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Severn-Thames Transfer. A Review of Biological Data.
Volume I - Main Report.

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CONFIDENTIALITY STATEMENT

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EXECUTIVE SUMMARY

General

The overall aim of the study was to assemble existing data on the fish, macro-invertebrate, macrophyte and algal assemblages of the River Thames for assessing the possible impacts of any Severn-Thames transfer schemes. The principal impacts of the transfer scheme are considered briefly for each group and future sampling schemes are recommended which should allow the impacts of any release of augmentation water to be evaluated.

The data were held in a variety of different formats and different approaches were adopted for each of four major taxonomic groupings. In the case of macro-invertebrates and macrophytes, available data were incorporated in a Microsoft Access 7 relational data-base supplied to the Agency. Key features of the data are provided in the text of chapters 3 (macro-invertebrates) and 4 (macrophytes). The fish and plankton data and comments on their significance are presented in text form in chapters 2 (fish) and 5 (plankton).

Fish

The fish chapter contains, a summary and interpretation of the main findings of all known surveys of fish stocks. This is supported by a set of summary information from each significant report produced on the section of river of interest and by key tables and figures from these reports. The latter is held in Volume 2 - Appendices.

There is a considerable variation in the times and temperatures associated with the spawning of the main fish species. Adult fish have a greater range of habitat tolerance than juvenile fish and studies have shown that spawning habitat is more precise and thus of greater importance than feeding and refuge habitats. Variations in spawning characteristics arise due to local conditions, to repeat spawning (eg gudgeon and ruffe), to older fish spawning earlier than smaller fish (eg roach) and to intra-specific variation between years due to environmental factors.

Water velocity is an important factor in determining the effect of the transfer on the fish populations. Flows at and immediately after spawning could determine the year class strength of many species in the Thames. Critical velocities are related to fish size and water temperature. These critical values are velocities which displace at least 50% of the larvae in three minutes. Preferred velocities are much lower. Velocities >2 cm s^{-1} can lead to displacement of newly hatched fry. Only 3% of the area of the Thames has flows of less than 2 cm s^{-1} during the time when small fry are present and these areas may be vital to the success of certain species.

Good marginal habitats for fry are shallow and gently sloping with macrophyte cover and marginal vegetation. An increase in water level is likely to cause flooding of the marginal vegetation where fry can take refuge. The augmentation of flow is likely to occur during mid to late summer which means that late spawners are more likely to be affected. Even though the areas of refuge may not be affected, it is likely that there will be some impact on distribution because fry venturing into stronger currents will be carried further downstream.

The importance of aquatic vegetation as feeding and refuge areas for fry is emphasised. Macrophytes in general, and *Nuphar* in particular, can be damaged by high flows. Thus any changes in the hydrological regime of the Thames that damage marginal plants would be detrimental to the feeding, growth and survival of young-of-the-year (0 group) fish.

The abundance of food may be affected by increased turbidity resulting from increased flows. Phytoplankton production may be reduced due to the lower light levels. This in turn would reduce the biomass of the zooplankton on which the 0 group fish are feeding and possibly make food more difficult to find.

The principal impact of sedimentation on fish occurs during the egg and early larval stage. For early spawners, there is unlikely to be any effect of water transfer as the fry will have passed the early larval stage. For late spawners, the increased velocity may redistribute fine sediment and this may settle on fish eggs in low flow areas reducing hatching success.

The water that is transferred from the Severn will undergo a period of settlement before being introduced into the Thames. Therefore, the augmentation process is unlikely to increase the sediment load in the Thames. There may be local redistribution of the natural Thames sediments over a very short time period and this may affect the feeding rates of some fish species. However, routine maintenance dredging is likely to have a more substantial impact on the fish populations.

Marked decreases in dissolved oxygen (DO) concentrations could cause fish kills. If the transferred water is well aerated then any problems resulting from inadequate DO concentrations will be eliminated in the transferred water.

The temperature of water from the Severn is expected to be similar to that of the Thames when it is released into the river and thus should not have any implications to spawning, recruitment or growth of fish.

