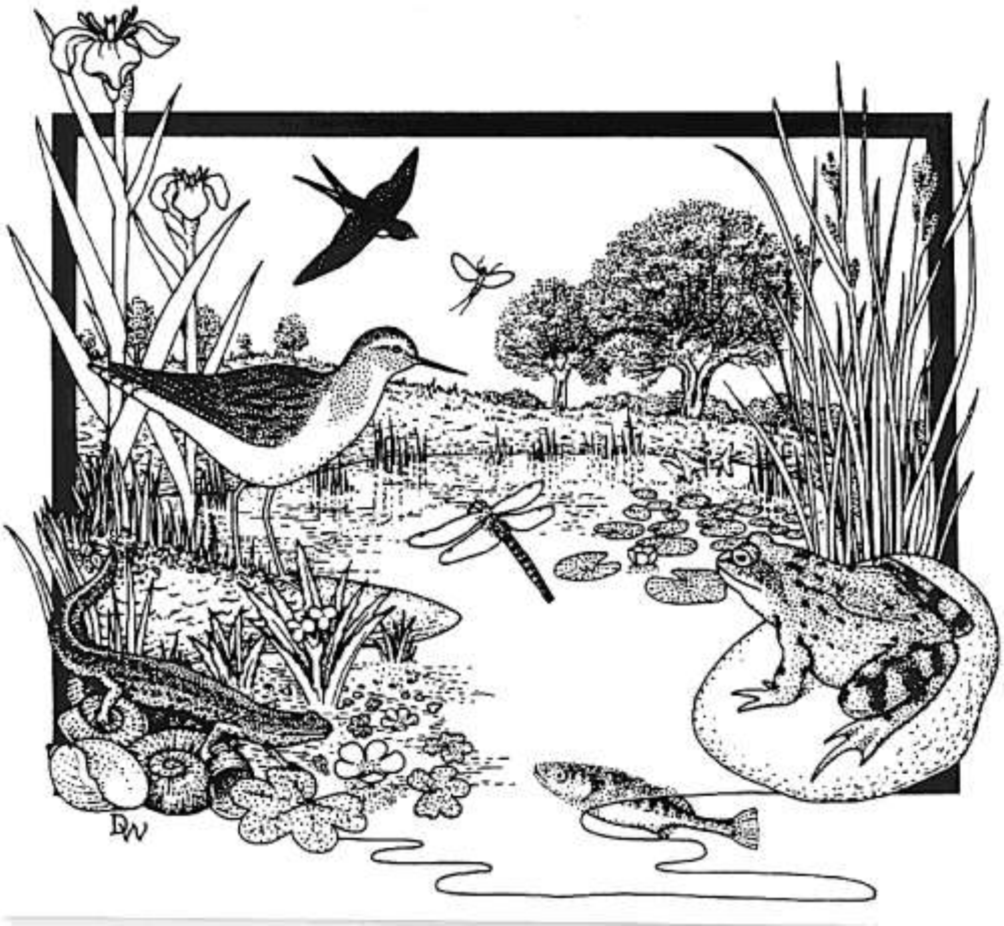
A spring survey of the aquatic macroinvertebrates of the Montgomery Canal



November 2003

The Ponds Conservation Trust: Policy & Research
c/o Oxford Brookes University
Gipsy Lane, Headington
Oxford OX3 0BP

Summary

This report describes the results of a macroinvertebrate survey of the Montgomery Canal together with a review of existing biological and chemical data previously gathered from the area.

The Montgomery Canal supports a macroinvertebrate assemblage typical of 'minimally impaired' canals, with species richness and rarity values close to the national average for high quality canals. The canal supports moderate numbers of Nationally Scarce macroinvertebrate species but is not currently known to support any BAP or Red Data Book species. Surveys of dragonflies conducted in 1997 recorded 8 breeding species: a good total, but below the level regarded as the qualifying number for selection as a SSSI on the basis of the dragonfly population.

Surveys undertaken during the present project at 10 sites along the canal indicate that, with the exception of the Rednal site, the fauna generally increases in richness from north to south. Species richness was lowest at Queen's Head and highest at Buttington Cross. Combined with CANOCO analysis, this indicates that the canal can be broadly divided into two sections: a northern, boated, more species poor section and a southern lightly or unboated section, which generally has a richer fauna.

Environment Agency water quality monitoring data were available from four sites on the canal: Queen's Head, Parson's Bridge, Buttington Cross and Aberbechan. Queen's Head has the poorest water quality of the four sampling locations with nutrient and ammonia concentrations significantly higher than elsewhere. Levels of nitrate nitrogen and orthophosphate phosphorus at Queen's Head are sufficiently high to cause detrimental impacts on aquatic ecosystems, particularly aquatic plants. Water quality at the three other sites is good, in terms of nutrient concentrations, with phosphorus concentrations on the mesotrophic-eutrophic boundary.

Environment Agency data show significant differences in pH at the four sampling locations although all sites can be classified as circumneutral. Mean pH at Parson's Bridge and Aberbecahan was 7.12 and 7.21, respectively, with mean pH values of 7.43 and 7.45 at Buttington Cross and Queen's Head, respectively. Surprisingly there were no significant differences in suspended sediment concentrations between the four sampling locations, although there was a slight suggestion that concentrations were higher at the most southerly site: Aberbechan. Mean dissolved oxygen concentrations increased from Queen's Head (73.6%) to Aberbechan (87.7%).

The differences between the invertebrate assemblages of the northern and southern sections of the canal are probably due mainly to the markedly poorer water quality in the northern section. Boat traffic probably exacerbates these effects by further reducing the abundance of submerged aquatic, and possibly marginal, vegetation.

Recommendations are made about the future monitoring of the canal invertebrate assemblages: a further two seasons of baseline survey work should be undertaken covering spring and autumn and more detailed studies of the relative importance of water quality and boating be undertaken.

Contents

Summary 2
Contents 3
1. Introduction 5
1.1 Background 5
1.2 Aims of the project 5
2. Initial data review 5
2.1 Review of existing invertebrate data from the Montgomery Canal 5
2.1.1 Introduction 5
2.1.2 Surveys in the 1980s by the Montgomery Canal Ecological Survey 6
2.1.3 1997 survey of the Montgomery Canal 6
2.1.4 Sites in the PSYM database on the Montgomery Canal 7
2.2 Review and analysis of Environment Agency water quality data from 1990 onwards from the Montgomery Canal 8
2.2.1 Introduction 8
2.2.2 pH 8
2.2.3 Dissolved oxygen concentrations 9
2.2.4 Suspended sediment concentrations 11
2.2.5 Nutrients and ammonia 11
2.2.6 Summary of results of water quality monitoring 12
3. Invertebrate survey 13
3.1 Methods 13
3.1.1 The survey method used 13
3.1.2 Sampling locations 13
3.1.3 Date of survey 15
3.1.4 Laboratory processing of samples 15
3.1.5 Assessment methods 15
3.2 Results 16
3.2.1 Composition of the macroinvertebrate fauna 16
3.2.2 Assessment of the conservation value of the canal 18
3.2.3 Factors affecting the composition of invertebrate assemblages in the Montgomery Canal 20
3.2.4 PSYM analysis of the ecological quality of Montgomery Canal invertebrate assemblages 21
3.2.5 Glossary of terms used in the PSYM system 23

4. Conclusions and recommendations for future monitoring ... 27
4.1 Conclusions ... 27
4.2 Recommendations for future monitoring ... 28
4.2.1 General recommendations ... 28
4.2.2 Separating the effects of boat traffic from other environmental factors (geology, water quality) ... 28
4.3 Recommendations for an invertebrate monitoring methodology for the new canal reserves ... 29
4.4 Further information on PSYM results ... 29
4.5 Water quality and plants ... 29
5. References ... 30
Appendix 1. The PSYM manual ... 31
Appendix 2. Invertebrate species recorded at sites on the Montgomery Canal in the 1997 PSYM database creation project ... 47
Appendix 3 Figures 1(a) – (d) ... 49
Appendix 4. Location of survey sites, and field recording sheets, for 2003 Montgomery Canal invertebrate survey ... 51
1. Lower Frankton (SJ370318) ... 51
2. Rednal (SJ350275) ... 52
3. Queen’s Head (SJ341269) ... 53
4. Aston Locks (SJ335263) ... 54
5. Maesbury Marsh (SJ305248) ... 55
6. Vyrnwy Aqueduct (SJ254197) ... 56
7. Parson’s Bridge (SJ264189) ... 57
8. Bank Lock (SJ260130) ... 58
9. Buttington Cross (SJ241089) ... 59
10. Aberbechan (SO142934) ... 60

A spring survey of aquatic macroinvertebrates in the Montgomery Canal

1. Introduction

1.1 Background

The Montgomery Canal is one of the United Kingdom's highest quality aquatic ecosystems, long recognised as a site of considerable importance for its aquatic plants and supporting a rich invertebrate fauna.

Of a total length of 55 km, 39 km of the canal are designated as a Site of Special Scientific Interest, primarily in Wales[1]. The Welsh section of the canal is also designated as a candidate Special Area for Conservation (cSAC) under the Habitats Directive.

The Montgomery Canal is particularly renowned for its diverse assemblage of aquatic plants including the Annexe II Habitats Directive species *Luronium natans*, and the Nationally Scarce species *Potamogeton compressus*. It also supports populations of the water quality sensitive species *Potamogeton alpinus*, *P. friesii, P. praelongus, Hydrocharis morsus-ranae* and *Hottonia palustris*.

Although the flora of the Montgomery Canal has been extensively investigated, few recent data are available describing the invertebrate fauna.

1.2 Aims of the project

The main aim of the present project was to collect baseline data on the aquatic macroinvertebrate fauna of the Montgomery Canal to establish a baseline for future monitoring of the waterway. Macroinvertebrate data were collected using the Canal PSYM method, developed by the Environment Agency and the Ponds Conservation Trust for assessing canal ecological quality. A copy of the PSYM manual (which covers both pond and canal monitoring) is included in Appendix 1 of this report.

In addition a review of existing macroinvertebrate and chemical data from the Montgomery Canal was undertaken.

2. Initial data review

2.1 Review of existing invertebrate data from the Montgomery Canal

2.1.1 Introduction

The most extensive data describing the invertebrate assemblages of the Montgomery Canal come from two major surveys: the 1980s Montgomery Canal Ecological Survey (Briggs 1988) and the more recent, but less comprehensive, studies commissioned by British Waterways (1999). Neither survey used standard methods for recording invertebrates making these data difficult to compare with the results of other studies. However, both give a good indication of the general fauna of the canal.

Comparative data from high quality canals throughout England and Wales, collected by the Environment Agency and the Ponds Conservation Trust during the creation of the canal PSYM database, provides additional data, and allows a more objective assessment of the status of the Montgomery Canal to be made. However, only three sites on the Montgomery Canal were surveyed for this project.

---

[1]Two sections of the Montgomery Canal are designated as SSSIs: in England, the short section from Aston Locks to Keepers Bridge; in Wales, the full length of the canal from Llanymynech on the border to Freestone Lock, just outside Newtown, is designated as SSSI.

2.1.2 Surveys in the 1980s by the Montgomery Canal Ecological Survey

Surveys described in Briggs (1988) found a total of 143 species in the main macroinvertebrate groups (158 taxa were recorded in total including Diptera and *Pisidium* identified to species level). The groups with the largest number of species were water beetles (43 species), molluscs (22 species excluding *Pisidium* spp.) and caddis flies (19 species). The total represents about 18% of the UK macroinvertebrate fauna in the groups surveyed. The relatively rich snail and caddis faunas are typical of permanent still, or slowly flowing, waters.

The 1980s Montgomery Canal survey programme was based on a fairly intensive sampling programme with samples taken at 1 km intervals over 42 km of the canal, and surveys undertaken in two seasons (spring and summer). Given the relatively high intensity of sampling and the non-standard methods used it is difficult to compare the species richness of the Montgomery Canal with that of other sites and surveys. However, it is clear that the canal, as a whole, compares well with other top quality sites: for example, at the Pinkhill Meadow experimental pond creation site in Oxfordshire, which is a complex of approximately 40 ponds and pools from 1 m^2 to 0.5 ha in area, 156 species were recorded between 1990 and 1995 (PCTPR, unpublished data).

Of the invertebrate species recorded in the original 1980s surveys, six are now regarded as Local or Nationally Scarce (Table 1).

Table 1. Local and Nationally Scarce macroinvertebrate species recorded in the 1980s surveys of the Montgomery Canal

Sphaerium rivicola (River orb mussel)	Local
Corixa dentipes (A lesser water boatman)	Local
Cymatia coleoptrata (A lesser water boatman)	Local
Haliplus heydeni (A crawling water beetle)	Nationally Scarce
Noterus crassicornis (A diving beetle)	Nationally Scarce
Ilybius guttiger (A diving beetle)	Nationally Scarce

2.1.3 1997 survey of the Montgomery Canal

The 1997 survey of the canal considered only molluscs and dragonflies.

The survey recorded 17 species of snails and mussels, indicative of a reasonably rich fauna, all being common species. Note that the failure to record smaller snail species such as Leach's Bithynia (*Bithynia leachii*) and the White Ram's-horn (*Gyraulus albus*), both found in the 1980s surveys and fairly common in the current surveys reported here, casts some doubt on the quality of the 1997 survey work.

Eight breeding species of Odonata were recorded in the 1997 surveys with observations made of a further 11 species recorded on or close to the canal without evidence of breeding. The number of species recorded breeding in the canal is good, but below the regional threshold (12 species) for consideration as a Site of Special Scientific Interest on the basis of the dragonfly population. The most notable **breeding** species recorded was the Club-tailed Dragonfly (*Gomphus vulgatissimus*) which is a Nationally Scarce species mainly restricted to a small number of larger rivers, including the Severn. There are a small number of UK non-river breeding records.

2.1.4 Sites in the PSYM database on the Montgomery Canal

Background to PSYM

PSYM, the Predictive System for Multimetrics (pronounced sim), was developed by the Environment Agency and the Ponds Conservation Trust to assess the biological quality of standing waters (lakes, ponds, canals, ditches, lagoons) in England and Wales. To date working PSYM modules have been developed for ponds (including small lakes up to 5 ha) and canals.

PSYM for canals uses a number of invertebrate measures (known as metrics), that are combined together to give a single value which represents the waterbody's overall quality status.

Using the method involves the following steps:

(i) Simple environmental data are gathered for each canal site from desk data (e.g. maps) and field evidence (e.g. location, altitude, substrate etc.).

(ii) Biological surveys of the macroinvertebrate communities are undertaken and net samples are processed.

(iii) The biological and environmental data are entered into the PSYM computer programme which:

(a) uses the environmental data to predict which animal families should be present in the canal if it is undegraded,

(b) takes the real animal lists and calculates a number of metrics.

Finally the programme compares the predicted animal metrics with the real survey metrics to see how similar they are (i.e. how near the waterbody currently is to its ideal/undegraded state). The metric scores are then combined to provide a single value which summarises the overall ecological quality of the waterbody.

The selection of baseline 'minimally impaired' sites in Canal PSYM was based on the premise that water quality should be good and that moderate boat use was a normal part of the canal environment. Minimally impaired canal sites were drawn from the following canals: Ashby, Basingstoke, Bridgewater and Taunton, Cannock Extension, Grand Union, Grantham, Huddersfield Narrow, Kennet and Avon, Lancaster, Leeds-Liverpool, Llangollen, Leven, Monmouthshire and Brecon, Montgomery, Newport, Oxford, Pocklington, Ripon, Shropshire Union and Stourbridge.

PSYM results from the Montgomery Canal

Three sites on the Montgomery Canal were surveyed as part of the creation of the PSYM database in spring 1997. These were at Queens Head (SJ340269), Wern (SJ252143) and Buttington Cross (SJ242089).

The lists of invertebrate species recorded in standard spring PSYM samples from these sites are given in Appendix 2. The three Montgomery sites supported 21, 43 and 45 species in a standard PSYM sample (mean 36.3 species), very similar to the mean for minimally impaired canals in the PSYM database (37.1 species).

2.2 Review and analysis of Environment Agency water quality data from 1990 onwards from the Montgomery Canal

2.2.1 Introduction

Water quality monitoring data, collected by the Environment Agency, are available from four sites on the Montgomery Canal from 1990 onwards (see Figure 3). These are:

- Queens Head (SJ3390026800)
- Parsons Bridge (SJ2645018960)
- Buttington Cross (SJ2410008900)
- Aberbechan (SO1425093530).

Data are available from these sites for the following determinands: pH, alkalinity, total hardness, biochemical oxygen demand, total ammonia, unionised ammonia, total oxidised nitrogen, suspended solids, total chloride, nitrate, nitrite, orthophosphate and dissolved oxygen.

Differences in water quality at the four sampling stations were analysed, as part of the current project, using ANOVA. Results of statistical analyses are summarised briefly in the following sections.

For each determinand critical biological levels are given:

- *Suspended sediments*. The concentrations at which impacts on fish populations are recognized are given. Critical levels for invertebrates or plants are not available.
- *Total oxidized nitrogen*. The concentrations typical of minimally impaired still waters are given; levels above this are likely to contribute to eutrophication, increasing algal populations at the expense of macrophytes. Invertebrates and fish are not generally thought to be affected by total oxidised nitrogen directly at the concentrations which impact plant communities.
- *Orthophosphate phosphorus*. The concentrations typical of minimally impaired still waters are given; levels above this are likely to contribute to eutrophication, particularly promoting the growth of algae at the expense of macrophytes. Invertebrates and fish are not thought to be directly impacted by phosphorus at the concentrations causing eutrophication, except as a result of indirect effects due to habitat loss.
- *Ammonia*. Concentrations dangerous to fish are given. Other groups of organisms are generally thought to be less sensitive to ammonia than fish.

Note pH and dissolved oxygen concentrations vary over a wide range naturally in minimally impaired waters. For this reason specific levels damaging to biota cannot be given.

2.2.2 pH

Water in the Montgomery Canal is typically circumneutral in pH and varies over about 1 pH unit in the course of the year (Appendix 3 Figures 1a-d). There are significant differences in pH along the canal with Queens Head and Buttington Cross having a higher mean pH than Parsons Bridge and Aberbechan (Figure 1).

There is no evidence of any trends in pH over the last decade.

It is not possible to define an ideal 'baseline' value for pH since a full range of pHs can potentially be observed in natural environments.

