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Estuarine Pollution as a Probable Cause of Increase of Estuarine Birds

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A long-term increase of estuarine birds does not always appear to be a good indication of the improvement of the environmental quality of an estuary. This paper shows that an incontestable ecological deterioration in a part of the Scheldt estuary has led probably to a greater food supply for intertidal birds. They respond to this phenomenon by visiting the area in increasing numbers, and the period of migration of birds on other feeding grounds nearby differs from theirs.

Whether long-term bird counts along an estuary are appropriate for evaluating its pollution status is a question so far poorly examined. Probably the lack, or incompleteness of basic data from the past is responsible. Indeed, a lot of data have to be available, such as an objective evaluation of the past and the present degree of pollution of the estuary, as well as the former and the present structure of the macrobenthic community and their predators, especially birds and fishes. An accurate comparison between the past and present is possible only when all these data have been described quantitatively.

Harrison & Grant (1976) stated that since the Thames estuary improved by major sewage works, birds have returned there due to the re-establishment of a wide diversity of prey organisms. The same phenomenon was observed in the Clyde estuary in Scotland, but here the recovery was not as advanced as in the Thames (McKay *et al.*, 1978). It is questionable if increasing bird populations are always reliable criteria of an improved or a restored estuarine environment. This paper attempts to show that rising bird numbers can also be connected with deterioration.

Our study area was a part of the heavy polluted Western Scheldt estuary at a distance of 56–74 km from its mouth. Pollution set in here a few years after the Second World War. Measurements of a number of environmental parameters in the 1950s, by Van Meel (1958) and by Leloup & Konietzko (1956) showed clearly that at that time, the extent of the pollution was still at a low level. At the end of the 1960s, the situation had changed drastically. In our studied part, De Pauw (1975) observed a heavy input of organic matter, accompanied with an incomplete mineralization. For long periods during spring and autumn, the overlying water showed a depletion of oxygen, while the BOD_5^{20} values usually exceeded 10 mg l^{-1}. Prior to the severe pollution, the macrofauna of the intertidal sediments had been investigated by Leloup & Konietzko (1956), and Maebe & Van der Vloet (1956) presented an extensive paper on bird counts in the same area. The records of these authors were important as a basis for comparison with present data.

Material and Methods

The Western Scheldt, a part of the delta area, is situated in the south-western Netherlands. The study area extends from Lillo-Fort (Belgium) downstream to a few kilometres beyond the Belgian–Dutch frontier (51°18′–51°25′N and 04°08′–04°17′E, Fig. 1). This Lillo-Rilland area includes the drowned land of Saeftinghe, by far the largest saltmarsh (approx. 3000 ha) in the south-west of the Netherlands. Environmental factors are very unstable here. The water chlorinity fluctuates between 0.3 and 12 g Cl^{-} l^{-1}, while dissolved oxygen values are between 0.4 and 10.2 mg l^{-1}. A more detailed account on the abiotic characteristics of the area are presented in the papers of Wolff (1973), De Pauw (1975) and Saeijs (1977). Van der Kooij (1982) presents an extensive review on the numerous sources of pollution. Among other things, we note increasing amounts of heavy metals, polycyclic aromatic hydrocarbon compounds and organochlorine pesticides. Beeftink (1957) gives a good description of the vegetation in the surrounding saltmarshes.

The distribution of the eight sampling stations, situated near the mid-tide level and corresponding with those of Leloup & Konietzko (1956), is given in Fig. 1. The survey was carried out between April 1982 and October 1984. At each station, two samples were taken monthly with a cylindrical corer of 70.08 cm^2 area and 10 cm deep, and bulked; the total sample was therefore 142 cm^2 in area. Three times a year the particle size analysis in