Although not known categorically, the probability of fish parasites or pathogens being transferred is high but the probability of there being effects on the fish communities of the Thames is considered to be low.

The species compositions of the Severn and the Thames are very similar. There is some concern over the potential introduction of zander which occur in the Severn at the abstraction point. It is reported that some stocking of elvers from the Severn has already taken place in the upper Thames so the transfer of this species is unlikely to be a problem.

The normal expectation is that any changes in fish population structure will become evident at the fry stage first. For this reason, the surveys of fry and juvenile fish already being carried out annually for South West Oxfordshire Reservoir Proposal should be continued. In addition, factors affecting fry survival should be examined. Surveys of larval and juvenile habitat should be carried out to ensure that these areas are conserved. Studies on the food availability, feeding and growth of fry should be maintained. In order to more closely monitor the immediate impacts of Severn-Thames transfer, similar fry and juvenile fish surveys should be initiated in the reaches most likely to be affected, including a control reach.

Macro-invertebrates

The macro-invertebrate data-base holds information on 379 individual samples containing, between them, information on 487 distinct taxa. The specific habitat requirements of most of these taxa were analyzed. The 487 taxa included 14 with national conservation status.. Brief details of the national and local distribution, habitat preferences and ecology of these 14 and two other rare taxa are given. Detailed macro-invertebrate data are presented in Volume 2.

The ecological quality of the study reach was generally good, as assessed by applying RIVPACS procedures to the water industry macro-invertebrate samples collected between 1977 and 1995. However, available data suggested that the section of river immediately downstream of the probable water release point near Buscot is taxon-poor. This section of river was last sampled in 1977 following dredging, severe drought and flooding.

Habitat preferences and zonation patterns of macro-invertebrate taxa were examined. More taxa had apparent preferences for the section of river downstream of Oxford than upstream, macrophyte habitats rather than in non-vegetated marginal and midstream zones, and floating vegetation rather than either emergent plants or gravel substrata.

Most macro-invertebrate species are resilient to gradual change because this is the normal seasonal and annual pattern. Sudden changes in discharge are more likely to have a deleterious effect, particularly upon those species living at the waters' edge, including those associated with marginal and floating macrophytes.

Increased sediment loads and turbidity could have a range of direct and indirect impacts on aquatic macro-invertebrates. The accumulation of fines may impact habitat diversity and quality directly on river bed or indirectly through its impact on plants. Whereas most macro-invertebrate species would be more likely to be disadvantaged than favoured by increased siltation and turbidity, some filter-feeding species would be likely to benefit.

No discernable impacts upon macro-invertebrates are expected resulting from temperature differences in the Thames and the released water, which are anticipated to be small. Furthermore, most macro-invertebrate taxa have a relatively broad range of tolerance to naturally occurring chemicals and no substantial impacts are expected from the differences in normal baseline chemistry of the Severn and Thames. Studies have also showed that both rivers appeared to be relatively free of micro-organic contamination.

It is feasible that specimens of macro-invertebrates may be transferred from the Severn to the Thames but this is not likely to be a problem. The zebra mussel, *Dreissena polymorpha* (Pallas), which occurs in the Severn, is a potential nuisance species but it also occurs in the lower Thames and does not appear to have colonised the St John's to Caversham section of the river. Transfer of disease is not considered to be an important issue.

To demonstrate that the ecological quality of the study section of the river remains within the normal temporal range, routine monitoring should be maintained at all current Agency sites with an existing time series of data of at least five years. In addition, as a matter of urgency, routine monitoring needs to be instigated in the section of river between Buscot and Grafton Locks, immediately downstream of the probable water release point. New monitoring sites are also recommended between Grafton and Radcot Locks and between Shifford and Northmoor Locks.

To demonstrate that faunal diversity is maintained during years of augmentation, it is recommended that a regular habitat specific sampling programme is established with faunal identification at species level. Ideally this should be co-ordinated with the recommended macrophyte sampling programme.

