# *Aquatic macroinvertebrates as an indicator of water quality after an incident of organic pollution in the Bourne Stream, Dorset*

A S216 Environmental Science, Open University Project

**By Sean Meyrick**

# Contents

## Title

*Aquatic macroinvertebrates as an indicator of water quality after an incident of organic pollution in the Bourne Stream, Dorset.*

## Introduction

The Bourne stream runs for approximately 7km from Canford Heath before discharging into the sea at Bournemouth.[1] The Middle and lower reaches flow through urbanised areas of housing and light industry. Urbanisation reduces the permeable surface area available for infiltration and drainage, increasing surface runoff.

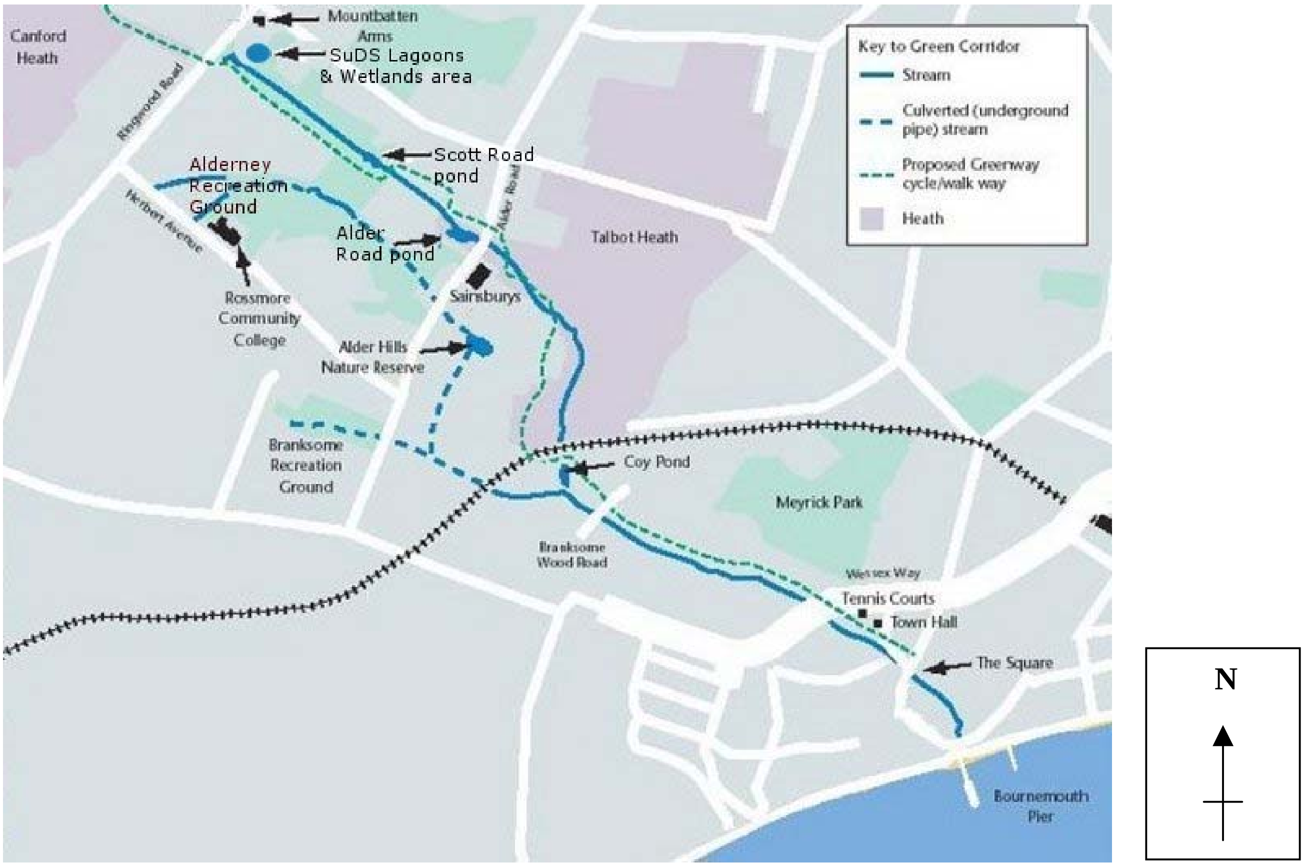



**Fig 1**. A map of the Bourne Stream, Dorset from its source to discharge points on Bournemouth Beach.[2]

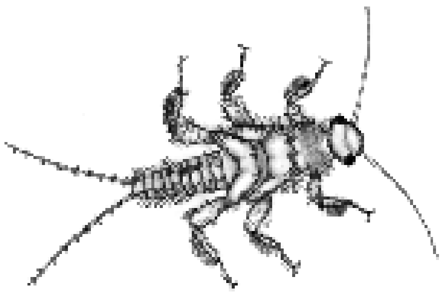
Surface runoff can contain heavy metals, chloride from road salting and organic materials. Organic compounds are materials derived from living or once-living organisms. This includes carbohydrates, proteins and fats produced by the hydrolysis of organic waste, petrochemical residues i.e. oil and petrol and other agricultural, industrial and domestic effluents.

Oxygen is necessary for aerobic processes such as growth and reproduction. Increased organic pollutants reduce oxygen levels due to increased biological Oxygen demand (BOD); a generic term for the oxygen requiring activities of aquatic organisms. Oxygen is removed from the water, as organic materials are oxidised by biological processes. These include conversion of ammonia to nitrates, decomposition reactions and microbial respiration.  Maintaining oxygen levels is an essential factor in keeping water clean. Low $O_2$ levels reduce the capacity for a body of water to clean itself.

