Hydrobiologia **294**: 23–34, 1994.

Distribution of the genus *Gammarus* (Amphipoda: Gammaridae) in the River Hunte and its tributaries (Lower Saxony, northern Germany)

Wolfgang Janetzky
Carl von Ossietzky Universität Oldenburg, ICBM-AG Aquatische Ökologie, Postfach 2503, D-26111 Oldenburg, Germany

Received 12 January 1993; in revised form 21 October 1993; accepted 17 November 1993

Key words: Gammarus fossarum, Gammarus pulex, Gammarus roeseli, distribution, Hunte, Lower Saxony

Abstract

In 1990 and 1991 the distribution of the genus *Gammarus* was examined in the River Hunte and its tributaries (Lower Saxony, northern Germany). In contrast to data from the literature, *Gammarus fossarum* and *G. roeseli* were just as abundant as *G. pulex*, which had been known to inhabit rivers and brooks in northern Germany. *G. pulex* was most frequent (1990 at 57 out of 70 and 1991 at 37 out of 39 sampling sites) followed by *G. fossarum* (at 52 and 32 sampling sites, respectively), whereas *G. roeseli* was locally restricted (at 7 and 6 sampling sites, respectively). *G. fossarum* and *G. pulex* were distributed up to the level of the city of Oldenburg; further north their distribution is limited by tidal influences and they are replaced by *G. zaddachi*. The possibility of using gammarids as indicators of water quality, as it has been done in low mountain ranges, is discussed.

Introduction

Among crustaceans the gammarids in particular have been investigated for their suitability to serve as indicators for general statements on the quality of water bodies, since under near-natural conditions they occur in all rivers and brooks of central Europe (Meijering, 1989).

Originally only the three gammarid species *Gammarus fossarum* KOCH, *Gammarus pulex* (LINNAEUS) and *Gammarus roeseli* GERVAIS occurred in the running waters of Germany:

Gammarus fossarum mainly occurs in the central and eastern low mountain ranges of Europe and colonizes mountain rivers. The species' northern limit of distribution are the foothills of the low mountain ranges. While above 450 m altitude only this species occurs, below 400 m there are mixed populations of *G. fossarum* and *G. pulex*. 100 m is thought to be the lower limit for *G. fossarum*. *Gammarus pulex* predominantly occurs in the lowland brooks and rivers of northwestern Europe. In the low mountain ranges the southern limit of distribution is at 400 m altitude. Below 300 m *G. pulex* occurs along with *G. roeseli*.

Gammarus roeseli mainly occurs in the western and central low mountain ranges as well as in the lowlands located at their foot. Even more than *G. pulex* this species is a characteristic lowland brook species which is also found in larger water bodies (all data from Meijering, 1971; Meijering & Pieper, 1982).

Varying tolerances of the different species with respect to environmental changes reflect the different variation ranges in the abiotic conditions of their habitats:

- The tolerance of strong water currents is highest with *Gammarus fossarum*. It is lower with *G. pulex* and the lowest values were observed with *G. roeseli* (Meijering 1971, 1985).
- As for rises in temperature, *Gammarus pulex* exhibits a higher resistance than *G. fossarum* (Meijering, 1985).
- Decreases in the oxygen concentration due to waste water are only tolerated to a low degree by *Gammarus fossarum*, whereas *G. pulex* and *G. roeseli* are relatively resistant to O_2 -decreases (Jahr *et al.* 1980; Meijering, 1989, 1991; Meijering *et al.*, 1974; Scholz & Meijering, 1975).

- *Gammarus pulex* is more resistant to the acidification of waters than *G. fossarum* (Brehm & Meijering, 1982; Meijering, 1984, 1989, 1991; Meijering & Pieper, 1985).

Due to the graded resistances to these milieu factors, at least in those cases in which the different gammarid species occur jointly negative changes in the water quality are indicated by the gradual loss of species and positive changes by the recolonization of the water. By comparing populations from unpolluted with those from polluted waters it is possible to draw conclusion concerning the general burden of water systems (Meijering & Pieper, 1982).

Since there are only two publications available on the limnetic systems of the North German Plain (Späh, 1980; Suhrhoff, 1991), the investigations presented here are to provide information regarding the distribution of gammarids in the Hunte river and selected tributaries. At the same time the applicability of the above-mentioned indicator system of low-mountain-range brooks to lowland waters is to be examined.

Study site

The River Hunte originates in several spring brooks (140–180 m altitude) at the northern rim of the Wiehengebirge, which directly borders the North German Plain. South of the Mittellandkanal the character of the Hunte changes from a low-mountain-range brook to a lowland river. The Hunte, which in its further course is fairly broad, runs through natural landscapes that are typical of Lower Saxony (geest, mire lowlands, marshes) before it flows into the River Weser at Elsfleth (Fig. 1).

After the 1990 survey mapping of the catchment area of the Hunte the investigations performed in 1991 focussed on exemplary seven water sections (Fig. 1, indicated by arrows and names) at which the effects of anthropogenic impacts on the water bodies were examined. These model sections will be briefly characterized in the following:

Hunte 1

The Hunte flows through a river-bed which is initially 4.5 m wide and broadens trapezoidally to 12 m due to the backwater effect of a mill weir. The surrounding area is used agriculturally up to the embankment. On the shore reed canarygrass and brookgrass reed thickets are growing; the water body itself is the habitat of an aquatic vegetation rich in species.

Hunte 2

The river-bed of the Hunte is extended in a trapeziform way; the bottom and the banks are stabilized with rock fill. In the further course of the river there are several weirs that determine the water properties (in particular water current). The occurrence of macrophytes is limited to a narrow shoreline of reed canarygrass and brookgrass.

Hunte 3

Through shortenings in the river course in the 19th century and the removal of the damming weirs in the 1950s the flow velocity of the Hunte increased, which resulted in heavy erosion processes which in turn deepened the river to a level of 2–3.5 m below the upper edge of the land. The course of the river, which is still very meandering, exhibits heterogeneous shore and riverbed structures (e.g. sliding and bulging slopes, shallow water areas). The shore vegetation consists of meadows and high herbaceous plants, an aquatic vegetation is only sparsely present.