Macrophytes

Few macrophyte surveys have been undertaken on the Thames. The only available information comprises a longitudinal survey from St John's to Benson's Lock, undertaken by the Freshwater Biological Association (FBA) in 1978, and two River Corridor surveys conducted by Ecosurveys Ltd in 1992. The FBA data are presented in the main report. The key sections of the River Corridor Surveys are presented in Volume 2.

Twenty-three macrophyte taxa were recorded in the FBA Survey. Some were distributed over the study section of the river. However, others showed evidence of longitudinal zonation. The break point in the zonation of many taxa was at, or about, Godstow Lock, near Oxford.

The main concerns arising from the proposed transfer are the passage of seeds, turions or other propagules, the opportunity for spawning vigourous novel hybrids and for the carriage of pathogenic organisms. There is a small risk of a virulent, invasive spread of a new hybrid, or of a die-back of existing flora through the introduction of a new strain of pathogen.

Macrophyte assemblages should be monitored in four reaches; St John's, Buscot (two sites), Grafton and Shifford. Sampling sites should be at or near the existing or recommended routine macro-invertebrate sampling sites in order that results can be cross-referenced. The recommended sampling methodology is the Mean Trophic Rank (MTR) method. It is recommended that the FBA's 1977 survey is repeated before the first release of augmentation water and thereafter at five-yearly intervals to co-incide with the habitat-specific macro-invertebrate sampling.

Plankton

The appraisal of the impact of water transfer upon the planktonic communities of the Thames was supported by a series of Microsoft Access files whose current names and contents are listed within the chapter.

A brief review of the ecology of phytoplankton populations in large rivers indicated that no substantial risk to the algal quality of either river or abstracted water arises from the proposed transfer. Whatever may be the objections to such a transfer, the likely impact on the phytoplankton of the Thames is not one of them.

The impact on zooplankton is not considered a major issue, although knowledge of what species are present, or likely to be present, in British rivers is less well-developed than that of the phytoplankton.

An adequate basis for determining the effects of transfers of Severn water on the phytoplankton of the Thames could reasonably be established with a fortnightly programme of samples, which should be instigated before any engineering work is implemented.

The principal variables that should be monitored are the biomass of Severn phytoplankton transferred, sampled at or just above abstraction point and in the aqueduct at the point of discharge into the Thames, and the biomass of Thames phytoplankton above the point of discharge, 1-2 km below the point of discharge and at stations approximately 5km, 10km, 25km and 50km further downstream. Zooplankton should be enumerated from larger volumes of the same water.

1 INTRODUCTION

1.1 Context of the Study

In 1995, the National Rivers Authority (Thames Region) commissioned a literature review of the ecological consequences of a transfer of water from the River Severn to the River Thames. The review (Mann & Bass 1995) included a series of recommendations on additional studies that would aid future policy decisions on water resource management within the West Area of the Thames Region.

The four priority research areas were:

- water chemistry
- geomorphology
- river zooplankton interactions
- a review of biological data

The Environment Agency accepted each of these recommendations and the Institute of Freshwater Ecology were commissioned to undertake the four inter-linked studies.

This report is the review of biological data. The other studies are being reported separately.

The rationale for the biological review was that, whilst extensive sampling had been undertaken on the Thames by the Environment Agency, its predecessor organisations, its agents and research organisations, the full extent of existing biological data on the River Thames between St John's and Caversham Lock was poorly known. Furthermore, such data as are known to exist have not been collated into either an accessible data-base or hard copy reports.

In order to understand better the possible impacts, if any, upon the biota of this reach that may result from any Severn-Thames transfer scheme, it is valuable to know more about the baseline biological assemblages before the scheme is implemented.

At the instructions of the Environment Agency the review is confined to the main channel of the River Thames between St John's Lock, near Lechlade, and Caversham Lock at Reading. This is the section of the river considered to be most vulnerable to the potential impacts of the augmentation of flow using water originating from the River Severn.