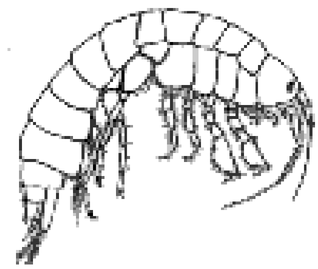
Increased organic content reduces ambient oxygen levels immediately downstream of a pollution point. As BOD increases, oxygen level drop i.e. there is an inverse relationship between BOD and oxygen concentration. As the stream flows away from the incident, organic levels decrease. They settle as sediment, become diluted or are processed by bacteria to less noxious substances. For example ammonia, produced by decaying organic waste, is oxidised to less toxic nitrites and nitrates by nitrosomonas and nitrobacter bacteria[3]. As pollutants decrease BOD consumes less oxygen and ambient $O_2$ levels return to normal.

Freshwater macroinvertebrates are defined as animals without backbones that are visible to the naked eye. They are ideal indicators of long-term water quality due to their relative longevity and long term residence in the stream.

Invertebrate families exhibit different sensitivities to organic pollution, specifically the resultant low oxygen levels, a characteristic that makes them effective water quality indicators. Each family is are assigned a biotic score between 1 and 10 according to this tolerance with no weighting given to the relative abundance of individual organisms. Pollutant intolerant species like mayflies are assigned a high score, tolerant organisms like worms a low score and shrimps, an intermediate organism a mid range score**. (Fig 2)** The definite biotic score is the Biological Monitoring Working Party (BMWP)[4] (Appendix 1)



Stone fly larvae (Capniidae) **10**



fresh water shrimp (Gammariidae) **6**

Flat worms (planaria) **1**

Roundworms (nematodes) **1**

Fig 2. Examples of aquatic macro invertebrates with their BMWP score in bold. **Image source**[5]

