	0.27	0.13	**2.06**
greater sandeel	0.54	0.12	**4.51**	0.44	0.12	**3.81**
dragonet	-0.09	0.16	-0.59	0.30	0.16	1.88
turbot	-0.22	0.16	-1.35	-0.04	0.16	-0.23
gobies	0.19	0.15	1.32	0.53	0.15	**3.62**
brill	0.18	0.16	1.14	0.36	0.15	**2.34**
dab	-0.87	0.08	**-10.84**	0.01	0.08	0.17
flounder	0.30	0.16	1.90	0.30	0.15	1.94
plaice	-0.34	0.15	**-2.31**	0.25	0.14	1.77
sole	-0.09	0.16	-0.54	-0.61	0.15	**-4.05**

Dutch coastal zone

	Brown shrimp density			Runoff		
Species	estimate	se	t-value	estimate	se	t-value
eel	0.37	0.13	**2.96**	-0.09	0.13	-0.70
herring	0.32	0.13	**2.38**	0.28	0.14	**2.09**
sprat	0.23	0.15	1.53	0.29	0.15	1.93
smelt	0.39	0.15	**2.69**	-0.25	0.15	-1.71
cod	-0.08	0.16	-0.48	0.18	0.16	1.13
poor cod	0.04	0.16	0.27	-0.06	0.17	-0.39
bib	-0.01	0.16	-0.07	0.10	0.16	0.60
whiting	0.07	0.14	0.46	0.41	0.15	**2.84**
5-bearded rockling	0.22	0.14	1.63	0.36	0.14	**2.63**
eelpout	0.46	0.14	**3.35**	-0.02	0.14	-0.18
pipefishes	0.40	0.13	**3.09**	0.33	0.13	**2.52**
tub gurnard	0.31	0.14	**2.29**	-0.13	0.14	-0.93
grey gurnard	-0.20	0.15	-1.34	0.14	0.15	0.93
bull rout	0.24	0.13	1.88	0.02	0.13	0.12
hooknose	0.03	0.16	0.17	-0.22	0.16	-1.40
sea snail	0.19	0.15	1.28	0.33	0.15	**2.19**
sea bass	0.12	0.15	0.79	0.15	0.15	0.97
lesser weever	0.07	0.13	0.51	0.09	0.14	0.65
butterfish	0.11	0.15	0.69	0.24	0.15	1.57
sandeel	0.09	0.14	0.68	-0.49	0.14	**-3.55**
greater sandeel	0.24	0.13	1.85	-0.20	0.14	-1.45
dragonet	-0.05	0.14	-0.35	-0.35	0.14	**-2.39**
gobies	0.35	0.13	**2.63**	-0.45	0.14	**-3.30**
turbot	0.25	0.15	1.61	0.06	0.16	0.38
brill	0.40	0.14	**2.87**	0.10	0.14	0.74
scaldfish	-0.10	0.12	-0.80	-0.20	0.13	-1.53
dab	0.25	0.16	1.55	0.03	0.16	0.20
flounder	0.33	0.15	**2.28**	0.23	0.15	1.54
plaice	0.49	0.14	**3.46**	-0.22	0.14	-1.53
sole	0.40	0.14	**2.86**	-0.16	0.14	-1.13
solenette	0.07	0.13	0.54	-0.07	0.13	-0.52