Dadau

The brook Dadau flows in a straight bed with an oversized, trapeziform cross section. Due to the damming effect of the aquatic vegetation, which is increased by the lack of shading of the water and nutrient input from the surrounding areas, which are intensively cultivated, the water current decreases so severely during the main vegetation period that the Dadau acquires the character of a still water body.

Katenbäke 1 & 2 (Fig. 1)

From the course of the brook Katenbäke two model sections were selected, one of them being part of the upper course (Katenbäke 1) and the other one of the lower course (Katenbäke 2).

Katenbäke 1: In part the upper course has been regulated and extended into a trapeziform cross section with a width of 2 m; the bottom and the bank have been stabilized with rock fill which is partly sanded. The surrounding area is used agriculturally, partly up to the embankment; in other parts, however, there are also woody plants along the shore. The aquatic vegetation is mainly composed of bur-reed and stocks of others of the bur-reed families.

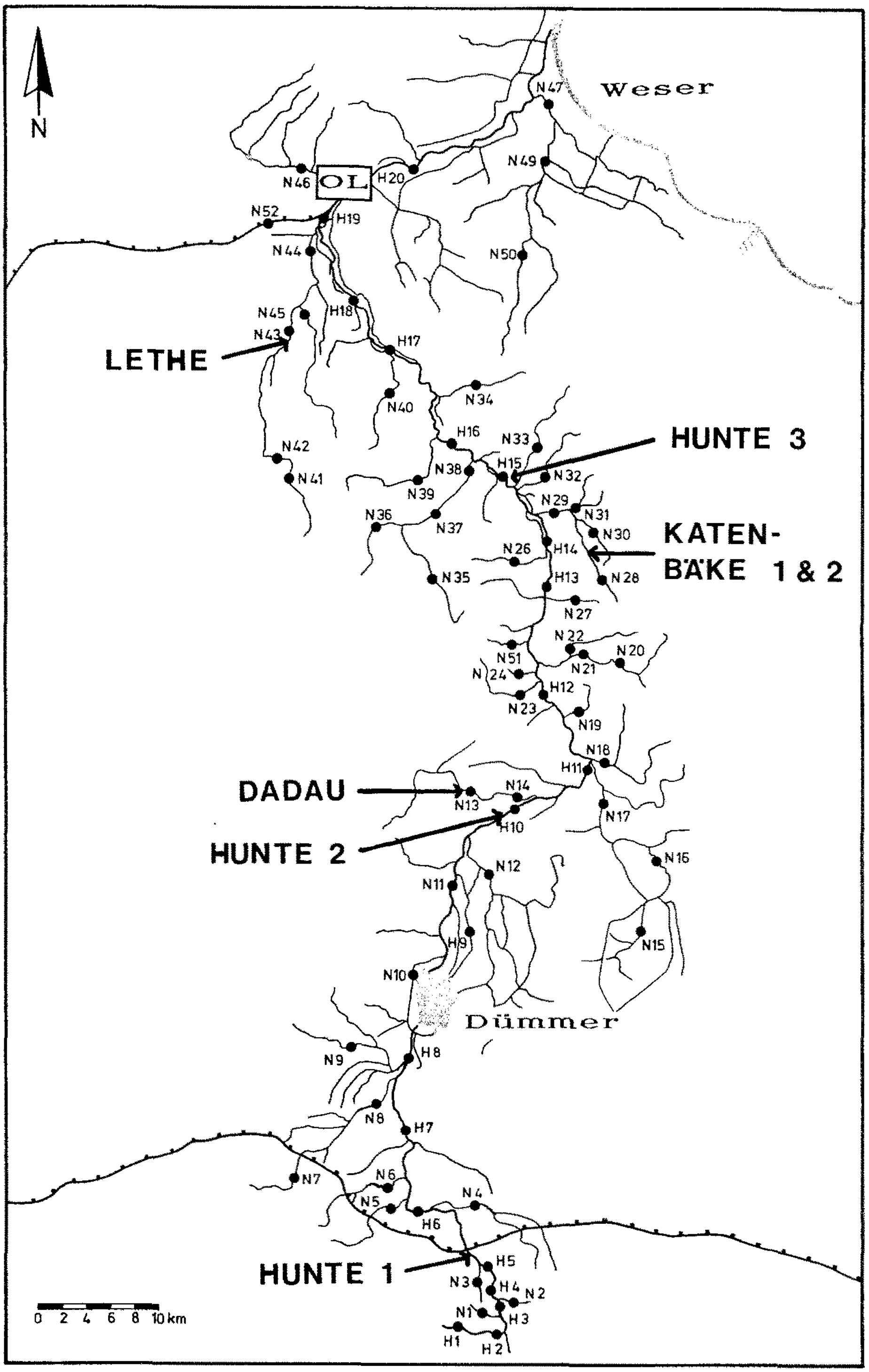

Fig. 1. Locations of the sampling sites of the survey mapping in 1990 (H: Hunte; N: tributaries) and the model sections (indicated by arrows and names) in the catchment area of the Hunte. OL: Oldenburg.

Katenbäke 2: The lower course, which has also been regulated has been fixed with rock fill which is partly sanded. Just as with the upper course the surrounding area is used agriculturally, Woody plants grow at only a few places along the banks; an aquatic vegetation is hardly present.

Lethe (Fig. 1)
The river Lethe exhibits a natural, meandering course (e.g. sandbanks, shore break-offs). Woody plants are only sparsely present along the banks; in the water an extensive macrophytic vegetation has developed.

Methods

For a preliminary survey mapping of the Hunte and selected tributaries 70 sampling sites (20 in the Hunte, 50 in the tributaries; Fig. 1) were investigated in 1990 for the occurrence of gammarids. For a more detailed mapping of individual water sections 39 sampling sites were investigated in 1991, some of did not correspond to those of the preceding year. The investigations focussed on the sampling sites in the model sections mentioned (monthly sampling from March to October).

