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Diversity and conservation of terrestrial arthropods in tidal marshes along the River Schelde: a gradient analysis

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Abstract

A large number of tidal marshes (in a gradient from fresh to salt water conditions) along the river Schelde (Belgium), were sampled with standardised effort during spring 1992. A total of 154 species of ground beetles, spiders, isopods and amphipods was recorded. Species richness was high in many large and small sites. Regression and DCCA analyses of these data indicate that the diversity of the fauna does not appear to be related to the area of the investigated sites but significantly increases from salt to freshwater conditions. The highest number of species, however, was recorded in some intermediate habitats, where brackish species, with high interest for conservation, co-occur with species of both saline and freshwater conditions. Many terrestrial arthropods respond clearly to the salinity gradient along this tidal river. Saltmarshes are highly differentiated from freshwater tidal marshes, due to the presence of several halophilic and halobiontic species or freshwater species, respectively. Other species prefer oligohaline habitats or show no response towards the salinity gradient. Secondary differentiation of terrestrial arthropod communities occurs along an ecological gradient from freshwater tidal marshes with litter accumulations to sites with barren soil, temporarily often with cracks. Despite the heavy pollution of the river Schelde, very rare arthropod species still survive in its tidal marshes. The observed communities are of high conservation interest, in a regional as well as in a larger west European context.

Keywords: Tidal marshes; Diversity; Ecology; Terrestrial arthropods; Salinity gradient

1. Introduction

Tidal marshes are among the more restricted natural terrestrial habitats, world-wide covering <0.01% of the total surface (Meire and Kuijken, 1988). These special habitats combine high productivity with extreme abiotic conditions related to the tidal influence of saline water, sometimes far inland. Unfortunately, tidal marshes are also subject to many environmental problems and threats, which have caused a recent dramatic decline in area (e.g. through embankment, industrial activities, harbour extensions) and water quality (due to pollution; Scrimshaw and Lester, 1996). They have therefore become an important nature conservation concern, especially in many estuaries of western Europe (Dijkema et al., 1984).

The Schelde rises in France and flows for some 350 km through the region of Flanders (Belgium) and The Netherlands to the North Sea. Sea water enters and leaves the estuary twice a day. The tidal effect is apparent up to the city of Gent (as much as 160 km inland of the river mouth), but the upstream limit of sea water penetration is Antwerpen city (Peters, 1975). Although severely reduced over past centuries, a long gradient of tidal marshes persists along the river, unique in western Europe (Hoffmann and Meire, 1997; Meire et al., 1997).

The river Schelde basin suffers severe water and sediment pollution (Peters, 1975; Dijkema et al., 1984; Stronkhorst, 1993; Boeije, 1992). Site assessment studies of tidal marshes for conservation have been rare and until now largely based upon birds (e.g. Meire et al., 1994), benthic organisms (Mees et al., 1994; Ysebaert et al., 1994) or plants alone (e.g. Hoffmann, 1995). Although neglected in tidal marshes, terrestrial arthropods are by far the most species-rich group and play an important role in ecosystem functioning.

Many tidal marshes of the Schelde basin have been reduced to a very small size today, mainly by embankment for polder reclamation and, more recently, by the

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continuous extension of Antwerpen's harbour activities. Even in such small marsh remnants, investigations of terrestrial arthropods as indicators remain meaningful, which is not the case for larger animals with lower abundance. Saltmarshes usually take the form of discrete 'islands', mostly sharply delimited from neighbouring terrestrial communities and thus of particular interest for investigating species-area relationships for conservation purposes (cf. minimal size of nature reserves) (Adam, 1990). Many terrestrial arthropods are furthermore well-known bio-indicators used in ecological monitoring and site assessment studies for regional nature conservation purposes (for the Flemish region, e.g. Maelfait and Baert, 1988; Maelfait et al., 1994; Desender, 1996; Maelfait, 1996). This is also the case for saltmarshes (e.g. Treherne and Foster, 1977; Verschoor and Krebs, 1995a) where halobiontic invertebrates (only known from saltmarshes) occur together with halophilic (preference for saline habitats) or halotolerant species.