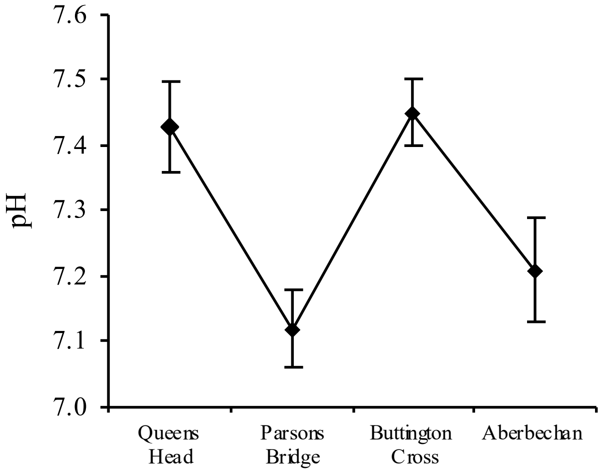


Figure 1. Mean pH at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

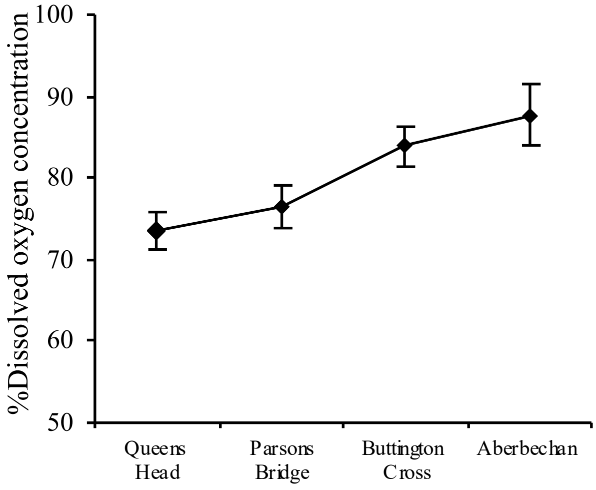


Figure 2. Mean dissolved oxygen concentration at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

2.2.3 Dissolved oxygen concentrations

Dissolved oxygen concentrations vary significantly along the canal with a mean of 74% at Queens Head rising to 84% at Aberbechan (Figure 3). There were no long-term trends in dissolved oxygen concentrations through the survey period.

It is not possible to specify a natural baseline dissolved oxygen concentration for canals at present.

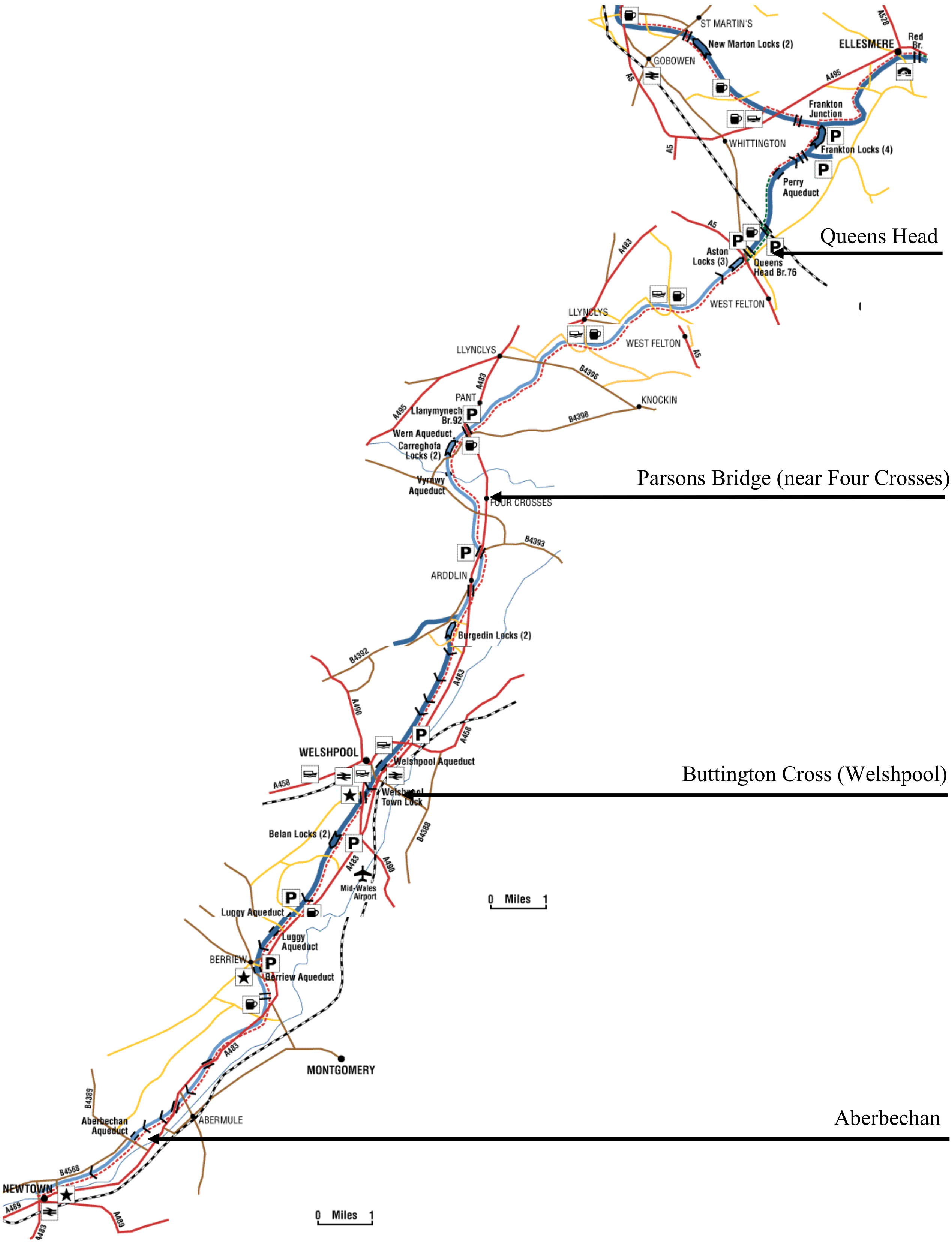


Figure 3. Environment Agency water chemistry sampling stations on the Montgomery Canal

2.2.4 Suspended sediment concentrations

Suspended sediment concentrations are generally below the level regarded by the European Inland Fisheries Association as damaging to fish populations. Although suspended sediment concentrations were highest at Aberbechan, the differences between the four sampling stations were not statistically significant. There were no long-term trends in suspended sediment concentrations.

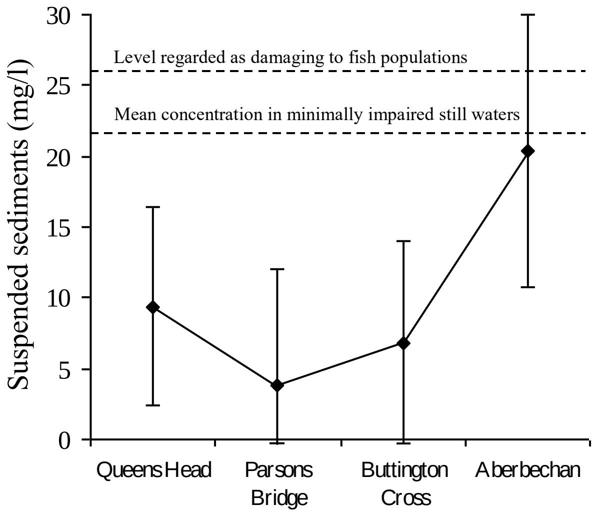


Figure 4. Mean suspended sediment concentrations at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

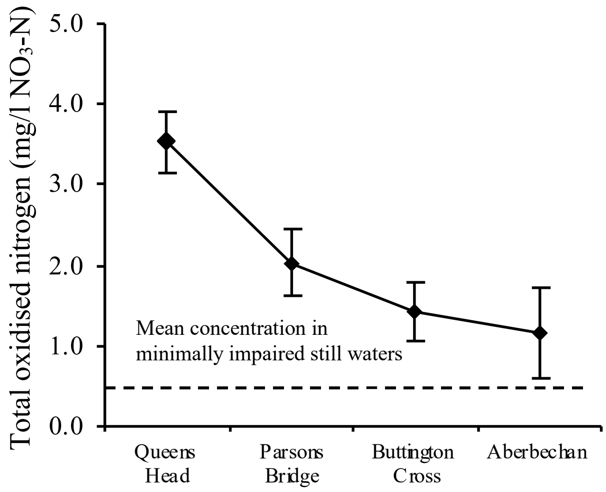


Figure 5. Mean total oxidised nitrogen concentrations at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

2.2.5 Nutrients and ammonia

Mean total oxidised nitrogen concentrations varied significantly along the canal, being highest at Queens Head and lowest at Aberbechan (Figure 5). Concentrations were considerably above mean concentration seen in minimally impaired in natural still waters (0.5 mg/l NO_3-N) (PCTPR, unpublished data). There was no evidence of a long-term trend in total oxidised nitrogen concentrations.

Mean orthophosphate phosphorus concentrations also varied significantly between sites, again being highest at Queens Head (Figure 6). Concentrations were above the level seen in minimally impaired still waters at Queens Head, but below this level at all other sites. There was no evidence of long-term trends in nitrate or phosphate concentrations.

Mean total ammonia concentrations were highest at Queen's Head but all sites had concentrations which were similar to those seen in the cleanest rivers (Environment Agency Class 1 River Ecosystems) (Figure 7).

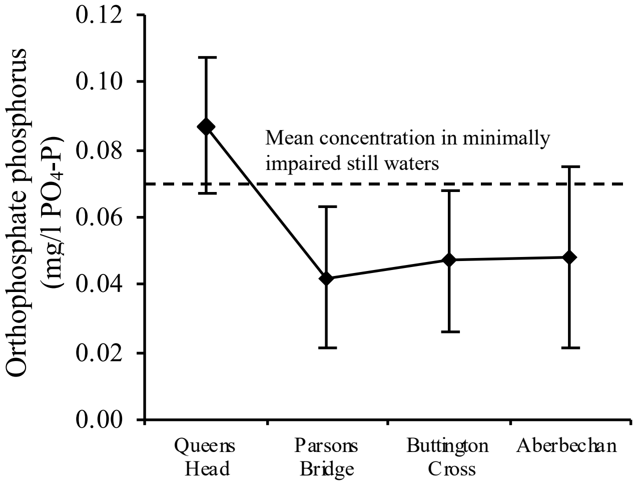


Figure 6. Mean orthophosphate phosphorus concentrations at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

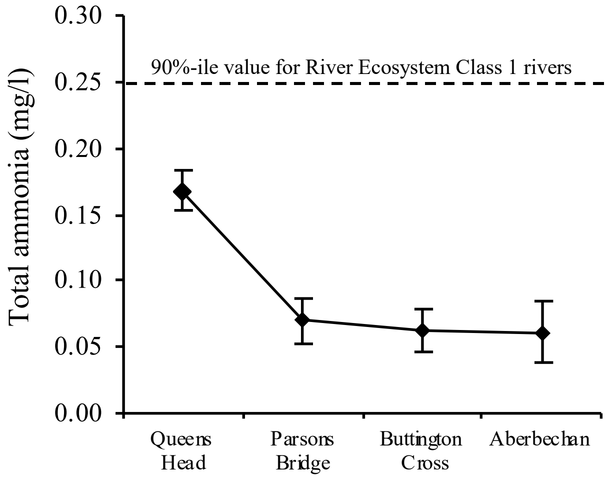


Figure 7. Mean total ammonia concentrations at four sampling locations on the Montgomery Canal, 1990-2003. Error bars show 95% confidence limits.

2.2.6 Summary of results of water quality monitoring

Environment Agency monitoring data indicate that phosphorus concentrations were significantly elevated in the Queen's Head section of the canal. Levels were high enough to cause impacts on aquatic plant communities. Changes to plant communities initiated by raised phosphorus concentrations could potentially have indirect impacts on invertebrate assemblages through loss or alteration of plant habitats.

Total oxidised nitrogen concentrations were significantly elevated in all section of the canal, although highest in the Queen's Head section. Levels were high enough to cause impacts on plant assemblages and, as with phosphorus, could cause indirect impacts on invertebrate assemblages as a result of loss or alteration of plant habitats. Ammonia concentrations were also highest in the Queen's Head section of the canal, but levels are unlikely to be high enough to cause major impacts.

pH, suspended sediment and dissolved oxygen levels were unlikely to have significant damaging impacts on either aquatic plant or invertebrate communities.

3. Invertebrate survey

3.1 Methods

3.1.1 The survey method used

The survey of macroinvertebrates for the present project was undertaken using the standard canal PSYM methodology (see Appendix 1).

This sampling technique used in PSYM is based on the following rationale:

1. Canals are steep-sided and relatively deep waterbodies, so the area-related hand-net sampling methodologies appropriate for rivers (e.g. typical RIVPACS sampling) cannot be directly applied to canals. In particular: (i) hand-net methods are difficult to apply to the deepest open-water areas of canals, (ii) most invertebrate species are concentrated in a narrow band at the canal edge, so that an area-based sampling method can considerably under-sample invertebrate diversity.

2. The sampling technique used to collect canal invertebrate samples for PSYM was developed as a hybrid between the ‘three-minute hand-net sample’ currently used for sampling shallow rivers, and the ‘one-minute hand-net sample + dredge hauls’ method recommended for sampling deep rivers.

3. The method comprises:

(i) A one-minute search for invertebrates which may be overlooked in hand net and dredge sampling (e.g. pond skaters, whirligig beetles)

(ii) A two-minute semi-continuous hand-net sampling of the canal margin, shallows and any emergent plant habitats present. This sample typically covers a bank length of 5 m to 15 m.

(iii) Four net hauls from deeper bottom sediments along a canal length of approximately 10 m, elutriated on site to wash out the bulk of muds and fine sands. These should be taken at c. 3 m intervals along the canal sampling length.

4. Two directly compatible field techniques can be employed to gather the four bottom sediment sample hauls from deeper areas, the choice depending on canal depth and accessibility:

(i) where canals are shallow enough to wade, bottom samples can be collected using a hand-net haul (c.3m length) taken perpendicular to the bank,

(ii) where canals are too deep to use a hand net, bottom samples are collected using a dredge with a hand net sub-sample filling ca. one quarter of the pond net then taken from this dredged material. It is recommended that the bank and bottom samples are kept separate, since this makes the samples easier to sort in the laboratory.

The Canal PSYM sampling method is designed to replicate the effort associated with a three minute hand-net sample ensuring compatibility with other Environment Agency river sampling, and also sampling of pond invertebrates undertaken for the National Pond Survey.

3.1.2 Sampling locations

Samples were collected at 10 locations identified by British Waterways staff (Figure 8). A list of sites is given in Table 2, and locational information about each site shown in Appendix 4. A wide range of environmental data were collected including information on substrate types, bank structure, vegetation abundance, shade, water and sediment depths, adjacent land use and basic water quality (pH, conductivity, dissolved oxygen concentration).

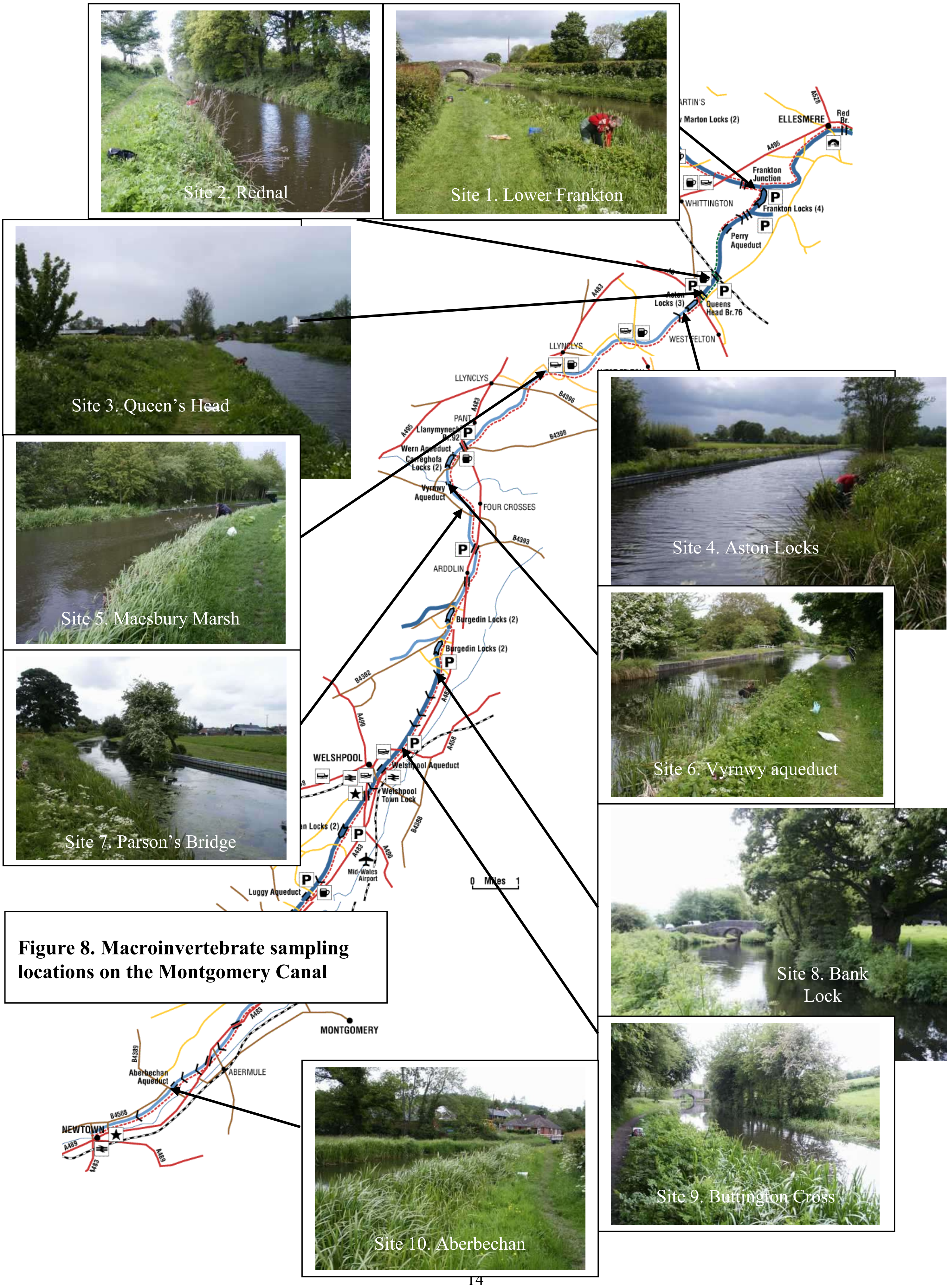


Figure 8. Macroinvertebrate sampling locations on the Montgomery Canal

Table 2. The location of macroinvertebrate sampling sites on the Montgomery Canal

Site number	Site name	Grid Reference	Date of survey
1.	Lower Frankton	SJ370318	19th May 2003
2.	Rednal	SJ350275	19th May 2003
3.	Queen's Head	SJ341269	19th May 2003
4.	Aston Locks	SJ335263	19th May 2003
5.	Maesbury Marsh	SJ305248	19th May 2003
6.	Vyrnwy Aqueduct	SJ254197	28th May 2003
7.	Parson's Bridge	SJ264189	28th May 2003
8.	Bank Lock	SJ260130	28th May 2003
9.	Buttington Cross	SJ241089	28th May 2003
10.	Aberbechan	SO142934	28th May 2003

Note: Detailed sampling location sketches are held by PCTPR.