The samples were taken semiquantitatively by means of a surber-sampler (0.35 × 0.35 m; Downing & Rigler, 1984; Schwoerbel, 1986) and fixed with ethanol (final concentration 70%). The gammarids were sorted in a laboratory and identified by means of a binocular microscope, WILD M8 (Goedmakers, 1972; Lincoln, 1979; Meijering, 1989; Pinkster, 1970, 1972; Schellenberg, 1942). Since there is hardly any difference between juvenile specimens of *Gammarus fossarum* and *G. pulex* (<0.5 mm, incomplete development of the properties which are variable in any case; cf. Meijering, 1972; Schellenberg, 1937), they were recorded as G. spec.

At each sampling site temperature, pH value (both WTW pH 96), oxygen concentration (WTW oximeter 196) and conductivity (WTW LF 95) of the water were measured. The water current was measured in the area of the streamline by means of a drifting item. Since the measuring appliances did not always function properly, the number of measurements (*n*) is indicated in the presentation of the corresponding results.

Results

In contrast to previous reports (Jazdzewski, 1980; Pinkster, 1978), *Gammarus fossarum* and *G. roeseli* could be detected together with *G. pulex* in the Hunte and its tributaries. 62 (*i.e.* 89%) of the 70 water sections investigated during the survey mapping in 1990 were colonized by gammarids. The species that occurred most frequently were *G. pulex* (57 out of 70 sampling sites, *i.e.* 81%) and *G. fossarum* (52 out of 70 sampling sites, *i.e.* 74%), whereas *G. roeseli* was found at only 7 of the 70 sampling sites (10%; Fig. 2).

Within the water system of the Hunte the distribution of *Gammarus fossarum* and *G. pulex* ranged from the Wiehengebirge (H1) to the level of the city of Oldenburg (H18, N46, N50). The distribution of *G. roeseli* was restricted to the Hunte (H5-H8) and two of its tributaries (N4, N6). The most northern sampling site at which *G. roeseli* occurred was located in the Hunte close to Schäferhof (H8) and probably marks the distribution limit of this species.

Below the city of Oldenburg up to the entry of the river into the Weser the Hunte is influenced by the tides. Here the limnetic gammarid species are replaced by the brackish-water species *Gammarus zaddachi* SEXTON (H20, not indicated in Fig. 2). The evidence of *G. pulex* in the also tidally affected 'Ollen' (N47) is based on the detection of one specimen.

The single finding of *G. tigrinus* SEXTON, a brackish-water species, in the Hunte in the vicinity of Bohmte (H6, not indicated in Fig. 2) is probably due to the influence of the Mittellandkanal (Aumann *et al.* 1992; Janetzky *et al.* 1992; evaluation of the data obtained in 1990 with respect to the natural structure of the investigation area: cf. Meurs *et al.*).

This paper focusses on the results obtained in 1991 with respect to the possible role of gammarids as indicators of water quality in lowland water bodies and the possibility of transferring corresponding results obtained in running waters of low mountain ranges to lowland waters, respectively (cf. Introduction).

The 39 water sections investigated in 1991, 37 (95%) were colonized by gammarids. *Gammarus pulex* was found at all 37 (95%) sites, whereas *G. fossarum* occurred at 32 (82%) and *G. roeseli* at 6 (15%) sites.

In the following the results obtained at the sampling sites in the model sections will be presented:

The results for the chemical and physical measurements for the model sections of the River Hunte are given in Table 1.

