An Investigation of Ecological Change in the Rivers Kennet and Lambourn

Report for the period April 1998 -March 1999

J F Wright, R J M. Gunn, J M Winder,
J H Blackburn, R Wiggers, K Vowles and R T Clarke

Institute of Freshwater Ecology
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This report presents the results of a repeat survey of invertebrates and plants on the Rivers Kennet and Lambourn. It is intended for use by the Agency's staff and others interested in the ecology and management of chalk rivers and the effects of low flows on them.

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The study would not have been possible without the active cooperation and help of riparian landowners and river keepers. Once again, the team was allowed access to each study site and for this we are most grateful. At Bagnor, we were granted access to the River Lambourn by Mr C. Robins of the Donnington Grove Country Club and Ms E. Alison of the Berkshire Buckinghamshire and Oxfordshire Naturalists Trust (who manage Rack Marsh). At the Littlecote Estate we received help and advice from Head Keeper Mr P. Woolnough and at Savernake we received similar assistance from Head Keeper Mr J. Hounslow.

KEY WORDS

Chalk streams; low flows; ecological change; macrophytes; macroinvertebrates

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EXECUTIVE SUMMARY

The Kennet and Lambourn catchments are important regionally for water supply, fisheries and conservation. There is a need for reliable long-term data on the ecology of these chalk streams to ensure effective management and to fulfill the UK Biodiversity Action Plan. Between 1971 and 1979, an intensive study was conducted on the macrophytes and macroinvertebrate assemblages at a shaded site on the River Lambourn at Bagnor. Between 1974 and 1976, further studies took place at three sites on the River Kennet. Two of these sites were located downstream of Marlborough (Upper and lower sites at Savernake) and the third site was at Littlecote, upstream of Hungerford.

In 1997 the Environment Agency (Thames Region) commissioned the Institute of Freshwater Ecology (IFE) to re-examine these four sites in summer (June/July) and winter (December) using the 1970s protocols. The macrophytes were mapped and a quantitative sampling programme for the macroinvertebrate fauna was undertaken at each site. The objective was to provide information on long-term ecological changes and the impact of the 1996-97 drought. The results have been fully reported in Wright *et al.* (1999a).

The winter of 1997/98 marked the end of the prolonged drought of 1996/97. There was an urgent need to record any long-term consequences of this drought and start to collect information on the rate at which recovery took place. This important opportunity was recognised by the IFE and the Environment Agency and this report gives the major results of the sampling programme for macrophytes and macroinvertebrates undertaken in June 1998.

The shaded site on the River Lambourn at Bagnor is now heavily shaded by trees on one bank and by tall marginal vegetation on the other through recent lack of management. In 1997 submerged macrophytes occupied a smaller area of the riverbed than in the 1970s, whereas silt and marginal emergents were more important. These changes were believed to be due to a combination of lack of management and the 1996/97 drought.

In June 1998, despite a substantial increase in discharge, growth of all submerged macrophytes was poor and the area of deposited silt remained high. The very limited increase in the area of *Berula* and the failure of *Ranunculus* to increase under conditions of moderate discharge are at odds with the response of these macrophytes to similarly favourable discharge conditions in the 1970s. Excessive shading, the impact of siltation and even the cropping of macrophytes by signal crayfish are possible causes of this slow response.

Despite this, there is evidence of long-term stability in macroinvertebrate family composition at this site between the 1970s and the late 1990s. During the 1970s, quantitative sampling of five habitats yielded between 42 and 47 families in June each year, In June 1997, at the height of the drought, 42 families were captured, whilst in June 1998, 45 families were recorded from the same five habitat types.

Examination of the densities of some families characteristic of fast-flowing chalk streams such as Baetidae (mayflies) and Simuliidae (Blackflies) indicated that by June 1998 there was evidence of some recovery from the very low populations of June 1997. However, the combination of low levels of submerged vegetation and only modest densities of these taxa compared to the 1970s indicated that 'recovery' was incomplete.

The 100 m study site on the River Kennet at Littlecote remains an important trout fishery, as in the 1970s. The river is allowed to run freely, and even in the 1996/97 drought *Ranunculus* covered 44.2% of the site in July 1997, although it had not yet been cut. Emergent marginal vegetation was beginning to offer an alternative habitat for some macroinvertebrates. In contrast, the estimated cover of *Ranunculus* in June 1998 was 71.5%, bar cutting had already taken place and all marginal emergents had been removed by the high winter flows.

Macroinvertebrate family richness was marginally lower in June 1998 at 32 families compared to the 35 families in July 1997, possibly as a result of the loss of the adjacent marginal vegetation. Because *Ranunculus* remained as an important habitat throughout the drought, Baetidae and Simuliidae maintained modest populations in 1997, which then increased in June 1998. Densities of Gammaridae (*Gammarus pulex*) were very high in June 1998 in both *Ranunculus* and gravel. The marginal vegetation which remained until Decenmber 1997 may have been an ideal refuge with abundant food for *G. pulex* until this habitat was removed by winter flows, when this important chalk stream macroinvertebrate may have moved into the adjacent *Ranunculus* and gravel.

The two study sites on the River Kennet at Savernake suffered progressive loss of *Ranunculus* during the 1990s and all attempts at promoting re-growth by habitat management failed. In July 1997, in the second year of the drought, the dominant macrophyte on the lower site was *Schoenoplectus* (17.4% cover) whereas on the upper site *Ranunculus* was dominant with just 6.5% cover. During the winter of 1997/98 two potentially important events occurred. First, phosphate stripping commenced at Marlborough STW. Second, the drought came to an end, and although winter discharge was not exceptional, a particularly wet spring led to very high discharge in May 1998, immediately prior to mapping.

The June 1998 mapping demonstrated that there had been spectacular growth of *Ranunculus* on each site. On the lower site *Ranunculus* had become the dominant macrophyte with 43.6% cover, far higher than the area noted at any time during the mid-1970s or in 1997. On the upper site *Ranunculus* occupied 48.8%, again a spectacular increase since 1997, although only marginally higher than the area occupied in the mid-1970s under favourable discharge conditions. It was apparent that, under favourable conditions, *Ranunculus* was capable of rapid recovery, presumably due to the survival of root systems within the gravel substratum.

Despite these major changes in habitats for macroinvertebrates, taxon richness at family level remained relatively stable at each site with a total of 33 families recorded at each of the lower and upper sites in July 1997 and 32 families at each of the two sites in June 1998. There were, however, some minor differences in family composition between sites and years.

Of greater importance were significant differences in the density of some families between July 1997 during the drought and in June 1998, under high flows. Several families normally associated with conditions of nutrient enrichment (Glossiphoniidae, Erpobdellidae, Asellidae) which occurred at high densities in July 1997 were present at significantly lower densities in June 1998.In contrast, populations of Baetidae, which had been at low population densities during the drought showed significant increases. These are encouraging signs, but further analyses are required to determine the extent of the recovery from this prolonged drought.

1. INTRODUCTION

1.1 Background

In 1997, the Environment Agency, Thames Region, commissioned the Institute of Freshwater Ecology to undertake studies on the macrophytes and macroinvertebrate assemblages at four sites on the Rivers Kennet and Lambourn. These included two sites on the River Kennet (Savernake upper and lower) downstream of Marlborough, a further location on the same river upstream of Hungerford (Littlecote) and a fourth site on the River Lambourn (Bagnor – shaded site). Each one of these sites had been the focus of detailed studies by a team of freshwater ecologists in the 1970s, and valuable historical data were available for each location. The low flows of 1996 and the worsening drought conditions through the spring of 1997 provided the impetus for a re-examination of these sites.

Macrophyte mapping followed by quantitative sampling of the macroinvertebrates on major habitat types was undertaken in each of June/July 1997 and December 1997, using the 1970s protocols in order to ensure compatibility of the data. The results, including a photographic record comparing all sites in the 1970s and 1997, together with an appraisal of changes in the macrophytes and macroinvertebrate assemblages over this period was included in a comprehensive report to the Environment Agency (Wright *et al.* 1999a).

There was always an intention that this study would be continued beyond the 1996-97 drought, and Environment Agency staff accompanied IFE staff during the field work of 1997 in order to gain familiarity with the techniques. When the drought ended in winter 1997/98 and spring of 1998 was notable for high rainfall, it was apparent that a resampling programme had great potential to provide valuable information on the rate at which both the macrophytes and the macroinvertebrates were capable of responding to the end of a prolonged drought. The winter of 1997/98 also marked the beginning of a programme of phosphate stripping at Marlborough sewage treatment works.

As the optimum time for sampling in June 1998 approached, it became clear that the Environment Agency would be unable to devote manpower to the mapping and sampling programme at the four sites. In view of the potential loss of valuable data, the IFE team stepped in to repeat the mapping and sampling programme for June, on the understanding that the Environment Agency also had an interest in the results and would attempt to find financial resources to support the collection and processing of the samples for summer 1998. Financial help was secured, and this report gives information on the mapping and macroinvertebrate sampling programme on the four sites, a brief appraisal of the response to the end of the drought and recommendations for further work.

1.2 Objectives

The overall objective is:

> *'to improve the Environments Agency's knowledge of chalk stream ecology in order to increase our ability to manage chalk streams in a sustainable manner'*

The contract specification also lists eleven specific objectives:

1. To liaise with land agents at Bagnor, Littlecote and Savernake and get agreement to map and sample in June 1998.

2. To map each of Bagnor, Savernake (lower) and Savernake (upper) as in 1997, to determine change in the percentage cover of macrophytes and other habitats. At Littlecote, to prepare a sketch map from which an *estimate* of percentage cover may be obtained (full mapping too time-consuming).

3. To undertake quantitative sampling of the macroinvertebrates fauna at the 4 sites as follows:

    Bagnor – 30 sampling units
    Littlecote – 10 sampling units
    Savernake (lower) – 10 sampling units
    Savernake (upper) – 10 sampling units

    This is the same sampling effort as used in summer 1997.

4. To take photographs of the sites to document their status and for comparison with summer 1997.

5. To process the 60 quantitative sampling units at family level, as in 1997.

6. To input the June 1998 macroinvertebrate data from the 4 sites into an Access97 computer database and to verify it.

7. To populate the plant database with the mapping data for June 1998 in order to create maps and cover data for Bagnor, Savernake (lower) and Savernake (upper).

8. To analyse the macrophyte and macroinvertebrate data in relation to the data for summer 1997.

9. To compile the raw data collected in this survey and collate it for future reference by the Agency.

10. To produce a progress report on the work undertaken, together with information on the structure of the results database and a summary of any conclusions and recommendations.

11. To produce a scientific paper analysing the results of one or more aspects of this series of surveys.

2. FLOW REGIME

2.1 R. Lambourn at Shaw

Information on the discharge regime of the River Lambourn has been supplied by the Thames Region of the Environment Agency. The nearest gauging station to the Bagnor study site was at Shaw, approximately 2 km downstream. It is important to recognise that whereas the river occupies a single channel at Shaw, it is divided into two channels at Bagnor. In the 1970s, two study sites were chosen on the northern channel at Bagnor because it was of wadeable depth and was more typical of the river as a whole, whereas much of the southern channel was deep and slow-flowing. Hence, when examining the discharge regime at Shaw it should be borne in mind that the discharge through the shaded site at Bagnor is substantially lower than at Shaw, but the seasonal regime in any given year will mimic the picture obtained at Shaw.

The discharge regime on the River Lambourn at Shaw from January 1990 to December 1998 is presented in Figure 2.1. This period included a two-year drought in 1991 and 1992, followed by a period of three years (1993-95) when the characteristic discharge regime resumed with high peak flows early in the year. Then followed a further two-year period of drought (1996-1997) in which there were no high flows in the winter of 1996/97. High rainfall through the winter of 1997/98 brought an end to the drought, but peak flows remained below those experienced between 1993 and 1995. However, the wet spring resulted in a mean discharge in May 1998 (immediately prior to sampling) which approached the monthly mean values recorded in each of 1993-96 and was over twice the discharge recorded in May 1997. Thus, in the 1990s, the river experienced two separate episodes of low discharge over a protracted period, something not seen in the 1970s despite the historic drought of 1976 (See Fig. 2.1 in Wright *et al.* 1999a).

