Loughborough University of Technology
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Freshwater Environments
Research Group

FEG

LINKING HYDROLOGY AND ECOLOGY
RIVER WISSEY

ANNEX B
April 1993

ANNEX B

AQUATIC MACROPHYTES OF THE RIVER WISSEY:
their influence on instream hydraulics and sedimentation.

Undertaken for the National Rivers Authority, Anglian Region

By

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SUMMARY

This document is one of a series of Annexes which accompany the report 'The River Wissey: the link between hydrology and ecology' prepared for the National Rivers Authority by the Freshwater Environments Group at Loughborough University.

This paper describes a study of the growth and recession of aquatic macrophytes in the River Wissey. It relates the changes in macrophyte abundance to flow and sediment characteristics and discusses the implications of instream hydraulic parameters for invertebrate and fish faunas.

The River Wissey supports a typical chalk stream flora. Aquatic macrophytes at three sites on the main river showed marked seasonal changes in abundance during 1992. These changes were accompanied by alterations in the composition of bed sediments arising from differences in flow velocity patterns, and variations in water depth.

The role of aquatic macrophytes in providing habitat diversity is fundamental to faunal distribution in rivers and may be of particular importance in optimizing low flow conditions for faunal communities.

B1   INTRODUCTION

There is mounting concern in parts of the United Kingdom about the effects of low flows on the ecology of river habitats. This is particularly true in chalkland regions such as East Anglia where proposals to increase the abstraction of water from aquifers for supply has threatened the ecological balance of several chalk streams.

Ecological assessments of rivers, in advance of water resource schemes, are increasingly including studies of river macrophytes. More specifically, in the wake of proposals to regulate river flows, macrophyte surveys have been employed on the River Wye (Brooker *et al* 1978) and the River Lambourn (Ham *et al* 1981, Ham *et al* 1982, Wright *et al* 1982, Wright and Berrie 1987) to obtain baseline data on the structure and functioning of the ecosystems under normal flow conditions.

The present study set out to examine the dynamics of aquatic macrophyte growth and recession on the River Wissey in Norfolk, to relate the changes to flow and sediment characteristics, and to discuss the implications of instream hydraulic parameters for the invertebrate and fish fauna.

B2   THE FLORA OF THE RIVER WISSEY

The River Wissey rises at East Bradenham (TF 945 085) and flows 58 km westwards to join the River Great Ouse, 3 km west of Hilgay (TL 590 990). Draining the Chalk Breckland which, in the eastern half of the catchment in particular, is overlain by boulder clay and fluvio-glacial sands, the river has a naturally regulated flow regime, although flashy events may be generated within the boulder-clay headwaters.

Botanical records for the River Wissey are few: *Potamogeton berchtoldii* Fieber (Small Pondweed) was recorded at East Bradenham in 1962 and at Stoke Ferry in 1977; *Potamogeton pusillus* L. (Lesser Pondweed) was found at Northwold in 1970 and *Ranunculus aquatilis* var. *penicillatus* was sighted at Hilborough in 1954 (Beckett, pers. comm.).

In 1979, Nigel Holmes surveyed eight sites on the Wissey, six of which are located within the part of the catchment under investigation in the present study. These surveys contributed to a larger project which classified British rivers according to their flora (Holmes 1983). In the upper part of the catchment, where the Chalk is overlain by boulder-clay, the reach at Bradenham (TF 913 087) was classed as a spring-fed stream in a clay catchment. The floral community on which the classification was based (Community A4iii) is associated with steep and high-sided narrow streams which resemble ditches. Aquatic macrophytes characteristic of the grouping and present at Bradenham tended to be disturbance-tolerant and widespread species including *Pilularia dysenterica* L. (Pillwort), *Apium nodiflorum* (L.) Lag. (Fool's Water-cress) and *Rorippa nasturtium-aquaticum* (L.) Hayek. (Water-cress).

Downstream, at North Pickenham (TF 865 067), the river was designated a highly managed, unstable, sand river, represented by a species-poor macrophyte community (A1iii) because of intensive management practices and the instability of the sand substratum. Characteristic aquatic species at the site included *Vaucheria sessilis, Enteromorpha* sp., *Cladophora glomerata, A.nodiflorum, Mentha aquatica* L. (Water-mint), *Myosotis scorpioides* L. (Water Forget-Me-Not), *R.nasturtium-aquaticum, Veronica beccabunga* L. (Brooklime), *Lemna minor* L. (Common Duckweed) and *Phalaris arundinacea* L. (Reed Canary-grass).

Three sites in the middle Wissey - east of Hilborough (TF 833 009), at Langford Hall (TL 839 964) and at Didlington (TL 771 967) - were grouped as fast-flowing calcareous small rivers on

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mixed substrates. The River Wissey is cited as one of the most characteristic rivers of this grouping (Community type A1vi). The diversity of channel-bed sediments made for species-rich plant assemblages including *V.sessilis, Callitriche obtusangula* Le Gall (Blunt-fruited Water-starwort), *Veronica anagallis-aquatica* L. (Blue Water-speedwell), *C.glomerata, Sparganium erectum* L. (Branched Bur-reed) and *Zannichellia palustris* L. (Horned Pondweed).

A further two locations, at Oxborough (TL 732 995) and Hilgay (TL 621 988), were recognized as canalized fenland reaches on clay and sand (Community type A1ii). Communities at these sites contained a combination of species typical of sluggish fenland rivers as well as species more common on clay including *Ceratophyllum demersum* L. (Rigid Hornwort), *Polygonum amphibium* L. Gray (Amphibious Bistort), *Veronica catenata* Pennell (Pink Water-speedwell), *Elodea nuttallii* (Planchon) H. St. John (Nuttall's Waterweed), *Glyceria maxima* (Hartman) O. Holmb. (Reed Sweet-grass) and *Sagittaria sagittifolia* L. (Arrowhead).

The last site, at Wissington Sugar Factory (TL 664 977), was categorized as an artificial channel in tidal reaches (A1i). Although the Wissey is not tidal at this point, it supports a very impoverished flora typical of other rivers in the group. *C.demersum, Ranunculus circinatus* Sibth. (Fan-leaved Water-crowfoot) *Phragmites australis* (Cav.) Trin. ex Steudal (Common Reed), *V.sessilis, Enteromorpha* sp., *C.glomerata, P.amphibium, Elodea canadensis* Michaux (Canadian Waterweed), *G.maxima, L.minor* and *P.arundinacea* were the main characteristic species.

B2.1   Aquatic Macrophyte Survey Sites

The area of the River Wissey catchment under investigation in the present study and the distribution of the macrophyte survey sites are illustrated in Figure B2.1. Three sites which supported submerged aquatic plants were located on the main River Wissey at points corresponding with reaches selected as macroinvertebrate sampling stations (see Annex E). The site at Didlington (TL 801 942) was situated in an area of rough grassland and pasture. At its widest point, the river channel measured approximately 14 m but narrowed to 11.25 m at the lower end of the survey reach. A shingle beach was evident on the left bank. The site supported much *Ranunculus* sp., together with *Z.palustris, Callitriche* sp., filamentous algae, *R.nasturtium-aquaticum* and other emergents such as *Carex* sp., *V.beccabunga, M.aquatica* and *M.scorpioides.*

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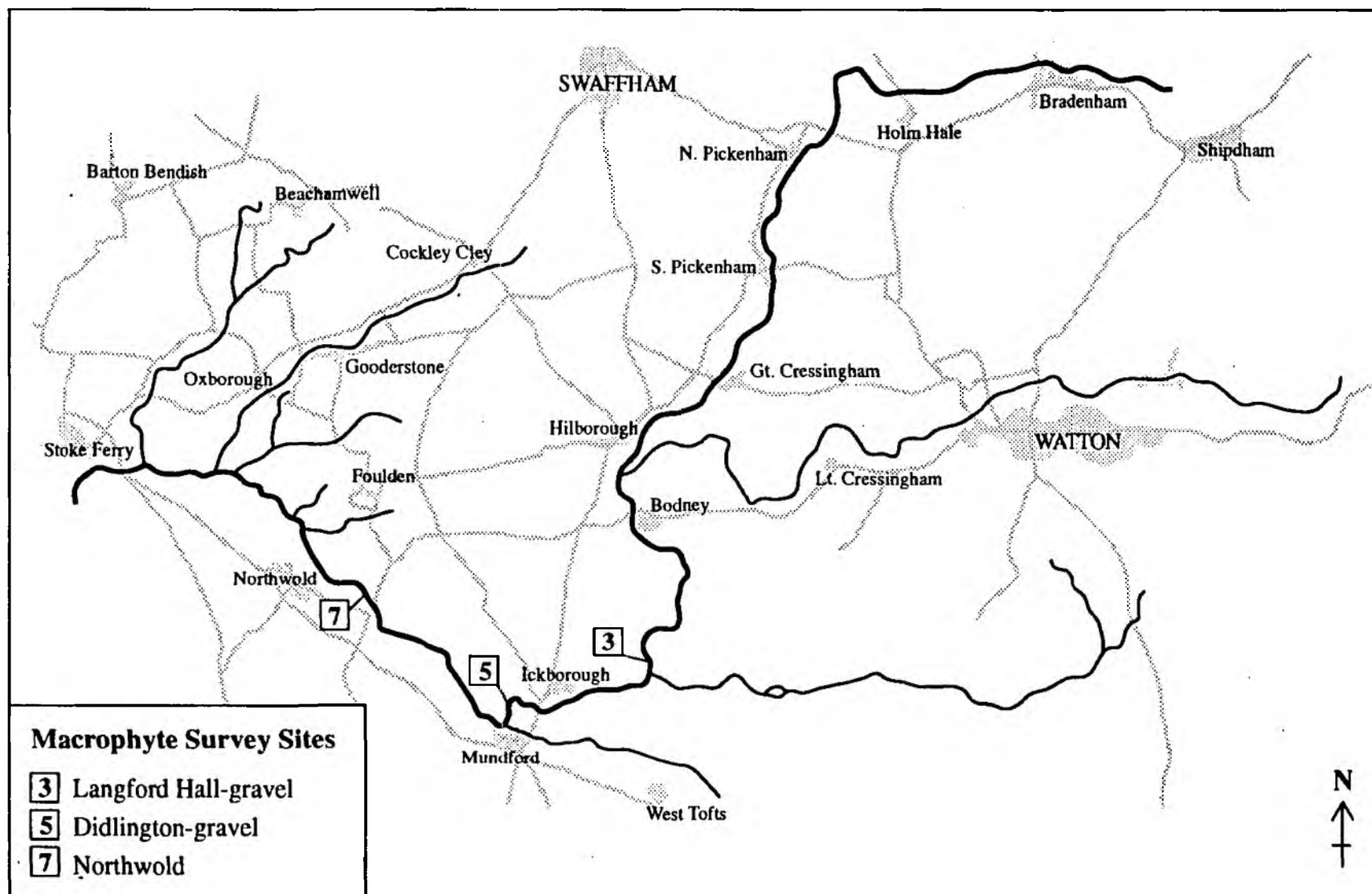
Figure B2.1 Map of the River Wissey and tributaries, indicating the location of macrophyte survey sites.

Langford Hall-gravel (TL 839 964) was located on the edge of woodland on the Ministry of Defence Training Area at West Tofts. The channel varied in width from 11 m to 13.5 m and the reach, in summer, fostered extensive *Ranunculus* beds. Also present were *Z.palustris*, filamentous algae, *R.nasturtium-aquaticum*, *Berula erecta* (Hudson) Cov. (Lesser Water-parsnip), *A.nodiflorum*, *S.erectum* and *G.maxima*.

The survey reach at Northwold (TL 767 971) was sited on a bend, in an area of rough pasture. Measuring between 12.25 m and 13.5 m wide, the river sustained considerable macrophyte growth particularly of *Ranunculus* sp. and *R.nasturtium-aquaticum*. *Z.palustris*, filamentous algae, *A.nodiflorum*, *M.scorpioides*, *G.maxima* and *P.arundinacea* were also recorded at the site.

B3   METHODOLOGY

Many methods are available for studying the dynamics of aquatic macrophytes. The use of biomass and production (Edwards and Owens 1960, Dawson 1976) is more relevant to the detailed study of single species and was rejected for use in the present project which focused on the whole community. The general, more extensive, survey strategy (Butcher 1933, Holmes and Whitton 1977) is applicable for phytosociological studies but is inappropriate for documenting more subtle temporal changes which occur at a single site. The present study adopted the use of cover data. Although plant biomass and cover do not necessarily exhibit a simple linear relationship (Dawson 1976), percentage cover is recognized as a good measure of plant abundance (Kershaw 1985).

The dynamics of aquatic macrophyte growth and recession in the River Wissey were monitored using a modification of the 'rectangles method' described in detail by Wright *et al* (1981) and adopted by Ham and co-workers on the River Lambourn (Ham *et al* 1982). A 10-m reach was selected at each site. On one of the banks a straight baseline was established and temporary stakes were placed at 1-m intervals along it. A similar set of stakes were fixed on the opposite bank. Permanent posts were located at the extremes of the reach to allow its exact relocation for subsequent surveys.

At the start of each mapping operation, a temporary grid was set up between the stakes by drawing strings across the river to create a series of transects. A tape measure, marked at 0.25-m intervals, was positioned across the river at the centre of each transect, thus forming a 0.5 m by 0.25 m grid over the surface of the water.

Mapping was always carried out from downstream to upstream so that any silt disturbed by walking across the river bed did not restrict visibility. The recorder began by noting the location of the river banks and the water margins to the nearest 0.25 m. The dominant biotope (substratum or macrophyte) was then determined for each rectangle, or cell, under water, but where a macrophyte and substratum each occupied 50 percent, the plant was given dominance. The sediment associated with the dominant macrophytes was noted and, similarly, macrophytes overlying dominant sediment types were recorded. The channel-bed sediments were classified as cobbles, gravel, sand and silt, based on the Wentworth Scale (1922). Botanical nomenclature followed Stace (1991).

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The sites were visited on 3 occasions (January 1992, May 1992 and October 1992) which coincided with the main invertebrate surveys (see Annex E). The January and October surveys also included the measurement of water depths at the intersections between the cells of the survey grid.

A time series of maps, illustrating the dominant biotopes, was produced for each site to demonstrate the patterns of macrophyte growth and recession. The significance of temporal changes at a particular site and spatial differences between sites regarding their substrate composition (number of cells containing different substrata), their macrophyte composition (number of cells dominated by different plant species) and their gross biotope make-up (number of cells dominated by different substrata and macrophytes) was established by applying Chi-square analyses. In each case, the total number of cells at a site was based on the number of cells which remained submerged at the time of all three surveys.