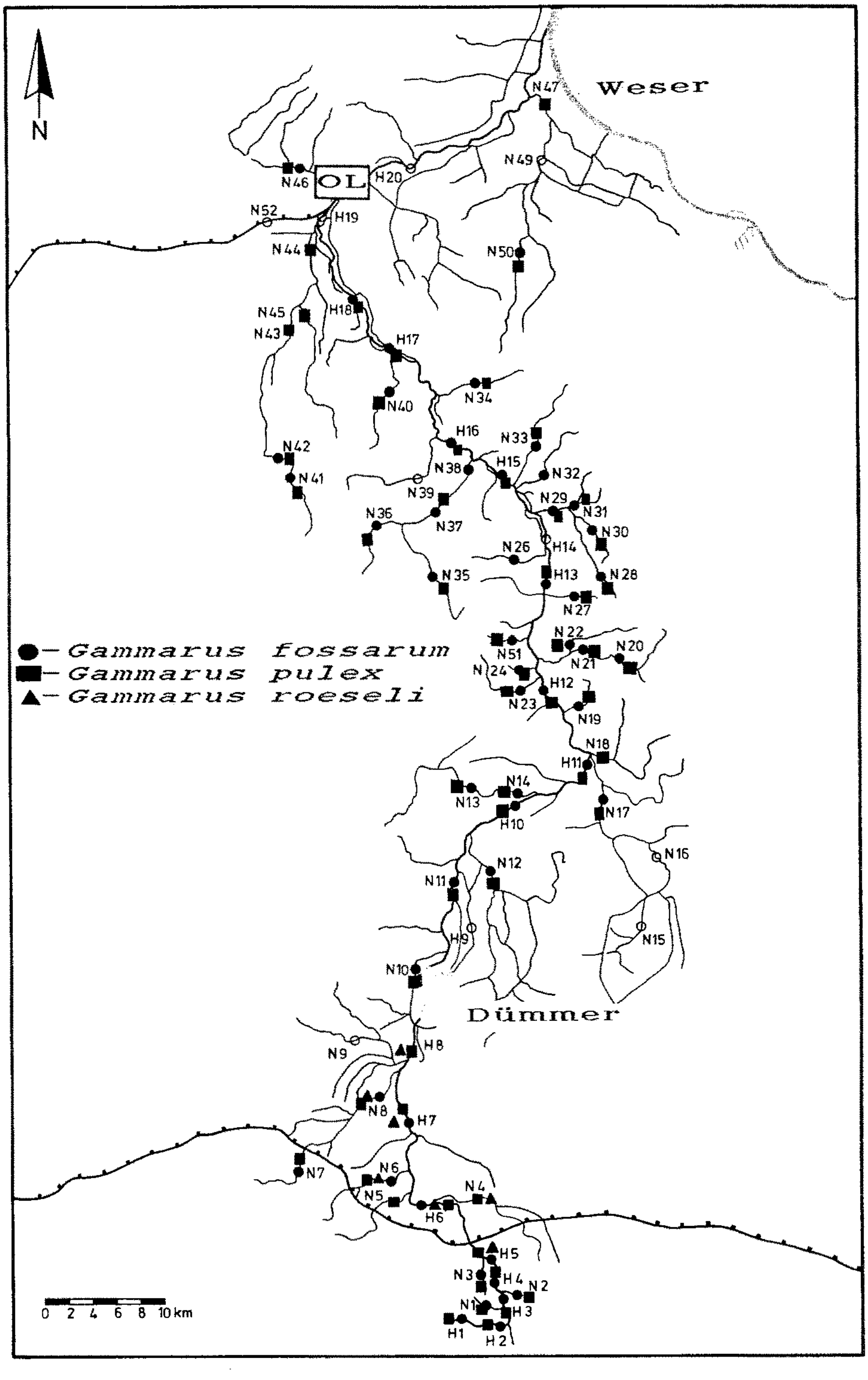

Fig. 2. 1990 survey mapping: Distribution of limnetic gammarids in the catchment area of the Hunte. OL: Oldenburg. (After Janetzky *et al.*, 1992; redrawn.)

Table 1. Chemical and physical characteristics of investigated Hunte sections; the mean ($\overline{x}$), the number of measurements (n, in brackets) and the ranges are shown

Sampling site:	Hunte 1 (H5-4)	Hunte 2 (H10)	Hunte 3 (H15.1)
Current (m s^{-1})	0.0 (8)	0.06 (5)	0.37 (5)
		0.00-0.13	0.30-0.5
Temperature (°C)	14.40 (8)	14.40 (8)	14.90 (8)
	9.10-20.9	8.70-18.20	9.20-21.6
Conductivity (μS cm^{-1})	602 (8)	540 (8)	484 (8)
	522-680	398-760	400-630
PH-value	7.9 (5)	7.5 (6)	7.8 (7)
	7.5-8.1	7.2-7.7	6.9-8.9
Oxygen content (mg l^{-1})	10.1 (8)	10.7 (5)	13.0 (6)
	5.3-12.0	8.0-15.4	9.7-18.2

The main difference between the investigated sections is the water current: due to a mill weir, the upper Hunte section (H5.4; Table 1) has no measurable water current, whereas in the lower Hunte section (H15.1) a mean current of 0.37 m sec^{-1} was measured. The sections cannot be further differentiated without additional measurements.

Hunte 1

In the area of the model section (sampling site H5.4) *Gammarus pulex* was detected during the entire investigation period (March–October), *G. fossarum* occurred in March and September and *G. roeseli* was only observed in August.

The mean density of individuals of the gammarids (incl. G. spec.) was 4 specimens m^2 (range <1–10 specimens m^2, in July and October respectively). With the exception of the sampling in March (dominance of *G. fossarum*) *G. pulex* was dominant in the gammarid community (Fig. 3).

Beyond the model section the investigated water sections were colonized by *G. fossarum* and *G. pulex*. In this area *G. fossarum* dominated in the spring brooks of the Hunte, as well as in the brooks Bremkebach and Glanebach (N1 and N2, respectively; Fig. 1). From sampling site H2 on (Fig. 1) the dominance relations of the gammarid populations in the Hunte shifted from *G. fossarum* to *G. pulex*. Evidence for *G. roeseli* could be found in the Hunte from sampling site H3 on (Fig. 1). This species was dominant in the gammarid communities of the riverine section stretching from below the model section (north of the Mittellandkanal) to the Lake Dümmer.

Hunte 2

In the model section (sampling sites H10, H10.1, H10.2) *Gammarus pulex* could be detected in seven out of eight samplings (exception: April) and *G. fossarum* was found in six samplings. In contrast to this only one specimen of *G. roeseli* was detected in June at sampling site H10.2 (not indicated in Fig. 4).

The mean density of individuals of gammarids (incl. G. spec.) was 29 specimens m^2 (range <1–140 specimens m^2, in April and October respectively). Similarly to the river section 'Hunte 1' the gammarid communities of 'Hunte 2' were dominated by *G. pulex* (Fig. 4).

Hunte 3

In the model section (sampling site H15.1) *Gammarus pulex* was detected in 5 samplings (March, April, August–October) and *G. fossarum* was found in six samplings (March–May, August–October).

The mean density of individuals of gammarids (incl. G.spec.) was 56 specimens m^2 (range 0–206 specimens m^2, June and September respectively). When both species were present *G. pulex* was dominant in general. The only exception was the sampling in August, in which *G. fossarum* dominated (Fig. 5).

The results for the chemical and physical measurements for the model sections of the different tributaries are given in Table 2.

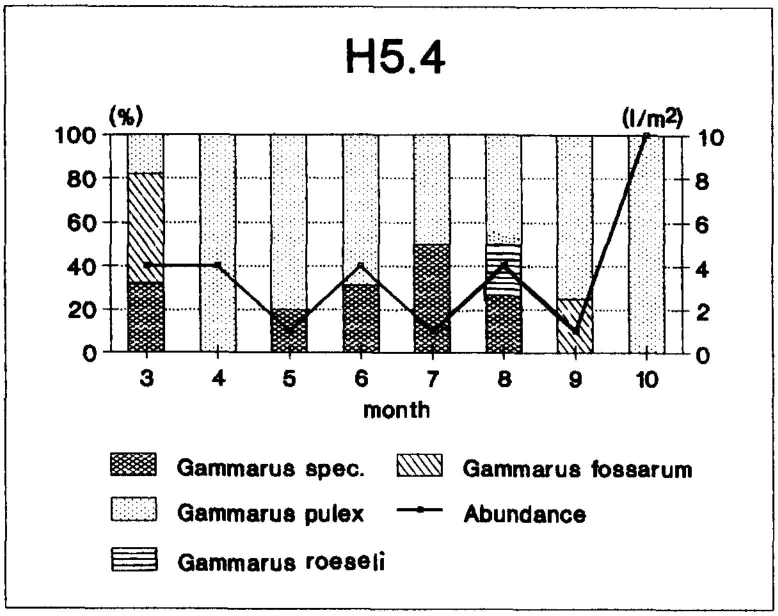

Fig. 3. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the river Hunte at sampling site H5.4.

