Institute of Freshwater Ecology

SURVEY OF MACROINVERTEBRATES ON THE RIVER THAMES AT DIDCOT

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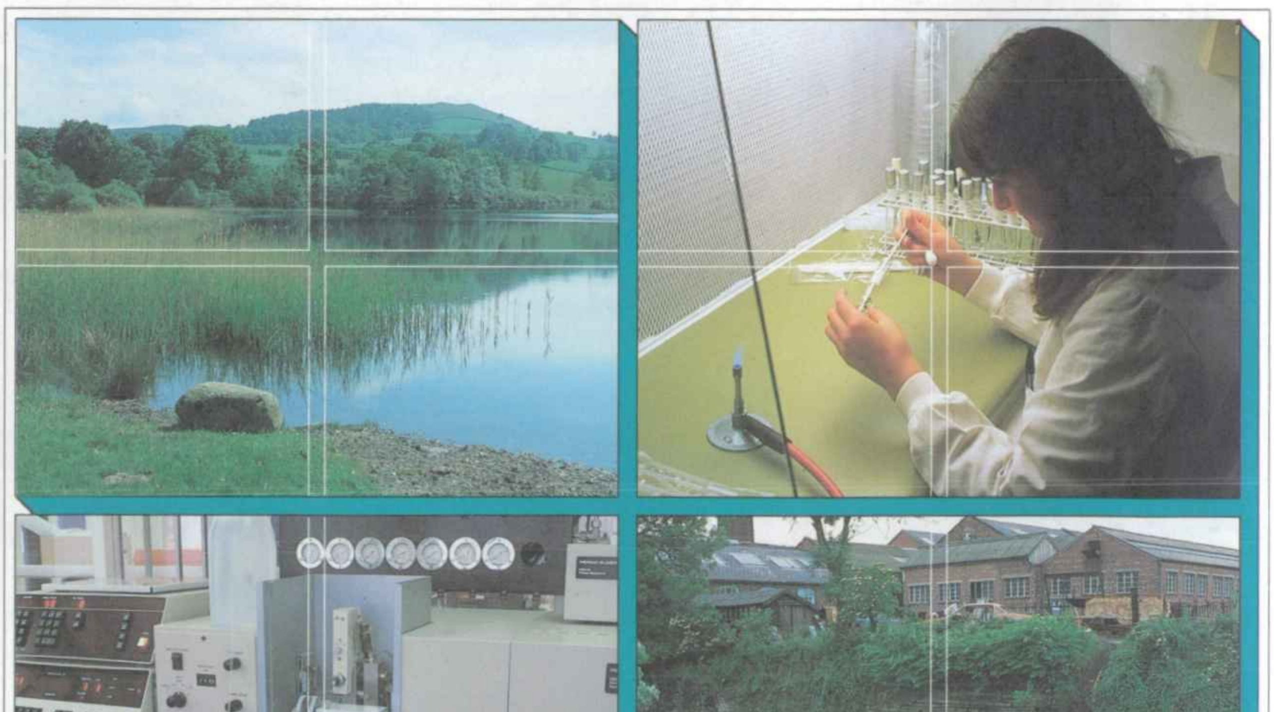
A Report to National Power PLC



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CONTENTS

EXECUTIVE SUMMARY

1. Biological surveys of the macroinvertebrate fauna of the R.Thames were undertaken in the vicinity of Didcot Power Station abstraction and discharge points and Radley Ash Handling discharge point in July 1996.

2. In each case, the aims were to determine whether any short range biological effects could be detected and to provide baseline information for future comparison.

3. At Didcot, three sampling zones, each 250 m in length were chosen. The first (zone A) was upstream of the abstraction point, the second (zone B) was between the abstraction and discharge point, and the third (zone C) was below the discharge point. At Radley, two zones each 450 m in length were chosen. Zone D was upstream of the discharge and Zone E was downstream.

4. Each one of zones A, B and C at Didcot was divided into five 50 m long sections of river. Within each 50 m section, one 15 sec marginal pond-net sample and one 5 m long dredge sample of the river-bed was taken from each of the left and right banks. The precise locations were chosen using random numbers. Ten replicate pond-net and ten replicate dredge samples were therefore available in each of zones A, B and C.

5. Zones D and E at Radley were divided into nine 50 m long sections of river. Both pond-net and dredge samples were taken as before, but sampling was confined to the right bank. As a result, nine replicate samples were available for each of zones D and E.

6. All samples from Zones A-E were processed in the laboratory and the identifications presented at BMWP family level.

7. At Didcot, the pond-net samples from the right (south) bank (that is, zones A, B and C considered as a block) had a lower mean number of BMWP taxa (also BMWP score and ASPT) than those from the left bank. These differences, which were statistically significant, were thought to be a consequence of the greater diversity noted in the macrophytes and substrata encountered on the left bank.

8. When the fauna from dredge samples in zone A (control) was compared with zone B (downstream of the abstraction point), there was no evidence in samples from either bank of a deleterious impact on the fauna due to abstraction. In fact, left bank dredges had a higher number of BMWP taxa in zone B than zone A.

9. When the dredge samples from zone C (downstream of the discharge point) were compared with those from zone A and also zone B, there were no statistically significant differences in the average number of BMWP taxa and BMWP scores between zones C and A or between C and B on either bank. This was despite the visually distinctive pattern of samples on the right bank downstream of the discharge point at Didcot.

10. Marginal pond-net samples did show evidence of lower numbers of BMWP taxa and scores on the right bank of zone C compared to zone B (but not zone A). The reason for this result is most likely to be due to poor quality habitat rather than a direct impact of cooling water discharged from Didcot.

11. The first two dredge samples from the right bank of zone C downstream of the discharge point had lower numbers of BMWP taxa than all other dredge samples on either bank in any of the three zones. The probability of getting the lowest number of taxa in the first sample below the discharge and the second lowest immediately below that is only about 0.5%. These results suggest a very localised effect of the discharge on the fauna of the right bank. Note that this impact on the fauna was not observed in the dredge samples from the left bank of zone C.

12. The sandy substratum encountered in the first dredge sample on the right bank in zone C is a relatively inhospitable habitat for the benthic fauna, and therefore the physical effects of the discharge on the river bed, together with any changes in temperature and effluent within the cooling water may all contribute to the impoverished fauna.

13. At the Radley Ash Handling sampling zones (D and E), there were statistically significant differences in the pond-net samples. Zone D, upstream of the discharge point had a more restricted number of BMWP taxa than Zone E, and once again this appeared to be a consequence of the limited habitat which characterised Zone D compared with Zone E.

14. The dredge samples at Radley revealed that there were no statistically significant differences between Zones D and E for each of the three BMWP indices.

15. During this study a small number of threatened and rare species of macroinvertebrates were noted in dredge samples. They include a threatened mayfly (*Ephemera lineata*), a nationally scarce dragonfly (*Gomphus vulgatissimus*) and a rare leech (*Boreobdella verrucata*).

1. INTRODUCTION

1.1 Background to Contract

In May 1996, Dr G. Bignold and Dr A. Heath of National Power visited the IFE River Laboratory to discuss the practical aspects of biological sampling on the River Thames in the location of the main power station abstraction and discharge points at Didcot and the Radley ash handling discharge point from Pumney Farm ditch. Following this meeting, Dr Bignold prepared a specification for the study, including a number of alternative options. After further discussion and clarification, the IFE submitted a detailed proposal to National Power including options with and without the Radley site study and with sample processing and analysis at different taxonomic levels.

In June 1996, National Power confirmed that Option 3 of the IFE proposal met their requirements. A survey of both the Didcot and Radley sections was therefore planned with identification of the macroinvertebrate fauna to be taken to BMWP family level.

1.2 Contract Requirements

1.2.1 Aim of the survey

The aim of the present survey is to obtain data at locations near to:

a). The Main Power Station abstraction and discharge points at Didcot

b). Radley Ash Handling discharge point from Pumney Farm ditch

in order to ascertain whether any short range biological effects can be detected and to provide a basis for future comparison.

1.2.2 Locations of interest

1. <u>Main Power Station Abstraction and Discharge Points</u>

Zone A : Thames upstream of Abstraction

From confluence of Thames with Culham Cut at	NGR 451100 194850
to abstraction point at	NGR 451600 194700

Zone B : Thames between Power Station CW Abstraction and Discharge

From Abstraction point at	NGR 451600 194700
to discharge point at	NGR 451800 194600

Zone C : Thames downstream of discharge

From discharge point at	NGR 451800 194600
to a point 500 m downstream at	NGR 452300 194500

2 Radley Ash handling Discharge Point from Pumney Farm Ditch

Zone D Thames Upstream of Pumney Farm Ditch

From 500 m upstream of Pumney Farm Ditch	NGR 453100 197300
to confluence with Pumney Farm Ditch	NGR 452700 197050

Zone E : Thames Downstream of Pumney Farm Ditch

From confluence with Pumney Farm Ditch	NGR 452700 197050
to 500 m downstream of Pumney Farm Ditch	NGR 452200 196700

Note: Throughout this report, the terms left and right bank are as recognised by an observer looking downstream.

1.2.3 Survey Requirements

In each of zones A, B and C, five locations are to be chosen by the IFE along each bank and at each location one marginal pond-net sample and one dredge sample are to be taken (i.e. ten pond-net and ten dredge samples per zone). A record of the local habitat of the chosen locations will be prepared, indicating the position of each sample.

In each of zones D and E, three locations are to be chosen by the IFE along the right bank only (left bank is extensively wooded and heavily shaded), and within each location three marginal pond-net samples and three dredge samples are to be taken (i.e. nine pond-net and nine dredge samples per zone). As before, a record of the local habitat of the chosen locations will be prepared, indicating the position of each sample.

For each pond-net sample, a record will be taken of the marginal vegetation sampled, and for each dredge sample, a visual assessment of the substratum composition will be made.

Initial processing of the dredge samples will be undertaken in the field to reduce the bulk of the material to be returned to the laboratory for sorting. In the case of each pond-net sample, all macroinvertebrates are to be sorted from the accompanying material in the laboratory. For each dredge sample, subsampling should be undertaken when considered necessary, taking account of the volume of the substratum and the abundance of the fauna.

From each individual pond-net and dredge sample, a listing of the BMWP families present is to be compiled. BMWP score, Number of Scoring Taxa and Average Score Per Taxon (ASPT) are to be calculated for each pond-net and dredge sample separately. (See Appendix 1 for a brief explanation of the BMWP score system). Results should be displayed visually. Tables with the BMWP indices for all samples, plus mean and standard deviation for each index, by sampling method and zone are to be included in the report. Appropriate statistical tests should be used to determine whether there are significant differences between zones A, B and C on the first study section and between zones D and E on the second study section.

Vials containing the specimens from each sample will be retained, in case there is a future need to count individuals or take identifications further.

2. STUDY SITES

2.1 Selection of sampling sites

2.1.1 Zones A to C

Within each of zones A, B and C, a 250 m length of river was selected for sampling. In zone A it extended from 300 m to 50 m upstream of the abstraction point for the cooling water. The total length of zone B (between the abstraction point and the discharge point downstream) was approximately 350 m. The 250 m used for sampling started just 25 m downstream of the abstraction point and ended 75 m upstream of the discharge point. The sampling reach in zone C commenced approximately 25 m downstream of the discharge point. A diagrammatic representation of zones A to C is given in Figure 1.

In each zone, the 250 m length of river was divided into five 50 m sections (numbered 1-5 from up to downstream) and in each section one marginal 15 second pond-net sample and one deep-water dredge sample were taken from each bank. Within each 50 m section, the position chosen for sampling was determined by the use of random numbers as follows. Each section was divided into ten 5 m subsections, numbered from 0-9. A table of random numbers was used to select one 5 m section which was accepted as long as it satisfied three basic criteria. These were that the bank was accessible with safety, that it lacked artificial reinforcement and that it was not excessively shaded by trees, thus making marginal/dredge sampling impractical. If a site was rejected, then an alternative location was obtained using the same procedure. Once selected, a location was used for the pond-net and also for the dredge sample. In each zone, the procedure was repeated in the five 50 m sections and on each of the two banks. As a result of this protocol, ten replicate pond-net and ten replicate dredge samples were obtained in each zone.

2.1.2 Zones D and E

In each of zones D and E, a 450 m length of river was selected for sampling. The upstream zone D extended from 500 m to 50 m upstream of the Pumney Farm ditch. The limits of zone E were from 50 m to 500 m downstream of the Pumney Farm ditch. All sampling was undertaken from the right (North) bank of the river. A diagrammatic representation of zones D and E is given in Figure 2.

Within each zone, the 450 m length of river was divided into three 150 m sections (numbered 1, 2 and 3), each one of which was then further sub-divided into three 50 m lengths (A, B and C). This gave nine 50 m sections numbered 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 3C from up to downstream in each zone. One marginal 15 second pond-net sample and one deep-water dredge sample were taken in each 50 m section using the earlier procedure based on random numbers. This generated a series of nine replicate pond-net and nine replicate dredge samples for each zone.

2.2 Recording of local habitat and sample features

For each 50 m section within zones A-E, a simple sketch map was drawn. This indicated the main visual features on the bank, including the occurrence of trees, and the location at which the marginal and dredge samples were taken. It should be pointed out that all distance measurements along the river bank were paced, rather than measured with a tape. The sampling team were familiar with this technique and the sketch maps have sufficient detail to enable each section to

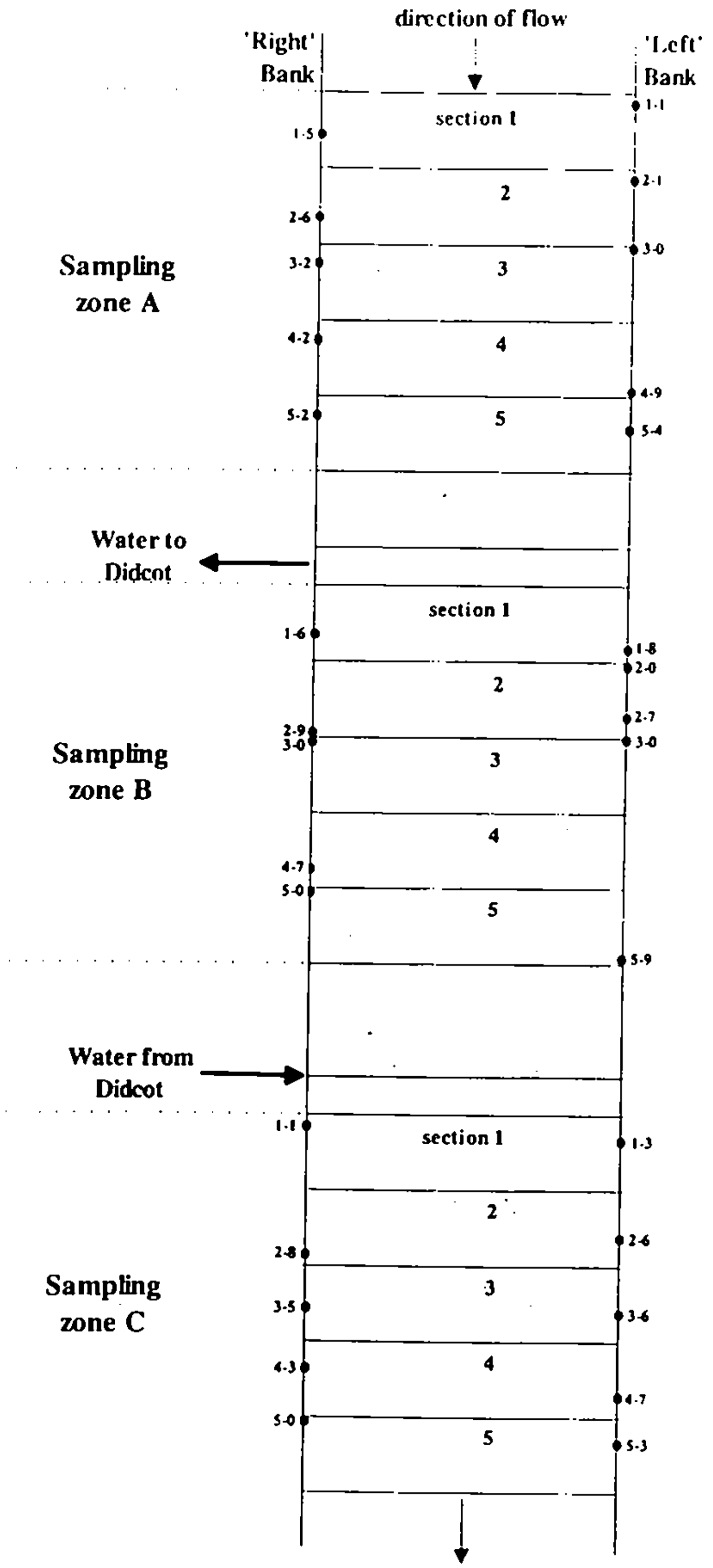

Figure 1 A diagrammatic representation of zones A, B & C, indicating the position of the abstraction & discharge points & also the biological sampling sites on each bank.