B4   RESULTS

B4.1   Temporal Changes in Aquatic Macrophytes

B4.1.1 Didlington-gravel

Didlington-gravel developed extensive beds of *Ranunculus* sp. during 1992. Very little macrophyte growth was recorded in January but by May the *Ranunculus* had started to spread, and by October the species dominated over 40 percent of the cells at the site (Figure B4.1.1a). Temporal comparisons of the site, based on the macrophyte composition, were all significant (Table B4.1a, Appendix B4.1). Likewise the site changed significantly during the season in terms of its gross biotope make-up (p<0.0001; Table B4.1b, Appendix B4.1).

The bed sediments at Didlington-gravel also exhibited seasonal variations. Bed sediment composition in January and May was very alike (p=0.2304; Table B4.1c, Appendix B4.1), but was dissimilar from that recorded in October (p<0.0001). Early in the year gravel was the dominant substratum but the deposition of silt beneath developing macrophyte beds during the latter part of the season produced a shift towards finer bed sediment (Figure B4.1.1a). Throughout the year, gravel was distributed over the shallower, faster-flowing areas of the reach while the finer bed sediments were located along the channel margins and under macrophyte stands. *Ranunculus* development centred on areas dominated by gravel. Although the plant attracted silt deposition, the river-bed in open water between the macrophytes remained very coarse (Figures B4.1.1b-B4.1.1d, Appendix B4.1.1).

Figure B4.1.1e illustrates the relationship between plant cover and mean water depths at Didlington-gravel. For January, when few cells were dominated by macrophyte growth, the shape of the depth curve is more a function of bed morphometry than vegetation. At the lower end of the reach (below 7 m) elevated mean water depths are associated with the pool of the 'riffle-pool' sequence rather than increased plant cover. For October, raised mean water depths throughout the reach are related to increased macrophyte abundance. The riffle-pool sequence remains evident in October, but water depths in this lower part of the site are enhanced by plant growth.

(a) January 1992.

(b) May 1992.

(c) October 1992.

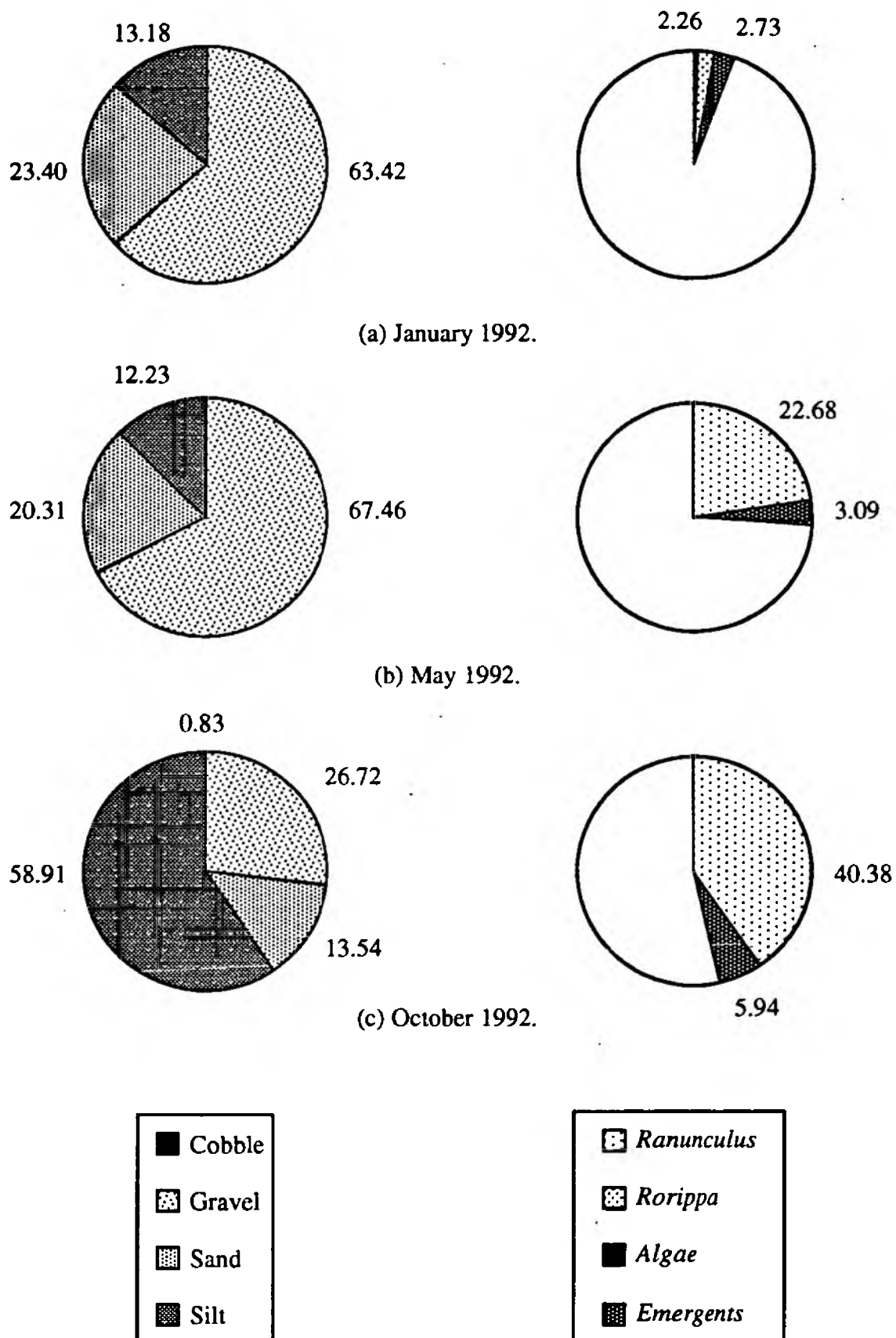| ■ Cobble | ⬚ Ranunculus |
▨ Gravel	▨ Rorippa
▦ Sand	■ Algae
▨ Silt	▦ Emergents

Figure B4.1.1a Didlington-gravel: substrate and dominant macrophyte composition, expressed as a percentage of the total number of cells at the site (n = 842).
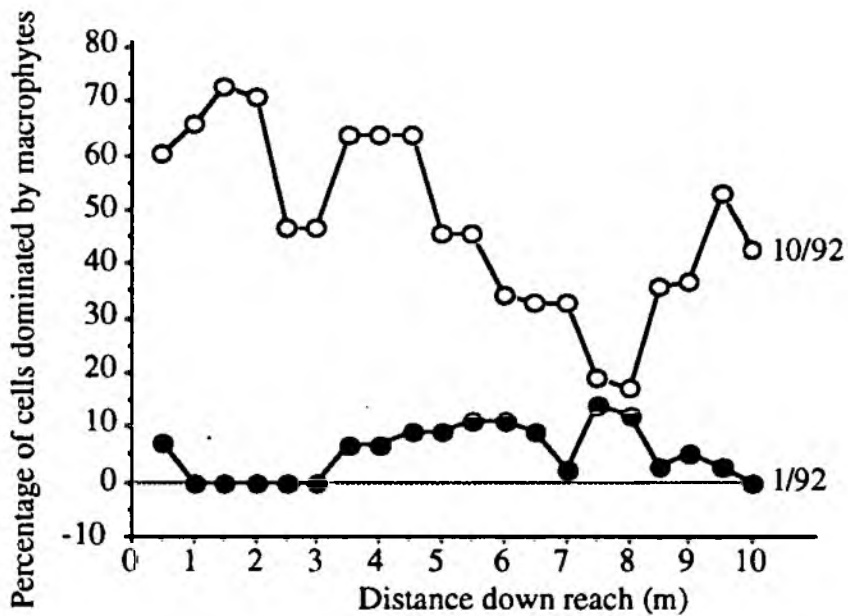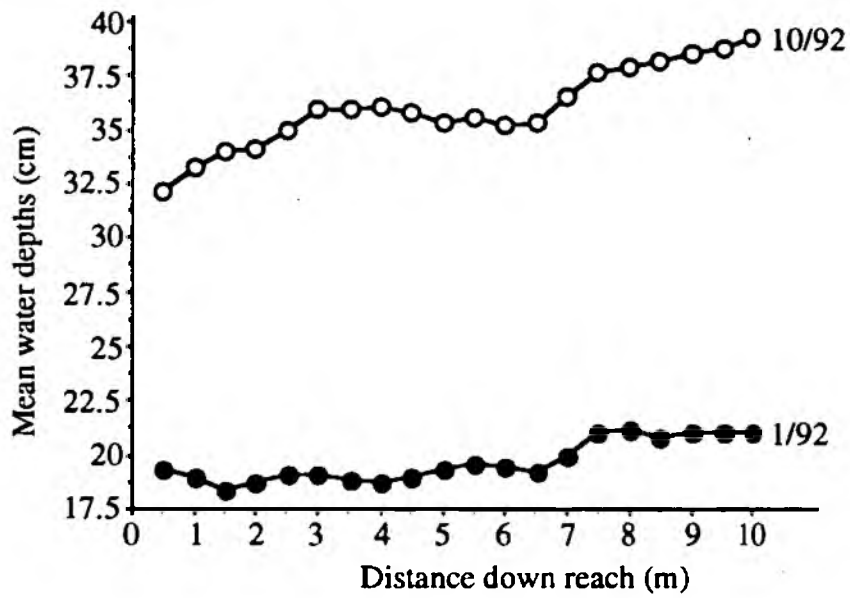
Figure B4.1.1e Longitudinal section of Didlington-gravel
illustrating mean depths and percentage of cells dominated by
macrophytes at transects down the 10-m reach.

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B4.1.2 Langford Hall-gravel

Significant temporal changes regarding macrophyte composition, substrate composition and gross biotope make-up were observed at Langford Hall-gravel (Tables B4.1a-B4.1c, Appendix B4.1;.Figures B4.1.2a-B4.1.2c, Appendix B4.1.2). In January, the only dominant macrophyte growth noted was of emergents, predominantly *R.nasturtium-aquaticum* and *G.maxima*. During the ensuing months, the *R.nasturtium-aquaticum* died back and the remaining emergents senesced so that, in May, only 5.67 percent of cells at the site was dominated by vegetation (Figure B4.1.2d). By October, however, *Ranunculus* sp. had developed extensively to occupy a large proportion of the reach. The abundance of emergents had also increased considerably.

The substrate composition of Langford Hall-gravel varied markedly during 1992. In January, the substrate was dominated by gravel with approximately equal proportions of sand and silt (Figure B4.1.2d). Between January and May, sand was deposited over most of the reach and the proportion of gravel at the site was substantially reduced. Expansion of the marginal vegetation during the summer months caused increased silt accumulation which reduced the dominance of the sand in October.

The positive relationship between macrophyte abundance and mean water depth is strongly depicted in Figure B4.1.2e. Longitudinal fluctuations in mean water depths at the site in January are mirrored by increases in plant cover. Elevated water depths in October are likewise associated with macrophyte growth.

B4.1.3 Northwold

In many respects, the pattern of macrophyte development at Northwold was similar to that at Langford Hall-gravel. Very little dominant macrophyte growth was recorded at Northwold in January; that which was noted was primarily marginal vegetation, including *R.nasturtium-aquaticum* and *G.maxima*. These species died back during the following three months, and in May macrophyte growth was dominated by algae (Figure B4.1.3a). The situation was changed in October when large beds of *Ranunculus* sp. and *R.nasturtium-aquaticum* occupied the site.

In January 1992, Northwold was characterized by a gravel-dominated river-bed (Figure B4.1.3b). However, deposition of sand on the slower-flowing, shallow areas of the reach, between January and May, resulted in a significant alteration in the substrate composition (Figure B4.1.3a). Figure

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(a) January 1992.

(b) May 1992.

(c) October 1992.

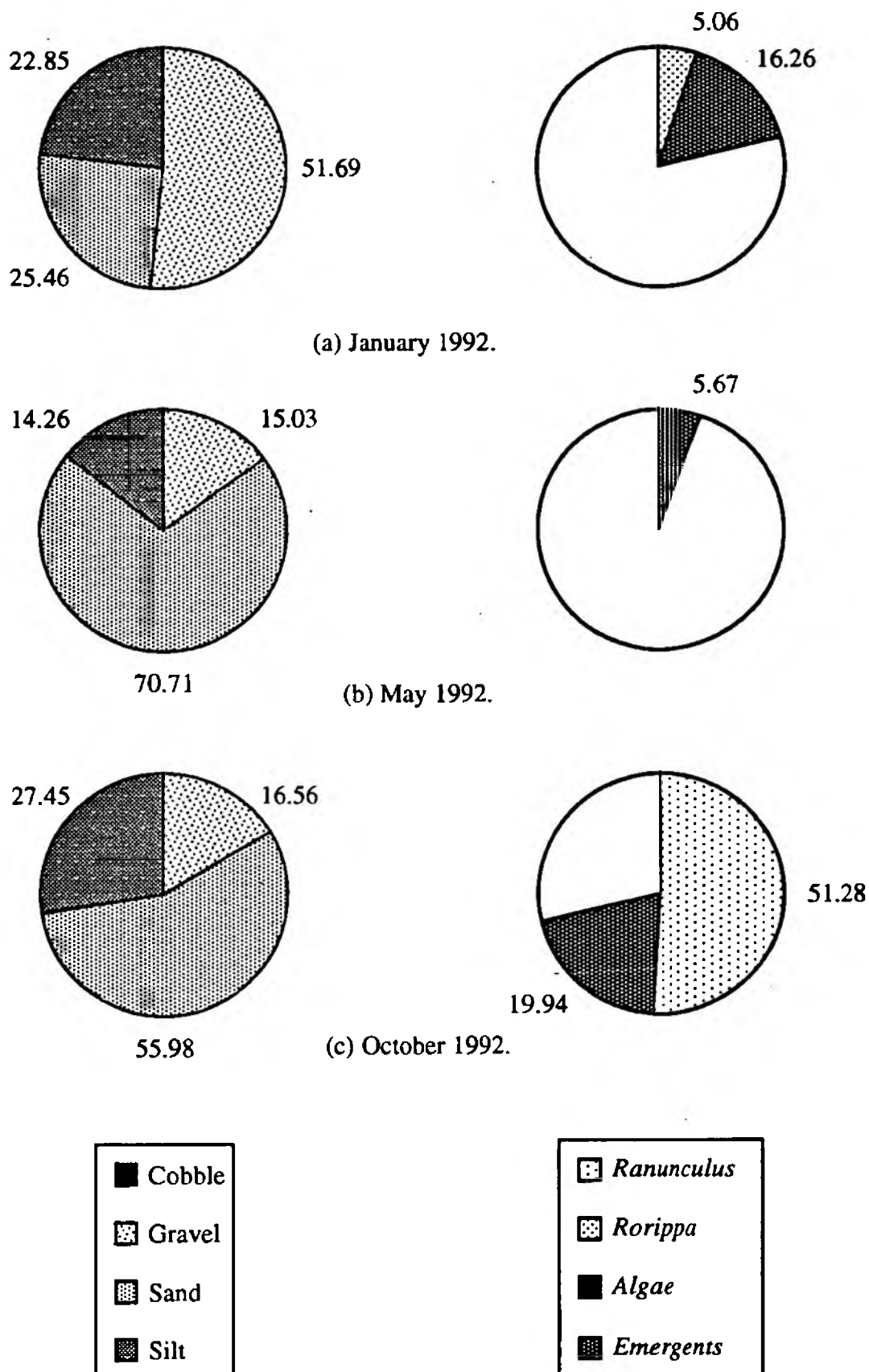|			
■ Cobble		⊡ *Ranunculus*	
▨ Gravel		▨ *Rorippa*	
▨ Sand		■ *Algae*	
▨ Silt		▨ *Emergents*	