2.2 R. Kennet at Knighton

The Environment Agency also supplied monthly mean flows for the River Kennet at Knighton, which is located approximately 8 km downstream of the Savernake study section and 2 km upstream of Littlecote. Again, the monthly mean discharge from January 1971 to December 1979 is available in a previous report (See Fig 2.3 in Wright *et al.* 1999a).

Figure 2.2 presents the discharge regime at Knighton between January 1990 and December 1998. The protracted drought of 1991-92 and the progressively more severe drought of 1996-97 are apparent, separated by those years (1993-5) in which the characteristic discharge regime prevailed. As previously noted on the R.Lambourn at Shaw, winter rains in 1997/98 marked the end of the drought but peak discharge fell short of that recorded in the mid-1990s. However, in spring 1998, the rainfall was sufficient to result in a monthly mean discharge in May 1998 that exceeded the values recorded in the same month in all earlier years shown in Fig. 2.2. In particular, the mean discharge in May 1998 was almost four times the mean discharge recorded in May 1997.

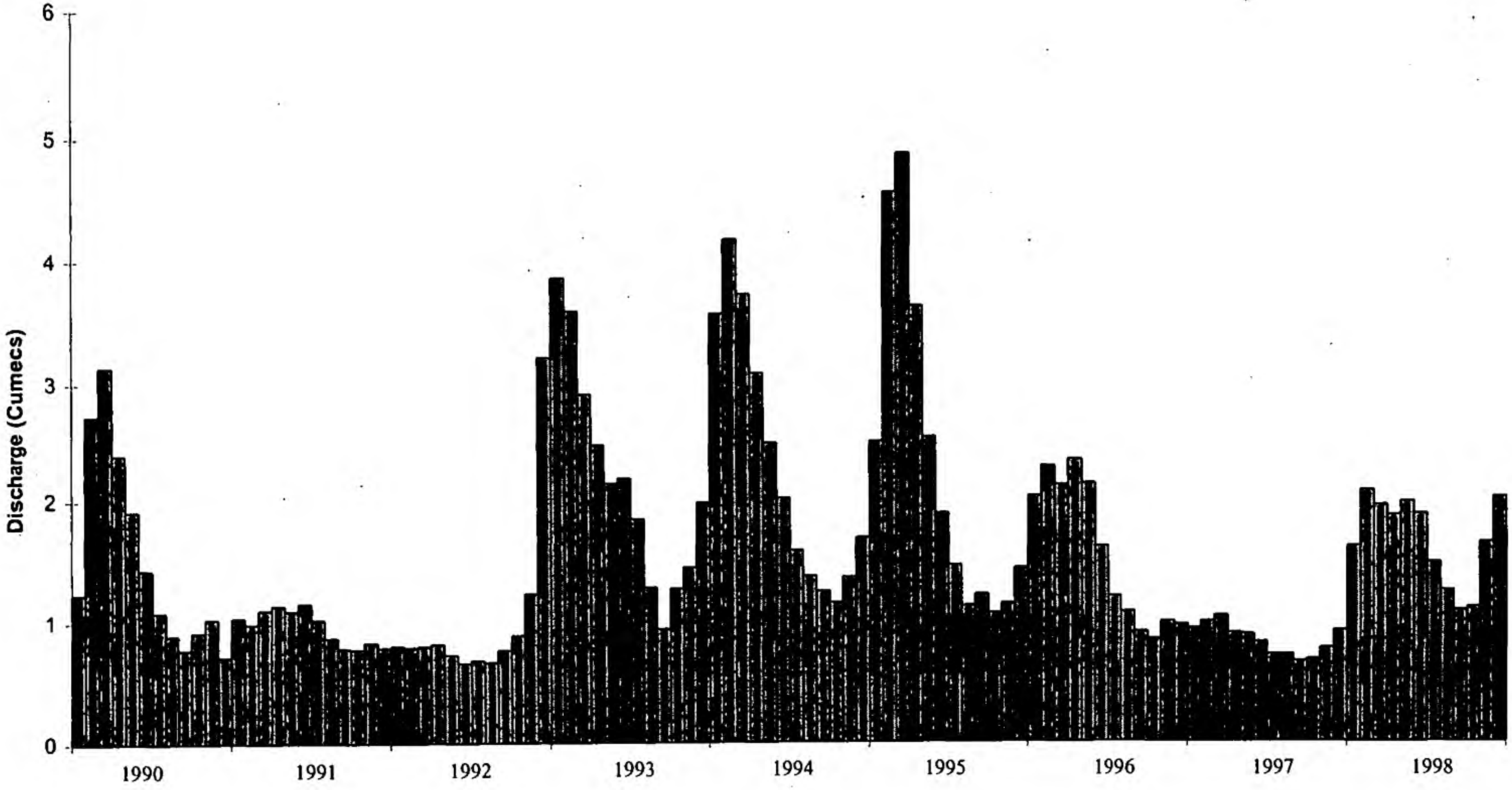

Figure 2.1. Monthly mean discharge on the R.Lambourn at Shaw, January 1990 - December 1998

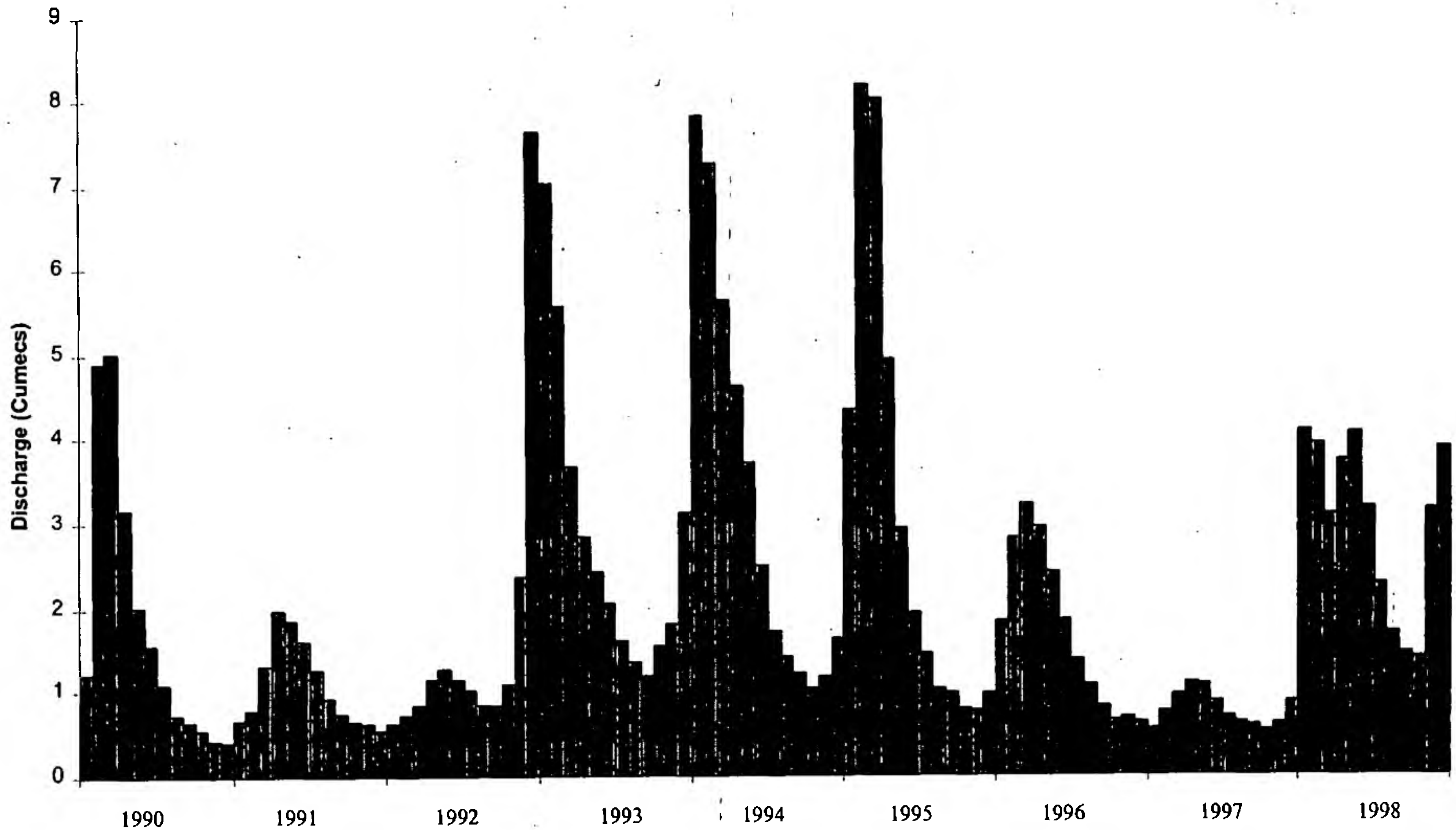

Figure 2.2. Monthly mean discharge on the R.Kennet at Knighton, January 1990 - December 1998

3. THE STUDY SITES

A comprehensive photographic record of the four study sites during the 1970s and in 1997 was given in Wright *et al.* (1999a). The purpose of this section is to provide brief comments on additional photographs taken at each site in June 1998.

3.1 The R. Lambourn at Bagnor (shaded site), June 1998

Figure 3.1a is a view looking upstream taken in June 1998. The cover of submerged macrophytes is now even lower than in June 1997 (see Fig.3.1e in Wright *et al.* 1999a) when *Callitriche* was the dominant macrophyte. Trees and bushes still overhang the river on the left-hand side of the photograph but the growth of emergent marginal vegetation on the right hand side is slightly less invasive than in June 1997 when discharge was very low. The precise location and extent of each submerged and emergent macrophyte is documented on the map prepared before each sampling occasion.

Fig.3.1b shows one of the larger beds of *Berula* within the 50m study site. From the maps it is apparent that all beds present in June 1997 survived, but there has only been a small increase in the total area of *Berula* over the past 12 months.

Fig. 3.1c is a view of a series of small beds of *Ranunculus* within the study site. In view of the higher discharge down the R.Lambourn in June 1998 compared with June 1997, the poor growth response of the *Ranunculus* was unexpected, particularly in view of the fact that it was growing on clean gravel and unhindered by the presence of large beds of *Berula*.

Fig. 3.1d is a photograph of one of a number of specimens of the signal crayfish (*Pacifasticus leniusculus*) observed at the site during the sampling operation. The native crayfish (*Austropotamobius pallipes*) which was common in the 1970s has not been observed on the site in 1997/98. Most specimens of *P. leniusculus* were seen within beds of *Berula*.

3.2 R. Kennet at Littlecote, June 1998

Fig. 3.2a is a general view of the site in June 1998 from the upstream limit looking downstream. This picture is in striking contrast to the condition of the river in June 1997 (see Fig. 3.2g in Wright *et al.* 1999a). At that time there was no surface-flowering *Ranunculus* and the water level was so low that emergent vegetation covered most of a shallow gravel area on the right hand side of the picture. By June 1998, the emergent vegetation was gone, and the deeper left-hand side of the channel had surface-flowering *Ranunculus*.

Fig.3.2b was taken from the middle of this 100 m site looking downstream. It is apparent that the *Ranunculus* has been growing well and that it has already been subjected to bar-cutting.

3.3 R. Kennet at Savernake (lower and upper sites), June 1998

Savernake Lower

Fig.3.3a provides a general view of the site in June 1998, looking upstream. (It may be compared with Fig.3.3e in Wright *et al.* 1999a). During the winter of 1997/98, Mr John Hownslow, the River Keeper, undertook some remedial work on the far bank (see right hand side of Fig. 3.3a) with the objective of narrowing the channel and therefore increasing the current speed in order to encourage the movement of silt and the growth of *Ranunculus*.

During the winter there were two notable events which affected the river at Savernake. They were the end of the drought and the start of phosphate stripping at Marlborough sewage treatment works. Whereas in June 1997 the dominant submerged macrophyte was *Schoenoplectus lacustris* (17.4%) and *Ranunculus* (0.9%) was scarce, by June 1998 *Ranunculus* was dominant and the water level was considerably higher, as a result of the higher discharge and weed growth.

Fig. 3.3b shows a close-up of surface *Ranunculus* on the site in June 1998. A few aerial stems of *Schoenoplectus* are also visible in midriver.

