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Changes in the fish fauna of the Oosterschelde estuary – a ten-year time series of fyke catches

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Abstract

Frequency of occurrence of fish species was monitored on a fortnightly basis in four fykes and a weir in the Oosterschelde estuary from 1979 through 1988. This was done in order to record changes in the fish fauna that may have occurred as a response to the construction of a storm-surge barrier in the mouth of the Oosterschelde (1984–1986) and the concomitant building of compartmentalization dams in the landward part. These compartmentalization dams reduced the freshwater inflow into the system. Principal component analysis using the annual averages in frequency of occurrence suggests a slight shift occurred in the fish community separating a cluster of years 1979–1984 from the cluster 1985–1988. Many of the changes in individual species could be attributed to fluctuations in yearclass strength or were part of changes occurring on a wider geographical scale. The only impact of the construction works seems to be the decrease in a number of anadromous fish. Fish traps seem to be useful as a monitoring tool for a number of species. The value of the data collected could be improved if catch size and length-frequency data are recorded.

Introduction

Fish traps have until recently rarely been used in fisheries research (Hinz, 1989). Their suitability for the monitoring of biological effects on the fish fauna has been emphasised by Ruth & Berghahn (1989). If fishing is strictly standardised fykes may also be used for the study of long-term trends in flatfish populations (Van der Veer *et al.*, 1992).

Fyke nets have the advantage of being relatively unselective (Ruth & Berghahn, 1989). They sample demersal fish of stony ground, *i.e.* species that are difficult to catch using towed gears. Fykes also catch pelagic species that are only caught incidentally in a beam trawl (Hinz, 1989).

In this study the frequency of occurrence of fish species has been monitored on a fortnightly basis in four fykes and a weir in the Oosterschelde from 1979 through 1988. This was done in order to record changes in the fish fauna that may have occurred as a response to the engineering works in the area. A storm-surge barrier was constructed in the mouth of the Oosterschelde and the building of compartmentalization dams in the landward part reduced the freshwater inflow into the system. In 1984 the impact of the construction works on the hydrodynamics of the system was still very limited. The biggest changes occurred in 1985 and by mid 1987 the new situation was implemented (Nienhuis & Smaal, 1994).

Materials and methods

Commercial fishermen were asked to monitor the catches of four fyke nets and a weir on a fortnightly basis from 1979 through 1988 at different localities in the Oosterschelde (Fig. 1). Both types of gear are described in Nédélec (1982).

The four fykes are located close to the dykes and are deployed for catching eel *Anguilla anguilla* Linnaeus 1758. Fykes are emptied on average every three days. Mesh size is 21 mm stretched.

The weir is a traditional fishery directed at the anchovy *Engraulis encrasicolus* Linnaeus 1758. There are two leaders (often several hundred metres long) of stakes set out on an intertidal flat and converging towards the gully. Fish swimming over the shallow areas at high tide are driven towards the chamber in the V-shaped point of the gear when leaving the tidal flat. When the gear is operated actively large schools of anchovy are directed from the chamber into the net attached to the fyke opening of the chamber. Outside the anchovy season and between active catches there is a fyke net attached to this opening and the device functions more or less like a normal fyke net.

A total of 860 samples were used in the analysis. In the summer of 1986 fishing was hampered because of the presence of large quantities of coelenterates in the Oosterschelde. The time series is incomplete for the easterly stations. The locality Zandkreek was only sampled in spring and autumn. There are no data for this station for 1987. Ice floes destroyed the weir during the winters of 1984–1985, 1985–1986 and 1986–1987 and fishing could only be resumed in April.