Figure B4.1.2d Langford Hall-gravel: substrate and dominant macrophyte composition, expressed as a percentage of the total number of cells at the site (n = 652).
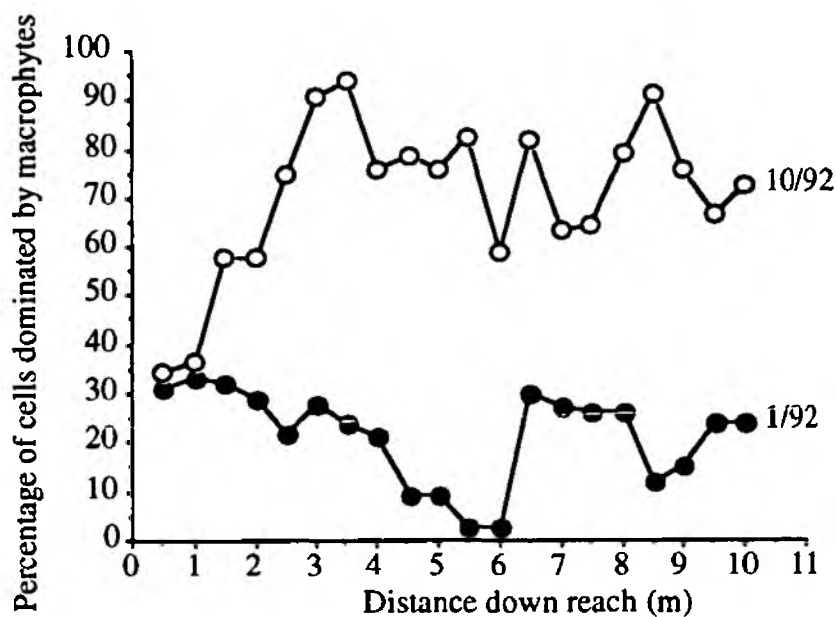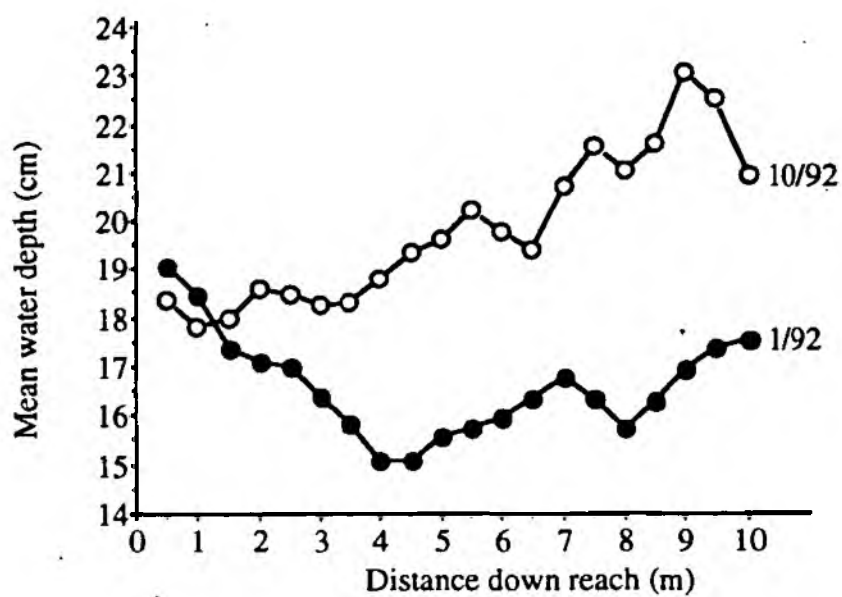
Figure B4.1.2e Longitudinal section of Langford Hall-gravel illustrating mean depths and percentage of cells dominated by macrophytes at transects down the 10-m reach.

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B4.1.3c shows the divide between the sandy, shallow areas and the deeper, swifter-flowing part of the channel near the right bank which, in May, remained dominated by gravel. The development of extensive weed beds between May and October was accompanied by a considerable rise in the proportion of silt at Northwold (Figure B4.1.3a). Much of the finer material (sand and silt) was deposited beneath, or alongside macrophyte beds; the open channels between plant stands were dominated by gravel (Figure B4.1.3d).

Figure B4.1.3e examines the relationship between water depth and plant cover at Northwold. In January, mean water depths showed little variation down the reach and, not surprisingly, were relatively unaffected by scant macrophyte growth. In October, variations in the abundance of vegetation were reflected by fluctuations in mean water depth.

B4.2   Spatial Variations in Aquatic Macrophytes

Between-site comparisons, survey by survey, revealed significant differences between the reaches regarding their macrophyte composition, substrate composition and their gross biotope make-up (Tables B4.2a-B4.2c, Appendix B4.2).

Macrophyte composition at Didlington-gravel and Northwold, in January 1992, was very similar (p=0.8187; Table B4.2a, Appendix B4.2). We have seen that both sites, at this time, supported limited vegetation which included the emergent *R.nasturtium-aquaticum* (see sections B4.1.1 and B4.1.3). By May, this species had disappeared from both reaches, and *Ranunculus* development had commenced at Didlington-gravel but not at Northwold. Northwold, however, sustained small amounts of algae. Sizeable stands of *Ranunculus* sp. were recorded at Didlington-gravel and Northwold in October, and the proportions of emergent vegetation had increased at both sites since May. Large *Rorippa* beds were also noted at Northwold but not at Didlington-gravel.

Langford Hall-gravel, by contrast, supported considerably more emergent vegetation than Didlington-gravel and Northwold in January. Emergent species formed the only dominant cover at Langford Hall-gravel in May. By October, however, in accordance with the other sites, the reach at Langford Hall bore wide-spread *Ranunculus* beds and increased emergent vegetation.

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6.08

9.54

84.39

1.67 2.50

(a) January 1992.

2.86

64.12

33.02

1.78 4.29

(b) May 1992.

31.23

3.81

64.96

(c) October 1992.

30.27

7.75

27.65

■	Cobble
▨	Gravel
▦	Sand
▩	Silt

⋮⋮	*Ranunculus*
▨	*Rorippa*
■	*Algae*
▩	*Emergents*
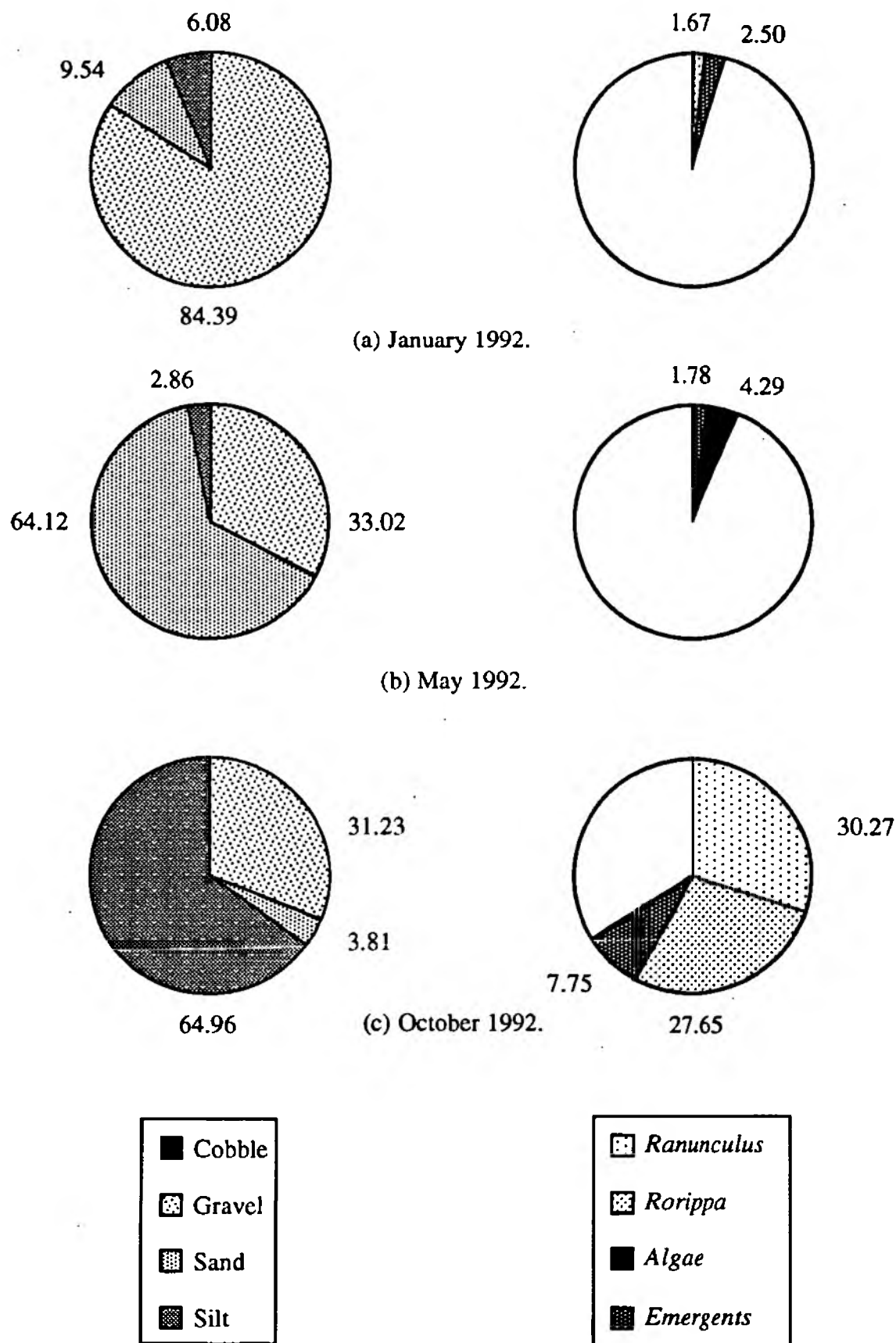
Figure B4.1.3a Northwold: substrate and dominant macrophyte composition, expressed as a percentage of the total number of cells at the site (n = 839).

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Gravel
Sand
Silt
Ranunculus sp.
Rorippa nasturtium-aquaticum
Zannichellia palustris
Algae
Emergents

1 m
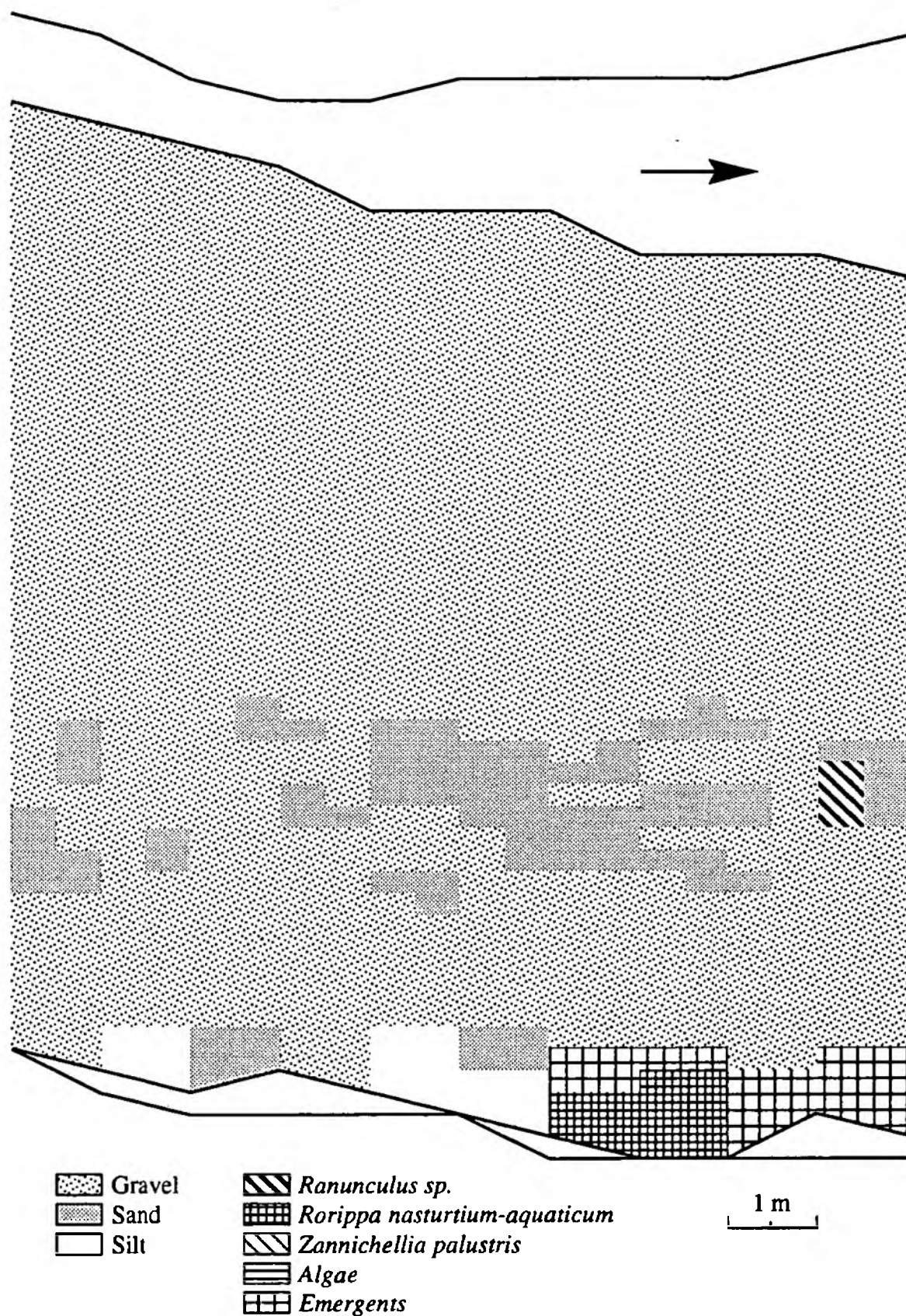
Figure B4.1.3b Northwold, January 1992.