Savernake Upper

Fig.3.3c is a view of the upper 50 m site at Savernake in June 1998 looking downstream. Surface-flowering *Ranunculus* is also present at this site, and it is clear that water depth is much greater than in July 1997. (See Fig. 3.3j in Wright *et al.* (1999a) showing small beds of *Ranunculus* in shallow water in July 1997).

Fig.3.3d was taken a little further upstream in June 1998 and shows more surface-flowering *Ranunculus*. This shot was taken from the same location as Fig.3.3i in Wright *et al.* (1999a) and confirms that the water level was much higher in June 1998. (The flow deflectors which were clearly visible in 1997 are hardlly detectable in this photograph.)

Figure 3.1 a) R. Lambourn at Bagnor (shaded site). June 1998. View upstream

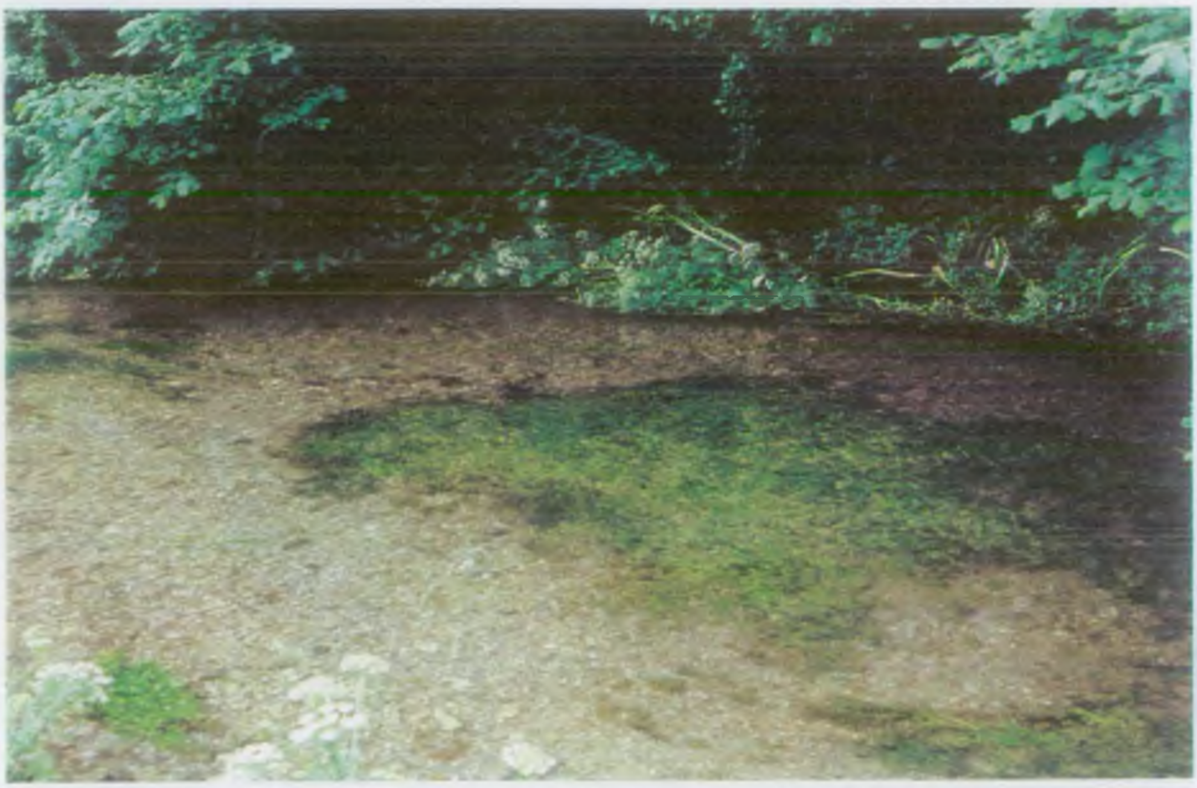

Figure 3.1 b) R. Lambourn at Bagnor (shaded site). June 1998. Carpet of *Berula*

Figure 3.1 c) R. Lambourn at Bagnor (shaded site). June 1998. *Ranunculus* beds

Figure 3.1 d) R. Lambourn at Bagnor (shaded site). June 1998. The signal crayfish (*Pacifasticus leniusculus*)

Figure 3.2 a) R. Kennet at Littlecote. June 1998. View downstream from the top of the 100 m site

Figure 3.2 b) R. Kennet at Littlecote. June 1998. View downstream from the middle of the 100 m site.

Figure 3.3 a) R. Kennet at Savernake (lower). June 1998. View upstream

Figure 3.3 b) R. Kennet at Savernake (lower). June 1998. *Ranunculus* beds

Figure 3.3 c) R. Kennet at Savernake (upper). June 1998. View downstream

Figure 3.3 d) R. Kennet at Savernake (upper). June 1998. View downstream

4. METHODS

Note: The methods section, as given in Wright *et al.* (1999a), is repeated here with only minor amendment to help readers who are unfamiliar with the procedures used in this study.

4.1 Macrophyte mapping

4.1.1 Field procedures

A detailed account of the field procedures involved in the 'rectangles' method of mapping was given in Wright *et al.* (1981), but a synopsis of the approach is repeated here.

Prior to mapping for the first time, it is essential to establish a straight baseline on one bank and hammer in a series of permanent stakes at 5 m intervals. This is best achieved with a transit compass, ranging poles and a measuring tape. Additional stakes are also required at 5 m intervals on the opposite bank at known distances from the baseline.

When mapping, a temporary grid of mapping strings is set out in order to create a 1 x 1 metre grid over the water surface. First, a 5 m tape, with numbered tags at 1 m intervals is placed between the 0 and 5 m stakes on the baseline, with a similar tape on the opposite bank. Next, a series of longer tapes (often six) which are similarly marked with numbered tags at one metre intervals are positioned across the river at one metre intervals upstream, thus linking successive metre locations on the baseline with the corresponding location on the opposite bank.

The mapping operation may be undertaken by two people, but was normally carried out by a team of three individuals. One person (the caller) stands in the river in order to describe the river-bed whilst a second (the recorder) stands on the baseline bank and marks the prepared mapping sheet with information provided by the caller. A third person normally helps with repositioning the cross-river tapes when they are moved upstream.

Prior to mapping, it is essential to define the features to be distinguished. For example, decisions are required on whether macrophytes can be identified to species at all times or whether species with similar morphology are to be recorded as a single taxon. The range of substrata to be recorded must also be defined. From visual inspection, all particles greater than 2 mm were designated as gravel whilst those of 2 mm or less were termed silt. In practice, this last category included both sand and silt. The term silt was also retained in cases where decaying organic matter such as tree leaves was present at a given location. Note that all categories were as determined visually, irrespective of the composition of the substratum under the visible surface.

At the start of mapping, the caller enters the river downstream of the cross-river tape connecting 0 m on the baseline with 0 m on the opposite bank. The position of the nearside bank is determined to the nearest 0.5 m and relayed to the recorder on the bank who then marks the position of the bank on a blank map consisting of 50 x 100 cm rectangles representing the full 50 m length of river to be mapped. The caller then views the 1 m strip of river between cross-river tapes at 0 and 1 m upstream. The tapes with their numbered tags form a 1 m grid across the river, and each square of the river-bed below can be divided longitudinally, by eye, into two 1 x 0.5 m rectangles. A metal-tipped pole used by the caller was found to be particularly useful in delimiting the metre square, by holding it vertically at the corners of the square prior to assessing each rectangle. The dominant substratum or macrophyte is then determined for each rectangle, but where a macrophyte and a non-macrophyte each occupy 50%, the macrophyte is given dominance. The substratum underlying the macrophyte is also determined.

For this project the Environment Agency confirmed that only the dominant macrophyte was to be recorded, as this is the only information used in calculating the percentage cover of the habitats on each site. (In the 1970s, additional habitats within the rectangle were also recorded, although in practice this information was not used in later analyses. Collection of this additional information would have increased the time for field mapping).

Information on each rectangle is passed to the recorder until the location of the opposite bank is given. The caller then moves one metre upstream and continues the mapping process towards the baseline for the strip of river between the tapes positioned 1 to 2 m upstream. This process continues until the entire grid provided by the first positioning of the cross-river tapes has been completed. The tapes are then repositioned upstream for further mapping and this process is continued until the entire site has been mapped.

This account describes the mapping procedure on the River Lambourn at Bagnor, where the river is narrower than to the River Kennet. However, the submerged and marginal emergent vegetation at Bagnor include a wide range of species, which increase mapping times. Similarly, the presence of overhanging branches and thick bushes and trees on the far bank makes the positioning of mapping strings more difficult. Once tapes have been repositioned prior to mapping, checks are made that all the 1 m tags on the mapping strings are aligned in order to avoid mapping inaccuracies.

Since the Kennet sites are wider than the River Lamboum, the need to check that tapes are in alignment is even more critical on the River Kennet. At Littlecote, where the site is a full 100 m in length, the baseline itself changed direction at 50 m in order to accommodate a change in alignment of the river. At this site, the baseline established on the mown bank in 1974 was relocated in 1997. However, for ease of mapping on this very wide site, additional stakes were located at the bottom of the bank, just above the water's edge and at known distances from the true baseline. On the River Kennet at Savernake, new stakes were required. They were positioned on the mown baseline bank and left proud, as requested by Mr Hounslow where they were in full view and could be avoided during mowing operations.

On all three Kennet sites (100 m site at Littlecote, two 50 m sites at Savernake) the greater river width coupled with the fact that the habitats on the river-bed were less complex allowed the mapping grid to be increased to 100 x 100 cm squares, as used in the 1970s. Only at the bank did the mapping regime revert to 50 x 100 cm rectangles where necessary, in order to document with greater accuracy the habitats at the waters edge.

4.1.2 Laboratory procedures

Within the laboratory, EXCEL spreadsheets were prepared to represent each of the four mapped sites. The baseline was numbered 0-50 m (0-100 m for Littlecote), whilst rectangles at right-angles to the baseline were numbered 0-0.5, 0.5-1, 1-1.5 m and so on, allowing sufficient space to include the full distance from the baseline to the river, the width of the river itself and the far bank for the full length of the site. Each spreadsheet was then populated with mapping information on the dominant habitat type for each 100 x 50 cm rectangle. In the case of the Kennet sites, where 100 x 100 cm squares had been designated within the river, pairs of rectangles were substituted on the map, although single 100 x 50 cm rectangles were recorded at the river margins where these had been mapped at the site.

An automated procedure was then employed for counting the rectangles of each habitat type, from which the total area (m^{-2}) and the percentage cover of each habitat was derived. The percentage cover data are presented in Chapter 5 of this report.

Please note: The June 1998 computer maps are being supplied to the Environment Agency as EXCEL computer files and hence are not included within this report.

4.2 Sampling for macroinvertebrates

4.2.1 Field procedures

The Lambourn sampler (Hiley *et al.* 1981) was used to obtain samples of macroinvertebrates on each of the four study sites, as in the 1970s. The dimensions of the sampler were 20 x 25 cm, resulting in a sampling unit of 0.05 m^2. For each habitat, five sampling units were taken in each season.

In general, the choice of habitats to be sampled on each site was made with a view to maximising the comparisons which could be made with samples taken in the 1970s. There was one exception to this general rule on the River Lambourn at Bagnor. The recent lack of management related to fisheries interests has resulted in the development of both low growing and tall marginal emergent species, at a time when submerged macrophytes were poorly represented. Although no comparisons would be possible with the 1970s, the area of this variable but potentially important habitat warranted further investigation.

Quantitative sampling for macroinvertebrates on the major habitats took place after the mapping operation and was dependent on the availability of the map. In order to select potential locations for the five sampling units on each habitat, a series of four digit random numbers were used. The first two numbers represented distance along the baseline (0-50 or 0-100 m in the case of Littlecote) and the second two digits represented distance at right angles from the baseline. Thus, most of the four digit numbers represented locations within the mapped site and in this way sampling locations were chosen for each habitat type.

It was normal to obtain not just five sampling locations for each habitat type (representing the five sampling units required) but to have two reserve locations in case any of the original five proved to be inappropriate when sampling was underway. Ideally, mapping and sampling took place on separate days, with selection of the locations for sampling carried out in the laboratory. However, in cases where it was essential to undertake sampling on the same day after mapping, it was feasible to draw on a store of four digit random numbers and undertake the selection of sampling locations in the field.