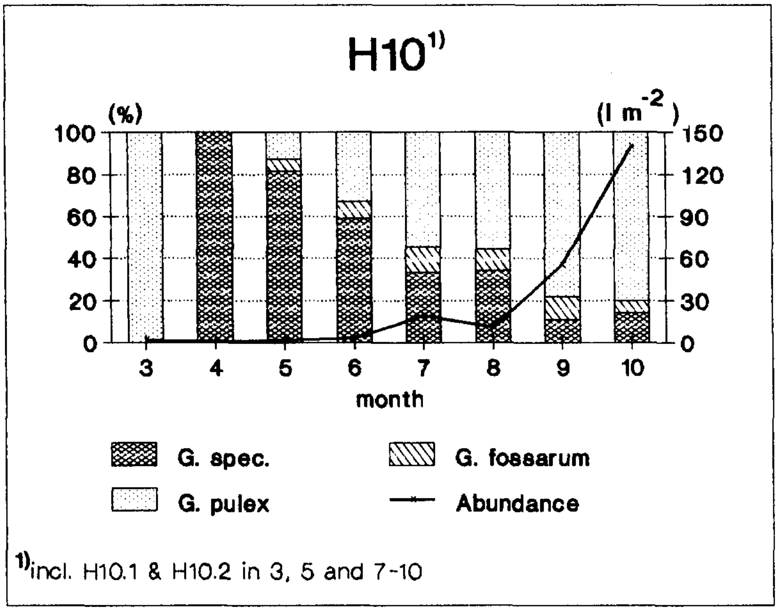

Fig. 4. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the river Hunte at sampling site H10 (incl. H10.1, H10.2).

The tributary 'Dadau' differs from the other brooks in respect of its water current, which is relatively low. Due to the vegetation growing in this brook, the Dadau changes its character from running to still water during the year. As mentioned for the Hunte, there are too few measurements to justify further comment.

Dadau

In the model section (sampling site N13) *Gammarus pulex* could be detected during the entire investigation period (March to October). *G. fossarum* was found in six samplings (April, May, July–October).

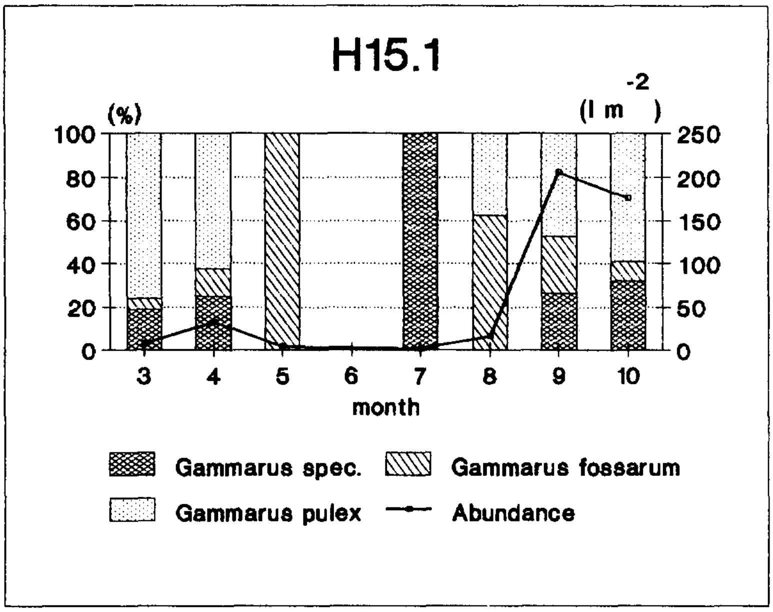

Fig. 5. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the river Hunte at sampling site H15.1.

Table 2. Chemical and physical characteristics of investigated tributaries; the mean ($\bar{x}$), the number of measurements (n, in brackets) and the ranges are shown

Sampling site:	Dadau	Katenbäke		Lethe
	(N13)	(N28.1)	(N29.1)	(N43)
Current (m s^{-1})	0.09 (6)	0.43 (7)	0.17 (7)	0.35 (6)
	0.0-0.29	0.18-0.67	0.0-0.28	0.2-0.53
Temperature (°C)	13.6 (8)	14.0 (8)	14.3 (8)	14.2
	9.2-16.3	8.9-19.5	8.0-23.3	10.4-16.9
Conductivity	304 (8)	363 (8)	396 (8)	197(8)
(μS cm^{-1})	275-400	290-500	344-500	175-250
PH-value	7.2 (6)	7.4 (6)	7.9 (6)	7.2 (7)
	6.7-7.9	6.8-7.8	7.4-8.4	6.0-8.2
Oxygen content	7.1 (5)	12.1 (7)	11.2 (7)	11.3 (5)
(mg l^{-1})	3.9-19.3	6.4-19.7	8.8-13.0	9.3-13.7

From March to June the mean density of individuals of gammarids (incl. G. spec.) was 11 specimens/m2 (range 1-31 specimens m^2, June and March respectively). From July to October the mean was 359 specimens m^2 (range 224–455 specimens m^2, October and August respectively). An increase in the density of individuals is probably due to a reproduction cycle which is adapted to the main vegetation period (increase in food supply). This assumption is supported by the fact that a relatively great number of juvenile animals were present in the months of July to September (102, 81 and 54 specimens m^2 respectively). When *G. pulex* and *G. fossarum* occurred jointly, *G. pulex* was dominant (Fig. 6).