The aim of this paper is to consider the diversity, community structure and conservation value of tidal marsh arthropods along a gradient of the river Schelde, by considering the following questions: (1) How diverse are the communities?; (2) Can a significant part of the diversity be related to the size and/or the salinity of the sites examined?; (3) Are there communities intermediate between those of saltmarshes and freshwater tidal marshes?; (4) Are environmental factors other than salinity important for structuring the communities?; and (5) What are the implications for nature conservation of these habitats?

2. Material and methods

2.1. Sampling and identification of invertebrates

Twenty eight tidal marshes, in a gradient from fresh to salt water conditions were sampled during May and early June 1992 along the Flemish part of the river Schelde (Fig. 1, sites 5–14, 21–28) and one of its main affluents, the river Durme (Fig. 1, sites 15–20). After prospecting more than 50 sites, 28 sites (including one inland and three coastal saltmarshes for comparison; Fig. 1, sites 1–4) were sampled with a time-standardised effort of catch (sites were omitted for sampling when open vegetation types were absent). Sampling consisted of one man-h of catch (combined hand collecting/quadrat sampling technique: terrestrial arthropods were taken within an area of several m^2) on each site. Terrestrial amphipods, isopods, spiders and carabid beetles were collected, making up the majority of the terrestrial macro-invertebrates in the soil surface stratum of most sites. Samples were only taken in more or less open vegetation types and thus restricted to one habitat type on each site, as far as possible avoiding gradients to

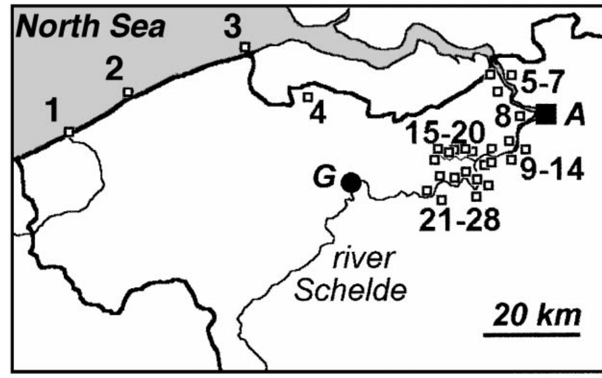

Fig. 1. Location of the sampling sites along the Belgian coast (1–3), the inland Molenkreek (4), the river Schelde (5–14, 21–28) and the river Durme (15–20); A: city of Antwerpen; G: Gent.

adjacent habitats. Each sampling site was categorised for size (ha), soil type, vegetation cover (%), development of litter layer, degree of salinity (discrete classes, cf. Beeftink, 1965; Peters, 1975; Claessens, 1988), as well as distance from the North Sea (as a variable reflecting the salinity gradient). Comparable data on salinity are not yet available for all sampling sites. Simple regressions on sea distance of available salinity measurements (mgCl/l; 15 data pairs, spanning the entire transect studied; Institute of Nature Conservation, unpublished data) showed a highly significant negative relationship (raw data: $r^2 = 0.83$, $p < 0.001$; log-transformed data: $r^2 = 0.98$, $p < 0.001$).

More than 4000 specimens were obtained, sorted and identified to species level. Although the sampling effort on each site was relatively limited, we consider that the sampling technique used provided reliable results for the habitat under study. For three of the investigated sites, a comparison of the present results with those of pitfall trapping series for a complete year cycle (Desender and Maelfait, unpublished) indeed showed that the time-standardised hand collecting method gave a fairly complete picture of the spring arthropod communities (respectively, 80, 82 and 89% of total species collected during 3 months of pitfall trapping with three traps on each site; 100% of abundant species on each site).

2.2. Analyses

Diversity was analysed by means of species richness (because of the relatively limited sampling effort on each site), once by including all species, and once without those occurring in very low abundance (< 3 individuals on a given site) (cf. Desender, 1996). Multiple regression (on raw as well as on log-transformed data) was used to evaluate the relative contribution of area (habitat size) and distance to the sea (as an index of decreasing salinity influence) on diversity.

The conservation value of the obtained terrestrial arthropods was partly derived from a 'Red list' for the ground beetles in Flanders (Desender et al., 1995), partly from other faunistic data (Maelfait, unpublished).