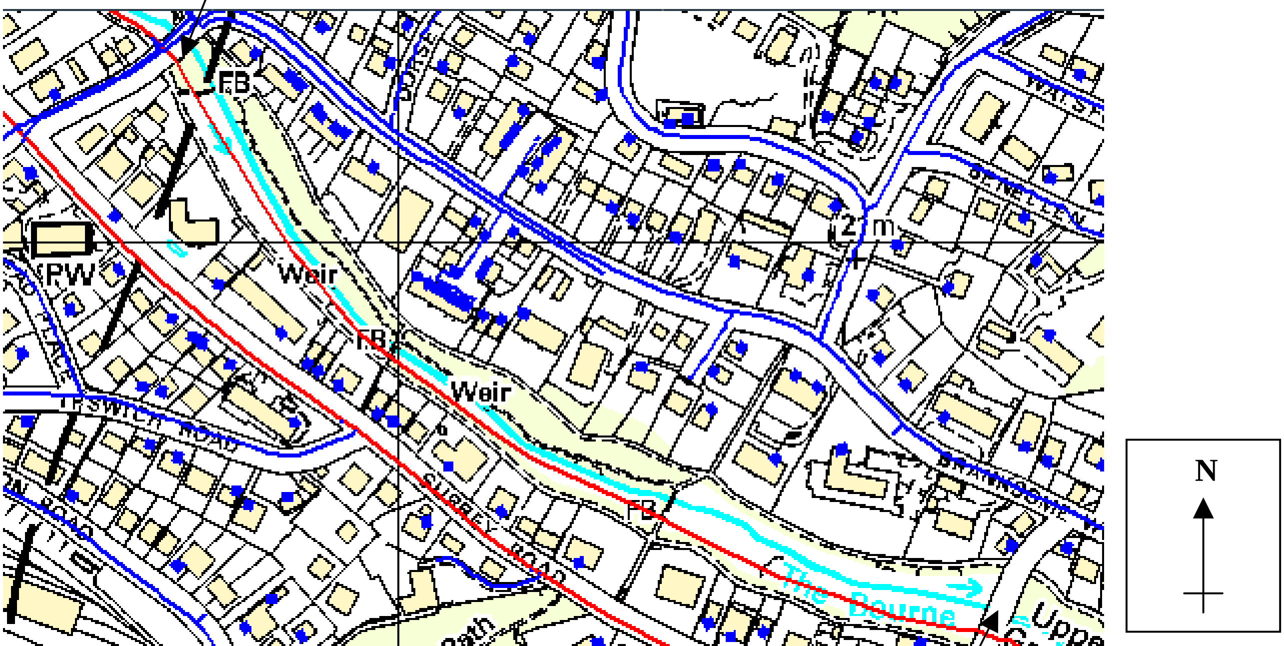
This project will analyse pollution tolerances of invertebrates to assess the environmental impact of organic runoff from a road bridge. The reach the Branksome Wood Road **Grid reference SZ068921** and Prince of Wales Road **Grid reference SZ073917 (fig3)** will be analysed. At both sites the potential for rapid and sustained runoff is increased due to the steep nature of the topography where the roads runs up and down the valley, either side of the stream.

The abundance of pollutant intolerant invertebrates is expected to increase relative to the distance away from the point of pollution

The project will test the hypothesis that -

*"Organic pollution reduces the aquatic macroinvertebrate diversity of a stream*

Branksome wood road (**SZ068921)**




Prince of Wales Road (SZ073917)

**Fig 3**. A detailed map of the project area. From the upstream Branksome Wood Road bridge to the down stream Prince of Wales Road bridge.[6]

**Materials and Method**

Data was collected on the 25th June 2005.

Invertebrate populations were sampled using a standard 3-minute kick-sampling regime.[7] A flat-bottomed net, mesh size 1mm, was used. The head was placed firmly on the substrate to ensure all invertebrates were trapped. The substrate was agitated vigorously by foot upstream of the net trapping any dislodged invertebrates. To standardise the test the substrate in each sample was agitated for three minutes. The net contents were emptied into a white tray to aid identification. Invertebrates were identified in situ with the aid of a hand lens to family level. All samples were released back to the stream.

A point 5m upstream of the Branksome Road Bridge was sampled. An assumption was made that this upstream point was pollution free. The invertebrate diversity at this point provided a control biotic index.

Immediately after the bridge the stream flows along a concrete channel. It was decided that this lack of natural substrate could influence the result. The first sample was therefore taken 40m downstream of the bridge where the natural stream substrate started. Sites were sampled downstream of this point at 50m intervals with the following exceptions.

Site E- There were access problems so samples was taken at the nearest accessible point upstream.

Site G – Rocks present in this section created turbulence in the stream. Turbulence increases the surface area of a stream and hence the oxygen content of water due to surface diffusion. As no other sample point was affected by turbulence this could affect the results. A point 5m upstream was sampled where there was no visible turbulence.

To enable an average score to be calculated three separate samples were taken at each site, one mid stream with the other two 25cm from each bank.

The following parameters were recorded at each site. Water temperature, water depth and stream width. (Appendix 2). Water Temperature was measured with a hand held thermometer placed midstream for 60 seconds. Water depth was measured at the mid stream point and the stream width between the top surfaces of each bank.