With the closure of the Oesterdam in the au-

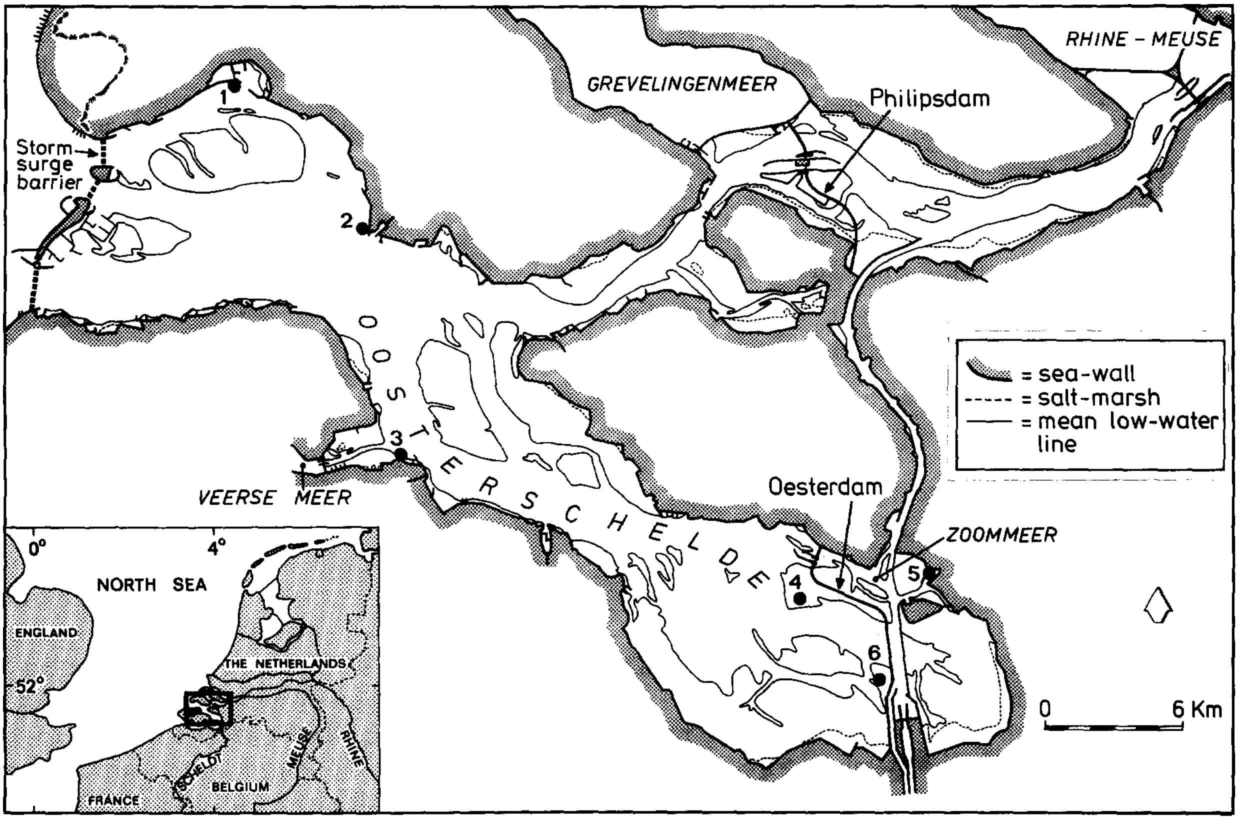

Fig. 1. Oosterschelde estuary with sampling localities; 1 = Schelphoek; 2 = Zierikzee; 3 = Zandkreek; 4 = Speelmansplaat (weir)); 5 = Bergen op Zoom (until 1986); 6 = Oesterdam (after autumn 1987); Inset: Oosterschelde estuary in The Netherlands on the North Sea.

tumn of 1986 the station Bergen op Zoom became part of the Zoommeer. The Zoommeer remained connected rather indirectly to the Oosterschelde through the Philipsdam until April 1987. In the summer of 1987 the Zoommeer became a freshwater lake. Starting in the autumn of 1987 a new locality called 'Oesterdam' was introduced into the monitoring scheme to 'replace' the Bergen op Zoom locality (Fig. 1). However the fish fauna caught in the new locality differs substantially from the fauna at Bergen op Zoom. The data for the Oesterdam were thus not included in the analysis. Repeating all the analyses without the time series data for the Bergen op Zoom locality did not affect the results in any substantial way. All species present in the fyke or the weir were noted. The presence of a fish species in each station was expressed as the percentage of catches in which the species occurred (frequency of occurrence) in a single year. The frequency of occurrence data for the five sampling localities as reported by Meijer (1989), were averaged to yield an annual frequency of occurrence for the 'Oosterschelde'. This annual frequency of occurrence was subjected to the correspondence analysis option in the package CANOCO (Ter Braak, 1987) in order to quantify total community variation. On the basis of the result of this analysis the same data were subjected to the principal component analysis (PCA) option in CANOCO. The frequency of occurrence data were arc sin transformed for normalisation (Sokal & Rohlf, 1981) prior to the PCA. The analysis was repeated after elimination of the species which occurred only in a single year and the species inadequately sampled or difficult to identify. Nilsson's pipefish *Syngnathus rostellatus* Nilsson 1855 and sand goby *Pomatoschistus minutus* Pallas 1769 are too small to be reliably retained and detected in the net. Sand gobies are also liable to predation by larger fish in the catch. Grey gurnard *Eutrigla gurnardus* Linnaeus 1758 was only identified by the fishermen operating the weir. Solenette *Buglossidium luteum* Risso 1810 is rather difficult to identify and may be overlooked in large catches.

A Wilcoxon two sample test (Sokal & Rohlf, 1981) was performed on the annual frequency of occurrence data of the individual species to look for significant differences between the clusters of years distinguished along the first PCA axis. For ranking the frequency of occurrence data differences of less than 1% between years were discarded and indices for those years were considered to be ties.

The product-moment correlation coefficient and Kendall's rank correlation coefficient (Sokal & Rohlf, 1981) were calculated between the arc sin transformed frequencies of occurrence and yearclass strength indices for a number of species.

Results

A total of 67 species were recorded (Table 1). Ten species occurred on average in more than 50% of catches, 11 species occurred in 25–50% of catches, 12 species in 10–25% of catches, 7 species in 5–10 % of catches and 7 species in 1–5% of catches. Another 12 species occurred in less than 1% of catches but were found in at least two years, 9 species were only recorded in a single year.

The correspondence analysis showed that community variation is within a narrow range (less than 1.5 standard deviation units) along the first axis (eigenvalue = 0.03). Thus a linear method (PCA) is more appropriate in this case (Ter Braak & Prentice, 1988).

