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Fish assemblages across a salinity gradient in the Zeeschelde estuary (Belgium)

Jan Breine[1]*, Joachim Maes[2], Frans Ollevier[3] & Maarten Stevens[4]

[1] Research Institute for Nature and Forestry, Duboislaan 14, B-1560 Groenendaal, Belgium and Laboratory of Aquatic Ecology and Evolutionary Biology, Katholieke Universiteit Leuven, Charles Deberiotstraat 32, B-3000 Leuven, Belgium.
[2] European Commission, Joint Research Centre, Institute for Environment and Sustainability, Rural, Water and Ecosystem Resources Unit, Via E. Fermi 2749, I-21027 Ispra (VA), Italy.
[3] Laboratory of Aquatic Ecology and Evolutionary Biology, Katholieke Universiteit Leuven, Charles Deberiotstraat 32, B-3000 Leuven, Belgium.
[4] Research Institute for Nature and Forestry, Kliniekstraat 25, B-1070 Brussels, Belgium.

* Corresponding author: Jan Breine, E-Mail: jan.breine@inbo.be

ABSTRACT. Between 1991 and 2008 a total of 71 fish species was recorded in the brackish and fresh water zone of the Schelde estuary (Zeeschelde). The results were obtained from fish surveys from the cooling water filter screens of the power plant at Doel (between 1991 and 2008) and fyke net surveys along the length of the estuary between 1995 and 2008. Species abundance in the different salinity zones was analysed using the fyke net data only. The ten most abundant species represent 90.8% of the total number of individuals caught. In decreasing order of abundance: flounder *(Platichthys flesus),* roach (*Rutilus rutilus*), herring (*Clupea harengus*)*,* eel (*Anguilla anguilla*), pike-perch (*Sander lucioperca*), sole (*Solea solea*)*,* common goby (*Pomatoschistus microps*), seabass (*Dicentrarchus labrax*), three-spined stickleback (*Gasterosteus aculeatus*) and white bream (*Blicca bjoerkna*). With fyke nets 33 species were caught in the tidal freshwater zone, 43 species in the oligohaline zone and 59 species in the mesohaline zone. Each salinity zone is characterised by a typical fish assemblage, although some species are shared between all three salinity zones: e.g. three-spined stickleback (*Gasterosteus aculeatus*), Prussian carp (*Carrasius gibelio*), roach (*Rutilus rutilus*) and eel (*Anguilla anguilla*). Diadromous species occur in all zones and make up, on average up 22% of the species richness. Freshwater species comprise about 70% of the species in the tidal freshwater zone. In the oligohaline zone the contribution of the freshwater species to the species richness is less while marine migrants become more abundant. As expected, the contribution of marine migrants and estuarine species is higher in the mesohaline zone. The recent increase in species richness in the freshwater and oligohaline zone coincides with a remarkable increase in dissolved oxygen since 2007.

KEYWORDS: fish assemblages, spatial variation, low salinity zone, functional guilds

INTRODUCTION

Estuaries play a key role in nutrient cycling and transformation, and are an essential habitat in the life cycle of many organisms, in particular fish and waterfowl (COLCLOUGH et al., 2005; MCLUSKY & ELLIOTT, 2004). An estuary is the part of a river that is under tidal influence and is characterised by a continuous salinity gradient (FAIRBRIDGE, 1980). Hence fish assemblages in estuaries are very diverse and composed of marine, estuarine, freshwater and migrating species (HENDERSON, 1988; LOBRY et al., 2003). ELLIOTT & DEWAILLY (1995) assessed the fish assemblage structure in 17 European estuaries. They identified functional guilds according to the habitat use of each fish species encountered. This guild approach facilitates the comparison of fish assemblages across different estuaries (e.g. LOBRY et al., 2003). Recently FRANCO et al. (2008) validated the functional guild approach. Estuaries in Northwest Europe have been the subject of considerable research focussing on the functioning of the different habitats (e.g. DOLBETH et al., 2007; ELLIOTT et al., 2007). Their role as nursery and feeding areas, refuges and migration routes have been described for specific estuaries such as the Zeeschelde (MAES et al., 2007, 2008), the mudflats in the Westerschelde (CATTRYSSE et al., 1994) and the Forth estuary (ELLIOTT et al., 1990). Other research focused on spatiotemporal patterns in fish composition and assemblage structure indicating that fish communities differ in space and time (POTTER et al., 1997; MARSHALL & ELLIOTT, 1998; ARAÚJO et al., 1999; THIEL & POTTER, 2001; JOVANOVICK et al., 2007; SELLESLAGH & AMARA, 2008; SELLESLAGH et al., 2009). Spatial patterns in estuarine species assemblages are mainly correlated with salinity (HENDERSON, 1989), while temporal variations are mostly the result of migration of young fish (MAES et al., 1998; THIEL & POTTER, 2001).

The fish community in the Zeeschelde, the Belgian part of the Schelde estuary, has been studied since the 1990s. However, studies in the earlier years were generally limited to the mesohaline and oligohaline zone, occasionally including one site in the freshwater zone (e.g. VAN DAMME et al., 1994; MAES et al., 1997; MAES et al., 1998, b; MAES et al., 1999, MAES et al., 2004; STEVENS, 2006; STEVENS et al., 2006; CUVELIERS et al., 2007; BUYSSE et al., 2008 and GUELINCKX et al., 2008). VRIELYNCK et al. (2003) give a historical overview of fish species present in the salt and brackish parts of the Zeeschelde and its tributaries. The Rupel (oligohaline tributary) and Durme (freshwater tributary) have been surveyed annually since 2004 (e.g. VAN THUYNE & BREINE, 2008). Since 2007 volunteers monitor fish all year round at different sites along the salinity gradient of the Zeeschelde, including the tidal freshwater zone.

The main aim of this study is to describe the fish assemblage along the salinity gradient in the Zeeschelde estuary based on sampling results in the mesohaline, oligohaline and tidal freshwater zone and to provide an overview of its temporal and spatial variation (measured as species richness and abundance).

MATERIAL AND METHODS

Study area

The river Schelde is a tidal lowland river with its origin in the northern part of France (St. Quentin), and its mouth in the North Sea near Vlissingen, The Netherlands. With a total length of 355 km, the fall is approximately 100 m and the mean depth about 10 m (BAEYENS et al., 1998). The main river and tributaries are rain-fed, with a minimal discharge in summer and autumn, causing the salt water to penetrate further upstream in these seasons. At the mouth the average tidal range is 4.2 m (average spring tide in period 2000-2010). The tide penetrates 160 km upstream where the average tidal range is 2.34 m (average spring tide in period 2000-2010).

In the Zeeschelde (the Belgian part of the estuary, Fig. 1) three zones are distinguished based on the Venice system (1959): a mesohaline zone (5-18) between Zandvliet and Antwerpen, an oligohaline zone (0.5-5) between Antwerpen and Temse, including the Rupel tributary, and a tidal freshwater zone till Gent including the Durme tributary. In Gent the effect of the tide is abated by a complex of sluices. The Rupel is an oligohaline tributary. The tidal part of the Durme was interrupted downstream of Lokeren in the 1960's and functions now as a large freshwater tidal creek of the main river. The tidal amplitude in the Durme is quite large (average 5.40 m at Tielrode); therefore habitat conditions change drastically between incoming and outgoing tides. Both Rupel and Durme have important mudflats (26 and 24 ha) and marshes (43 and 100 ha).

The oligohaline zone has been impacted for decades by untreated sewage water from metropolitan Brussels. From 1925 onwards fish was absent in the Rupel river (VRIELYNCK et al., 2003). Also the industrial areas of Lille (France), Gent and Antwerpen (Belgium) and Vlissingen (The Netherlands) had a major negative impact on the estuarine water quality (VAN ECK et al., 1991). For years the Zeeschelde downstream of Antwerpen remained anoxic, creating an effective barrier for diadromous fish (MAES et al., 2007, 2008). As water treatment efforts increased and diffuse pollution along the river reduced, the water quality improved and a shift in oxygen regime and nutrient cycling was observed (MARIS et al., 2008, VAN DAMME et al., 2005; VAN DEN BERGH et al., 2005). Since March 2007 most sewage water from Brussels is treated and since then the oxygen concentration in the River Rupel increased markedly (VAN THUYNE & BREINE, 2008; STEVENS et al., 2009). However, the Zeeschelde still receives significant discharges of untreated industrial and domestic waste water, as well as diffuse pollution from agricultural runoff, resulting in a poor water quality in a large part of the estuary.

Data collection

Data were collected at 32 different sites in the Zeeschelde and its tributaries (Fig. 1). Samples were taken using fyke nets between 1995-1999 and 2001-2008 in the mesohaline zone and between 1997-1999 and 2001-2008 in the other salinity zones. Collections at the cooling water intakes of the power station at Doel (Fig. 1, #23) were made between 1991-2001 and 2003-2008. The Doel data set was used to complete the species list of the mesohaline zone (presence/absence). All field work was performed by trained fish biologists and trained volunteers using a standardised protocol (see BREINE et al., 2007). All fish were identified to species level, counted and released back into the estuary. Occasional cross examination in the laboratory assured the quality of the fish identification.