A second control sample was made after the second road bridge using the same methodology.

**Results.**

Identified invertebrates were assigned biotic score using the BMWP index. Scores were calculated for all three-sample points at each location. (Appendix 3)

The families present over the entire stretch are outlined in **Table 1** along with appropriate biotic scores.

| GROUP | FAMILIES | BMWP SCORE |
|---|---|---|
| Worms | Lumbricidae | 1 |
| Worms | Tubificidae | 1 |
| Swimming mayfly | Baetidae | 4 |
| Mosquitos (larvae) | Culicidae | 0 |
| Snail | Lymnaeidae | 3 |
| Snail | Physidae | 3 |
| Hog louse | Asellidae | 3 |
| Shrimps | Gammaridae | 6 |
| Snails ( limpet) | Ancylidae | 6 |
| Beetles (whirligig) | Gyrinidae | 5 |
| Dragonflies | Coenagriidae | 6 |
| Midges | Chironomidae | 2 |
| Leeches | Hirudidae | 3 |
| Caddis- flies | Hydropschidae | 5 |
| Flatworm | Planariidae | 5 |
| Caddis-flies | Limnephilidae | 7 |
| **Totals** | **16 Families** | **61** |

**Table 1.** A list of invertebrate families found in the Bourne Stream between Branksome Wood Road and the Prince of Wales Road with the corresponding BMWP values.

The average BMWP scores were calculated for each sample site. **(Table 2)**

| Site | Distance from Road Bridge/Meters | Average BMWP Score |
|---|---|---|
| Control | - 5 m | 25 |
| A | 40 | 9 |
| B | 100 | 10 |
| C | 150 | 10 |
| D | 200 | 13 |
| E | 245 | 21 |
| F | 300 | 15 |
| G | 345 | 18 |
| H | 400 | 16 |
| I | 450 | 19 |
| J | 500 | 16 |
| K | 550 | 16 |
| L | 600 | 26 |
| N | 650 | 21 |
| Control | 5 | 5 |

**Table 2**. The average BMWP score recorded at each test site.

Average BMWP scores were plotted against distance downstream of the pollution point on a XY Scatter graph. (**Fig 4)** A Best-fit line was drawn through the data.