3.1.3 Date of survey

Surveys were carried out on the 19th and 28th May 2003.

3.1.4 Laboratory processing of samples

Invertebrate samples were returned to the laboratory where they were live-sorted following standard PSYM procedures.

3.1.5 Assessment methods

The characteristics of the invertebrate assemblages of the Montgomery Canal were assessed in terms of their basic faunal composition, the nature conservation value of the assemblages and in terms of overall ecological quality.

Information on the composition of the fauna gives basic background data on the nature of canal invertebrate assemblages, which generally have received relatively little attention. In the present study such data allow broad comparisons of the fauna in the 1980s to be made with the present fauna.

Conservation value assessments allow the value of the sites to be assessed in terms of the occurrence of uncommon species. Commonly, such methods are used by nature conservation agencies to identify sites of high wildlife importance. Assessments were made in terms of species richness (the total number of species) and the occurrence of uncommon species (using a Species Rarity Index). Both methods have been widely used by conservation scientists.

The ecological quality of the canal was assessed to determine the extent to which the canal deviates from a minimally impaired baseline condition. This measurement is more concerned with the overall condition of the canal rather than the occurrence of uncommon species, although sites of high ecological quality often support uncommon species. Ecological quality was assessed using the Canal PSYM system which has been developed jointly by the Environment Agency and the Ponds Conservation Trust. At present this is the only such system available for assessing canals in terms of their invertebrate assemblages.

The two assessment methods (conservation value and ecological quality) are complementary in that they assess different aspects of the quality of the canal. Conservation value simply gives an indication of how many species occur, with particular emphasis on species that may be of conservation concern (e.g. Red Data Book species or BAP species). Ecological quality is concerned more broadly with the overall condition of the canal.

3.2 Results

3.2.1 Composition of the macroinvertebrate fauna

A total of 88 macroinvertebrate species were recorded at the 10 canal sites. In terms of species richness the fauna was dominated by water beetles (24 species), molluscs (19 species) and caddis flies (16 species). The proportions of species in the principal invertebrate groups were very similar to those seen in the 1980s surveys of the canal (Figure 9). Four Nationally Scarce and 4 Local invertebrate species were recorded. A full list of the species found is given in Table 3.

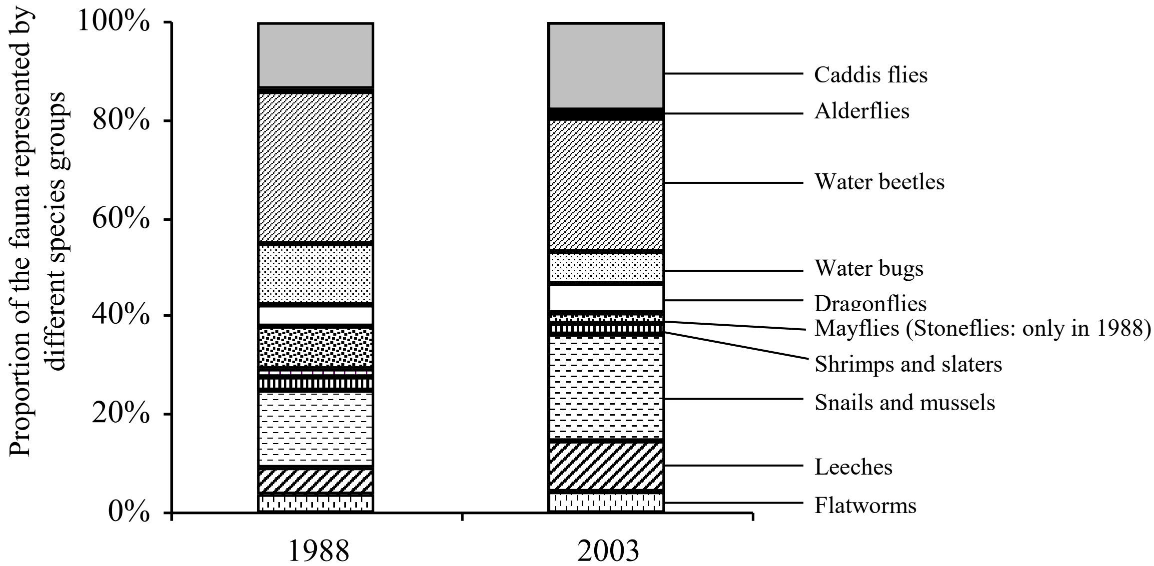


Figure 9. The species composition of the macroinvertebrate fauna of the Montgomery Canal: 1988 and 2003.

There was some evidence that the proportions of the fauna represented by different species varied systematically along the canal (Figure 10). In the northern section, from Lower Frankton to Maesbury Marsh, the proportion of the fauna represented by each major species group was rather variable.

In contrast, samples from the southern section of the canal, from Vyrnway Aqueduct to Aberbechan, showed proportions of species in different groups that were rather more consistent. For example, caddis flies and water beetles typically comprised about 40% of the species recorded.

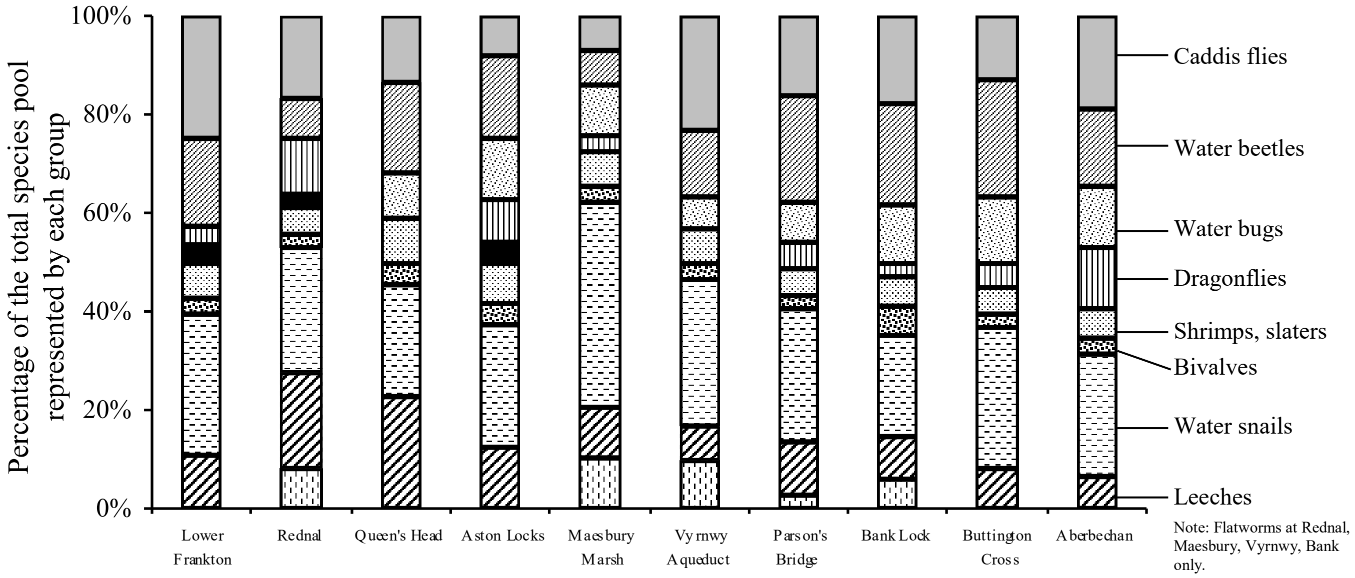


Figure 10. The proportion of the macroinvertebrate fauna represented by different faunal groups in the Montgomery Canal.

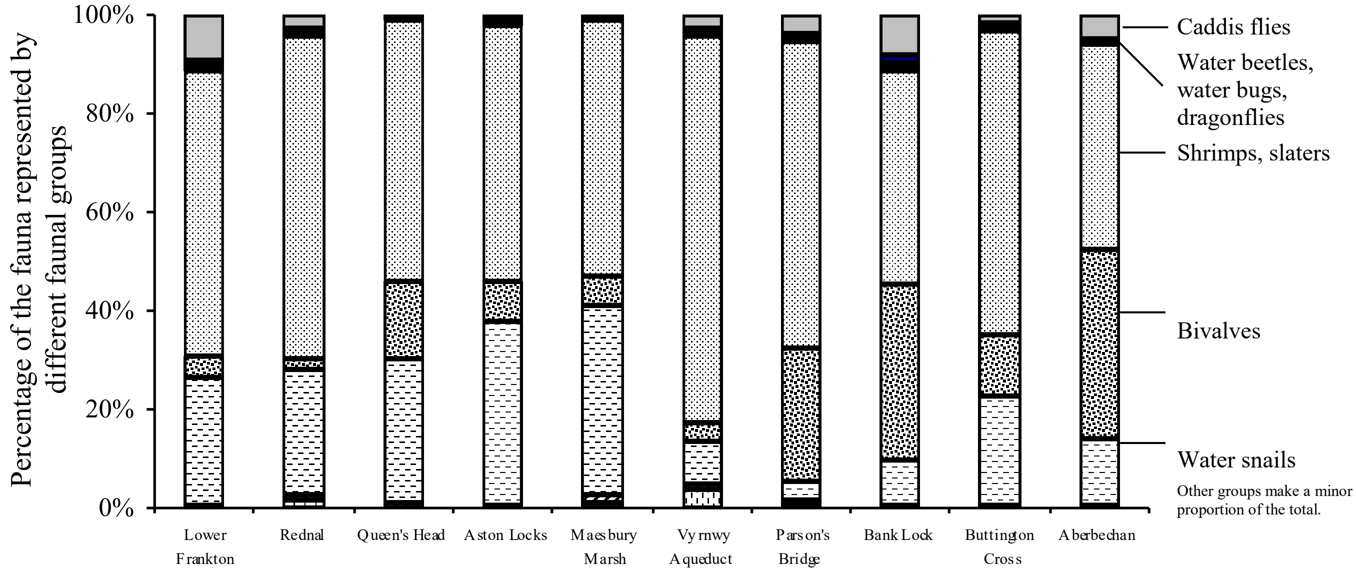


Figure 11. The relative abundance of different macroinvertebrate groups in the Montgomery Canal.

In terms of the abundance of individual animals there are clearer patterns along the canal. Numerically, the fauna is dominated by shrimps and water slaters which make up 50-80% of the total number of larger macroinvertebrates (Figure 11). However, there is a marked difference in the proportions of molluscs in the northern and southern sections of the canal. To the north (Lower Frankton to Maesbury), water snails represent about one third of all individuals. Bivalves comprise a correspondingly small proportion of the fauna. In the southern section of the canal the position is more or less reversed with horny orb mussels, *Sphaerium corneum*, representing up to one third of the total number of individuals, and water snails generally around 10% of all individuals.

3.2.2 Assessment of the conservation value of the canal

Macroinvertebrate assemblages on the Montgomery Canal were typical in terms of their species richness compared to other high quality canals in the UK. The mean number of macroinvertebrate species in a 3 minute spring PSYM sample from high quality canals was 37.1, compared to 32.2 for the 10 sites in the present survey (Figure 12).

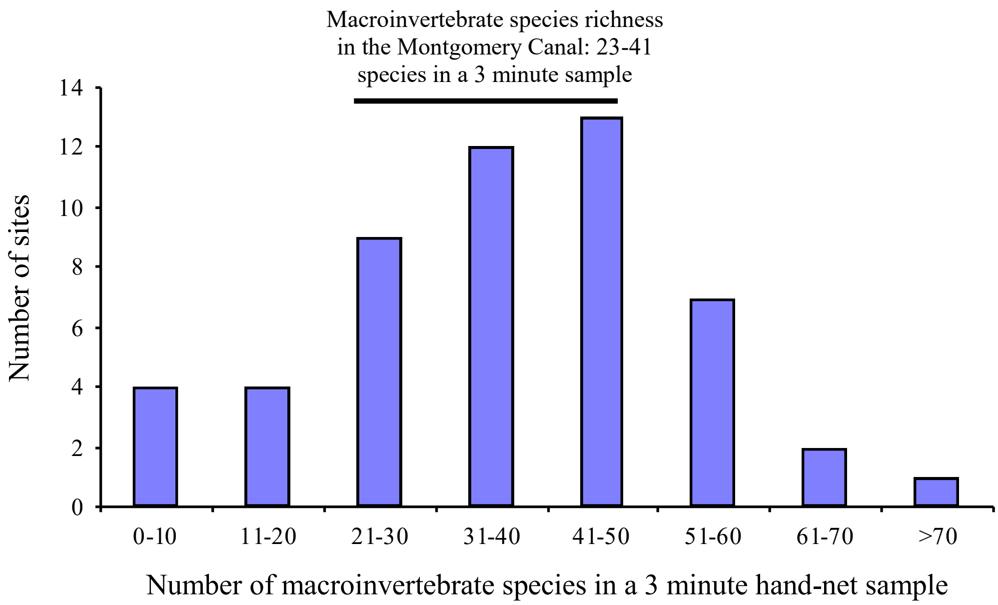


Figure 12. macroinvertebrate species richness in minimally impaired canals: a comparison of sites in the present survey of the Montgomery Canal with other high quality sites in the PSYM database

In the present survey the canal supported a small number of Nationally Scarce species, all of which were water beetles. These were:

- *Gyrinus aeratus*: a whirligig beetle
- *Gyrinus urinator*: a whirligig beetle
- *Ilybius fenestratus*: a diving beetle
- *Noterus crassicornis*: a flightless diving beetle.

Only one of these species was recorded in the 1980s surveys (the flightless *Noterus crassicornis*). Two other Nationally Scarce species recorded in the 1980s surveys (*Haliplus heydeni* and *Ilybius guttiger*) were not recorded although this is perhaps not surprising given the comparatively limited amount of sampling undertaken in the present study.

There was a significant correlation between location on the canal and sample species richness (Spearman R = 0.64; $p<0.05$) (Figure 13) the number of macroinvertebrate species generally increasing north to south along the canal.

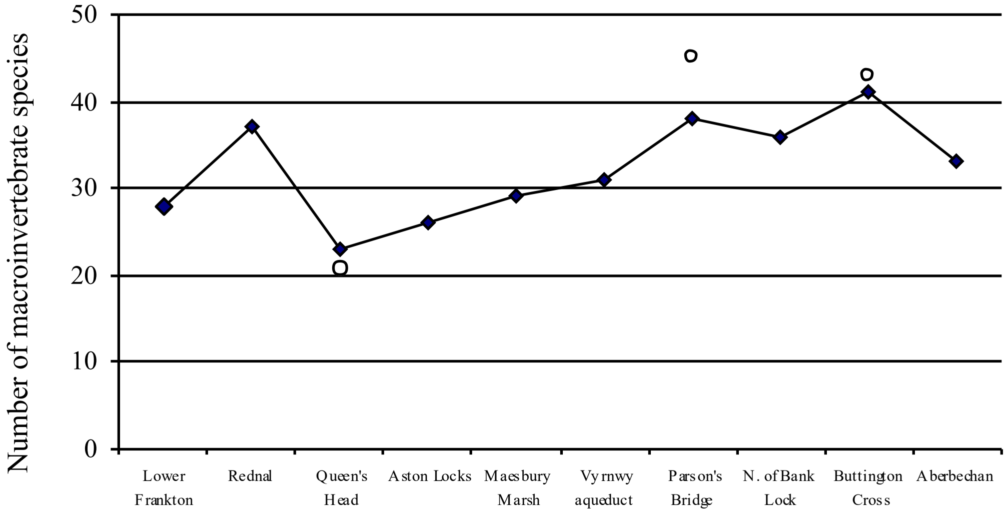


Figure 13. Number of macroinvertebrate species in PSYM samples collected from 10 locations on the Montgomery Canal: diamonds indicate sites surveyed in spring 2003; for comparison, circles showing sites in the PSYM database surveyed in spring 1997 are also given

There was no evidence of significant trends in the Species Rarity Index (SRI) values for the canal (Figure 13). The highest SRI was at Rednal and the lowest at Maesbury Marsh indicating that uncommon species were evenly spread amongst the sites. All sites except Lower Frankton and Maesbury Marsh supported Nationally Scarce species. Sites in the southern half of the canal did not have significantly higher SRI values than those in the more boated northern half.

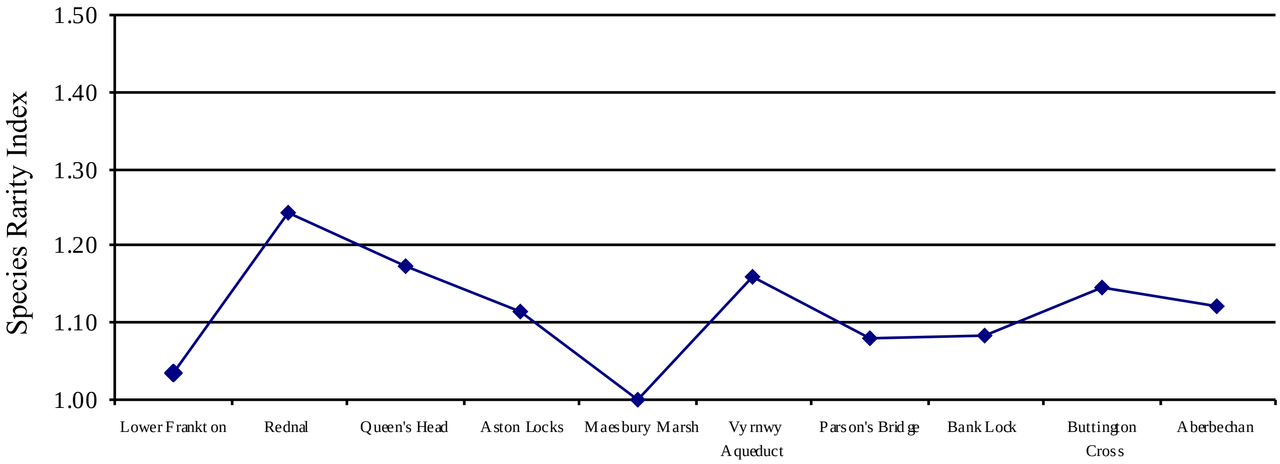


Figure 14. Species Rarity Index values for invertebrate assemblages on the Montgomery Canal

3.2.3 Factors affecting the composition of invertebrate assemblages in the Montgomery Canal

A CANOCO analysis (canonical correspondence analysis) was undertaken to investigate further the patterns in macroinvertebrate assemblage structure and the environmental factors which could be influencing those patterns.