Data were collected by assignments from

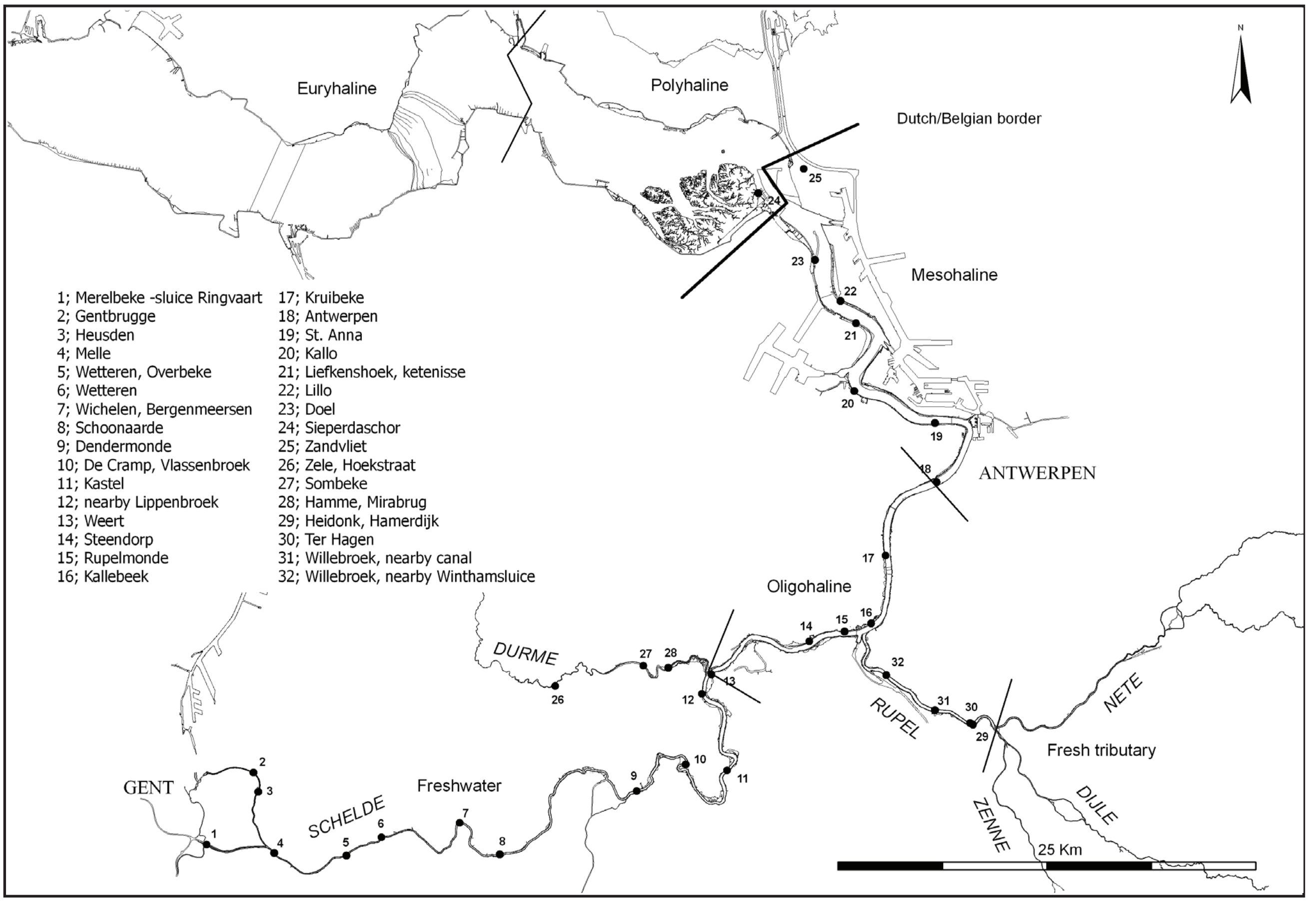

Fig. 1. – Map of the Zeeschelde Estuary with indication of the sampling sites.

TABLE 1

An overview of the sites surveyed between 1991 (including Doel) and 2008. All sites were surveyed with fyke nets except the cooling circuit at Doel.

RIVER	SITE (number in Fig. 1)	PERIOD	NUMBER OF SURVEYS (1 survey = 24 h)	NUMBER OF FYKES
Schelde	Merelbeke (1)	2003	2	1
Schelde	Merelbeke – sluice Ringvaart (1)	2002	12	1
Schelde	Gentbrugge (2)	1997	1	1
Schelde	Heusden (3)	2002	11	1
Schelde	Melle (4)	1997	4	1
Schelde	Melle (4)	2002	12	1
Schelde	Overbeke, Wetteren (5)	2007-2008	4	2
Schelde	Wetteren (6)	2007	4	2
Schelde	Uitbergen, Wichelen (7)	2008	4	2
Schelde	Schoonaarde (8)	1997	2	1
Schelde	Dendermonde (9)	1997	4	1
Schelde	De Cramp, Vlassenbroek (10)	2007-2008	44	1
Schelde	Kastel (11)	2002-2007	17	2
Schelde	Lippenbroek (12)	2006-2008	158	1
Schelde	Weert (13)	2007-2008	43	1
Schelde	Steendorp (Notelaar) (14)	2008	6	2
Schelde	Steendorp (14)	2002-2007	14	2
Schelde	Steendorp (14)	1997	4	1
Schelde	Steendorp (14)	1998	8	1
Schelde	Steendorp (14)	2001	5	1
Schelde	Rupelmonde (15)	2007-2008	62	1
Schelde	Kallebeek (16)	1997	1	1
Schelde	Kruibeke (17)	1997	4	1
Schelde	Antwerpen (18)	1997	4	1
Schelde	Antwerpen (18)	1998	8	1
Schelde	Antwerpen (18)	2001	6	1
Schelde	Antwerpen (18)	2002-2007	12	2
Schelde	Antwerpen (18)	2007-2008	398	1
Schelde	St. Anna (19)	2004-2005	304	1
Schelde	Kallo (20)	1995-1998	11	1
Schelde	Kallo (20)	2008	25	1
Schelde	Liefkenshoek, Ketenisse (21)	2007-2008	185	1
Schelde	Lillo (22)	1995	4	1
Schelde	Doel (23)	1991-2008	170	
Schelde	Sieperdaschor (24)	1997-1999	9	1
Schelde	Zandvliet (25)	1995-2004	197	1
Schelde	Zandvliet (25)	2005-2007	6	2
Durme	Zele (26)	2004-2008	5	2
Durme	Sombeke (27)	2004-2007	4	2
Durme	Hamme, Mirabridge (28)	2004-2008	5	2
Rupel	Heidonk, Hamerdijk (29)	2004-2008	5	2
Rupel	Heidonk, Hamerdijk (29)	2007-2008	56	1
Rupel	Ter Hagen (30)	2007-2008	29	1
Rupel	Willebroek, near canal (31)	2004-2008	5	2
Rupel	Willebroek, Wintham sluice (32)	2004-2008	5	2

the Flemish Environmental Agency (VMM), Association of Industrial Companies of North Antwerpen (VIBNA, Vereniging van de Industriële Bedrijven van Noord-Antwerpen), Department of Mobility and Public Affairs, division Maritime Access (MOW) and the Research Institute for Nature and Forest (INBO, Instituut voor Natuur- en Bosonderzoek). For the period 1997-1999 data from the mesohaline reach near Sieperdaschor (Fig. 1, #24) were obtained from a volunteer fishing with paired fykenets.

Table 1 gives an overview of the survey campaigns at the sites, illustrating differences of sampling effort between the zones.

For each sampling location, monthly oxygen concentrations in the different salinity zones were obtained from the OMES database (http:www.vliz.be/projects/omes/) (i.e. 32). If not available, data from the nearest sites within the zone were used. In the OMES project, tidal-independent oxygen measurements are taken monthly from a boat. Maris et al (2008) compared these point measurements with continuous measurements (2 week periods) and observed no time-related differences in oxygen values. For each year (1997-2008) the annual average values were calculated using this data.

Sampling gear

Fyke nets

At each location one or two 'paired-fyke' nets were deployed near the low-tide mark for two tidal cycles (24 h) and emptied the next day (Table 1). Some sites were surveyed during two successive days. Each paired-fyke consists of two fyke ends of 2.2 m long, linked by an 11 m leader net (0.5 cm mesh size). The largest hoop measures 0.8 m and has an oblate basis of 1.2 m to make sure that the net stays upright. Fish are directed by the leader into the fyke and collected in the last chamber with a mesh size of 8 mm.

Intake screens at the power station Doel

The cooling water is drawn through a multiple intake system (25 m^3s^{-1}) at 2 m above the bottom of the estuary and filtered by two vertical travelling screens with a mesh size of 4 mm. The screens prevent larger organisms and debris from obstructing the condensers (Maes et al., 2004).

Data analysis

The oxygen variation between the salinity zones was assessed with a nested ANOVA (log (x+1) transformed monthly data). The numbers of individuals caught with fyke nets were transformed to catch per unit effort (CPUE); i.e. the total number of individuals is divided by the number of fykes used and the number of days. CPUE data were pooled per month, season and year, log (x+1) transformed and analysed with a non-metric multidimensional scaling (NMDS) ordination to examine the spatial organization of the fish assemblage. Only data from samples that were taken in the same month and year in all three salinity zones were retained for the analysis. This corresponds, for the period 1997-2008, with 28 pooled CPUE data for each zone. Dissimilarity matrices were calculated from log (x+1) transformed fish abundance data, using Bray-Curtis distances. The NMDS ordination was created using random starting configurations and iterated until solutions converged. The vegan package in R 2.6.2 was used for the analysis (Oksanen et al., 2006, R Development Core Team). To reduce the effect of rare species, only the 15 most abundant species in each salinity zone were included for analysis (i.e. 22 species). To test for spatial differences in the fish assemblages a Discriminant Analysis (DA) was applied to the same data. The estimated distinctiveness of fish assemblages was calculated using Wilk's Lambda criterion (λ) (Castillo-Rivera et al., 2002). This value ranges from 1 (similar groups) to 0 (different groups). A PCA with spring (March-May) and autumn (September-November) catches assessed the species contribution within each salinity

TABLE 2

Annual minimum (min), maximum (max) and average dissolved oxygen values (mg l^{-1}) for the different zones in the tidal Zeeschelde between 1997 and 2008 (source OMES).