The field procedure for taking macroinvertebrate samples was as follows. All sampling was carried out from the downstream limit of the site working upstream. Mapping tapes were positioned as required to locate the first sample on the river-bed and the Lambourn sampler was then lowered over the chosen location and forced into the substratum to a depth of 6 cm using both hand and foot pressure. The removal of all plant material and substratum to a depth of approximately 6 cm was carried out by hand, with further help from a small trowel for cutting through weed and removing substratum into the collecting net at the downstream limit of the sampler. Where gravel and macrophyte samples included sizeable stones, these were carefully examined and stone-cased caddis and molluscs were removed and placed in the collecting net before the stones were discarded. This variation to the original protocol was found to be appropriate in view of the fact that densities of Glossosomatidae (ie Agapetus spp.) were much lower in June than in December. The large collecting net was then removed from the frame of the sampler and by carefully dipping the net and its contents into the current, the contents were concentrated into the bottom of the net.

Once on the bank, the sample was transferred into a labelled polythene one litre container. On occasions, large samples required two or even three containers. A small quantity of water plus 40% formaldehyde was added to each container in order to fix and preserve the macroinvertebrate fauna. The final solution was approximately 5% formalin. The need to move the mapping tapes periodically in order to collect samples from the river-bed and then transfer the net contents to labelled polythene bags meant that the ideal team for sampling was three or more team members.

4.2.2 Laboratory procedures

The opportunity to fix and preserve the samples in the field removed the need for immediate treatment of each sample on return to the laboratory. It also decreased the level of damage to specimens as a result of repeated handling.

The sorting and identification procedure for each sampling unit was as follows. The sample was placed in the upper of a pair of 45 and 12 mesh sieves and the formalin removed by thorough washing. At this stage, any macrophytes in the upper sieve were thoroughly searched for attached macroinvertebrates before being discarded. Similarly, large stones were checked for caddis and molluscs before being removed. The coarse and fine mesh fractions were then processed separately.

First, the coarse fraction was put into a series of trays and, on the basis of the amount of material and abundance of the macroinvertebrate fauna, a decision was reached on the proportion of the coarse fraction to be sorted and identified. This varied from the entire coarse fraction to a half or sometimes a quarter of the fraction. All specimens in the designated fraction were removed and identified to family level. The results were entered on a standard data sheet and a multiplication factor applied to estimate the total number of each family in the fraction.

The fine fraction was subjected to a similar procedure, except that the proportion sorted and identified normally varied from one half to one eighth of the total. Again, the number of individuals in each family were determined and entered on the same data sheet before an appropriate multiplication factor was applied. The totals from the coarse and fine fractions were then added to obtain the estimated number of macroinvertebrates in each family within the sampling unit. All sheets were independently checked for accuracy.

On completion of all samples from the 1998 sampling programme, the data from the five sampling units on each habitat, site and month were entered into a Microsoft Access database and verified. A query program was then developed in Access for calculating the mean density of each family from a set of five sampling units on a given habitat type.

The macroinvertebrate data for the shaded site on the River Lambourn in the 1970s had already been transferred to an Access Database in a separate IFE project. However, all the 1974 and 1975 data for the River Kennet at Littlecote and Savernake was also entered in order to be able to undertake selected comparisons with the results from the 1998 sampling programme.

One major group of macroinvertebrates, the Oligochaeta, was treated differently in the 1970s and 1997/98 research programmes. In the 1970s, no attempt was made to count the total number of oligochaetes per sampling unit. During the first twelve months of the study at Bagnor (March 1971 – February 1972), the view was taken that because some oligochaetes undergo fission and others are damaged during the processing of samples, the oligochaetes would be picked out and then weighed as a group. The one exception to this was the Lumbricidae which, being large, were counted individually and kept separate from all other Oligochaeta. In later years at both the River Lambourn and the River Kennet sites, the Lumbricidae were still counted individually, but no numerical information was available on other oligochaetes.

In 1997/98, the decision was taken to count the Lumbricidae as before, but also to count all other Oligochaeta and input both categories to the database, in order to have more comprehensive information for future reference. However comparison of densities observed in 1997/98 and the 1970s were limited to the Lumbricidae and when comparisons were made of macroinvertebrate 'family' richness between years, the Oligochaeta and Lumbricidae counted as one 'family' and all 1970s samples were assumed to include Oligochaeta.

Mann-Whitney U-tests were used on the density counts from the five sampling units from a given habitat to compare years (i.e. June 1998 and June 1997). Note that the Mann-Whitney U-test is a non-parametric ranking procedure and that it tests for differences between the median rather than the mean values. However, as Elliott (1977) points out, if the medians are significantly different, then so are the means, but this assumption is not part of the test. The tests were undertaken in Minitab. In cases where a family was absent from each of the five sampling units in a given year but present in some units of the other year, it was calculated that when the family was present in four units the level of significance was <0.05% and when present in all five sampling units, the level of significance was <0.01%.

5. RESULTS OF MACROPHYTE MAPPING

5.1 R. Lambourn at Bagnor (shaded site)

The results obtained by mapping the site in June 1998 have been inserted into Table 5.1 which also gives the equivalent information for June and December 1997, together with the maximum, minimum and mean percentage cover of the major habitat types for the site over the period January 1971 to December 1979. In addition, the table includes information on the total wetted area of the study site, expressed in square metres (m^2). As expected, the total area of the site in June 1998 exceeded the area recorded in both June and December 1997. However, the percentage cover of most habitat types in June 1998 remained similar to the values recorded in December 1997 and overall, conditions remained very different from the typical condition observed during the 1970s (See Fig. 5.1 in Wright *et al.* 1999a).

Table 5.1 R. Lambourn at Bagnor (shaded site). Total area of the 50 m site and the % cover of the major habitat types in June & December 1997 plus June 1998 (latter in bold). Historical data for January 1971 - December 1979 is presented as maximum, minimum and mean values.

Date(s)	Total Area m^{-2}	Percentage Cover Berula	Call	Gravel	Ran	Silt	Other
June 1997	387	5.8	24.9	29.3	6.2	17.6	16.2
Dec 1997	372	9.3	1.6	44.2	2.6	31.2	11.1
June 1998	**439**	**9.6**	**2.3**	**51.7**	**1.9**	**26.8**	**7.8**
71-79: Max	454	65.9	48.1	79.0	44.2	48.8	16.5
71-79: Min	336	0.5	0.0	5.7	0.1	2.8	0.0
71-79: Mean	409	38.3	10.3	26.3	13.7	9.7	1.5

Berula, the dominant macrophyte at the shaded site for most of the 1970s when the mean percentage cover was 38.3% (Table 5.1) still occupied less than 10% of the site in June 1998. This was unexpected, because on a single occasion in late 1978/early1979, when the percentage cover of *Berula* decreased to a very low level, recovery through recolonisation proceeded rapidly through the next few months. In the late 1990s, the most striking changes at the site (compared with the 1970s) with potential to affect the regrowth of *Berula* were greater shading by tree cover on one bank, the presence of more emergent vegetation on the other, lack of instream vegetation management for trout fishing and displacement of native crayfish by signal crayfish.

Callitriche occupied just 2.3% of the site in June 1998, which contrasts with the 24.9% in June 1997 when discharge was much lower. It was also lower than the long term mean (10.3%) from the 1970s.

Ranunculus, the third submerged macrophyte which was characteristic of this site in the 1970s also failed to thrive in June 1998. It occupied only 1.9% of the study site despite the favourable flow regime and dearth of other submerged species. As with *Berula*, this poor response by *Ranunculus* to the increase in discharge was unexpected.

The 'other' macrophyte category, that is the emergent macrophytes, showed a decrease in area from June 1997 (16.2%) to June 1998 (7.8%). This was expected and mainly reflected the inability of some low growing forms such as *Nasturtium* and *Veronica* to invade the waters edge under higher flow conditions. In June 1998 *Mentha* was the dominant emergent macrophyte.

The inevitable consequence of the poor growth of submerged and emergent macrophytes was that gravel and silt were the dominant habitat types in June 1998.The area of bare gravel increased progressively from June 1997 to June 1998 and by this time it covered approximately twice the mean area occupied during the 1970s.

The area of silt, which had increased between June and December 1997, remained high at 26.8% cover in June 1998, indicating that the accumulation of silt during the two-year drought would take some time to move downstream, particularly as the peak flows of winter 1997/98 had been modest.

5.2 R. Kennet at Littlecote

Mapping of the 100 m site at Littlecote is a full days work for a team of three. In view of the fact that, under high discharge conditions, the river bed is largely *Ranunculus* and gravel, it was apparent that a good approximation of percentage cover could be obtained by making a sketch map on the date of sampling, thereby saving valuable time. Hence, in Table 5.2 the estimated information on the area of the river and percentage cover of the major habitat types in June 1998 is given in bold but within brackets.

Table 5.2 R. Kennet at Littlecote. Total area of the 100m site and the % cover of the major habitat types in July and December 1997. Estimated values for June 1998 are given within brackets in bold. Historical data for April 1974 - June 1976 is presented as maximum, minimum and mean values.

Date(s)	Total Area m^{-2}	Percentage Cover Gravel	Ran	Silt	Others
July 1997	1244.5	35.9	44.2	3.1	16.8
Dec 1997	1310	30.5	38.9	0.9	29.7
June 1998	**(1245.5)**	**(27.7)**	**(71.5)**	**(0.0)**	**(0.7)**
74-76: Max	1395	71.7	84.0	11.6	3.4
74-76: Min	926	12.2	16.2	0.3	0.0
74-76: Mean	1225	38.8	57.2	2.4	1.6

The total area of the site was estimated at just under 1250 m^2 in June 1998. It was apparent that the winter increase in discharge had removed the emergent marginal vegetation which had previously increased in area between June and December 1997. Instead, the spring 1998 discharge regime favoured early growth of *Ranunculus* and at the time of sampling in early June the first bar-cutting had already been carried out. *Ranunculus* occupied an estimated 71.5% of the site and gravel was present on a further 27.7% of the 100 m site. The remaining 0.7% consisted of small beds of submerged *Berula* and *Veronica anagallis-aquatica*. Silt, which had failed to accumulate during the drought in 1997 due to the free-flowing nature of the site was apparently absent in June 1998.

5.3 R. Kennet at Savernake (lower and upper sites)

5.3.1 Savernake (Lower site)

The results obtained by mapping this site in June 1998 are given in bold in Table 5.3 and can be seen alongside the equivalent information for June and December 1997. The summarised data for the period from April 1974 to April 1976 has also been included to provide a broader context.

The total area of the site increased from the values noted in July and December 1997 due to the higher discharge regime. However, it remained below the mid-1970s mean, at least in part as a consequence of the bank maintenance undertaken during the winter of 1997/98. Here, the objective was to decrease the total width of the site for any given discharge in order to increase current speed, thereby favouring the removal of silt and encouraging the regrowth of *Ranunculus*.

The major changes in submerged macrophytes at this site between the mid-1970s and 1997 (Table 5.3) were described in the previous report (Wright *et al.* 1999a). *Schoenoplectus* which had occupied around 60% of the site in the mid-1970s remained the dominant macrophyte in 1997, but was recorded in less than a third of the area it occupied in the mid-1970s. *Ranunculus*, which was subdominant in the mid-1970s was still present in 1997, but occupied less than 1% of the study site.

Table 5.3 R. Kennet at Savernake (Lower). Total area of the 50 m site and the % cover of the major habitat types in July & December 1997 plus June 1998 (latter in bold). Historical data for April 1974 - April 1976 is presented as maximum, minimum and mean values.

Date(s)	Total Area	Percentage Cover				
	m^{-2}	Gravel	Ran	Schoen	Silt	Other
July 1997	569.5	61.2	0.9	17.4	18.2	2.5
Dec 1997	536.0	53.6	0.2	11.8	14.1	20.3
June 1998	**617.5**	**26.8**	**43.6**	**7.3**	**5.6**	**16.7**
74-76: Max	686.0	38.6	19.3	66.5	23.5	3.2
74-76: Min	553.0	14.5	0.0	55.0	1.0	0.0
74-76: Mean	661.3	25.9	4.3	60.0	8.6	1.2

The end of the drought, the exceptionally high discharge recorded in the month (May) prior to mapping and the start of phosphate stripping at Marlborough sewage treatment works may all have contributed to the remarkable resurgence of *Ranunculus*. Despite the small biomass of macrophyte observed in July and December 1997, the root systems of *Ranunculus* must have remained in place over much of this site, thus allowing this plant to exploit the return of favourable conditions.