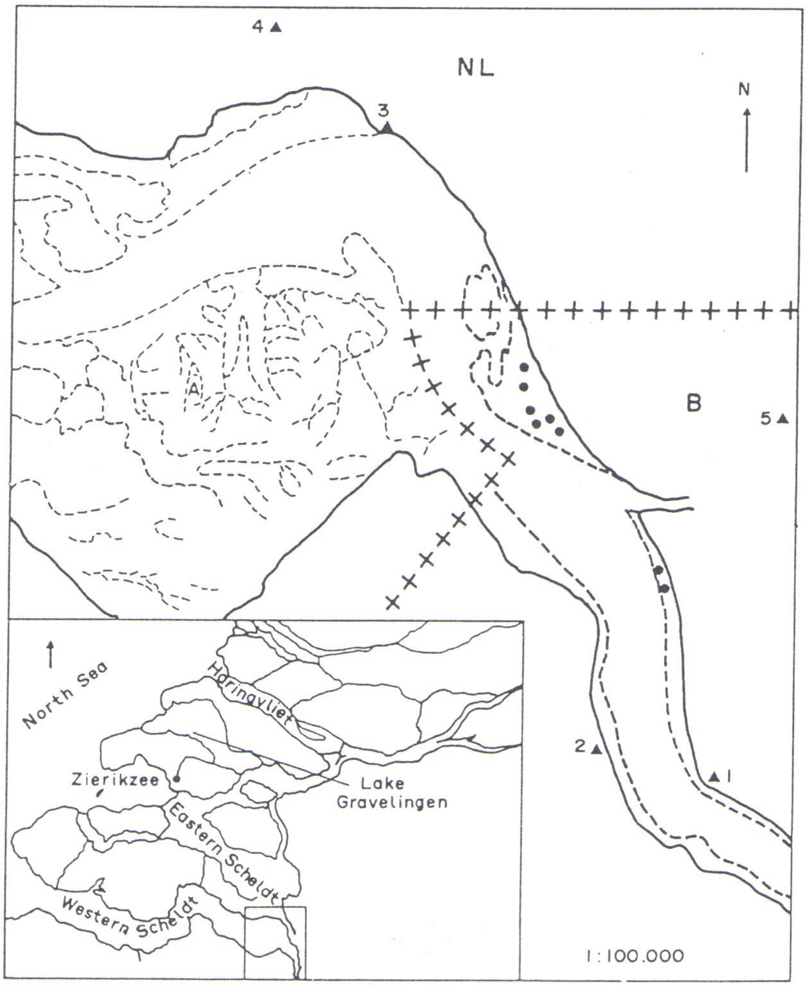

Fig. 1 The studied Lillo–Rilland area within the Delta region of the rivers Rhine, Meuse and Scheldt. Villages of 1: Lillo-Fort; 2: Doel; 3: Bath; 4: Rilland; 5: Zandvliet. A: Drowned land of Saeftinghe; ●: sampling stations.

another bulked sample was performed, by the standard methods of Morgans (1956), using graded sieves on the Wentworth scale. The median particle diameter and the rate of sorting of the sediments were expressed in the phi-notation (Inman, 1952; Folk, 1966). The distribution of the grain-size classes showed a homogeneous composition of the sediments. The mudflats belonged to the muddy sand component with a median grain-size diameter of 104 μm (range 72–122 μm; $n = 48$) or 3.26 φ (range 3.03–3.64 φ; $n = 48$). The sediments were poorly sorted, with a mean sorting coefficient of 0.47 φ (range 0.32–0.60 φ; $n = 48$). A rough estimate of the organic carbon content of the sediments was determined by loss on ignition according to Morgans (1956). The values of this loss varied between 0.7% and 17.6%. Higher values were found in the upstream sediments of the southern part of the investigated area, where heavier water pollution occurred ($F = 7.989$; $P < 0.01$). Significant seasonal differences could be detected between the periods March–June, July–October, and November–February, values being highest during the former ($F = 4.373$: $P < 0.025$).

The method of Beukema (1974) was followed for the examination of the dry weight and the ash-free dry weight (AFDW) of the macrobenthos per unit area. The structure of the macrobenthic community was investigated by analysis of diversity (H) following Brillouin's formula (Legendre & Legendre, 1983) and of evenness (J) according to Pielou (1966). The relationship between the macrofaunal communities of every pair of stations was examined (Q mode) by the distance coefficient of Bray & Curtis and additionally by a Spearman rank correlation (Legendre & Legendre, 1983; Daget, 1976). For the former calculations, the total of individuals per species per month were distributed over five geometric classes.