YEAR	FRESHWATER			OLIGOHALINE			MESOHALINE		
	min	average	max	min	average	max	min	average	max
1997	1.4	3.3	7.4	1.0	2.2	6.0	5.6	5.6	7.1
1998	1.7	4.6	9.2	1.7	3.4	8.1	4.8	6.8	9.1
1999	0.9	2.8	11.7	0.8	2.1	4.6	3.1	6.0	6.7
2000	1.6	2.3	3.3	2.6	4.3	8.2	3.1	5.6	10.0
2001	1.2	3.6	6.6	1.9	4.2	5.1	3.7	5.3	6.0
2002	4.0	6.1	8.5	1.7	4.0	7.2	4.8	6.4	10.1
2003	4.1	5.1	8.0	3.2	4.4	5.5	5.3	7.7	11.8
2004	6.2	5.5	13.4	2.5	4.0	6.3	2.2	6.5	10.2
2005	5.3	5.8	9.4	1.2	2.5	9.4	1.9	3.9	9.8
2006	1.7	5.7	10.2	0.9	3.0	6.7	2.6	7.9	10.8
2007	4.5	7.0	9.0	1.2	5.2	8.5	1.9	7.0	8.6
2008	4.3	7.8	10.2	2.5	6.1	9.2	5.1	7.1	8.9

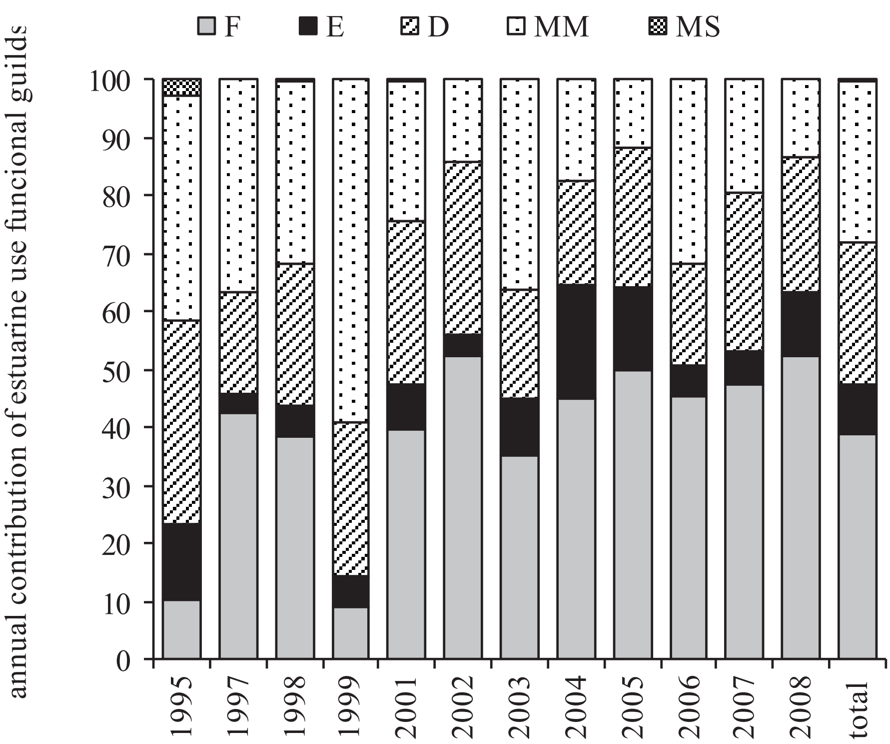

Fig. 2. – The annual contribution (% CPUE) of the estuarine use functional guilds in the Zeeschelde between 1995 and 2008. (F: freshwater species; E: estuarine residents; D: diadromous species; MM: marine migrant species; MS: marine stragglers).

zone. We used the ten most abundant species in each salinity zone for this analysis.

RESULTS

Dissolved oxygen

Minimum, maximum and average annual values, for dissolved oxygen in the different salinity zones for the years 1997-2008 are presented in Table 2. They indicate in general and for all zones an increase in dissolved oxygen over this period. The increase of the average annual dissolved oxygen concentration during the observation period is highest in the freshwater zone. There is a significant difference in monthly oxygen concentration between the different zones (ANOVA: $F=10.315$; $p<0.001$). The lowest minimum and average values are recorded in the oligohaline zone.

Fish inventory

Fyke net catches

In total 66 species were caught between 1995 and 2008 (Table A, annex). In the mesohaline zone, 59 species were caught during 741 fishing occasions (day catches) between 1995 and 2008. In the oligohaline 43 species were collected during 632 fishing occasions between 1997 and 2008. In the freshwater zone 33 species were caught during 336 fishing occasions between 1997 and 2008. Figure 2 gives an overview of the total catch in the Zeeschelde (period 1995-2008) with regard to the guild composition.

In the Zeeschelde we distinguished five functional guilds (ELLIOTT et al., 2007; FRANCO et al., 2008). Their annual contribution changes over the years. In the early 1990's nearly no fish were caught in the freshwater and oligohaline zone. This is reflected by the low contribution of freshwater species. Their contribution became more important from 2001 onwards. The annual guild contribution in each salinity zone is described further in the text.

Zone differences

Between 1997 and 2008, 28 fishing occasions took place in the same month in all the salinity zones (Table 3). During these surveys, 59 species were caught of which 22 were selected for the NMDS ordination.

The NMDS ordination shows a clear distinction between the different zones (Fig. 3). The catches in the different salinity zones form three distinct groups. For the freshwater zone (Dots) summer and autumn catches form two separate groups. The spring catches are scattered alongside these two groups. In the oligohaline zone (Triangles) summer and spring catches form two separate groups. The winter and autumn catches are situated along these groups. In the mesohaline zone (Squares) we observe a large overlap among the seasons with spring and summer catches forming separate groups.

Species such as plaice (*Pleuronectes platessa*), herring (*Clupea harengus*), seabass (*Dicentrarchus labrax*) and smelt (*Osmerus eperlanus*) are typical for the mesohaline zone. In the oligohaline zone the presence of common goby (*Pomatoschistus microps*) and herring is responsible for the differentiation from the freshwater zone, while the presence of freshwater species is responsible for the separation from

TABLE 3

Common fishing occasions in the three salinity zones.

YEAR	1997	2002	2003	2004	2005	2006	2007	2008
MONTH	3 9 12	3 9	9	3 4 9	3 4	9	3 4 5 6 7 8 10 11 12	1 4 5 6 7 8 9

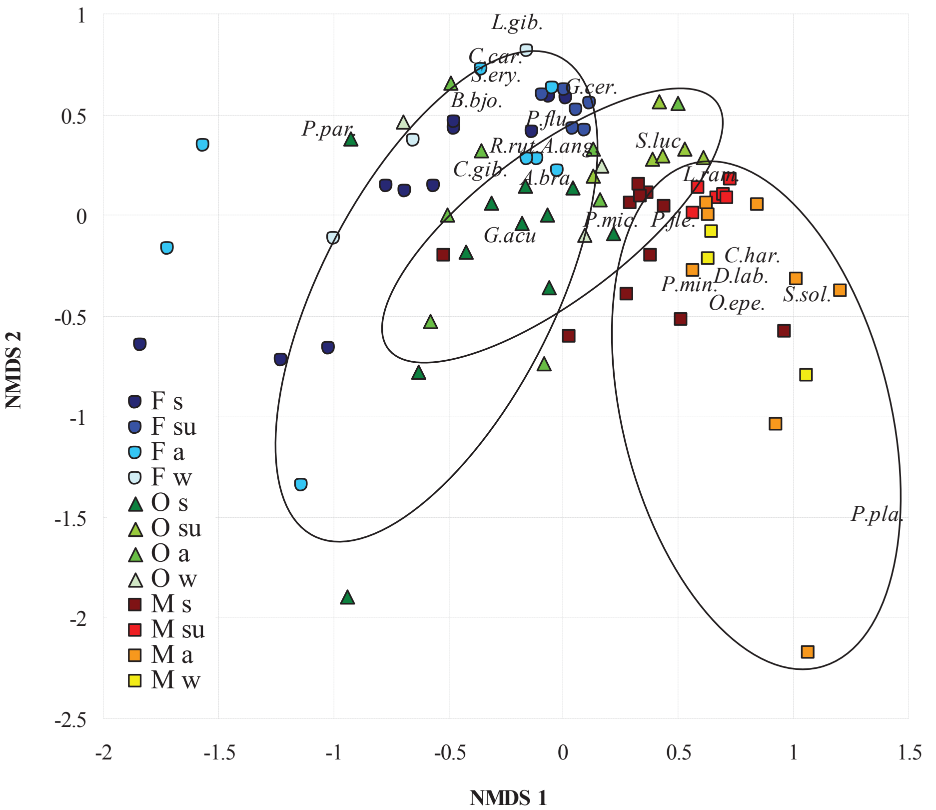

Fig. 3. – Non-metric multidimensional scaling (NMS) ordination of fish abundance data (CPUE) for the different salinity zones of the Zeeschelde estuary between 1997 and 2008 (n=84) (F: freshwater ●; O: oligohaline ▲; M: mesohaline ■; s: spring; su: summer; a: autumn; w: winter). For fish abbreviations see Table A in annex.

the mesohaline zone. Some ordination points of different zones are close together due to species with a comparable abundance in all zones e.g. three-spined stickleback (*Gasterosteus aculeatus*), white bream (*Blicca bjoerkna*), Prussian carp (*Carassius gibelio*), roach (*Rutilus rutilus*) and eel (*Anguilla anguilla*). This explains also the overlap observed for the freshwater and oligohaline zone.

The DA on the log-transformed CPUE of species with zone as grouping variable revealed a significant difference between the zones: λ= 0.029, p<0.0001, with more than 95% correctly classified cases.

Freshwater zone

In the freshwater zone 33 species were collected between 1997 and 2008 (Table A, annex). We grouped fish into guilds or functional groups according to Franco et al. (2008) to facilitate comparison between the salinity zones. Freshwater species comprised 69.7% of the total species richness and contributed 78.9% to the total number of individuals recorded (Total, Fig. 4). The marine migrants contributed only 0.04% to the total number caught and were only recorded during 2008. Diadromous species make up 18.2% of the species richness and 19.3% of the individuals recorded. In 1997 only a few diadromous specimens were caught but this guild was well represented from 2005 onwards. Two estuarine species (common goby *Pomatoschistus microps* and sand goby *P. minutus*) have been encountered yearly in the freshwater zone since 2006. They had already been recorded occasionally in 1997 and 2004. Estuarine species contributed 1.7% to the total number of individuals caught. The annual guild contribution (relative percentage) is given in figure 4.