Schoenoplectus continued to decrease in area, compared to 1997, but this is may be a result of the early summer growth of *Ranunculus*. Later in the year, if *Ranunculus* is cut or dies back, it is possible that beds of *Schoenoplectus* would become more apparent.The explosive growth of *Ranunculus* inevitably led to a decrease in the area of gravel, which is now back to the long-term mid-1970s mean, although the area is inevitably responsive to weed cutting or the dieback of weed. Of greater interest is the loss of silt, which decreased from 18.2% in July 1997 to just 5.6% in June 1998, a figure below the mid-1970s mean.

The area of 'other' macrophytes remained high at 16.7% and this comprised 8.4% *Callitriche*, supplemented by marginal emergents of which *Veronica anagallis-aquatica* and *Mentha aquatica* were dominant.

5.3.2 Savernake (Upper site)

Table 5.4 presents information on the total area and percentage cover of the major habitats on the upper site at Savernake in June 1998, together with the equivalent information for July and December 1997, and the summary data for 1974-76.

In June 1998, the total area was noticeably greater than in 1997 as a result of the end of the drought. However, it remained substantially lower than in the mid-1970s, predominantly due to the planting of marginal emergents and the cutting of marginal willows to narrow the effective river width (See Wright *et al.* 1999a). Note that the river-bed beneath the cut willows was not included in the calculation of total mapped area because it was not possible to obtain macroinvertebrate samples from this area, despite the fact that it was under water.

Table 5.4 R. Kennet at Savernake (Upper). Total area of the 50 m site and the % cover of the major habitat types in July and December 1997 plus June 1998 (latter in bold). Historical data for April 1974 - April 1976 is presented as maximum, minimum and mean values.

Date(s)	Total Area	Percentage Cover				
	m^{-2}	Gravel	Ran	Schoen	Silt	Other
July 1997	551.0	64.5	6.5	2.7	22.0	4.4
Dec 1997	541.5	52.5	8.1	2.2	19.2	17.9
June 1998	**604.5**	**36.2**	**48.8**	**1.7**	**4.1**	**9.2**
74-76: Max	806.0	70.9	45.2	28.5	28.3	9.1
74-76: Min	597.0	23.4	0.0	12.5	1.4	0.0
74-76: Mean	766.0	49.5	19.1	21.8	7.0	2.5

The increase in the area of *Ranunculus* at the upper site was even more spectacular than on the lower site and the 48.8% cover recorded in June 1998 was not only much higher than in 1997, it was also higher than any value recorded during the mid-1970s. Note also that in July 1997, the *Ranunculus* comprised small beds in shallow water which was easily cropped by waterfowl, but in June 1998 the substantial biomass of weed within the water column impeded water flow and was partly responsible for increasing the water depth.

Schoenoplectus was still present, but its area had diminished marginally from 1997, probably due to overgrowth by *Ranunculus*. In June 1998 'other' macrophytes included 5.6% *Callitriche* and a range of minor marginal taxa.

The area of gravel was lower than that observed during 1997 due to the spectacular growth of *Ranunculus* and in fact, the area of gravel and was less than the mid-1970s mean value. The increased winter and spring discharge removed large quantities of silt previously deposited during the drought of 1996/97 and the June 1998 cover of just 4.1% was also lower than the mid-1970s mean.

6. RESULTS OF MACROINVERTEBRATE SAMPLING

Please note: Information on the abundance of each macroinvertebrate family in each of the five sampling units for each habitat and study site is held in an Access Database being made available to the Environment Agency. In consequence, the raw data will not be presented within this report.

6.1 R. Lambourn at Bagnor (shaded site)

6.1.1 Family richness

The number of families of macroinvertebrates recorded on each habitat type (i.e. total number of families from 5 sampling units) in June 1998 is shown in Table 6.1 in bold. This table also gives the equivalent information for June 1997 and the maximum, minimum and mean number of families recorded per habitat during the detailed studies undertaken in the 1970s. (**Note**: the 1970s data-set is restricted to seven years data comprising 1971 plus 1974-79 when the laboratory processing technique was the same as that used in 1997 and 1998. In 1972 and 1973, it was necessary to pool and then sub-sample the five sampling units from a given habitat). No macroinvertebrate samples were taken from emergent macrophytes during the 1970s because they rarely occupied a significant area of the river-bed. However, in 1997 and 1998 they did warrant additional sampling to determine their characteristic fauna.

Table 6.1 **R. Lambourn at Bagnor (shaded site) in June 1997 & June 1998 (latter in bold). Number of families of macroinvertebrates recorded on each habitat (total from 5 sampling units). Maximum, minimum and mean values derived from 7 years (1971+1974 to 1979) are also given.**

Date(s)	Ber	Call	Grav	Ran	Silt	Emerg.
June 1997	30	32	25	31	24	33
June 1998	**37**	**32**	**24**	**26**	**27**	**34**
1970s: Max	41	39	36	41	33	No data
1970s: Min	22	30	27	29	23	No data
1970s: Mean	33.1	33.0	31.9	33.9	28.2	No data

With the single exception of *Berula*, the number of families recorded on each habitat was lower in June 1998 than the mean value from seven years of sampling in the 1970s. *Berula* held 37 families in June 1998, compared to 30 in June 1997 and a 1970s mean of 33.1. Although this macrophyte only occupied 9.6% of the riverbed in June 1998, it remained the dominant species and afforded food resources and some refuge from the current. *Ranunculus*, which occupied a mere 1.9% cover in June 1998 (cp 6.2% in June 1997) was less taxon-rich than in June 1997 (26 vs 31 families). Thus, in June 1998, *Ranunculus* joined the non-macrophyte habitats gravel and silt in being less taxon-rich. Emergent macrophytes remained an important refuge for a range of different families.

In June 1997, a total of 46 families were recorded, of which 42 were found in the five habitats sampled in the 1970s. In June 1998 the figure rose to 52 families on all six habitat types, of which 45 were found on the five habitats sampled in the 1970s. In the seven years 1971 plus 1974-79, the total number of families from five habitats varied from 42 to 47. The total of 45 families from five habitats in June 1998 was therefore within the 1970s range.

6.1.2 Family composition and abundance data for June 1998

Table 6.2 presents a list of the 52 families of macroinvertebrates and their mean densities on each of the six habitat types sampled in June 1998. Note that the Oligochaeta and Lumbricidae, although presented separately, are counted as a single 'family' in this report. See section 4.2.2 in Wright *et al.* (1999a) for an explanation of the need for this protocol. The faunal list for June includes 17 'families' of non-insects and 35 families of insects (cp 16 and 30 in June 1997).

The following differences were noted between the families recorded in June 1997 and June 1998.

June 1997 only

Mollusca:	Valvatidae
Ephemeroptera:	Heptageniidae
Megaloptera:	Sialidae
Diptera:	Ptychopteridae

June 1998 only

Mollusca:	Lymnaeidae
Crustacea:	Niphargidae
Ephemeroptera:	Leptophlebiidae
Coleoptera:	Scirtidae
Trichoptera:	Bereidae
	Sericostomatidae
Diptera:	Psychodidae
	Stratiomyidae
	Ephydridae
	Muscidae

Note that although there were a total of 10 families recorded in June 1998 (but not in June 1997), eight of these families were recorded on the site in December 1997, the exceptions being Scirtidae and Muscidae. These last two were both known from the site in the 1970s.

The densities of individuals in many of the families on this site vary considerably between seasons due to life cycle phenomena, but they also vary between years (Wright and Symes 1999b; Wright *et al.* in press). Hence, selected between-year comparisons were undertaken for some habitat types (Section 6.1.3) in a preliminary attempt to pinpoint those components of the macroinvertebrate assemblage which were sensitive to environmental change.

Table 6.2 R. Lambourn at Bagnor (shaded site), June 1998. Mean densities of macro-invertebrate families (nos. per 0.05 m^{-2}) based on 5 sampling units for each habitat type.

Family name	Berula	Callitriche	Emergents	Gravel	Ranunculus	Silt
Planariidae	2.00	0.00	0.00	2.20	0.80	0.40
Dendrocoelidae	0.40	0.00	0.00	0.00	0.00	0.00
Hydrobiidae	12.00	81.00	8.00	1.60	2.00	2.40
Physidae	0.00	0.40	0.00	0.00	0.00	0.00
Lymnaeidae	0.00	0.00	0.80	0.00	0.00	0.00
Planorbidae	4.80	1.00	0.20	0.00	0.00	0.40
Ancylidae	0.20	0.00	0.40	0.00	0.20	0.00
Sphaeriidae	8.20	18.40	1.20	0.20	0.60	3.00
Oligochaeta	197.60	100.80	45.00	34.00	34.20	26.60
Lumbricidae	3.20	0.40	1.20	2.40	3.40	0.20
Piscicolidae	0.00	0.40	0.00	0.00	0.00	0.00
Glossiphoniidae	2.60	1.00	0.00	0.00	0.00	0.00
Erpobdellidae	2.60	0.20	0.20	0.00	0.20	0.40
Hydracarina	0.80	0.40	0.20	0.00	0.80	0.00
Astacidae	0.00	0.60	0.00	0.00	0.00	0.00
Asellidae	6.00	4.60	17.00	0.00	0.00	14.60
Gammaridae	301.20	114.20	39.40	120.80	208.60	103.60
Niphargidae	0.00	0.00	0.20	0.00	0.00	0.00
Baetidae	86.60	20.40	1.60	41.20	56.00	9.00
Leptophlebiidae	0.00	0.00	0.00	0.00	0.00	1.60
Ephemeridae	5.00	1.80	0.40	3.60	3.40	1.40
Ephemerellidae	30.80	43.20	0.40	2.60	12.80	4.40
Caenidae	8.00	4.40	1.00	0.40	0.20	1.00
Nemouridae	0.20	0.00	0.00	0.00	0.00	0.00
Leuctridae	10.20	0.40	0.20	2.60	2.80	1.20
Veliidae	0.00	0.00	1.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.80	0.00	0.00	0.00
Dytiscidae	0.00	0.40	0.20	0.00	0.00	1.20
Scirtidae	0.00	0.00	0.40	0.00	0.00	0.00
Elmidae	9.80	4.60	1.00	2.00	6.60	1.00
Rhyacophilidae	0.80	0.00	0.00	0.00	1.60	0.20
Glossosomatidae	12.80	1.60	0.40	115.80	79.40	6.20
Hydroptilidae	0.00	0.40	0.00	0.20	0.00	0.00
Psychomyiidae	0.00	0.20	0.00	1.80	0.40	0.00
Polycentropodidae	2.20	0.80	0.20	0.20	0.00	0.40
Hydropsychidae	0.00	0.00	0.00	0.00	0.20	0.00
Lepidostomatidae	0.60	0.20	0.00	0.00	0.00	0.00
Limnephilidae	21.80	5.80	9.80	1.20	0.20	0.80
Goeridae	0.40	0.00	0.00	0.80	1.00	0.00
Beraeidae	0.40	0.00	0.00	0.00	0.00	0.00
Sericostomatidae	2.40	0.40	0.40	0.00	0.00	0.00
Leptoceridae	37.40	5.00	0.20	15.60	10.80	3.40
Tipulidae	5.40	1.40	4.40	2.40	4.20	3.00
Psychodidae	0.00	0.00	0.80	0.00	0.00	0.00
Dixidae	0.40	0.00	5.20	0.40	0.00	0.20
Ceratopogonidae	63.80	8.60	14.40	1.40	0.40	2.80
Simuliidae	1078.60	73.80	5.60	19.40	618.00	14.80
Chironomidae	248.00	373.60	322.60	16.80	80.20	209.40
Stratiomyidae	0.40	0.00	0.00	0.00	0.00	0.00
Empididae	4.80	0.60	0.40	0.40	1.20	1.60
Syrphidae	0.40	0.00	0.00	0.00	0.00	0.00
Ephydridae	0.00	0.00	0.80	0.00	0.00	0.00
Muscidae	0.40	0.00	0.00	0.00	0.00	0.00

6.1.3 Between-year comparisons

A comparison between June 1997 (low discharge) and June 1998 (higher discharge) provided an ideal opportunity to determine the early response of the individual families of macroinvertebrates to the aftermath of the two-year drought. As in the previous report (Wright *et al.* 1999a), the Mann-Whitney U-test was used on the density counts from the five replicate sampling units from a given habitat type in each year (see Section 4.2.2 for an explanation of this test). The first tests between June 1997 and June 1998 were carried out on the dominant macrophyte (*Berula*) and the dominant non-macrophyte substratum (gravel) and are presented in Table 6.3. Additional tests on the other four habitat types at this site were also made, but are only reported briefly within the text where they underline the results for *Berula* and gravel.