The proposed augmentation point is between St John's Lock and the next downstream lock at Buscot. Caversham Lock, on the western outskirts of Reading, is about 110km downstream of Lechlade. The first sizeable conurbation downstream of Lechlade is Oxford which is about 50km away. Between Oxford and Reading are several smaller riparian towns including Abingdon, Wallingford and Goring. Three major tributaries, the Windrush, Evenlode and Cherwell enter this section of the Thames from the north. The Windrush and Evenlode join the Thames upstream of Oxford and the Cherwell at the downstream edge of the city.

1.2 Objectives of the Study

The overall objective of the study is to assemble existing data on the algal, macrophyte, macro-invertebrate and fish assemblages of the River Thames for use in assessing the possible impacts of any Severn-Thames transfer schemes.

The specific objectives are as follows:

- to seek and collate existing information on the flora and fauna of the main River Thames between St John's Lock near Lechlade and Caversham Lock, Reading.
- to identify key features of the existing biota, including the presence of taxa of national and local conservation status and any particular autecological requirements of important component species of the flora and fauna.
- to provide a baseline against which to interpret future change.
- to develop a long-term sampling strategy for monitoring the impact, if any, of implemented transfer schemes.

1.3 Strategy of the Study

The data required for the study was sought from all potential data-holders and from the literature. In practice the only major data-holders proved to be the Environment Agency and the Institute of Freshwater Ecology. Some of the Agency's data holding had been obtained through its own or its predecessors' commissioned contracts with Pond Action and the Freshwater Biological Association.

No major sources of published faunal or macrophyte distribution data were discovered in the published literature although one of this reports authors, (CSR) has contributed to a published review of phytoplankton in large rivers which includes an evaluation of data from the Thames (Reynolds & Descy 1996).

The principal data sources were therefore internal Environment Agency reports and external reports commissioned by them or their predecessors, together with their routine and monitoring and special investigation data held on their internal data-base. These data were supplemented by surveys conducted by the Freshwater Biological Association and by data on chironomid pupal exuviae data held in electronic files by Les Ruse (Environment Agency, Thames region).

The data were held in a variety of different formats and different approaches were adopted for each of four major taxonomic groupings:

- fish
- macro-invertebrates
- macrophytes
- plankton

In the case of macro-invertebrates and macrophytes available data were incorporated in a specially devised Microsoft Access 7 relational data-base and this is provided to the Agency as an output of the study. Key features of the data are provided in the text of chapters 3 (macro-invertebrates) and 4 (macrophytes).

The fish and plankton data and comments on their significance are presented in text forms in chapters 2 (fish) and 5 (plankton).

The fish chapter is supported by a set of summary information from each significant report produced on the section of river of interest and by key tables and figures from these reports. In this way all the important information is held together in a single bound document.

The appraisal of the impact of water transfer upon the planktonic communities of the Thames is supported by a series of Microsoft Access files whose current names and contents are listed within the chapter.

1.4 Bibliography

Mann, R J K and Bass, J A B (1995) *Literature Review of the Severn-Thames Transfer.* A Report by the Institute of Freshwater Ecology to the National Rivers Authority Thames Region.

Reynolds, C S and Descy, J P (1996). The production, biomass and structure of phytoplankton in large rivers. *Archiv für Hydrobiologie (Supplementband)*, **113**, 161 - 187.

2 FISH

2.1 Introduction

The objective of the review of fish data was to obtain information on the autecology and population statistics of the fish species present in the study reach between St John's Lock and Caversham Lock and to collate these in a series of tables, thus drawing the key information together in a single bound report. The principal source of information was assumed to be the grey literature (ie commissioned reports) held by the Environment Agency.

Paul Logan (Regional Scientist, Environment Agency - Thames Region) contacted the relevant fisheries biologists in the Agency and IFE were supplied with all known reports. IFE then contacted Dave Willis (Fisheries Scientist, Environment Agency - Thames Region) to check that there were no more data available for consideration in this report.

The reports considered the stretch of the Thames between St John's and Caversham locks. The title page, executive summary and/or conclusions and key tables are reproduced here in the Appendix 2.1. Reference in the text to tables in these reports will cite the original table number and the report reference. Abbreviations used are EAU (Environmental Advisory Unit), RHBNC (Royal Holloway and Bedford New College) and KES (King's Environmental Services). The reaches of the review section of the Thames covered by the reports consulted are shown in Figure 2.1.