Community structure and reaction of the species to environmental gradients were explored quantitatively by means of an unconstrained indirect gradient analysis (DCA = detrended correspondence analysis, Ter Braak, 1988) as well as a DCCA (detrended canonical correspondence analysis) with the ordination axes constrained by combinations of environmental variables (degree of salinity, development of litter layer, soil type, and vegetation cover). These ordinations were performed on the data for the 33 most abundant species. General ecology of the species was mainly derived from Baert (1996), De Keer and Maelfait (1988), Desender (1985, 1989a), Desender et al. (1995), Duffey (1991), Lincoln (1979), Lindroth (1985, 1986), Locket and Millidge (1953), Locket et al. (1974), Polk (1959) and Wiehle (1960).

3. Results

3.1. Diversity and value for regional nature conservation

A total of 154 species was obtained in this limited sampling comprising 98 carabid beetle species, 45 spiders, nine woodlice and two terrestrial amphipods. Fig. 2 shows the total number of species belonging to the studied taxa on each sampling site, ordered along the sampled saline–freshwater gradient (cf. Fig. 1) and indicating the occurrence of halophilic species and those of special conservation interest. Rare species occurred along the complete transect.

The observed species richness was high for most sites, with a tendency to be lower in pure saltmarshes (sites 1–4), and more elevated in some of the intermediate, brackish sites (sites 5–9). A multiple regression of the total number of species per site on area (habitat

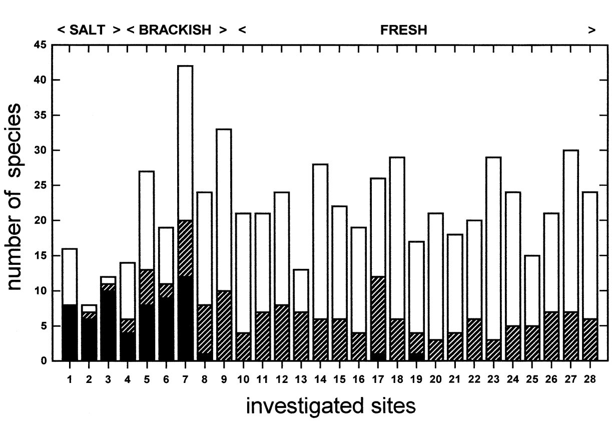

Fig. 2. Species richness on each sampling site; the sites are ordered from left to right according to increasing sea distance (= decreasing salinity influence). Also indicated are the number of halobiontic or halophilic species (black columns) and other species of special faunistic interest (hatched columns).

size) and sea distance (as a measure of decreasing salinity influence) invariably showed a highly significant contribution of the salinity gradient to the observed species richness, the lowest diversity being found in saltmarshes [Fig. 3(A) and (B); Table 1]. There was no significant relationship between species richness and habitat size. Indeed, very small sites of < 0.2 ha as well as large sites all yielded between 10–30 species among the studied taxa.

A similar multiple regression analysis of the observed species richness excluding species in very low abundance [Fig. 3(C) and (D), Table 1] again showed a significant contribution of the salinity gradient, but without the very high diversity of some intermediate brackish sites. Halobiontic species as well as those more typical of freshwater marshes did occur in some of these brackish sites, but mostly in very low numbers.

3.2. Gradient analysis of the terrestrial arthropod communities

Both the DCA and DCCA yielded comparable results, indicating that the included variables in the DCCA explain a significant part of the observed variation in the data. The DCCA scores along the first and second ordination axis are plotted on Fig. 4(A) (sample scores) and Fig. 4(B) (corresponding species scores). Both ordination axes have relatively high eigenvalues (0.76 and 0.25, respectively, accounting for 21.2 and 7.1% of the total variation in the data set) and higher order axes do not raise the percentage of explained variance in the data significantly (1.3% for axis 3). Ellipses enclose observed groups of samples [Fig. 4(A)] or species [Fig. 4(B)]. Correlation values between environmental variables and first and second ordination axis are given in Table 2. The detailed sampling distribution over the 28 studied marshes is given in Table 3 for selected species.