CANOCO shows the degree of similarity between different samples in terms of the composition of their invertebrate assemblages and relates these to environmental variable s (Figure 15).

Axis 1 of the CANOCO analysis, which represents the major axis of variation in the dataset, separated the sites into two main groups: the boated northern section of the canal (Lower Frankton to Maesbury Marsh) and the southern unboated or low movement sections (Vyrnwy Aqueduct to Aberbechan). The analysis indicated that the major environmental variables related to this pattern were boat traffic levels, secchi depth (i.e. water transparency) and location on the canal.

Axis 2 of the CANOCO plot linked aquatic vegetation abundance and dissolved oxygen concentrations to differences in the invertebrate assemblages.

It should be noted that correlating environmental variables are not necessarily the causal factors affecting invertebrate assemblage composition but reflect the major gradient of change to be seen in the canal. It should also be noted that the CANOCO analysis includes only very limited chemical data (dissolved oxygen concentrations, conductivity and pH) as these were the only chemical variables available at all the sampling locations.

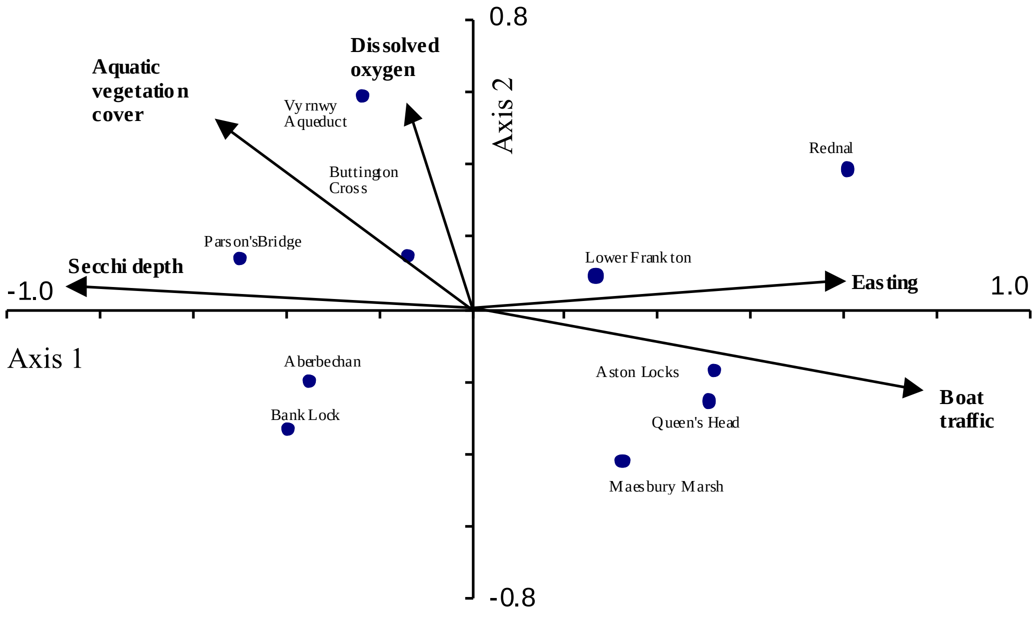


Figure 13. CANOCO analysis of macroinvertebrate and environmental data from the Montgomery Canal. Circles show invertebrate samples; arrows indicate strength and direction of environmental variables influencing the analysis.

3.2.4 PSYM analysis of the ecological quality of Montgomery Canal invertebrate assemblages

PSYM analysis of invertebrate assemblage data indicated that most sites were of good quality. However, two sites, Aston Locks and Maesbury Marsh, had PSYM scores below 9, indicating significant impairment. These sites, together with Queen's Head, all had low EPT metric (Ephemeroptera, Plecoptera, Trichoptera) values in the PSYM analysis. Within PSYM, EPT is a biological measure that reflects the chemical quality of the water, and suggests that there may be underlying chemical factors impacting the biota at these locations.

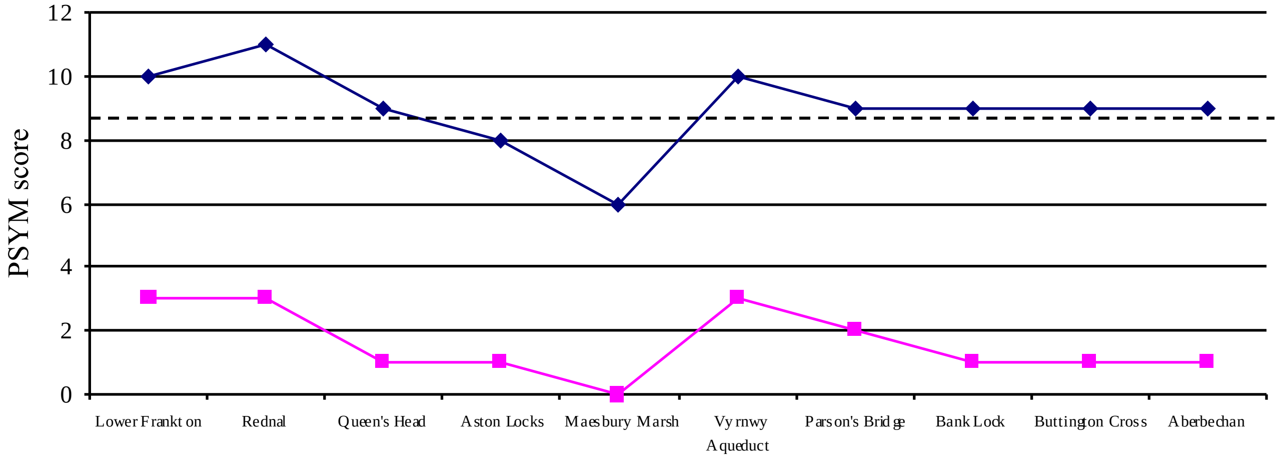


Figure 16. PSYM scores for the 10 macroinvertebrate survey sites on the Montgomery Canal. Diamonds indicate the overall PSYM score; squares show the score for EPT alone.

Table 3. Results of PSYM analysis of Montgomery Canal macroinvertebrate assemblages

A glossary of terms used in this table is given on the following page

		ASPT	EPT	NINV	NCOL	Total IBI	%
Lower Frankton	Observed	5.00	5	20	2		
	Predicted	5.05	4.88	28.29	3.60		
	EQI	0.99	1.03	0.71	0.56		
	IBI	3	3	2	2	**10**	**83%**
Rednal	Observed	4.74	4	23	2		
	Predicted	5.04	4.94	28.29	3.58		
	EQI	0.94	0.81	0.81	0.56		
	IBI	3	3	3	2	**11**	**92%**
Queen's Head	Observed	4.11	2	18	3		
	Predicted	5.06	4.89	28.21	3.61		
	EQI	0.81	0.41	0.64	0.83		
	IBI	3	1	2	3	**9**	**75%**
Aston Locks	Observed	4.43	2	21	2		
	Predicted	5.06	4.87	28.14	3.61		
	EQI	0.87	0.41	0.75	0.55		
	IBI	3	1	2	3	**8**	**67%**
Maesbury Marsh	Observed	4.89	1	19	1		
	Predicted	5.04	4.95	28.18	3.57		
	EQI	0.77	0.20	0.67	0.28		
	IBI	3	0	2	1	**6**	**50%**
Vyrnwy Aqueduct	Observed	4.40	3	20	3		
	Predicted	5.05	5.21	29.06	3.63		
	EQI	0.87	0.58	0.69	0.83		
	IBI	3	2	2	3	**10**	**83%**
Parson's Bridge	Observed	4.35	2	23	2		
	Predicted	5.04	5.14	29.05	3.62		
	EQI	0.86	0.39	0.79	0.55		
	IBI	3	1	3	2	**9**	**75%**
Bank Lock	Observed	4.23	2	22	2		
	Predicted	5.11	5.34	28.53	3.66		
	EQI	0.83	0.37	0.77	0.55		
	IBI	3	1	3	2	**9**	**75%**
Buttington Cross	Observed	4.48	2	21	3		
	Predicted	5.07	5.19	28.73	3.63		
	EQI	0.88	0.39	0.73	0.83		
	IBI	3	1	2	3	**9**	**75%**
Aberbechan	Observed	4.47	2	19	3		
	Predicted	5.12	5.51	28.58	3.67		
	EQI	0.87	0.36	0.66	0.82		
	IBI	3	1	2	3	**9**	**75%**

3.2.5 Glossary of terms used in the PSYM system

ASPT	Average Score per Taxon (from the BMWP system). One of four metrics (biological measures) used in the PSYM system to describe invertebrate assemblages.
EPT	Ephemeroptera, Plecoptera, Trichoptera. One of four metrics (biological measures) used in the PSYM system to describe invertebrate assemblages
NCOL	Number of Coleoptera families. One of four metrics (biological measures) used in the PSYM system to describe invertebrate assemblages.
NINV	Number of macroinvertebrate families. One of four metrics (biological measures) used in the PSYM system to describe invertebrate assemblages.
Observed	Values derived from the field data collected during the survey.
Predicted	Computer predicted values made by the PSYM programme.
EQI	The ratio between the observed and predicted value. Essentially this is a measure of how close to the minimally impaired baseline condition each metric is.
IBI	Index of Biotic Integrity. The EQI value normalised onto t a four point (0,1,2,3) scale. Individual IBI values are added together to calculate the overall PSYM score.
%	The percentage of the maximum IBI score possible. For Canal PSYM the maximum IBI score possible is 12 (4 metrics x a maximum individual score of 3). Scores between 75% and 100% indicates that the site fully reaches its ecological potential.

Table 4. List of macroinvertebrate species recorded in the Montgomery Canal (continued)

Species/Group	R[2]	Lower Frankton	Rednal	Queen's Head	Aston Locks	Maesbury Marsh	Vyrnwy aqueduct	Parson's Bridge	Bank Lock	Buttington Cross	Aberbechan
TRICLADIDA											
Dendrocoelum lacteum	1		3			6	2				
Dugesia polychroa	1		1			8			1		
Dugesia tigrina	1						1				
Polycelis tenuis	1		41			4	93	13	7		
HIRUDINEA											
Erpobdella octoculata	1	2	10	6	5	28	31	14	9	8	7
Erpobdella testacea	1	1									
Glossiphonia complanata	1	2	2		2			1			
Glossiphonia heteroclita	2		2				1			1	
Haemopis sanguisuga	1		1	2		3			1		1
Helobdella stagnalis	1		23	13		2		1	1		
Hemiclepsis marginata	2		2	2							
Piscicola geometra	1			2	3			1			
Theromyzon tessulatum	1		1							1	
MOLLUSCA											
Acroloxus lacustris	1	19	37		3			4			
Anisus vortex	1		9			7		4		24	32
Bithynia leachi	1	157	400	303	200	350			3	213	113
Bithynia tentaculata	1	210	301	252	500	315	19	14	244	243	172
Gyraulus albus	1		9			8			1	12	3
Gyraulus crista	1	6									
Hippeutis complanatus	1					13		3		15	
Lymnaea peregra	1	7			7	12	21	45	7	28	27
Lymnaea stagnalis	1		3			6	132	3	2	4	3
Lymnaea palustris	1	5				8					
Physa fontinalis	1					1	8	1	1		
Planorbarius corneus	1	1	1	1	1	6	8	2		3	4
Planorbis carinatus	1		9	1	6	9	34	3	5	19	13
Planorbis planorbis	1		3			3	2	1			
Potamopyrgus antipodarum	1	1					1			1	
Valvata cristata	1			1							
Viviparus viviparus	1						1			3	
BIVALVIA											
Anodonta cygnaea	1								1		
Sphaerium corneum	1	63	70	302	154	113	100	520	1000	317	1000
ARACHNIDA											
Argyroneta aquatica	1		4	1	2					1	
MALOCOSTRACA											
Asellus aquaticus	1	375	1000	500	500	500	572	350	239	509	544
Crangonyx pseudogracilis	1	520	1000	507	500	500	1500	857	1000	1050	553

[2]Column R shows the Species Rarity Score where 1 = Common, 2 = Local, 4 = Nationally Scarce.

Table 4. List of macroinvertebrate species recorded in the Montgomery Canal (continued)

Species/Group	R[3]	Lower Frankton	Rednal	Queen's Head	Aston Locks	Maesbury Marsh	Vyrnwy aqueduct	Parson's Bridge	Bank Lock	Buttington Cross	Aberbechan
EPHEMEROPTERA											
Caenis horaria	1		24		10						
Caenis luctuosa	1	24									
ODONATA											
Aeshna cyanea	1		1								2
Calopteryx splendens	1	1			2						
Coenagrion puella/pulchellum	1		1			2		2	3		3
Erythromma najas	2		4							1	1
Ischnura elegans	1		5		4			3		3	3
HEMIPTERA											
Gerris lacustris	1				1	1				1	1
Microvelia reticulata	1			1	3						
Notonecta glauca	1				2		15	4	2	3	2
Notonecta marmorea	1						15	1	3	3	
Sigara dorsalis	1			2		3		3	9	2	2
Sigara falleni	1					1			21	1	4
MEGALOPTERA											
Sialis lutaria	1						66	2	8	8	5
COLEOPTERA											
Anacaena limbata	1	3		1		5		2			
Cercyon marinus	2	1									
Enochrus coarctatus	1							1			
Gyrinus aeratus	**4**						**3**				
Gyrinus substriatus	1				1						
Gyrinus urinator	**4**		**1**								
Haliplus flavicollis	1						1		3	7	1
Haliplus lineatocollis	1	1									
Haliplus lineolatus	1	1		2						6	
Haliplus ruficollis	1								5	1	2
Helophorus aequalis	1							1			
Helophorus brevipalpis	1							2			
Hydraena riparia	1					5					
Hydrobius fuscipes	1									1	1
Hygrotus inaequalis	1				2						
Hygrotus versicolor	2						1			2	
Hyphydrus ovatus	1						3	7	34	7	
Ilybius fenestratus	**4**							**1**	**3**	**1**	**1**
Ilybius quadriguttatus	1									1	
Laccobius bipunctatus	1	3									
Laccophilus hyalinus	1							3	9		
Nebrioporus depressus	1								1		
Noterus clavicornis	1		1	5	1			4	1	5	2
Noterus crassicornis	**4**		**1**	**7**	**1**						

[3]Column R shows the Species Rarity Score where 1 = Common, 2 = Local, 4 = Nationally Scarce.

Table 4. List of macroinvertebrate species recorded in the Montgomery Canal (continued)

Species/Group	R[4]	Lower Frankton	Rednal	Queen's Head	Aston Locks	Maesbury Marsh	Vyrnwy aqueduct	Parson's Bridge	Bank Lock	Buttington Cross	Aberbechan
LEPIDOPTERA											
Cataclysta lemnata	1								1	1	
Elophila nymphaeata	1				1						
TRICHOPTERA											
Anabolia nervosa	1		3	2	3		9		28		10
Athripsodes aterrimus	1		49	1			8			5	2
Beraea pullata	1	112									
Ceraclea dissimilis	1	8									
Ceraclea fulva	1							1			
Cyrnus flavidus	1		5								
Cyrnus trimaculatus	1	1									
Glyphotaelius pellucidus	1						2	2		2	
Halesus radiatus	1	2	7						2		4
Limnephilus flavicornis	1					1	1	13	10	12	3
Limnephilus lunatus	1	12	11	2	12	1	20	9	92	3	16
Limnephilus marmoratus	1						34	26	90	20	100
Micropterna lateralis	1	1									
Mystacides longicornis	1										
Oecetis testacea	1	4									
Triaenodes bicolor	1		12				1	18	3		
OTHER TAXA											
Ceratopogonidae		7		1			1			1	
Chironomidae		512	100	500	396	1000	1000	550	1000	650	1000
Chrysomelidae			1								
Dryopidae							1				
Helodidae				1				1			
Oligochaeta		50	25	100	100	510		35	300	16	20
Pisidium sp		500	150		200	500	1000	1500	1000	1300	1000
Psychodidae		10				10					
Ptychopteridae				9							
Syrphidae		1									
Tipulidae		10	1		7		1	5	1	1	
Number of species		28	37	23	26	29	31	38	36	41	33

[4]Column R shows the Species Rarity Score where 1 = Common, 2 = Local, 4 = Nationally Scarce.

4. Conclusions and recommendations for future monitoring

4.1 Conclusions

The present study indicates that the macroinvertebrate fauna of the Montgomery Canal is typical of high quality canal sites and is dominated by species of water beetles, molluscs and caddis flies. The fauna also includes a moderate number of uncommon species. The overall composition of the fauna appears to have changed little since the 1980s. However, CANOCO analysis does indicate that the fauna of the main navigable section differs from that of the un-navigable, or lightly trafficed, southern section. This suggests that, as the canal has gradually been reopened to navigation some changes in the invertebrate fauna will have occurred.

The present study indicates that, with the exception of the Rednal area, macroinvertebrate species richness generally increases southwards. CANOCO analysis showed that the sampling stations could be clearly separated into those on the northern boated section of the canal (Lower Frankton to Maesbury) and the southern section where boat traffic is low or absent. Despite the differences in the composition and richness of the fauna above and below Maesbury, all of the canal sections except Lower Frankton and Aston Lock had one or more Nationally Scarce water beetles. There was little evidence, from the current survey, that the number of scarce species was affected by boat traffic levels.

The PSYM analysis considered the available information in a different way, using invertebrate family data to assess the overall ecological quality of the canal for invertebrates.

PSYM analysis indicates that most sites on the canal are of good ecological quality with only Aston Locks and Maesbury Marsh clearly below the level expected of high quality canals (75% of the maximum possible score). In contrast to the analysis of species richness and rarity PSYM does not strongly separate the northern and southern sections of the canal[5].

Chemical monitoring of the canal by the Environment Agency also strongly suggests that the canal may be separated into two main areas on water quality grounds: the poorer quality northern section and the higher quality southern section.

Overall, the results indicate that:

- the Montgomery Canal supports a high quality invertebrate assemblage
- increased boat traffic will probably reduce the species richness of the macroinvertebrate assemblages of the canal
- there may be some underlying water quality problems stressing the invertebrate assemblages widely in the canal, affecting both the poorer quality northern end of the canal, and the cleaner south.

[5]It should be noted that Canal PSYM does not currently include a plant component, which means that it does not reflect the botanical quality of the canal, and is not directly sensitive to eutrophication or turbidity effects.

4.2 Recommendations for future monitoring

4.2.1 General recommendations

Based on the current findings the following recommendations are made:

- Carry out the planned second season of sampling, using the canal PSYM methodology to provide a better understanding of the overall richness of the invertebrate assemblage.
- Repeat the spring survey in the next year or two to ensure that the results obtained were not due to unusual seasonal variation.
- Subsequently, repeat at five yearly intervals; analyse samples at species level to give information that can be used to assess the conservation value of the canal, as well as undertake a PSYM analysis.
- Consider including further Montgomery Canal sites in the PSYM database to ensure that the canal is adequately represented. This should be done before the sections are opened up to boating.