Table 6.3 R. Lambourn at Bagnor (shaded site). Mean densities of families (nos 0.05 m^{-2}) on *Berula* (June 1997 and 1998) and Gravel (June 1997 and 1998). Families listed are those for which there were significant differences between years, based on the Mann-Whitney U-test. (* =P< 0.05; ** =P< 0.01) **See text for further explanation.**

Family	Berula		Gravel	
	1997	1998	1997	1998
Planorbidae	0.0	4.8 **		
Baetidae	5.2	86.6 *	0.2	41.2 **
Ephemeridae	78.0 *	5.0	36.2 *	3.6
Ephemerellidae	73.6 *	30.8		
Hydroptilidae	2.8 **	0.0		
Psychomyiidae			0.2	1.8 *
Leptoceridae	9.6	37.4 *		
Simuliidae	0.0	1078.6 **	0.0	19.4 **

There were 8 families for which Mann-Whitney U-tests indicated significant differences between June 1997 and June 1998 on *Berula* and/or gravel. The mean densities of these families are given in order to put the results of the Mann-Whitney U-tests into context. It is inappropriate to attempt to interpret every result, and the main focus will be on taxa that gave a similar response on *Berula*, gravel and other habitat types.

Results for some families of Ephemeroptera (mayflies) and in particular the Baetidae, Ephemeridae and Ephemerellidae were particularly interesting, with a number of significant differences between years on both *Berula* and gravel. Baetidae, in which most species have a requirement for fast-flowing water, occurred at very low densities in June 1997. In June 1998, there were significant differences (increases) not only on *Berula* and gravel, but also on *Callitriche*. These increases were expected in view of the increase in discharge (Wright *et al.* in press). However, they fall short of the densities observed in the 1970s, possibly because of the detrimental impact of the prolonged drought of 1996-97. In addition, the small areas of favourable macrophyte habitat (*Berula* and *Ranunculus*) would have a detrimental impact on the overall population densities on the 50 m study site.

Densities of *Ephemera danica* (Ephemeridae), the fisherman's mayfly, were very high in June

1997 and the two year life-cycle of this species means that there was probably a spectacular emergence of subimagos in late May 1998, in advance of the June 1998 sampling operation. Throughout the 1970s, the one-year old cohort of larva in even years was always small and hence, it was expected that densities of *E .danica* would be low in June 1998. With the single exception of *Callitriche* (n.s), *E.danica* was significantly less abundant in each of the remaining five habitat types in June 1998 compared to June 1997.

Ephemerella ignita (Ephemerellidae), the blue-winged olive, which favours the protection of macrophyte cover, was not very abundant in June 1997 compared to some densities recorded in the 1970s. In June 1998 there was a further significant decrease in abundance not only on *Berula* but also on *Ranunculus* and emergent vegetation. The prolonged nature of this drought and low cover of the submerged macrophyes may have contributed to this situation.

The significant differences in the densities of Simuliidae between June 1997 and 1998 were anticipated in view of the increase in discharge (Wright *et al.* in press). The higher densities for June 1998 were noted on all six habitats samples, including *Berula* and gravel (Table 6.3). However, with the exception of the submerged macrophytes *Berula* and *Ranunculus*, which occurred in only limited patches on the riverbed, the densities were not exceptional and it was apparent that overall, the density on the site remained relatively low in relation to the June 1998 discharge regime.

6.2 R. Kennet at Littlecote

6.2.1 Family richness

The River Kennet at Littlecote is characterised by *Ranunculus* growing on a gravel substratum and hence the 1970s and 1990s sampling programmes have been confined to these habitat types. In Table 6.4, the June 1998 results (in bold) have been placed alongside the data for 1997 (when sampling took place in July) and also the June 1975 and 1974 results.

Table 6.4 R. Kennet at Littlecote. Number of families of macroinvertebrates recorded on *Ranunculus* and gravel in July & December 1997, plus June 1998. Historical data for 1975 (June and December) and 1974 (June only) are also given.

Year	June/July		December		Total for Year
	Ranunculus	Gravel	Ranunculus	Gravel	(Ran + Grav)
1997	32	31	43	34	47
1998	**31**	**29**	No data	No data	No data
1975	30	33	35	33	42
1974	30 (29)*	28	No data	No data	-

* Figure in brackets refers to data from 5 replicate samples taken on recently cut *Ranunculus*.

In June 1998, the number of families on each of *Ranunculus* and gravel, though marginally lower than the number recorded in July 1997, was broadly similar not only to 1997 but also to June of 1974 and 1975. A total of 35 families was recorded on the site in July 1997, compared to 32 families in June 1998.

6.2.2 Family composition and abundance data for 1998

Table 6.5 lists the 32 families of macroinvertebrates captured at Littlecote in June 1998 together with their mean densities on gravel and *Ranunculus*. The fauna includes 12 families of non-insects and 20 families of insects (cp 12 and 23 families respectively in July 1997).

Table 6.5 R. Kennet at Littlecote, June 1998. Mean densities of macroinvertebrate families (nos. 0.05 m^{-2}) based on 5 sampling units for each habitat.

Family name	Gravel	Ranunculus
Planariidae	3.40	4.40
Dendrocoelidae	0.20	0.60
Physidae	0.00	0.40
Planorbidae	0.20	0.60
Ancylidae	2.80	5.00
Sphaeriidae	3.20	1.80
Oligochaeta	109.40	85.40
Lumbricidae	1.00	1.80
Piscicolidae	0.00	0.60
Glossiphoniidae	1.60	2.80
Erpobdellidae	4.20	5.60
Asellidae	0.80	1.00
Gammaridae	1219.40	1123.60
Baetidae	200.40	159.00
Ephemerellidae	39.80	158.60
Caenidae	30.60	54.80
Leuctridae	17.80	3.60
Calopterygidae	0.00	0.40
Elmidae	19.40	13.60
Rhyacophilidae	2.60	1.40
Glossosomatidae	0.40	0.40
Psychomyiidae	3.60	0.00
Polycentropodidae	2.00	2.60
Hydropsychidae	2.60	1.40
Lepidostomatidae	0.80	0.60
Limnephilidae	0.40	0.40
Goeridae	0.60	1.00
Sericostomatidae	0.20	1.60
Leptoceridae	18.80	10.00
Tipulidae	2.40	0.40
Ceratopogonidae	6.80	15.20
Simuliidae	6.20	249.40
Chironomidae	6.40	51.00

The following differences were noted between the families recorded in July 1997 and June 1998:

July 1997 only	**June 1998 only**	
Hydracarina	Mollusca:	Physidae
Crustacea: Niphargidae	Hirudinea:	Piscicolidae
Ephemeroptera: Ephemeridae	Odonata:	Calopterygidae
Hemiptera: Corixidae		
Megaloptera: Sialidae		
Diptera: Empididae		

Some families, including Niphargidae, Corixidae and Sialidae may have found conditions more suitable under the low flow conditions of July 1997, but the absence of Ephemeridae in the June 1998 samples is more likely to be due to the two-year life cycle of this species (see Section 6.1.3). The occurrence of two damselfly nymphs in the family Calopterygidae in June 1998 appears to be the first record of this taxon at Littlecote.

6.2.3 Between-year comparisons

Table 6.6 lists the 8 families for which Mann-Whitney U-tests indicated significant differences between July 1997 and June 1998. Apart from the low discharge in 1997 compared to 1998, it must also be recognised that the later sampling time in 1997 may be responsible for changes in densities of some macroinvertebrates between years.

Table 6.6 R. Kennet at Littlecote. Mean densities of families (nos. 0.05 m^{-2}) on *Ranunculus* (July 1997 and June 1998) and Gravel (July 1997 and June 1998). Families listed are those for which there were significant differences between years, based on the Mann-Whitney U-test.
(* =P< 0.05; ** =P< 0.01)

Family	Ranunculus		Gravel	
	1997	1998	1997	1998
Sphaeriidae	28.4 *	1.8		
Oligochaeta			23.2	109.4 *
Glossiphoniidae	26.8 *	2.8		
Hydracarina	6.4 *	0.0		
Gammaridae			325.2	1219.4 *
Baetidae			53.8	200.4 *
Caenidae	210.0 *	54.8		
Lepidostomatidae	23.4 *	0.6		

Overall, the macroinvertebrate assemblage at Littlecote did not appear to be severely affected by the 1996/97 drought, thanks in part to the management regime of allowing the river to run freely. As a consequence, a number of families that require fast-flowing water (e.g. Baetidae and Simuliidae) maintained modest populations at a time when they were very low at both Bagnor and Savernake. Thus, only on gravel was there a significant increase in the densities of Baetidae in June 1998.

Densities of Gammaridae, which had been quite high in gravel and particularly in *Ranunculus* in July and December 1997, increased further on both habitats in June 1998 (Table 6.5), resulting in a significant increase on gravel. It is possible that the large areas of marginal vegetation at the site through much of 1997 provided an ideal habitat and food resource for *Gammarus pulex* and when the winter increase in discharge led to the removal of marginal vegetation, densities of this species increased further in both *Ranunculus* and gravel.

6.3 R. Kennet at Savernake (lower and upper sites)

6.3.1 Family richness

Further upstream at Savernake, *Schoenoplectus* and gravel were sampled on the lower site in June 1998, in order to retain conformity with the July 1997 and 1970s sampling regime (Table 6.7).

In June 1998, the number of families recorded on *Schoenoplectus* was 26, and although this was below the 31 families recorded in July 1997, it was similar to values recorded in the 1970s. In contrast, gravel supported 30 families in June 1998, somewhat higher than in all previous years. A total of 33 families was recorded on the site in July 1997 compared with 32 families in June 1998..

Table 6.7 R. Kennet at Savernake (Lower site). Number of families of macroinvertebrates captured on *Schoenoplectus* and gravel in July & December 1997, plus June 1998 (latter in bold). Historical data for 1975 (June and December) and 1974 (June only) is also given.

Year	June/July		December		Total for Year
	Schoenoplectus	Gravel	Schoenoplectus	Gravel	(Schoen+Grav)
1997	31	27	33	32	39
1998	**26**	**30**	No data	No data	No data
1975	27	24	32	29	35
1974	26	28	No data	No data	-

The equivalent data on family richness for the upper site at Savernake is presented in Table 6.8. At this site *Ranunculus* and gravel were sampled in July 1997 and this protocol was retained in June 1998. *Ranunculus*, which was growing prolifically, yielded 27 families in June 1998, compared to 28 families in July 1997 when growth of this macrophyte was very stunted. Only 23 families were recovered from the samples taken on gravel in June 1998, a figure lower than any of the previous years for which data were available. However, the total of 33 families captured on the site in June 1997, compared with 32 families in June 1998, mirrored the findings on the lower site at Savernake.

Table 6.8 **R. Kennet at Savernake (Upper site). Number of families of macroinvertebrates captured on *Ranunculus* and gravel in July & December 1997, plus June 1998 (the latter in bold). Historical data for these habitats plus *Schoenoplectus* in 1975 and 1974 (June only) is also given.**

Year	June/July			December			Total for Year
	Schoen	Ran	Gravel	Schoen	Ran	Gravel	(All habitats)
1997	No data	28	29	No data	32	27	38
1998	**No data**	**27**	**23**	-	-	-	-
1975	29	No data	29	32	31	31	37
1974	No data	29	27	No data	No data	No data	

6.3.2 Family composition and abundance data for 1998

A list of the 32 families of macroinvertebrates recorded on the lower site at Savernake in June 1998, together with their mean densities on gravel and *Schoenoplectus* is presented in Table 6.9. The fauna includes 13 families of non-insects and 19 families of insects (cp 14 and 19 families respectively in July 1997).