Counts and estimates of estuarine bird species were performed at the high tide roosts, situated at the southern boundary of the land of Saeftinghe. Intertidal birds originating from the whole area congregate here, but recently, overtiding by some tens to some hundreds of birds at the saltmarshes of the nearby Eastern Scheldt became obvious. That is why the numbers at the former roosts underwent a few corrections. Averages were calculated from four to five peak counts during the maximum spring and autumn migration every year from 1947 until 1955 (Maebe & Van der Vloet, 1956; Van der Vloet, in press) and from 1979 until 1983 (van de Wiel, 1982, 1983, and personal records). Only the maximum autumn migration was taken into account for species whose numbers were not important during the maximum spring migration.

Results

Table 1 shows the relationship between the macrofaunal communities of the eight stations. Differences between before and after the increased pollution are very obvious. The latter period indicates a good comparability for the stations with regard to their descriptors. The higher mean of the distance coefficient of Bray & Curtis and the lower mean of the Spearman's r-value during the former period, indicate the presence of a more heterogeneous community concerning its composition and structure. As we will see later, these differences between the past and the present are related to the low diversity indices of the macrobenthic community during the recent investigation.

TABLE 1

Relationship between the macrofaunal communities of all possible sample pairs of the stations in the past and the present ($n = 28$).

	1952–1953*	1982–1984†	Significance between the periods‡
Distance coefficient of Bray & Curtis	0.297 (±0.149)	0.063 (±0.029)	$P < 0.001$
Spearman's rank correlation	0.122 (±0.051)	0.816 (±0.128)	$P < 0.001$

*Calculated from original data of Leloup & Konietzko (1956).
†Own data.
‡Student's t-test.

At present, a dramatic fall of species richness is unmistakeable and only four species remain (Table 2). Among others, *Nereis diversicolor* and *Corophium volutator* are in most parts of the investigated area significantly more numerous than 30 years ago (Table 3). Whereas *Macoma balthica* (range over a year: 0–399 ind. m^{-2}) and *Hydrobia ulvae* (range over a year: 37–210 ind. m^{-2}) are at present much less frequent than *N. diversicolor* and *C. volutator* and there are no indications that their number have changed substantially since the earlier survey. A few *Capitella capitata* and *Lanice conchilega* were found in samples; they do not occur in samples taken in classical stations, but their numerical importance may be neglected. Generally speaking, the density of the whole macrofauna shows a trend towards a massive long-term increase compared to the former data of Leloup & Konietzko (1956).

The mean total biomass of the macrofauna, expressed in g AFDW m^{-2} per unit area, reaches the highest values between May and December (Fig. 2). Here again we note the importance of *N. diversicolor* and of *C. volutator*, which together contribute up to 94.2% (±4.7%) of the total yearly biomass. Because of the lack of original data in the paper of Leloup & Konietzko (1956), we were not able to compare directly the actual biomass with the biomass from the past. However, taken into account the significant numerical increases of the polychaetes and *C. volutator*, a gain of the total macrofauna biomass per unit area seems more than probable.

TABLE 2

Species richness of macrobenthic taxa in the sediments of the studied area before and after the severe pollution

	September 1952–August 1953 (Leloup & Konietzko, 1956)	April 1982–October 1984 (Own data)
Polychaeta	5	only *Nereis diversicolor*, numerous
Amphipoda	6	only *Corophium volutator*, numerous
Decapoda	4	only *Carcinus maenas*, rarely
Mollusca	9	2 *Hydrobia ulvae* and *Macoma balthica*

TABLE 3

Changes in the abundance (mean number m^{-2}) of the main prey of intertidal birds in the Lillo–Rilland area between 1952–1953 (Leloup & Konietzko, 1956) and 1983 (own data)