The results of the PCA on the same data are depicted in Fig. 2. In the sample plot (Fig. 2 bottom) two main clusters can be found in the plane formed by the first two axes (eigenvalues 0.33 and 0.19) with a group 1981–1983 clearly separated from the group 1985–1987 along the first (horizontal) axis. The years 1979 and 1980 are quite far apart within the left upper quadrant of the plane and are clearly separate from the 1981–1983 group along the second (vertical) axis. The year 1984 lies close to the origin. Towards the right of the plane the years 1985–1987 form a rather compact group. The year 1988 lies in the right upper quadrant.

The species plot (Fig. 2 top) is the output for

Table 1. List of species caught in Oosterschelde estuary, ranked according to frequency of occurrence.

Species occurring in > 50% of catches	
Platichthys flesus Linnaeus 1758	0.96
Anguilla anguilla L. 1758	0.90
Zoarces viviparus L. 1758	0.82
Pleuronectes platessa L. 1758	0.80
Myoxocephalus scorpius L. 1758	0.76
Trisopterus luscus L. 1758	0.66
Clupea harengus L. 1758	0.63
Solea solea L. 1758	0.60
Limanda limanda L. 1758	0.52
Merlangius merlangus L. 1758	0,52
Species occurring in 25–50% of catches	
Gadus morhua L. 1758	0.47
Mugilidae species	0.45
Atherina presbyter Cuvier 1829	0.44
Sprattus sprattus L. 1758	0.40
Dicentrarchus labrax L. 1758	0.38
Belone belone L. 1758	0.38
Trachurus trachurus L. 1758	0.32
Alosa fallax Lacépède 1758	0.31
Syngnatus acus L. 1758	0.28
Ciliata mustela L. 1758	0.27
Pholis gunnellus L. 1758	0.26
Species occurring in 10–25% of catches	
Scophthalmus rhombus L. 1758	0.24
Scomber scombrus L. 1758	0.23
Pollachius pollachius L. 1758	0.21
Cyclopterus lumpus L. 1758	0.20
Engraulis encrasicolus L. 1758	0.18
Agonus cataphractus L. 1758	0.17
Ammodytes tobianus L. 1758	0.16
Trigla lucerna L. 1758	0.15
Gasterosteus aculeatus L. 1758	0.14
Oncorhynchus mykiss Walbaum 1792	0.13
Callionymus lyra L. 1758	0.13
Liparis liparis L. 1758	012
Species occurring in 5–10% of catches	
Entelurus aequoreus L. 1758	0.09
Osmerus eperlanus L. 1758	0.08
Dasyatis pastinaca L. 1758	0.08
Sardina pilchardus Walbaum 1792	0.06
Scophthalmus maximus L. 1758	0.06
Salmo trutta L. 1758	0.05
Taurulus bubalis Euphrasen 1786	0.05
Species occurring in 1–5% of catches	
Pollachius virens L. 1758	0.02
Pomatoschistus minutus Pallas 1769	0.02
Mullus surmuletus L. 1758	0.02
Raniceps raninus L. 1758	0.02
Eutrigla gurnardus L. 1758	0.01
Gobius niger L. 1758	0.01
Petromyzon marinus L. 1758	0.01
Species occurring in < 1% of catches	
Lampetra fluviatilis L. 1758	
Conger conger L. 1758	
Microstomus kitt Walbaum 1792	
Syngnathus rostellatus Nilsson 1855	
Spondyliosoma cantharus L. 1758	
Melanogrammus aeglefinus L. 1758	
Galeorhinus galeus L. 1758	
Labrus bergylta Ascanius 1772	
Buglossidium luteum Risso 1810	
Scyliorhinus canicula L. 1758	
Scomberesox saurus Walbaum 1792	
Species recorded only in a single year	
Pomatoschistus microps Krøyer 1838	
Trachinus draco L. 1758	
Squalus acanthias L. 1758	
Crenilabris melops L. 1758	
Arnoglossus laterna Walbaum 1792	
Hyperoplus lanceolatus le Sauvage 1824	
Trisopterus minutus L. 1758	
Balistes carolinensis Gmelin 1789	
Salmo salar L. 1758	

the dataset without the species occurring in only a single year and without the inadequately sampled species. The plot with all species is similar except that a number of species around the origin can not be depicted because of lack of space. Species situated around the extremes of the figure along the first axis are the ones which have shown the biggest changes in frequency of occurrence between the years 1979–1984 and the years 1985–1988. Towards the left of the figure (species typical for the years before the barrier impact) are five bearded rockling *Ciliata mustela* Linnaeus 1758, brill *Scophthalmus rhombus* Linnaeus 1758, sardine *Sardina pilchardus* Walbaum 1792, allis shad *Alosa fallax* Lacépède 1758, Mugilidae species (presumably both thick-lipped grey mullet *Chelon labrosus* Risso 1826 and thinlipped grey mullet *Liza ramada* Risso 1826), sand-smelt *Atherina presbyter* Cuvier 1829, rainbow trout *On-*