▨ Gravel	◥◣ Ranunculus sp.
▦ Sand	▦ Rorippa nasturtium-aquaticum
☐ Silt	◩ Zannichellia palustris
	☰ Algae
	⊞ Emergents

1 m
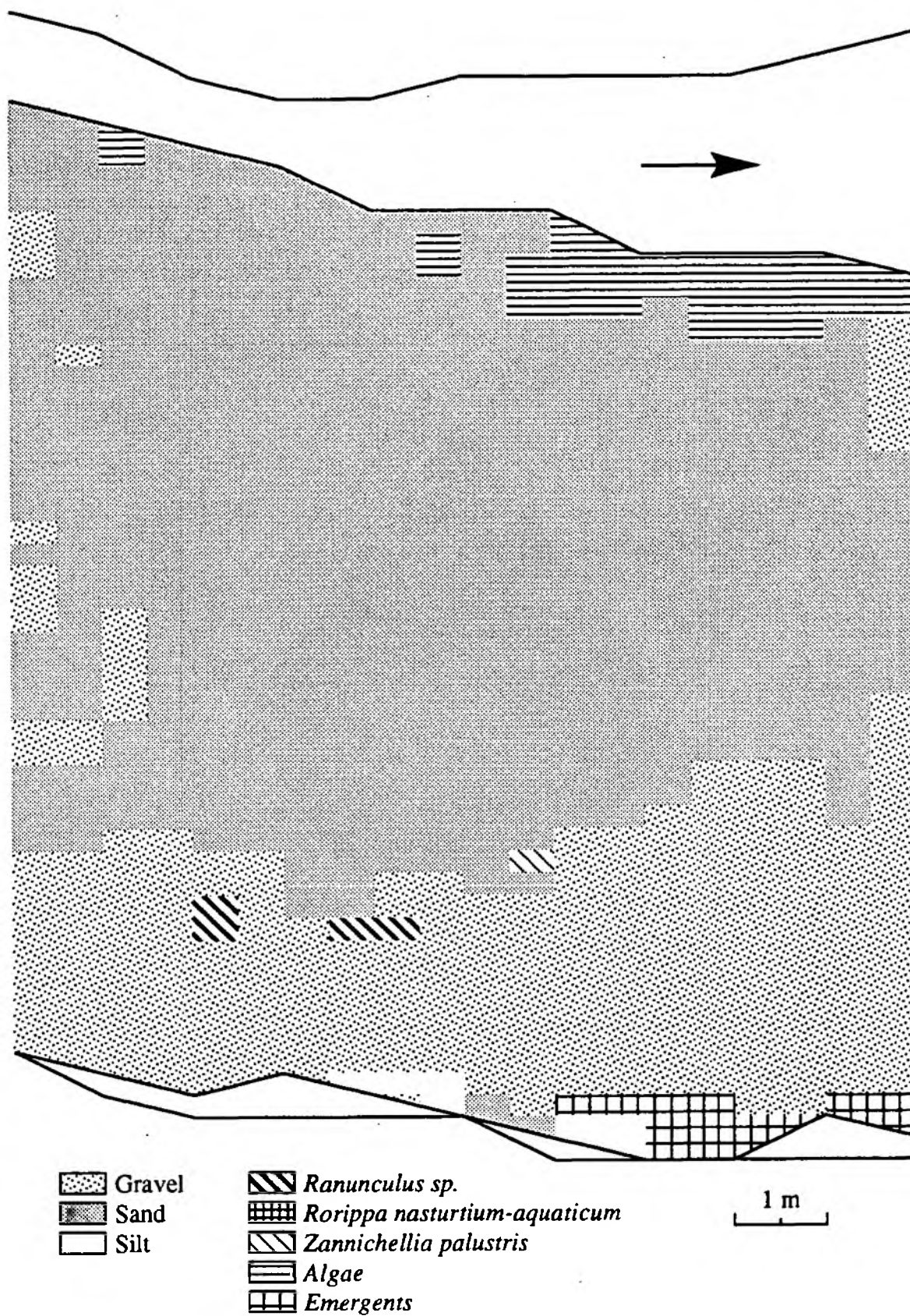
Figure B4.1.3c Northwold, May 1992.

Gravel
Sand
Silt

Ranunculus sp.
Rorippa nasturtium-aquaticum
Zannichellia palustris
Algae
Emergents

1 m
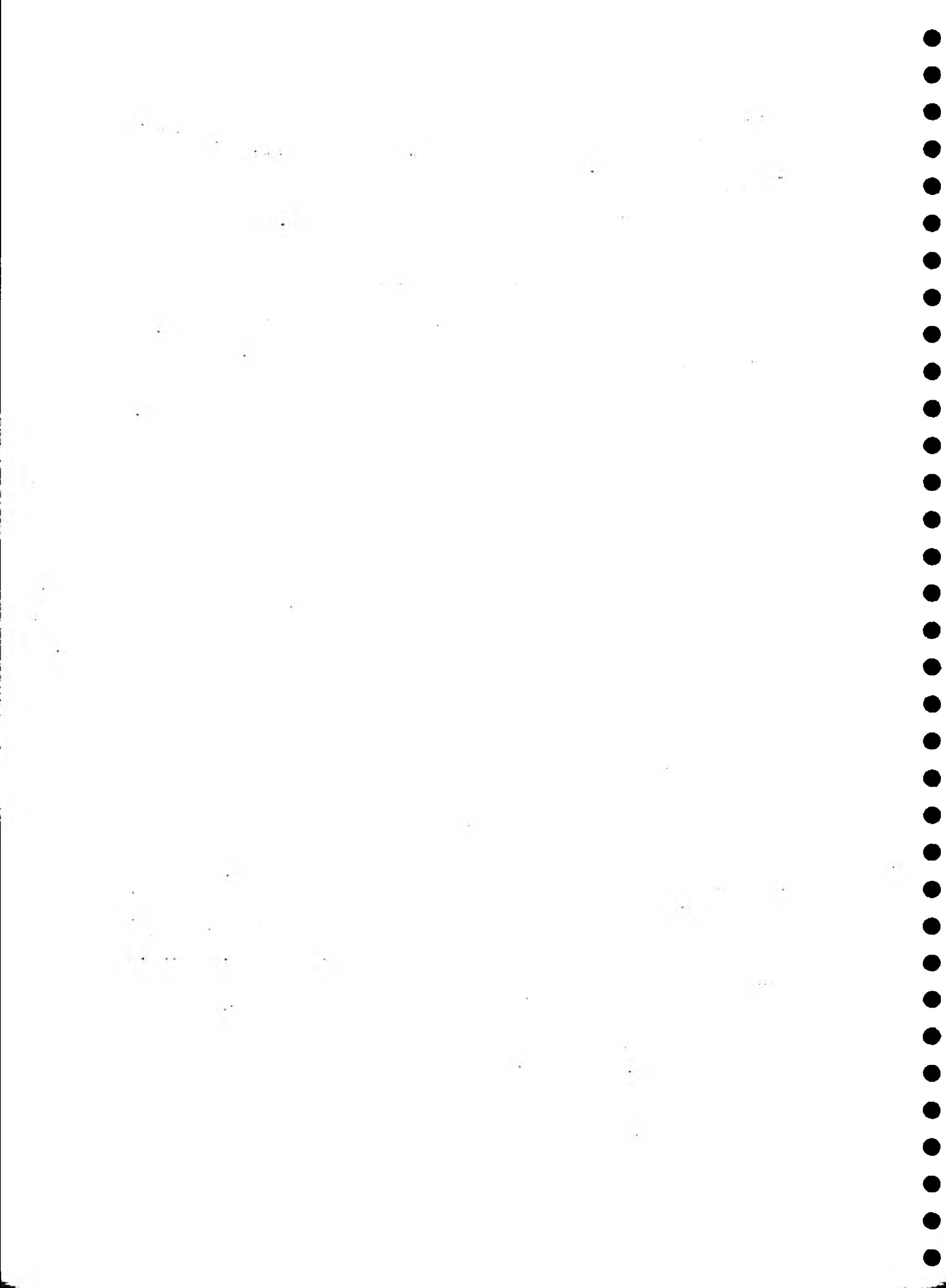
Figure B4.1.3d Northwold, October 1992.

Figure B4.1.3e Longitudinal section of Northwold illustrating mean depths and percentage of cells dominated by macrophytes at transects down the 10-m reach.

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In January, a time of limited macrophyte development, the substrate at all three sites was dominated by gravel, but in varying proportions. The ratio of sand to silt was very similar (3:2) at Didlington-gravel and Northwold, while at Langford Hall-gravel, these substrata were almost in direct proportion. Gravel continued to dominate the river-bed at Didlington-gravel in May, but at Langford Hall and Northwold sand had replaced gravel as the principal substratum, although there was considerably more coarse material at Northwold. In October, the substrates at Didlington-gravel and Northwold were both dominated by silt which had accumulated beneath weed beds, but the proportion of gravel at Northwold was greater than that at Didlington. The dominant substratum at Langford Hall, in October, was sand but the silt fraction at the site had increased as a result of the deposition precipitated by macrophytes.

The distribution and abundance of aquatic macrophytes is determined by the complex interaction of physical, chemical and biological variables. Thus, it is very difficult, near impossible, to isolate individual factors as being responsible for the presence or absence of a species a a particular site.

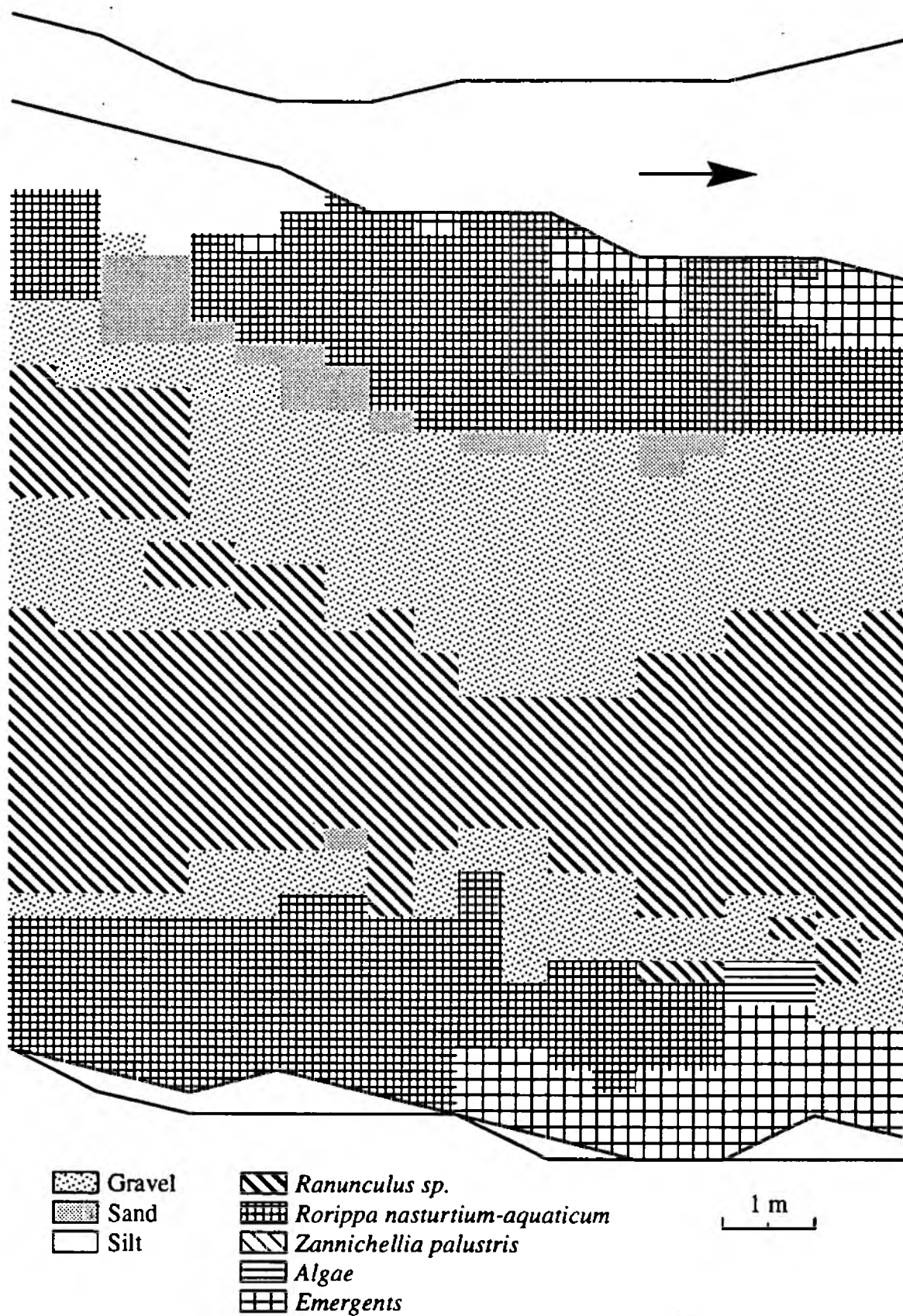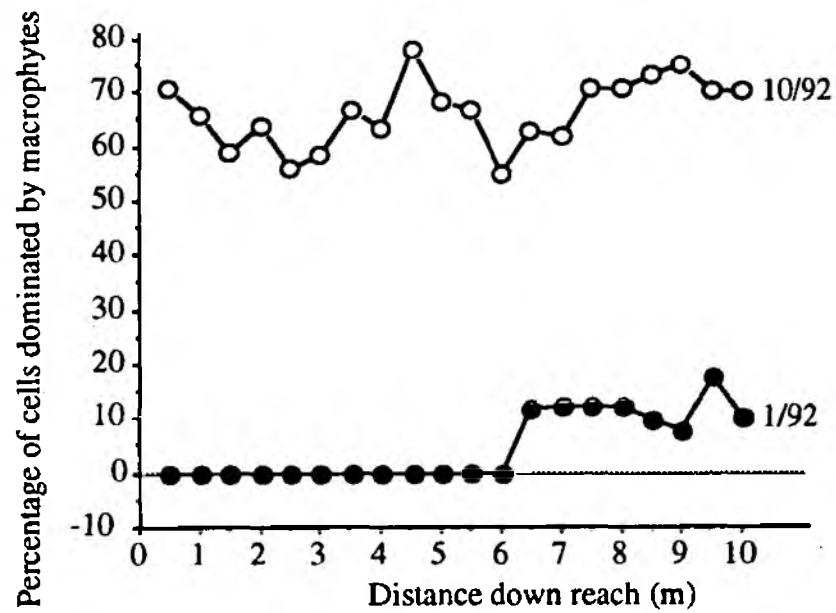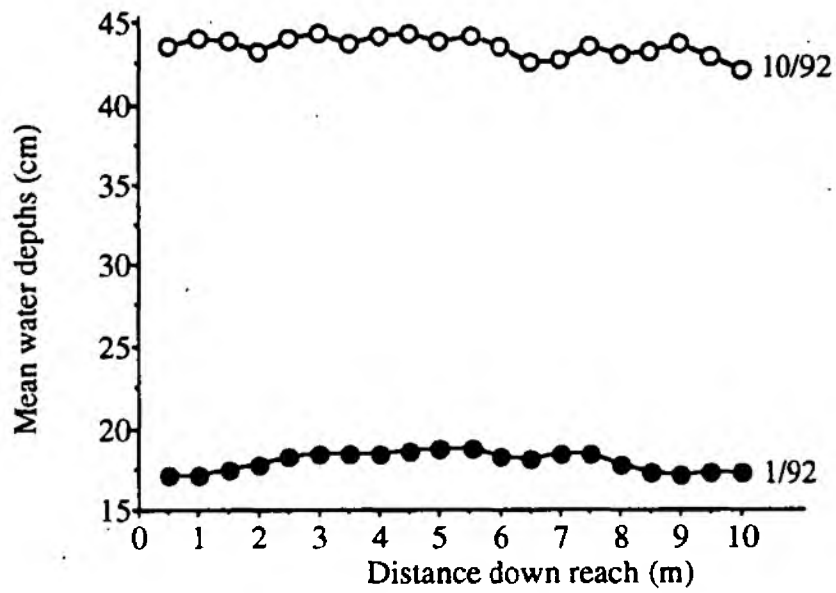The principal differences in macrophyte composition at the three sites on the River Wissey relate to the earlier proliferation of *Ranunculus* at Didlington-gravel and the development of *R.nasturtium-aquaticum* at Northwold. The causes of these spatial variations are unaccountable but factors which might have been contributory are mentioned below. It should be recognized, however, that the observations are merely speculative.