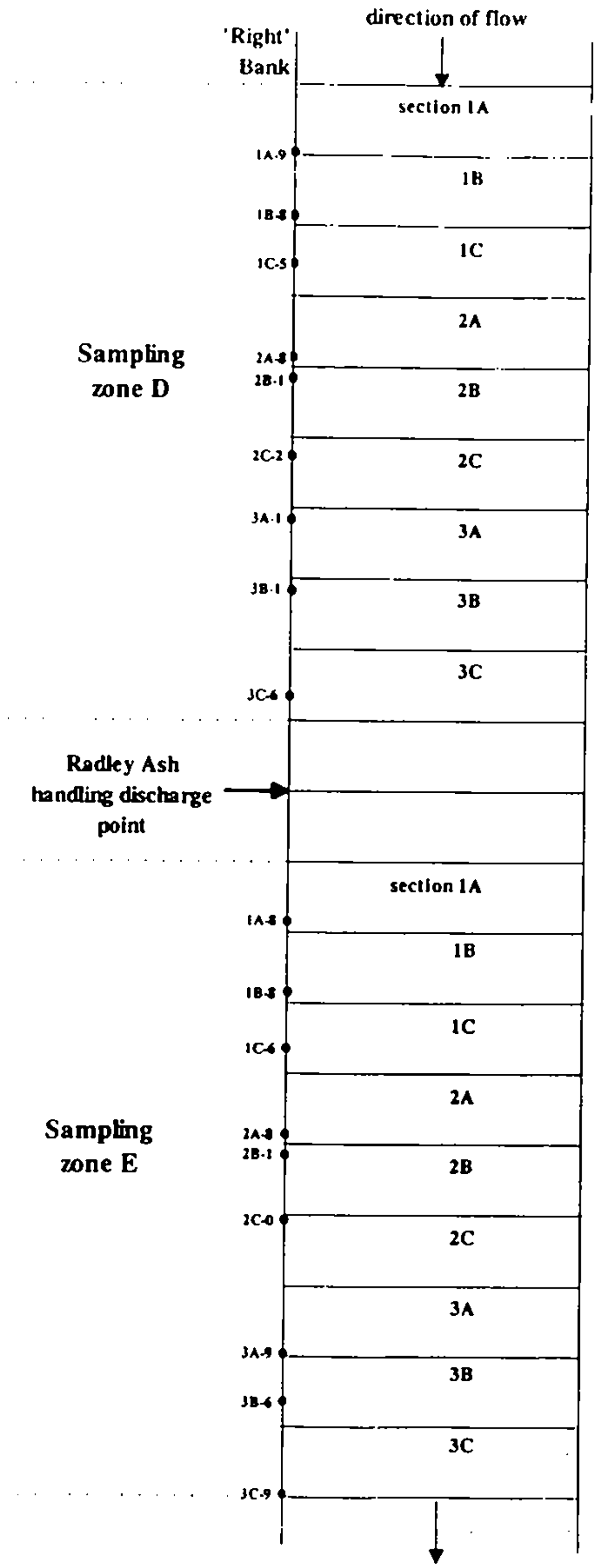

Figure 2 A diagrammatic representation of zones D & E, indicating the position of the Radley Ash handling discharge point & also the biological sampling sites on the right bank.

be recognised, should further sampling be required in future. In addition, photographs showing bankside and marginal vegetation were taken in each section and are available as a set of labelled colour transparencies.

The practical problems of obtaining relevant information on river-bed composition which can be associated with the fauna in the dredge samples were discussed in the original proposal. Inevitably, the dredge itself will have a tendancy to loose an unknown proportion of fine material as it is pulled through the water towards the bank. Nevertheless, by using the same dredging technique, the subjective information obtained on bed composition for each sample should be of value when viewed in relation to the macroinvertebrate fauna taken in the same dredge.

In practice, several sources of information were available for documenting the major features of the dredge samples. First, a visual assessment of the dominant substratum within each dredge sample was made, together with a record of other categories of substratum present. Second, a photograph was taken of each dredge sample. Finally, as the samples were being sorted in the laboratory, any further categories of substratum were noted, together with the presence of leaves, woody material, algae and macrophytes.

In the case of the marginal pond-net samples, field records were taken of the substratum and macrophytes which were being sampled, and further information on the species of macrophyte and other material in the samples was recorded during laboratory sorting.

3. METHODS FOR INVERTEBRATES

3.1 Field Procedures

Once a given sampling location had been selected within a 50 m section, a 15 second pond-net sample was collected from the margin of the river, followed by a deep-water dredge sample. Pond-net samples were taken with a standard net (1 mm mesh, 230 x 255 mm frame, 275 mm bag depth) on a 1.5 m handle using a kick and sweep technique. Where possible, all habitats along the river margin within the 5 m subsection were included ie roots and stems of each variety of plant as well as the marginal substratum. Submerged and emergent vegetation were sampled by pushing the net into them using a variety of forward and upward movements. The substratum was sampled by skimming the bottom edge of the net through the surface layer and occasionally by stirring up the surface by foot and passing the open net through the disturbed sediment. The sample time of 15 seconds represents the time of active sampling, and excludes any time taken to reach a particular habitat.

Large mineral and vegetable particles were rinsed within the semi-submerged net and discarded after checking that no animals remained attached to them. Any fine sediment was washed through the net. The remainder of the sample, was then transferred to a polythene bag, adding any material that was attached to the mesh of the net. River water was added to the bag followed by sufficient 40% formaldehyde to make the resultant concentration approximately 5%. This ensured that the sample would be fixed and preserved. The volume of liquid was limited to that required to allow the fixative to permeate the whole sample. A waterproof label was placed inside the bag which was then sealed with a knot and placed in a labelled, air-tight, polythene sample jar. The pond-net was turned inside out, washed thoroughly in the river and inspected for animals after each sample was completed.

Deep-water qualitative dredge samples were taken from the bank using a medium Naturalist's dredge (also known as a rectangular dredge). The dredge was 5 kg in weight with a 46 x 20 cm aperture and fitted with a 1 mm mesh collecting net protected by a sleeve of heavy cotton material. A stout towing rope, marked at 2.5 m intervals, was attached to one of the arms of the dredge. The two arms were connected by a weak link with a breaking strain of about 25 kg to prevent the arms separating during normal use but allowing separation should the dredge become stuck, thus giving a better chance of retrieval.

After attaching the loose end of the rope to a fixed object on the bank, the dredge was thrown as far as possible into the main channel of the river. Where conditions allowed, it was thrown at the lower end and retrieved from the upstream end of the 5 m sampling subsection, such that the trawl was diagonally across the sample area in an upstream direction. The dredge was trawled for a distance of 5 m along the bed of the river. This was achieved by pulling the rope from close to the water surface in a series of short tugs, thus maximising the chances of the edge of the dredge digging into the substratum. When 5 m of rope had been recovered, the angle of pull was maximised and the dredge retrieved at speed, which caused it to glide over the substratum rather than digging into it. When it reached the bankside the dredge was removed from the water, the contents were visually assessed for estimation of particle size and displayed and labelled for a photograph.

On occasions, the net became snagged around the mouth of the dredge on or after entry into the water, resulting in a poor catch, in which case a new sample was collected. Similarly, when the dredge became caught on an underwater obstacle and could only be retrieved by breaking the weak link, the process was repeated to obtain a representative sample

Once the sample had been photographed, it was reduced in volume by transfering small aliquots to the pond-net which was then dipped in the river several times to allow fine particles to wash through the mesh. Any large mineral or vegetable particles were removed as described above. The sample was then transferred to one or two polythene bags, depending on the amount of material, and fixed with formaldehyde as described above.

It was considered that a representative sample would constitute a volume of material within the range 0.5-2.0 l. When the sample was smaller than 0.5 l in volume, the collecting net was emptied and a further trawl was made in another part of the 5 m subsection. The two parts of the sample were then combined. On no occasion was more than two trawls required to achieve a representative sample. When the dredge sample exceeded 2.0 l in volume after removal of fine and large particles, it was washed through two large stacked sieves, mesh sizes 1.7 mm and 355 µm, and a sub-sample taken from each sieve to produce a final volume not exceeding 2.0 l. After each sample the dredge, pond-net and sieves were washed thoroughly. Appendix 2 provides additional information on those samples where two trawls were required, cases where subsampling was necessary and the instances where the final volume of the sample occupied two rather than one polythene sample jar (each jar 1.25 l in volume).

3.2 Laboratory Procedures

3.2.1 Pond-net samples

Each sample was washed thoroughly with tap water through a 500 µm sieve to remove formaldehyde and silt, then examined carefully by spreading small aliquots under water in a gridded, white, flat-bottomed tray and sorting through the material by eye. All animals found were placed in a labelled vial containing preservative (70% industrial methylated spirit). The fauna was then identified to BMWP family level and recorded. Empty mollusc shells and caddis cases were not included as records of a taxon. Although a qualitative survey was required, the animals were returned to the vial and stored so that further identification to species level or an estimation of percentage composition was possible.

3.2.2 Dredge samples

Each dredge sample was analysed as above, with the exception that for samples where a particular taxon occurred in great abundance (>50 specimens), not all representatives of that taxon were removed from the sample. This was achieved either by subsampling, where animals were picked out from a constant proportion of the gridded tray, or, once approximately 30 specimens of that taxon were removed, by counting further individuals and leaving the specimens in the tray. In the former case, a multiplication factor would be applied in any future calculation of proportional abundance.

4. STATISTICAL METHODS

All statistical analyses were carried out for each of the three BMWP indices (number of BMWP taxa, BMWP score and ASPT) and separately for the pond-net and dredge samples.

At the Didcot study site, two-way analysis of variance with interaction (2-way ANOVA) was used to give variance ratio F tests for overall differences between the three zones (A-C) and two banks (left/right). The interaction (zone by bank) measures the extent to which the difference between the three zones varies between the two banks, and vice versa. If the bank differences or interaction are statistically significant then it is important to examine each bank separately. The 15 values of each BMWP index for each bank were then analysed separately by one-way ANOVA using an F test for differences in mean values between the three zones on a particular bank. This was followed by Student t tests for differences in mean value between each pair of zones (A-B, A-C, B-C); these t tests assumed unequal within-zone variability as seemed appropriate from the data. The 1-way ANOVA and t tests were also repeated using their non-parametric equivalents, the Kruskal-Wallis ANOVA by ranks and Mann-Whitney rank tests. These tests are influenced less by odd outlier values and assess the tendency for index values to be lower in one zone than another. Low values of a test statistic's probability significance level (p) are taken to indicate that differences exist (between zones or banks as appropriate). A p value of less than 0.05 was taken to indicate a probable difference (no allowance being made for the number of pairs of zones being tested as all three pairwise zone comparisons were of prior interest).

At the Radley Ash Handling Discharge point, overall differences between the upstream and downstream zones (D and E) were assesed by both t tests and Mann-Whitney tests, as described above.

5. RESULTS

5.1 Main Abstraction and Discharge points at Didcot

5.1.1 Location of samples in zones A to C

Figure 1 gives a diagrammatic representation of the River Thames in zones A to C. Water is abstracted for use at Didcot Power station 50 m downstream of the lower limit of zone A and is discharged into the R.Thames approximately 25 m upstream of the start of zone C. Zone B commences 25 m downstream of the abstraction point and ends 75 upstream of the discharge point. The precise locations at which all pond-net and dredge samples were taken, based on the stratified random sampling protocol, are shown for each bank, Note that in zone B, on the left bank, section 4 had artificial bank reinforcement throughout (as did much of section 3) and therefore sampling criteria were not met. To ensure that a total of five samples were available for the left bank of zone B, a further sample was taken from section 2 (sample number 2-7)

5.1.2 Habitat features for pond-net and dredge samples

Background information on the habitat characteristics of the pond-net sampling locations is given in Table 1. The dominant substratum recorded on the sketch map at the time of sampling, together with other particles recorded on the field sketch map and observed in the samples within the laboratory are noted. The table also includes a listing of the macrophytes sampled, and the range of macrophytes/organic material observed within the sample during laboratory sorting. The dominant substratum on the left (north) bank varied more between sampling locations than the right (south) bank where the dominant substratum was normally compacted clay. Whereas *Nuphar lutea*, the yellow water lily, was the most frequently encountered macrophyte on the left bank, *Sparganium emersum* occupied this position on the right bank. In general terms, it appeared that the left bank was more natural, and that the right bank was prone to more disturbance by fishermen.

Information on the characteristics of the dredge samples is presented in Table 2. For each sample, the dominant substratum type and other particles observed within the dredge are recorded. Further information on the macrophytes/organic matter present, as noted on the sketch map and seen during the laboratory processing of each sample is also presented. The dominant substratum particle varied from sample to sample, and there appeared to be a tendency for zone B to be dominated by coarser particles. Nevertheless, throughout zones A to C most samples included a wide range of particle types, from coarse particles to the detritus recorded in most samples during laboratory processing. Many samples from the left (north) bank were also notable for the presence of *Nuphar lutea*, *Sparganium emersum*, algae and allochthonous material (leaves, twigs and stems), whereas samples from the right (south) bank rarely included more than *Sparganium emersum* and algae.

Table 1 Habitat features for the pond-net samples taken in zones A to C. For further explanation see section 5.1.2.