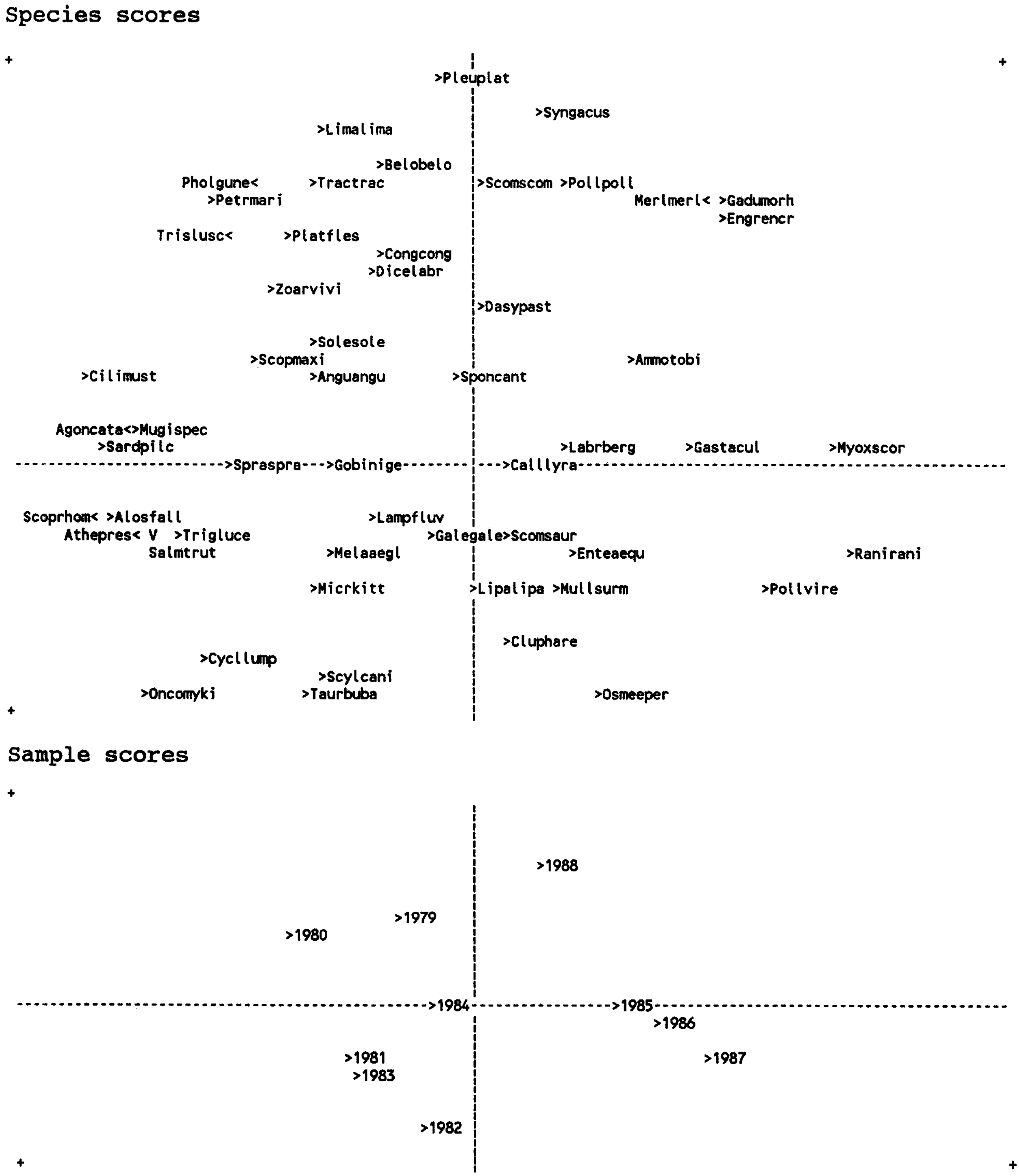

Fig. 2. Result of the Principal Component Analysis for the first two axes. Species scores and sample scores are depicted on the same scale. Species names have been shortened to the first four letters of the genus name plus the first four letters of the species name.

corhynchus mykiss Walbaum 1792, sea trout *Salmo trutta* Linnaeus 1758, tub gurnard *Trigla lucerna* Linnaeus 1758, lumpsucker *Cyclopterus lumpus* Linnaeus 1758, sea lamprey *Petromyzon marinus* Linnaeus 1758, sprat *Sprattus sprattus* Linnaeus 1758, etc. Towards the right of the figure we find the species typical for the years after the barrier impact: tadpole-fish *Raniceps raninus* Linnaeus 1758, bull-rout *Myoxocephalus scorpius* Linnaeus 1758, saithe *Pollachius virens* Linnaeus 1758, cod *Gadus morhua* Linnaeus 1758, anchovy *E. encrasicolus*, whiting *Merlangius merlangus* Linnaeus 1758, three-spined stickleback *Gasterosteus aculeatus* Linnaeus 1758, sandeel *Ammodytes tobianus* Linnaeus 1758, etc.

Significant differences for individual species (Wilcoxon two sample test) between the year blocks as distinguished by the PCA (1979–1984 versus 1985–1988) are shown in Table 2. Significant decreases are found for allis shad *A. fallax*, sea trout *S. trutta*, rainbow trout *O. mykiss*, five-bearded rockling *C. mustela*, sand-smelt *A. presbyter*, tub gurnard *T. lucerna*, lumpsucker *C. lumpus*, sand goby *P. minutus* and brill *S. rhombus*. Significant increases are found for cod *G. morhua*, tadpole-fish *R. raninus* and bull-rout *M. scorpius*.

Table 2. Results of the Wilcoxon two-sample test for species showing significant differences in frequency of occurrence (FO) between clusters of years as distinguished by PCA.