Research has shown that the nature of the channel bed appears to be important in limiting the distribution of *Ranunculus fluitans* Lam. (River Water-crowfoot), the dominant species of *Ranunculus* at the River Wissey survey sites. Brian (1983) found a close correlation between the occurrence of *R.fluitans* and old fords and collapsed bridges, and Cook (1966) suggested that *R.fluitans* is limited in limestone streams by a lack of stable, smooth pebbles on the river bed in which to anchor firmly. The bias towards a stable, coarse substratum and a preference for deeper water (often >1.0 m) (Haslam 1976) may, in part, have limited the early development of *R.fluitans* at Langford Hall-gravel and Northwold where large areas of the reaches were covered by sand and were relatively shallow.

R.nasturtium-aquaticum requires moderately fast-flowing, sandy or gravelly conditions (Haslam 1978, Thommen and Westlake 1981). The species is also very plastic and its height and luxuriance are related to water depth (Howard and Lyon 1952). The reach at Langford Hall, as mentioned

above, tends to be relatively shallow and at Didlington the deeper parts of the site are slower-flowing and covered with silt, factors which might restrict the development of *R.nasturium-aquaticum.*
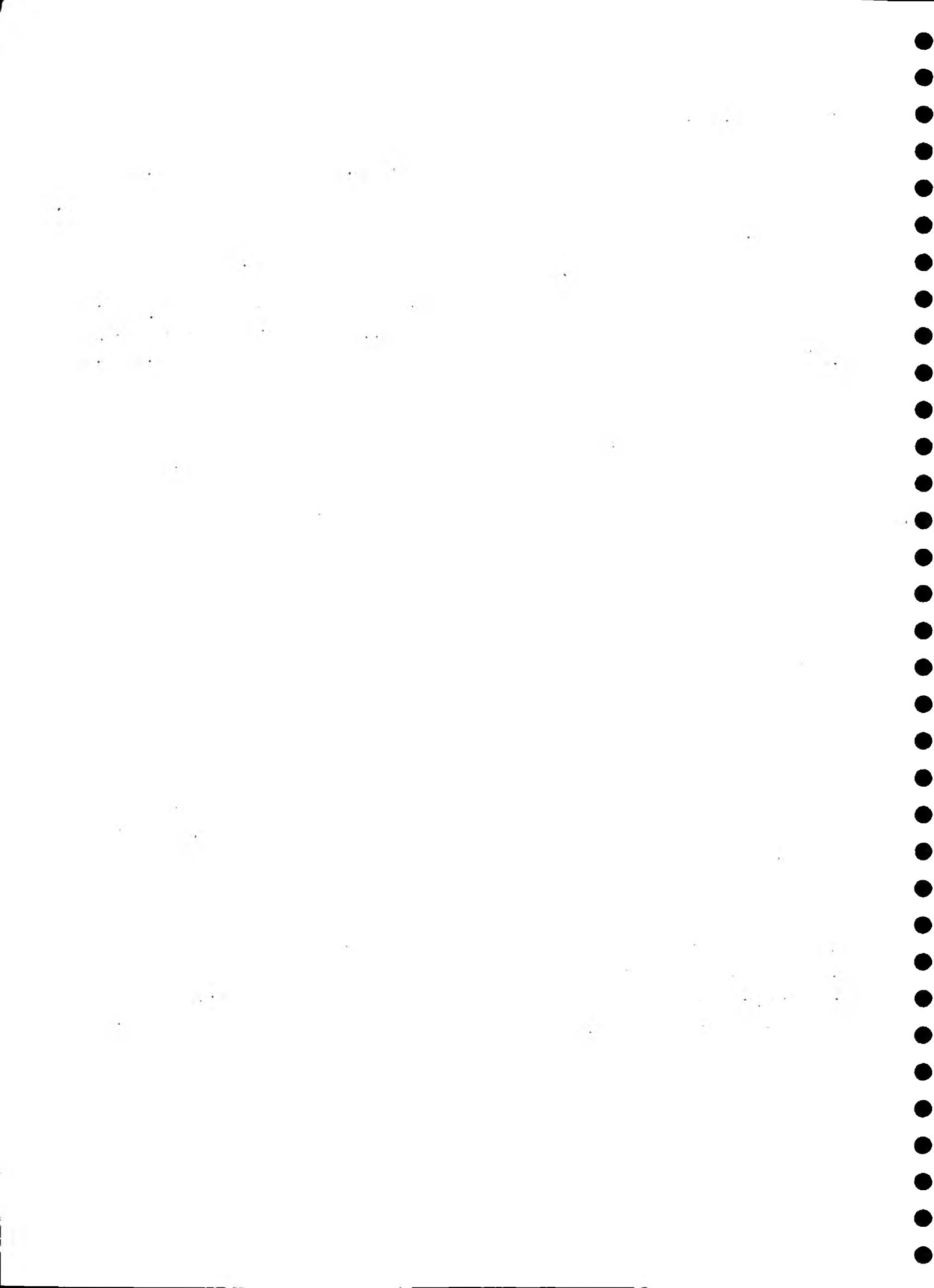
B5 DISCUSSION

Water flow in river channels is generally referred to in terms of discharge. However, for instream biological studies discharge is of little immediate interest. More important is a knowledge of the hydraulic conditions where the flora and fauna exist (Statzner *et al* 1988, Chambers *et al* 1991).

Water velocity has long been acknowledged as the paramount feature of running water (Hynes 1970). It is recognized as one of the principal factors regulating the growth and distribution of submerged aquatic plants in lotic ecosystems (Butcher 1933, Haslam 1978), and variations in velocity, through their action on substrata (vegetable or mineral), produce a diversity of microhabitats to which the aquatic fauna is adapted.

Velocity distribution patterns alter transversely and longitudinally within river channels as discharges are reduced. The impacts of low discharge may be minimized in rivers with dense stands of instream macrophytes because of the mediating effects of aquatic plants on water flows. The influences of aquatic macrophytes on instream hydraulics and sedimentation, and their implications for invertebrate and salmonid fish populations will be examined during the course of this discussion.

B5.1 The Influence of Macrophytes on Instream Hydraulics and Sedimentation

As early as the 1920's, Butcher (1933) recognized that the biomass and species composition of submerged plant communities could be altered by changes in water velocity and that, in turn, aquatic plants could modify flow patterns in streams. Depending on the location, extent and density of the vegetation, aquatic macrophytes may alter the magnitude and direction of currents within the channel and, through their modification of flow velocities, cause changes in patterns of sedimentation (Pitlo and Dawson 1990).

Madsen and Warncke (1983) investigated water velocities around and within weed beds of *Callitriche stagnalis* Scop.. In relation to open water currents, water velocities at the margin of weed beds and inside plant stands, 5 cm from the edge, were reduced by 25-76 percent and 58-92 percent respectively. These figures are comparable with the results of Marshall and Westlake (1985) who demonstrated that water velocity in plant stands may only be one-tenth of that in open

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water at a lowland river site. Madsen and Warncke (1983) also report that water velocities recorded in the centre of plant stands (15 cm from the margin) were not significantly different from those at the periphery (5 cm) and that the most pronounced reduction in velocity was witnessed on the edge of weed beds.

In a study of the effects of aquatic macrophytes on the stream micro-environment, Gregg and Rose (1982) examined the impacts of two species of macrophytes (*Ranunculus aquatilis* L. (Common Water-crowfoot) and *Rorippa nasturtium-aquaticum* L. Hayek (Water-cress)) which differ in habitat, growth and morphology. The authors concluded that both plants obstruct the flow of water and cause a compensatory increase in current velocity above them. However, peak flow velocities around stands of *R.nasturtium-aquaticum* were faster than those around beds of *R.aquatilis*. The disparity appears to be related to the increased hydraulic resistance offered by the broad-leaved, thick-stemmed *R.nasturtium-aquaticum* which held up flow at the stream bed to a greater extent and so produced higher counteracting velocities above the plant stands.

In addition to their observations on water velocities, Gregg and Rose (1982) also detailed the differential accumulation of fine sediments on and/or beneath unvegetated and vegetated substrata. Significantly more silt, sand and fine gravel (Phi Scale 1-4) accumulated in trays containing *R.aquatilis* than in trays without macrophytes.

The effects of seasonal changes in aquatic plant biomass on instream hydraulic characteristics, principally Manning's 'n' values, water depth and velocity, and surface water elevation were reported by Vinson *et al* (1992). Between October and March, Manning's n decreased from 0.09-0.14 to 0.01-0.05. During the same period, water surface elevation fell 0.3-0.5 m. and the wetted channel area was reduced by 40-78 percent, almost entirely as a result of changes in water depth. Water velocities increased 40-79 percent between the seasons. The abundance of aquatic vegetation reflected the same seasonal trend. In October, macrophytes covered 60-90 percent of the channel area, but by March most of the plants had senesced or had been consumed by water fowl. Those which remained covered less than 5 percent of the channel area.

The present study does not quantify the effects of macrophytes on instream hydraulics but serves to illustrate many of the principles described above. Figures B4.1.1b-B4.1.1d and B4.1.3b-B4.1.1d neatly depict the inter-relationships between macrophyte distribution, water velocity and substrata. In view of the above discussion, one might reasonably assume that water velocities in the

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open channels between macrophyte beds were substantially greater than those within the plant stands. The patterns of substrate distribution illustrated in the figures are in accordance with this premise - coarse particulates primarily occur in the faster-flowing parts of the reach and between macrophyte beds while the finer material is associated with the slacker flows along channel margins and within macrophyte beds.

The marked proliferation of macrophytes between May and October at the three survey sites on the River Wissey was accompanied, without exception, by an increase in the proportion of silt at the sites (see Figures B4.1.1a, B4.1.2d, B4.1.3a). This suggests that aquatic macrophytes were modifying stream flows sufficiently to increase the deposition of fine particulates.

Finally, the effects of macrophyte abundance on water levels is adequately described by Figures B4.1.1e, B4.1.2e and B4.1.3e which demonstrate that increased plant cover produces an elevation in mean water depths.

B5.2 The Implications of Aquatic Macrophytes and Their Effects on Instream Hydraulics for Invertebrate and Salmonid Fish Populations

Aquatic macrophytes are capable of affecting very different conditions in stream microhabitats. Since many of these conditions are fundamental to the faunal distribution in rivers, macrophytes have an implied ecological effect. The role of macrophytes in providing habitat diversity may be of particular importance in the optimization of low flow conditions for faunal communities.

In an unvegetated channel, a reduction in discharge is usually accompanied by a reduction in the water depth and width of the channel, and a reduction in flow velocity, leading to increased deposition of fine suspended sediments. The presence of aquatic macrophytes in a channel, however, may counter the above effects of low discharge in two ways. Firstly, plant cover increases the hydraulic resistance which causes a reduction in overall flow velocity and thereby raises water levels. Secondly, weed beds, through their capacity to change the magnitude and direction of currents within the channel, produce different patterns of sedimentation.

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B5.2.1 Water Level

One of the principal effects of a reduction in the depth and width of a river is the overall decrease in potentially colonizable habitat available to aquatic fauna. Research by Cowx *et al* (1984) demonstrated that a contraction in the area of wetted river bed affected a considerable reduction in total numbers of invertebrates. For fish communities, a diminution of the various habitats required by different life-stages inevitably results in increased competition for space and food resources. Fish may become restricted to shallow pools which can become too warm, stagnant or overcrowded to sustain normal populations and growth rates (Hynes 1958, Larimore *et al* 1959). Trout are known to be markedly territorial and density-dependent mortality is recognized as a major population regulatory process, particularly during the juvenile post-emergent phase (Gee *et al* 1978). These potential impacts of reduced depth and channel width arising from low discharge may, however, be mitigated by the 'ponding' effect macrophytes exert on water levels.

B5.2.2 Substrate

Substrate character has profound influences upon the instream biota. Invertebrates use substrata as refugia, for anchorage, and for food collection. Several authors have documented the association of different invertebrate communities with specific biotopes. For example, communities dominated by Simuliidae and Ephemeroptera show an association with *Ranunculus* sp. (Harrod 1962, Westlake *et al* 1972) and communities dominated by Crustaceae are typically supported on *Apium nodiflorum* and *Rorippa nasturtium-aquaticum* (Westlake *et al* 1972) while members of the Sphaeriidae (molluscs in the genus *Pisidium*) and Glossosomatidae (trichopteran larvae in the genus *Agapetus*) predominate on silt and gravel respectively.

The effect of loss of habitat in reducing total density of invertebrates has been considered. Other work has shown, however, that for some invertebrates habitat quality rather than habitat quantity is important. The impact of the 1976 drought has variously been examined at two sites on a perennial reach of the River Lambourn. Both sites suffered from siltation and a poor growth of *Ranunculus* sp. which Ham *et al* (1981) attributed to the extraordinary accumulation of epiphytic algae and detritus on the surface of the plants. Invertebrate habitat availability was thus limited by the restricted growth of *Ranunculus*. However, densities of chironomid lavae which exploited the algae and associated detritus were appreciably higher on a range of habitats in 1976 than in years of higher discharge (Wright 1978). This implies that food available on the macrophytes (ie. quality of

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macrophytes) was more important than the area (quantity) of macrophyte in allowing high populations of chironomids to occur.