The following differences were noted between the families recorded in July 1997 and June 1998.

Lower Savernake - July 1997 only

Mollusca:	Hydrobiidae
Mollusca:	Physidae
Coleoptera:	Haliplidae
Trichoptera:	Glossosomatidae
Trichoptera:	Hydroptilidae
Diptera:	Empididae

Lower Savernake – June 1998 only

Tricladida:	Dendrocoelidae
Hemiptera:	Corixidae
Coleoptera:	Hydrophilidae
Trichoptera:	Rhyacophilidae
Trichoptera:	Hydropsychidae

It would be unwise to over-interpret the significance of these differences not only because of the slight differences in the time of sampling, but more particularly because lack of occurrence in the samples for a given year does not necessarily imply that a family was absent from the site, merely that it was uncommon. Of the five families recorded in June 1998 but not in July 1997, three (Dendrocoelidae, Rhyacophilidae and Hydropsychidae) were recorded at the site in December 1997.

Table 6.10 gives a listing of the 32 families of macroinvertebrates and their mean densities on gravel and *Ranunculus* in June 1998. The faunal list for June includes 15 families of non-insects and 17 families of insects (cp 15 and 18 respectively in July 1997).

Table 6.9 **R. Kennet at Savernake (Lower site) June 1998. Mean densities of macroinvertebrate families (nos. 0.05 m^{-2}) based on 5 sampling units for each habitat**

Family name	Gravel	Schoenoplectus
Planariidae	4.20	3.00
Dendrocoelidae	0.20	0.20
Planorbidae	0.00	0.20
Ancylidae	0.40	0.20
Sphaeriidae	1.40	4.40
Oligochaeta	69.00	116.80
Lumbricidae	1.40	0.60
Piscicolidae	0.20	0.20
Glossiphoniidae	0.20	1.20
Erpobdellidae	5.20	5.60
Hydracarina	0.20	0.20
Asellidae	14.20	2.20
Gammaridae	265.40	609.00
Niphargidae	4.00	0.20
Baetidae	87.80	215.60
Ephemerellidae	70.40	18.80
Caenidae	4.60	0.80
Corixidae	0.20	0.00
Dytiscidae	0.60	0.00
Hydrophilidae	0.20	0.00
Elmidae	1.60	4.40
Sialidae	0.20	0.00
Rhyacophilidae	0.00	1.00
Polycentropodidae	3.40	1.40
Hydropsychidae	0.20	0.00
Limnephilidae	1.20	0.60
Goeridae	0.20	0.00
Sericostomatidae	0.40	1.40
Leptoceridae	8.00	6.20
Tipulidae	3.80	4.40
Ceratopogonidae	2.20	0.20
Simuliidae	3.00	210.00
Chironomidae	84.20	801.20

Table 6.10 **R. Kennet at Savernake (Upper site) June 1998. Mean densities of macroinvertebrate families (nos. 0.05 m^{-2}) based on 5 sampling units for each habitat.**

Family name	Gravel	Ranunculus
Planariidae	2.80	4.60
Dendrocoelidae	0.20	0.00
Valvatidae	0.20	0.00
Hydrobiidae	0.00	0.20
Lymnaeidae	0.00	0.20
Planorbidae	0.00	0.40
Sphaeriidae	0.00	0.20
Oligochaeta	45.00	11.00
Lumbricidae	0.40	0.20
Piscicolidae	0.60	1.20
Glossiphoniidae	2.20	1.20
Erpobdellidae	11.00	2.60
Hydracarina	0.00	0.20
Asellidae	12.60	4.40
Gammaridae	319.40	202.80
Niphargidae	0.80	0.00
Baetidae	99.00	133.80
Ephemerellidae	67.60	271.80
Caenidae	7.40	5.60
Corixidae	0.00	0.20
Dytiscidae	0.80	0.20
Hydrophilidae	0.00	0.20
Elmidae	4.20	1.60
Rhyacophilidae	0.60	0.20
Hydroptilidae	0.00	0.40
Polycentropodidae	0.00	0.40
Limnephilidae	0.40	1.20
Sericostomatidae	0.80	0.40
Leptoceridae	4.60	1.20
Tipulidae	0.20	0.00
Ceratopogonidae	0.40	0.00
Simuliidae	9.00	230.80
Chironomidae	19.00	45.60

The following family differences were noted between July 1997 and June 1998.

Upper Savernake - July 1997 only

Mollusca:	Physidae
Mollusca:	Ancylidae
Megaloptera:	Sialidae
Trichoptera:	Glossosomatidae
Trichoptera:	Goeridae
Diptera:	Empididae

Upper Savernake – June 1998 only

Mollusca:	Hydrobiidae
Mollusca:	Lymnaeidae
Hemiptera:	Corixidae
Coleoptera:	Hydrophilidae
Trichoptera:	Polycentropodidae

These listings have some similarities with the lower site at Savernake. Thus, Physidae, Glossosomatidae and Empididae were recorded at both sites in July 1997 but not in June 1988. Similarly, Corixidae and Hydrophilidae were captured at both sites in June 1998 only. However, some of these observations may link to life cycle features and be a consequence of slight differences in sampling time rather than a product of the higher discharge regime in 1998.

6.3.3 Between-year comparisons

Table 6.11 lists the 8 families for which Mann-Whitney U-tests indicated significant differences between July 1997 and June 1998 on one or more of the habitats sampled on the lower site at Savernake. The comments made for the Littlecote site on differences in the timing of the field sampling in 1997 and 1998 also apply to these results.

In a previous report (Wright *et al.* 1999a) it was noted that this was the only site at which leeches in the family Glossiphoniidae occurred at significantly higher densities in 1997 compared to 1975. Another non-insect family, Asellidae, also occurred at significantly higher densities on *Schoenoplectus* in summer 1997 than in 1975. Both of these families (and also Erpobdellidae) score just 3 on the BMWP score system. This indicates that they can be expected to increase in density under conditions of enrichment. It is therefore, of interest that each of the Glossiphoniidae, Erpobdellidae and Asellidae occurred at significantly lower densities on *Schoenoplectus* in June 1998 compared to July 1997. There was also a highly significant decrease in Glossiphoniidae on gravel over this period. Both the increase in discharge and the commencement of phosphate stripping at Marlborough sewage treatment works may be relevant to these changes. The slight differences in sample collection times must also be taken into account.

Table 6.11 R. Kennet at Savernake (Lower site). Mean densities of families (nos 0.05 m^{-2}) on *Schoenoplectus* (July 1997 and June 1998) and Gravel (July 1997 and June 1998). Families listed are those for which there were significant differences between years, based on the Mann-Whitney U-test. (* =P< 0.05; ** =P< 0.01)

Family	Schoenoplectus		Gravel	
	1997	1998	1997	1998
Piscicolidae	5.0 *	0.2		
Glossiphoniidae	53.6 *	1.2	22.8 **	0.2
Erpobdellidae	13.4 *	5.6		
Asellidae	46.2 *	2.2		
Baetidae	37.6	215.6 *	0.8	87.8 *
Ephemerellidae	62.0 *	18.8		
Dytiscidae	2.6 *	0.0		
Rhyacophilidae	0.0	1.0 *		

In contrast, mayflies in the Baetidae had undergone significant increase on both habitats from their very low population densities in July 1997. However, the significant decrease in Ephemerellidae on *Schoenoplectus* was unexpected and mirrored the situation at Bagnor, where there was also a significant decrease on *Berula*.

Table 6.12 presents the Mann-Whitney U-test results for the upper site at Savernake. Here there was further evidence of significant decreases in the densities of Glossiphoniidae (*Ranunculus* and gravel) and Asellidae (gravel) in June 1998.

As expected, there were significant increases in the density of Baetidae on both *Ranunculus* and gravel in June 1998. There were also significant increases in Ephemerellidae on both habitats, unlike the lower site at Savernake, where there was a significant decrease on *Schoenoplectus*. Unfortunately no samples were collected on *Ranunculus* at the lower site to determine whether high populations of Ephemerellidae were present on the macrophyte which dominated this site in June 1998.

Significant increases were also observed for Simuliidae on gravel, but on *Ranunculus* densities had been modest in July 1997 and doubled in June 1998, without demonstrating a significant increase.

Finally, densities of Chironomidae were significantly higher in July 1997 than in June 1998, as might be anticipated, because a number of species tend to reach very high densities under conditions of low flow and/or slight enrichment.

Table 6.12 R. Kennet at Savernake (Upper site). Mean densities of families (nos 0.05 m^{-2}) on *Ranunculus* (July 1997 and June 1998) and Gravel (July 1997 and June 1998). Families listed are those for which there were significant differences between years, based on the Mann-Whitney U-test.
(* =P< 0.05; ** =P< 0.01)

Family	Ranunculus		Gravel	
	1997	1998	1997	1998
Lumbricidae	9.2 **	0.2	16.6 *	0.4
Glossiphoniidae	17.2 *	1.2	16.6 *	2.2
Asellidae	34.4 *	4.4		
Baetidae	10.8	133.8 *	2.8	99.0 *
Ephemerellidae	67.2	271.8 *	17.6	67.6 *
Elmidae	8.4 *	1.6		
Limnephilidae	0.0	1.2 *		
Ceratopogonidae			4.00 **	0.4
Simuliidae			0.2	9.0 *
Chironomidae	254.8 *	45.6	160.4 *	19.0

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

7.1.1 R. Lambourn at Bagnor

Background information relating to this site through the 1970s and in 1997 was given in Wright *et al.* (1999a). In 1997, it was apparent that the shaded site had undergone substantial change since the 1970s due to the lack of the river management for trout fishing and recent the effects of the prolonged drought of 1996-97. Lack of management allowed the initial encroachment of marginal emergents on the baseline bank, and this process increased during the drought. In addition, lack of control of the bank-side trees and bushes on the far bank increased shading with some potential for restricting the growth of submerged vegetation.

In 1997, the poor growth of *Ranunculus* and the progressive build-up of silt was thought to be largely due to the drought. The reason for the limited area of *Berula* was less clear, but in view of the large areas of clean gravel, it was anticipated that it (and also *Ranunculus*) would increase in area quite rapidly following the end of the drought.

Although the discharge over the winter of 1997/98 was unexceptional, heavy rainfall in spring 1998 provided what appeared to be favourable conditions for the progressive recovery of the macrophytes and macroinvertebrate assemblages.

The total area of the site increased as expected (Table 5.1), but the three submerged macrophytes (*Berula*, *Ranunculus* and *Callitriche*) failed-to-undergo substantial increase in area. This was totally unexpected in the case of *Berula* and *Ranunculus*. Each one of the limited beds of *Berula* first mapped in June 1997 had survived over the next twelve months but the increase in proportion of the site covered by *Berula* was very limited (5.8% to 9.6%) and failed to match the major recovery of *Berula* in the late 1970s from a low of 0.5% in February 1979 to 40.9% in December 1979. Similarly, given the mean discharge in May 1998, we anticipated that *Ranunculus* would undergo rapid growth, as observed on the three Kennet sites. The presence of a large area of silt on site (26.8%) indicated that the accumulation of this fine material both at Bagnor and upstream would take time to be dispersed downstream.

Shading of the site, both by trees and some emergent vegetation and the continued presence of silt may have held back growth of submerged macrophytes. A further possibility for consideration is the potential impact of signal crayfish. Adults are known to feed on both detritus and living macrophyte and the introduction of signal crayfish to previously crayfish-free waters has resulted in reduction of weed biomass in some areas (Hogger 1988, Elser, Junge & Goldman 1994).

The sampling programme in June 1997 and 1998 has also provided information on whether the macroinvertebrate fauna of an unmanaged site during, and immediately after, a drought differs from the 1970s faunal assemblage, when the river was intensively managed for trout and experienced a wide range of discharge conditions.

Overall, the family composition at Bagnor has remained remarkably stable between the 1970s and late 1990s. Of the five habitats sampled in both periods, 42 families were recorded in

June 1997 and 45 in June 1998. In the seven-year period 1971 plus 1974-79, when similar sampling protocols applied, the number of families captured on these same five habitats in June varied from 42 to 47. Thus, in the late 1990s, the family richness has not deviated beyond the 1970s range and richness has marginally increased with the increase in discharge. When the additional habitat encompassing emergent macrophytes is included, the total number of families rose from 46 in June 1997 to 52 in June 1998.