	Average FO 1979–1984	Average FO 1985–1988	
Species with decreased FO			
Alosa fallax	0.38	0.20 **	$p<0.02$
Salmo trutta	0.07	0.02 **	$p<0.02$
Oncorhynchus mykiss	0.18	0.05 *	$p<0.05$
Ciliata mustela	0.33	0.18 *	$p<0.05$
Atherina presbyter	0.51	0.32 *	$p<0.05$
Trigla lucerna	0.19	0.09 ***	$p<0.01$
Cyclopterus lumpus	0.24	0.14 *	$p<0.05$
Pomatoschistus minutus	0.03	0.01 **	$p<0.02$
Scophthalmus rhombus	0.29	0.16 *	$p<0.05$
Species with increased FO			
Gadus morhua	0.38	0.63 **	$p<0.02$
Raniceps raninus	0.01	0.03 *	$p<0.05$
Myoxocephalus scorpius	0.69	0.88 ***	$p<0.01$

Discussion

The use of multivariate techniques in ecology is a rather controversial point at present (review in James & McCulloch, 1990). We have tried to follow their advice as closely as possible and have only used the techniques as a descriptive tool in an exploratory analysis. Following Jongman *et al.*, (1987) we first explored the data using a correspondence analysis (CA), this being a very general (unimodal) model. This gives us the level of variability in the data, which is low, *i.e.* all samples (years) are located within less than 1.5 standard deviations. Ter Braak & Prentice (1988) suggest that non-linear models (like the CA) are inappropriate in these circumstances and linear models (like the PCA) should be used. Following James & McCulloch (1990) we transformed the data for normalisation and used the variance-covariance matrix instead of the correlation matrix. Despite the fact that the Wilcoxon two sample test does not really provide information that is not already apparent from the multivariate analysis it is included in this study because many scientists still feel uncomfortable about the fact that no statistical significance levels are given in the multivariate techniques.

The qualitative dataset, as presently available, is of limited value to describe the changes that occurred in the fish fauna of the Oosterschelde during the construction period. The data can only be used for an exploratory analysis and are certainly not appropriate for any causal investigation. The incompleteness of the time series for the easterly stations may have affected the results.

First of all it is impossible to establish if the fauna caught in the fish traps is in any way representative for the fish fauna of the Oosterschelde. It most certainly cannot be considered to be a random sample: the 5 localities investigated were purposely chosen by the fishermen who, from their experience, selected the best spots to catch either eel or anchovy. Although the fishermen have recorded a crude measure of catch size (1–5, 6–20 and > 20) these data were not available for analysis. For some species we know only single individuals were caught, e.g. allis shad *A. fallax*. As the size of the catches is unknown for all other species the frequency of occurrence is certainly not a measure of fish abundance. Abundant species or species for which the gear is rather selective, *i.e.* eel *A. anguilla* and flounder *Platichthys flesus* Linnaeus 1758 will be almost always present in the catches and changes in abundance would have to be extremely drastic to become apparent. Eel catches are a case in point. Though the frequency of occurrence has decreased slightly the change is not significant. Both in Britain (Swaby & Potts, 1990) and the German Wadden Sea (Tiews, 1990) eel catches have been declining in recent years. The same phenomenon has probably occurred in the Oosterschelde as one of the commercial eel fishermen, involved in the sampling scheme, has had to give up because the fishery was no longer profitable. The other fishermen have had to diversify their fishing activities.

Similarly for schooling species like herring *Clupea harengus* Linnaeus 1758 and sprat *S. sprattus* frequency of occurrence seems not to be a sensitive measure for change. It is a well established fact that with the restoration of herring stocks in the North Sea during the 1980's sprat stocks have gone down again to their pre-1970 levels (Garrod, 1988, Daan *et al.*, 1990). Although a trend in the 'right' direction (increase in herring, decrease in sprat) is recorded in the frequency of occurrence of both species, these trends are not significant.

Catches of the allis shad *A. fallax* always refer to single adult individuals. For this species a change in the frequency of occurrence either reflects a change in phenology, *i.e.* the season in which the fish is present in the Oosterschelde has expanded or contracted or the change reflects a genuine change in abundance. The significant decrease in frequency of occurrence in *A. fallax* thus probably reflects a true change in abundance linked to the reduction of freshwater inflow in the Oosterschelde (Nienhuis & Smaal, 1994). Decreases in other anadromous species *i.e.* sea lamprey *P. marinus*, lampern *Lampetra fluviatilis* Linnaeus 1758 and sea trout *S. trutta* may have occurred for the same reason.

The changes in frequency of occurrence of both lamprey species are not significant mostly because these species are very rarely caught. This means there are a lot of zeroes in the time series that turn up as ties in the Wilcoxon two sample test. Still, frequency of occurrence is seven times lower for sea lamprey and four times lower for lampern in the years 1985–1988. All four species are rare or vulnerable in most of Northwest Europe because of pollution problems in their riverine habitat and engineering works on their migration routes (Aprahamian & Aprahamian, 1990; Swaby & Potts, 1990). For the structure and function of the fish community in the Oosterschelde ecosystem the decline in these species is probably unimportant. However, for the species themselves the marginal habitat offered by the Oosterschelde may have been one of their last refuges from which recolonisation of true estuaries, like the Westerschelde, could have originated after the restoration of water quality in these habitats.