Sampling Location				Dominant substratum	Other particles present						Macrophytes sampled																
				Sketch	*Sketch (+ 2 page sheet)*						*Sketch*						*Laboratory notes*										
Zone	Bank	Section	Sub-section		Pebbles	Gravel	Sand	Silt	Clay	Detritus	Nuphar	Phalaris	Phragmites	Scirpus	Sparganium erectum	Sparganium emersum	Algae	Detritus	Grass	Leaves	Moss	Nuphar	Roots	Sparganium emersum	Twigs and stems
A	L	1	1	Clay (compacted)	1	1					1				1		1			1		1			1
A	L	2	1	Clay (compacted)						1		1		1			1	1		1		1		1	
A	L	3	0	Boulders	1	1	1	1			1				1		1			1		1			1
A	L	4	9	Silt						1				1		1		1				1			1
A	L	5	4	Clay (compacted)				1		1	1			1		1	1			1		1		1	1
B	L	1	8	Silt						1	1						1	1				1	1		
B	L	2	0	Detritus				1					1				1	1							
B	L	3	0	Sandy gravel	1					1	1				1		1	1		1		1			
B	L	2	7	Detritus						1	1		1				1	1							
B	L	5	9	Sand	1			1		1	1				1	1	1	1				1			
C	L	1	3	Sandy gravel							1				1					1				1	
C	L	2	6	Detritus							1				1		1					1		1	1
C	L	3	6	Clay (compacted)				1			1					1	1				1	1			1
C	L	4	7	Clay (compacted)							1				1	1				1		1		1	
C	L	5	3	Clay (compacted and granules)						1							1	1							
A	R	1	5	Clay (compacted)						1	1			1	1			1		1		1		1	
A	R	2	6	Clay (compacted)				1						1		1									
A	R	3	2	Clay (compacted)						1					1		1	1		1		1		1	
A	R	4	2	Boulders			1	1	1	1	1				1	1	1	1							
A	R	5	2	Clay (compacted)						1	1				1			1							
B	R	1	6	Clay (compacted)						1					1		1	1							
B	R	2	9	Clay (compacted)				1							1									1	
B	R	3	0	Clay (compacted)				1							1		1			1		1		1	
B	R	4	7	Clay (compacted)						1	1				1			1						1	
B	R	5	0	Clay (compacted)						1	1				1			1							
C	R	1	1	Silt						1		1			1		1	1		1					
C	R	2	8	Clay (compacted and granules)						1					1	1		1							
C	R	3	5	Clay (compacted)											1										
C	R	4	3	Clay (compacted)	1	1	1			1								1							
C	R	5	0	Clay (compacted and granules)						1								1							

Table 2 Habitat features for the dredge samples taken in zones A to C

Sampling Location				Dominant substratum	Other particles present										Macrophytes sampled															
				Sketch	*Sketch (+ 2 page sheets)*										*Sketch*							*Laboratory notes*								
Zone	Bank	Section	Sub-section		Boulders	Cobbles	Pebbles	Peat	Gravel	Sand	Silt	Clay	Detritus	Large Unionid shells	Detritus	Nuphar	Phalaris	Phragmites	Scirpus	Sparganium emersum	Sparganium erectum	Algae	Detritus	Leaves	Moss	Nuphar	Peat	Roots	Sparganium emersum	Twigs and stems
A	L	1	1	Clay (compacted)		1										1			1	1		1		1	1				1	1
A	L	2	1	Clay	1	1										1	1		1	1		1	1	1					1	1
A	L	3	0	Pebbles	1											1				1						1			1	
A	L	4	9	Gravel									1						1		1	1	1	1		1			1	1
A	L	5	4	Detritus							1		1			1			1		1	1	1			1				
B	L	1	8	Gravel (compacted)			1						1			1		1					1			1				
B	L	2	0	Pebbles							1							1				1	1			1				
B	L	3	0	Gravel			1			1			1			1				1		1	1						1	
B	L	2	7	Cobbles			1	1					1			1		1					1			1	1		1	
B	L	5	9	Pebbles (compacted)										1		1			1	1	1		1			1				
C	L	1	3	Pebbles (compacted)						1						1				1				1					1	
C	L	2	6	Pebbles (compacted)					1	1						1				1			1	1		1			1	
C	L	3	6	Silt		1										1					1		1						1	
C	L	4	7	Pebbles (compacted)									1	1		1				1	1		1			1			1	
C	L	5	3	Silt			1		1	1												1	1						1	
A	R	1	5	Silt	1	1	1		1			1		1		1			1	1		1	1						1	
A	R	2	6	Detritus										1					1		1	1	1			1			1	
A	R	3	2	Silt	1	1						1								1			1							
A	R	4	2	Silt	1		1		1	1		1								1	1	1	1						1	
A	R	5	2	Silt					1											1			1							
B	R	1	6	Cobbles (compacted)			1													1			1						1	
B	R	2	9	Pebbles		1			1	1				1						1									1	
B	R	3	0	Pebbles		1			1											1		1	1						1	
B	R	4	7	Pebbles		1			1							1				1			1						1	
B	R	5	0	Gravel			1									1				1			1						1	
C	R	1	1	Sand							1									1			1							
C	R	2	8	Detritus							1									1	1		1						1	
C	R	3	5	Clay (granules)					Cl				1							1			1							
C	R	4	3	Silt			1		1	1			1										1							
C	R	5	0	Cobbles (compacted)					1		1	1											1		1			1	1	

5.1.3 Macroinvertebrate data for pond-net and dredge samples

The raw data on the occurrence of BMWP families for each block of five samples in zones A, B, and C (left bank pond-net, left bank dredge, right bank pond-net, right bank dredge) may be found as a series of tables in Appendix 3. At the foot of each table BMWP score, the Average Score Per Taxon (ASPT) and the number of BMWP taxa are also given for each individual sample.

From the sixty pond-net/dredge samples examined in zones A, B and C, a total of 46 BMWP families were recorded. The number of BMWP families found per zone, bank location and sample type, as derived from amalgamating the results for each block of five samples, is shown in Table 3. Pond-net samples from the right bank were less taxon rich than those from the left bank for each of the three river sections. Differences in the macrophytes of these two banks were noted in section 5.1.2. Taxon richness from five deep water dredge samples was surprisingly similar (range 28-35 taxa) for each zone/bank combination but lowest for the right bank of section C. A more detailed statistical appraisal is given below.

Table 3 Total number of BMWP taxa per zone, bank & sampling method (n=5 samples)

BANK/METHOD	ZONE A	ZONE B	ZONE C	**Total for method**
Left/Pond-net	36	33	32	**41**
Left/Dredge	31	32	35	**39**
Right/Dredge	33	35	28	**37**
Right/Pond-net	24	29	24	**36**
Total for Zone	**42**	**40**	**43**	**46**

The individual sample results at BMWP family level are presented visually by zone, bank location and sample type in Figure 3 (BMWP taxa), Figure 4 (BMWP score) and Figure 5 (ASPT). The visual patterns of the results in Figures 3 and 4 were very similar, as would be expected. The correlation between BMWP taxa and BMWP score was 0.96 over the 30 pond-net samples and 0.98 over the 30 dredge samples, indicating that BMWP score is mostly a measure of number of BMWP taxa; thus further discussion will concentrate on results for BMWP taxa. The mean (and standard deviation) for the number of taxa, BMWP score and ASPT, based on the five samples from each zone, bank location and sample type are presented in Table 4. This indicates that in each of the three zones, the pond-net samples from the right bank have a lower mean number of BMWP taxa, mean BMWP score and mean ASPT than those from the left bank. These overall differences between banks are all statistically significant, as shown by 2-way ANOVA, (Table 5).

For the individual dredge samples, differences between zones and banks were only statistically significant ($p<0.05$) for number of BMWP taxa, although a significant bank-zone interaction for ASPT also suggested the data should be examined separately for each bank.

Table 4 Mean values and standard deviation for the number of BMWP taxa, BMWP score & ASPT by zone, bank & sampling method.

A. BMWP Taxa

BANK/METHOD	ZONE A		ZONE B		ZONE C	
	Mean (±S.D.)	Range	Mean (±S.D.)	Range	Mean (±S.D.)	Range
Left/Pond-net	19.8±2.28	16-22	22.0±2.55	18-25	16.2±6.06	7-21
Left/Dredge	23.4±1.52	22-25	25.8±1.48	24-28	23.6±2.07	20-25
Right/Dredge	23.0±3.46	17-25	23.2±3.96	17-27	16.2±7.53	5-23
Right/Pond-net	14.6±3.78	11-20	16.4±1.67	15-19	12.2±1.64	10-14

B. BMWP Score

BANK/METHOD	ZONE A		ZONE B		ZONE C	
	Mean (±S.D.)	Range	Mean (±S.D.)	Range	Mean (±S.D.)	Range
Left/Pond-net	89.8±15.58	73-112	107.4±16.26	88-133	74.0±27.40	31-102
Left/Dredge	113.2±16.48	97-134	131.6±11.26	121-148	126.6±14.36	103-141
Right/Dredge	119.6±18.35	89-133	120.2±24.28	83-143	80.2±41.96	15-114
Right/Pond-net	59.2±20.74	41-92	74.6±4.22	70-80	52.8±7.82	42-59

C. ASPT

BANK/METHOD	ZONE A		ZONE B		ZONE C	
	Mean (±S.D.)	Range	Mean (±S.D.)	Range	Mean (±S.D.)	Range
Left/Pond-net	4.53±0.442	3.85-5.09	4.87±0.303	4.48-5.32	4.59±0.476	4.05-5.10
Left/Dredge	4.82±0.393	4.41-5.36	5.10±0.169	4.84-5.29	5.36±0.184	5.15-5.64
Right/Dredge	5.20±0.104	5.04-5.32	5.16±0.252	4.88-5.50	4.67±0.938	3.00-5.25
Right/Pond-net	3.99±0.373	3.67-4.60	4.57±0.300	4.21-4.88	4.33±0.339	3.82-4.70

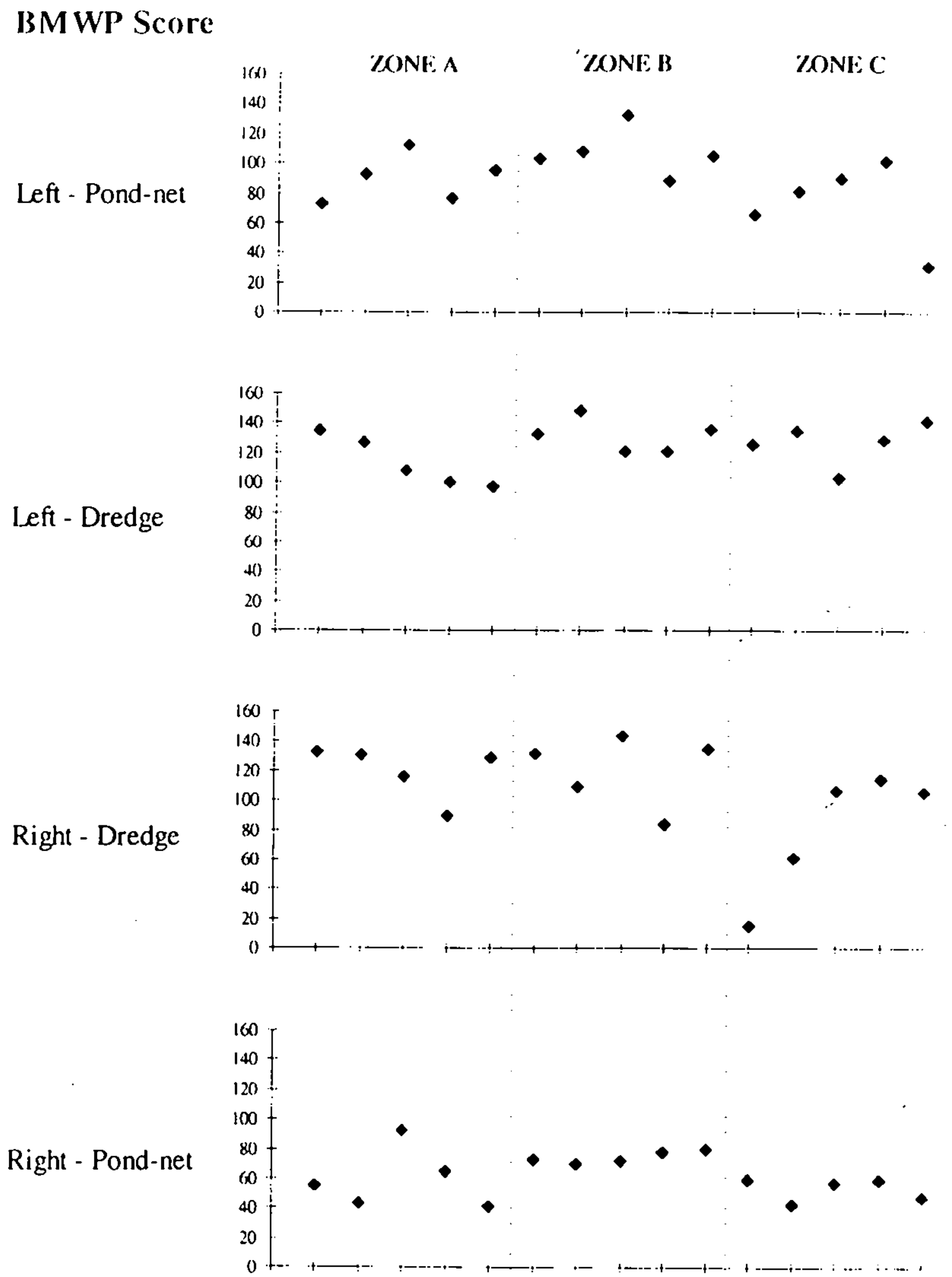

Figure 4 BMWP scores recorded in the pond-net and dredge samples from the left & right banks of zones A, B & C.