4.2.2 Separating the effects of boat traffic from other environmental factors (geology, water quality)

Separating the effects of boat traffic from other environmental factors, such as geology and water quality, is at present difficult. This is because the poorer water quality northern section of the canal has higher boat traffic, and better water quality southern section has low boat traffic making it currently difficult to assess the relative importance of the two risk factors.

However, it is well-known that, in general, increased boat traffic reduces aquatic plant abundance and diversity. For this reason there seems little doubt that as boat traffic frequency increases further south, botanical richness and abundance will decline. In theory, if there is no change in nutrient status associated with the boat traffic increase, this impact would be reversible. However, if nutrient concentrations also increase, then damage to plant communities is likely to be permanent and effectively irreversible.

However, although it is generally true that both poor water quality and high levels of boat traffic are damaging to aquatic vegetation the situation is likely to be complex at specific loactions. This can be seen in Newbold’s (2001) comments on the relative importance of boats, water quality and dredging in the Rednal/Queen’s Head area. Because of this there is a need for further integration of the water quality and botanical data (see recommendation in 4.5 below). It should also be noted that fish can have a profound influence on vegetation composition and abundance in freshwaters: indeed fish removal is a widely recognised technique for promoting vegetation recovery in eutrophicated waters.

An indication of the relative importance of boats versus water quality could probably most easily be obtained by thorough monitoring of the reintroduction of boat traffic to the southern sections of the canal. This should be directly related to water quality.

Recommendation: Annual monitoring of the invertebrate stations used for the present project should be undertaken during any period of boat traffic increase. Water quality samples should be collected at the same locations (preferably by the Environment Agency at least quarterly and ideally monthly) to assess the extent to which changes in water quality occurred at the same time.

4.3 Recommendations for an invertebrate monitoring methodology for the new canal reserves

There are likely to be two main objectives for assessing the quality of the invertebrate assemblages of the new canal reserves:

(i) Comparison with the canal

(ii) Assessment of the quality of the new waterbodies in a wider context.

To allow direct comparison with the canal, the new waterbodies should be sampled using the Canal PSYM method (i.e. sampling of a typical short (10-15 m) length of bank combined with deeper water dredging). Generally it would be beneficial to have more than one sample per site (2-3 would be adequate) to improve confidence in the results. However, if a large number of waterbodies required sampling it would be acceptable to reduce the sampling to a single location.

Given that the new waterbodies are likely to be rather pond-like in character it might also be worth considering collecting some data to enable them to be compared directly with ponds, using the Pond PSYM method and the detailed species level data in the National Pond Survey database. For a pond assessment, the NPS/PSYM method involves sampling the whole of the waterbody from representative habitats in a single 3 minute sample.

This NPS/PSYM pond assessment method would typically generate longer species lists than the Canal PSYM technique simply because the full range of habitats present in the waterbody are sampled. It therefore gives a better indication of the overall contribution of the waterbody to biodiversity. It would also allow the new water bodies to be compared with the database of information available about ponds which is considerably larger than that available for canals.

Note that the Pond PSYM method could also provide an objective assessment method for macrophyte vegetation monitoring.

4.4 Further information on PSYM results

The main PSYM datasets from canals (approximately 120 sites) are described in Environment Agency R&D reports on the development of PSYM (Williams *et al.* 1998, Biggs *et al.* 2000). These can be supplied by PCTPR or are available from the Environment Agency.

4.5 Water quality and plants

The present study has not considered in detail the vegetation survey data collected at various times on the canal in the context of the water quality data.

Given the importance of the water quality for the aquatic flora **it is recommended that a short study is undertaken to link more fully the water quality and plant survey data**. Ideally this work should be undertaken jointly by PCTPR and Dr Chris Newbold, who has undertaken the most recent botanical survey of the canal.

It should also be noted that fish can have a major impact on vegetation abundance in freshwater ecosystems. At present, we are not aware of any data on fish populations in the Montgomery Canal. We recommend therefore that **consideration be given to a baseline fish survey to determine whether fish populations could be having a significant impact on the aquatic plant assemblages**.

5. References

Biggs, J., P. Williams, M. Whitfield, G. Fox and P. Nicolet (2000). *Biological techniques of still water quality assessment. Phase 3. Method development.* Environment Agency R&D Technical Report E110. Environment Agency, Bristol.

Briggs, J. (ed.) (1988). *Montgomery Canal ecological survey. Survey report 1985-88*. Montgomery Canal Ecological Survey, Llanymynech.

British Waterways (1999). *Montgomery Canal ecological surveys. The report of the 1997 surveys with comparisons to the 1980s surveys*. British Waterways, Gloucester.

Kerney, M. (1999). *Atlas of the land and freshwater molluscs of Britain and Ireland*. Harley Books, Colchester.

Williams, P., J. Biggs, M. Whitfield, A. Corfield, G. Fox and K. Adare (1998). *Biological techniques of still water quality assessment. Phase 2. Method development.* Environment Agency R&D Technical Report E56. Environment Agency, Bristol.

Appendix 1. The PSYM manual

A guide to monitoring the ecological quality of ponds and canals using PSYM

Environment Agency Project Leader
Shelley Howard
Environment Agency Midlands Region
Sapphire East
550 Streetsbrook Road
Solihull
West Midlands B91 1QT

Pond Action [now Ponds Conservation Trust: Policy & Research (PCTPR)]
c/o Oxford Brookes University
Gipsy Lane
Headington
Oxford OX3 0BP
Telephone: 01865 483278
E-mail: info@pondstrust.org.uk
Please contact PCTPR if you have any queries about PSYM

MONITORING THE QUALITY OF STILL WATERS USING PSYM

1. Introduction

PSYM, the Predictive SYstem for Multimetrics, (pronounced sim) has been developed to provide a method for assessing the biological quality of still waters in England and Wales.

The method uses a number of aquatic plant and invertebrate measures (known as metrics)[6], which are combined together to give a single value which represents the waterbody's overall quality status.

Using the method involves the following steps:

1. Simple environmental data are gathered for each waterbody from map or field evidence (area, grid reference, geology etc.).
2. Biological surveys of the plant and animal communities are undertaken and net samples are processed.
3. The biological and environmental data are entered into the PSYM computer programme which:
   (i) uses the environmental data to predict which plants and animals should be present in the waterbody if it is undegraded,
   (ii) takes the real plant and animal lists and calculates a number of metrics[1].

Finally the programme compares the predicted plant and animal metrics with the real survey metrics to see how similar they are (i.e. how near the waterbody currently is to its ideal/undegraded state). The metric scores are then combined to provide a single value which summarises the overall ecological quality of the waterbody. Where appropriate, individual metric scores can also be examined to help diagnose the causes of any observed degradation (e.g. eutrophication, metal contamination).

2. Background

2.1 Why was the method developed?

Historically, the Environment Agency and other statutory bodies have undertaken relatively little monitoring of still waters (lakes, ponds, canals, ditches etc.). The absence of a standardised assessment method was a major barrier to the assessment of these waterbodies.
The PSYM methodology provides a standard assessment method for still waters which enables a variety of organisations involved in waterbody management to consider water quality in a broad national context. It provides the Environment Agency with a means to assess still water quality for General Quality Assessment (GQA) and other reporting purposes, and can be used in partnership with others such as DEFRA or English Nature. The method also enables public or private sector NGOs (e.g. consultants, community groups) to improve general standards of assessment in waterbody management plans or environmental impact assessments, and provides a means of assessing management techniques.

2.2 About PSYM

PSYM is a waterbody quality assessment methodology which essentially combines the predictive approach of RIVPACS[7] with multimetric-based methods used for ecological quality assessment in the United States.

In multimetric assessments, a range of variables (metrics) each related to degradation is used to assess water quality giving a broad-based assessment of quality. The values from individual metrics are combined to give a single measure which aims to represent the overall ecological quality of the waterbody. Combining this with predictive techniques gives a powerful method for comparing waterbodies of any type with their undegraded counterpart.

The PSYM methodology directly parallels the approach defined in the EU Water Framework Directive. This includes requirements for (i) comparisons with minimally impacted baseline conditions, and for (ii) assessments to be based on multiple parameters related to degradation.

2.3 Which waterbodies can be monitored using the method?

The PSYM approach is potentially applicable to all still waterbody types (e.g. lakes, ponds, temporary ponds, canals). However, to apply the method, specific data need to be collected from each waterbody type. These data are used both to (i) develop equations which can be used to predict the species which should occur at an undegraded site and (ii) to identify which biotic measures (e.g. species richness, ASPT) are the most effective at tracking degradation in that waterbody type.

---

[6]Metrics are variables such as species richness or rarity which can be used to help identify how damaged a waterbody's community is. They have been shown to have a strong monotonic relationship with degradation.

[7]RIVPACS. The River InVertebrate Prediction And Classification System, developed by the Institute of Freshwater Ecology and Environment Agency (Wright et al. 1984, Wright 1995).

So far, the method has been developed for use on two still waterbody types (i) canals (ii) ponds[8] and small lakes (up to about 5 ha in area). An extension of the method for temporary ponds is currently being developed independently by PCTPR with support from the Freshwater Biological Association. Methods have not, so far, been developed for assessing the quality of large lakes, ditches or brackish waters.

The baseline dataset used to develop the metrics for ponds was based on survey data from sites with broad coverage of England and Wales from a wide range of altitudes (0-550m), and land types (representative coverage of ITE land classes), so the resulting model is suitable for sites across England and Wales.

2.4 Why assess water quality using both plants and invertebrates?

Ideally, PSYM should use information from both the plant and animal communities present in a waterbody. This is because, together, plants and animal groups span a complementary range of sensitivities to potential degradation factors. Plants are, for example, particularly sensitive to waterbody nutrient status, whereas animals typically exhibit greater oxygen sensitivity.

Matrix analysis suggests that in most waterbodies, the most effective *plant* group to use for assessment is likely to be either diatoms or macrophytes. The most effective *animal* groups are likely to be macroinvertebrates and/or potentially fish in large permanent waters. Combining a plant and animal group from these assemblages gives a range of taxa which span a number of trophic levels, occupy a variety of waterbody habitats (e.g. can be found in the littoral zone and open water) and are long-lived, so that they can provide a temporally and spatially integrated measure of the current ecosystem state. Invertebrate, diatom and macrophyte assemblages are also relatively species-rich groups, ensuring that a good cross section of waterbody biodiversity is included in the quality assessment.

In ponds, macroinvertebrates and macrophytes have been chosen as the most practical and effective taxa for quality assessment. In canals, the choice was macroinvertebrates and diatoms, although the method has so far only been developed for macroinvertebrates. Macrophytes were assessed as being less suitable for canal assessment because the high turbidity and artificial banks which characterise most navigated canals often means that very few higher plant species are present, regardless of overall water quality.

2.5 Do you have to use both plant and invertebrates for PSYM pond assessments?

Although PSYM pond quality assessments should be made using both plant and invertebrate assemblages, a partial assessment can be made using just one assemblage if necessary. If this is the case, macroinvertebrates are likely to be the best single choice of organisms for assessing overall waterbody quality. Macrophytes, however, have the advantage of being very quick to survey and can be used, if necessary, as a rapid bio-assessment method.

2.6 How are the plant and invertebrate metrics chosen?

Metrics are biological measures (such as taxa richness) which vary with anthropogenic degradation and can, therefore, be used to measure the extent of ecosystem degradation. The concept underlying multimetric assessment is that by using a number of different measures and summing these together, an overall assessment of environmental degradation can be made. For canals, at present, only an invertebrate option is available.

Metrics are chosen by correlating known degradation gradients (nutrient levels, heavy metal levels, presence of road runoff etc.) with a wide list of *possible* test metrics e.g. family richness, number of exotic species, EPT (number of Ephemeroptera, Plecoptera and Trichoptera families). The 'test' list is narrowed-down to a list of viable metrics by looking at the significance of relationships between each potential metric and anthropogenic degradation gradients. For invertebrates, metrics are chosen at the highest taxonomic level i.e. family or order level rather than species-level to reduce effort (although species level information can be derived from the samples if needed for conservation work). In practice, there were generally at least equally strong correlations between family-level macroinvertebrate metrics and degradation as there were between species-level metrics and degradation. This enables family-level macroinvertebrate data to be used for quality assessments in both ponds and canals. Plant metrics are generally based on species level information.

[8]Waterbodies between 1m^2 and 2 ha in area which usually retain water throughout the year (Collinson *et al,.* 1994). Includes both man-made and natural waterbodies.

Analyses have shown that the most effective metrics for assessing environmental degradation in ponds and canals are:

Ponds

Invertebrates
- Average score per taxon (ASPT)
- Number of dragonfly (Odonata) and alderfly (Megaloptera) families (F_OM)
- Number of beetle (Coleoptera) families (F_COL)

Plants:
- Number of submerged and emergent plant species (SM_NTX)
- Trophic ranking score for aquatic and emergent plants (TRS_ALL)
- Number of uncommon plant species ((PL_NUS)

Canals

Invertebrates
- Average score per taxon (ASPT)
- Number of Ephemeroptera, Plecoptera and Trichoptera families (F_EPT)
- Number of beetle families (F_COL)
- Number of invertebrate families (INV_NFA)

Note that in canals methods for assessing the chosen plant group (diatoms) have not yet been developed.

In order to calculate predictions for these metrics the PSYM model predicts which taxa will be found at a site. An example of a predicted and observed taxa list is given in the following table.

Predicted and observed taxa lists for pond plants and macroinvertebrates for Asham Meads field pond, Oxfordshire.

Species	Predicted (probability of occurrence)	Observed	Species	Predicted (probability of occurrence)	Observed
Wetland plants			*Macroinvertebrates*		
Agrostis stolonifera	0.76	✓	Lymnaeidae	1.00	✓
Juncus effusus	0.75	✓	Planorbidae	1.00	✓
Epilobium hirsutum	0.66	✓	Glossiphoniidae	1.00	✓
Solanum dulcamara	0.64	✓	Coenagrionidae	1.00	
Juncus articulatus	0.61	✓	Corixidae	1.00	✓
Alisma plantago-aquatica	0.58	✓	Haliplidae	1.00	✓
Glyceria fluitans	0.54	✓	Dytiscidae	1.00	✓
Typha latifolia	0.52		Hydrophilidae	1.00	✓
Lycopus europaeus	0.52		Notonectidae	0.80	✓
Mentha aquatica	0.50	✓	Baetidae	0.78	✓
Juncus inflexus	0.48	✓	Asellidae	0.76	✓
Galium palustre	0.43	✓	Libellulidae	0.75	
Sparganium erectum	0.42		Gerridae	0.64	✓
Eloeocharis palustris	0.39	✓	Leptoceridae	0.61	
Deschampsia caespitosa	0.38	✓	Sialidae	0.61	
Myosotis scorpioides	0.30	✓	Hydraenidae	0.58	✓
			Limnephilidae	0.56	✓
Aquatic plants			Aeshnidae	0.53	
Lemna minor	0.67	✓	Crangonyctidae	0.49	✓
Callitriche spp.	0.52	✓	Caenidae	0.45	✓
Chara spp.	0.44		Planariidae	0.42	
Potamogeton natans	0.32	✓	Erpobdellidae	0.39	
			Hydrobiidae	0.32	

2.7 Which physical and chemical variables are used in the predictions?

As in RIVPACS, the PSYM method assesses quality by comparing actual and predicted quality scores for each waterbody. The predictions of unimpaired waterbody quality are made using physico-chemical data gathered from the waterbody.

In *ponds* the main predictors of unimpaired community type fall into nine major variable categories. Of these, three are relatively invariant (e.g. grid reference, altitude, base geology) which need only be assessed once. The remaining six categories of variables require on-site field measurement when each assessment is made. These are area, pH, shade, grazing, presence of an inflow and emergent plant cover. In *canals*, the main predictive variables are grid reference, altitude, alkalinity, substrate and boat traffic.

2.8 How are metrics scored?

When a waterbody is assessed, each individual metric is calculated and compared to the computer predicted score for that metric. The relationship between observed and expected is presented as a percentage of similarity, and then transformed to a 4 point scale e.g. 0, 1, 2 and 3 where 0 represents poor quality, and 3 represents good quality (i.e. no deviation from expected). All metric scores are then summed to give an overall quality index, which is presented as a percentage of the maximum score and, potentially, forms the basis of General Quality Assessment (GQA) categorisation of a site.

2.9 Diagnosis

The main objective of the PSYM method is to assess the overall condition of freshwater ecosystems. The system does not, in itself, diagnose the cause, or causes, of degradation. Indeed it is considered inappropriate for a general quality assessment method to be biased towards the evaluation of a single impact. However, there is considerable potential for data which are collected using the scheme to be re-interpreted to diagnose the causes of degradation. Individual metrics can indicate aspects of water quality and the raw data can be reanalysed to give pollution indices, such as trophic scores or acidification indices.

3. Assessing pond quality using Pond PSYM

3.1 Introduction

Pond PSYM has currently been developed for use in the Summer season (June, July, August), and is based on assessments of both macroinvertebrate and macrophyte assemblages.

3.2 Sites which can be included

Pond PSYM can be used on ponds and small lakes up to about 5 ha in area in England and Wales. The method can, in theory be used to assess the quality of seasonal ponds, but in practice it 'over-predicts' for ponds which are highly seasonal (i.e. which dry hard every year), and is best restricted to ponds which are either permanent, or semi-seasonal (i.e. which dry occasionally in very hot years). An extension of the method is currently being developed for use with fully temporary ponds.

3.3 Field data collection

The environmental data which need to be collected from each pond to use Pond PSYM include:

(i) *locational and other data* used for data processing. This includes: site name and code, county and nearest town, six or eight figure grid reference as necessary to identify the site, survey date, surveyor, site description.

(ii) *predictive variables* used in the pond PSYM programme to predict the undegraded biota for the pond. This includes: map-based locational information (six figure grid reference, altitude), together with site data describing shade, the presence of an inflow, cover of emergent plants, pond base geology and pH.

Collecting predictive variable data

The methods used to collect the main predictive variable data are briefly outlined below.

Grid reference: six figure reference, taken from 1:50,000 or 1:25,000 OS maps, input into the model as Easting and Northing (100 km cell reference followed by 3 figures).

Altitude: in metres above sea level, taken from 1:50,000 or 1:25,000 OS maps.

pH: measured either (i) in the field in a bucket of water taken from a representative area of the pond, or (ii) using a water sample collected in the field and analysed later in the laboratory. For laboratory analysed samples, use acid washed bottles stored in a cool place after collection (e.g. cold box) and analyse within one day of collection.