The surveys of fry and adults in the R.Thames conducted in recent years in response to the South West Oxfordshire Reservoir Proposal give a baseline indication of the status of fish stocks in these reaches.

Information has also been taken from sources identified in Mann & Berrie (1994).

2.2 Fish Species in the Thames

Fish species have been split into three categories (Mann and Berrie 1994).

Category A contains 9 key species which are considered high priority in terms of their abundance and angling interest. Four species in Category B are considered non-key species and the four in Category C are the minor fish species (Table 2.1).

2.2.1 Distribution

None of the consulted reports provide full distribution data on fish species in the section of the river of interest to this review. Furthermore, following extensive enquiries, this information could not be found within the Environment Agency.

It is assumed that all of the species listed in Table 2.1 are widely distributed over the relevant section of the Thames..

Not present in the St-John's to Caversham Lock reach is the zander or pikeperch, a species present in the River Severn and also in the lower reaches of the Thames.

Figure 2.1 **A map of the reaches (shown in green) which have been surveyed for features of their fish populations and reported upon in one or more documents consulted during this review. The locations of locks are shown as red dots on this and subsequent maps.**

Table 2.1 **A categorisation of the fish species present in the River Thames between St John's Lock and Caversham Lock.**

Category	Scientific name	Common name
A: Key species	*Barbus barbus*	Barbel
	Alburnus alburnus	Bleak
	Abramis brama	Common bream
	Leuciscus cephalus	Chub
	Leuciscus leuciscus	Dace
	Gobio gobio	Gudgeon
	Perca fluviatilis	Perch
	Esox lucius	Pike
	Rutilus rutilus	Roach
B: Non-key species	*Cyprinus carpio*	Carp
	Gymnocephalus cernua	Ruffe
	Blicca bjoerkna	Silver bream
	Tinca tinca	Tench
C: Minor species	*Cottus gobio*	Bullhead
	Phoxinus phoxinus	Minnow
	Gasterosteus aculeatus	Stickleback
	Barbatula barbatula	Stone loach

2.2.2 Spawning habitat requirements

The species can be divided into four groups depending on the substratum needed for spawning. These are :

- lithophils — those requiring rock or gravel with benthic larvae eg barbel, dace and chub
- phytolithophils — non-obligatory plant spawners eg common bream, perch, roach and ruffe
- phytophils — obligatory plant spawners eg carp, tench, silver bream and pike
- psammophils — sand spawners eg gudgeon

The specific habitat requirements, including information on spawning substrata, river depths and current speeds for the 13 species identified in categories A and B (Table 2.1) are given in Table 1 of Mann and Berrie (1994) and restated in Volume 2, Appendix 2.1 of the current report..

2.2.3 Spawning times and temperatures

There is a considerable variation in the times and temperatures associated with the spawning of the 13 species. Variations arise due to local conditions, to repeat spawning (eg gudgeon and ruffe), to older fish spawning earlier than smaller fish (eg roach) and to intra-specific variation between years due to environmental factors. Data for the 13 species are given in Table 2 of Mann and Berrie (1994).

2.3 Juvenile fish surveys

2.3.1 Habitat requirements of larval and juvenile fish

Critical flow velocities are related to fish size and water temperature. The relationships for dace and roach are given in Mann and Berrie (1994). These critical flows are velocities which displace at least 50% of the larvae in 3 minutes. Preferred velocities are very much lower.

A study by EAU (1991) was intended to develop the methodology for subsequent fry surveys in order that comparative data might be produced on fry abundance and density, species composition and survival rates in the middle Thames. Fry were chosen for study, as it was expected that they would rapidly respond to environmental shifts by changes in population structure. Future studies developed this theme.