An abrupt change apparently occurs between the faunal assemblages of coastal saltmarshes, the inland saltmarsh and the marshes north of Antwerpen [sites 1–7, A1, Fig. 4(A)], on the one hand, and the tidal marshes from Antwerpen to Gent [A2, Fig. 4(B)], on the other hand. The first ordination axis, indeed, is highly significantly correlated to decreasing salinity ($r = -0.949$, $p < 0.01$; Table 2). In the plot of the species' scores [Fig. 4(B)], several species show a pronounced response to the salinity gradient. Some only occur at the sites with the highest salinity [B1, Fig. 4(B)] or at brackish sites [B2, Fig. 4(B)]; > 15 species only occur in the marshes from Antwerpen city onwards to Gent [B3–B5, Fig. 4(B)]. There are also several species occurring more or less independently of the salinity gradient [situated in the centre of Fig. 4(B)].

A first group of halobiontic or halophilic species is characteristic of sites with a high or intermediate salinity

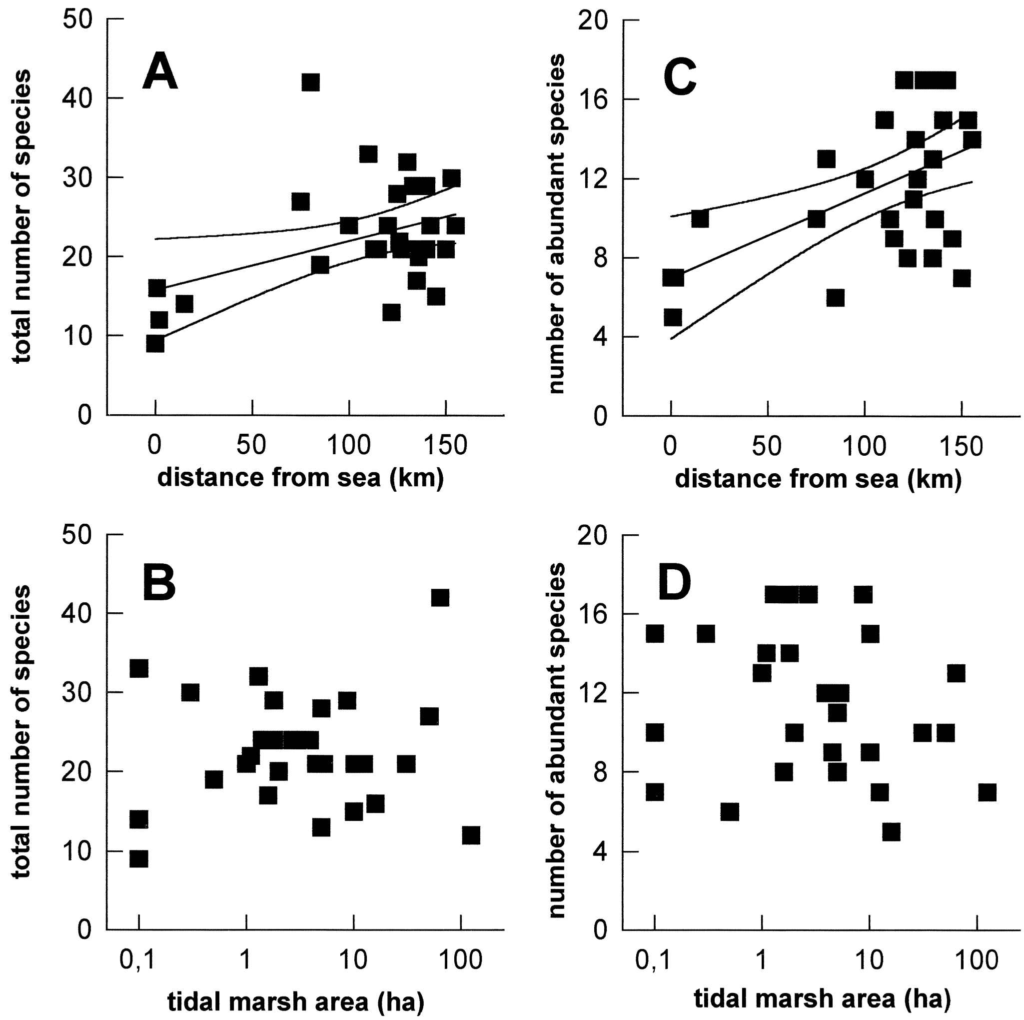

Fig. 3. Regression of the total number of species per site on (A) sea distance and (B) area (logarithmic scale); (C) and (D) are similar regressions based on the abundant species only. Significant regression lines added with 95% confidence limits: (A) $Y=15.8+0.062X$, $r^2=0.17$, $p<0.05$; (B) $Y=7.0+0.043X$, $r^2=0.29$, $p<0.01$. See Table 1 for multiple regression statistics.