A PCA with annual spring and autumn catch

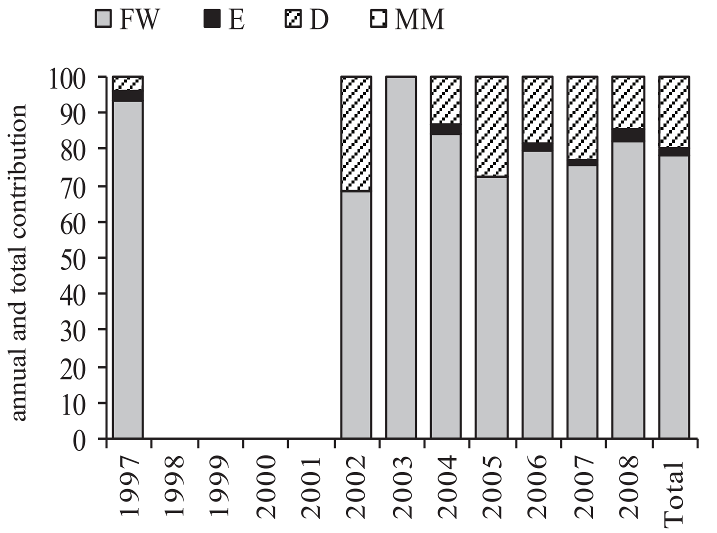

Fig. 4. – The annual and total contribution (% CPUE) of the estuarine use functional guilds in the freshwater zone of the Zeeschelde between 1997 and 2008. (F: freshwater species; E: estuarine residents; D: diadromous species; MM: marine migrant species).

data (CPUE, log (x+1) transformed) groups all the results obtained before 2007 to the right of the first axis (Fig. 5). Factor 1 explains 39.8% and the second factor 17.9% of the variance.

The gradual increase in number of individuals separates the 2007 and 2008 catches from the previous years. The 2002 catches are separated because of the presence of white bream (*Blicca bjoerkna*, factor loadings -0.07;-0.95) and flounder (-0.36;-0.86). The year 2002 was a very wet one (Maris et al., 2008). The catch results in 2008 are similar to those in 2007 but they are separated in the scatterplot mainly because of pike-perch (-0.94;0.07), rudd (*Scardinius erythrophthalmus*, -0.98;0.04), Prussian carp (*Carrasius gibelio*, -0.95;0.14) and perch (*Perca fluviatilis*, -0.95;-0.01).

The CPUE log (x+1) transformed data of the freshwater zone are represented in figure 6. All survey data are included in order to to show the trend in fish abundance over the years. The figure shows that the abundance and species richness increase from 2004 on and that roach is the most abundant species in the freshwater zone contributing 27.9% of the total number of individuals. An increasing number of flounder (21.5%), pike-perch (8.1%), white bream (7.2%) and rudd (4.7%) were caught since 2005. At present the most abundantly caught species are flounder, common goby, pike-perch, roach and white bream.

Oligohaline zone

In the oligohaline zone 43 species were caught between 1997 and 2008 (Table A). 53.5% are freshwater species, contributing 62.9% to the total abundance. Nine marine migrant species contribute 5.3% to the total abundance, while they contribute 20.9% to the species richness. Some of the marine migrants, e.g. herring (*Clupea harengus*), were collected yearly but the highest number (CPUE) of marine migrants was caught in 2007 and 2008. Diadromous species make up 19.9% of the species and 14% of the individuals caught. Of this guild only eel and flounder were caught in all years, the other diadromous species were caught regularly since 2007. The two estuarine species, common and sand goby, were recorded in the oligohaline zone since 2003 and 1997 respectively. Since 2007 the greater pipefish (*Syngnathus acus*) was also caught and contributes, together with the two gobies, 11.9% to the total abundance. Occasionally marine stragglers venture in the oligohaline zone, e.g. Lozano's goby (*Pomatoschistus lozanoi*) and the

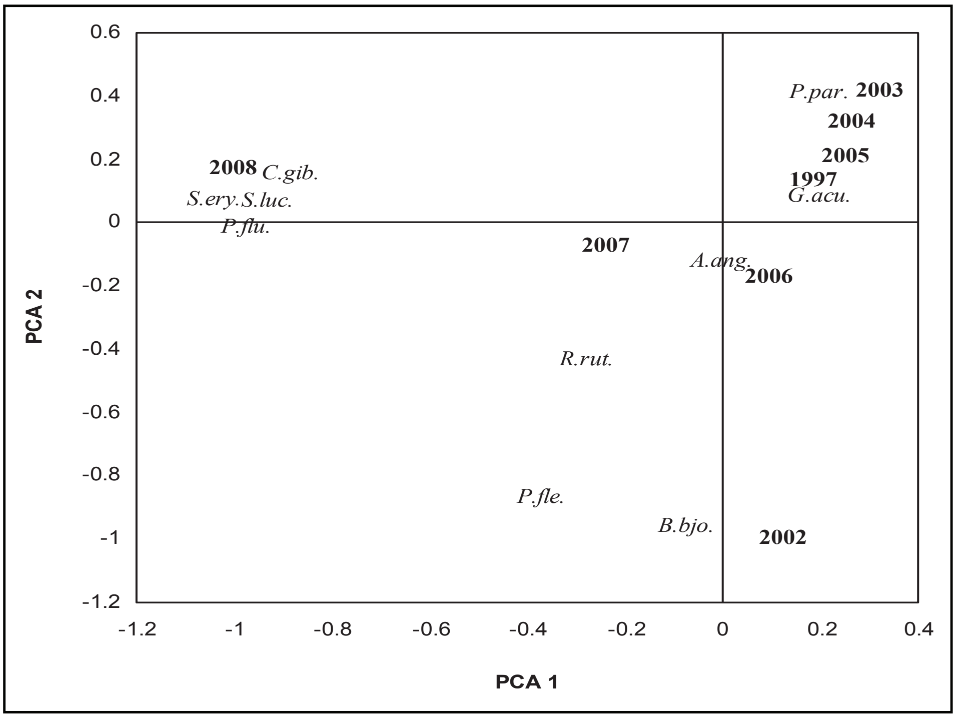

Fig. 5. – Scatterplot of factor loadings categorized by year obtained by PCA with log (x+1) transformed number of individuals caught (CPUE) and factor loadings of the ten most abundant species in the freshwater zone of the Zeeschelde estuary between 1997 and 2008 (spring and autumn catches, n=26). Abbreviations see Table A in annex.

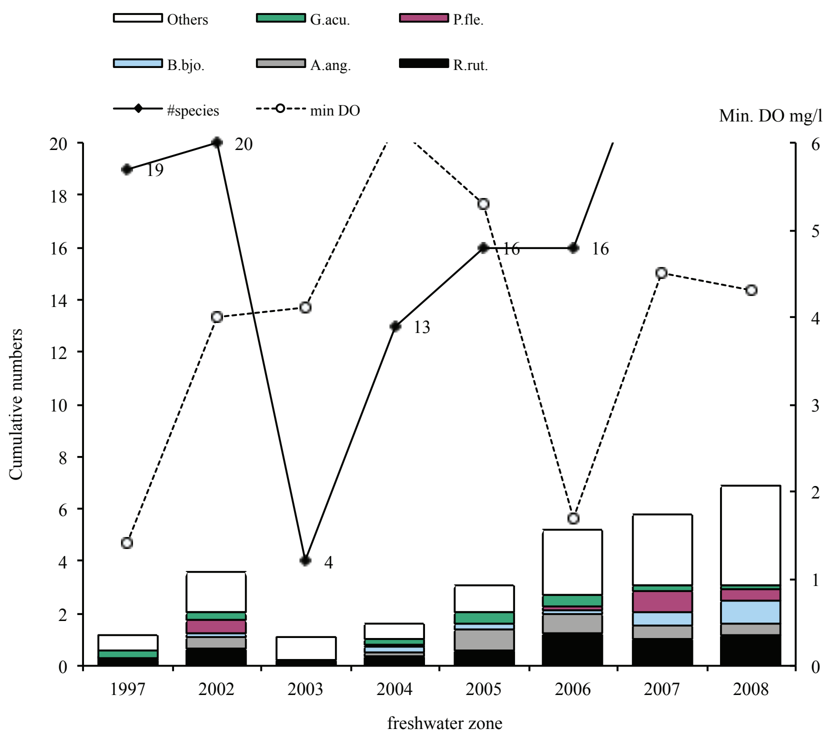

Fig. 6. – Species richness (figures on full line) and the catch per unit effort (cumulative numbers, log (x+1) transformed) for fish species caught in the freshwater zone of the Zeeschelde between 1997 and 2008 (abbreviations see Table A, annex). Only the on average five most abundant species are indicated with a specific pattern. Dotted lines connect the minimum recorded DO for a particular year.

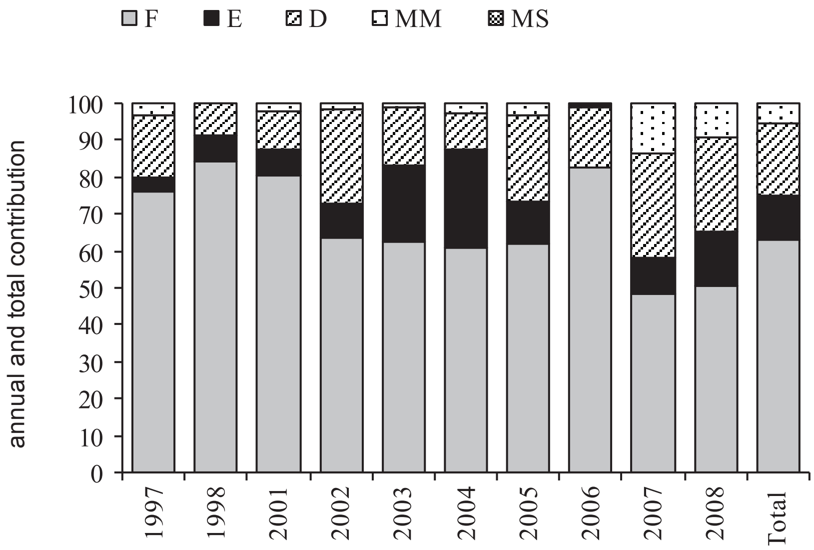

Fig. 7. – The annual and total contribution (% CPUE) of the estuarine use functional guilds in the oligohaline zone of the Zeeschelde between 1997 and 2008. (F: freshwater species; E: estuarine residents; D: diadromous species; MM: marine migrant species; MS: marine stragglers).