Westerschelde

	Beam trawl effort			Total phosphate		
Species	estimate	se	t-value	estimate	se	t-value
eel	-0.09	0.17	-0.55	-0.06	0.16	-0.36
herring	-0.03	0.15	-0.17	-0.47	0.15	**-3.24**
sprat	0.22	0.16	1.40	0.33	0.16	**2.11**
smelt	-0.42	0.13	**-3.26**	-0.60	0.13	**-4.66**
cod	-0.25	0.16	-1.64	0.30	0.15	1.97
bib	0.21	0.16	1.30	-0.06	0.16	-0.37
whiting	0.22	0.15	1.48	0.49	0.15	**3.33**
5-bearded rockling	0.27	0.16	1.64	-0.07	0.16	-0.41
eelpout	-0.20	0.16	-1.27	-0.35	0.16	**-2.25**
pipefishes	-0.17	0.17	-1.02	0.05	0.16	0.28
tub gurnard	-0.19	0.16	-1.21	0.32	0.15	**2.08**
grey gurnard	-0.28	0.14	-1.98	0.40	0.14	**2.94**
bull rout	0.04	0.17	0.24	-0.09	0.16	-0.54
hooknose	-0.08	0.14	-0.57	0.53	0.14	**3.76**
sea snail	-0.11	0.12	-0.93	0.65	0.12	**5.47**
sea bass	-0.02	0.11	-0.22	-0.77	0.10	**-7.44**
lesser weever	-0.19	0.13	-1.54	-0.71	0.12	**-5.95**
sandeel	-0.03	0.17	-0.16	-0.04	0.16	-0.26
greater sandeel	0.24	0.14	1.74	-0.43	0.14	**-3.14**
dragonet	0.07	0.16	0.41	-0.22	0.16	-1.36
gobies	0.12	0.17	0.73	-0.10	0.17	-0.63
brill	-0.12	0.16	-0.76	-0.29	0.16	-1.80
dab	0.36	0.13	**2.75**	0.65	0.13	**5.07**
flounder	-0.08	0.17	-0.45	0.08	0.17	0.48
plaice	0.09	0.16	0.54	-0.32	0.16	**-2.03**
sole	-0.36	0.16	**-2.28**	0.13	0.15	0.84

4 Discussion

4.1 Observed patterns

Although the trend analyses for individual species showed large variations, there are several large scale patterns that emerged from these 37 year time series. Firstly total fish densities expressed both in numbers and biomass have decreased strongly since the mid-1980s after an initial increase between 1970 and 1980. This dome-shaped pattern was apparent in all three areas (Figure 3.1.1). The DFA allowed to investigate the common signal in the series of 34 species densities, after correction for the two most dominant explanatory variables. Densities showed similar common trends for the two inshore areas. The common trend for the Dutch coastal zone showed a time lag compared to the Wadden Sea and the Westerschelde (Figure 3.3.1). The canonical correlations (Figure 3.3.2) indicate which species contribute most to the common trend and although the common trend was similar for the Westerschelde and the Wadden Sea, the species contributing most to this trend differed. For the Dutch coastal zone, recently increasing species such as solenette, scaldfish and lesser weever mainly contributed to the common trend (Figure 3.3.2). This explains why the common trend differs from that in the inshore areas, where all these species are less predominant.

Apart from differences in absolute densities the same species sometimes showed different trends in the three areas (e.g. bib, pipefishes, sandeel, plaice). Of these plaice is the only species that shows significant opposite trends (decrease in Wadden Sea and increase in Westerschelde, stable in Dutch coastal zone). The trends in the Wadden Sea and the coastal zone are consistent with the offshore movement of juvenile plaice (van Keeken et al. 2007). Species that showed a decreasing trend in all three areas were hooknose and dab, although the rate of decrease differed. Lesser weever and greater sandeel increased in all areas. The number of species showing recent declines was highest in the Wadden Sea and in the Dutch coastal zone (Table 3.2.1). The Dutch coastal zone is characterized by a number of species with recent strong increases, part of which can be attributed to relatively new species colonizing the area such as lesser weever and sea bass. Solenette and scaldfish show sudden increases since the late 1980s, but inhabited the coastal waters from the start of the series in low densities. They are completely absent from the inshore areas because they avoid low-salinity waters (Amara et al. 2004). The recent increases have been assumed to be related to the increase in seawater temperature, however Amara et al. (2004) showed that small scale solenette distribution was not influenced by temperature. Species that are practically absent from the Westerschelde but are relatively common in the other two areas include poor cod, butterfish and turbot.