[B1, Fig. 4(B)]. The distribution of four carabid beetles and one amphipod is given in Table 3. *Pogonus chalceus* is a halobiontic ground beetle occurring in saltmarshes, especially on spots with scattered vegetation. *Bembidion normannum* is another halobiontic ground beetle with a more restricted distribution. *B. varium* occurs on brackish shores on sun-exposed clay with patchy vegetation but also at the margins of freshwater (Table 3). *B. minimum* predominantly occurs in saltmarshes on moist clayey soil. *Orchestia gammarella* is a halobiontic amphipod from saltmarshes, where it occurs in high densities under all kinds of detritus.

In the ordination analysis, species, normally absent from saltmarshes but typical of oligohaline or freshwater habitats with relatively poor litter accumulation, are grouped to the right, along the first axis [B3, Fig. 4(B)]. Quantitative data are given in Table 3 for two spiders and three carabid beetles. Although widespread in Belgium, *Diplocephalus permixtus* is a rare linyphid spider of marshy habitats and wet grasslands. The carabid *Agonum albipes* is a common shore-dwelling species, occurring along brackish or freshwater. The adults usually live near the water-edge, in open spots on almost barren soil, notably clay-mixed sand, gravel or even stones. *Tmeticus affinis* is a rare spider of extremely wet habitats: it was discovered in a relatively high number of freshwater tidal marshes. The carabid *Demetrias imperialis* occurs in freshwater or brackish reedbeds. The beetle often runs about on the reeds or hides in leaf-sheaths. *Agonum micans* occurs on eutrophic freshwater shores, often in rather shaded sites. It is especially typical of banks along large rivers.

Along the second ordination axis (explaining only 7% more of the total variation), species in the lower right show a clear preference for the freshwater situations with a well developed litter layer [B4, Fig. 4(B)]: one carabid beetle, one terrestrial amphipod and three terrestrial isopods. The ground beetle *Agonum thoreyi*

Table 1
Percentage of variation (ANOVA sum of squares table) accounted for by different variables in multiple regressions of total number of species (or number of abundant species) on area and sea distance (as a measure of decreasing salinity); regressions with raw as well as log-transformed dependent and independent variables (see text and Fig. 3 for further explanation)

	Sum of squares	Significance
Total species (raw data):		
Multiple r^2	0.21	$p<0.05$
Area:	60	*n.s.*
Sea distance	233	$p=0.016$
Total species (log-transformed data):		
Multiple r^2	0.42	$p=0.001$
Area:	0.006	*n.s.*
Sea distance:	0.245	$p<0.001$
Abundant species (raw data):		
Multiple r^2	0.29	$p=0.014$
Area:	27	*n.s.*
Sea distance:	112	$p=0.003$
Abundant species (log-transformed data):		
Multiple r^2	0.36	$p=0.004$
Area:	0.022	*n.s.*
Sea distance:	0.197	$p=0.002$

Dejean is indeed known to prefer freshwater or brackish reed swamps with litter accumulations. *Orchestia cavimana* Heller is a relatively rare amphipod occurring under litter on river banks, where its seems to replace the congeneric *Orchestia gammarella*, which occurs exclusively on saltmarshes. *Oniscus asellus* Linnaeus is a very common isopod from wet litter accumulations. *Porcellio scaber* Latreille is an equally common litter-dwelling isopod. *Trachelipes rathkei* Brandt, on the other hand, is a relatively rare isopod, often found in litter accumulations on river banks. At the upper right along the second ordination axis, four species are grouped with a preference for open sun-exposed microhabitats without litter (B5, Fig. 4(B)), namely the riparian carabid beetles *Bembidion articulatum* (Panzer), *Dyschirius aeneus* (Dejean), *Elaphrus riparius* (Linnaeus) and *B. tetracolum* Say. *B. articulatum* is a common ground beetle occurring on moist sand or clay soil, mostly on barren spots, often hidden in cracks. It shows a very high species score along the second axis, which indeed can be interpreted as a gradient from sites with litter accumulations [low scores, B4, Fig. 4(B)] to sites with barren soil, temporarily often with cracks [high scores, B5, Fig. 4(B)]. This second axis is, as expected, significantly and negatively correlated with development of the litter layer ($r=-0.664$, $p<0.01$; Table 2).