Of equal relevance in terms of ecosystem functioning are the densities of the macroinvertebrates on the various habitat types. Some characteristic families of fast-flowing chalk streams such as Baetidae (Mayfly larvae) and Simuliidae (Blackfly larvae) had fallen to remarkably low abundance in June 1997, the second summer of the recent drought (Wright *et al.* in press). The following summer (June 1998) there was clear evidence of a partial recovery. However, the limited areas of some of the favoured habitats means that for the study site as a whole, the abundance of some characteristic chalk stream invertebrates remained relatively low and would need a further year or longer to recover. In addition, families such as Ephemerellidae (Mayflies) showed differing responses between sites (e.g lower densities in June 1998 at Bagnor but higher densities at Savernake upper where *Ranunculus* grew exceptionally well).

7.1.2 R. Kennet at Littlecote

In summer 1997, the discharge at Littlecote was greater than in the severe drought of 1976 and *Ranunculus* covered 44.2% of the 100 m site in July 1997. As a result, it continued to provide suitable habitat for a wide range of macroinvertebrate families and this section of the river was not as severely affected as the two study sites at Savernake. The development of marginal emergents through the summer and into the following winter also provided both habitat and food resources for a wide range of macroinvertebrates, some of which may then have moved onto gravel and *Ranunculus.*

In June 1998, it was apparent that all marginal emergents had been removed by the winter flows, which had also provided good conditions for the spring growth of *Ranunculus*. The percentage of the site covered by *Ranunculus* was estimated to be 71.5% and a bar-cut had already taken place.

Macroinvertebrate family richness was marginally lower in June 1998 (32 families) than in July 1997 (35 families). The loss of marginal habitats under conditions of higher discharge may have contributed to this slight decrease in richness. In view of the fact that *Ranunculus* continued to be an important habitat throughout the 1996/97 drought, families such as Baetidae and Simuliidae were able to maintain modest populations and hence the difference between the July 1997 and June 1998 abundance was less extreme. One notable family at this site, the Gammaridae, represented by *Gammarus pulex*, developed very high population densities by June 1998. It is possible that the marginal vegetation which continued to increase in area until December 1997 may have been a nursery for gammarids which then moved into Ranunculus and gravel when the winter flows removed the *Nasturtium* and other marginals.

7.1.3 R. Kennet at Savernake

The River Kennet at Savernake has suffered progressive loss of *Ranunculus* below Marlborough for some years and in an attempt to promote regrowth, a combination of management techniques have been used. These have included allowing the river to run freely, use of current deflectors, removal of vertical boarding and reduction of channel width by planting marginal emergents etc.

At sites on the River Lambourn, there is observational evidence that in years of low discharge, the growth of *Ranunculus* is restricted by the accumulation of epiphytic algae and associated detritus on the surface of the plants (Ham *et al.* 1981, Wright and Berrie 1987). At Savernake, the potential for this problem to be compounded in low flow years by the presence of nutrients from Marlborough STW, and other diffuse sources resulting from agricultural activities within the catchment was raised in Wright *et al.*(1999a).

In Wright *et al.* (1999a) it was also argued that in summer 1997, the Littlecote study site was capable of supporting good growth of *Ranunculus* but the similar discharge regime failed to promote growth of *Ranunculus* at Savernake, despite the various management treatments listed above. The question therefore arises as to whether water quality, in addition to water quantity is also relevant to this problem.

In 1997, the dominant macrophytes of the lower and upper sites at Savernake differed, just as they had in the 1970s. At the lower site, *Schoenoplectus* was dominant as it had been in 1974-75, but the total area of this macrophyte was much reduced. The new management regime with reduced water levels and faster current may have produced less than optimal conditions for this macrophyte. Alternatively, it is possible, though unproven, that surface algae suppressed the growth of the strap-like leaves or that swans or other wildfowl cropped it in the absence of abundant *Ranunculus*. Although small quantities of *Ranunculus* were present, the area was minimal and substantially lower than in 1974-75. Silt had also accumulated as a result of the two-year drought.

Prior to remapping the lower site in June 1998, three events had taken place overwinter. First, the far bank (opposite the mapping baseline) had been subject to management involving overall reduction in river width to further encourage faster current speeds for a given discharge regime. Second, phosphate stripping had commenced around November 1997 at Marlborough sewage treatment works. Finally, the two-year drought came to an end and in particular, the month preceeding mapping in June 1998 was notable for heavy rain and increased discharge.

On reaching the lower site in June 1998 in order to re-map, it was immediately apparent that a remarkable change had taken place on this section of river. *Ranunculus* had undergone spectacular growth during the preceding months and this, combined with the discharge regime, meant that water levels were very high. In fact *Ranunculus* now dominated this site and the total area of *Ranunculus* was 43.6% in June 1998, compared to 0.9% in July 1997. This strongly suggests that, despite the poor performance of *Ranunculus* in previous years during the 1990s, some root systems remained in place and were available to respond to the return of favourable conditions. As a consequence of all these changes, the area of macrophytes at the lower site available as habitat for supporting high densities of macroinvertebrates was much increased.

On the upper site at Savernake, prior to 1997, efforts were made by the River Keeper to encourage the regrowth of *Ranunculus* by reducing the channel width and by using current deflectors. In 1997, the optimum location for the growth of *Ranunculus* was where the current deflectors increased local current speed. Despite this, the total area of *Ranunculus* remained below 10% on both sampling occasions in 1997, and weed occurred as thin beds in shallow water, making it possible for wildfowl to limit the density and progressive colonisation of this macrophyte.

In June 1998, the growth of *Ranunculus* on the upper site was even more spectacular than at the lower site and it covered 48.8% of the site. In many ways this mirrored the normal response of this macrophyte to non-drought years in the 1970s. Thus, in April and May 1974 growth of *Ranunculus* was also spectacular, reaching about 40% cover and requiring a major weed-cut in early June to reduce the volume of surface-flowering weed. Further growth then took place through the summer of 1974, resulting in the need for a second cut in September. By contrast, in spring and early summer 1975, a maximum of 27 swans fed selectively on *Ranunculus* and it appears that their grazing pressure held back the increase in area of weed until July (University of Reading, 1977). Despite this, by late summer the site had around 35% cover of *Ranunculus.*

These various observations demonstrate the potential of this macrophyte to dominate the upper site at Savernake and indicate that, under favourable conditions it retained this capability in 1998. These results bring into focus the question of why growth of this macrophyte was reported to be poor in the mid-1990s when the discharge regime was apparently favourable for *Ranunculus*. In theory, heavy cropping of weed by waterfowl might restrict growth early in the season. Alternatively, if *Ranunculus* was restricted through smothering by epiphytic algae in spring (despite the favourable discharge conditions), this might also limit its role later in the season. Unfortunately, in the absence of hard evidence, these suggestions remain speculative.

In view of the limited number of quantitative samples (five macrophyte plus five gravel) taken for macroinvertebrates on each of the lower and upper sites at Savernake, it is inevitable that there will be some differences in family composition between years. Some families are favoured by drought conditions and others by conditions of high flow. In each case this may affect the chance of capture. However, there were no major changes in family richness between July 1997 and June 1998 and somewhat surprisingly, a total of 33 families was recorded on each site in July 1997, whilst a total of 32 families was recorded on each site in June 1998.

Of greater interest were changes in the density of some of the families of macroinvertebrates. At the lower site, leeches in the family Glossiphoniidae and crustaceans in the family Asellidae occurred in significantly higher densities in July 1997 than in the mid-1970s within beds of *Schoenoplectus*. These families normally achieve a more prominent role in the community under conditions of nutrient enrichment and organic pollution. They may have been able to increase their numbers more effectively as a result of the two year drought, but their increased abundance also suggests that changes in water quality were taking place. On the upper site, the densities of Asellidae were again significantly higher in July 1997 than in the mid-1970s whilst densities of Chironomidae were significantly higher on gravel (lower site) and *Ranunculus* (upper site) in summer 1997 compared to 1975. The reason for the higher densities of chironomid larvae at Savernake appears to be the greater availability of food in the form of algae and associated detritus on the surface of the gravel (lower site) and also on the slow-growing *Ranunculus* at the upper site.

In contrast, at each of the two sites at Savernake, mayfly larvae in the family Baetidae were present in significantly lower densities in July 1997 than in the mid-1970s. This follows the pattern of previous observations on the River Lambourn at Bagnor, but not at Littlecote on the River Kennet, where healthy growth of *Ranunculus* did provide adequate conditions for modest densities of larvae.

The quantitative sampling programme for macroinvertebrates undertaken in June 1998 followed the ending of the drought, commencement of phosphate stripping, the aftermath of a wet spring and the spectacular re-growth of *Ranunculus*. At the lower site it was particularly notable that there were significant decreases in the abundance of three families (Glossiphoniidae, Erpobdellidae and Asellidae) normally associated with conditions of enrichment. Similar observations were made for the Glossiphoniidae, Asellidae and Chironomidae at the upper site. At each site there were significant increases in the abundance of Baetidae from the low populations recorded in July 1997. These are all encouraging signs, but there will be a need to examine the results for the 1970s and late 1990s in more detail to determine the extent of the recovery from the recent prolonged drought.

7.2 Recommendations

The studies undertaken by the IFE in June/July and December 1997 were designed to re-establish each of the four sites first investigated in the 1970s, and to investigate the extent to which ecological changes had taken place. They also provided an opportunity to document the percentage cover of each major habitat type on each site and to record the densities of each family of macroinvertebrates during the height of a two-year drought. In June 1998, similar studies on each of these four sites revealed a number of post-drought changes, but it was also apparent that most sites still differed from their condition in the 1970s, for a variety of reasons.

The general recommendation from the current study is that it is important to continue the current mapping and sampling programme at these sites because:

A) Long-term monitoring is necessary in order to record and interpret the scale of natural between-year variation and also the response to extreme events such as droughts.

B) Following the 1996/97 drought, it was apparent that only partial 'recovery' had occurred by June 1998 with respect to macrophytes and/or macroinvertebrates at some sites. Further mapping and sampling will be required to determine whether each site returns to the 1970s baseline condition.

C) Continued monitoring of these sites can provide useful information on the value of particular management practices at some sites and the lack of management at others.

D) With each additional year of macroinvertebrate sampling, coupled with the opportunity to interrogate the 1970s database, there are scientific opportunities to examine the persistence of species, variation in the structure of faunal assemblages and the impact of invasive species (e.g. signal crayfish). All these topics are relevant to the conservation of the chalk stream ecosystem and the retention of biodiversity.

Some specific recommendations related to the individual study sites are given below:

R. Lambourn at Bagnor.

1. At this site it is important to continue to monitor the submerged macrophyte community to determine whether the total area of macrophyte is now increasing to the levels observed in the 1970s. The current non-interventionist management strategy at Bagnor has undoubtedly influenced the flora and further mapping will yield information of wider relevance to river management and conservation.

2. It is also important to determine whether the densities of some characteristic chalk stream macroinvertebrates including Baetidae and Simuliidae have returned to their pre-drought densities.

3. Continued monitoring at Bagnor would provide an opportunity to keep a watching brief on the signal crayfish and its potential for long-term impact on this site.

4. There would also be merit in having the capacity to determine the proportion of the total discharge which flows through the north and the south channels of the river at Bagnor.

R. Kennet at Littlecote

5. The management strategy adopted at this site has been maintained over a long period of time, and it offers a useful 'baseline' against which to monitor the more complex changes that have occurred at Savernake. Hence it would be valuable to continue to monitor both the macrophyte and macroinvertebrates of this site as a control.

R. Kennet at Savernake

6. The long-term decline of *Ranunculus* at Savernake was reversed in spectacular manner in spring 1998. Continued mapping is advisable to confirm the new equilibrium and search for an explanation.

7. Further studies on the macroinvertebrates are required to document recovery after the 1996/97 drought. If the current management practices are maintained, then the fauna may start to have more in common with the Littlecote site downstream, rather than Savernake in the 1970s, when the river was managed as a deep, flow-flowing channel.

8. Rehabilitation work is planned for this section of the R. Kennet under a separate project and therefore the long-term monitoring planned within this project will have wider relevance.

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