4.2 Possible causes of observed patterns

The interpretation of the variables that explained a significant part of the variation in the time trends of the individual species in the DFA is complicated by the collinearity between the variables. In the interpretation, a significant effect of a variable may reflect the role of another collinear variable. For example, for the Wadden Sea there was strong collinearity between seals and cormorants, and between cormorants and phosphate. Therefore we must keep in mind that any effect found might be explained by one of these variables, or even some other variable not incorporated but related to all of these. Other problems with variables used are that short term variation can be large and is not captured in overall means. Also variables that may be relevant such as turbidity (Bolle et al. 2001) and other food groups such as zooplankton and benthos were not available and could not be included. Furthermore the analyses do not give an explanation for patterns observed, they merely indicate correlative relations.

Temperature was significant in explaining part of the variations in the time trends among individual species in the Dutch coastal zone, but not in the Wadden Sea nor in the Westerschelde, while the NAO winter index was not significant in any of the five best DFA models. Recently a large volume of publications has attributed changes in fish densities and distributions to climate change and rise of sea water temperature (Roessig et al. 2004, Rose 2005, Harley et al. 2006, Portner & Knust 2007). Let us first look if we find indications that species with a warm water preference (Lusitanian) show different trends from species with a cold water preference (boreal) (Table 2.1.1). Increases since 1985 (in any of the three areas) were observed more often in Lusitanian (11; 65%) than in boreal species (7; 47%). Declines since 1985 occurred in 5 Lusitanian (29%) and 8 boreal (53%) species (based on the fact that the series consist of 16 boreal and 18 Lusitanian species). This suggests that Lusitanian species show a stronger response than boreal species. The decline in eelpout in the Wadden Sea observed since 1985 corroborates the decline in the coastal waters in Germany that was caused by the increase in temperature above the thermal maximum of the species (Portner & Knust 2007).

Another option is to explore if patterns can be detected in species with different food preferences. As before, we scored the number of species of each food group that showed increases or decreases since 1985 in any of the areas (combination of Tables 2.1.1 and 3.2.1): 0% of planktivores showed a decrease while 57% increased, equal numbers (45%) of shrimp/fisheaters increased and decreased, and 43% of benthivores decreased while 57% increased (based on 7 planktivores, 11 shrimp/fisheaters and 14 benthivores). In conclusion the significant increases and decreases seem to have occurred in all food groups, but relatively more planktivores and benthivores showed increases than the other groups. It should be noted however that the majority of Lusitanian species is also benthivore.

Naturally food and temperature preferences are only two of the possible variables that might explain differences in trends between areas and species. Alternative possibilities can be sought in functional guilds (whether species inhabit the area permanently or only part of the year (Elliott & Dewailly 1995)), age-groups, thermal tolerance (range of their distribution), longevity of species, whether or not the species is commercially exploited and whether or not it concerns species with strong preferences for bottom structures such as mussel beds. Separate DFA analyses on any of these species subgroups may come up with different common trends and allow better interpretations of observed patterns.

The fact that a similar dome-shaped pattern occurred in the two inshore areas would suggest similar mechanisms. Also on individual species level, there are more species declining in the Wadden Sea and Westerschelde than in the Dutch coastal zone. Explanations can be sought in factors related to bottom-up processes (food), top-down processes (predation, fishing) or changes in habitat suitability. In all three areas, DFA showed a significant contribution of variables related to bottom-up (phosphate, run off) and top-down processes (fishing effort, seals).

The significant effect of river run off, phosphate and nitrate in the DFA may reflect the effect of eutrophication of the coastal waters. In the 1960s and 1970s, eutrophication has likely resulted in an increase in primary and secondary production (Beukema & Cadee 1988, Colijn et al. 2002) and may explain the observed increase in fish biomass (Figure 3.1.1). Also the growth rate of plaice is positively related to eutrophication (Rijnsdorp & van Leeuwen 1996, Teal et al. 2008). It is still debated whether the more recent decrease in nutrients resulted in a decrease in the productivity of the coastal waters (Cadee & Hegeman 2002, Philippart et al. 2007). However, Kuipers & van Noort (2008) recently showed that shortly after 2000 the persistently high primary production under low P-discharge of the Rhine seems to have come to an end, with a time lag of more than 10 years.