Many species show intermediate patterns. Some show a more gradual response to the salinity gradient including a number of halophilic species which occur on relatively more oligohaline sites than others [B2, Fig. 4(B) and Table 3]. Examples are the halophilic and very rare

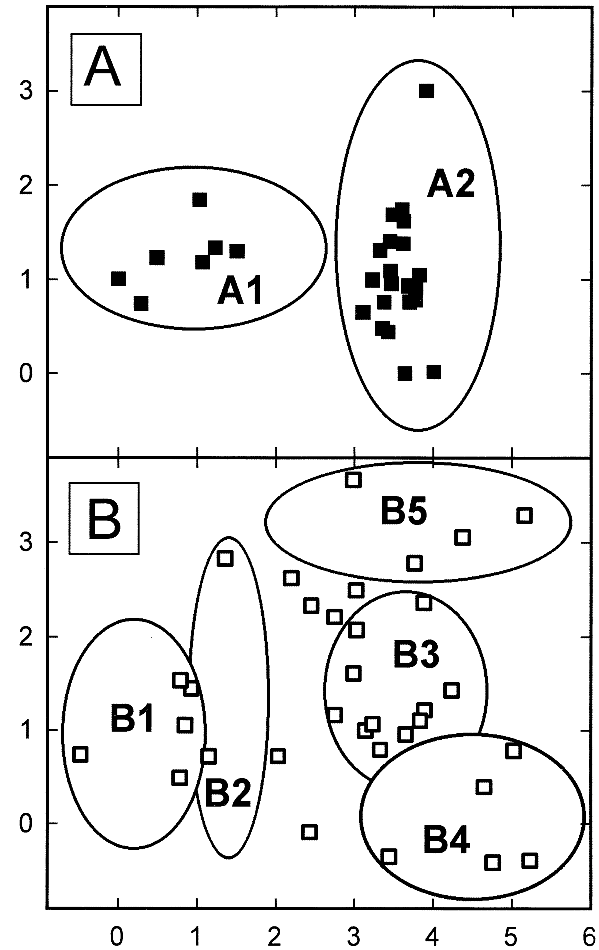

Fig. 4. DCCA sample scores (4A) and species scores (4B) along the first and second ordination axis; added ellipses enclose major groups of samples (A1–A2) and species (B1–B5). See text for further explanation.

linyphid spider *Baryphyma duffeyi* and the carabid *Bembidion maritimum*, a species endangered in our region, and restricted to sites of brackish *Spartina* or reed beds without litter. Other species occur more or less independently of salinity, their distribution pattern being determined by other habitat characteristics. *Hypomma fulvum* Bösenberg, for example, is a species of very wet habitats (fens, marshes, swamps) and appears to be closely linked to the presence of old reed *Phragmites australis*. Indeed the egg cocoon of this particular species seems to be exclusively constructed on the dead reed

Table 2
Correlation coefficients between environmental variables and DCCA first and second axis

	DCCA axis 1	DCCA axis 2
Salinity	−0.949	0.141
Litter	0.565	−0.664
Soil type	−0.446	−0.029
Vegetation cover	0.289	0.037

Table 3
Quantitative occurrence of some typical terrestrial invertebrate species along the investigated gradient (sites 1–28, cf. Fig. 2)

	Salt				Brackish					Fresh																			
Species Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	total
Pogonus chalceus (Marsham)	34	67	71	18																									190
Bembidion normannum Dejean			68	27																									95
Bembidion varium (Olivier)		5		41	20	22	7																						95
Bembidion minimum Fabricius	18	4	5		20	7	8																						61
Orchestia gammarella (Pallas)	50	30	20	25	49	58	28																						260
Baryphyma duffeyi Millidge					22		26																						48
Bembidion maritimum Stephens						29	5									3		11											48
Diplocephalus permixtus (Cambridge)								4		1	16	14	39	8	12	9	22	21	11		15	30	4	42	24	60		11	3 13
Agonum albipes (Fabricius)							1	46	23	8	54	48	21	20	30	8	18	17	42		29	47	11	18	5	32	27	12	514
Tmeticus affinis (Blackwall)								7		5	5	7	2		2	3	2	10			3	2	7		2			8	65
Demetrias imperialis (Germar)							1	1	9		1						3	2				3			11				30
Agonum micans Nicolai									41	36	21	10	3	13	10	2	5			2	3	17	8		17	29	11	41	264