	1952–1953		1983		Significance between two periods‡
	n	$X \pm \sigma_X$ (range)	n†	$X \pm \sigma_X$ (range)	
Polychaetes*					
Lillo, same stations	5	1080 ± 265 (600–1500)	12	3465 ± 222 (2240–4760)	$P < 0.001$
Zandvliet, same stations	7	3728 ± 1300 (300–12 300)	12	2322 ± 175 (1537–3320)	NS
Lillo and Zandvliet, different stations	9	1433 ± 482 (0–7800)	12	2646 ± 192 (1869–3829)	$P < 0.01$
Corophium volutator					
Lillo, same stations	5	120 ± 73 (0–300)	12	1633 ± 510 (0–11 060)	$P < 0.05$
Zandvliet, same stations	7	85 ± 55 (0–300)	12	7891 ± 2420 (295–29 744)	$P < 0.001$
Lillo and Zandvliet, different stations	9	466 ± 152 (0–2700)	12	6614 ± 2524 (492–28 420)	$P < 0.001$

*Five species in 1952–1953, only *Nereis diversicolor* in 1983.
†Monthly mean from eight stations.
‡Mann–Whitney U-test.

As can be expected in case of disproportion concerning the species distribution, diversity and evenness values of the macrobenthic community are seriously affected during the present investigation (Fig. 3). Brillouin's diversity index fluctuates between 0.42 and 1.44, with its lowest values during the period March–June. Although we do not know to what extent Huston's (1979) dynamic equilibrium hypothesis may have played a part in the observed phenomena, all the field evidence presently available suggests the presence of a stressed environment, in which human interference, as expressed by man-made pollution, is responsible for the major changes.

As seen in Table 4 and in Fig. 2, the migration pattern of the whole intertidal bird community fits the seasonal fluctuations of the total macrobenthic biomass rather well. In each species, peak passages in the studied area are noted between May and October. The most dense spring distribution of the ringed plover (*Charadrius hiaticula*), the grey plover (*Pluvialis squatarola*) and the bar-tailed godwit (*Limosa lapponica*) can be noted in May, the first month of the year during which the biomass is increasing. The peak autumn migration, which is much

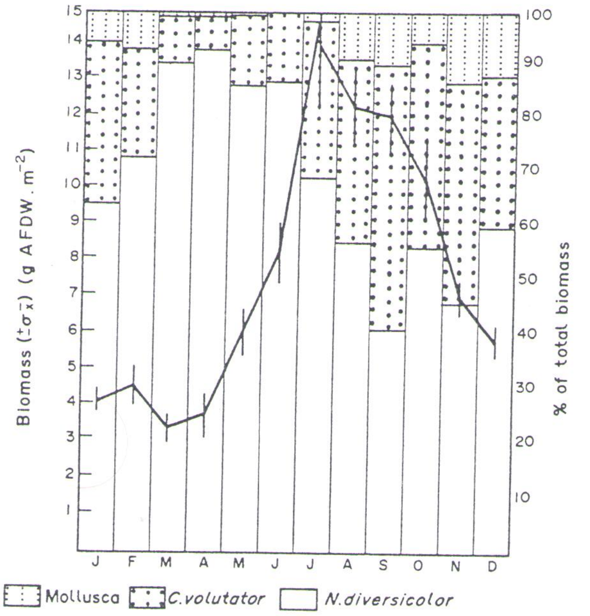

Fig. 2 Mean total biomass per month (in g AFDW m^{-2}) of the macrofauna in the Lillo–Rilland area between April 1982 and October 1984 and the biomass of *Nereis diversicolor*, *Corophium volutator* and Mollusca as a percentage of the total biomass.