Research by Canton *et al* (1984) on a third order montane stream demonstrated that drought has variable effects on different invertebrate communities. Canton *et al* observed that many taxa (eg. *Hydroptila* sp., *Ophiogomphus severus* Hagen, *Cricotopus* sp., *Eukiefferiella* sp., *Palpomyia* sp. and *Tipula* sp.) exhibited higher densities during a period of low flow, followed by reduced numbers after the resumption of more normal flows. Other taxa (eg. *Baetis* sp. and *Glossosoma* sp.) exhibited the opposite pattern with significantly higher densities during the normal flow period. Similar results were documented by Extence (1981) and Wright and Berrie (1987). Certain taxa were found to exploit the lower flow conditions, while others, including Baetidae and Simuliidae, were adversely affected by siltation or organic pollutants and were recorded at reduced densities.

Fish communities are dependent on substrata which provide conditions suitable for successful spawning, afford protection from predation during alevin and juvenile stages, and supply a diverse and abundant invertebrate fauna from which they may feed. Fish species diversity has been correlated with stream habitat complexity (Gorman and Karr 1978) and there is considerable evidence that diversity and biomass of fish is influenced by the physical configuration of the channel (Brooker 1981).

Research indicates that salmonids require a loose gravel substrate so that the female can cut redds (Stuart 1953, 1954). The proportion of fine particles appears to be an important feature in spawning gravel and authors agree that a low content of fine material is advantageous as it reduces compaction and assists egg incubation and fry emergence (Reiser and White 1990). Embryo survival in salmonids is inversely proportional to the quantity of fine sediments present in gravels. As the proportion of fines increases so gravel permeability declines which leads to a reduction in dissolved oxygen availability and allows the build up of toxic metabolic waste products (Hamor and Garside 1976, Reiser and White 1990). In contrast, the rate of entrapment of alevins in gravels (a significant cause of salmonid mortality) is positively correlated with the proportion of fine particles (Milner *et al* 1981).

Aquatic macrophytes affect river substrates in two ways, by providing morphological, or structural, variation and by modifying water velocities which, in turn, creates spatial variation in the

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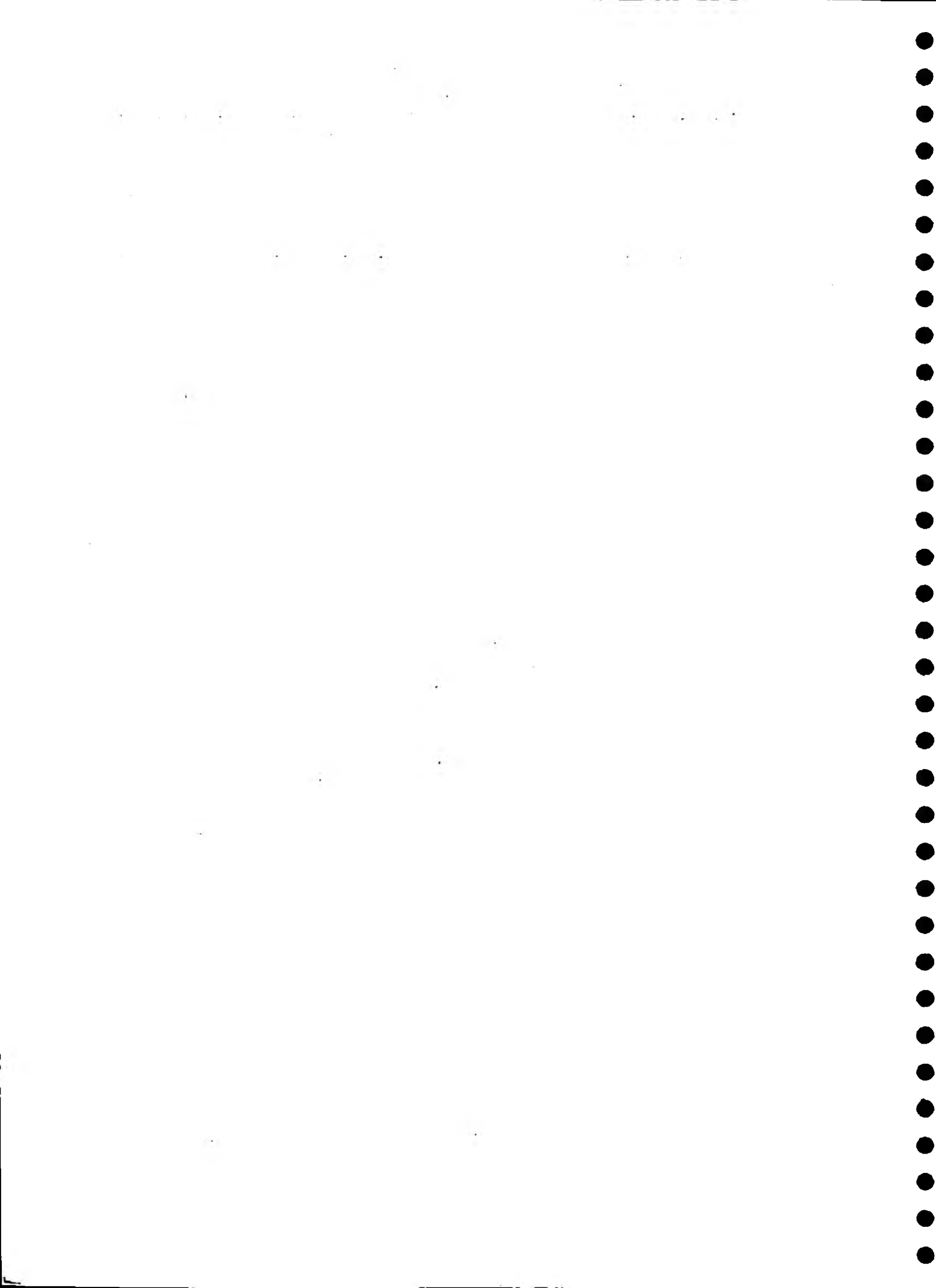
composition of inorganic substrata. In view of the role of aquatic plants in promoting habitat heterogeneity and the importance to fauna of habitat quality rather than habitat quantity, the presence of aquatic vegetation in river channels may lessen the impacts of low discharge. Under conditions of low flow, the proportions of available habitats may be reduced and absolute faunal densities may decline, but because the fauna are mobile and able to use refugia to survive, faunal diversity may be maintained, provided adverse conditions are not protracted and do not affect macrophyte growth.

B6   CONCLUSIONS

B6.1   The Flora of the River Wissey

The River Wissey supports a typical chalk stream flora and exhibits a longitudinal zonation of species. *A.nodiflorum* and *R.nasturtium-aquaticum* tend to dominate in the headwaters but *B.erecta* is important at some sites in the upper reaches (eg. Beachamwell and Eastmoor). Further downstream, where the flow is perennial, *Callitriche* sp. and *S.erectum* can be found with the above species.

In the middle reaches, *R.fluitans* is often dominant in the open channel and tall monocotyledons such as *G.maxima*, *S.erectum* and *P.arundinacea* become more prominent at the river margins. Finally, elevated nutrient status in the silted lower reaches of the river allows the development of semi-eutrophic and eutrophic species such as *E.canadensis*, *Sparganium emersum* Rehmann (Unbranched Bur-reed), *Carex acutiformis* Ehrh. (Lesser Pond-sedge), *Myriophyllum spicatum* L. (Spiked Water-milfoil) and *Z.palustris*.

B6.2   Patterns of Macrophyte Development

The frequency of mapping employed in the present study was insufficient to pinpoint the exact months in which macrophytes began to develop but allows some estimations to be made regarding the growth cycles of individual species.

The patterns of macrophyte development observed at sites on the River Wissey are similar to those witnessed in other English chalk streams (Dawson 1976, Dawson *et al* 1978, Ham *et al* 1981, Ham *et al* 1982, Thommen and Westlake 1981). Thommen and Westlake (1981) found that the cover of *R.nasturtium-aquaticum* in the Bere Stream, Dorset, was lowest in March, after autumn and winter floods had washed away most of the overwintering plants and frost had killed many emergent parts. Growth of the species usually commences before, and continues after, flowering which generally occurs between May and October. Large beds of *R.nasturtium-aquaticum* may persist in late autumn until the seasonal increase in discharge.

At sites on the River Wissey, the least cover of *R.nasturtium-aquaticum* was recorded in May. The species was observed in small quantities in January but by May ceased to dominate cells. Vigorous

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growth occurred at Northwold between May and October, but *R.nasturtium-aquaticum* failed to reappear as a dominant macrophyte at Didlington-gravel and Langford Hall-gravel.

Ham and co-workers (Ham *et al* 1981, Ham *et al* 1982) observed the growth and recession of aquatic macrophytes in unshaded and shaded sections of the River Lambourn. The cover of Ranunculus *penicillatus* Ssp. *pseudofluitans* (Syme) S. Webster began to increase in March-April and was maximal in August. The growth cycle of the same species in the Bere Stream (Dawson 1976, Dawson *et al* 1978) showed an annual pattern similar to the River Lambourn but displaced in time so that maximum cover occurred in April-May. Less research has been conducted on the growth cycle of *R.fluitans*. However, Eichenberger and Weilenmann (1982), in a study of the development of the species in artificial canals showed that *R.fluitans* shows a yearly periodicity and that growth began in April-May and continued until September.

In the River Wissey, growth of *R.fluitans* at Didlington-gravel commenced before May. In January, the species was recorded dominant in less than one percent of cells at the site but by May dominated 22.68 percent of cells (Figure B4.1.1a). Further expansion occurred between May and October when *R.fluitans* was noted as dominant in 40.38 percent of cells.

At Langford Hall-gravel and Northwold, *R.fluitans* dominated very few cells in January and May and the percentage of cells in which the plant was merely present did not alter significantly (55.98%-58.74% at Langford Hall and 25.03%-24.24.67% at Northwold) which suggests that any growth occurring at these sites was insignificant. By October, however, *R.fluitans* dominated a large proportion of cells at both sites (Figures B4.1.2d and B4.1.3a). No explanation can be given for the variation in the onset of *Ranunculus* development at different sites on the River Wissey.

B6.3 The Influence of Aquatic Macrophytes on Instream Habitats

The distribution and density of aquatic macrophytes greatly influences instream hydraulics and sedimentation in the River Wissey. The seasonal increase in plant cover has the effect of elevating water levels which may help maintain channel width during periods of low flow. The development of weed beds alters flow velocity distribution patterns in the channel, affecting different patterns of sedimentation. Flow velocity is reduced within the plant stands which precipitates the deposition of fine sediments, while compensatory increases in flow velocity between the weed beds generates

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local scour and helps maintain a coarser substratum. Absolute flow velocities around and within weed beds were not determined in the present study but currents within plant stands were visibly slower than in the channels in between. Other workers have demonstrated, however, that velocities in plant stands may only be one-tenth of those in open water (Madsen and Warncke 1983, Marshall and Westlake 1985).

Aquatic macrophytes create habitat heterogeneity which is of ecological significance for invertebrate and fish populations, and may be particularly important for optimizing low flow conditions for aquatic fauna. Thus, relatively simple management of weed beds should be ensured to provide a diversity of plant species and, hence, a range of flow velocity, substratum and morphology requirements for aquatic fauna.

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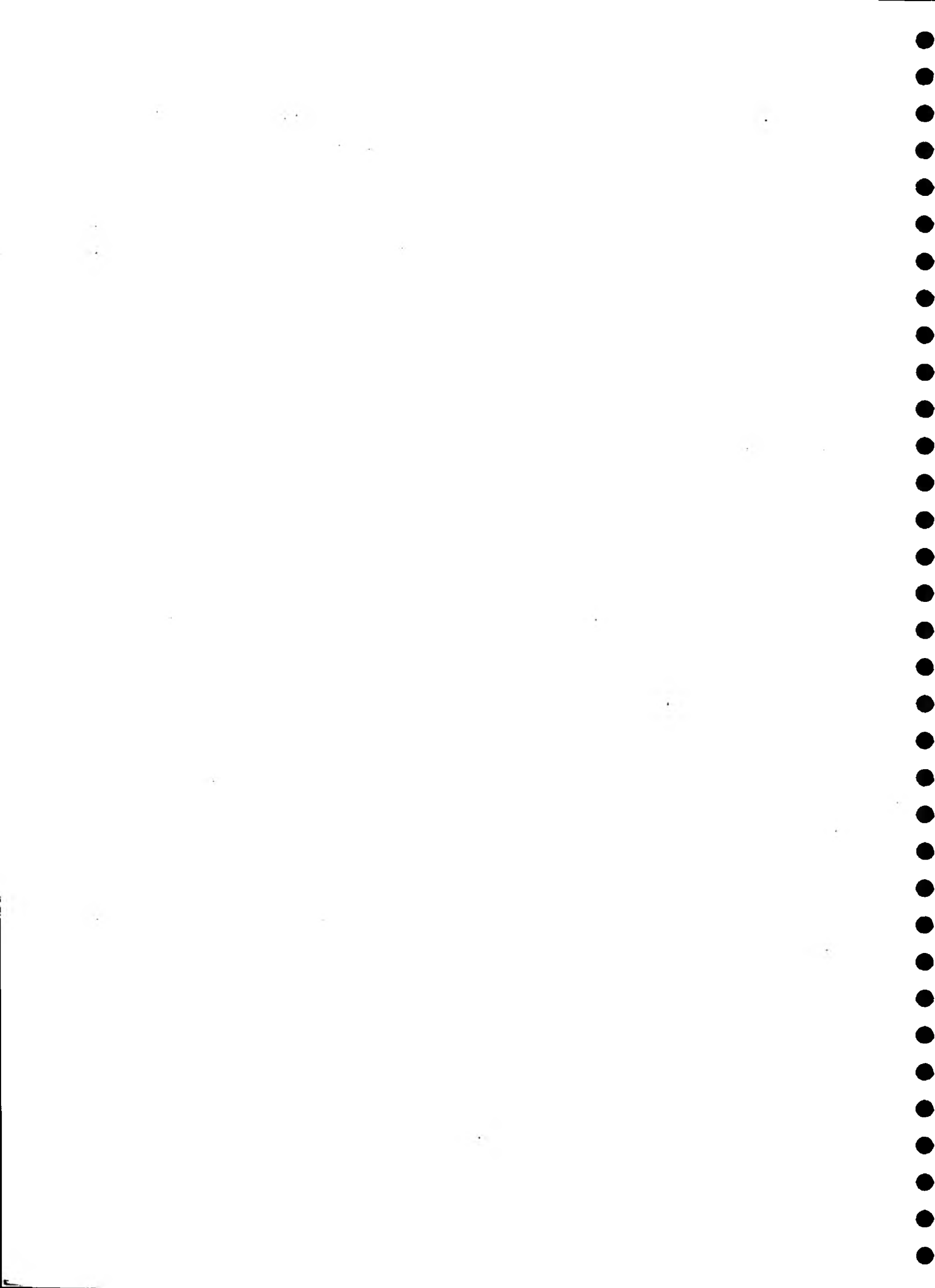
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APPENDICES

B4.1   Temporal Comparisons of Sites Based on Their Biotopes

B4.1.1 Didlington-gravel: Macrophyte Maps

B4.1.2 Langford Hall-gravel: Macrophyte Maps

B4.2   Spatial Comparisons of Sites Based on Their Biotopes

Appendix B4.1   Temporal Comparisons of Sites Based on Their Biotopes.