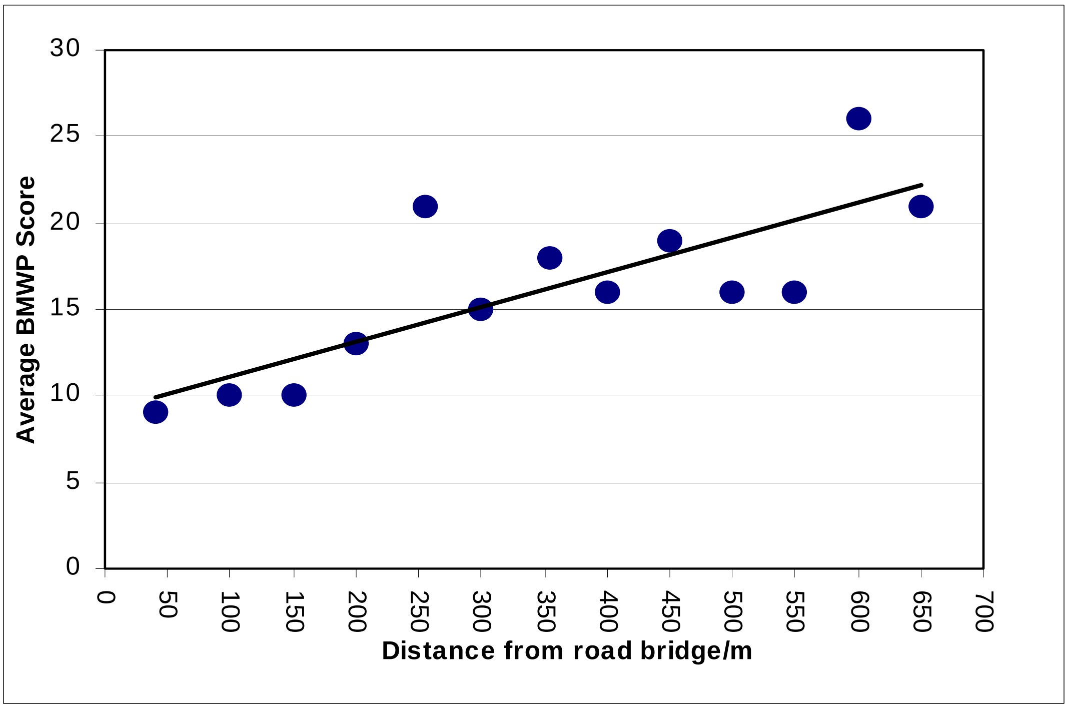



**Fig 4**. An XY scatter graph with average BMWP scores plotted against distance from pollution point/m

Visual inspection of the graph indicates a positive relationship between distance from the pollution point and biotic score. The Excel correlation function gives a correlation coefficient of 0.792 indicating a positive correlation[8]. In principle the experimental data supports the hypotheses. To ensure that this result was not caused by random variation or sampling errors a statistical test is required.

The following points were noted re the data itself..

- It was reasonably scattered.
- The plot did not have a U or inverted U shape
- There were more than seven replicates.
- BMWP data is non-parametric i.e. does not consist of tangible measurement, e.g. length or mass etc.

On this basis and the fact that the experiment is testing the strength of association between two factors, i.e. distance from incident and biotic score, the Spearman Rank Correlation Coefficient[8] statistical test was selected.

The Null hypotheses being tested is

*"Organic pollution has no affect on the macroinvertebrate population of a stream"*

A statistical analysis using the Spearman Rank coefficient was conducted using a spreadsheet package.[9]

The results of the Spearman rank analysis were (Appendix 4)

Spearman Rank - $R_s$ = 0.786
Number of data sets N = 13
Critical value at 5% probability = 0.591
Critical value at 2% probability = 0.712
Critical Value at 1% probability = 0.777

**Conclusion**

The $R_s$ value of 0.786 exceeds the critical value of probability at 1,2 & 5% hence the null hypotheses *"Organic pollution has no affect on the macroinvertebrate population of a stream"* is firmly rejected.

An overall BMWP score of 61 for the project site indicates a stream of good water quality[10]. There are however local areas of the stream with very low BMWP scores indicative of poor water quality. These appear to be related to the two road bridges.

The results confirm that invertebrate levels increase in relation to the distance from the pollution point. There is an immediate drop from a biotic score of 25 in the control section prior to the pollution incident to a level of 9 immediately after. This trend is corroborated by the results taken before and after the second bridge, a score of 21 and 5 respectively. This data does suggest a link between the road bridges and aquatic invertebrate diversity.

Before this factor can be solely attributed to the inflow of organic materials and the resultant low oxygen levels caused by biological processes further testing would need to be undertaken.

An analysis of the dissolved oxygen content with an oxygen meter would confirm the exact oxygen levels at each sample site.

There were many drainage pipes under both bridges and at several points along the stream reach. It would be therefore prudent to sample the water to ensure that invertebrate life was not being affected by high levels of inorganic pollutants, heavy metals, nitrates or increased chloride levels possible due to inflow from these sources as well as general runoff. Ideally a map of all the known inflows would be required.

For completeness the parameters of stream width and depth (Appendix 2) should be analysed against the biotic scores to see if these factors affect invertebrate populations.

Not withstanding the above the initial results do confirm the original hypotheses that ***"Organic pollution reduces the aquatic macroinvertebrate diversity of a stream."***

**Total words 1461**

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**1** Bourne Stream Partnership. [Online] Available from http://www.bournestreampartnership.org.uk/about_the_bourne_stream.htm [accessed 1st July 2005]

**2** Bourne Stream Partnership. [Online] Available from http://www.bournestreampartnership.org.uk/map_of_stream.htm [Accessed 22nd July 2005]

**3** Walker, C. Microbes in the environment in *Microbes*, The Open University, Milton Keynes 2001. S204 Uniformity and Diversity. Book 4.