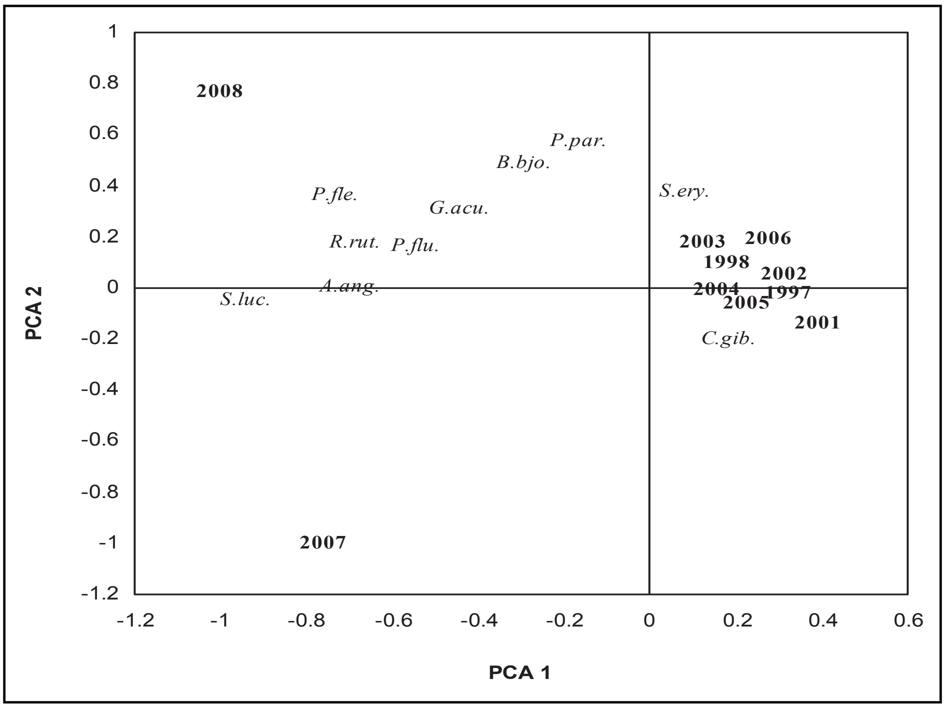

Fig. 8. – Scatterplot of factor loadings categorized by year obtained by PCA with log (x+1) transformed number of individuals caught (CPUE) and factor loadings of the ten most abundant species in the oligohaline zone of the Zeeschelde estuary between 1997 and 2008 (spring and autumn catches, n=26). Abbreviations see Table A in annex.

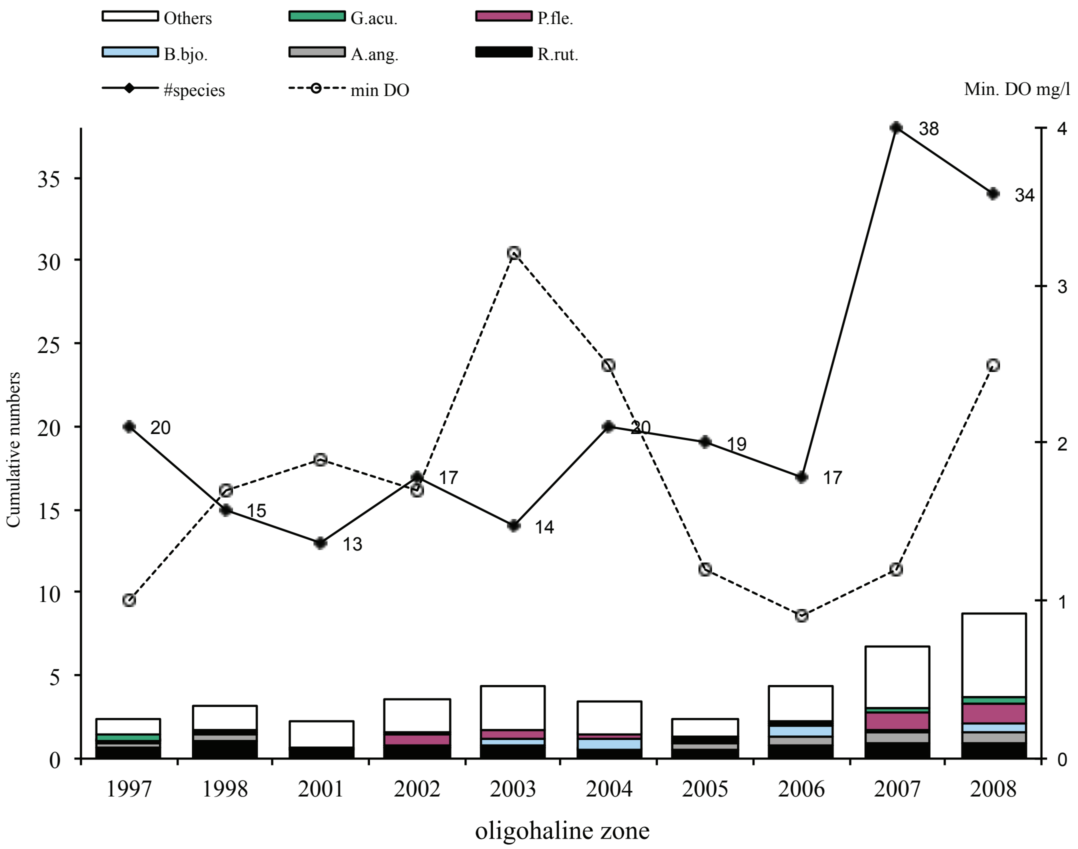

Fig. 9. – Species richness (figures on full line) and the catch per unit effort (cumulative numbers, log (x+1) transformed) for fish species caught in the oligohaline zone of the Zeeschelde between 1997 and 2008 (abbreviations see Table A, annex). Only the on average five most abundant species are indicated with a specific pattern. Dotted lines connect the minimum recorded DO for a particular year.

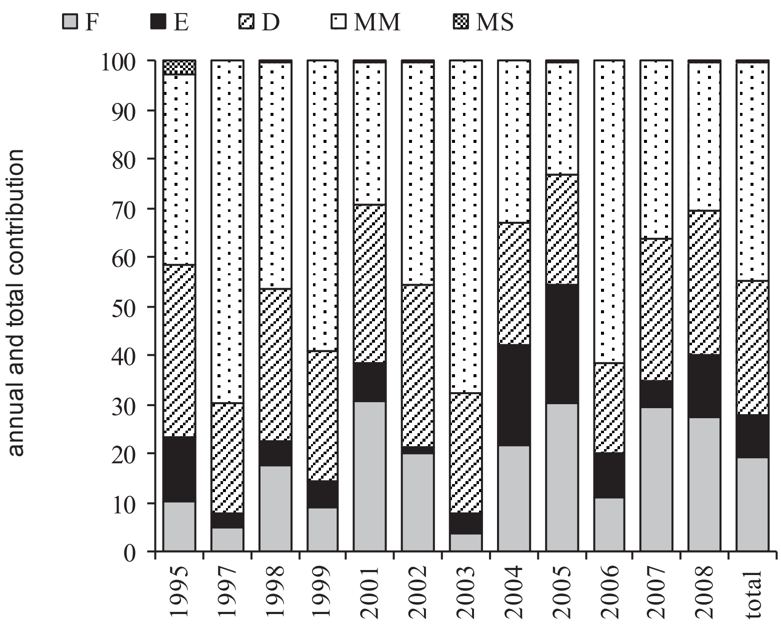

Fig. 10. – The annual and total contribution (% CPUE) of the estuarine use functional guilds in the mesohaline zone of the Zeeschelde between 1995 and 2008. (F: freshwater species; E: estuarine residents; D: diadromous species; MM: marine migrant species; MS: marine stragglers).

lesser weever (*Echiichthys vipera*). The annual and total guild presence (CPUE) is given in figure 7.

Figure 8 shows the scatterplot of a PCA with annual catch data (spring and autumn CPUE, log (x+1) transformed). Most catches cluster together on the right side of the first PCA axis, but the samples of 2007 and 2008 are separated from them and from each other. Factor 1 explains 41.2% and the second factor 17.0% of the variance.

In 2007 and 2008 more species and individuals (CPUE) were caught. They are separated from the other years mainly by the presence of pike-perch (*Sander lucioperca*, -0.93;-0.04). The difference between these two years is the result of differences in numbers caught.

The CPUE log (x+1) transformed data in the oligohaline zone of the Zeeschelde shows a remarkable increase in number of individuals in 2007 and 2008 (Fig. 9). Roach is again the most frequently caught species. The pike-perch and rudd catches increase since 2006. Species richness increased in 2007 but decreased again in 2008.