TABLE 4

Time of peak migration, average peak counts and maximum numbers of the important intertidal species at the Saeftinghe roosts before and after the severe pollution

Species	Peak migration	1947–1955 (Maebe & Van der Vloet, 1956; Van der Vloet, *in litt.*)		1979–1983 (van de Wiel, 1982, 1983, and own records)		Approximate rate of increase
		$\bar{X}$	Max.	$\bar{X}$	Max.	
Haematopus ostralegus	mid June–end August	210	460	520	750	2.4
Pluvialis squatarola	begin–end May	185	500	760	1,800	4.1
	mid July–mid September	115	350	560	950	4.8
Charadrius hiaticula	begin–end May	345	1500	270	350	—
	begin August–end September	400	1200	290	560	—
Numenius arquata	end June–end September	595	1300	760	1,330	1.2
Limosa lapponica	begin–end May	110	200	980	1,820	8.9
	mid July–end August	115	400	400	840	3.4
Tringa hypoleucos	mid July–begin September	80	150	85	120	—
T. totanus	mid June–end August	135	280	375	1,220	2.7
T. erythropus	mid June–mid October	200	360	690	1,165	3.4
Recurvirostra avosetta	mid April–mid May	some tens		230	350	4.6
	end June–mid October	125	240	550	900	4.4
Larus ridibundus	mid June–August	6500–7000*		14 000		2.0

*The number of breeding pairs at the drowned land of Saeftinghe was used as the standard.

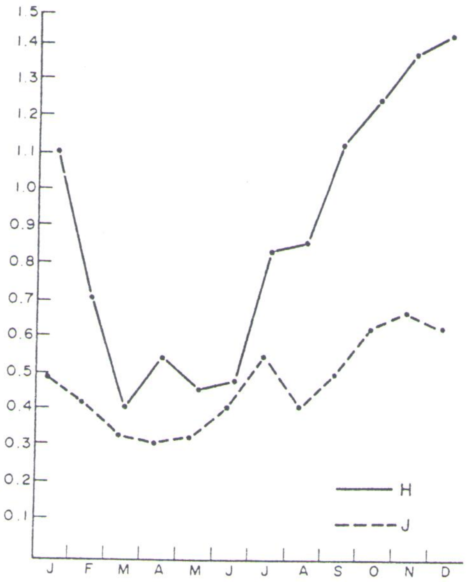

Fig. 3 Mean diversity ($H_{\mathrm{Brill.}}$) and mean evenness (J) of the macrobenthic community at the Lillo–Rilland area, April 1982–October 1984.

more important than the peak of spring, begins here rather early, from mid-June till mid-July. This applies to all important species, except the ringed plover. During the same period, the shelduck (*Tadorna tadorna*) and the black-headed gull (*Larus ridibundus*) reach their maximum summer assemblies. For most of the important species, the peak autumn migration also ends early, in August or September; only the spotted redshank (*Tringa erythropus*) and the avocet (*Recurvirostra avosetta*) still visit the mudflats in high numbers during October. From this month onwards, bird life on the mudflats declines markedly, but every year dunlins (*Calidris alpina*) appear in substantial numbers (up to 2,220 on 8 October). However, in the Zwin area and along the Belgian coast, at a distance of only about 65 km to the west of our studied area, the time of the maximum autumn migration is generally different. It begins and ends at least a fortnight later (Lippens, 1963) than in the Lillo–Rilland area for the oystercatcher (*Haematopus ostralegus*), the grey plover, the bar-tailed godwit, the redshank (*T. totanus*), the spotted redshank and the avocet. This important difference over a short distance is probably correlated with a great availability of food in the Lillo–Rilland area during July–August (Fig. 2). Table 4 shows also the approximate rate of increase with respect to the average peak numbers in this area between the first and the second survey. A clear upward trend cannot be denied.

Discussion

The brackish waters of the investigated region were of a highly unstable and unpredictable nature and this is likely the reason, according to Sanders' (1968) theory of environmental stability, for the low macrobenthic species number noted 30 years ago by Leloup & Konietzko (1956). However, compared to the results of these authors, the species richness has reduced noticeably since then. This as well as the fact that two species among the remaining four increased in number, resulted in low diversity and evenness values of the macrofauna community. Long-term changes in the macrobenthic fauna of the German Wadden Sea show the same trend (Reise, 1982; Riesen & Reise, 1982). According to a large number of other papers cited by Gray (1979) and McLusky (1981), the high proportion of some organisms, increasing over the years, can be attributed to an adaptation to disturbances within the habitat. In the Western Scheldt area both *N. diversicolor* and *C. volutator* have a flexible life history and one may suppose that they underwent short-term genetic selection. In this way they profited a lot of the newly created environment. *C. volutator*, an extremely numerous species in the mudflats of Britain's most polluted estuary (Gray, 1976), also brood their young. It therefore can be classified among the progressive species in the sense of Leppakoski (1975).