flowerheads of the previous year. In Belgium it is an uncommon species occurring almost exclusively in very wet reedbeds with accumulation of litter, needed for its overwintering. *Erigone atra* (Blackwall) is a very eurytopic and typical spider for disturbed situations without litter and with sparse vegetation.

4. Discussion

4.1. Diversity of tidal marsh communities

As expected, the investigated saltmarshes are dominated by halobiontic or halophilic terrestrial invertebrates. These are species well adapted to the extreme osmotic and microclimatological conditions occurring in such habitats (Treherne and Foster, 1977). The intermediate brackish sites also contain such halobiontic species, but in addition possess several species also occurring in freshwater marshland. Species from both ecological groups thus co-occur in some of these brackish sites at their mutual limits of ecological tolerance. This results in an overall higher species richness, which can increase even further due to the occurrence of some typical and very rare species from brackish habitats. Several of these brackish species appear to be severely threatened, not only in our region but all over western Europe (Desender and Turin, 1989) through loss of habitat: many brackish marshes along the Schelde indeed have disappeared in recent decades through embankment and polder reclamation (Beeftink, 1975).

Species richness along the studied transect was not significantly explained by area (habitat size). The possibility remains that this was partly caused by edge effects in some small to very small tidal marshes (in many cases reduced to narrow 'strips'). Species richness may have been inflated in these very small marshes by (accidental) immigration from nearby habitats, thus masking an existing species-area relationship for a pure tidal marsh fauna. Small and especially narrow tidal marshes should, when possible, be enlarged as a conservation measure, not only to reduce possible edge effects, but also to decrease possible negative effects of small population sizes for typical species.

Nevertheless, the variation in species richness along the transect of tidal marshes was significantly explained by the salinity gradient, especially when only taking the more abundant species into account: a higher salinity clearly corresponded to species-poorer communities. Some earlier studies on saltmarsh beetles (Treherne and Foster, 1977; Verschoor and Krebs, 1995a,b) concluded that probably relatively few species are adapted to the extreme physiological conditions resulting from a high salinity and regular submergence of saltmarshes.

Odum (1988) reviewed the comparative ecology of tidal freshwater marshes and saltmarshes and described hypothetical trends in total species numbers for different higher taxa along the estuarine gradient (but mentioning that particularly at intermediate salinities much more data are required): vascular plant species diversity gradually decreased towards saltmarshes, whereas the number of species of benthic invertebrates (both macro- and microfauna) appeared to be lower in tidal freshwater mudflats than in either saltmarsh or nontidal freshwater habitats. Odum (1988) concluded that the small amount of comparative data on invertebrates, however, made it impossible to validate either the lower number of benthic species in tidal freshwater marshes or the reasons for this. Insects and other terrestrial arthropods were not even treated.

Our results show that, for these animals, a reverse trend is observed, which corresponds partly to the gradient of species richness as observed for plants. Studies on plants in coastal marsh communities of the northern Gulf of Mexico also recorded a significant and negative effect of salinity on species richness (Grace and Pugesek, 1997). In a study of the vegetation in saltmarshes of Morecambe Bay (UK), Gray and Bunce (1972) noted that some marshes in transitional habitats, at the interface between brackish and freshwater influences, were characterised by high species diversity. Beeftink (1975), on the contrary, suggested a lower plant species richness in the intermediate salinity range (due to increased instability) as compared to saltmarshes. Hoffmann (1995) found about twice as many plant species in freshwater tidal marshes as in the remaining saltmarshes along the river Schelde; brackish sites were not distinguished from saltmarshes. Comparison of these data with our results is difficult because the sampling effort in Hoffmann's study was not constant between sites. In this way it is more difficult to disentangle effects of area and/or habitat or microhabitat diversity on species richness along the salinity gradient (see also Kohn and Walsh, 1994). Data on plant species richness in British saltmarshes (but not along a salinity gradient) likewise did not indicate a significant species-area relationship for plants (Adam, 1990). However, the data suggested that, for a given salinity level, habitat or microhabitat diversity rather than area *per se* were the significant factors controlling species richness.