Mesohaline zone

In the mesohaline zone 59 species were collected between 1995 and 2008 (Table A). Of these, 33.3% are freshwater species, contributing 19.3% to the total abundance. Marine migrant species are well represented, comprising 26.6% of the species and contributing 44.5% to the total number of individuals with herring, flounder and sole as the most abundant species. Marine migrants occurred in all annual catches. About 15% of the species were diadromous species, contributing 27% of the total number of individuals caught. Diadromous species were always present in the annual catches. Ten estuarine species (16.6% of

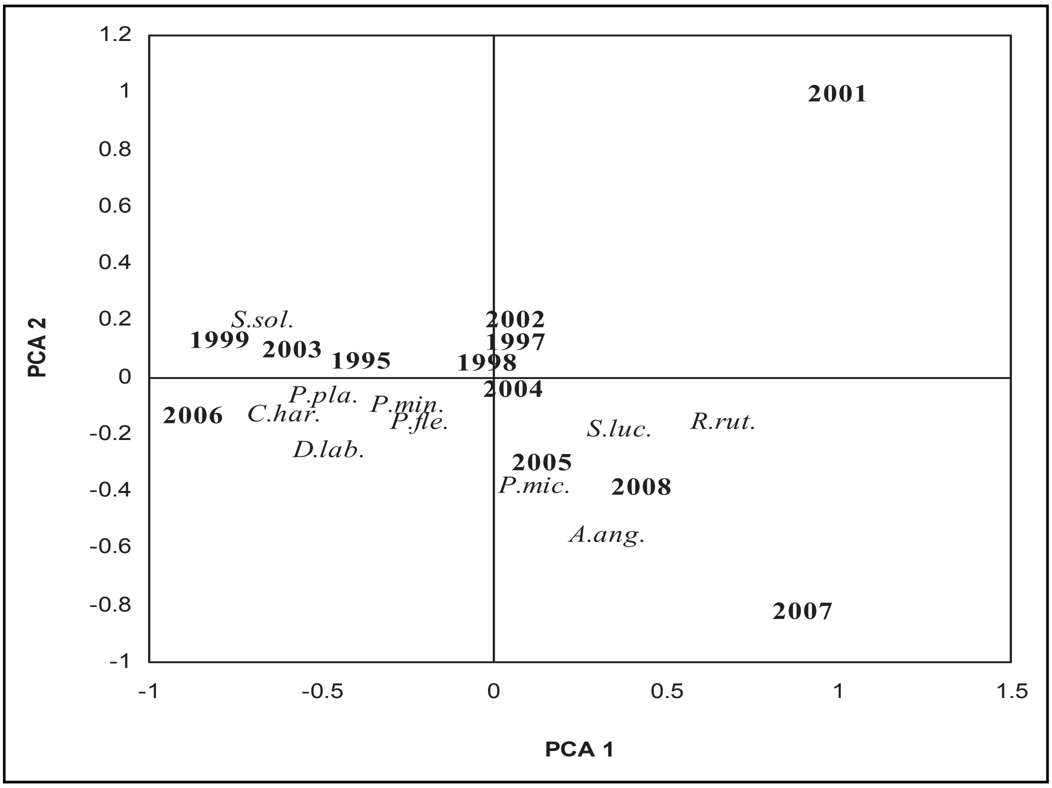

Fig. 11. – Scatterplot of factor loadings categorized by year obtained by PCA with log (x+1) transformed number of individuals caught (CPUE) and factor loadings of the ten most abundant species in the mesohaline zones of the Zeeschelde estuary between 1995 and 2008 (spring and autumn catches n=48). Abbreviations see Table A in annex.

total species number) were caught, contributing 8.8% to the total catch. The marine stragglers contributed 8.3% to the species and 0.2% to the total number of individuals caught. The annual and total guild distribution (relative percentage) is shown in figure 10.

The result of the PCA shows a more dispersed pattern than the ones observed in the freshwater and oligohaline zones (Fig. 11). Factor 1 explains only 18.8% and the second factor 16.0% of the variance. The ordination shows that the data obtained in 2001 and 2007 are separated from the other results. During these years the catches of sole (-0.66;0.20), seabass (-0.47;-0.24), herring (-0.60;-0.12) and plaice (-0.48;-0.05) were low. Catches in 2008 are less distinct than in the other salinity zones due to a decrease in numbers of individuals (Fig. 12) and in species richness. The more dispersed general pattern reflects the higher annual catch variations in the mesohaline zone compared with the other zones.

The catch per unit effort (log (x+1) transformed) in the mesohaline zone of the Zeeschelde is given in figure 12. The figure shows an increase in CPUE between 1995 and 2001 followed by a decrease until 2005. In 2006 and 2007 the annual CPUE was high, but in 2008 again a decrease was observed.

Doel

At the intake screens of the power station at Doel 66 species were collected between 1991 and 2008 of which snake pipefish (*Entelurus aequoreus* (Linnaeus, 1758)), solenette (*Buglossidium luteum* (Risso, 1810)), painted

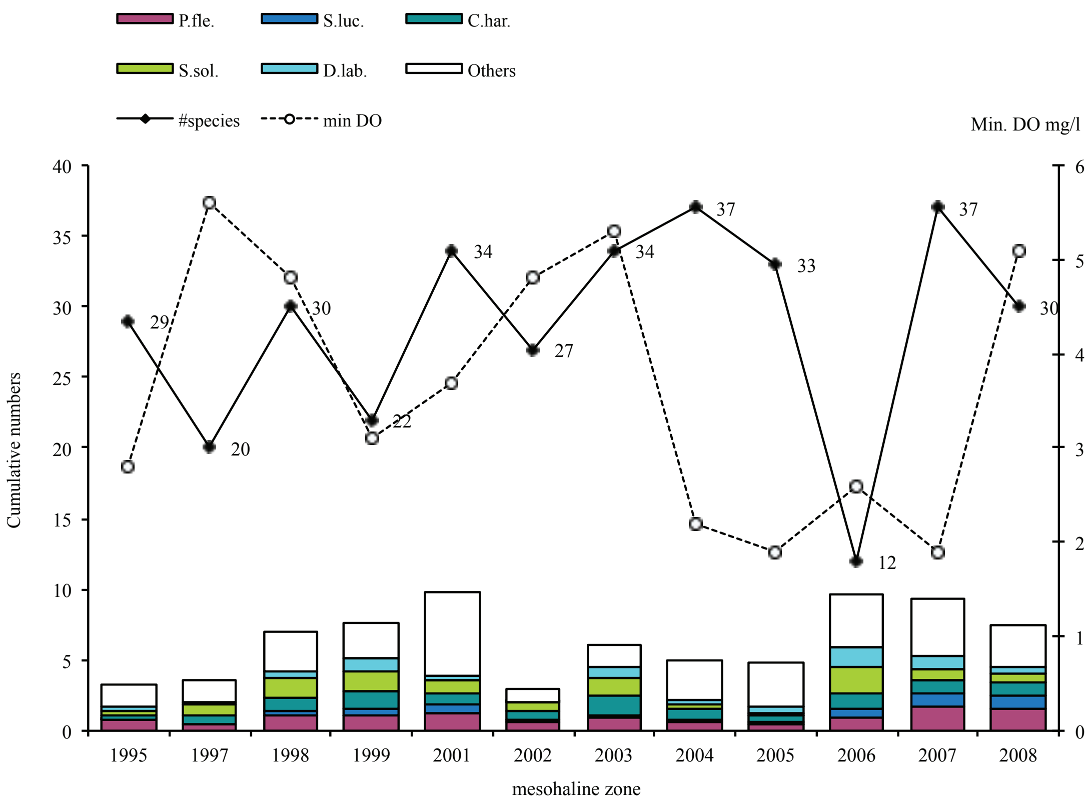

Fig. 12. – Species richness (figures on full line) and the catch per unit effort (cumulative numbers, log (x+1) transformed) for fish species caught in the mesohaline zone of the Zeeschelde between 1995 and 2008 (abbreviations see Table A, annex). Only the on average five most abundant species are indicated with a specific pattern. Dotted lines connect the minimum recorded DO for a particular year.

goby (*Pomatoschistus pictus* (Malm, 1845)), dragonet (*Callionymus lyra* (Linnaeus, 1758)) and great sandeel (*Hyperoplus lanceolatus* (Le Sauvage, 1824)) were not caught with fykes. This brings the total of fish species caught in the Zeeschelde estuary to 71.

DISCUSSION

Dissolved oxygen

One of the main abiotic variables influencing the presence of fish in an estuary is the dissolved oxygen concentration (DO) (MAES et al., 1998; ARAÚJO et al., 2000; TURNPENNY et al., 2006; MAES et al., 2007, 2008). The significant difference in monthly oxygen concentration between the different zones was also observed by SOETAERT et al (2006). DO within the Zeeschelde has increased continuously since 1996 (Table 2, MARIS et al., 2008). The changes observed in the fish assemblages in the freshwater and oligohaline zones become evident from 2007 onwards (Figs. 6 and 9). As a result of the activation of the water purification plant (Brussels North, March 2007) the oxygen concentration in the River Rupel increased strongly and fish started to re-colonise this river (VAN THUYNE & BREINE, 2008). A similar improvement was observed in the Thames estuary where the return of fish species was a striking feature linked with the recovery from pollution (WHEELER, 1969, 1979; ANDREWS & RICKARD, 1980; ATTRILL, 1998). Between 1997 and 2006 the average oxygen concentration in the oligohaline zone remained below 5 mg l^{-1}, i.e. the norm value as stipulated by the MINISTERIE VAN VOLKSGEZONDHEID EN LEEFMILIEU (1987; VLAREM II, 1995). Although in 2007 an improvement was recorded, still 54.6% of the OMES records were below 5 mg l^{-1} (MARIS et al., 2008). The mesohaline zone has a higher oxygen concentration due to oxygen rich water coming in from the Westerschelde. This could explain why, compared to the other zones, in this zone no significant increase in fish catches was observed between 1995 and 2007. In the late 1970s temporal anoxia was common in the upstream part of the Zeeschelde (SOETAERT et al., 2006). In the freshwater part of the Zeeschelde an improvement of oxygen concentration is observed between 1998 and 2002 which is due to a higher discharge (wet years) and a higher primary production during the summer months (MARIS et al., 2008). Between 2002 and 2007 the biological oxygen demand decreased in the freshwater part (MARIS et al., 2008). Although the freshwater zone has high DO concentrations for the period 2007-2008, even in summer, the norm of 5 mg l^{-1} (VLAREM II, 1995) is not always reached (MARIS et al., 2008).