A major problem in the interpretation of the observed changes is to distinguish changes possibly linked to the construction works in the Oosterschelde from natural fluctuations in the size of fish populations over wider areas. This can only be done for species for which we have data on year class strength or for species for which we have reliable data from other areas. In the German Wadden Sea the bull-rout *M. scorpius* increased in the bycatch of shrimp fisheries from 1970 until 1986. Since then it is on the decline again (Tiews, 1990). The increase in frequency of occurrence in the Oosterschelde therefore possibly bears no relationship to the construction works except if the population would remain at the present high level while it is declining elsewhere. From the beam trawl data it appears that *M. scorpius* is much less abundant in 1989 than in the years before (Hostens, unpubl. data). Similarly the decline in the tub gurnard *T. lucerna* is observed both in the Wadden Sea (Tiews, 1990) and the Oosterschelde and may therefore be part of a more general trend in this species.

The rainbow trout *O. mykiss* is not indigenous to the Delta but was introduced into the brackish lake Veerse Meer for 'sports' fisheries. Veerse Meer communicates with the Oosterschelde and the decrease probably reflects population changes in Veerse Meer.

The decrease in frequency of occurrence of the five-bearded rockling *C. mustela* is not matched by a similar decrease in the Wadden Sea. It is a species with a highly variable abundance and has not shown any consistent trend over the past 35 years (Tiews, 1990). A longer time series for the Oosterschelde and more information on the ecological requirements of the species are needed to judge if there may have been an impact of the construction works.

For the sand-smelt *A. presbyter* and the lumpsucker *C. lumpus* the decrease in frequency of occurrence does not seem to have a straightforward explanation. Although lumpsucker declined quite strongly in the Wadden Sea during the 1960's the population seems to have stabilised since then, with even a slight increase during the 1980's (Tiews, 1990). For the sand-smelt there are no data from the Wadden Sea. Both species and the garfish *Belone belone* Linnaeus 1758, which has also decreased (N.S.), spawn in the Oosterschelde and attach their eggs to algae (Wheeler, 1969). If a link exists between the decline in these three species and the construction works it is unclear in what way the impact operated. Needless to say there may be absolutely no link to the construction works, nor any link between the decline in the separate species. One hypothesis may be that the ice floes that moved around the Oosterschelde during the winters of 1984–1985, 1985–1986 and 1986–1987 temporarily damaged the spawning habitat.

For the brill *S. rhombus* no time series for other areas are available. It is therefore difficult to speculate about possible causes.

The increase in the tadpole-fish *R. raninus* seems to be a colonisation phenomenon. The species was first caught in 1982, before the start of the construction works. Initially it was confined to the most seaward stations. It reached the more easterly stations in 1986. It is a species which recently colonised the neighbouring saline Grevelingenmeer (Doornbos, 1985). The lake communicates with the sea through a sluice which may be the source for the increase in tadpole-fish in the Oosterschelde. Possibly the colonisation was helped by the decreased wave action and the reduced current velocities in parts of the Oosterschelde (Vroon, 1994).

For a number of species of commercial fish the Oosterschelde estuary is a nursery area and changes in frequency of occurrence may mainly reflect fluctuations in year class strength. For several species good estimates of yearclass strength for the North Sea covering the time period of this investigation have been published (Rijnsdorp *et al.*, 1991). A notable example is cod *Gadus morhua*. This species has clearly increased in the Oosterschelde and at first sight there seems to be no correlation between frequency of occurrence and year class strength of the same year (Product-moment correlation coefficient $r = 0.09$, N.S.), nor with year class strength of the year before (product-moment correlation coefficient $r = -0.38$, N.S.) (Fig. 3). Thus we might conclude that juvenile cod is using the Oosterschelde more intensively since the construction works. An *ad hoc* explanation could then be that the increased transparency of the water is advantageous for visual predators such as cod and whiting. The next step would be to link the decrease in the sand goby *P. minutus*, one of the preferred prey of juvenile cod and whiting (Vea Salvanes, 1986) to the increase of their predators. However, there is considerable spatial variability in the distribution of the juvenile cod stocks and the strong year class of 1985 was concentrated in the Southern Bight (Rijnsdorp *et al.*, 1991). Thus the high frequency of occurrence in 1985 was probably mainly caused by this phenomenon. Also, in the absence of length-frequency distributions of the fish caught, it is impossible to know which year class is being sampled. From the beam trawl data it appears that small 0-group cod were already present in the Oosterschelde in June 1985 and 1988. In other years, with smaller year classes it is mainly the 1-group cod that visits the Oosterschelde in winter (Hostens & Hamerlynck, 1994). A further complication is due to the fact that the data are at present only available on an annual basis. The 0-group and 1-group cod from a strong year class affect the frequency of occurrence data