4.2. Conservation of tidal marsh terrestrial arthropods: the need for more empirical studies

Despite the heavy pollution of the river Schelde itself and the severe reduction in tidal marsh area, rare species still occur along the complete transect. Conservation of all remaining brackish tidal marshes along the Schelde is therefore of high priority for terrestrial arthropods. This will not be an easy task, however, as the few remaining tidal marshes in the intermediate salinity range are situated close to the continuously extending harbour of Antwerpen. Moreover, at the moment we are still largely ignorant of management measures that would be necessary for sustaining populations on these remaining marshes.

Adam (1990) raised already many arguments in favour of protecting the largest possible area and proportion of saltmarsh sites on a global scale. Some of the rare species of the Schelde tidal marshes are now being investigated in more detail, especially with regard to their susceptibility to heavy metal contamination (Maelfait, 1996) and their population genetics (Desender et al., 1998). Observed genetic differentiation between saltmarsh populations of some carabid species again suggests protecting the maximum number of isolated marshes (Desender et al., 1998). Many rare species occur in small and isolated tidal marshes, which might have population dynamic as well as population genetic consequences, such as genetic erosion.

One of the shortcomings in our data is the relatively low number of studied marshes at intermediate salinities. Sampling has therefore been performed recently in additional brackish marshes along the river Schelde, mainly situated in The Netherlands. As far as we know, however, there are no comparable data yet available from sampling series along other tidal rivers with a similar extensive salinity gradient. Such empirical studies are urgently needed in other estuaries in western Europe in order to evaluate if and where similar or possibly also other terrestrial arthropod communities are occurring.

Many species from the present study show limited distributions, at least in our country or region, and thus represent high values for regional or even European conservation. Such species have narrow or special ecological requirements (cf. Desender et al., 1995). The spider *Tmeticus affinis*, for example, is only known from three other localities in Belgium. All are reedbelts in very wet places. In other countries, the species occasionally also occurs in other wet eutrophic grassy vegetation, sometimes even in high numbers, declining strongly after long inundations (Casemir, 1962). Crocker and Felton (1972) and Pühringer (1975) found *Tmeticus affinis* together with the rare *Tetragnatha striata*. *Diplocephalus permixtus* has never been found in Belgium in such high abundance as in the freshwater part of the Schelde estuary. For the halobiontic ground beetle *Bembidion normannum* there are only few recent data available. *Bembidion minimum* is still relatively common in saltmarshes as well as on brackish sites sometimes further inland, i.e. in the polder region. *Bembidion maritimum* has a pronounced preference for brackish tidal marshes and is very rare, although locally sometimes abundant. Its distribution is restricted to estuaries in north-western Europe. This beetle has declined considerably recently (Desender et al., 1995), but still survives along the river Schelde in the surroundings of Antwerpen and in some small and isolated nature reserves along the river Durme. More recently we have discovered an abundant population of this species in the large Saeftinghe tidal marshes of the river Schelde. This observation confirms its preference for brackish sites, as mean salinity in this area is about 10 (Hemminga et al., 1996).

All of these small and congeneric ground beetle species possess a high power of dispersal and are able to fly, a characteristic found in many, but not all, carabid beetles from riparian habitats (Den Boer et al., 1980; Desender, 1989b). This accounts for the fact that low numbers of stray individuals of these species can sometimes be found outside their preferred habitat (Desender, 1996). On the other hand, the recent decline of such species shows that the mere possession of high dispersal power will not be sufficient for survival (cf. Den Boer, 1990) in the long run, if their habitats are further altered, reduced or isolated. At the same time, this characteristic offers possibilities for possible future experiments of marsh creation and rehabilitation. Many of these special tidal marsh arthropods are indeed still occurring along the Schelde and could possibly colonise newly appearing or created marshes. The ability to create habitat should, however, not be used in partial justification for the destruction of existing areas (Adam, 1990). Complete protection accompanied by appropriate conservation management measures is first and urgently needed, as well as more empirical data on other tidal rivers.

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