**4** Gowing, D et al. Life, in *Water and Life*, The Open University, Milton Keynes 2002. S216 Environmental Science. Block 3

**5** Fore, L. *Field Guide to Freshwater Invertebrates*[online] Available from http://www.seanet.com/~leska/Online/Guide.html [Accessed 25th July 2005]

**6** Bournemouth & West Hampshire Water plc.[online] www.bhwwater.co.uk *intranet.*

**7** Gowing, D et al. DVD ROM *Teign valley Virtual Field Trip* The Open University, Milton Keynes 2002. S216 Environmental Science. Block 1

**8** Using the Spearman Rank Correlation Coefficient Booklet. S216 Environmental Science 2003 The open University. Milton Keynes

**9** Gardner, M. (Associate Lecturer Open University). *Statistics by Mark Gardener* [online] Open University. Available from http://webfc2.open.ac.uk/Login/Open%20University/OU%20Students%20Association/OUSA%20Signpost/OUSA%20S328%20Dark%20Green/?Items=21-40&Folders=1-32767 [ Accessed 5th June 2005 ]

**10** River Ouzel invertebrates. *BMWP Scores and water quality.* [Online] available from http://www.open.ac.uk/Nature_Trail/R_invert.htm [Accessed 10th July 2005]

The author would like to acknowledge that the following sources have been extensively used in the production of this report.

**Taxonomic classification and identification**

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*Identifying freshwater invertebrate life.* [online] PDF http://publications.environment-agency.gov.uk/epages/eapublications.storefront/42eb5e1a03444ac6273fc0a802960661/Search/Run?Attributes=1005&1005=04&SearchCombination=And&Attributes=1027&1027=Y&Listheader=Conservation%20and%20EcologyT The Environment Agency Almondsbury (2004)

**General interest and inspiration**

Freeman, D. CDROM *Riverside Explorer (version 1.0).* The Environment Agency Almondsbury (2000)

The author would also like to thank Sarah Austin, Project Manager for the Bourne Stream Partnership for her kind permission to reproduce the map in fig1.

# Appendices

Appendix 1

| Group | Families | score |
|---|---|---|
| mayflies | Siphlonuridae, Heptageniidae, Leptophlebidae<br>Ephemerellidae, Ecdyonuridae, Potaminthidae, Ephemeridae | 10 |
| stoneflies | Taeniopterigidae, Leuctridae, Capniidae, Perlodidae<br>Perlidae, Chloroperlidae | 10 |
| Caddis-flies | Phryganeidae, Mollannidae, Beraeidae, Odontoceridae<br>Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae<br>Sericostomatidae. | 10 |
| River bugs | Aphelocheiriidae | 10 |
| caddid-flies | Philopotamidae, Glossosomatidae | 8 |
| dragonflies | Lestidae, Agriidae, Gomphidae, Cordulegasteridae<br>Aeshnidae, Corduliidae, Libellilidae | 8 |
| mayflies | Caenidae | 7 |
| stoneflies | Nemouridae | 7 |
| caddis-flies | Polycentropidae, Rhyacophilidae, Limnephilidae | 7 |
| snails | Neritidae, Viviparidae, Ancylidae | 6 |
| caddis-flies | Hydroptilidae | 6 |
| mussels | Unionidae | 6 |
| shrimps | Corophidae, Gammaridae | 6 |
| dragonflies | Platycnemididae, Coenagriidae | 6 |
| bugs | Mesovelidae, Hydrometridae, Gerridae, Nepidae, Naucoridae<br>Notonectidae, Pleidae, Corisidae | 5 |
| beetles | Hydrophilidae, Clambidae, Elmidae, Dryopidae, Haliplidae<br>Hygrobiidae, Dytiscidae, Gryinidae, Helodidae, Chrysomelidae | 5 |
| caddis-flies | Hydropsychidae | 5 |
| true flies | Tipulidae, Similiidae | 5 |
| flatworms | Planariidae, Dendrocoelidae | 5 |
| mayflies | Baetidae | 4 |
| alderflies | Sialidae | 4 |
| leeches | Pisicolidae | 4 |
| snails | Valvatidae, Hydrobidae, Lymnaeidae, Physidae, Planorbidae | 3 |
| pea cockles | Sphaeridae | 3 |
| leeches | Glossiphonidae, Hirudidae, Erpobdellidae | 3 |
| hoglouse | Asellidae | 3 |
| midges | chironomidae | 2 |
| worms | Tubificidae, Naididae, Lumbricidae | 1 |