The first of these was a survey of fry carried out by RHBNC (Duncan 1992a). This emphasised the importance of categorising the microhabitats in the Thames. The two main habitats were 'deep' and 'water-lilies' and a third was categorised as 'shallow'. The authors indicated that there are other important microhabitats:

- those with *Scirpus* beds
- shallow sites with fringing vegetation
- mixed monocotyledons, *Scirpus and Typha* with some water-lilies
- weir pools

A specific investigation, by RHBNC, of the Sutton Pools area (Duncan 1992b) concluded that there was no strong evidence that this was an outstanding nursery area for fry living near the shore but that there was a possibility that it might be a good spawning area because of the lack of disturbance by boat traffic.

Following this survey, which was designed to determine whether results could be compared with a previous survey in 1991, an annual monitoring programme was carried out in three distinct habitat-types,

- shallow with macrophytes
- shallow without macrophytes
- deep without macrophytes

These were broader categories than many of those identified in the 1992 survey.

KES (1994) identified deep sites as having eroding banks. Such sites were mainly macrophyte free. Shallow gradually shelving sites were associated with sedimenting areas of the river. These were often rich in macrophytes. As expected in natural situations, the difference between these habitat-types was not clear cut, the weediest deep site contained more macrophytes than the least weedy shallow sites. However, within a sub-set, ie reach of the river, the shallow macrophyte sites always had more weed than the sites designated as being 'without macrophytes'. A similar relationship occurred with depth.

Generally, the surveys suggest that the habitat preferences of 0+ and 1+ fish were similar although the relationship with habitat-type was less significant for 1+ fish (KES 1995). Eight species were treated separately and minor species, bullhead, ruffe, stone loach, barbel, minnow and stickleback were considered together. All relationships were considered to be tentative.

Roach, perch, pike, gudgeon and bream were all positively correlated with macrophyte areas. Perch prefered the deeper sites whereas pike, bleak and gudgeon prefered the shallows. Chub were significantly correlated with macrophyte poor areas and prefer sand or gravel substrate as do gudgeon (Table 17, KES 1995).

The minor species can be tentatively divided into those preferring macrophyte cover (bullhead, ruffe and stone loach) and those preferring sandy substrata (barbel, minnow and stickleback).

2.3.2 Food requirements and growth

The stomach contents of fry of five species, roach, gudgeon, silver bream, chub and perch were identified from individuals taken from different habitats in the Thames. The requirements for each species are shown in Tables 7, 9 and 11 in Mann *et al.* (1995). In general, the diet changed from rotifers to micro-crustacea and insect larvae as the fry grew, with prey size related to mouth gape. Larger 0 group perch and gudgeon preferred copepods whereas other species preferred Cladocera. The most striking difference was the switch by roach from an invertebrate diet to one dominated by detritus.

Prior to the switch, the growth rate was similar to that expected from other studies, but afterwards, the growth rate was lower than expected due to the poorer quality of the food. Mann *et al.* (1995) emphasise the importance of aquatic vegetation as feeding and refuge areas for fry. The report lists other papers which came to the same conclusion. In addition, a paper is cited which suggests that macrophytes, and *Nuphar* in particular, can be damaged by high flows. Thus any changes in the hydrological regime of the Thames that damage marginal plants would be detrimental to the feeding, growth and survival of 0 group fish.

The abundance of food may be affected by increased turbidity resulting from increased flows. Phytoplankton production may be reduced due to the lower light levels. This in turn would reduce the biomass of the zooplankton on which the 0 group fish are feeding and possibly make food more difficult to find.

2.3.3 Velocity effects

Roach, bream, pike and perch are the most sensitive to high water velocities (Table 19 KES 1995). Bream fry for instance have a maximum preferred velocity of only 0.05 m s^{-1}. Even dace, which are considered to prefer fast flowing rivers, have requirements for very slow flows. Newly hatched fry congregate in areas where the velocity is less than 0.02 m s^{-1}. Water velocity is considered to be one of the most important in determining the effect of the transfer on the fish populations. Flows at and immediately after spawning could determine the year class strength of many species in the Thames. KES (1995) characterise the fish species into spring and summer spawners. They report the flows in the Thames over the study years as high, low or average and show that for roach, the most abundant fish species, the highest density occurs in the year of very low flow and the lowest in the year of maximum flow. The same is seen for bream. No such relationships are shown for the spring spawners. Whilst the positive relationships are only based on four year's data it is very likely that water velocity could be a key factor in this transfer scheme particularly in the summer.