Pond area: this is the area lying within the outer edge of the pond (see 3.4 below). The pond dimensions can be measured using a tape, or by careful pacing. A small sketch can help to make this estimate. For large ponds it can be easier to use an OS map outline, with the dimensions checked in the field. Note that for the predictions, area data are used as log values so, particularly for large ponds, estimates do not need to be highly accurate.

Pond overhung: the percentage of the pond area which is *directly overhung* (e.g. by trees, scrub etc.).

% of pond edge grazed by livestock: the percentage of the perimeter of the pond to which livestock have active access. Note that if cattle, sheep, horses etc. are not grazing at the time of the survey, their presence can be detected by other features such as poaching of the ground.

Pond base: the rock type underlying the pond (beneath the sediment). This can often be assessed directly in the field, or be determined using a geology map. In the field, push the handle of the pond net through the sediment into the base. Exact measurement is not necessary, only broad categorization into one of three percentage categories: 1= 0%-32%, 2=33%-66%, 3=67%-100%.

Inflow: whether or not the pond has a surface inflow. This can be a direct or indirect inflow from a river, stream, ditch, spring or seepage. The inflow can be *dry* at the time of the survey.

Emergent plant cover: the percentage of the pond covered by emergent plant species. The term 'emergent plant species' includes all species listed as emergents on the wetland plant recording sheet. It includes these species regardless of their habit at the time of the survey (e.g. some emergent species may be growing predominantly under water at the time of the survey). It does not include any other species e.g. terrestrial species or plants specifically defined as 'submerged' or 'floating-leaved' plant species on the wetland plant recording sheet.

Estimates of the percentage cover of emergent plants should be made for the whole area within the outer edge of the pond, not the current water area. The cover of sparsely growing stands of plants (e.g. occasional bulrush plants with much open water between), should be estimated as if they were growing closely together. The easiest way of doing this is to imagine all emergent plants pushed together on one side of the pond, with an estimate then made of what proportion of the pond this covers.

At present it is recommended that for those variables for which field estimates are made (pH, area, overhanging trees, grazing, base type and emergent plant cover) the objective of measurement should be to obtain estimates that are within 5-10% of the long term mean. It is expected that further work will be undertaken to refine understanding of the effects of variation in measurements in the future.

3.4 Defining the outer edge of the pond

Identifying the 'outer edge' of the pond is important for many of the physico-chemical survey assessments and for undertaking the plant survey. In all cases, the definition of pond 'outer edge' is 'the upper level at which water stands in winter'.

In practice, the outer edge is usually readily discernible from one or more site characteristics. The best of these is usually the distribution and/or morphology of wetland plants. For example, it may be marked by a fringe of soft rush (*Juncus effusus)* or by thick bundles of fine roots growing out of the trunks of willows etc. Alternatively, the line can often be seen as a 'water mark' on surrounding trees or walls and is sometimes evident as a break of slope. The outer boundary of the pond will usually, of course, be dry at the time of the survey.

3.5 Plant survey methodology

The aim of plant recording is to make a complete list of wetland plants present within the outer edge of the pond. The field recording sheet gives a definitive list of the plant species regarded as 'wetland'. Terrestrial plants and wetland plants growing outside the outer edge of the pond are not recorded. The wetland plant recording sheet includes *submerged* macrophytes, *floating-leaved* species and *emergent* macrophytes, and these groups are used separately in analysis.

Pond macrophytes are surveyed by walking or wading the entire perimeter of the dry and shallow water areas of the waterbody. Deeper water areas are sampled either using a pond net or by grapnel thrown from shallow water or from a boat.

Most wetland plants are readily identifiable using a hand lens. However, with a few species (especially fine-leaved *Potamogeton* and *Callitriche* spp.) it may be necessary to remove a small amount of plant material for later microscopic examination and confirmation.

Record macrophyte species found on the attached wetland plant recording sheet.

3.6 Invertebrate survey methodology

The pond invertebrate survey methods used for PSYM are based on standard three minute hand-net sampling methods developed for the National Pond Survey (Pond Action, 1998).

The NPS invertebrate survey techniques were developed 'post-RIVPACS' in 1989-90, and were designed to be closely compatible with the original RIVPACS sampling methods, whilst allowing for differences between river and pond habitat types. The main differences between pond and river sampling methods are that:

- RIVPACS allocates sampling time on an area basis (i.e. more time is spent sampling extensive habitats). In pond PSYM, time is allocated according to mesohabitat types (i.e. if six main habitat types are identified time is divided equally amongst these). This change was made to allow for the fact that many ponds have extensive biologically uniform areas of open water and silt, and narrow but highly diverse marginal zones.
- In Pond PSYM the 3 minute survey subsamples are taken around the entire pond site whereas in RIVPACS samples are collected from an area that can be covered comfortably in three minutes: typically a river length of 5-20 m.

3.7 Selecting mesohabitats for invertebrate surveys

All the main mesohabitats in the pond are sampled so that as many invertebrate species are collected from the site as possible. Examples of typical mesohabitats are: stands of *Carex* (sedge); gravel- or muddy-bottomed shallows; areas overhung by willows, including water-bound tree-roots; stands of *Elodea*, or other submerged aquatics; flooded marginal grasses; and inflow areas. As a rough guide, the average pond might contain 3-8 mesohabitats, depending on its size and complexity. It is important that vegetation *structure*, as well as plant species composition, is considered when selecting mesohabitats: it is better to identify habitats consisting of e.g. soft floating leaves, stiff emergent stems, etc. than to make each different plant species a separate habitat. Mesohabitats are identified during the initial walk around the pond examining vegetation stands and other relevant features (this can be combined with the initial plant survey stage).

Invertebrate sampling method

(i) The three-minute sampling time is divided equally between the number of mesohabitats recorded: e.g. for six mesohabitats, each will be sampled for 30 seconds. Where a mesohabitat is extensive or covers several widely-separated areas of the pond, the sampling time allotted to that mesohabitat is *further divided* in order to represent it adequately (e.g. into 6 x 5 second sub-samples).

(ii) Each mesohabitat is netted vigorously to collect macroinvertebrates. Stony or sandy substrates are lightly 'kick-sampled' to disturb and capture macroinvertebrate inhabitants. N.B. deep accumulations of soft sediment are avoided, since these areas typically support few species and collecting large amounts of mud makes later sorting extremely difficult. Similarly, large accumulations of plant material, root masses, and the like should not be taken away in the sample: the idea is to dislodge and capture the animals without collecting an unmanageable sample.

The sample is placed in the labelled bucket for later sorting in the laboratory. Note: the three-minute sampling time refers solely to 'net-in-the-water' time, and does not include time moving between adjacent netting areas around the pond.

(iii) Amphibians or fish caught whilst sampling are noted on the recording sheet and returned to the pond.

Additional invertebrate sampling

A further 1 minute (total time, *not* net-in-the-water time) is spent searching for animals which may otherwise be missed in the 3-minute sample. Areas which might be searched include the water surface (for whirligig beetles, pond skaters etc.) and under stones and logs (for limpets, snails, leeches, flatworms etc.). Additional species found are added to the main 3-minute sample.

3.8 Processing invertebrate samples

Invertebrate sorting and identification methods follow the standard laboratory techniques. Invertebrate samples are identified to *family* level for most groups and class level for oligochaetes.

Record findings in the columns on the field sheet as follows. If present and so included in ASPT calculation, record in the "ASPT" column, if a dragonfly or alderfly family also record in the "OM" column, or if a Coleoptera family in the "Cole." column.

3.9 Data processing and analysis

Biotic data are used by pond PSYM to calculate three plant metrics and three invertebrate metrics:

Plants:

- Number of submerged and emergent plant species (PL_NTX)
- Trophic ranking score for aquatic and emergent plants (TRS_ALL)
- Number of uncommon plant species (PL_NUS)

Invertebrates:

- Average score per taxon (ASPT)
- Number of dragonfly (Odonata) and alderfly (Megaloptera[9]) families (F_OM)
- Number of beetle (Coleoptera) families (F_COL).

Calculating the pond metrics from taxon lists

1. Number of submerged and emergent plant species

This is simply the sum of the number of submerged plant taxa plus number of emergent plant taxa observed at the site. The terms 'submerged' and 'emergent' taxa refer only to the species listed in these groups on the field sheet - not to plants of any species which happen to be submerged below water or growing round the edge of the pond at the time of the survey.

The calculation does *not* include the number of floating-leaved species present. This is because the pond data suggest that the number of floating-leaved plants occurring at a site does not decline significantly with increasing degradation. The metric is therefore improved by omitting this plant group.

[9] Note that there is only one family of Megaloptera in the UK (the Sialidae) and that the metric F_OM is concerned with the combined total of Odonata and Megaloptera, not the occurrence of the family Megaloptera alone.

2. Trophic Ranking Score (TRS)

TRS is a measure of the average trophic rank for the pond. This is calculated by assigning each plant species with a trophic score based on its affinity to waters of a particular nutrient status. The trophic scores used in the present study were based on work undertaken on lakes by Palmer (1989). Plant scores in this system vary between 2.5 (dystrophic i.e. very nutrient poor conditions) and 10 (eutrophic, i.e. nutrient rich conditions).

Unfortunately, not all plants have trophic scores. This situation has arisen because the current TRS values for standing waters (Palmer *et al.*, 1992) are based only on analysis of lake data, and many plant species which are common in ponds occurred at too low a frequency in lakes to give them a score. Nigel Holmes's Mean Trophic Ranking method, which was developed for assessing the nutrient status of running water communities, cannot be used in the current analysis because trophic values for some plant species can vary between still and running waters (N. Holmes *pers. comm.*).

The TRS value for a site is calculated as follows:

(i) The trophic scores from each plant species present at the site are summed together.

(ii) The summed score is divided by the total number of plant species which have a trophic ranking score (NOTE not the total number of plants at the site) to give the TRS.

3. Uncommon species index

Uncommon species are those which have a rarity score of 2 or more. The number of these species is simply summed to give the number of uncommon species.

Uncommon species refers to species which can be described as 'local', 'nationally scarce' or 'Red Data Book'. Descriptions of these categories are given below.

Status[10]	Rarity score	Definition
Common	1	Recorded from >700 10x10 km grid squares in Britain
Local	2	Recorded from between 101 and 700 grid squares in Britain
Nationally Scarce	4	Nationally Scarce. Recorded from 15-100 grid squares in Britain
At risk	8	Red Data Book: Category "At risk"
Vulnerable	16	Red Data Book: Category "Vulnerable"
Endangered	32	Red Data Book: Categories " Endangered" or "Highly Endangered"

The rarity score for each species is given on the plant recording sheet so the number of species with a rarity score of 2 or more can be easily calculated.

4. Average Score Per Taxon (ASPT)

ASPT is calculated, as in RIVPACS, by summing the BMWP[11] scores for all taxa present at the site and dividing by the total number of BMWP taxa present.

5. Number of dragonfly and alderfly families

This metric is the sum of the number of Odonata and Megaloptera families which occur at the site.

6. Number of beetle families

This metric is the sum of the number of Coleoptera families present at the site. The metric has a relationship with bank quality as well as water quality.

[10]The rarity status values for Scarce and RDB species are based on existing definitions derived from the Red Data Books and other authorities. The definition of 'local' has been used to define species which are not uniformly common and widespread in Britain: with plants this refers specifically to species recorded from between 101 and 700 10 x 10 km squares (approximately 25% of all 10 km in England, Wales and Scotland).

[11] BMWP (Biological Monitoring Working Party) scores assigned to taxa defined by Maitland (1977), so each is allocated a value from 1 to 10 depending on its known tolerance to organic pollution, a higher score indicates lower tolerance.

4. Assessing canal quality using Canal PSYM

4.1 Introduction

Canal PSYM has currently been developed for use in the Spring season (March, April, May), and is based on a macroinvertebrate assessment only[12]. Two canal PSYM models have been developed in response to the potential problem of obtaining bottom samples. The basic model uses combined edge and bottom samples, but where this is not possible, a second model can be used for which only edge samples are taken.

4.2 Sites which can be included

Canal PSYM can be used to assess the quality of any section of canal, including both reinforced and natural bank sections. The term canal, does not however include major navigations (i.e. canalised rivers), such as the Lee Navigation and Stort Navigation, since these were excluded from the canal survey as many sections are essentially riverine in character.

4.3 Field sheet data collection

Field data collected from each canal site include:

(i) *locational and other data* used simply to identify the site and enable the site to be re-found for monitoring purposes. These data include information on: site name and collection code, canal name, nearest town, six or eight figure grid reference (depending on the degree of accuracy needed to locate the site precisely), survey date, surveyor, description of site.

(ii) *predictive variables* used in the PSYM programme to predict the minimally impaired biota for the canal. This includes map- or desk-based information (grid reference, altitude, number of boats) and field-based measurements (alkalinity, canal substrate).

Field variables

The environmental data which need to be collected from each site to use Canal PSYM depend on whether (i) only edge samples are taken or (ii) combined edge and bottom samples are used. For (i) Northing, altitude, turbidity, substrate and boat traffic are required. For (ii) Easting, Northing, altitude, alkalinity, substrate and boat traffic are needed. Details are as follows.

Easting: 100 km cell reference followed by 4 figures, from 1:25,000 OS maps.

Northing: 100 km cell reference followed by 4 figures, from 1:25,000 OS maps.

Altitude: in metres above sea level, taken from 1:50,000 or 1:25,000 OS maps.

Turbidity*:* Secchi depth in cm.

Total Alkalinity: measured as meq l^{-1}. Analysed in the laboratory from a water sample collected in the field.

Canal substrate: a field estimate of the percentage of the canal sediment composition that is sand. Sediment composition often varies across the canal, with the edge area usually coarser than the bottom substrate in deeper water. Where this is the case, two substrate measurements should be made, one in shallow water and one in deep water and the average calculated.

Number of boats: measured in thousands of boat movements per annum. These data can be provided by British Waterways (or other canal authority as appropriate).

4.4 Invertebrate sampling

Canals are steep-sided and relatively deep waterbodies, so the area-related hand-net sampling methodologies appropriate for rivers (e.g. typical RIVPACS sampling) cannot be directly applied to canals. In particular: (i) hand-net methods are difficult to apply to the deepest open-water areas of canals, (ii) most invertebrate species are concentrated in a narrow band at the canal edge, so that an area-based sampling method can considerably under-sample invertebrate diversity.

[12]Ideally PSYM should also include a plant-based assessment, however this has not yet been developed. In canals, diatoms have been identified as the most suitable plant assemblage for assessing quality, since macrophytes often occur in very low abundance where water is at all turbid and banks are reinforced.

The sampling technique used to collect invertebrate samples for this was developed as a hybrid between the 'three-minute hand-net sample' currently used for sampling shallow rivers, and the 'one-minute hand-net sample + dredge hauls' method recommended for sampling deep rivers. The method will also be used by CEH in future canal surveys.

The method comprises:

1. A one-minute search.

2. A two-minute semi-continuous hand-net sampling of the canal margin, shallows and any emergent plant habitats present. This sample typically covers a bank length of 5m to 15m.

3. Four net hauls from deeper bottom sediments along a canal length of approximately 10 m, elutriated on site to wash out the bulk of muds and fine sands. These should be taken at c. 3m intervals along the canal sampling length.

Two directly compatible field techniques can be employed to gather the four bottom sediment sample hauls from deeper areas, the choice depending on canal depth and accessibility:
(i) where canals are shallow enough to wade, bottom samples can be collected using a hand-net haul (c.3m length) taken perpendicular to the bank, (ii) where canals are too deep to use a hand net, bottom samples are collected using a Naturalist's dredge with a hand net sub-sample filling ca. one quarter of the pond net then taken from this dredged material. It is recommended that the bank and bottom samples are kept separate, since this makes the samples easier to sort in the laboratory.

4.5 Processing samples

Invertebrate sorting and identification methods follow the standard laboratory techniques used for processing invertebrate samples. Invertebrate samples are identified to *family* level for most groups and class level for oligochaetes.

Record findings in the columns on the field sheet as follows. If present and so included in ASPT calculation, record in the "ASPT" column, if a dragonfly or alderfly family also record in the "OM" column, or if a Coleoptera family in the "Cole." column.

4.6 Data processing and analysis

Invertebrate family data are used by PSYM to calculate four metrics:

- Average score per taxon (ASPT)
- Number of Ephemeroptera, Plecoptera and Trichoptera families (F_EPT)
- Number of beetle (Coleoptera) families (F_COL)
- Number of invertebrate families (INV_NFA)

4.7 Data interpretation and diagnosis

In analyses it was shown that ASPT and EPT scores both correlated strongly with a wide variety of water quality parameters, including heavy metals, suspended solids and chemical water quality (i.e. the overall chemical quality class based on suspended solids, BOD and ammonia concentrations). These metrics, however, showed few relationships with bank degradation variables.

In contrast, invertebrate family richness, and particularly beetle, bug and snail richness, showed strong relationships with bank structure and boat traffic, but very few relationships with water quality attributes.

These differences in degradation sensitivity make it possible to assess both water quality and bank effects separately. Thus where the main aim of canal assessments is to investigate water quality, then metrics based on ASPT and EPT taxa will be most effective. If boat traffic and hard bank structure effects are of concern, then parameters based on taxon richness or bug and beetle species or family richness can be combined into the final integrity index, i.e.:

A. Canal water quality assessment = ASPT + EPT.

B. Canal bank quality assessment = No. Coleoptera families + No. invertebrate families.

Total canal ecological quality = A + B.

Calculating the canal metrics from taxon lists

1. Average score per taxon (ASPT)

ASPT is calculated by summing the BMWP scores for all taxa present at the site and dividing by the total number of BMWP taxa present.

2. Number of Ephemeroptera, Plecoptera and Trichoptera families (F_EPT)

The sum of the number of Ephemeroptera, Plecoptera and Trichoptera families recorded in the sample.

3. Number of Coleoptera families (F_COL)

This metric is simply the sum of the number of Coleoptera families present at the site.

4. Number of invertebrate families (INV_NFA)

The number of all invertebrate taxa recorded on the survey form.

5. References and additional reading

Maitland, P.S. (1977). *A coded checklist of animals occurring in fresh water in the British Isles*. Institute of Terrestrial Ecology, Edinburgh.

Palmer, M.A. (1989). A botanical classification of standing waters in Great Britain. *Research & survey in nature conservation*, **19**. Nature Conservancy Council, Peterborough.

Palmer, M.A., S.L. Bell and I. Butterfield (1992). A botanical classification of standing waters in Britain - applications for conservation and monitoring. *Aquatic Conservation - Marine and Freshwater Ecosystems*. **2**, No. 2, 125-143.

Pond Action (1998). *A guide to the methods of the National Pond Survey*. Pond Action, Oxford.