Table B4.1a Temporal comparison of sites based on their macrophyte composition.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v DDGR 5/92	149.919	3	0.0001
DDGR 1/92 v DDGR 10/92	221.538	2	0.0001
DDGR 5/92 v DDGR 10/92	7.194	2	0.0274
LFDHG 1/92 v LFDHG 5/92	353.619	2	0.0001
LFDHG 1/92 v LFDHG 10/92	273.816	2	0.0001
LFDHG 5/92 v LFDHG 10/92	79.901	1	0.0001
NTHWD 1/92 v NTHWD 5/92	50.550	4	0.0001
NTHWD 1/92 v NTHWD 10/92	58.768	3	0.0001
NTHWD 5/92 v NTHWD 10/92	374.065	4	0.0001

Table B4.1b Temporal comparison of sites based on the number of cells in which substrate or macrophyte types exceed 50 percent.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v DDGR 5/92	223.734	6	0.0001
DDGR 1/92 v DDGR 10/92	538.544	6	0.0001
DDGR 5/92 v DDGR 10/92	149.350	6	0.0001
LFDHG 1/92 v LFDHG 5/92	335.446	4	0.0001
LFDHG 1/92 v LFDHG 10/92	528.570	5	0.0001
LFDHG 5/92 v LFDHG 10/92	692.575	4	0.0001
NTHWD 1/92 v NTHWD 5/92	605.286	7	0.0001
NTHWD 1/92 v NTHWD 10/92	733.756	6	0.0001
NTHWD 5/92 v NTHWD 10/92	1005.314	7	0.0001

Table B4.1c Temporal comparison of sites based on their substrate composition.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v DDGR 5/92	3.185	2	0.2034
DDGR 1/92 v DDGR 10/92	394.131	3	0.0001
DDGR 5/92 v DDGR 10/92	419.593	3	0.0001
LFDHG 1/92 v LFDHG 5/92	283.067	2	0.0001
LFDHG 1/92 v LFDHG 10/92	195.167	2	0.0001
LFDHG 5/92 v LFDHG 10/92	38.834	2	0.0001
NTHWD 1/92 v NTHWD 5/92	537.734	2	0.0001
NTHWD 1/92 v NTHWD 10/92	635.096	2	0.0001
NTHWD 5/92 v NTHWD 10/92	926.653	2	0.0001

B4.1.1   Didlington-gravel: Macrophyte Maps

Legend:

- Cobble
- Gravel
- Sand
- Silt
- *Ranunculus sp.*
- *Rorippa nasturtium-aquaticum*
- *Zannichellia palustris*
- *Algae*
- *Emergents*

1 m
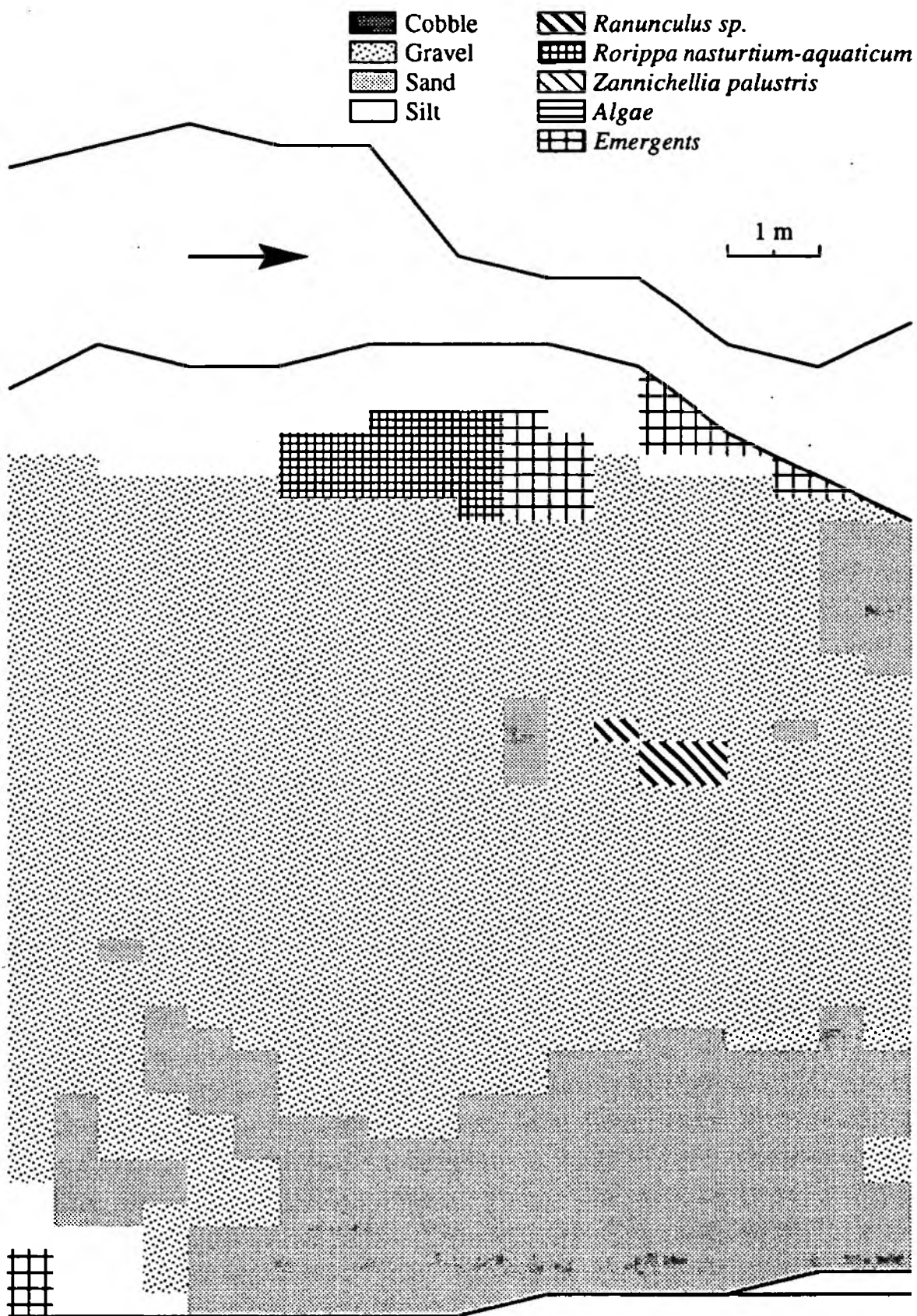
Figure B4.1.1b Didlington-gravel, January 1992.

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Legend:

- Cobble
- Gravel
- Sand
- Silt
- *Ranunculus sp.*
- *Rorippa nasturtium-aquaticum*
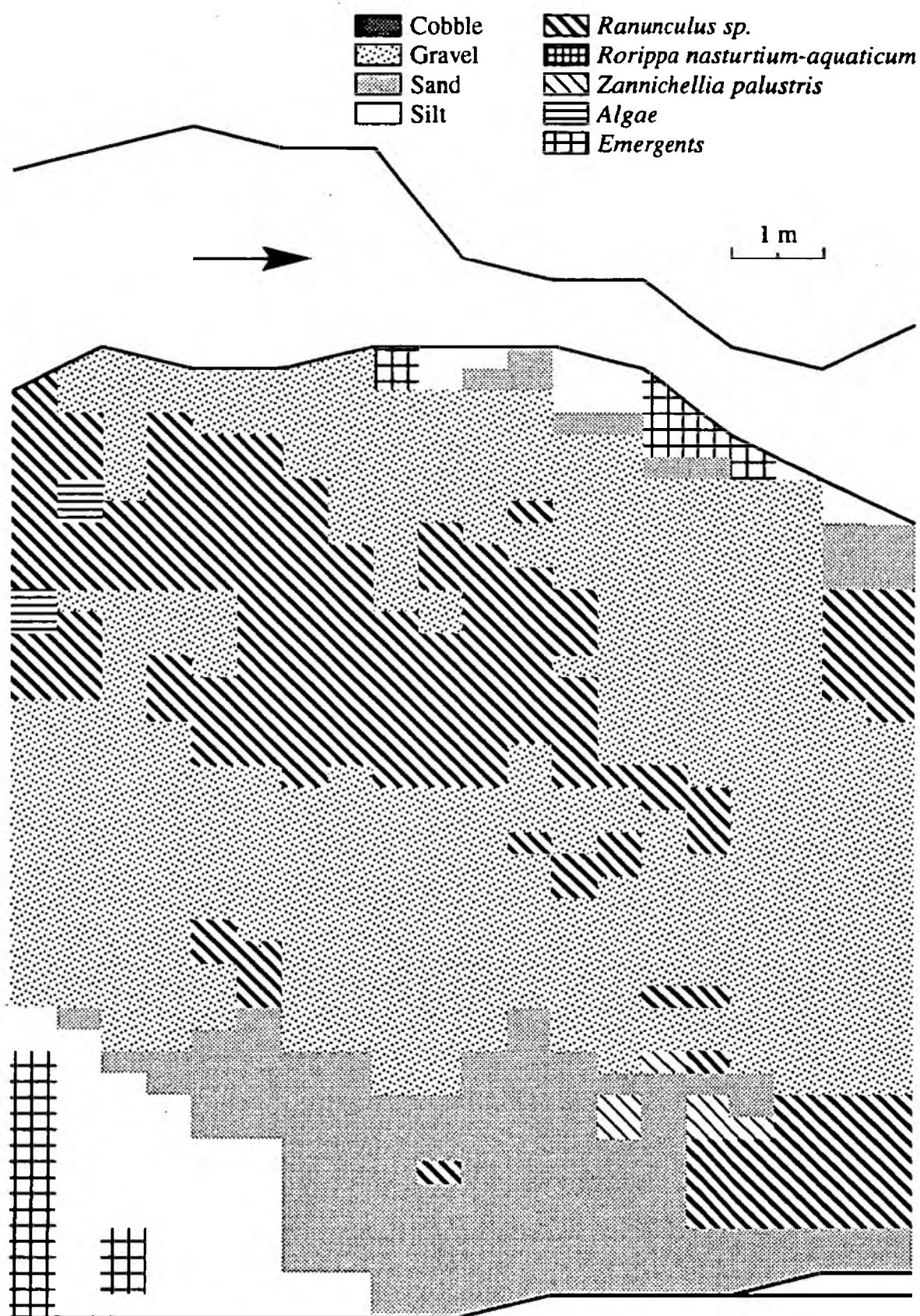- *Zannichellia palustris*
- *Algae*
- *Emergents*

1 m

Figure B4.1.1c Didlington-gravel, May 1992.

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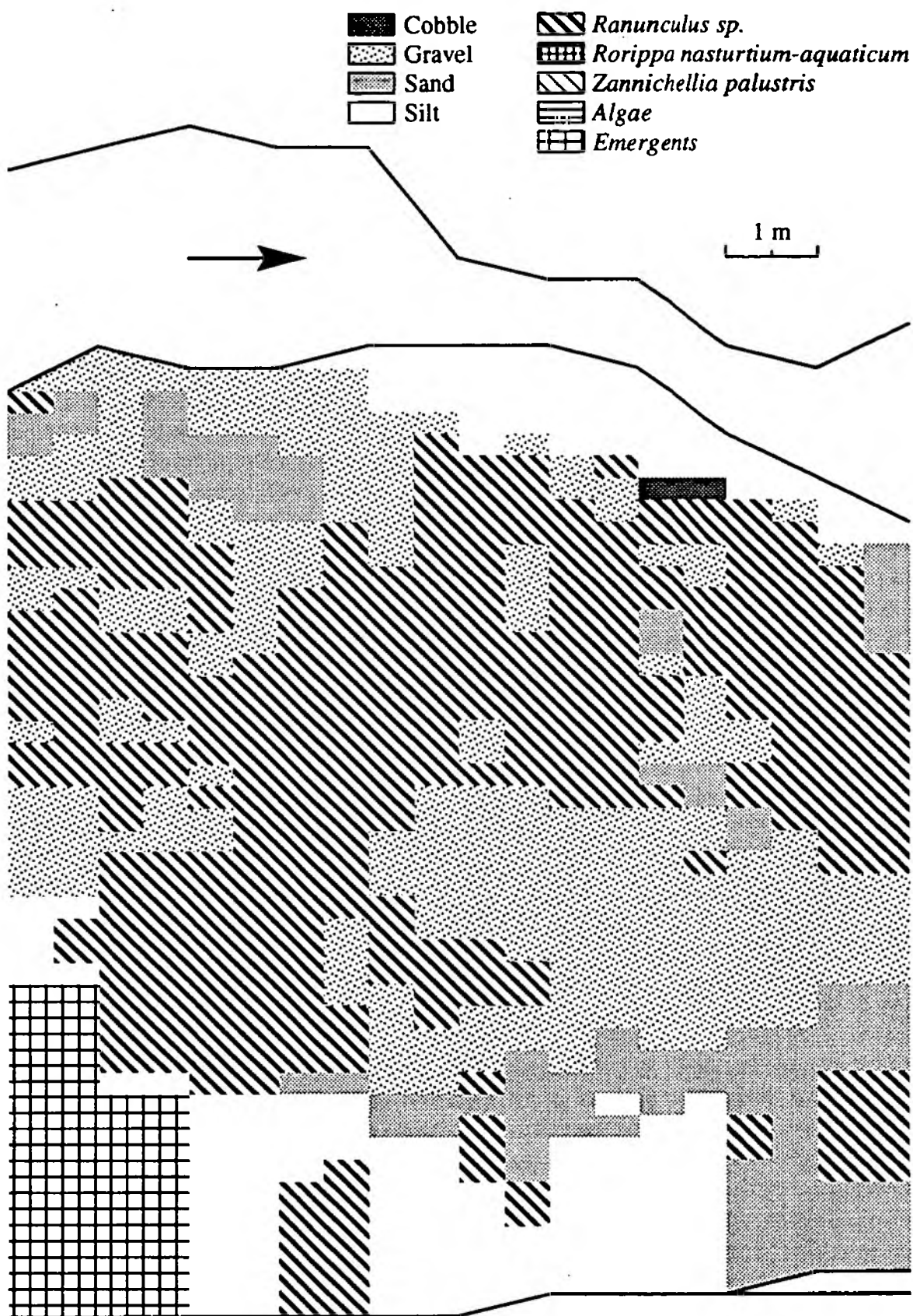
Figure B4.1.1d Didlington-gravel, October 1992.