Katenbäke

In the upper course of the Katenbäke (N28.1) *Gammarus pulex* and *G. fossarum* were detected during the entire investigation period (March to October).

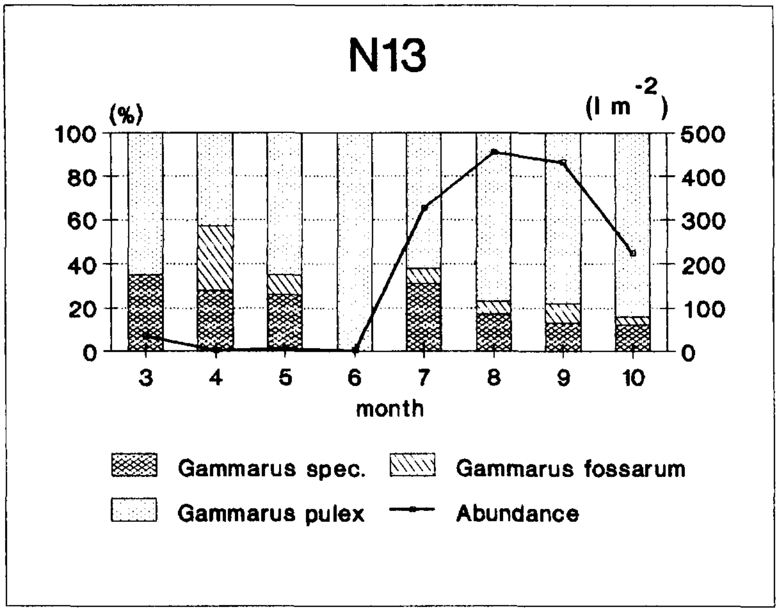

Fig. 6. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the brook Dadau.

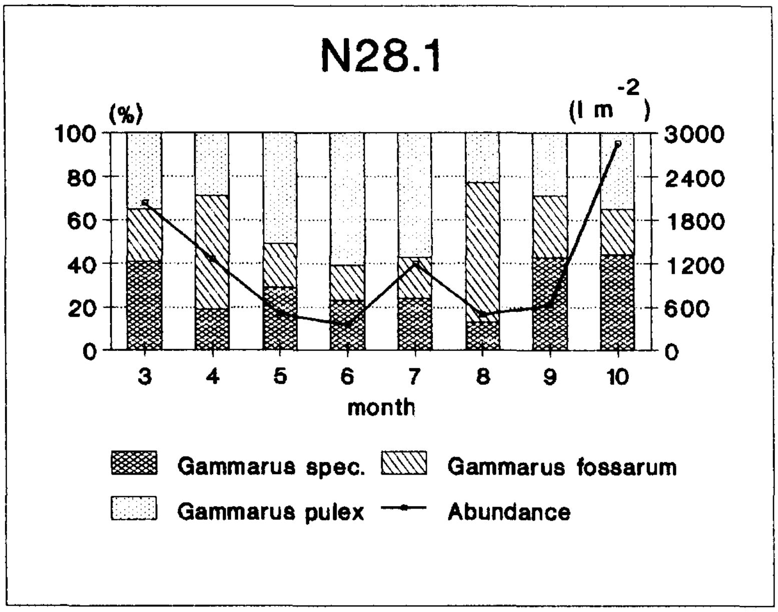

Fig. 7. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the upper course of the brook Katenbäke (N28.1).

The mean density of individuals (incl. G. spec.) was 1166 specimens m^2 (range 353–2859 specimens m^2, June and October respectively). With the exception of the months April and August *G. pulex* was dominant. However, in some cases there was a large proportion juvenile animals, the species of which could not yet be determined (Fig. 7).

In the lower course of the brook (N29.1) *G. pulex* was found only in six (March, April, July–October) out of eight samplings; *G. fossarum* was detected in four samplings (March, April, September, October). The mean density of individuals was much lower than in the upper course (44 specimens m^2, range 2–203 specimens m^2; May, August and March respectively).

But with the exception of March *G. pulex* was also dominant here.

Lethe

In the model section (sampling site N43) *Gammarus pulex* could be detected in seven out of eight samplings (June excepted); *G. fossarum* was found only in one sampling (September).

The mean density of individuals of gammarids (incl. G. spec) was 57 specimens m^2 (range 3–110 specimens m^2, August and May, October respectively; Fig. 8).

Further sampling sites located on the river Lethe were also colonized by *G. pulex* and *G. fossarum*, whereas in the two inlets of the Lethe, 'Sager Meerkanal' and 'Korrbäke', no gammarids were detected.

Discussion

To be able to evaluate the general state of the water by considering the presence and composition of gammarid communities, it is crucial to have a certain knowledge of the distribution of the species to be considered in the evaluation.

On the basis of distribution data published so far (Jazdzewski, 1982; Pinkster, 1978) only *Gammarus pulex* would be expected to occur in the limnetic systems of the North German Plain; thus *G. fossarum* and *G. roeseli* should be lacking in the species spectrum. In tidally influenced waters (lower course of the Hunte) the occurrence of the brackish-water species *G. zaddachi* and *G. tigrinus* may be expected.

An earlier investigation by Späh (1980) has already shown that the area limits mentioned for the gammarid species (Brauckmann 1987, Meijering 1971 and others) have to be changed. Aside from *G. pulex* Späh (1980) also detected *G. fossarum* and *G. roeseli* in running waters of the northern Wiehengebirge. Suhrhoff (1991) detected *G. fossarum* in the lower course of the Hunte. The evidence is described by Suhrhoff (1991) as 'from a zoogeographical viewpoint...very non-typical' but he does not allow for the possibility that the distribution data published previously tend to reflect research activities rather than the presence (or absence) of certain species.