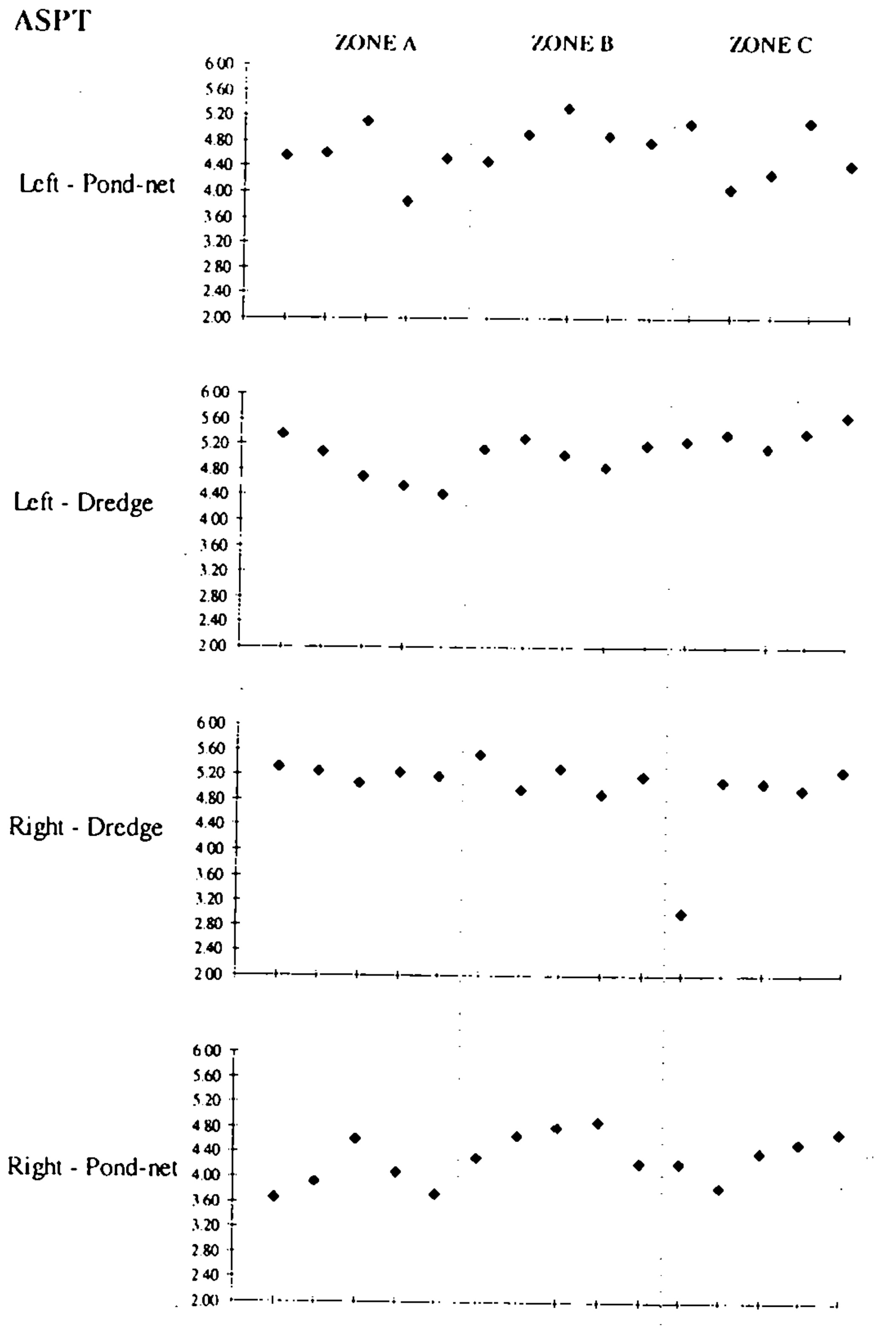

Figure 5 Average Score Per Taxon (ASPT) recorded in the pond-net & dredge samples from the left & right banks of zones A, B & C.

The 2-way ANOVA indicated differences between the three zones for each BMWP index for pond-net samples (Table 5). For both pond-net and dredge samples, the average value of each BMWP index was higher in zone B than zones A or C for both the left and right bank, except for ASPT in the dredge samples (Table 4). Further statistical analyses examined the data separately for each bank (Table 6). For the pond-net samples, zone B had a statistically significant ($p<0.05$) higher average number of BMWP taxa and BMWP score than zone C on the right bank and there was some indication that this also applied to the left bank (Table 6). For the dredge samples, only the left bank samples showed any significant ($p<0.05$) differences between zones: number of BMWP taxa was higher in zone B than zone A, whilst ASPT was higher in zone C than both zones A and B.

These standard statistical tests, of necessity, assess differences in the average BMWP index values for each zone and bank, with no regard to the longitudinal patterns of the sample values within each section. It is important and useful to examine the patterns of values in relation to their distance up and downstream of both the abstraction and discharge point (Figs 3, 4 and 5).The number of taxa in the individual dredge samples taken from the left bank in zones A,B and C were relatively similar (range 20-28 taxa) (Fig. 3). However, on the right bank, the first two dredge samples from zone C were less taxon-rich and had lower BMWP scores than all other dredge samples in any zone. The probability of the two lowest of 15 values on one bank occurring in two adjacent samples by chance is 13% (=14/105), whilst the chance of getting the observed pattern with the lowest value immediately below the discharge point and the second lowest immediately downstream is only about 0.5% (1/(15x14)). The ASPT results for the dredge samples (Fig. 5) tended to follow the pattern observed for the number of BMWP taxa, except that only the first sample from the right bank of zone C was very low. Approximately 150m downstream of the discharge point (ie the sample in section C3) number of taxa and ASPT had returned to the range of levels found in right bank dredge samples throughout zones A and B. These results suggest a very localised effect of the discharge on the benthic fauna.

It is also apparent that in all zones, dredge samples have a higher mean number of BMWP taxa than the adjacent pond-net samples. However, it is important to realise that different sampling procedures were used to obtain these results and, refering back to Table 3, there were, overall, a wider range of BMWP taxa recorded in the five pond-net samples from the left bank of zone A (36 taxa) than in the five dredge samples (31 taxa).

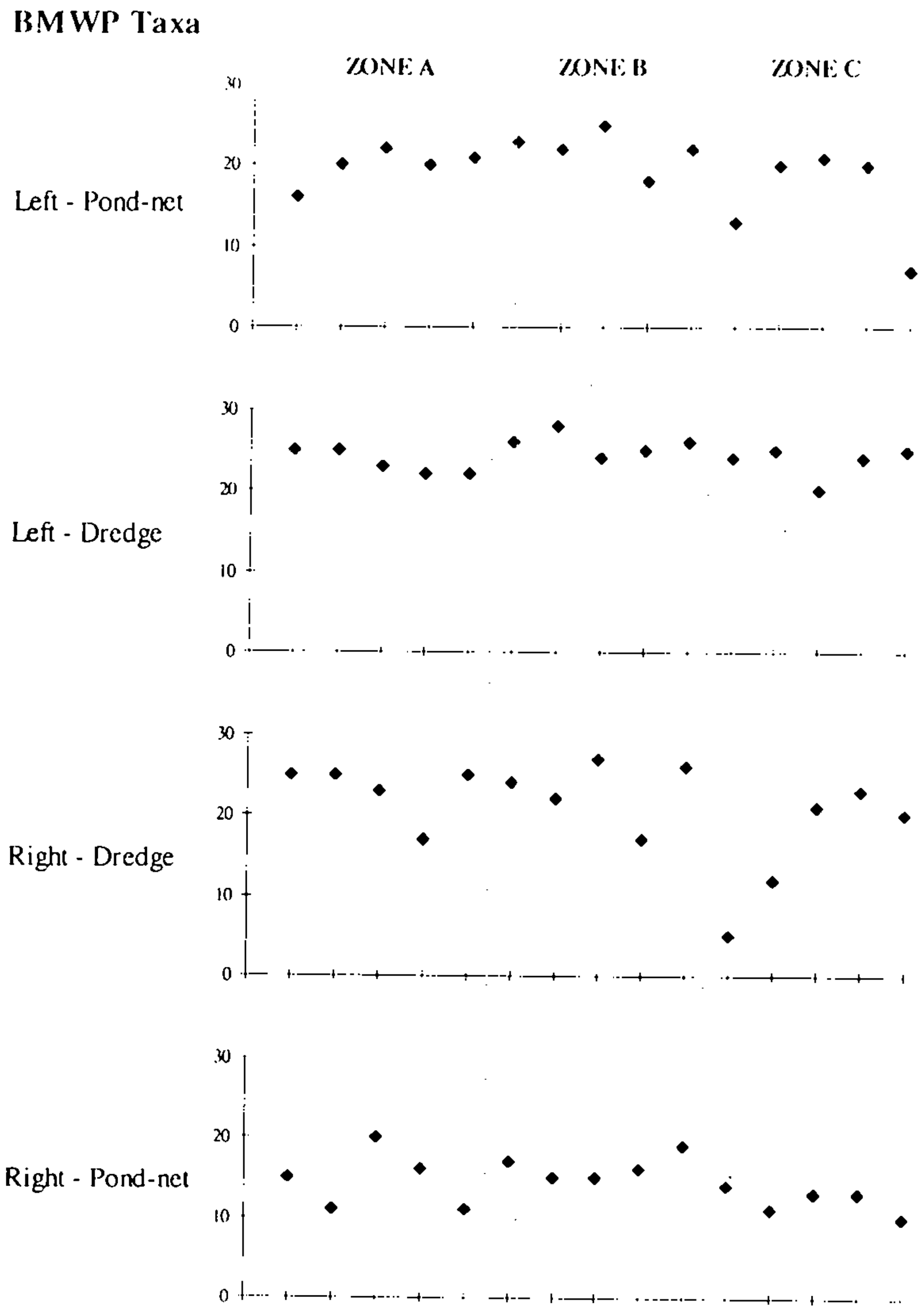

Figure 3 Number of BMWP taxa recorded in the pond-net and dredge samples from the left and right banks of zones A, B & C.

Table 5 Analysis of variance F tests for differences at Didcot between the individual zones (A, B and C) and banks (left/right) and any interaction effect (Zone*Bank) for each BMWP index for pond-net and dredge samples. df = degrees of freedom; p = significance probability level of F test value; * highlights p values less than 0.05.

Sample type	BMWP Index	Source of variation	df	Mean Square	F	p
Pond-net	Taxa	Zone	2	63.33	5.57	0.0103*
		Bank	1	182.53	16.06	0.0005*
		Zone*Bank	2	1.73	0.15	0.8594
		Residual	24	11.37		
	Score	Zone	2	1928.7	6.55	0.0054*
		Bank	1	5964.3	20.26	0.0001*
		Zone*Bank	2	94.9	0.32	0.7276
		Residual	24	294.5		
	ASPT	Zone	2	0.537	3.75	0.0381*
		Bank	1	0.998	6.97	0.0143*
		Zone*Bank	2	0.054	0.38	0.6892
		Residual	24	0.143		
Dredge	Taxa	Zone	2	56.23	3.62	0.0423*
		Bank	1	90.13	5.80	0.0240*
		Zone*Bank	2	32.03	2.06	0.1491
		Residual	24	15.53		
	Score	Zone	2	1275.8	2.23	0.1194
		Bank	1	2201.6	4.01	0.0566
		Zone*Bank	2	1804.0	3.29	0.0547
		Residual	24	548.3		
	ASPT	Zone	2	0.045	0.23	0.7960
		Bank	1	0.049	0.25	0.6197
		Zone*Bank	2	0.753	3.86	0.0353*
		Residual	24	0.195		

Table 6 Statistical tests for differences between the individual zones (A, B and C), considered separately for each bank for each BMWP index for pond-net and dredge samples at Didcot. p(F), p(K) = significance test probability levels of a one way analysis of variance F test (with 2 and 12 degrees of freedom) and Kruskal-Wallis analysis of ranked values respectively. * highlights p values less than 0.05. Differences between pairs of zones were assessed by Student t tests (assuming unequal variability within zones) and Mann-Whitney test of ranks and the direction of differences with $p<0.05$ are indicated (eg A>C indicates zone A has higher values than zone C)

Sample type	BMWP	Bank	p(F)	p(K)	Differ by	Differ by
Pond-net	Taxa	Left	0.111	0.075		
		Right	0.069	0.047*	B>C	B>C
	Score	Left	0.071	0.075		B>C
		Right	0.056	0.045*	B>C	B>C
	ASPT	Left	0.395	0.472		
		Right	0.058	0.075	B>A	B>A
Dredge	Taxa	Left	0.086	0.075	B>A	
		Right	0.099	0.097		
	Score	Left	0.148	0.241		
		Right	0.092	0.085		
	ASPT	Left	0.026*	0.041*	C>A and B	C>A
		Right	0.290	0.402		

5.2. Radley Ash Handling Discharge point

5.2.1 Location of samples in zones D and E

Figure 2 gives a diagrammatic representation of the River Thames in zones D and E. Each zone was 450 m in length, and whereas zone D ended 50 m upstream of the discharge point, zone E commenced 50 m downstream of the discharge point. As before, the precise locations for all pond-net and dredge samples were determined using the stratified random sampling protocol, but for zones D and E sampling was confined to the right bank.

5.2.2 Habitat features for pond-net and dredge samples

Background information on the habitat characteristics of the pond-net sampling locations is given in Table 7. As in the similar table relating to zones A to C, it includes the dominant substratum and other particles at the sampling site, a listing of the macrophytes sampled and the range of macrophytes/organic material observed within the sample during laboratory sorting.

Within zone D, beyond the tall bankside herbs, there was no marginal emergent vegetation and sampling was undertaken on a narrow solid clay ledge. *Nuphar lutea* was the only submerged macrophyte noted during sampling, and this was confined to just five of the nine samples. In contrast, zone E displayed much greater habitat diversity. The dominant substratum varied from sample to sample and several different emergent macrophytes and submerged macrophytes were recorded when the nine pond-net samples were taken.

Information on the characteristics of the dredge samples is presented in Table 8. Once again, the dominant substratum type and other particles observed within each dredge sample are recorded, together with the range of macrophytes/organic matter noted in the field and during the laboratory processing of each sample.

Without exception, the dominant substratum particle in zone D was clay in one of its many forms, although most dredge samples also included other categories of particles. The only macrophyte collected by dredge samples in this zone was *Nuphar lutea*. Clay was the dominant particle for the first three samples taken in zone E, after which further categories from silt to pebbles were dominant in some samples. As in zone D, additional particle categories normally accompanied the dominant substratum type, but a wider range of submerged macrophytes were encountered.

5.2.3 Macroinvertebrate data for pond-net and dredge samples

The raw data on the occurrence of BMWP families for each block of nine samples in zones D and E may be found as a series of tables in Appendix 4. At the foot of each table the BMWP score, the Average Score Per Taxon (ASPT) and the number of BMWP taxa are also given for each individual sample.

From the 36 pond-net/dredge samples examined in zones D and E, a grand total of 40 BMWP families were recorded. The number of BMWP families found per zone and sample type, derived by amalgamating the results for each block of nine samples, is shown in Table 9. The pond-net samples from zone D yielded just 20 BMWP families, in contrast to zone E, where 37 families were found. There is little doubt that the poor habitat diversity noted in the marginal area of zone D had a major influence on the limited range of taxa recorded. The 37 BMWP families recorded

Table 7 Habitat features for the pond-net samples taken in zones D and E.

Sampling Location				Dominant substratum	Other particles present						Macrophytes sampled													
				Sketch	*Sketch (+ 2 page sheets)*						*Sketch*							*Laboratory notes*						
Zone	Bank	Section	Sub-section		Cobbles	Pebbles	Gravel	Sand	Silt	Detritus	Elodea	Glyceria	Nuphar	Phalaris	Phragmites	Sparganium emersum	Typha	Algae	Detritus (Laboratory notes)	Grass	Leaves	Nuphar (Laboratory notes)	Roots	Sparganium emersum (Laboratory notes)
D	R	1A	9	Clay (compacted, nodules and granules)														1		1	1			
D	R	1B	8	Clay (compacted)														1			1	1		
D	R	1C	5	Clay (compacted, nodules and granules)														1						
D	R	2A	8	Clay (compacted)			1						1					1						
D	R	2B	1	Clay (compacted and nodules)			1			1			1						1					
D	R	2C	2	Clay (compacted)									1									1	1	
D	R	3A	1	Gravel				1		1			1						1	1				
D	R	3B	1	Clay (compacted)			1						1								1			
D	R	3C	6	Clay (compacted)																			1	
E	R	1A	8	Silt						1				1					1					
E	R	1B	8	Clay (compacted)		1	1	1		1					1				1					
E	R	1C	6	Clay (compacted)			1	1		1				1					1					
E	R	2A	8	Clay (compacted)						1	1		1			1		1	1		1			
E	R	2B	1	Clay (compacted and nodules)						1								1	1					
E	R	2C	0	Gravel and clay nodules			1	1					1								1	1		
E	R	3A	9	Clay (nodules)			1	1	1	1		1						1	1					1
E	R	3B	6	Silt and clay nodules						1									1					
E	R	3C	9	Detritus	1	1			1	1							1		1					

Table 8 Habitat features for the dredge samples taken in zones D and E.