B4.1.2   <u>Langford Hall-gravel: Macrophyte Maps</u>
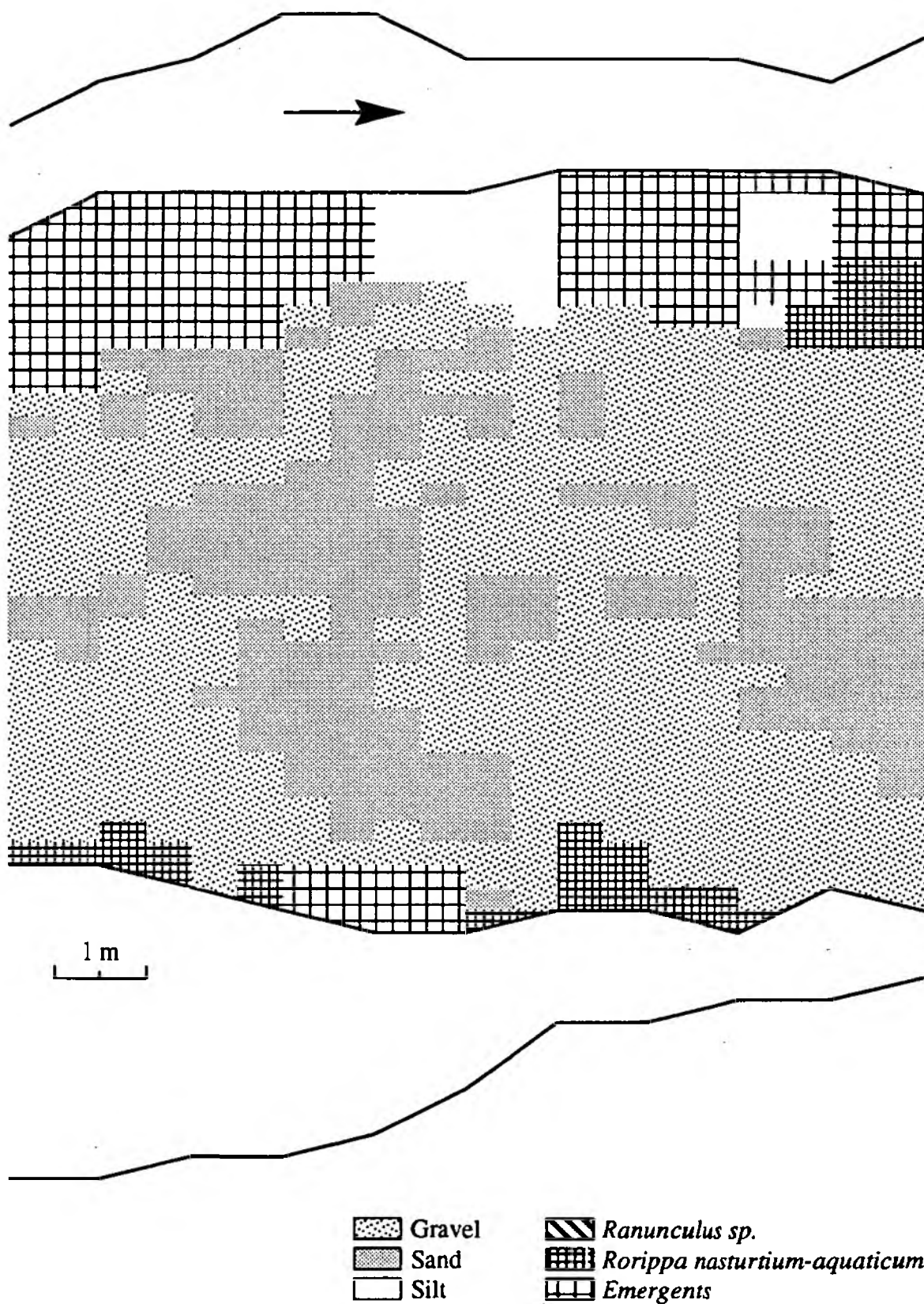
Gravel
Sand
Silt

Ranunculus sp.
Rorippa nasturtium-aquaticum
Emergents

Figure B4.1.2a Langford Hall-gravel, January 1992.

Gravel **Ranunculus sp.**
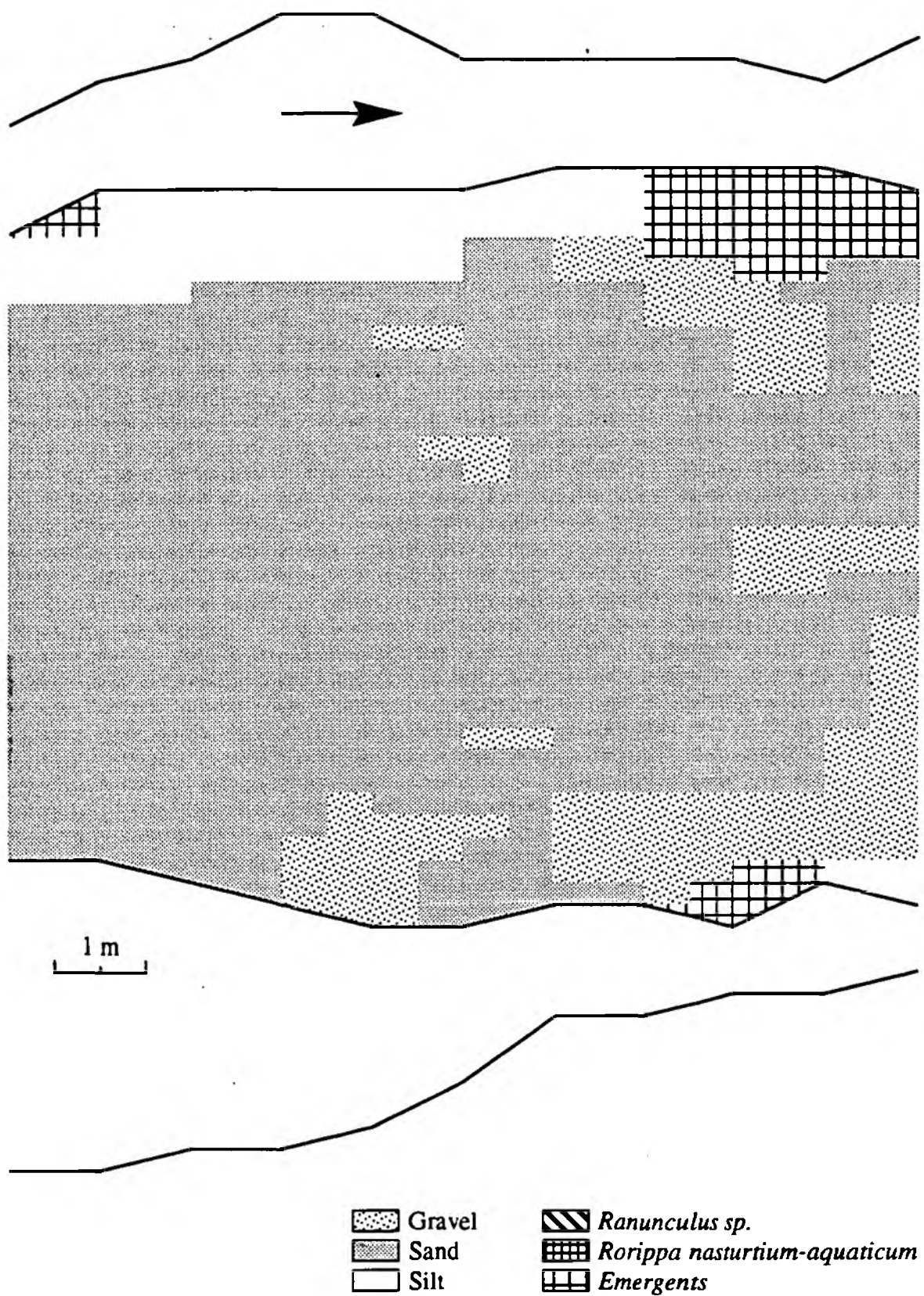**Sand** **Rorippa nasturtium-aquaticum**
Silt **Emergents**

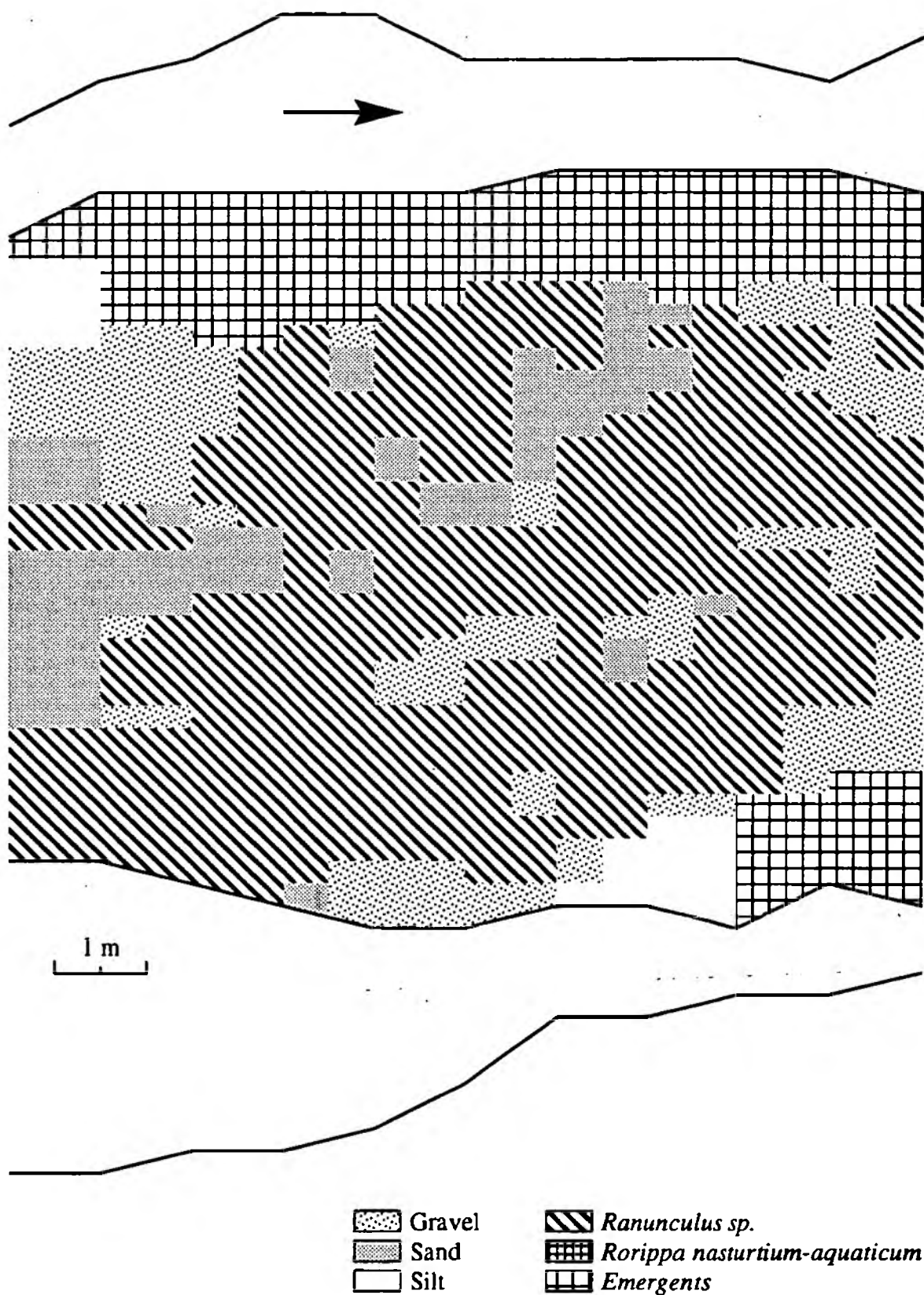Figure B4.1.2b Langford Hall-gravel, May 1992.

Figure B4.1.2c Langford Hall-gravel, October 1992.

Appendix B4.2 Spatial Comparisons of Sites Based on Their Biotopes.

Table B4.2a Spatial comparison of sites based on their macrophyte composition.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v LFDHG 1/92	22.065	2	0.0001
DDGR 1/92 v NTHWD 1/92	**0.400**	**2**	**0.8187**
LFDHG 1/92 v NTHWD 1/92	14.736	2	0.0006
DDGR 5/92 v LFDHG 5/92	133.697	2	0.0001
DDGR 5/92 v NTHWD 5/92	171.416	3	0.0001
LFDHG 5/92 v NTHWD 5/92	48.448	3	0.0001
DDGR 10/92 v LFDHG 10/92	29.418	1	0.0001
DDGR 10/92 v NTHWD 10/92	228.566	3	0.0001
LFDHG 10/92 v NTHWD 10/92	262.518	3	0.0001

Table B4.2b Spatial comparison of sites based on their substrate composition.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v LFDHG 1/92	29.065	2	0.0001
DDGR 1/92 v NTHWD 1/92	96.013	2	0.0001
LFDHG 1/92 v NTHWD 1/92	189.324	2	0.0001
DDGR 5/92 v LFDHG 5/92	448.350	2	0.0001
DDGR 5/92 v NTHWD 5/92	339.322	2	0.0001
LFDHG 5/92 v NTHWD 5/92	110.352	2	· 0.0001
DDGR 10/92 v LFDHG 10/92	305.233	3	0.0001
DDGR 10/92 v NTHWD 10/92	53.170	3	0.0001
LFDHG 10/92 v NTHWD 10/92	513.054	2	0.0001

Table B4.2c Spatial comparison of sites based on the number of cells in which substrate or macrophyte types exceed 50 percent.

Site Comparison	Chi-square	DF	p
DDGR 1/92 v LFDHG 1/92	280.210	6	0.0001
DDGR 1/92 v NTHWD 1/92	109.792	5	0.0001
LFDHG 1/92 v NTHWD 1/92	224.975	5	0.0001
DDGR 5/92 v LFDHG 5/92	550.044	5	0.0001
DDGR 5/92 v NTHWD 5/92	516.710	6	0.0001
LFDHG 5/92 v NTHWD 5/92	136.671	6	0.0001
DDGR 10/92 v LFDHG 10/92	150.354	5	0.0001
DDGR 10/92 v NTHWD 10/92	368.761	7	0.0001
LFDHG 10/92 v NTHWD 10/92	329.818	6	0.0001