Preston, C.D., D.A. Pearman and T.D. Dines (Eds) (2002) *New Atlas of the British and Irish Flora*, Oxford University Press, Oxford.

Wright, J.F. (1995). Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology*, **20**, 181-197.

Wright, J.F., D. Moss, P.D. Armitage and M.T. Furse (1984). A preliminary classification of running-water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data. *Freshwater Biology*, **14**, 221-256.

More detailed information describing the PSYM methodology is given in the following reports:

Williams, P., J. Biggs, L. Dodds, M. Whitfield, A. Corfield and G. Fox (1996). *Biological techniques of still water quality assessment. Phase 1 Scoping Study*. Environment Agency R&D Technical Report E7. Environment Agency, Bristol.

Williams, P., J. Biggs, M. Whitfield, A. Corfield, G. Fox and K. Adare (1998). *Biological techniques of still water quality assessment. Phase 2. Method development.* Environment Agency R&D Technical Report E56. Environment Agency, Bristol.

Biggs, J., P. Williams, M. Whitfield, G. Fox and P. Nicolet (2000). *Biological techniques of still water quality assessment. Phase 3. Method development.* Environment Agency R&D Technical Report E110. Environment Agency, Bristol.

Pond PSYM Fieldsheet

Site and sample details

Site name ____________________ Code No. ______________ Grid ref. (   ) ____________________
Recording format: (SU)345 678 *or* (41)345 678

Location ____

Site access details ____

Survey date ______________ Surveyor ______________________________

Notes ____

____

Environmental data

Altitude (m)		pH	
Shade: % pond overhung		% emergent plant cover	
Inflow (absent = 0, present = 1)		Pond area (m^2)	
% of pond margin grazed			

Sketch of pond

Pond base: categorise into one of three groups: 1=0%-32%, 2=33%-66%, 3=67%-100%

Clay/silt _________ Sand, gravel, cobbles _________ Bed rock _________

Peat _________ Other _________

MACROINVERTEBRATE LIST

Group 1 taxa (BMWP:10)	ASPT	OM	Cole.
Siphlonuridae			
Heptageniidae			
Leptophlebiidae			
Ephemerellidae			
Potamanthidae			
Ephemeridae			
Taeniopterygidae			
Leuctridae			
Capniidae			
Perlodidae			
Perlidae			
Chloroperlidae			
Aphelocheiridae			
Phryganeidae			
Molannidae			
Beraeidae			
Odontoceridae			
Leptoceridae			
Goeridae			
Lepidostomatidae			
Brachycentridae			
Sericostomatidae			
No. of taxa			

Group 2 taxa (BMWP:8)	ASPT	OM	Cole.
Astacidae			
Lestidae			
Calopterygidae (Agriidae)			
Gomphidae			
Cordulegasteridae			
Aeshnidae			
Corduliidae			
Libellulidae			
Philopotamidae			
Psychomyiidae			
No. of taxa			

Group 3 taxa (BMWP:7)	ASPT	OM	Cole.
Caenidae			
Nemouridae			
Rhyacophilidae (Glossomatidae)			
Polycentropodidae			
Limnephilidae			
No. of taxa			

Group 4 taxa (BMWP:6)	ASPT	OM	Cole.
Neritidae			
Viviparidae			
Ancylidae (Acroloxidae)			
Hydroptilidae			
Unionidae			
Corophiidae			
Gammaridae (Crangonyctidae)			
Platycnemididae			
Coenagriidae			
No. of taxa			

Group 5 taxa (BMWP:5)	ASPT	OM	Cole.
Planariidae (Dugesiidae)			
Dendrocoelidae			
Mesovelidae			
Hydrometridae			
Gerridae			
Nepidae			
Naucoridae			
Notonectidae			
Pleidae			
Corixidae			
Haliplidae			
Hygrobiidae			
Dytiscidae (Noteridae)			
Gyrinidae			
Hydrophilidae (Hydraenidae)			
Dryopidae			
Elmidae			
Hydropsychidae			
Tipulidae			
Simuliidae			
No. of taxa			

Group 6 taxa (BMWP:4)	ASPT	OM	Cole.
Baetidae			
Sialidae			
Piscicolidae			
No. of taxa			

Group 7 taxa (BMWP:3)	ASPT	OM	Cole.
Valvatidae			
Hydrobiidae (Bithyniidae)			
Lymnaeidae			
Physidae			
Planorbidae			
Sphaeriidae			
Glossiphoniidae			
Hirudinidae			
Erpobdellidae			
Asellidae			
No. of taxa			

Group 8 taxa (BMWP:2)	ASPT	OM	Cole.
Chironomidae			
No. of taxa			

Group 9 taxa (BMWP:1)	ASPT	OM	Cole.
Oligochaeta			
No. of taxa			

TOTAL NO. OF TAXA			
TOTAL BMWP SCORE			
ASPT			
NO. OF OM TAXA			
NO. COLEOPT. TAXA			

Plant recording sheet (score through each species present)

RS = Rarity Score, TRS = Trophic Ranking Score

RS	TRS	Emergent plants
1		Achillea ptarmica
1		Acorus calamus
1		Agrostis canina
1	*LP*	Agrostis stolonifera
32		Alisma gramineum
2		Alisma lanceolatum
1	9	Alisma plantago-aquatica
2		Alopecurus aequalis
4		Alopecurus borealis
1		Alopecurus geniculatus
2		Anagallis tenella
2		Andromeda polifolia
1		Angelica archangelica
1		Angelica sylvestris
2		Apium graveolens
1	10	Apium nodiflorum
32		Apium repens
2		Baldellia ranunculoides
2	10	Berula erecta
2		Bidens cernua
1		Bidens connata
1		Bidens frondosa
2		Bidens tripartita
2		Blysmus compressus
2		Bolboschoenus maritimus
2*		Butomus umbellatus
2		Calamagrostis canescens
2		Calamagrostis epigejos
8		Calamagrostis purpurea
8		Calamagrostis stricta
16		Calamogrostis scotica
1		Calla palustris
1	7	Caltha palustris
1		Cardamine amara
1		Cardamine pratensis
2		Carex acuta
1	10	Carex acutiformis
4		Carex appropinquata
2		Carex aquatilis
2		Carex curta
2		Carex diandra
1		Carex disticha
1		Carex echinata
2	10	Carex elata
4		Carex elongata
1		Carex flacca
1		Carex hostiana
2		Carex laevigata
2	4	Carex lasiocarpa
2	4	Carex limosa
1	5	Carex nigra
1		Carex oedocarpa
1		Carex otrubae
1		Carex panicea
2	10	Carex paniculata
1		Carex pendula
2	10	Carex pseudocyperus
1		Carex pulicaris
1	10	Carex riparia
1	5.3	Carex rostrata
2		Carex spicata
2		Carex vesicaria
1		Carex viridula
16		Carex vulpina
1		Carex sp.
2		Catabrosa aquatica
4		Cicuta virosa
2		Cirsium dissectum
1		Cirsium palustre
2		Cladium mariscus
1		Conium maculatum
1		Crassula helmsii
1		Crepis paludosa
16		Cyperus fuscus
4*		Cyperus longus
2		Dactylorhiza sp (undet.)
32		Damasonium alisma
1		Deschampsia cespitosa
2		Drosera anglica
1		Drosera binata
1		Drosera capensis
2		Drosera intermedia
1		Drosera rotundifolia
16		Dryopteris cristata
2		Eleocharis acicularis
8		Eleocharis austriaca
2		Eleocharis multicaulis
1	*LP*	Eleocharis palustris
2		Eleocharis quinqueflora
2		Eleocharis uniglumis
2		Epilobium alsinifolium
2		Epilobium anagallidifolium
1		Epilobium brunnescens
1		Epilobium ciliatum

RS	TRS	
1		Epilobium hirsutum
1		Epilobium obscurum
1		Epilobium palustre
1		Epilobium parviflorum
2		Epilobium tetragonum
2		Epipactis palustris
1	*LP*	Equisetum fluviatile
1		Equisetum palustre
1		Erica tetralix
1	2.5	Eriophorum angustifolium
16		Eriophorum gracile
2		Eriophorum latifolium
1		Eriophorum vaginatum
1		Eupatorium cannabinum
1		Filipendula ulmaria
2		Galium boreale
8		Galium constrictum
1		Galium palustre
2		Galium uliginosum
1		Geum rivale
2		Glyceria declinata
1	*LP*	Glyceria fluitans
1	10	Glyceria maxima
2		Glyceria notata
1		Gnaphalium uliginosum
1	*LP*	Hydrocotyle vulgaris
2		Hypericum elodes
1		Hypericum tetrapterum
4		Hypericum undulatum
2		Impatiens capensis
1		Impatiens glandulifera
4*		Impatiens noli-tangere
1	*LP*	Iris pseudacorus
1		Isolepis setacea
1		Juncus acutiflorus
1		Juncus articulatus
1		Juncus bufonius agg.
1	5.3	Juncus bulbosus
2		Juncus compressus
1		Juncus conglomeratus
1	*LP*	Juncus effusus
2		Juncus foliosus
1		Juncus inflexus
32		Juncus pygmaeus
2		Juncus subnodulosus
4		Lathyrus palustris
32		Leersia oryzoides
32		Liparis loeselii
1		Lotus pedunculatus
1		Luzula luzuloides
2		Luzula sylvatica
1		Lychnis flos-cuculi
1		Lycopus europaeus
1		Lysimachia nummularia
1		Lysimachia terrestris
4		Lysimachia thyrsiflora
2		Lysimachia vulgaris
16		Lythrum hyssopifolium
2		Lythrum portula
1		Lythrum salicaria
1	7.3	Mentha aquatica
16		Mentha pulegium
1	5.3	Menyanthes trifoliata
1		Mimulus guttatus
1		Mimulus luteus
16		Minuartia stricta
1		Molinia caerulea
1		Montia fontana
1	7.7	Myosotis laxa
1	9	Myosotis scorpioides
1		Myosotis secunda
4		Myosotis stolonifera
1		Myosotis sp (undet.).
2		Myosoton aquaticum
1		Myrica gale
1		Narthecium ossifragum
2		Oenanthe aquatica
1		Oenanthe crocata
2		Oenanthe fistulosa
2		Oenanthe fluviatilis
2		Oenanthe lachenalii
2		Oenanthe pimpinelloides
4		Oenanthe silaifolia
2		Osmunda regalis
2		Parnassia palustris
1		Pedicularis palustris
1	10	Persicaria hydropiper
1		Persicaria maculosa
2		Persicaria minor
4		Persicaria mitis
1		Petasites hybridus
1		Petasites japonicus
4		Peucedanum palustre
1	8.5	Phalaris arundinacea

RS	TRS	
1	7.3	Phragmites australis
4	5.5	Pilularia globulifera
2		Pinguicula lusitanica
1		Pinguicula vulgaris
1		Potentilla erecta
1	5.3	Potentilla palustris
1		Pulicaria dysenterica
16		Pulicaria vulgaris
1		Ranunculus ficaria
1	*LP*	Ranunculus flammula
2	10	Ranunculus hederaceus
2*		Ranunculus lingua
2		Ranunculus omiophyllus
32		Ranunculus ophioglossifolius
32		Ranunculus reptans
1	10	Ranunculus sceleratus
2		Rhynchospora alba
4		Rhynchospora fusca
2		Rorippa amphibia
8		Rorripa islandica
2	10	Rorippa microphylla
1	10	Rorippa nasturtium-aquaticum
1	10	Rorippa (undet.).
1		Rorippa palustris
2	10	Rumex hydrolapathum
2		Rumex maritimus
2		Rumex palustris
1		Sagina procumbens
1		Sagittaria subulata
2		Samolus valerandi
2	7.7	Schoenoplectus lacustris
32		Schoenoplectus pungens
2		Schoenoplectus tabernaemontani
32		Schoenoplectus triqueter
16		Schoenus ferrugineus
2		Schoenus nigricans
16		Scorzonera humilis
1		Scrophularia auriculata
1		Scutellaria galericulata
1		Senecio aquaticus
1		Senecio fluviatilis
32		Senecio paludosus
4		Sium latifolium
1	10	Solanum dulcamara
4		Sonchus palustris
1	8.5	Sparganium erectum
1		Stachys palustris
2		Stellaria palustris
1		Stellaria uliginosa
1		Symphytum officinale
16		Teucrium scordium
2		Thalictrum flavum
4		Thelypteris palustris
2		Tofieldia pusilla
1		Trichophorum cespitosum
1		Triglochin palustre
2	10	Typha angustifolia
1	8.5	Typha latifolia
2		Valeriana dioica
1		Vallisneria spiralis
1		Veronica anagallis-aquatica
1	10	Veronica beccabunga
2		Veronica catenata
1	5.5	Veronica scutellata
1		Veronica sp. (undet.)
1		Viola palustris
32		Viola persicifolia
1		Unknown exotic

Floating-leaved plants		
1		Azolla filiculoides
2		Hydrocharis morsus-ranae
1		Hydrocotyle ranunculoides
2		Lemna gibba
1	9	Lemna minor
1		Lemna minuta
1	10	Lemna trisulca
4		Luronium natans
1		Menyanthes trifoliata
1		Nuphar advena
2	8.5	Nuphar lutea
4	7	Nuphar pumila
2*	6.7	Nymphaea alba
1		Nymphaea sp. (exotic)
4*		Nymphoides peltata
1	9	Persicaria amphibia
1	*LP*	Potamogeton natans
1	3.7	Potamogeton polygonifolius
2		Riccia fluitans
2		Ricciocarpus natans
2		Spirodela polyrhiza
4		Wolffia arrhiza

* = uncommon species often introduced to sites (see Preston *et al.* 2002 for details), if so score species as 1.

RS	TRS	Submerged plants
2	6.3	Apium inundatum
1		Aponogeton distachyos
1		Cabomba caroliniana
2		Callitriche brutia
1	6.3	Callitriche hamulata
2	8.5	Callitriche hermaphroditica
2		Callitriche obtusangula
2		Callitriche platycarpa
1	7.3	Callitriche stagnalis
4		Callitriche truncata
1		C. stagnalis/platycarpa agg.
1		C. hamulata/brutia agg.
1		Callitriche sp. (undet.)
2	10	Ceratophyllum demersum
2		Ceratophyllum submersum
2	7.3	Chara sp.
1		Egeria densa
4	7	Elatine hexandra
4		Elatine hydropiper
2		Eleogiton fluitans
1		Elodea callitrichoides
1	7.3	Elodea canadensis
1	10	Elodea nuttallii
8		Eriocaulon aquaticum
1	6.3	Fontinalis antipyretica
2		Groenlandia densa
2	7.7	Hippuris vulgaris
2		Hottonia palustris
4		Isoetes echinospora
2	5	Isoetes lacustris
1		Lagarosiphon major
2	6.7	Littorella uniflora
2	5	Lobelia dortmanna
8		Ludwigia palustris
1	6.7	Myriophyllum alterniflorum
1		Myriophyllum aquaticum
2	9	Myriophyllum spicatum
4		Myriophyllum verticillatum
4		Najas flexilis
2	6.7	Nitella sp.
2		Oenanthe fluviatilis
16		Potamogeton acutifolius
2	5.5	Potamogeton alpinus
2	7.3	Potamogeton berchtoldii
4		Potamogeton coloratus
4		Potamogeton compressus
1	10	Potamogeton crispus
16		Potamogeton epihydrus
4	10	Potamogeton filiformis
2	10	Potamogeton friesii
2	7	Potamogeton gramineus
2	10	Potamogeton lucens
8		Potamogeton nodosus
2	8	Potamogeton obtusifolius
1	10	Potamogeton pectinatus
2	7.3	Potamogeton perfoliatus
2	8.5	Potamogeton praelongus
2	9	Potamogeton pusillus
8		Potamogeton rutilus
4	10	Potamogeton trichoides
2	10	Ranunculus aquatilis
2	10	Ranunculus baudotii
2	10	Ranunculus circinatus
2		Ranunculus fluitans
2	7	Ranunculus peltatus
2	8.5	Ranunculus penicillatus
2	8.5	Ranunculus trichophyllus
16		Ranunculus tripartitus
1		Ranunculus sp. (undet.)
1		Sagittaria latifolia
1		Sagittaria rigida
2		Sagittaria sagittifolia
2	4	Sparganium angustifolium
1	10	Sparganium emersum
2		Sparganium natans
1	2.5	Sphagnum sp.
4*		Stratiotes aloides
2	4	Subularia aquatica
		Tolypella sp.
2		Utricularia australis
2	4	Utricularia intermedia
2	4	Utricularia minor
2	5	Utricularia vulgaris
1		Vallisneria spiralis
2	10	Zannichellia palustris

		Number of emergent & submerged species
		Number of uncommon species (with a rarity score of 2 or more)
		Trophic Ranking Score

LP = species exhibiting little nutrient preference

Canal PSYM Fieldsheet

Site and sample details

Site name ______________________ **Code no.** ________ **Grid ref.(_____)** ______________

Recording format: (SU)3450 6780 *or* (41)3450 6780

Easting ______________________ **Northing** ______________________

Canal ______________________ **Location** ______________________

Survey date ______________ **Surveyors** ____________ **Which bank sampled** ______________

Environmental data

(a)(b) **Altitude (m):**		(a) **Turbidity (Secchi depth in cm):**	
(a)(b) **% sand in substrate:**		(b) **Alkalinity (meq l^{-1}):**	
(a)(b) **Boat traffic:** **(1000's of movements per year)**			

(a) required if edge samples only taken
(b) required for combined edge and bottom samples

Macroinvertebrate list

Group 1 taxa (BMWP:10)	ASPT	EPT	Cole.
Siphlonuridae			
Heptageniidae			
Leptophlebiidae			
Ephemerellidae			
Potamanthidae			
Ephemeridae			
Taeniopterygidae			
Leuctridae			
Capniidae			
Perlodidae			
Perlidae			
Chloroperlidae			
Aphelocheiridae			
Phryganeidae			
Molannidae			
Beraeidae			
Odontoceridae			
Leptoceridae			
Goeridae			
Lepidostomatidae			
Brachycentridae			
Sericostomatidae			
No. of taxa			

Group 2 taxa (BMWP:8)	ASPT	EPT	Cole.
Astacidae			
Lestidae			
Calopterygidae (Agriidae)			
Gomphidae			
Cordulegasteridae			
Aeshnidae			
Corduliidae			
Libellulidae			
Philopotamidae			
Psychomyiidae			
No. of taxa			

Group 3 taxa (BMWP:7)	ASPT	EPT	Cole.
Caenidae			
Nemouridae			
Rhyacophilidae (Glossomatidae)			
Polycentropodidae			
Limnephilidae			
No. of taxa			

Group 4 taxa (BMWP:6)	ASPT	EPT	Cole.
Neritidae			
Viviparidae			
Ancylidae (Acroloxidae)			
Hydroptilidae			
Unionidae			
Corophiidae			
Gammaridae (Crangonyctidae)			
Platycnemididae			
Coenagriidae			
No. of taxa			

Group 5 taxa (BMWP:5)	ASPT	EPT	Cole.
Planariidae (Dugesiidae)			
Dendrocoelidae			
Mesovelidae			
Hydrometridae			
Gerridae			
Nepidae			
Naucoridae			
Notonectidae			
Pleidae			
Corixidae			
Haliplidae			
Hygrobiidae			
Dytiscidae (Noteridae)			
Hydrophilidae			
Gyrinidae			
Dryopidae			
Elmidae			
Hydropsychidae			
Tipulidae			
Simuliidae			
No. of taxa			

Group 6 taxa (BMWP:4)	ASPT	EPT	Cole.
Baetidae			
Sialidae			
Piscicolidae			
No. of taxa			

Group 7 taxa (BMWP:3)	ASPT	EPT	Cole.
Valvatidae			
Hydrobiidae (Bithyniidae)			
Lymnaeidae			
Physidae			
Planorbidae			
Sphaeriidae			
Glossiphoniidae			
Hirudinidae			
Erpobdellidae			
Asellidae			
No. of taxa			

Group 8 taxa (BMWP:2)	ASPT	EPT	Cole.
Chironomidae			
No. of taxa			

Group 9 taxa (BMWP:1)	ASPT	EPT	Cole.
Oligochaeta			
No. of taxa			

	ASPT	EPT	Cole.
TOTAL BMWP SCORE			
ASPT			
NO. OF EPT TAXA			
NO. OF COLEOPT.			