Sampling Location				Dominant substratum	Other particles present							Macrophytes sampled													
				Sketch	Sketch (+ 2 page Sheets)							Sketch									Laboratory notes				
Zone	Bank	Section	Sub-section		Cobbles	Pebbles	Gravel	Sand	Silt	Clay	Detritus	Elodea	Glyceria	Nuphar	Phalaris	Phragmites	Scirpus	Sparganium emersum	Typha	Not recorded	Algae	Detritus	Elodea	Nuphar	Sparganium emersum
D	R	1A	9	Clay (lumps)			1							1							1			1	1
D	R	1B	8	Clay (lumps)						1	1									1		1			
D	R	1C	5	Clay (compacted)			1				1									1		1			1
D	R	2A	8	Clay (lumps)			1		1		1			1								1			
D	R	2B	1	Clay (lumps)			1		1		1			1								1			
D	R	2C	2	Clay (lumps)		1	1							1											
D	R	3A	1	Clay (nodules)			1							1								1			
D	R	3B	1	Clay (viscous)	1	1	1							1											
D	R	3C	6	Clay (viscous and nodules)																	1	1			1
E	R	1A	8	Clay (viscous)					1		1				1							1			
E	R	1B	8	Clay (viscous)		1	1									1		1				1			1
E	R	1C	6	Clay (lumps)	1	1	1	1							1							1			
E	R	2A	8	Silt (compacted)		1	1					1		1				1				1	1		
E	R	2B	1	Clay (lumps)			1							1											
E	R	2C	0	Gravel					1		1			1								1			
E	R	3A	9	Clay (nodules)			1	1	1				1												
E	R	3B	6	Gravel					1													1			
E	R	3C	9	Pebbles	1		1			1									1						

in zone E included all those found upstream in zone D. In the dredge samples, 32 BMWP taxa were found within each of zones D and E, and a total of 35 taxa occurred in the 18 dredge samples from zones D and E combined.

Table 9 Total number of BMWP taxa per zone, bank and sampling method (n=9 samples)

METHOD	ZONE D	ZONE E	**Total for method**
Dredge	32	32	**35**
Pond-net	20	37	**37**
Total for Zone	**33**	**39**	**40**

BMWP family level taxon-richness in zones D and E, based on nine samples, was therefore higher in zone E than zone D in the case of the marginal pond-net samples but identical for the deep water samples. (Note that it is inappropriate to compare the results in Tables 3 and 9 because they are based on five samples and nine samples respectively per zone, bank and sampling method.)

The individual sample results at BMWP family level are presented by zone and sampling method for Number of taxa, BMWP score and ASPT in Figures 6 to 8.

In zone D, the number of BMWP taxa per pond-net sample was limited to between 4 and 12 taxa. The range of BMWP scores was 17-59 and ASPT varied from 2.83 to 4.92. In contrast, the number of taxa in zone E varied from 6 to 23 (BMWP score 30-113) and ASPT was restricted to the range 4.00 to 5.19.

The dredge samples were not expected to demonstrate large differences between zones D and E, given the early results in Table 9. In practice, the number of BMWP taxa per sample in zone D varied considerably from 13 to 24 taxa per sample, the range of BMWP scores was 56 to 121 and ASPT varied between 4.12 and 5.29. Within zone E, the first sample downstream of the Pumney Farm ditch had just 13 BMWP taxa and a score of 56, the same as the lowest sample values observed in zone D. The remaining eight samples had a restricted range of 17 to 21 BMWP taxa (Scores 68-114). However, the first sample in zone E with the restricted fauna had an ASPT of 4.31, marginally higher than the lowest values recorded in both of zones D (4.12) and E (4.00).

The mean (and standard deviation) for the number of taxa, BMWP score and ASPT, based on the nine samples from each zone and sample type are presented in Table 10. For the dredge samples the mean values for each of the three BMWP indices in zones D and E are very similar, although all are slightly higher for zone E. However, for these dredge samples there were no statistical differences between zones D and E for any of the three BMWP indices when assessed by either t tests (all $p>0.16$) or Mann-Whitney tests (all $p>0.14$). Moreover 1-way ANOVA found no overall significant differences (all $p>0.45$) betweeen the six sections (D1,D2,D3,E1,E2,E3).

Table 10 Mean values and standard deviation for the number of BMWP taxa, BMWP score & ASPT by zone, bank & sampling method

A. BMWP Taxa

METHOD	ZONE D		ZONE E	
	Mean (±S.D)	Range	Mean (±S.D)	Range
Dredge	17.9±4.37	13-24	18.7±2.69	13-21
Pond-net	8.0±3.00	4-12	15.8±5.78	6-23

B. BMWP Score

METHOD	ZONE D		ZONE E	
	Mean (±S.D)	Range	Mean (±S.D)	Range
Dredge	84.3±26.35	56.0-121.0	93.1±19.71	56.0-114.0
Pond-net	33.7±15.60	17.0-59.0	71.9±26.90	30.0-113.0

C. ASPT

METHOD	ZONE D		ZONE E	
	Mean (±S.D)	Range	Mean (±S.D)	Range
Dredge	4.65±0.376	4.13-5.29	4.95±0.490	4.00-5.429
Pond-net	4.13±0.627	2.83-4.92	4.57±0.411	4.00-5.188

The results for the marginal pond-net samples clearly demonstrate that zone D has a more restricted number of BMWP taxa per sample than zone E, together with lower BMWP scores and ASPT values (Table 10). Student t tests using the nine samples per zone (treated as random samples over the zone) showed zone D have significantly lower mean values for number of BMWP taxa ($p=0.004$) and BMWP score ($p=0.003$), but the difference was less significant for ASPT ($p=0.099$). Non-parametric Mann-Whitney tests gave similar results ($p=0.013$ for taxa, $p=0.008$ for score and $p=0.158$ for ASPT).

The values for mean number of taxa and BMWP score in pond-net samples for zone D right bank are substantially lower than those recorded for either bank in zones A, B and C (Table 4). In addition, the taxon richness recorded in the dredge samples of both zones D and E fails to match that of dredge samples from zones A, B and the left hand bank of zone C (Table 4).

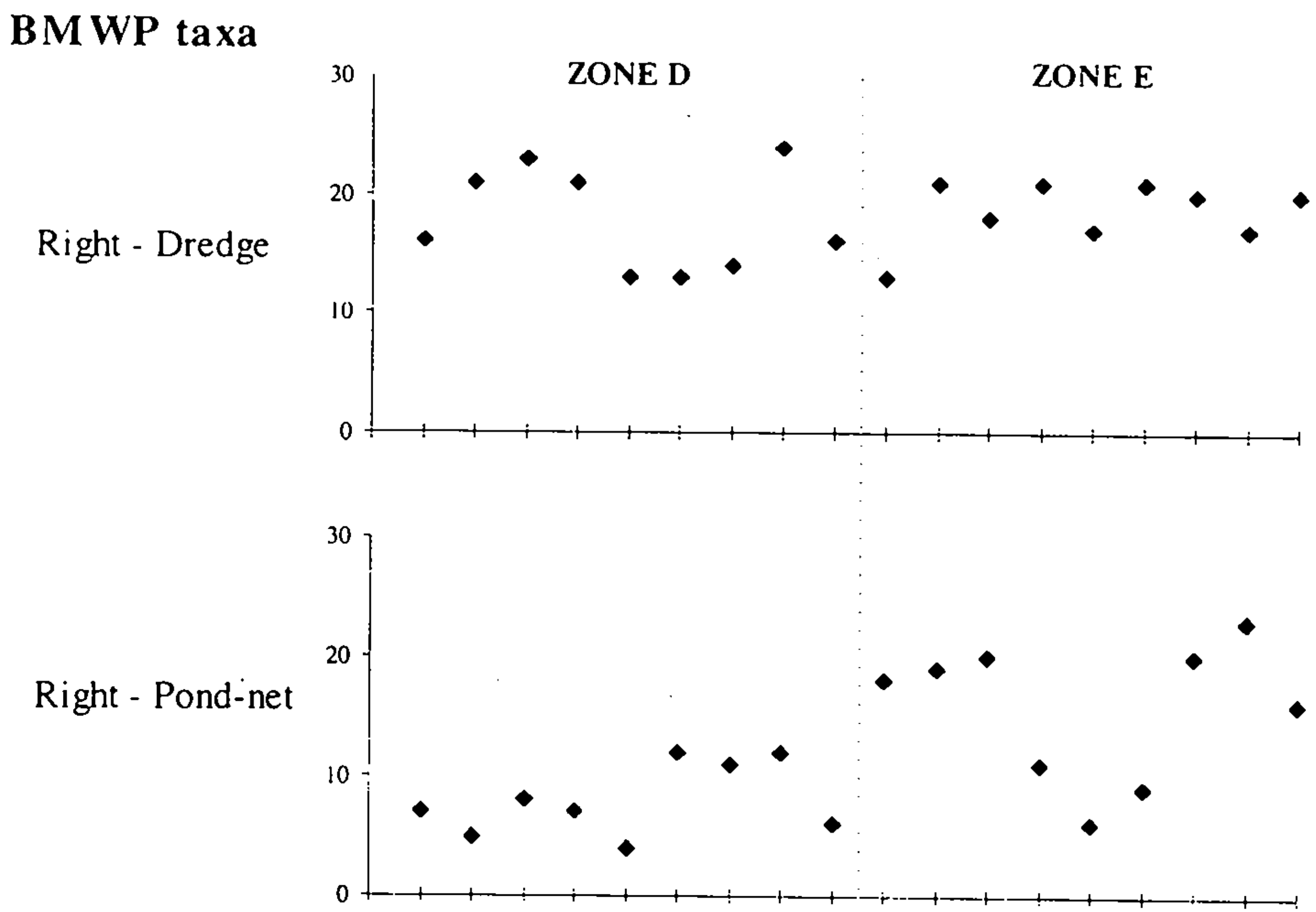

Figure 6 Number of BMWP taxa recorded in the pond-net and dredge samples from the right bank of zones D & E.

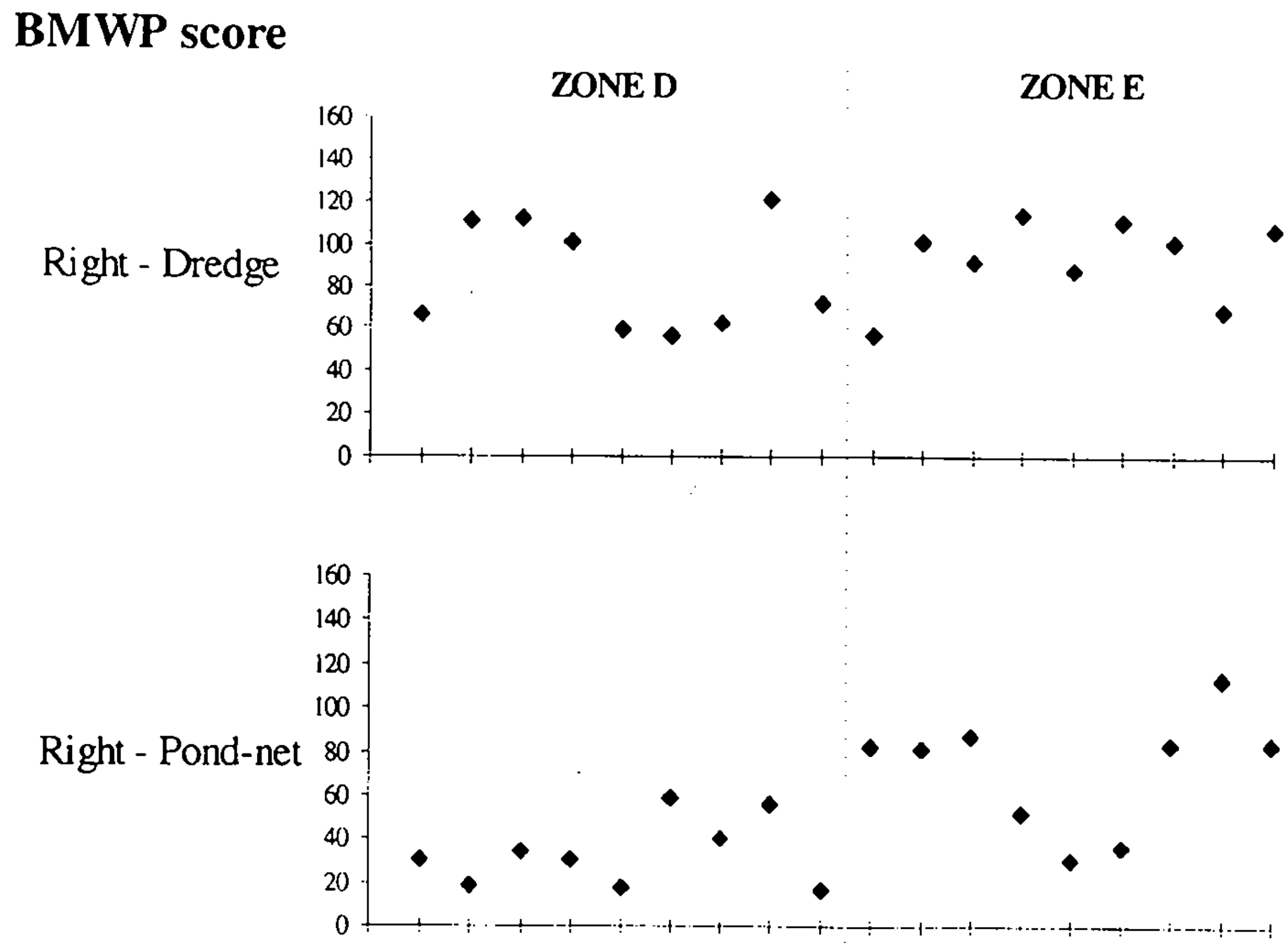

Figure 7 BMWP scores recorded in the pond-net and dredge samples from the right bank of zones D & E.