The Biological Monitoring Working Party (BWMP) biotic index[4]

# Appendix 2

| Site | Temperature/C$^{o}$ | Depth/m | Width/m |
|---|---|---|---|
| Control | 15 | 0.60 | 2.3 |
| 40 | 15 | 0.24 | 2.4 |
| 100 | 15 | 0.30 | 2.4 |
| 150 | 15 | 0.52 | 2.0 |
| 200 | 15 | 0.40 | 2.2 |
| 245 | 15 | 0.30 | 2.0 |
| 300 | 15 | 0.35 | 2.4 |
| 345 | 15 | 0.60 | 2.5 |
| 400 | 15 | 0.25 | 2.0 |
| 450 | 15 | 0.15 | 2.4 |
| 500 | 15 | 0.30 | 2.2 |
| 550 | 15 | 0.15 | 1.8 |
| 600 | 15 | 0.20 | 1.8 |
| 650 | 15 | 0.30 | 2.0 |
| Control | 15 | 0.09 | 2.70 |

Results of the measurements of water temperature/ C$^{o}$, Stream width/m and Stream depth/m at all test sites.

# Appendix 3

| | Sample sites | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family/BMWP Score | A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | C3 | D1 | D2 | D3 | E1 | E2 | E3 |
| Lumbricidae/1 | 1 | 1 | 1 | | | 1 | | | 1 | | 1 | | 1 | 1 | 1 |
| Tubificidae/1 | 1 | 1 | | | 1 | 1 | 1 | | 1 | | 1 | | | | 1 |
| Baetidae/4 | 4 | 4 | 4 | | 4 | 4 | 4 | | 4 | 4 | | 4 | 4 | 4 | 4 |
| Culicidae/0 | 0 | | | | | 0 | 0 | | 0 | | | 0 | 0 | | |
| Lymnaeidae/3 | 3 | 3 | | | | | 3 | 3 | | 3 | | | | 3 | |
| Physidae/4 | 3 | 3 | 3 | 3 | | 3 | 3 | 3 | | | | 3 | 3 | | |
| Asellidae/3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | 3 | | 3 | 3 | 3 |
| Gammaridae/6 | 6 | | 6 | | | | | | | | | | | | |
| Ancylidae/6 | 6 | | | | | | | | | | | | | | |
| Gyrinidae/5 | | | | | | | | | | | | | | | |
| Coenagriidae/6 | | 6 | | | | | | | | | | | | | |
| Chironomidae/2 | | 2 | 2 | 2 | | | 2 | | | 2 | 2 | 2 | | 2 | 2 |
| Hirudidae/3 | | | | | | | | | | 3 | | | | | |
| Hydropschidae/5 | | | | | | | | | | | | | | | |
| Planariidae/5 | | | | | | | | | | | | | 5 | | |
| Limnephilidae/7 | | | | | | | | | | | | | | | |
| Beetle larvae/5 | | | 5 | | | | | | | | | | | | |
| Totals | 27 | 23 | 24 | 8 | 8 | 12 | 16 | 9 | 6 | 15 | 7 | 9 | 16 | 13 | 11 |

| | Sample sites | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family/BMWP Score | F1 | F2 | F3 | G1 | G2 | G3 | H1 | H2 | H3 | I1 | I2 | I3 | J1 | J2 | J3 |
| Lumbricidae/1 | | 1 | | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Tubificidae/1 | | 1 | | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| Baetidae/4 | | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Culicidae/0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Lymnaeidae/3 | | | 3 | | | 3 | | 3 | 3 | 3 | | 3 | | 3 | |
| Physidae/4 | | 3 | 3 | | 3 | | | 3 | | | 3 | 3 | 3 | 3 | |
| Asellidae/3 | 3 | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Gammaridae/6 | 6 | 6 | 6 | 6 | | | | | 6 | | | | | | |
| Ancylidae/6 | | | | | | | | | | | | | | | |
| Gyrinidae/5 | | | | | | | | | | | | | | | |
| Coenagriidae/6 | | | | | | | | | | | | | | | |
| Chironomidae/2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | 2 | | 2 | |
| Hirudidae/3 | | | | 3 | 3 | 3 | | | | | | | 3 | | 3 |
| Hydropschidae/5 | 5 | | | | | | | | | | 5 | | | | |
| Planariidae/5 | 5 | 5 | 5 | | | | 5 | 5 | | | | | 5 | 5 | 5 |
| Limnephilidae/7 | | | | | | | | | | | | | | | |
| Beetle larvae/5 | | | | | | | | | | | | | | | |
| Totals | 21 | 20 | 23 | 18 | 13 | 15 | 16 | 22 | 17 | 14 | 17 | 17 | 20 | 22 | 16 |