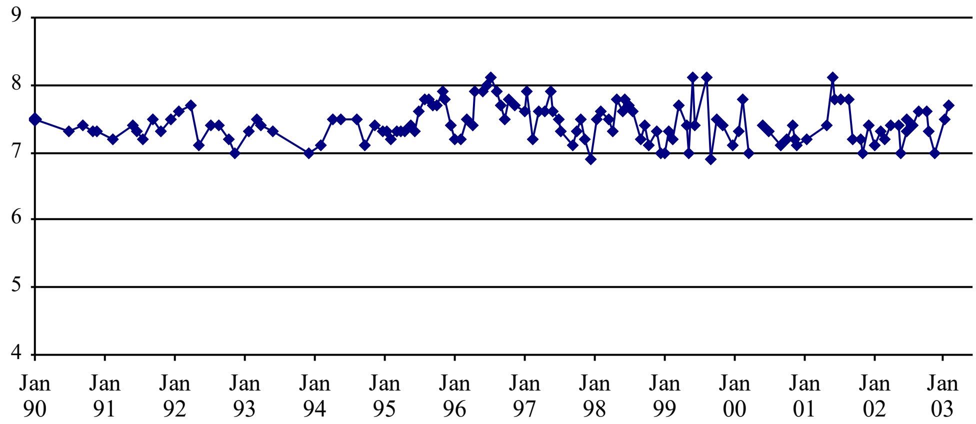
Appendix 2. Invertebrate species recorded at sites on the Montgomery Canal in the 1997 PSYM database creation project

	Buttington Cross	Wern	Queen's Head
Taxon	Number of individuals in a standard PSYM sample (combined edge and middle data)		
Polycelis nigra	20		28
Polycelis tenuis	138	11	16
Dugesia lugubris			3
Dendrocoelum lacteum	6		
Viviparus viviparus		9	
Valvata piscinalis	7		
Potamopyrgus antipodarum	1		
Bithynia leachi	13	4	57
Bithynia tentaculata	34	8	58
Physa acuta		1	
Physa fontinalis	7		1
Lymnaea auricularia	2		
Lymnaea palustris			1
Lymnaea peregra	11	4	500
Lymnaea stagnalis	1	10	1
Planorbis carinatus		2	94
Planorbis planorbis			1
Anisus vortex	63	5	506
Gyraulus albus	70	1	135
Armiger crista	4		
Hippeutis complanatus	22	6	3
Planorbarius corneus			2
Anodonta cygnea		1	
Sphaerium corneum	40	61	51
Sphaerium lacustre	9		1
Piscicola geometra	17		
Theromyzon tessulatum			2
Hemiclepsis marginata	4		1
Glossiphonia complanata	4		7
Glossiphonia heteroclita	8		10
Helobdella stagnalis	4	3	18
Haemopis sanguisuga		1	
Erpobdella octoculata	9	8	144
Erpobdella testacea			1
Argyroneta aquatica		7	
Asellus aquaticus	804	146	50
Asellus meridianus	1		
Crangonyx pseudogracilis	55	183	50
Cloeon dipterum	95		
Caenis horaria		9	
Caenis robusta	92	13	
Platycnemis pennipes		1	
Ischnura elegans	50	22	2
Enallagma cyathigerum	5	1	
Coenagrion puella/pulchellum	1		1
Erythromma najas	2		

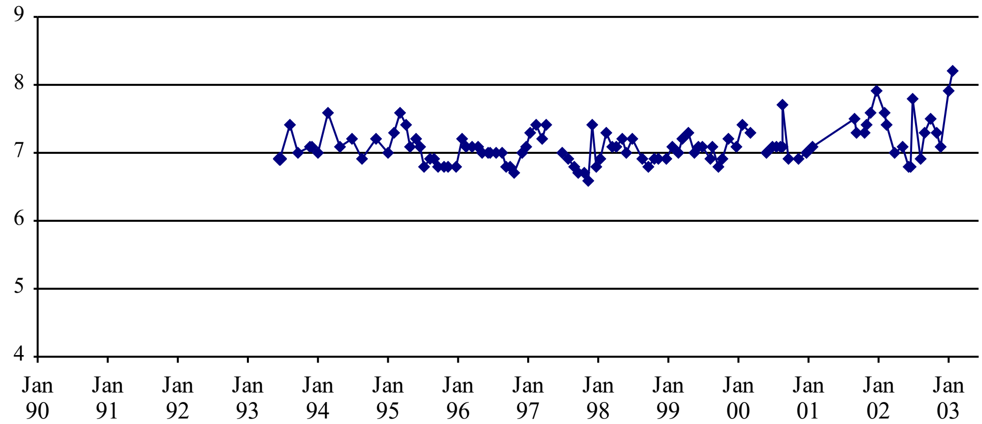
	Buttington Cross	**Wern**	**Queen's Head**
Taxon	Number of individuals in a standard PSYM sample (combined edge and middle data)		
Hydrometra stagnorum	1		1
Microvelia reticulata	6		
Gerris lacustris	1	2	4
Ilyocoris cimicoides	3		
Notonecta glauca	12		1
Notonecta marmorea			1
Cymatia coleoptrata	45		
Sigara dorsalis	22	1	
Sigara falleni	1	1	1
Haliplus fluviatilis	3	1	13
Haliplus immaculatus	24		
Haliplus lineatocollis	1		
Haliplus lineolatus	2	1	9
Haliplus ruficollis	3		
Haliplus wehnckei	2		
Noterus clavicornis	2	2	1
Laccophilus hyalinus	24	6	
Laccophilus minutus	1		1
Hyphydrus ovatus	4	2	18
Hygrotus inaequalis	1		
Hygrotus versicolor	1		
Nebrioporus depressus	1		
Ilybius fenestratus		3	
Coelostoma orbiculare			2
Anacaena limbata	6	3	1
Laccobius bipunctatus	3		
Enochrus melanocephalus	2		
Enochrus testaceus	1		
Dryops luridus	1		1
Helichus substriatus		7	
Sialis lutaria	8	19	1
Agraylea multipunctata	1		
Cyrnus flavidus		2	
Holocentropus picicornis	22		
Anabolia nervosa		1	
Limnephilus flavicornis			10
Limnephilus lunatus	22	7	3
Limnephilus marmoratus		6	
Athripsodes aterrimus	39	47	
Mystacides azurea		2	
Mystacides longicornis	1		
Triaenodes bicolor	29	9	1
Oecetis lacustris	2		
Nymphula nymphaeata	4	1	1
Oligochaeta	540		17
Chironomidae	740		6
Ceratapogonidae	45		1
Psychodidae			1

Appendix 3 Figures 1(a) – (d)

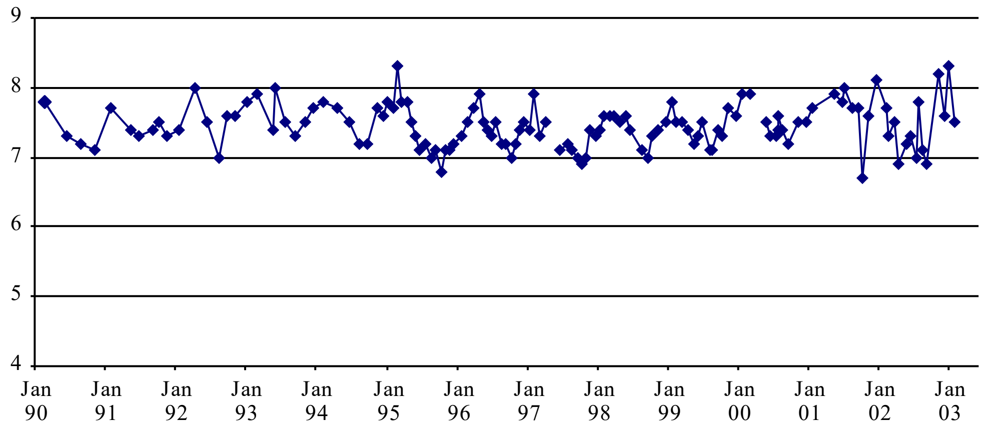
(a) pH at Queen's Head



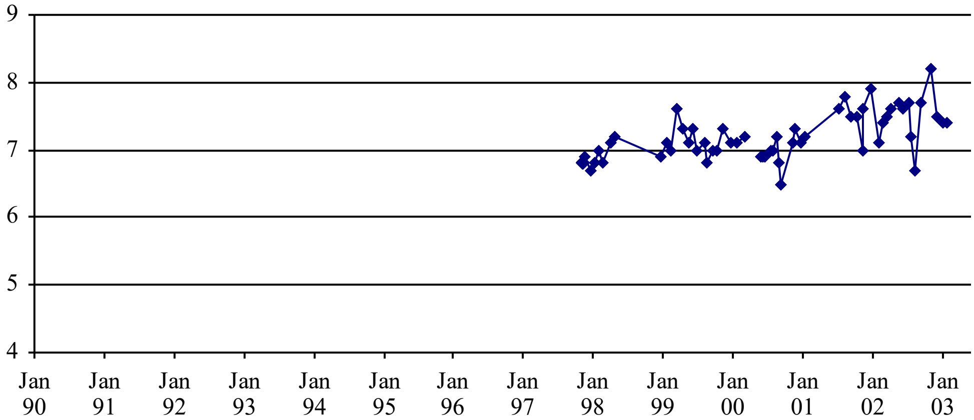
(b) pH at Parson's Bridge



(c) pH at Buttington Cross

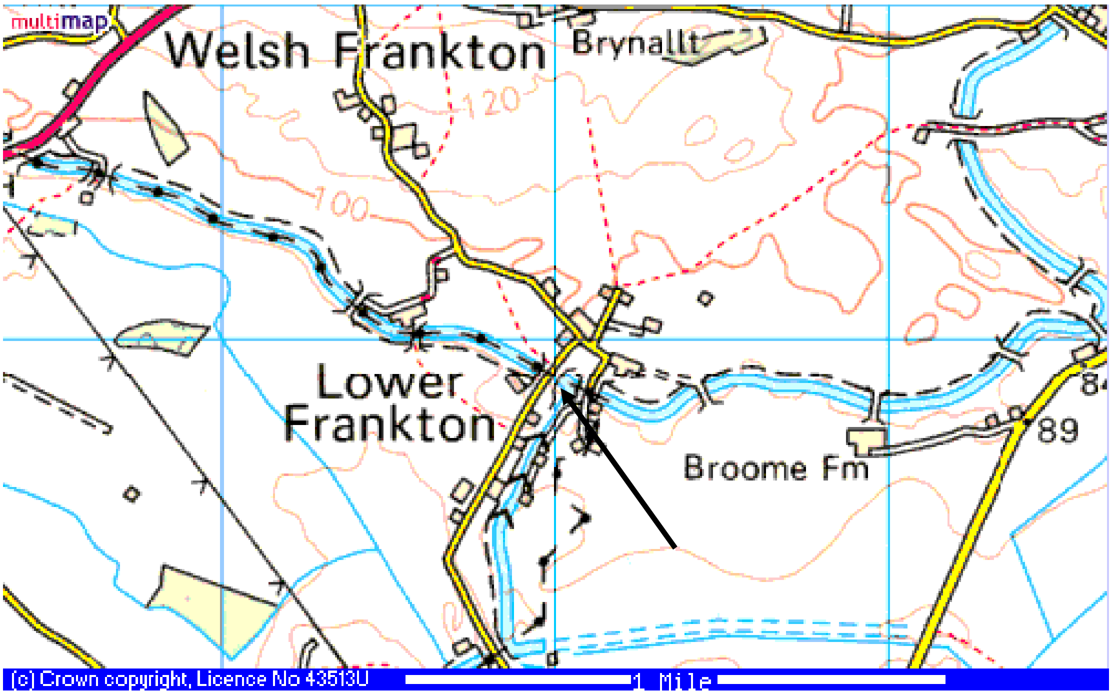


(d) pH at Aberbechan

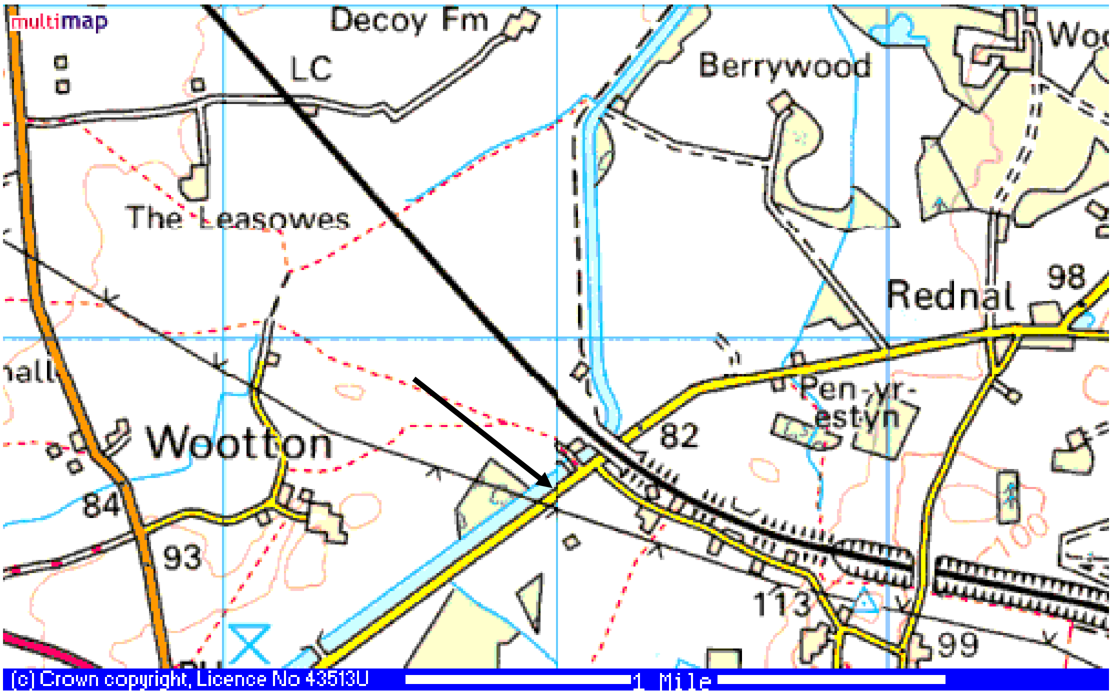


Appendix 4. Location of survey sites, and field recording sheets, for 2003 Montgomery Canal invertebrate survey

1. Lower Frankton (SJ370318)



2. Rednal (SJ350275)



3. Queen’s Head (SJ341269)

4. Aston Locks (SJ335263)

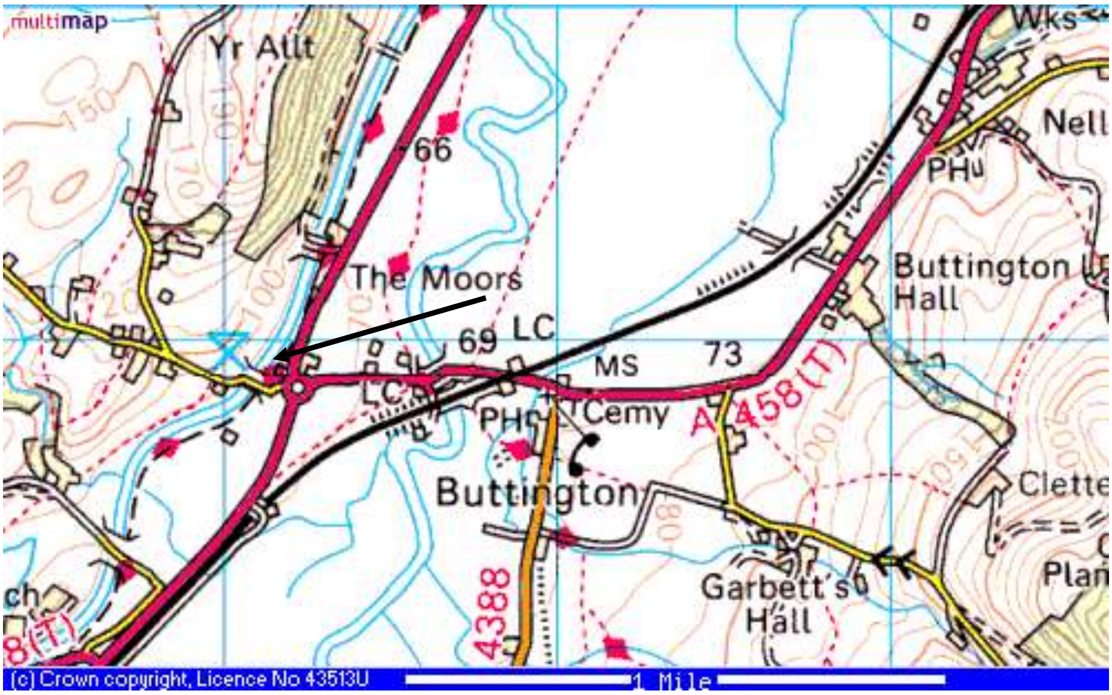
5. Maesbury Marsh (SJ305248)

6. Vyrnwy Aqueduct (SJ254197)

7. Parson's Bridge (SJ264189)

8. Bank Lock (SJ260130)

9. Buttington Cross (SJ241089)



10. Aberbechan (SO142934)