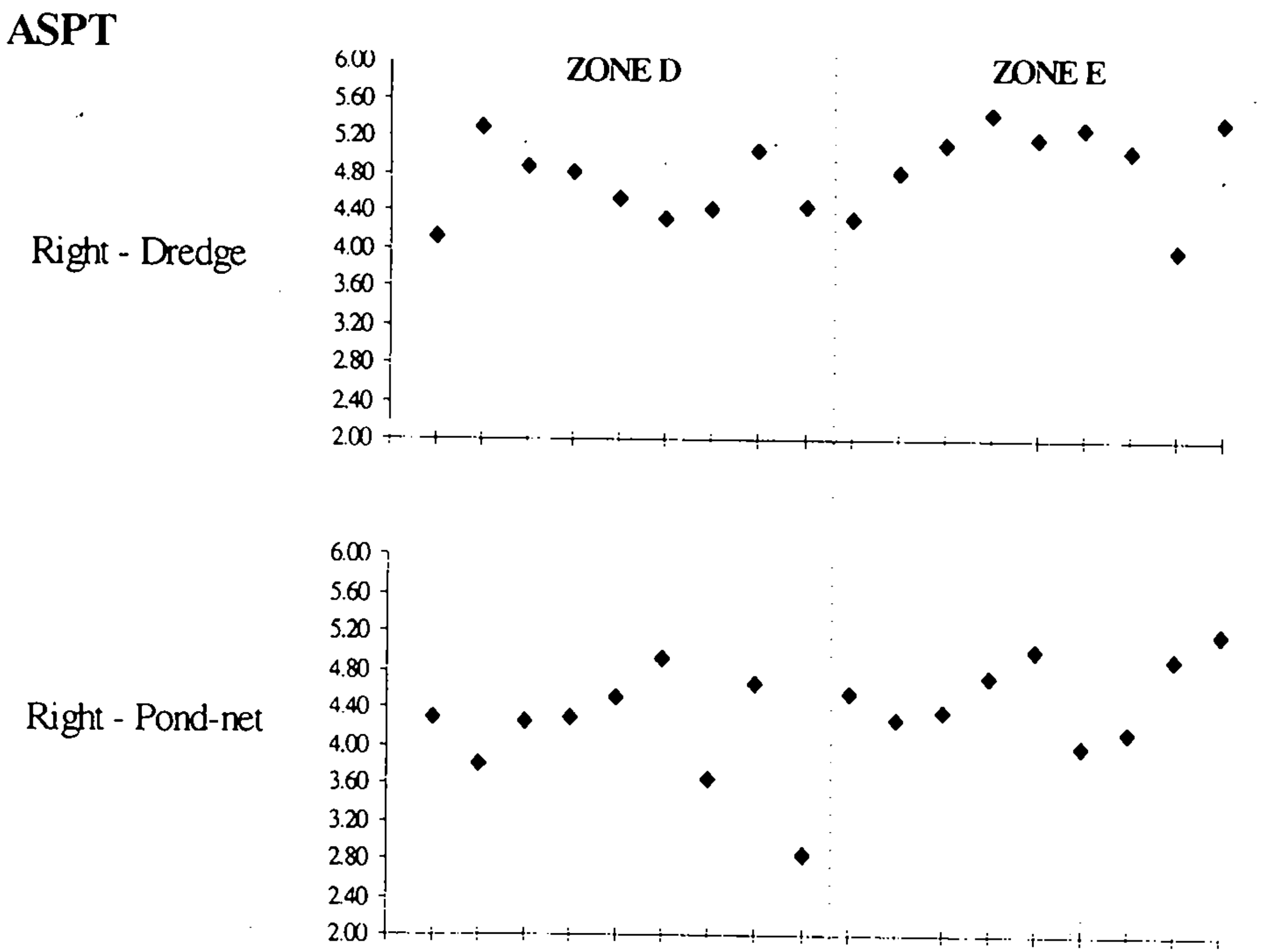

Figure 8 Average Score Per Taxon (ASPT) recorded in the pond-net and dredge samples from the right bank of zones D & E.

5.3 Rare taxa noted during the survey

This study has been reported at BMWP family level, in fulfillment of contract requirements. However, some families of macroinvertebrates include distinctive species and amongst these, three rare species have been recorded. (Note that these should not necessarily be regarded as a full listing of the rare taxa present in the samples collected at the study sites. This is because many species require more detailed examination before their identity can be confirmed).

The rare species include one Red Data Book (RDB) species, one Nationally Scarce species and a third species in a taxonomic group for which no RDB or Nationally Scarce designations have yet been made. In practice, Red Data Book species are designated because of perceived threat, the current categories being RDB 1 (Endangered), RDB 2 (Vulnerable) and RDB 3 (Rare). Although taxa in RDB categories 1-3 are categorized according to degree of threat and not rarity, they are unlikely to occur in more than 15 10 x 10 km squares of the National grid (Bratton, 1991). Nationally scarce species are designated as occurring in 100 or fewer 10 x 10 km squares of the National Grid.

Ephemera lineata Eaton (Ephemeroptera - a mayfly) RDB 2 status

Single specimens were recovered from right bank dredge samples in zones A and B only. These are welcome records of a species for which there are only very occasional records on the R.Thames, its tributaries and on the R.Wye (Bratton, 1990). The most recent records quoted by Bratton (1990) are two nymphs in the R.Wye near Hereford in 1957 and two further nymphs found in the R.Thames near Cookham in Berkshire in 1987. At the IFE we have an additional recent record this species on a tributary of the R.Thames in 1993.

Gomphus vulgatissimus (Linnaeus) (Odonata - a dragonfly) Nationally Scarce

Specimens were found in dredge samples only from zone A (1 left and 1 right bank sample), Zone B (1 rbs), Zone C (3 lbs, 1 rbs), Zone D (1 rbs) and Zone E (2 rbs). Normally a single or rarely two specimens were found in a given sample, but nevertheless the species occurred in every zone examined.

The larvae live in silt or mud in unpolluted rivers of moderate to slow flow and probably take three or more years to develop (Merritt, Moore and Eversham, 1996). *Gomphus vulgatissimus* is confined to seven river systems in southern Britain (Thames, Arun, Dee, Severn, Wye, Twyi, Teifi) and has disappeared from several additional rivers in southern England in the past thirty years. The species is vulnerable to pollution, and to the increased use of rivers by pleasure boats, the wash from which can dislodge and drown large numbers of emerging adults in May (Merritt, Moore and Eversham, 1996).

Boreobdella verrucata (Muller) (Hirudinea - a leech)

Single specimens were recorded in dredge samples from the left bank of zones A and C. In a Provisional Atlas of the Freshwater Leeches of the British Isles (Elliott and Tullett, 1982) this species was stated as being rare with just two records from England and a further four records in Ireland. Since then, the IFE team at the River Laboratory have recorded this species at one or two further sites on the R.Thames and also at a single site on the lower R.Trent, but it remains a rare and under-recorded species.

6. DISCUSSION AND CONCLUSIONS

6.1 General Considerations

A biological investigation into the possible impact of environmental stress may be conducted at one or more levels of organisation. For example, the study may focus on the macroinvertebrate assemblages (communities) present within the areas of interest, on the populations of one species, or the behaviour or physiology of individuals within a population. Where the investigation uses the entire macroinvertebrate fauna, both the method of sampling (qualitative vs quantitative) and the level of identification (eg BMWP family vs species level) have important consequences with regard to the costs and expertise required. Within the Environment Agency, most biological surveillance and monitoring is undertaken using qualitative sampling techniques with identification at BMWP family level. This can normally expose cases where environmental stress results in major changes to the invertebrate assemblages and was the approach taken in the present study on the R.Thames.

Large rivers are difficult to sample and it is well known that the fauna of the marginal areas can differ substantially from the fauna present in the sediments on the bottom of the river. Nevertheless, they form linked components of the same system and, for example, some dragonfly nymphs live and hunt within the silt on the river bed but require marginal vegetation when emerging as adults. In addition, marginal vegetation may act as a refuge for invertebrates at times of high flow or during a pollution incident and act as a reservoir of species for the recolonisation of the river bed and its submerged vegetation when conditions improve. Therefore, although the results of the benthic sampling programme are of primary importance in this study, the marginal samples are also relevant to a wider understanding of the structure and functioning of the system.

In view of the differing characteristics of the margins and river bed, different sampling techniques were used, each one designed to obtain the characteristic fauna of each location. Clearly, the habitat characteristics of the margins differ substantially from the river bed and hence, differences in the fauna are to be expected. However, it is also important to realise that habitat differences in, for example, the margins whether natural or man-made also influence the macroinvertebrate fauna, irrespective of polluting influences. On the river bed, the type of sediments, whether fine or coarse will also influence the fauna and whereas natural phenomena may produce differences in the substratum at different locations, made-made influences, including boat traffic and effluent discharges can affect the physical character of the substratum. Further impacts on the fauna may result from temperature and/or chemical effects of an effluent (Langford, 1983).

Turning to the specific investigations undertaken on the R.Thames, two separate areas were of interest. First, the Main Power Station abstraction and discharge points at Didcot and second, the Radley Ash Handling discharge point from Pumney Farm ditch. For the first study area, an upstream control zone (A) was required, followed by zone B between the abstraction and discharge points and finally zone C, downstream of the discharge point. For the second site, a control section (zone D) was chosen upstream of the Radley Ash Handling discharge point together with an equivalent section (zone E) below the discharge point. In both studies, the aims were to determine whether any short range biological effects could be detected and to provide baseline information for future comparison, if required at a later date.

Prior to the investigation, there was no information on whether any effects were to be expected or if there were effects, how far downstream they would impact on the fauna. Therefore it was important to design a sampling programme which was capable of demonstrating progressive recovery if short range biological effects were observed in the immediate vicinity of the discharge points. After consultation, 250 m study sites were chosen for each of zones A, B and C and 450 m study sections for zones D and E.

6.2 Didcot Study Site

At the Didcot Power Station study sites (zones A-C), biological impacts were theoretically possible in zone B, due to the abstraction of water between zones A and B and in zone C due to the discharge of power station cooling water between zones B and C. Examination of the full list of BMWP taxa for both sampling methods in the three sampling zones (Table 3) gave a total of 46 BMWP families in July 1996, indicative of a wide range of taxa in this lowland river.

Initial appraisal of the data for the individual samples (Table 4 and Figures 3-5) followed by ANOVA (Table 5) indicated that pond-net samples from the right bank had a lower mean number of BMWP taxa, mean BMWP score and mean ASPT than those from the left bank. It was concluded that these biological characteristics were most likely to be accounted for in terms of the greater diversity of the macrophyte and substrata encountered on the left bank compared with the right bank (Table 1). ANOVA on dredge samples showed statistically significant differences between the banks in relation to mean number of BMWP taxa (but not BMWP score or ASPT).

ANOVA (Table 5) also demonstrated statistically significant differences between the three zones for the marginal pond-net samples (all three BMWP indices) and for the dredge samples (number of BMWP taxa only). Visual examination indicated that both the pond-net and dredge samples (Table 4) the average value of each BMWP index was higher in zone B than in zones A or C for both the left and right bank, except for ASPT in the dredge samples.

Therefore, further statistical analyses were undertaken to examine the data separately for each bank (Table 6). It is important to bear in mind that these tests assess differences in the average BMWP index values for each zone and bank, with no regard to the longitudinal patterns of the sample values within each section.

The most pertinent questions for this study concern the possible impact of water abstraction on the fauna of zone B and of cooling water on the fauna of zone C. When zone A (control) was compared with zone B using BMWP family level data (Table 6), there was no statistical evidence of a deleterious impact on the fauna in zone B due to abstraction of water. In fact, in dredge samples from the left bank only, the number of BMWP taxa was higher in zone B than in zone A. In the marginal pond-net samples on the right bank, the average value of the ASPT for zone B was also significantly higher than in zone A.

Considering next the fauna in the dredge samples in zone C, there were no statistically significant differences in the number of BMWP taxa and BMWP scores between zones C and A or between zones C and B, despite the visually distinctive pattern of samples on the right bank downstream of the discharge from Didcot Power Station (Figures 3-5). In fact the ASPT on the left bank of zone C was higher than in zones A and B.

In contrast, the marginal pond-net samples did show statistically significant evidence of a lower number of BMWP taxa and BMWP score on the right bank of zone C compared to zone B and some similar evidence for the samples on the left bank. The reasons for this are unclear and are not necessarily linked to the discharge at Didcot. The pattern of the individual results for the right bank do not suggest a link with the discharge (Figures 3-5) and it is apparent from Table 1 that the right bank in zone C has poor habitat diversity.

However, the longitudinal pattern of dredge sample values on the right bank of the river bed in zone C, where a direct impact of the discharge from Didcot might be anticipated, did suggest a localised effect.

In the first dredge sample in zone C (1-1) the dominant substratum was found to be sand (Table 2). This is known to be a relatively inhospitable habitat which supports a limited range of taxa compared to silt and also more coarse substrata (Wright *et al*, 1994a). The absence of sand as a dominant substratum at any of the other sampling locations at Didcot suggests that it may be a physical consequence of the discharge of cooling water. The fauna at this site, which was removed from two sample pots (Appendix 2) included one or two individuals from three families of Mollusca (snails and mussels), but was dominated by Oligochaeta (true worms) and Chironomidae (non-biting midges). These are all taxa which have low BMWP scores and are known to be tolerant of a range of different environmental stresses.

In the second sample (2-8), which also required two sample pots, Oligochaeta and Chironomidae continued to dominate the fauna, but ten additional BMWP families were present. As previously indicated, the probability of getting the lowest number of taxa in the first sample below the discharge and the second lowest immediately below that is only around 0.5%

However, Figure 3 indicates that the remaining three dredge samples on the right bank of zone C were within the range of values observed in zones A and B. This indicates that the impact on BMWP family level richness is localised and that it is restricted to the right bank samples only, there being no significant impact on the samples taken from the left bank in zone C (Figure 3). If this study had been restricted to the first 100m downstream of the discharge, then the recovery would not have been detected.

6.3 Radley Study Site

The results of the sampling programme on this section of the R.Thames provide some instructive results. The marginal pond-net samples in zone D upstream of the Radley Ash Handling discharge point yielded 20 BMWP families only, compared to the 37 BMWP families downstream of the discharge point. Statistical tests based on the nine samples per zone, indicated that zone D had significantly lower mean values for number of BMWP taxa and BMWP score than zone E. This result appears to be an example of faunal richness being affected by the range of available habitats. Zone D lacked marginal emergent vegetation, then came a narrow clay ledge and *Nuphar lutea* was the only macrophyte observed during sampling. The reason for the limited range of habitats in zone D is unknown. In contrast, zone E displayed much greater habitat diversity with respect to the substratum, the submerged macrophytes and also the emergent macrophytes.

The dredge samples yielded 32 BMWP families in each of zones D and E. The mean values for each of the three BMWP values in zones D and E were also very similar, although they were all slightly higher in zone E. However, statistical tests indicated that there were no significant differences between the zones.

Figure 6 indicates that the first sample in zone E had the lowest number of BMWP taxa for that zone. This was in fact a very large dredge sample of viscous clay which was subsampled in the field yet still involved the laboratory examination of two pots of material (Appendix 2). Despite the restricted fauna at this location, it was no lower than the lowest value for the number of BMWP taxa and BMWP score recorded in zone D.