This paper indicates that the above-mentioned findings not only provide evidence of locally occurring populations but also demonstrate that aside from *G. pulex G. fossarum* regularly occurs in running waters of the North German Plain. The distribution of both species seems to be limited by the tidal influence: Below the city of Oldenburg only *G. zaddachi* could be detected. Evidence for *G. pulex* in the estuary of the also tidally influenced 'Ollen' consists in the detection of one specimen which had probably drifted from the upper course of this brook. In contrast to the two other species mentioned, *G. roeseli* could only be found in a relatively limited area between the northern rim of the Wiehengebirge and Lake Dümmer. Regarding this species it may be assumed that Lake Dümmer constitutes the area limit, since *G. roeseli* was not detected in flowing waters north of Dümmer.

The study presented here also disproves reports regarding the vertical distribution limit, according to which *G. fossarum* does not occur below 100 m altitude (cf. Introduction, Brauckmann, 1987; Meijering, 1971; Meijering & Pieper, 1982).

A major element in a gammarid-based evaluation of running waters (Meijering, 1971, 1989; Meijering & Pieper, 1982) is the zonation of the species in the water course, which changes with deteriorating water quality according to the varying tolerances of the individual species (cf. Introduction), resulting in the successive fall-out of certain species.

A gammarid zonation corresponding to the running waters of low mountain ranges was observed only in the upper course of the Hunte. Such a zonation, with a dominance of *G. fossarum* in the upper and *G. pulex* in the lower course of the river can only be assumed for running waters in a geest area, since regionally restricted investigations in this respect are still lacking.

Application of this evaluation system is also limited by the lack of comparative data that might provide information regarding distribution and possible zonation of gammarids in natural flowing water systems of the North German Plain. Only a comparison of gammarid communities occurring in polluted water with those found in non-polluted waters would make it possible to determine the extent of the water pollution.

Before the gammarid-based evaluation system can be employed in rivers and brooks of the North German Plain, the distribution of gammarids must be further investigated in combination with measurements of pollutants.

Despite the problems presented above, the gammarid-based evaluation system — if interlinked with the consideration of other bioindicators (e.g. Odonata) — has major advantages: a river or brook can be adequately evaluated by investigation of its aquatic

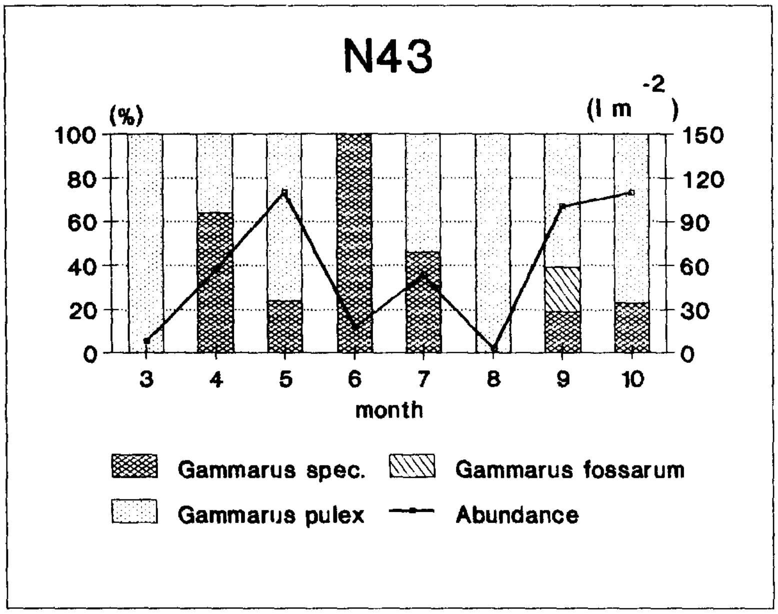

Fig. 8. 1991 detail mapping: Species composition (%) and density of individuals (I/m^2) of gammarids in the brook Lethe.

fauna. This is not possible with the saprobic system. With reference to the latter system Brauckmann (1987) stresses that almost all xenosaprobic-organisms and most of the organisms classified as oligosaprobic are linked to fast-running brooks that are cool or cold in summer and have a heterogenous bottom. In mountain and lowland brooks a change in the qualitative composition of the communities and the subsequent shifting towards β-mesosaprobic organisms is even induced by the structure of the river bed, the current regime and the substrate. This means that an unpolluted lowland brook — as opposed to an unpolluted mountain brook — is in principle evaluated more unfavourably.

Conclusions

1. Contrary to distribution data published so far, besides *Gammarus pulex* (LINNAEUS) *G. fossarum* KOCH also occurs regularly in flowing waters of the North German Plain.

2. The northern distribution limit of *G. pulex* and *G. fossarum* is determined by the tide.

3. *Gammarus roeseli* GERVAIS was detected in flowing waters south of Lake Dümmer; probably Lake Dümmer constitutes the area limit of the species.

4. A zonation of gammarids, as it has been described for running waters of low mountain ranges, was found only in waters of the northern Wiehengebirge.

5. An evaluation of the state of a river of brook based on the distribution and zonation of gammarids found in low mountain range brooks seems not to be applicable to lowland waters:

- on the one hand there have been no long-term and comprehensive investigations that might supply information on the distribution pattern of gammarids in flowing waters of the North German Plain,
- on the other hand comparative data for natural running waters are lacking, since the investigations currently carried out deal with the distribution pattern in waters already affected.

6. Against the background of 5 it does not seem to be useful to consider only gammarids when evaluating the general state of a water body. Instead, additional taxa should be investigated. An extensive investigation of the aquatic fauna may supply even more detailed information regarding the state of the water than the saprobic system, which is problematic if applied to lowland waters.

Acknowledgments

This study was supported by the 'Bundesministerium für Forschung und Technologie' (BMFT, re: 0339310E) and the 'Niedersächsisches Umweltministerium'. Thanks are due to H.-P. Anders and H.-G. Meurs for their assistance in identifying some of the gammarids and to Dr M. P. D. Meijering for reexamining some species. Thanks are also due to S. Osterkamp and Dr Biederman-Thorson for kind help with the English translation.

References

Aumann, U., W. Janetzky & E. Vareschi, 1992. Aquatische Fauna II (Crustaceen, Odonaten, Mollusken). Abschlußbericht des BMFT-Forschungsvorhabens 'Modellhafte Erarbeitung eines ökologisch begründeten Sanierungskonzeptes kleiner Fließgewässer am Beispiel der Hunte'. Carl von Ossietzky Universität Oldenburg, Oldenburg, 164 pp. (with supplement).