It is worth pointing out that conclusions drawn from studies scattered over tens of years cannot achieve the same level of reliability as single short-term studies. So the sample effort in the present study exceeded the one in the former study of Leloup & Konietzko (1956), in which data about the biomass of the macrofauna were lacking. As a consequence, it is not possible today to present a full comparison between their results and ours. But, as said above, a rise of the total macrofaunal biomass since the investigations from 30 years ago is very probable. In the absence of heavy mollusca, such as *Cerastoderma edule* and *Mytilus edulis*, the mean monthly macrofaunal biomass seems rather high in the studied area, when compared with values from other estuaries reviewed by Wolff (1983). It is not excluded that the almost complete disappearance of *Carcinas maenas* and zoobenthos-eating fishes contributed much to this situation. Before, fishes were abundantly present in this part of the Western Scheldt (Poll, 1945). Zijlstra (1979) calculated the total consumption by fishes on the flats of the German Wadden Sea at 2.8–4.6 g AFDW m^{-2} yr^{-1}, which proves the importance of the macrofauna as prey for fishes. Kuipers (1977) found that plaice (*Pleuronectes platessa*) consumed about 5 g AFDW m^{-2} yr^{-1} on the flats of the Balgzand (Dutch Wadden Sea). Concerning our study area, this untouched food supply can now be predated only by birds. So birds may profit by pollution in another way.

The increase of intertidal birds could be explained by several other causes apart from a degradation of the estuarine environment. Firstly, Tubbs (1977) in his study on wildfowl and waders on Langstone Harbour found a numerical increase of 9 on 13 examined species. Although this author accepted that a growing input of sewage effluent since the beginning of his survey had influenced the increase of some species, the fundamental reason for the larger numbers was attributed to a reduction in hunting pressure in north-west Europe since the 1940s. But in the whole Delta area, hunting pressure on waterbirds was always at a low level for at least half a century and cannot substantially have influenced the bird populations there. Moreover, the rate of increase of almost all the examined species is very striking for such a restricted area. The effect of a reduced hunting effect can be discounted.

Secondly, the closure of the Haringvliet and the Grevelingen estuaries in the early 1970s is said to be the reason for the influx of birds in other parts of the Delta area. Because of a drop in the food supply and a sudden fall of biomass of zoobenthos in the sediments of the former estuaries, many waders refuged to other parts of the Delta area (Saeijs & Baptist, 1977a, b). But counts done before 1970 in the Lillo–Rilland area already showed an increase of waterbirds. Furthermore, for compensating the loss of the disappeared estuaries, a great number of refuges are available in the whole Delta area. In our opinion, the dramatic increase of birds in a part of the Western Scheldt cannot be solely attributed to a loss of other foraging haunts.

Bird populations can show increasing trends owing to conditions of environmental pollution, as described before by Player (1971). He found increasing numbers of several species of diving ducks fed on worms and on seeds associated with areas polluted by domestic sewage. His observations were consistent with others elsewhere (Pounder, 1974; Campbell, 1978) and especially with the feeding habits of some dabbling ducks, such as the Wigeon (*Anas penelope*) and the Shelduck, which winter in polluted wates along the Scottish coast, particularly where distillery effluents are present (Pounder, 1976). However, none of these studies gave a comparison between past and present status of both macrofauna and birds at the same locality. Long-term increases of intertidal bird species seem an interesting phenomenon. Perhaps it may be used as a valuable indicator of environmental alteration by pollution, but further research is needed.

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