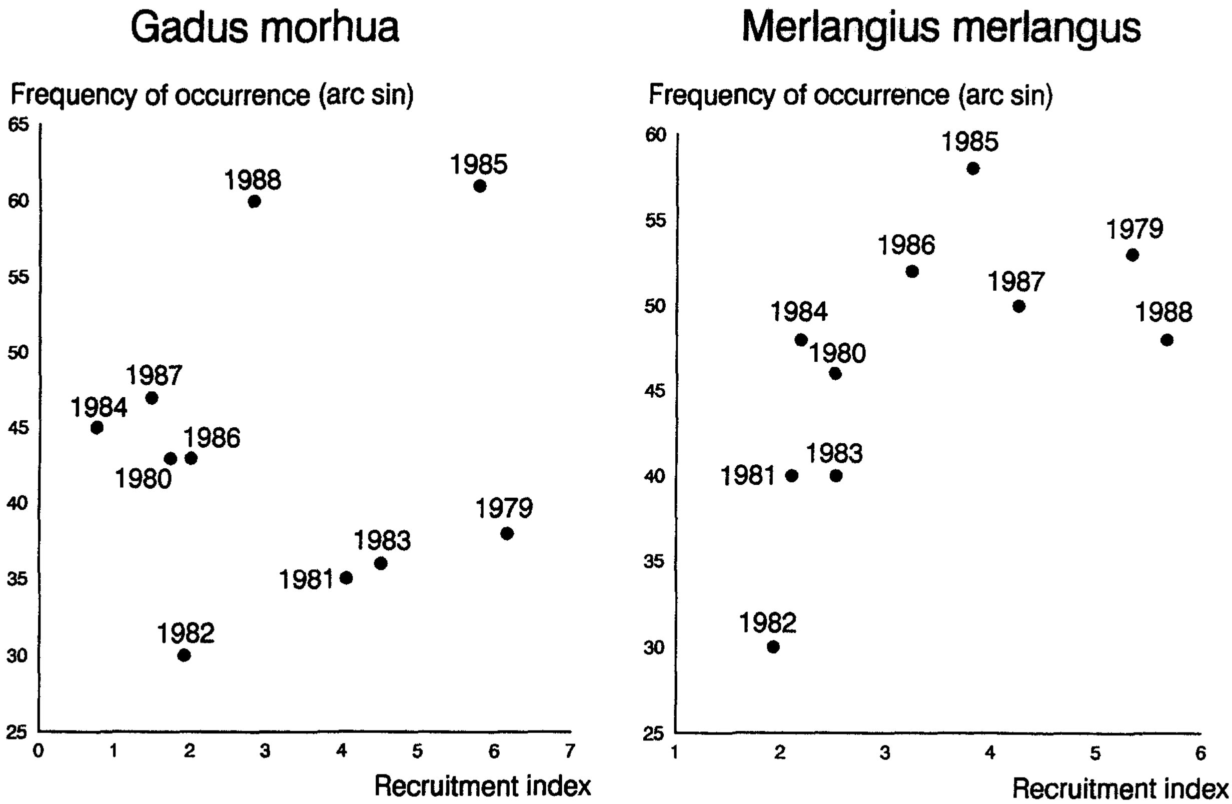

Fig. 3. Relationship between year-class strength expressed as a recruitment index (Anonymous, 1990) and frequency of occurrence in the Oosterschelde for cod (*G. morhua*) and whiting (*M. merlangus*).

of at least two years if they remain present in the Oosterschelde throughout the winter. We believe therefore that the increase in frequency of occurrence in cod is mainly due to the more southerly distribution of recent strong year classes (1985, 1988). For whiting *M. merlangus* an increase in recent years was suggested by the result of the PCA, though it was not significant in the Wilcoxon two sample test, mainly because of the high frequency of occurrence in 1979 (0.53), the second highest on record. For whiting there is a much better correlation between year class strength as estimated by the MSVPA (Anonymous, 1990) and frequency of occurrence in the Oosterschelde (product-moment correlation coefficient $r = 0.61$, $p < 0.1$, Kendall coefficient of rank correlation $\tau = 0.511$, $p < 0.05$) (Fig. 3). For whiting the increase in frequency of occurrence in recent years is thus probably mainly due to the exceptionally poor year classes from 1981 through 1984.

Conclusion

The main part of the observed changes in 'community structure' seems to have no relationship to the construction works and the associated changes in the Oosterschelde estuary. Only the decrease in frequency of occurrence of the anadromous fish seems likely to be linked to the decrease of fresh water inflow in the Oosterschelde. Still, catches in the fykes and the weir seem to reflect changes in abundance of many species quite well. The decrease of *A. cataphractus* and *S. rhombus* and the increase of *M. merlangus* were also observed in the beam trawl surveys (Hostens & Hamerlynck, 1994). For other species such as *A. tobianus* the two studies have conflicting results. The value of the data recorded by the fishermen would be greatly increased if data on size of the catches and length-frequency distributions could be included. Perhaps this would mean too much work for the commercial fishermen. Separate fish traps owned and operated by research institutes could provide relatively cheap and very valuable data on long-term trends in fish species. Care should be taken to assure that gear, location and operation remain extremely constant in time (see also Van der Veer *et al.*, 1992). Longer time-series, especially on non-commercial fish species, are an absolute requirement for the assessment of the ecological impact of civil-engineering works or other human activities on the fish community. Baseline studies from many different areas are needed to be able to distinguish natural fluctuations in abundance levels from those caused by man. For example the mere fact that the winters of 1984–1985, 1985–1986 and 1986–1987 were relatively severe may have been important in causing many of the changes observed within the relatively short time period considered here.