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Appendix 1. Brief explanatory note on the BMWP score system

It is now widely accepted that chemical monitoring and biological techniques for the assessment of river quality offer complementary approaches for the detection and appraisal of environmental stress. Biological methods based on individuals, populations and communities all have a role to play in the detection of stress, but the biological surveillance of communities, with special emphasis on characterising taxonomic richness and composition has been suggested as the most sensitive tool available for quickly and accurately detecting alterations in aquatic ecosystems (Cairns and Pratt, 1993).

A full appraisal of the macroinvertebrate fauna of a series of sites calls for considerable expertise because several hundred species of macroinvertebrates may be encountered during extensive survey work. However, for many routine surveys the collection of information at family level still offers valuable data on which to make an appraisal whilst saving valuable time and requiring a lower level of expertise.

Many of the early biological techniques used within Great Britain were developed to serve local needs and involved the use of score systems based on the taxa present, in order to provide managers with a simple interpretation of the faunal lists. A very simple system was used in the national River Pollution Survey in 1970 (Department of the Environment & The Welsh Office, 1971) but this was clearly inadequate. In order to develop a more satisfactory approach for the biological classification of all types of rivers, the Biological Monitoring Working Party (BMWP) was convened in 1976. It developed a new procedure through questionaires and discussion, and undertook a national testing exercise before proposing the BMWP score system for use in the 1980 River Quality Survey (National Water Council 1981). In practice, the committee were unable to recommend a system of biological classification of river quality, but offered the BMWP system as an approach for assessing the biological condition of a river (Biological Monitoring Working Party, 1978).

In the BMWP score system, a total of 83 families of macroinvertebrates have been allocated individual scores ranging from 1 to 10, based on the perceived tolerance to organic pollution of the most sensitive species in each family. The most pollution intolerant taxa, including many families of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) score 10 whereas those more tolerant of organic pollution have progressively lower scores, with the Oligochaeta (true worms) scoring just 1. The full list of BMWP 'families' and their scores are shown in the accompanying Table.

The BMWP score, one of the three indices which may be used to represent the biological condition of the site, is obtained by adding the scores of all the component families. The number of BMWP taxa present is also useful as a crude measure of site taxon richness. Finally, dividing the BMWP score by the number of scoring taxa gives a third index, the Average Score per Taxon (ASPT).

In general, high values of each of the three indices are thought to indicate good biological condition and low values are indicative of stress. However, there are dangers in taking this simplistic view. If, for example, sampling effort is doubled at a site, then there is a strong possibility of increasing the number of BMWP taxa found (and therefore the BMWP score). Hence, a standard sampling protocol is required whenever several sites are to be compared or one site is to be monitored over time. In one early test of the performance of this system (Armitage et al 1983) it was shown that sample replication led to substantial increases of both number of taxa and BMWP scores but had little effect on the ASPT. This is an important result and indicates that more information is obtained for less effort when ASPT is used.

A further potential pitfall when using the BMWP score system for national surveys was recognised in the 1980 River Quality Survey report (National Water Council,1981). It was accepted that the interpretation of results was a matter for professional experts because different types of river system and different sites along the length of a given system, support different macroinvertebrate communities in the absence of pollution and other forms of environment stress. More recently this problem has been tackled by the use of RIVPACS (River Invertebrate Prediction And Classification System), a technique developed by the Institute of Freshwater Ecology which offers a site-specific 'target' of the macroinvertebrate assemblage to be expected in the absence of environmental stress (Wright et al 1994b). Predictions can be offered at different taxonomic levels, including BMWP family level (with indices), and by comparing the observed fauna with the expected fauna, an assessment of the biological quality of a site can be made.

However, for detailed survey work on a short section of river (as in this study) where it is important to be able to compare the fauna through a replicated sampling programme in several zones, the RIVPACS approach with its own prescriptive sampling protocol is not ideal. Therefore, a separate protocol taylored to the specific questions to be addressed in this study was developed.

Note that the use of BMWP family level for identification of the fauna is in line with the taxonomic level used in the large majority of monitoring studies undertaken by the National Rivers Authority and more recently by the Environment Agency.

Allocation of scores in the BMWP system

Score 10

Siphlonuridae
Heptageniidae
Leptophlebiidae
Ephemerellidae
Potamanthidae
Ephemeridae
Taeniopterygidae
Leuctridae
Capniidae
Perlodidae
Perlidae
Chloroperlidae
Aphelocheiridae
Phryganeidae
Molannidae
Beraeidae
Odontoceridae
Leptoceridae
Goeridae
Lepidostomatidae
Brachycentridae
Sericostomatidae

Score 8

Astacidae
Lestidae
Calopterygidae
Gomphidae
Cordulegasteridae
Aeshnidae
Corduliidae
Libellulidae
Psychomyiidae (Ecnomidae)
Philopotamidae

Score 7

Caenidae
Nemouridae
Rhyacophilidae (Glossosomatidae)
Polycentropodidae
Limnephilidae

Score 6

Neritidae
Viviparidae
Ancylidae (Acroloxidae)
Hydroptilidae
Unionidae
Corophiidae
Gammaridae (Crangonyctidae)
Platycnemididae
Coenagriidae

Score 5

Mesoveliidae
Hydrometridae
Gerridae
Nepidae
Naucoridae
Notonectidae
Pleidae
Corixidae
Haliplidae
Hygrobiidae
Dytiscidae (Noteridae)
Gyrinidae
Hydrophilidae (Hydraenidae)
Clambidae
Scirtidae
Dryopidae
Elmidae
Hydropsychidae
Tipulidae
Simuliidae
Planariidae (Dugesiidae)
Dendrocoelidae

Score 4

Baetidae
Sialidae
Piscicolidae

Score 3

Valvatidae
Hydrobiidae (Bithyniidae)
Lymnaeidae
Physidae
Planorbidae
Sphaeriidae
Glossiphoniidae
Hirudinidae
Erpobdellidae
Asellidae

Score 2

Chironomidae

Score 1

Oligochaeta

Note: For the purposes of the BMWP scoring system, families given in brackets are to be included within the family which precedes them.

Appendix 2. Additional information on the dredge samples, including number of dredge trawls, the occasions when the volume of material necessitated sub-sampling, and instances where the final volume of the sample occupied two polythene sample jars.

Zone	Bank	Section	Number of dredge trawls	Subsample	Number of sample jars
A	L	1 - 1	1		1
A	L	2 - 1	1		1
A	L	3 - 0	1		1
A	L	4 - 9	1		1
A	L	5 - 4	1		1
A	R	1 - 5	1		1
A	R	2 - 6	1		1
A	R	3 - 2	1	one eighth	2
A	R	4 - 2	2		2
A	R	5 - 2	1		2
B	L	1 - 8	1		2
B	L	2 - 0	1		2
B	L	3 - 0	1		1
B	L	2 - 7	2		2
B	L	5 - 9	1		1
B	R	1 - 6	2		1
B	R	2 - 9	1		1
B	R	3 - 0	2		1
B	R	4 - 7	1		1
B	R	5 - 0	1		2
C	L	1 - 3	1		1
C	L	2 - 6	1		1
C	L	3 - 6	1		2
C	L	4 - 7	2		1
C	L	5 - 3	1		2
C	R	1 - 1	1		2
C	R	2 - 8	1		2
C	R	3 - 5	2		1
C	R	4 - 3	1		2
C	R	5 - 0	1		1
D	R	1A - 9	1		1
D	R	1B - 8	1		2
D	R	1C - 5	1		1
D	R	2A - 8	1		2
D	R	2B - 1	1	one half	2
D	R	2C - 2	1		1
D	R	3A - 1	1		1
D	R	3B - 1	1		2
D	R	3C - 6	1		2
E	R	1A - 8	1	one eighth	2
E	R	1B - 8	1		2
E	R	1C - 6	1		1
E	R	2A - 8	1		1
E	R	2B - 1	1		2
E	R	2C - 0	1		1
E	R	3A - 9	1		2
E	R	3B - 6	1	one half	1
E	R	3C - 9	1	one quarter	1

Appendix 3. Macroinvertebrate data at BMWP family level for pond-net and dredge samples in zones A-C. Information presented on the next twelve pages is as follows:

Zone A	Left	Pond-net samples	Sections 1-5
Zone B	Left	Pond-net samples	Sections 1-5
Zone C	Left	Pond-net samples	Sections 1-5
Zone A	Left	Dredge samples	Sections 1-5
Zone B	Left	Dredge samples	Sections 1-5
Zone C	Left	Dredge samples	Sections 1-5
Zone A	Right	Dredge samples	Sections 1-5
Zone B	Right	Dredge samples	Sections 1-5
Zone C	Right	Dredge samples	Sections 1-5
Zone A	Right	Pond-net samples	Sections 1-5
Zone B	Right	Pond-net samples	Sections 1-5
Zone C	Right	Pond-net samples	Sections 1-5

Zone A Left Pond-net samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)			+	+	
Viviparidae				+	+
Valvatidae	+	+	+	+	+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Physidae		+		+	+
Lymnaeidae	+	+	+	+	+
Planorbidae	+	+	+	+	+
Ancylidae (incl. Acroloxidae)					+
Unionidae		+			
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+		+	+	+
Erpobdellidae				+	+
Asellidae	+	+	+	+	+
Corophiidae	+		+		
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+		+	+
Baetidae	+	+	+		
Ephemeridae			+		
Ephemerellidae	+				
Caenidae			+		+
Notonectidae	+				
Corixidae		+	+	+	+
Haliplidae			+	+	+
Gyrinidae		+			
Dytiscidae (incl. Noteridae)		+	+	+	+
Hydrophilidae (incl. Hydraenidae)				+	
Elmidae		+	+		
Sialidae		+		+	
Hydroptilidae			+	+	
Polycentropodidae					+
Psychomyiidae (incl. Ecnomidae)	+	+			+
Phryganeidae		+	+		
Goeridae			+		
Molannidae			+		+
Leptoceridae	+	+			
Chironomidae	+	+	+	+	+
BMWP	**73**	**92**	**112**	**77**	**95**
ASPT	**4.56**	**4.60**	**5.09**	**3.85**	**4.52**
No taxa	**16**	**20**	**22**	**20**	**21**

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)		+	+		
Viviparidae	+	+	+		+
Valvatidae		+	+		+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Physidae	+				
Lymnaeidae	+	+	+	+	+
Planorbidae	+		+		
Ancylidae (incl. Acroloxidae)	+	+	+	+	
Unionidae		+		+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+	+	+		+
Erpobdellidae	+	+			+
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+	+	+
Baetidae	+	+	+	+	+
Caenidae		+	+	+	+
Platycnemididae	+				
Aeshnidae			+		
Corixidae	+				+
Haliplidae			+		
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Elmidae		+		+	+
Sialidae	+			+	+
Hydroptilidae	+		+	+	
Polycentropodidae	+		+		+
Psychomyiidae (incl. Ecnomidae)	+	+	+	+	
Phryganeidae			+		
Limnephilidae	+				
Molannidae		+	+		+
Leptoceridae		+	+	+	+
Chironomidae	+	+	+	+	+
BMWP	103	108	133	88	105
ASPT	4.48	4.91	5.32	4.89	4.77
No. Taxa	23	22	25	18	22

Zone C   Left   Pond-net samples   Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)				+	
Viviparidae	+	+	+	+	
Valvatidae		+	+		
Hydrobiidae (incl. Bithyniidae)		+	+	+	
Physidae		+	+		
Lymnaeidae	+	+	+	+	
Planorbidae		+	+	+	
Sphaeriidae	+	+	+		+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+	+	+	+	
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)		+	+	+	+
Baetidae	+	+	+	+	
Caenidae			+		
Platycnemididae				+	
Coenagriidae		+			
Corixidae		+		+	
Haliplidae		+			
Dytiscidae (incl. Noteridae)	+	+	+	+	
Hydrophilidae (incl. Hydraenidae)				+	
Elmidae		+			
Sialidae			+		
Hydroptilidae		+	+	+	
Polycentropodidae			+		
Phryganeidae				+	
Limnephilidae			+		
Goeridae	+				
Molannidae	+			+	+
Leptoceridae	+			+	
Tipulidae			+		
Chironomidae	+	+	+	+	+
BMWP	66	81	90	102	31
ASPT	5.08	4.05	4.29	5.10	4.43
No. Taxa	13	20	21	20	7

Zone A Left Dredge samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)		+	+		
Viviparidae	+	+	+	+	+
Valvatidae	+	+		+	+
Hydrobiidae (incl. Bithyniidae)	(? +)	+	+	+	+
Physidae					+
Lymnaeidae	+	+	+	+	+
Planorbidae	+	+	+	+	+
Ancylidae (incl. Acroloxidae)			+	+	+
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+	+	+	+	+
Erpobdellidae	+	+		+	+
Asellidae	+	+	+	+	+
Corophiidae	+	+	+		+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+	+	+
Baetidae	+	+	+	+	+
Caenidae	+	+	+	+	+
Coenagriidae			+		
Gomphidae	+				
Corixidae			+	+	
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Sialidae	+	+	+	+	+
Hydroptilidae	+	+	+		
Polycentropodidae	+	+	+	+	+
Psychomyiidae (incl. Ecnomidae)	+	+	+		
Phryganeidae	+	+			
Limnephilidae	+			+	
Molannidae	+	+		+	+
Leptoceridae	+	+			
Chironomidae	+	+	+	+	+
BMWP	**134**	**127**	**108**	**100**	**97**
ASPT	**5.36**	**5.08**	**4.70**	**4.55**	**4.41**
No. Taxa	**25**	**25**	**23**	**22**	**22**

BMWP familiy	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)			+	+	+
Viviparidae	+	+	+	+	+
Valvatidae	+	+	+		+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Physidae		+		+	
Lymnaeidae	+	+		+	+
Planorbidae	+	+	+	+	+
Ancylidae (incl. Acroloxidae)	+	+		+	+
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+	+	+	+	+
Erpobdellidae	+		+	+	+
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+	+	+
Baetidae	+	+	+	+	+
Caenidae	+	+	+		+
Calopterygidae		+		+	
Corixidae	+	+			
Haliplidae					+
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Elmidae	+				
Sialidae		+	+	+	
Hydroptilidae	+	+	+	+	
Polycentropodidae	+	+	+	+	+
Psychomyiidae (incl. Ecnomidae)		+	+	+	+
Phryganeidae	+	+			+
Limnephilidae	+	+	+	+	+
Molannidae	+	+	+		+
Leptoceridae	+	+	+	+	+
Chironomidae	+	+	+	+	+
BMWP	133	148	121	121	135
ASPT	5.12	5.29	5.04	4.84	5.19
No. Taxa	26	28	24	25	26

Zone C   Left   Dredge samples   Sections 1 5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)	+				
Viviparidae	+	+	+	+	+
Valvatidae		+		+	+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Lymnaeidae		+	+	+	
Planorbidae		+			+
Ancylidae (incl. Acroloxidae)				+	+
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Piscicolidae	+				
Glossiphoniidae	+	+	+	+	+
Erpobdellidae			+		
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+		+	
Baetidae	+	+		+	+
Ephemerellidae					+
Caenidae	+	+	+	+	+
Gomphidae		+	+		+
Aeshnidae		+			
Haliplidae			+		
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Elmidae	+				
Sialidae	+	+	+	+	+
Hydroptilidae	+	+		+	+
Polycentropodidae	+	+	+	+	+
Psychomyiidae (incl. Ecnomidae)	+		+	+	+
Phryganeidae		+		+	+
Limnephilidae	+	+		+	+
Goeridae			+		
Molannidae	+	+	+	+	+
Leptoceridae	+	+		+	+
Tipulidae	+				
Chironomidae	+	+	+	+	+
BMWP	**126**	**134**	**103**	**129**	**141**
ASPT	**5.25**	**5.36**	**5.15**	**5.38**	**5.64**
No. Taxa	**24**	**25**	**20**	**24**	**25**