Braukmann, U., 1987. Zoozönologische und saprobiologische Beiträge zu einer allgemeinen regionalen Bachtypologie. Arch. Hydrobiol., Ergeb. Limnol., Beih. 25: 1–355.

Brehm, J. & M. P. D. Meijering, 1982. Zur Säure-Empfindlichkeit ausgewählter Süßwasserkrebse (*Daphnia* und *Gammarus*, Crustacea). Arch. Hydrobiol. 95: 17–27.

Downing, J. H. & F. H. Rigler (eds), 1984. A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell, Oxford, 501 pp.

Goedmakers, A., 1972. *Gammarus fossarum* KOCH, 1835: Redescription based on neotype material and notes on its local variation (Crustacea, Amphipoda). Bijdr. Dierk. 42: 124–138.

Jahr, W., M. P. D. Meijering & W. Wüstendörfer, 1980. Zur Situation der Gattung *Gammarus* (Flohkrebse) im Vogelsberg. Beitr. Naturkde. Osthessens 16: 3–11.

Janetzky, W., U. Aumann, H.-G. Meurs & E. Vareschi, 1992. Zur Verbreitung der Gattung *Gammarus* (Gammaridae, Amphipoda) im Gewässersystem der Hunte (Niedersachsen). Verh. Ges. Ökol. 21: 391–394.

Jazdzewski, K., 1980. Range extensions of some gammaridean species in European inland waters caused by human activity. Crustaceana, Suppl. 6: 84–107.

Lincoln, R. J., 1979. British marine Amphipoda: Gammaridae. British Museum (Natural History), London.

Meijering, M. P. D., 1971. Die *Gammarus*-Fauna der Schlitzerländer Fließgewässer. Arch. Hydrobiol. 68: 575–608.

Meijering, M. P. D., 1972. Physiologische Beiträge zur Frage der systematischen Stellung von *Gammarus pulex* (L.) und *Gammarus fossarum* KOCH (Amphipoda). Crustaceana, Suppl. 3: 312–325.

Meijering, M. P. D., 1984. Die Verbreitung von Indikatorarten der Gattung *Gammarus* im Schlitzerland (Osthessen) in 1968 und 1982. In Umweltbundesamt (ed.), Gewässerversauerung in der Bundesrepublik Deutschland, Materialien 1/84: 96–105.

Meijering, M. P. D., 1985. Einflüsse einer Ortslage auf die Verbreitung von *Gammarus*-Arten in einem Bachsystem (Maarbach, Osthessen). Mittlg. Erg. Stud. Ökol. Umwelts. 10: 125–141.

Meijering, M. P. D., 1989. Flohkrebse (*Gammarus*) als Indikatoren für Sauerstoffschwund und Versauerung in Fließgewässern. DVWK Mitteilungen 17: 369–381.

Meijering, M. P. D., 1991. Lack of oxygen and low pH as limiting factors for *Gammarus* in Hessian brooks and rivers. Hydrobiologia 223: 159–169.

Meijering, M. P. D. & H. G. Pieper, 1982. Die Indikatorbedeutung der Gattung *Gammarus* in Fließgewässern. Decheniana, Beihefte 26: 111–113.

Meijering, M. P. D. & H. G. Pieper, 1985. Zur Verbreitung von *Gammarus* (Crustacea: Amphipoda) im Fulda-Eder-Abflußgebiet, mit besonderer Berücksichtigung der Bachversauerung. Mittlg. Erg. Stud. Ökol. Umwelts. 10: 93–123.

Meijering, M. P. D., A. G. L. Hagemann & H. E. F. Schröer, 1974. Der Einfluß häuslicher Abwässer auf die Verteilung von *Gammarus pulex* L. und *Gammarus fossarum* KOCH in einem hessischen Mittelgebirgsbach. Limnologica 9: 247–259.

Meurs, H.-G., W. Janetzky & E. Vareschi. On the distribution of the amphipod genus *Gammarus* in Lower Saxony (Germany). Hunte river system. Zool. Jb. Syst. Ökol. Geogr. Tiere (submitted).

Pinkster, S., 1970. Redescription of *Gammarus pulex* (Linnaeus, 1758) based on neotype material (Amphipoda). Crustaceana 18: 177–186.

Pinkster, S., 1972. On members of the *Gammarus pulex* group (Crustacea: Amphipoda) from Western Europe. Bijdr. Dierk. 42: 165–191.

Pinkster, S., 1978. Amphipoda. In Illies, J. (ed.), Limnofauna Europeae. Gustav Fischer Verlag, Stuttgart: 244–253.

Schellenberg, A., 1937. Kritische Bemerkungen zur Systematik der Süwassergammariden. Zool. Jb. Syst. Ökol. Geogr. Tiere 69: 469–516.

Schellenberg, A., 1942. Krebstiere oder Crustacea. IV: Flohkrebse oder Amphipoda. In Dahl, F. (ed.), Die Tierwelt Deutschlands, 40. Teil. Gustav Fischer Verlag, Jena, 252 pp.

Scholz, E. & M. P. D. Meijering, 1975. Vergleichende Untersuchungen zur Abwasserresistenz von *Gammarus pulex* L. und *Gammarus roeseli* Gervais in osthessischen Fließgewässern. Beitr. Naturkde. Osthessens, Heft 9/10: 81–85.

Schwoerbel, J., 1986. Methoden der Hydrobiologie. Süßwasserbiologie. Gustav Fischer Verlag (UTB 979), Stuttgart, 301 pp.

Späh, H., 1980. Die Invertebratenfauna der oberen Hunte und einige ihrer Nebenbäche. Inf. Naturschutz Landschaftspfl. 2: 345–363.

Suhrhoff, P., 1991. Limnologische Studie zur Sanierung der Hunte unterhalb Wildeshausen. STAWA Brake, Brake, 109 pp. (with supplements).