2.3.4 Temperature effects

The temperature of water from the Severn is expected to be similar to that of the Thames when it is released into the river and thus should not have any implications to spawning, recruitment or growth of fish.

2.3.5 Density of fry

In the Sutton Pools reach, shallow sites with vegetation were considered to be the most important in terms of density of fry, 90% of which were roach (Duncan 1992b).

Duncan (1992b) reports the densities of fry in the main habitats and shows densities two orders of magnitude higher in the 'water-lily' microhabitat than in the 'deep' microhabitat.

Densities and catch per unit effort were compared with previous surveys (Tables 4-6 KES 1995). In all years, roach were the most abundant with densities ranging from 1.88-10.55 individuals m^{-2}. Gudgeon, chub and bleak were the next most common species.

2.4 Adult Fish Surveys

2.4.1 Background

The first adult fish survey (EAU 1991b) revealed little useful information and is not commented upon here.

In 1993 and 1994 Simon Hughes (Fisheries Officer, NRA - Thames Region) carried out surveys of adult fish populations between Sandford and Benson Locks (Hughes 1993, 1994). Hydro-acoustic surveys were used for quantitative estimates. Boom boat electric fishing was used to provide qualitative data in the mid-channel and in the margins. In addition, the electric fishing CPUE has been taken as quasi-quantitative check on the acoustic results and an index of relative change between years.

An NRA survey of anglers (Hughes undated) revealed that pleasure anglers were in general very experienced but did not target specific fish species. Match results were in the upper quartile of national results, i.e. Class A, and this lead to the conclusion that the Thames supported a good mixed fishery.

2.4.2 Habitat requirements

Adult fish have a greater range of habitat tolerance than juvenile fish and it has been shown that spawning habitat is more precise and therefore of greater importance than feeding and refuge habitats (Mann and Berrie 1994 - see Volume 2, Appendix 2.1 of the current report).

2.4.3 Food and growth

In their 1994 report, the NRA comment that the relatively small changes in species diversity observed between reaches and years indicated a relatively stable population. Growth rates were compared with a 'national average'. Roach and pike both had poor growth rates and this appeared to be the factor limiting their populations. Chub and bream had growth rates similar to the national average.

The poor growth rate of roach, which was the most abundant fish species sampled, was thought to be due to intra-specific competition for food especially in the early years. This was not the case for pike which fed heavily on roach. Bio-accumulation of pollutants was a possible cause in this instance.

2.4.4 Density and species abundance

The total density and biomass estimates were determined by hydro-acoustic methods. The results were similar to those obtained elsewhere, on the Thames and on the rivers Wey and Vltava, using similar methodology (Table 35, NRA 1993).

Roach and bleak were the most abundant species present both in the centre and the margins of the river (Table 6, NRA 1993). Perch showed a preference for the margins comprising around 20% of the catch compared with 4% in the centre.

2.4.5 Disease

The fish from the 1994 NRA survey were in good to excellent condition both externally and internally. Ectoparasites were at a level considered to be normal.

2.5 Environmental Influences on the Fish Communities of the Thames

2.5.1 Background

A report was commissioned by Thames Water Utilities Ltd to elucidate these environmental influences with regard to constructing a pumped storage reservoir for water supply (Mann and Berrie 1994). The report reviews data from the Thames and the Great Ouse and considers other studies from the scientific literature. Water temperature, current velocity, food availability, refugia and spawning habitats are identified as key factors.

2.5.2 Water temperature

Above average temperatures lead to decreased egg incubation times, increased growth rates and swimming speeds of young fish and consequently higher survival rates and improved year class strengths. Sudden decreases in water temperature can interrupt spawning and may cause egg resorption.