Zone differences in fish assemblages

The difference in species richness and composition between the different zones is illustrated by the NMDS and the DA. The guild distribution changes gradually with the salinity (Figs. 4, 7 and 10). Although this shift is gradual which is illustrated by the overlap between the freshwater and oligohaline zones, our results indiquate that it is appropriate to distinguish three salinity zones for fish assemblages in the Zeeschelde. The observed shift in distribution is consistent with other estuaries in the North Sea area. THIEL & POTTER (2001) recorded a sequential change in the species composition from the most downstream site (high salinity) to the most upstream one (oligohaline) in the Elbe estuary. SELLESLAGH et al. (2009) reported a variable catch composition between intermediate and upper stations in the Somme estuary.

Freshwater zone

As expected, the fish assemblages in the freshwater zone of the Zeeschelde are dominated by freshwater species (68-100%), corresponding with observations in tidal freshwater along the Atlantic coast of North America (ODUM et al., 1988) and in a freshwater estuary in Estonia (VETEMAA et al., 2006). Freshwater individuals contributed 82.7% to the total catch between 1997 and 2008. The tidal freshwater zone is essentially a habitat for freshwater and diadromous species. An essential fish habitat consists of both the water column and underlying surface of a particular area. It contains all habitat characteristics essential to the long-term survival and health of particular fishes. Although this zone is characterised by the presence of freshwater species, its fish community is different from non tidal freshwater rivers e.g. thinlip mullet (*Liza ramada*), twaite shad (*Alosa fallax*) and smelt are not caught in non tidal freshwater rivers in Flanders. The difference in fish community is due to morphological characteristics, dynamics and its connection with the oligohaline zone. However, between 1997 and 2008 the number of estuarine species and marine migrants caught were limited to 3.5 and 0.2% respectively. In a highly polluted river like the Zeeschelde oxygen deficiency strongly affects the fish community structure. Over the years a gradual improvement in species richness is observed. A significant and steady increase in species richness and number of individuals is noted since 2004, the worst year observed being 2003 (Fig. 6). In addition concordant with the water quality (DO) improvements, a shift in fish assemblage structure occurred. In 1997 resistant freshwater species such as three-spined stickleback, Prussian carp and roach were dominant in numbers. Another indication of the water quality improvement is the presence of twaite shad, recorded in spring 2007. Other diadromous species observed since 2007 are smelt and thinlip mullet. Since summer 2007 herring and seabass (marine migrants) frequent this zone with abundance peaks in summer. This could be due to an increase in salinity during this season (less freshwater run off) combined with the improved water quality. For some species a seasonal pattern in frequency of occurrence and abundance can be distinguished. Ide (*Leuciscus idus*), Wells catfish (*Siluris glanis*), smelt, thinlip mullet, rudd, eel and pike-perch show a peak in summer. Some species such as lampreys are underestimated because of the low catch efficiency of fykes for this particular group. Concerning trophic level, omnivorous species such as roach, rudd, Prussian carp and eel are dominant in numbers. These are also species tolerant of poor water quality (Breine et al., 2007). Their dominance is an indication that although the water quality improved the habitat quality is still not optimal (Manolakos et al., 2007).

Oligohaline zone

This zone is characterised by a return of fish due to a continuous improvement of the water quality (DO; Maris et al., 2008). Since 2007 species richness is higher than in the freshwater zone and estuarine species and marine migrants have become more important, which corresponds with previous research in oligohaline waters (e.g. Rozas & Hackney, 1983). Between 1997 and 2008 the number of estuarine fish contributed 11.8%, diadromous 19.8% and the marine migrants 5.3% to the total catch. During this period freshwater individuals contributed 62.9% to the total catch. We therefore consider the oligohaline zone as a habitat for freshwater, estuarine, diadromous and marine migrant species. As already discussed, a higher oxygen concentration has been observed in the oligohaline zone since the treatment of Brussels' waste water began, enhancing the presence of fish (Fig. 9). In 1994-1995, the dissolved oxygen concentration was close to zero during most of the year. Only in winter 12 fish species were caught at the cooling water inlets in Schelle, all of which were freshwater species except smelt and eel, which are diadromous species (Maes et al., 1998). Between 1995 and 2007 a gradual increase in species was recorded (Guelinckx et al., 2008). Since 2008 twaite shad is occasionally recorded (Stevens et al., 2009). The anadromous lampreys are easily missed with fyke nets, but they are caught in summer at the lock-weir complex in Gent (Stevens et al., 2009). Upstream spawning grounds for twaite shad and lampreys are absent or inaccessible due to barriers (e.g. sluices, dams,…) (Stevens et al., 2009).

Mesohaline zone

This is the area where estuarine fish complete their life cycle and where fish from the upper and lower estuary seek refuge and food. Especially mudflats provide food for juveniles (HIDDINK & JAGER, 2002; STEVENS, 2006). As such we find representatives from all estuarine use functional groups. VAN DAMME et al. (1994) presented a checklist of 23 fish species for the mesohaline zone of the Zeeschelde belonging to five ecological guilds: marine migrants (2), diadromous species (3), estuarine species (9), marine stragglers (3) and freshwater species (6). Compared to the checklists of DE SELYS-LONGCHAMPS (38 sp., 1842) and POLL (40 sp., 1945, 1947) more than 15 species had disappeared from the lower Zeeschelde in 1994. The anadromous fishes recorded by DE SELYS-LONGCHAMPS (1842): sea lamprey (*Petromyzon marinus*), allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*), sturgeon (*Acipenser sturio*), shelly (*Coregonus lavaretus*) and the Atlantic salmon (*Salmo salar*) had all, except for twaite shad, already disappeared in 1945 (Poll, 1945). In 1991 the river lamprey was the only anadromous species persisting in the lower Zeeschelde (VAN DAMME et al., 1994). The status of anadromous fish populations remained problematic until recently (MAES et al., 1998, 1999). Overall ten diadromous species have been recorded, some abundantly (eel, smelt, thinlip mullet) but others are rare (river lamprey and sea trout). Species richness shows year by year variations, but a dominance of marine migrants was always observed. From the guild distribution (Fig. 10) we consider the mesohaline zone as an important habitat for most estuarine species, diadromous species and marine migrants. The vast majority of species recorded consisted of juveniles. When combining all our survey results (1995-2008) the guild distribution shows similarities with other European estuaries, e.g. the Elbe (ELLIOTT & DEWAILLY, 1995) and the Gironde (LOBRY et al., 2003). CABRAL et al. (2001) observed a dominance of marine migrants, marine stragglers and estuarine species in the mesohaline zone of the Tagus and SELLESLAGH et al. (2009) observed a dominance of marine migrants and estuarine species in three eastern English Channel macrotidal estuaries (Canche, Authie and Somme). The same authors found also a dominance of marine migrants and estuarine species in 15 other French estuaries, whereby the freshwater group showed the highest variation ranging from 0 to 37% of species richness.

No overall seasonal effect was observed although for some species a seasonal pattern was present. Sprat and herring are known to be winter migrants (MAES et al., 1998) however; herring is now more abundant in autumn compared to a previous winter. The gradual increase in densities of flounder could be an indication of global warming as described by THIEL et al. (2003). However, the seasonal pattern of this species is complex and not only influenced by temperature. There is an effect of inter-annual variations in recruitment (THIEL & POTTER, 2001) and the availability and abundance of food can also disrupt a seasonal pattern. Observed seasonal patterns can be the result of behavioural responses to changes in predation risk and are probably linked to a size-related behaviour (MAES et al., 1998). The main predators in the mesohaline zone are freshwater species, e.g. pike-perch and perch. Other predators are rarely caught, e.g. juvenile seabass, twaite shad and smelt are occasionally passing through. Large numbers of species enter the estuary to avoid predation (PIHL et al., 2002) and remain there for a short or longer period depending on water quality and food availability. Turbidity may be a driving force for fish migration into the estuary as those fish are attracted by the plume in the sea (MAES et al., 1998). We embrace the hypothesis mentioned by several authors that although some species can be considered as estuarine dependent, a large number of the individuals concerned use the mesohaline zone of an estuary on a facultative or opportunistic basis (POWER & ATRILL, 2003; MAES et al., 2004; GUELINCKX, 2008). Indeed several fish species show variable migration patterns that could be the result of habitat selection (MORRIS, 2003).

We are aware that the fish assemblages in the different salinity zones are also affected by physical habitat characteristics. Supralitoral zones (tidal marshes and flood systems) are most susceptible to human pressure. The loss of mudflats (dyke reinforcements) combined with dense ship transport and a very dynamic tide, enhance the erosion of tidal marshes (Van Braeckel et al., 2006). These mudflats and marshes are important for fish since they serve as feeding areas and shelter for many species (Cattrijsse & Hampel, 2006; Stevens, 2006). McLusky et al. (1992) commented on the historic loss of inter-tidal habitat and saltmarshes and estimated that the fish population in the Forth estuary was reduced by 66% as a consequence of those losses. The intertidal creek habitat accommodates juvenile fishes during the day, while larger specimens visit the creek by night, resulting in a reduction of space and energy competition (Shenker & Dean, 1979). Colclough et al. (2005) demonstrated that the restored inter-tidal saltmarshes in the Thames and Blackwater estuaries were utilised extensively by juvenile fishes, and species preferences for particular microhabitats were even observed. A decrease of habitat diversity in the freshwater zone is also reflected by impoverished fish diversity (e.g. Jansen et al., 2000; Sindilariu et al., 2006). There are clear differences in juvenile responses to environmental heterogeneity (Grenouillet et al., 2000). This has a direct effect on species richness (Belliard et al., 1999; Schiemer, 2000) and may affect the functional structure of the fish community. Juvenile fish will benefit from structured habitats and avoid substrates lacking any suitable shelter. The creation of shallow intertidal habitats will therefore enhance the restoration of the fish community as these new habitats can be used as nursery and spawning places, shelter and resting areas, as well as feeding grounds (Simoens et al., 2007).