For most species it would make good biological sense to analyse the data using a 'year' starting on March 21th. Very few 0-group will occur before that date and few 1-group or older using the Oosterschelde in winter will still be present around that time.

For ecologists it would be a great help if fisheries research institutes could publish time series of abundance indices for all the species they catch in their annual surveys. These data have been collected in a standardised way over extensive areas for about twenty years and could be immensely valuable for the interpretation of local changes.

Analysing the frequency of occurrence data with descriptive multivariate statistical techniques was successful in summarising the structure in the data, thus allowing us to suspect a slight change in community structure after 1984 and pointing out the species that underwent the most important changes.

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References

Anonymous, 1990. Report of the Roundfish Working Group. ICES CM 1990/Assess: 7 (mimeo).

Aprahamian, M. W. & C. D. Aprahamian, 1990. Status of the genus *Alosa* in the British Isles; past and present. J. Fish Biol. 37 (Suppl. A): 257–158.

Daan, N., P. J. Bromley, J. R. G. Hislop & N. A. Nielsen, 1990. Ecology of North Sea fish. Neth J. Sea Res. 26: 343–386.

Doornbos, G., 1985. The fish fauna of Lake Grevelingen (SW Netherlands: the role of fish in the food chain of a man-made saline lake some ten years after embankment of a former estuary. Ph. D. Thesis, University of Amsterdam, 169 pp.

Garrod, D. J., 1988. North Atlantic cod: fisheries and management to 1986. In J. A. Gulland (ed.), Fish population dynamics, second edition. John Wiley & Sons, Chichester: 185–218.

Gislason, H, 1989. The influence of variations in recruitment on multispecies yield predictions in the North Sea. ICES CM 1989/MSM: 15 (mimeo).

Hill, M. O., 1979. TWINSPAN a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, 90 pp.

Hinz, V., 1989. Monitoring the fish fauna in the Wadden sea with special reference to different fishing methods and effects of wind and light on catches. Helgoländer Meeresunters. 43: 447–459.

Hostens, K. & O. Hamerlynck, 1994. The mobile epifauna of the soft bottoms in the subtidal Oosterschelde estuary: structure, function and impact of the storm-surge barrier; Hydrobiologia 282/283: 479–496.

James, F. C. & C. E. McCulloch, 1990. Multivariate analysis in ecology and systematics: panacea or Pandora's box? Annu. Rev. Ecol. Syst. 21: 129–166.

Jongman, R. H. G., C. J. F. ter Braak & O. F. R. van Tongeren, 1987. Data analysis in community and landscape ecology. Pudoc, Wageningen, 299 pp.

Meijer, A. J., 1989. Monitoring-onderzoek aan de visfauna van de Oosterschelde. Rapportage Resultaten 1988. Bureau Waardenburg bv, Culemborg, 30 pp.

Nédélec, C., 1982. Definition and classification of fishing gear categories. FAO Fish. Techn. Pap. 222: 51 pp.

Nienhuis, P. H. & A. C. Smaal, 1994. The Oosterschelde estuary, a case study of a changing ecosystem: an introduction. Hydrobiologia 282/283: 1–14.

Rijnsdorp, A. D., N. Daan, F. A. van Beek & H. J. L. Heesen, 1991. Reproductive variability in North Sea plaice, sole, and cod. J. Cons. int. Explor. Mer 47: 352–375.

Ruth, M. & R. Berghahn, 1989. Biological monitoring of fish and crustaceans in the Wadden Sea – potential and problems. Helgoländer Meeresunters. 43: 479–487.

Sokal, R. R. & F. J. Rohlf, 1981. Biometry (second edition). W. H. Freeman, San Francisco, 959 pp.

Swaby, S. E. & G. W. Potts, 1990. Rare British marine fishes – identification and conservation. J. Fish Biol. 37 (Suppl. A): 133–143.

Ter Braak, C. J. F., 1987. CANOCO – a FORTRAN program for canonical community ordination by (partial) (detrended) (canonical) correspondence analysis, principal components analysis and redundancy analysis (version 2.1). ITI-TNO, Wageningen, 95 pp.

Ter Braak, C. J. P. & I. C. Prentice, 1988. A theory of gradient analysis. Adv. ecol. Res. 18: 271–317.

Tiews, K., 1990. 35-Jahres-Trend (1954–1988) der Häufigkeit von 25 Fisch- und Krebstierbeständen an der deutschen Nordseeküste. Arch. Fish Wiss. 40: 39–48.

Van der Veer, H. W., J. IJ. Witte, M. A. Beumkes, R. Dapper, W. P. Jongeman & J. van der Meer, 1992. Intertidal fish traps as a tool to study long-term trends in juvenile flatfish. Neth. J. Sea Res. 29: 119–126.

Vea Salvanes, A. G., 1986. Preliminary report from a comparative study of four gadoid fishes in a fjord of western Sweden. ICES C.M. 1986/G:71 (mimeo).

Vroon, J., 1994. Hydrodynamic characteristics of the Oosterschelde in recent decades. Hydrobiologia 282/283: 17–27.

Wheeler, A., 1969. The fishes of the British Isles and north west Europe. MacMillan, London, 613 pp.

Witte, J. IJ., H. W. van der Veer & J. van der Meer, in press. Intertidal fish traps as a tool to study long-term trends in juvenile flatfish. Neth. J. Sea Res.