Because fish are ectoterms, food intake (and also growth) is temperature sensitive (Fonds & Saksena 1978). This complicates the discussion whether the observed changes relate to decreased carrying capacity or increased temperature. To understand the interplay between these, we need information on the temperature sensitivity of growth for each species and on food conditions to evaluate whether individual species are able to use their growth potential (e.g. Teal et al. 2008). Not only may the fish themselves be temperature sensitive, but also their potential predators and prey. Crustaceans (brown shrimp and crab) have a higher temperature tolerance range than their predators and their prey (Freitas et al. 2007). Since mortality of 0-group plaice over the season is mainly attributed to predation by brown shrimp (van der Veer & Bergman 1987, Amara & Paul 2003), an increase in temperature could potentially lead to overall higher predation pressure by crustaceans with negative impacts on flatfish and bivalve recruitment (Freitas et al. 2007).

The significant effect of fishing effort (beam trawl) may reflect the impact of fishing on the size structure and species composition of the North Sea fish assemblage (Daan et al. 2005). Due to the fisheries related removal of larger predatory fish, both the abundance of small fish and small sized fish species has increased over the last 30 years. As several species inhabiting the coastal waters spend part of their life in offshore areas where they are directly or indirectly exposed to fisheries, the changes in the fish assemblage in offshore waters may affect the coastal fish assemblage as well. Shellfish and shrimp fisheries did not appear to have a significant effect series in the Wadden Sea or Westerschelde, although they did in the Dutch coastal zone. Shellfish fisheries will possibly influence the fish assemblage by removal of benthic prey for fish and by the influence on benthic habitats (Piersma et al. 2001, Hiddink 2003, Kraan et al. 2007).

The increase in fish predators over time (notably seals and cormorants) coincides with the decrease in total fish densities, but whether this correlation reflects a causal relationship is not clear at all. Although cormorants are known to feed on juvenile flatfish in the Wadden Sea (Leopold et al. 1998) and seals feed on a variety of fish species (Brasseur et al. 2004), more quantitative information on predation mortality and selectivity of fish predators is needed to get more insight in the nature of the correlation.

5 Recommendations on future research

The analyses presented in this report provide a description of the major changes in the fish community in inshore and coastal areas in the Netherlands and a first attempt to identify possible causal processes. However, at this stage the causes for the observed changes remain highly speculative. Above all, our study clearly showed that no single or simple set of environmental variables can be found to explain the observed patterns. An unequivocal interpretation of the effect of environmental variables was complicated by collinearity between explanatory variables, the omission of possibly relevant variables for which no data were available, and the diversity in species-specific reactions to changes. Furthermore, small scale spatial or temporal variations, of which we have little knowledge, may possibly obscure long-term patterns based on annual and area-aggregated means. In conclusion, correlative research alone is not sufficient to obtain a good understanding of the processes and causal factors underlying the observed trends in fish fauna.

More detailed research is required focussing on mechanisms and processes for specific (groups of) species. The fact that a similar dome-shaped pattern was observed in the common trend for both inshore areas and at the individual species level for several species does however suggest that similar factors are involved for different (groups of) species. Therefore future research focussing on (the interaction of) main environmental drivers is recommended. Based on the present study and the literature we hypothesize that these main environmental drivers include:

- temperature rise
- decrease in nutrients
- effects of fishing

However, the mechanism through which these main environmental drivers affect the abundance and distribution of fish may differ substantially between (groups of) species. The dominance of top-down (predation) or bottom-up (food availability) processes, and hence the influence of environmental changes may differ between species depending on their rank in the food chain. The effect of environmental variables may also vary between habitats (e.g. pelagic, demersal, substrate type) or between functional guilds (e.g. nursery ground species, seasonal visitors, residents). Therefore we recommend that future research is focussed on specific hypotheses for specific (groups of) species.

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Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. 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 2009 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation, with the last inspection being held on the 5th of October 2007.

Justification

Rapport C109/08

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

Approved:	Dr. Oscar Bos Scientist
Signature:	
Date:	29 December 2009

Approved:	Dr. Floris Groenendijk Head of Ecology Department
Signature:	
Date:	29 December 2009

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