CONCLUSIONS

The fish richness increased over the years 1991 to 2007 in the different salinity zones of the Zeeschelde. A similar observation has been recorded in many of the industrialised countries because of restoration and conservation efforts (Lotze et al., 2006). The gradual increase in oxygen concentration in the different salinity zones of the Zeeschelde estuary seems to have a positive impact on the species richness and confirms the model for diadromous fishes developed by Maes et al. (2007, 2008). A longitudinal shift in fish assemblages, numbers and species richness is mainly explained by the salinity gradient. This allowed us to define estuarine zones for different estuarine fish guilds. However, present fish communities do not reflect the assemblages recorded a century ago. The estuary and its tidal tributaries have been heavily influenced by anthropogenic pressures such as land claim, harbour expansion, dredging activities, embankments and urbanisation (Van Braeckel et al., 2006). The restoration of a natural sustainable fish assemblage will be enhanced by the creation of floodplains as spawning and nursery areas. Protection of the tidal marshes in all zones should be implemented in order to reduce further loss of habitat. Seasonal patterns are complex, which is due in part to a suite of opportunistic behaviour and partly because of external natural variation and human impacts. The most abundant species in the estuary are species that are tolerant of poor water quality. Some species are restricted to one zone while others frequent the whole estuary. Flounder and eel are the only diadromous species found in all zones. Freshwater eurytopic species with a high tolerance to harsh conditions are also present in all surveyed zones. Our results add to the information needed to understand estuarine dependence of fishes.

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ANNEX: TABLE A

Catch frequency for each fish species, expressed as percentage, for the different salinity zones of the Zeeschelde between 1995 and 2008. M: Mesohaline zone; O: Oligohaline zone and F: freshwater zone with the number of monthly catches for each zone between brackets. The estuarine use guild is given (FRANCO et al., 2008). D: Diadromous species; E: Estuarine species; FW: Freshwater species; MS: Marine stragglers (adventitious visitors); MM: Marine migrants (seasonal or juvenile migrant).

Scientific name	Abbreviation	Guild	Common name	M (90)	O (52)	F (49)
Abramis brama (Linnaeus, 1758)	A.bra.	FW	Bream	46.7	71.2	63.3
Acipenser baeri (Brandt, 1869)	A.bae.	D	Siberian sturgeon	6.7	0.0	0.0
Agonus cataphractus (Linnaeus, 1758)	A.cat.	E	Hook-nose	1.1	0.0	0.0
Alburnus alburnus (Linnaeus, 1758)	A.alb.	FW	Bleak	2.2	5.8	16.3
Alosa fallax (Lacepède, 1803)	A.fal.	D	Twaite shad	44.4	9.6	2.0
Ammodytes tobianus (Linnaeus, 1758)	A.tob.	MS	Sand-eel	3.3	0.0	0.0
Anguilla anguilla (Linnaeus, 1758)	A.ang.	D	Eel	85.6	88.5	85.7
Aphia minuta (Linnaeus, 1758)	A.min.	E	Transparent goby	1.1	0.0	0.0
Atherina presbyter (Risso, 1810)	A.pre.	MM	Sand smelt	21.1	1.9	0.0
Blicca bjoerkna (Linnaeus, 1758)	B.bjo.	FW	White bream	35.6	69.2	79.6
Carassius carassius (Linnaeus, 1758)	C.carr.	FW	Crucian carp	0.0	9.6	2.0
Carrasius gibelio (Bloch, 1782)	C.gib.	FW	Prussian carp	38.9	96.2	81.6
Chelidonichthys lucernus (Linnaeus, 1758)	C.luc.	MM	Tub gurnard	18.9	1.9	0.0
Chelon labrosus (Risso, 1827)	C.lab.	MM	Thick-lipped mullet	0.0	1.9	0.0
Ciliata mustela (Linnaeus, 1758)	C.mus.	MM	Fivebeard rockling	15.6	0.0	0.0
Clupea harengus (Linnaeus, 1758)	C.har.	MM	Herring	88.9	50.0	2.0
Cottus gobio (Linnaeus, 1758)	C.gob.	FW	Bullhead	1.1	3.9	4.1
Cyclopterus lumpus (Linnaeus, 1758)	C.lum.	MM	Lumpsucker	1.1	0.0	0.0
Cyprinus carpio (Linnaeus, 1758)	C.car.	FW	Carp	18.9	61.5	73.5
Dicentrarchus labrax (Linnaeus, 1758)	D.lab.	MM	Seabass	84.4	25.0	2.0
Echiichthys vipera (Cuvier, 1829)	E.vip.	MS	Lesser weever	2.2	3.9	0.0
Engraulis encrasicolus (Linnaeus, 1758)	E.enc.	MM	Anchovy	1.1	0.0	0.0
Esox lucius (Linnaeus, 1758)	E.luc.	FW	Pike	11.1	11.5	14.3
Gadus morhua (Linnaeus, 1758)	G.mor.	MM	Cod	25.6	1.9	0.0
Gasterosteus aculeatus (Linnaeus, 1758)	G.acu.	FW	Three-spined stickleback	46.7	61.5	73.5
Gobio gobio (Linnaeus, 1758)	G.gob.	FW	Gudgeon	0.0	7.7	0.0
Gymnocephalus cernuus (Linnaeus, 1758)	G.cer.	FW	Ruffe	35.6	46.2	59.2
Lampetra fluviatilis (Linnaeus, 1758)	L.flu.	D	River lamprey	5.6	11.5	16.3
Lepomis gibbosus (Linnaeus, 1758)	L.gib.	FW	Pumpkinseed	6.7	26.9	28.6
Leucaspius delineatus (Heckel, 1843)	L.del.	FW	Belica	0.0	7.7	6.1
Leuciscus cephalus (Linnaeus, 1758)	L.cep.	FW	Chub	0.0	0.0	2.0
Leuciscus idus (Linnaeus, 1758)	L.ide.	FW	Ide	7.8	32.7	22.5
Limanda limanda (Linnaeus, 1758)	L.lim.	MM	Dab	6.7	0.0	0.0
Liparis liparis (Linnaeus, 1760)	L.lip.	E	Sea snail	2.2	0.0	0.0
Liza ramada (Risso, 1827)	L.ram.	D	Thinlip mullet	42.2	26.9	8.2
Merlangius merlangus (Linnaeus, 1758)	M.mer.	MM	Whiting	20.0	1.9	0.0
Mullus surmuletus (Linnaeus, 1758)	M.sur.	MS	Red mullet	2.2	0.0	0.0
Myoxocephalus scorpius (Linnaeus, 1758)	M.sco.	E	Bull rout	11.1	0.0	0.0
Oncorhynchus mykiss (Walbaum, 1792)	O.myk.	FW	Rainbow trout	1.1	0.0	0.0

Scientific name	Abbreviation	Guild	Common name	M(90)	O(52)	F(49)
Osmerus eperlanus (Linnaeus, 1758)	O.epe.	D	Smelt	70.0	32.7	8.2
Perca fluviatilis (Linnaeus, 1758)	P.flu.	FW	Perch	61.1	86.5	71.4
Platichthys flesus (Linnaeus, 1758)	P.fle.	D	Flounder	98.9	61.5	61.2
Pleuronectes platessa (Linnaeus, 1758)	P.pla.	MM	Plaice	36.7	0.0	0.0
Pomatoschistus lozanoi (de Buen, 1923)	P.loz.	MS	Lozano's goby	1.1	1.9	0.0
Pomatoschistus microps (Krøyer, 1838)	P.mic.	E	Common goby	30.0	48.1	20.4
Pomatoschistus minutus (Pallas, 1770)	P.min.	E	Sand goby	54.4	40.4	12.2
Pomatoschistus sp.	P.spe.	E	Gobidae sp.	6.7	0.0	0.0
Psetta maxima (Linnaeus, 1758)	P.max.	MM	Turbot	1.1	0.0	0.0
Pseudorasbora parva (Temminck & Schlegel, 1842)	P.par.	FW	Stone morocco	13.3	59.6	77.6
Pungitius pungitius (Linnaeus, 1758)	P.pun.	FW	Nine spine stickleback	12.2	34.6	20.4
Rhodeus sericeus (Bloch, 1782)	R.ser.	FW	Bitterling	13.3	44.2	51.0
Rutilus rutilus (Linnaeus, 1758)	R.rut.	FW	Roach	74.4	100.0	93.9
Salmo salar (Linnaeus, 1758)	S.sal,	D	Salmon	2.2	0.0	0.0
Salmo trutta (Linnaeus, 1758)	S.tru.	D	Sea trout	8.9	0.0	0.0
Sander lucioperca (Linnaeus, 1758)	S.luc.	FW	Pike-perch	77.8	57.7	61.2
Scardinius erythrophthalmus (Linnaeus, 1758)	S.ery.	FW	Rudd	36.7	63.5	81.6
Scophthalmus rhombus (Linnaeus, 1758)	S.rho.	MM	Brill	7.8	0.0	0.0
Silurus glanis (Linnaeus, 1758)	S.gla.	FW	Wels catfish	0.0	13.5	12.2
Solea solea (Linnaeus, 1758)	S.sol.	MM	Sole	84.4	13.5	0.0
Sprattus sprattus (Linnaeus, 1758)	S.spr.	MM	Sprat	6.7	0.0	0.0
Syngnathus acus (Linnaeus, 1758)	S.acu.	E	Greater pipefish	17.8	9.6	0.0
Syngnathus rostellatus (Nilsson, 1855)	S.ros.	E	Nilsson's pipefish	1.1	0.0	0.0
Tinca tinca (Linnaeus, 1758)	T.tin.	FW	Tench	6.7	5.8	8.2
Trachurus trachurus (Linnaeus, 1758)	T.tra.	MS	Scad	6.7	0.0	0.0
Trisopterus luscus (Linnaeus, 1758)	T.lus.	MM	Pouting	34.4	7.7	0.0
Zoarces viviparus (Linnaeus, 1758)	Z.viv.	E	Viviparous blenny	6.7	0.0	0.0