Zone A Right Dredge samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)	+	+			
Viviparidae	+	+	+	+	+
Valvatidae	+		+		+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Lymnaeidae		+	+		+
Planorbidae	+				+
Ancylidae (incl. Acroloxidae)	+	+	+		
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Glossiphoniidae	+	+	+	+	+
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+			+
Baetidae	+	+	+		+
Ephemeridae	+				+
Caenidae	+	+	+	+	+
Platycnemididae	+	+			
Gomphidae				+	
Aeshnidae				+	
Corixidae		+			
Haliplidae			+		+
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Elmidae		+	+		+
Sialidae	+	+	+	+	+
Hydroptilidae	+		+		+
Polycentropodidae	+	+		+	+
Psychomyiidae (incl. Ecnomidae)	+	+	+		+
Phryganeidae	+		+		
Limnephilidae		+	+	+	
Molannidae	+	+		+	+
Leptoceridae		+	+		+
Chironomidae	+	+	+	+	+
BMWP	133	131	116	89	129
ASPT	5.32	5.24	5.04	5.24	5.16
No. Taxa	25	25	23	17	25

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)	+		+		
Viviparidae	+	+	+	+	+
Valvatidae					+
Hydrobiidae (incl. Bithyniidae)	+	+	+		+
Lymnaeidae		+		+	+
Planorbidae		+	+		+
Ancylidae (incl. Acroloxidae)	+	+		+	+
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+		+
Oligochaeta	+	+	+	+	+
Piscicolidae	+		+	+	+
Glossiphoniidae	+	+	+	+	+
Erpobdellidae		+	+	+	+
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+		+		
Baetidae	+	+	+	+	
Ephemeridae					+
Caenidae	+	+	+	+	+
Platycnemididae	+				
Calopterygidae			+		
Gomphidae			+		
Corixidae					+
Haliplidae	+				
Dytiscidae (incl. Noteridae)	+	+	+		+
Elmidae			+		
Sialidae		+	+	+	+
Hydroptilidae	+	+	+		+
Polycentropodidae	+	+	+	+	+
Psychomyiidae (incl. Ecnomidae)	+	+	+	+	+
Phryganeidae	+				
Limnephilidae			+		+
Molannidae	+	+	+	+	+
Leptoceridae	+	+	+		+
Chironomidae	+	+	+	+	+
BMWP	**132**	**109**	**143**	**83**	**134**
ASPT	**5.50**	**4.95**	**5.30**	**4.88**	**5.15**
No. Taxa	**24**	**22**	**27**	**17**	**26**

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Valvatidae			+	+	
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Lymnaeidae				+	+
Planorbidae			+	+	+
Unionidae	+	+	+	+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Piscicolidae			+		
Glossiphoniidae		+	+	+	+
Erpobdellidae			+	+	
Asellidae			+	+	+
Corophiidae		+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)			+	+	
Baetidae				+	+
Caenidae		+	+	+	+
Platycnemididae				+	
Calopterygidae			+		
Gomphidae					+
Dytiscidae (incl. Noteridae)			+	+	+
Sialidae		+		+	
Hydroptilidae		+	+	+	+
Polycentropodidae			+	+	+
Phryganeidae				+	+
Limnephilidae			+		
Molannidae		+	+	+	+
Leptoceridae		+	+	+	+
Tipulidae					+
Chironomidae	+	+	+	+	+
BMWP	**15**	**61**	**106**	**114**	**105**
ASPT	**3.00**	**5.08**	**5.05**	**4.96**	**5.25**
No. Taxa	**5**	**12**	**21**	**23**	**20**

Zone A Right Pond-net samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Viviparidae	+		+		+
Valvatidae	+		+		+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Lymnaeidae	+	+	+	+	
Planorbidae	+			+	
Unionidae			+	+	
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Piscicolidae			+		
Glossiphoniidae	+		+	+	
Erpobdellidae	+				
Asellidae	+	+	+	+	+
Corophiidae	+		+		
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+		+	
Baetidae	+	+	+	+	+
Caenidae			+		+
Platycnemididae			+		
Corixidae		+		+	
Dytiscidae (incl. Noteridae)		+	+	+	+
Sialidae			+	+	+
Hydroptilidae	+		+	+	
Polycentropodidae			+		
Psychomyiidae (incl. Ecnomidae)		+		+	
Molannidae			+		
Chironomidae	+	+	+	+	+
BMWP	**55**	**43**	**92**	**65**	**41**
ASPT	**3.67**	**3.91**	**4.60**	**4.06**	**3.73**
No Taxa	**15**	**11**	**20**	**16**	**11**

Zone B Right Pond-net samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Planariidae (incl. Dugesiidae)	+	+			
Viviparidae		+	+	+	
Valvatidae			+		+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+
Physidae					+
Lymnaeidae	+			+	+
Planorbidae					+
Unionidae	+			+	+
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+		+
Glossiphoniidae		+		+	
Asellidae	+	+	+	+	+
Corophiidae	+	+	+	+	
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+		+
Baetidae	+	+	+	+	+
Caenidae	+	+	+		
Coenagriidae				+	+
Gerridae					+
Corixidae	+			+	+
Dytiscidae (incl. Noteridae)	+		+	+	+
Elmidae	+	+			+
Sialidae	+				
Hydroptilidae		+	+	+	+
Polycentropodidae			+	+	
Psychomyiidae (incl. Ecnomidae)					+
Molannidae			+	+	
Leptoceridae		+			
Simuliidae	+				
Chironomidae	+	+	+	+	+
BMWP	**73**	**70**	**72**	**78**	**80**
ASPT	**4.29**	**4.67**	**4.80**	**4.88**	**4.21**
No. Taxa	**17**	**15**	**15**	**16**	**19**

Zone C Right Pond-net samples Sections 1-5

BMWP family	Section 1	Section 2	Section 3	Section 4	Section 5
Valvatidae	+		+		
Hydrobiidae (incl. Bithyniidae)		+	+	+	
Physidae	+				
Lymnaeidae	+		+		
Planorbidae		+			
Unionidae		+			
Sphaeriidae	+	+	+	+	+
Oligochaeta	+	+	+	+	+
Asellidae	+	+	+	+	+
Corophiidae		+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+	+	
Baetidae	+	+		+	+
Caenidae			+		+
Platycnemididae	+				
Calopterygidae				+	
Notonectidae			+		
Corixidae	+				
Haliplidae	+				
Gyrinidae				+	
Dytiscidae (incl. Noteridae)	+	+	+	+	+
Hydroptilidae				+	+
Polycentropodidae				+	
Molannidae	+		+		+
Chironomidae	+	+	+	+	+
BMWP	**59**	**42**	**57**	**59**	**47**
ASPT	**4.21**	**3.82**	**4.38**	**4.54**	**4.70**
No. Taxa	**14**	**11**	**13**	**13**	**10**

Appendix 4. **Macroinvertebrate data at BMWP family level for pond-net and dredge samples in zones D and E. Information presented on the next four pages is as follows:**

Zone D	Right	Dredge samples	Sections 1-5
Zone E	Right	Dredge samples	Sections 1-5
Zone D	Right	Pond-net samples	Sections 1-5
Zone E	Right	Pond-net samples	Sections 1-5

Zone D Right Dredge samples Sections 1-5

BMWP family	Section 1-A	Section 1-B	Section 1-C	Section 2-A	Section 2-B	Section 2-C	Section 3-A	Section 3-B	Section 3-C
Dendrocoelidae		+	+						
Planariidae (incl. Dugesiidae)			+	+		+			
Viviparidae	+	+	+	+	+	+	+	+	+
Valvatidae		+	+	+				+	+
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+	+	+	+	+
Lymnaeidae	+							+	
Planorbidae			+					+	
Ancylidae (incl. Acroloxidae)				+				+	
Unionidae	+	+	+		+		+	+	+
Sphaeriidae	+	+	+	+	+	+	+	+	+
Oligochaeta	+	+	+	+	+	+	+	+	+
Piscicolidae	+								
Glossiphoniidae	+	+	+	+	+	+	+	+	+
Asellidae	+	+	+	+	+	+	+	+	+
Corophiidae	+	+	+	+	+	+	+	+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)	+	+	+	+		+	+		
Baetidae	+					+	+	+	
Ephemeridae					+				
Caenidae		+	+	+	+	+	+	+	+
Gomphidae			+						
Libellulidae									+
Haliplidae			+	+	+			+	+
Dytiscidae (incl. Noteridae)	+	+	+	+				+	+
Elmidae				+					
Sialidae	+	+	+	+	+		+	+	+
Hydroptilidae		+	+	+				+	+
Polycentropodidae	+	+	+	+		+		+	
Psychomyiidae (incl. Ecnomidae)		+	+	+			+	+	
Limnephilidae		+	+	+				+	
Molannidae		+						+	
Leptoceridae		+						+	
Chironomidae	+	+	+	+	+	+	+	+	+
BMWP	66	111	112	101	59	56	62	121	71
ASPT	4.13	5.29	4.87	4.81	4.54	4.31	4.43	5.04	4.44
No. Taxa	16	21	23	21	13	13	14	24	16

Zone E Right Dredge samples Sections 1-5

BMWP family	Section 1-A	Section 1-B	Section 1-C	Section 2-A	Section 2-B	Section 2-C	Section 3-A	Section 3-B	Section 3-C
Planariidae (incl. Dugesiidae)					+				
Viviparidae	+	+	+	+		+	+	+	+
Valvatidae		+				+	+	+	
Hydrobiidae (incl. Bithyniidae)	+	+	+	+	+	+	+	+	+
Lymnaeidae		+		+		+		+	+
Planorbidae							+	+	
Ancylidae (incl. Acroloxidae)	+						+		
Unionidae	+	+	+	+	+	+	+		+
Sphaeriidae	+	+	+	+	+	+	+	+	+
Oligochaeta	+	+	+	+	+	+	+	+	+
Piscicolidae		+							
Glossiphoniidae	+	+	+	+	+	+	+	+	+
Erpobdellidae	+	+	+				+	+	+
Asellidae	+	+	+	+	+	+	+	+	+
Corophiidae	+	+	+	+	+	+	+		+
Gammaridae (incl. Crangonyctidae & Niphargidae)				+	+	+	+	+	
Baetidae		+							
Ephemeridae					+				
Caenidae		+	+	+	+	+	+		+
Calopterygidae				+					
Gomphidae		+							+
Haliplidae			+			+		+	
Dytiscidae (incl. Noteridae)		+	+	+	+	+		+	+
Sialidae	+	+	+	+	+	+	+	+	
Hydroptilidae				+			+		+
Polycentropodidae			+	+	+	+		+	+
Psychomyiidae (incl. Ecnomidae)			+	+		+		+	+
Phryganeidae	+	+		+		+	+		
Limnephilidae		+		+	+				+
Molannidae			+			+	+		+
Leptoceridae		+	+	+	+	+	+		+
Chironomidae	+	+	+	+	+	+	+	+	+
BMWP	56	101	92	114	88	111	101	68	107
ASPT	4.31	4.81	5.11	5.43	5.18	5.29	5.05	4.00	5.35
No. Taxa	13	21	18	21	17	21	20	17	20

Zone D Right Pond-net samples Sections 1-5

BMWP family	Section 1-A	Section 1-B	Section 1-C	Section 2-A	Section 2-B	Section 2-C	Section 3-A	Section 3-B	Section 3-C
Hydrobiidae (incl. Bithyniidae)		+	+	+			+	+	+
Lymnaeidae									+
Sphaeriidae						+	+	+	
Oligochaeta	+		+	+		+	+	+	+
Glossiphoniidae							+		
Asellidae	+	+	+		+	+	+	+	+
Corophiidae	+		+	+	+			+	
Gammaridae (incl. Crangonyctidae & Niphargidae)	+		+			+	+	+	
Baetidae						+	+	+	
Ephemeridae								+	
Corixidae							+		
Haliplidae		+	+	+		+	+	+	
Dytiscidae (incl. Noteridae)	+					+	+		+
Elmidae					+	+			
Sialidae					+				
Hydroptilidae		+		+				+	
Polycentropodidae	+			+		+		+	
Psychomyiidae (incl. Ecnomidae)			+			+			
Leptoceridae						+			
Chironomidae	+	+	+	+		+	+	+	+
BMWP	30	19	34	30	18	59	40	56	17
ASPT	4.29	3.80	4.25	4.29	4.50	4.92	3.64	4.67	2.83
No. Taxa	7	5	8	7	4	12	11	12	6

Zone E Right Pond-net samples Sections 1-5

BMWP family	Section 1-A	Section 1-B	Section 1-C	Section 2-A	Section 2-B	Section 2-C	Section 3-A	Section 3-B	Section 3-C
Dendrocoelidae							+		
Planariidae (incl. Dugesiidae)		+	+				+		+
Viviparidae	+	+	+					+	
Valvatidae							+	+	
Hydrobiidae (incl. Bithyniidae)	+	+	+			+	+	+	+
Physidae	+		+						
Lymnaeidae		+	+	+			+	+	
Planorbidae	+	+	+				+	+	+
Ancylidae (incl. Acroloxidae)	+	+	+						+
Unionidae		+						+	
Sphaeriidae	+	+	+			+	+	+	+
Oligochaeta	+	+	+			+	+	+	+
Piscicolidae				+		+			
Glossiphoniidae	+	+					+	+	
Erpobdellidae			+				+	+	+
Asellidae	+	+	+	+		+	+	+	+
Corophiidae			+	+	+	+		+	+
Gammaridae (incl. Crangonyctidae & Niphargidae)		+					+	+	+
Baetidae	+	+	+	+			+	+	
Ephemeridae									+
Caenidae		+		+			+		
Platycnemididae			+					+	
Notonectidae	+								
Corixidae		+	+		+			+	
Haliplidae	+			+	+		+		
Dytiscidae (incl. Noteridae)	+	+	+	+	+		+	+	
Hydrophilidae (incl. Hydraenidae)							+		
Elmidae	+		+						
Sialidae		+				+	+	+	+
Hydroptilidae		+		+					
Polycentropodidae			+	+	+				
Psychomyiidae (incl. Ecnomidae)	+		+					+	+
Phryganeidae								+	
Limnephilidae	+								
Molannidae								+	+
Leptoceridae	+					+	+	+	+
Chironomidae	+	+	+	+	+	+	+	+	+
BMWP	82	81	87	52	30	36	83	113	83
ASPT	4.56	4.26	4.35	4.73	5.00	4.00	4.15	4.91	5.19
No. Taxa	18	19	20	11	6	9	20	23	16

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