| | Sample sites | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family/BMWP Score | K1 | K2 | K3 | L1 | L2 | L3 | M1 | M2 | M3 | N1 | N2 | N3 | O1 | O2 | O3 |
| Lumbricidae/1 | 1 | 1 | | | 1 | | 1 | 1 | | 1 | 1 | 1 | | | |
| Tubificidae/1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| Baetidae/4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | |
| Culicidae/0 | 0 | | 0 | | 0 | | 0 | 0 | | 0 | 0 | | | | |
| Lymnaeidae/3 | | 3 | 3 | | | 3 | 3 | 3 | 3 | | 3 | | | | |
| Physidae/4 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | | | 3 | 3 | | | |
| Asellidae/3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | 3 | 3 | 3 |
| Gammaridae/6 | | | | | | | 6 | | 6 | 6 | | 6 | | | |
| Ancylidae/6 | | | | | | | | | | | | | | | |
| Gyrinidae/5 | | | | | | | 5 | | | | | | | | |
| Coenagriidae/6 | | | | | | | | | | | | | | | |
| Chironomidae/2 | | | 2 | | | | | 2 | 2 | 2 | 2 | 2 | 2 | | 2 |
| Hirudidae/3 | 3 | | | 3 | | | | | | 3 | | 3 | | | |
| Hydropschidae/5 | | | | | | | | | | | | 5 | | | |
| Planariidae/5 | 5 | | | 5 | | 5 | 5 | | 5 | | 5 | | | | |
| Limnephilidae/7 | | | | | | | 7 | | | | | | | | |
| Beetle larvae/5 | | | | | | | | | | | | | | | |
| Totals | 20 | 12 | 16 | 19 | 12 | 18 | 38 | 17 | 23 | 20 | 19 | 25 | 6 | 4 | 6 |

BMWP biotic scores for all 3 samples taken at each test site between Branksome Wood Road and the Prince of Wales Road

Appendix 4

| n | Data1 | Data2 | Rank1 | Rank2 | Rank diff | Diff Sq | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 40 | 9 | 1 | 1 | 0 | 0 | | | | | |
| 2 | 100 | 10 | 2 | 2.5 | -0.5 | 0.25 | | | | | |
| 3 | 150 | 10 | 3 | 2.5 | 0.5 | 0.25 | | | | | |
| 4 | 200 | 13 | 4 | 4 | 0 | 0 | | | | | |
| 5 | 245 | 21 | 5 | 11.5 | -6.5 | 42.25 | | | | | |
| 6 | 300 | 15 | 6 | 5 | 1 | 1 | | | | | |
| 7 | 345 | 18 | 7 | 9 | -2 | 4 | | | | | |
| 8 | 400 | 16 | 8 | 7 | 1 | 1 | | | | | |
| 9 | 450 | 19 | 9 | 10 | -1 | 1 | | | | | |
| 10 | 500 | 16 | 10 | 7 | 3 | 9 | | | | | |
| 11 | 550 | 16 | 11 | 7 | 4 | 16 | | | | | |
| 12 | 600 | 26 | 12 | 13 | -1 | 1 | | | | | |
| 13 | 650 | 21 | 13 | 11.5 | 1.5 | 2.25 | | | | | |
| 14 | | | | | | | | | | | |
| 15 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | Significance level | | |
| 22 | | | | | | | | | 5% | 2% | 1% |
| n | 13 | | | Total | 0 | 78 | | $r_s$ crit | 0.591 | 0.712 | 0.777 |
| | | | | | $r_s$ | 0.786 | | Significant | Yes | Yes | Yes |

Results of the statistical analysis and associated levels of significance, $R_s$ and number of data pairs[9]