2.5.3 Water velocity

Mann and Berrie (1994) suggest that velocities > 2 cm s^{-1} can lead to displacement of newly hatched fry. As different species spawn at different times, newly hatched fry can be present between April and July. Only 3% of the area of the Thames has flows of less than 2 cm s^{-1} during the time when small fry are present and these areas may be vital to the success of certain species.

Water velocity requirements for spawning depend on species, ranging from near zero for pike to 50 cm s^{-1} for dace and chub.

2.5.4 Food availability and fish refugia

Mann and Berrie (1994) class these two factors as interrelated especially for 0 group fish. The very slow flowing areas which provide the refugia for fish are often the very places where food supply is most abundant. Phytoplankton production and in consequence zooplankton production is influenced by river discharge as well as by the light regime. There is evidence to suggest that zooplankton biomass is the limiting factor for fish growth in the Thames overriding the influence of temperature. This food limitation is considered to be the reason why roach in the Thames switch to a detritus diet in July.

2.6 Effect of the Water Transfer on the Environmental Factors Influencing Coarse Fish

2.6.1 Flow changes

The effects of flow on fish, particularly fry, are reviewed by Mann and Bass (1996). Whilst river flow can alter the distribution of fry, this is not always the case. No effect on the distribution of fish was found after implementation of the Trent-Witham-Ancholme Transfer Scheme. In general, it is reported that newly hatched fry prefer water velocities of less than 2 cm s^{-1}. Whilst it has been estimated that the water velocities of these values are present in only 3% of the area of the Thames affected by the transfer, it is by no means certain that this proportion will decrease when the discharge is augmented.

Good marginal habitats for fry are shallow and gently sloping with macrophyte cover and marginal vegetation. An increase in water level is likely to cause flooding of similar habitat types within the marginal vegetation where fry can take refuge. The augmentation of flow is likely to occur during mid to late summer which means that late spawners are more likely to be affected.

Even though the areas of refuge may not be affected, it is likely that there will be some impact on distribution because fry venturing into stronger currents will be carried further downstream.

2.6.2 Sediments and turbidity

Mann and Bass (1996) comment that the principal impact of sedimentation on fish occurs during the egg and early larval stage. For early spawners, there is unlikely to be any effect of water transfer as the fry will have passed the early larval stage. For late spawners, the increased velocity may redistribute fine sediment and this may settle on fish eggs in low flow areas reducing hatching success. For those late spawners that use gravels in fast flows, eg. chub, the increase may in fact be beneficial because, under natural conditions, the reduced flows could have caused siltation in the spawning beds.

The routine maintenance dredging is likely to have a more substantial impact on the fish populations. The sensitivity of the fish to the composition of the river bed was shown by the 31-64% reduction in standing crop of chub and roach as a result of this activity. Mitigation occurred when crushed limestone and flint gravels were added which enhanced invertebrate and macrophyte colonisation and provided cover for some fish.

The water that is transferred from the Severn will undergo a period of settlement before being introduced into the Thames. Therefore, the augmentation process is unlikely to increase the sediment load in the Thames. There may be local redistribution of the natural Thames sediments over a very short time period and this may affect the feeding rates of some fish species.

2.6.3 Temperature effects

The temperature profile is not expected to alter during transfer times. Small changes in the temperature regime will affect the growth and development of fish, especially the fry, but this is not expected to be significant.

2.6.4 Chemical effects

Marked decreases in dissolved oxygen (DO) concentrations could cause fish kills. If the transferred water is well aerated then any problems resulting from inadequate DO concentrations will be eliminated in the transferred water there should be no problems.

The effect of the transfer of toxic substances is unpredictable.

2.6.5 Disease

Seventy-five species of parasite in 28 fish species have been recorded from the Thames. Although not known categorically, the probability of fish parasites or pathogens being transferred is high but the dangers associated with this are considered to be low.

2.6.7 Transfer of biota

Water transfer schemes are known to have resulted in fish movement to the recipient water (reviewed by Mann and Bass 1996). The species compositions of the Severn and the Thames are very similar. There is some concern over the potential introduction of zander which occur in the Severn at the abstraction point. Although present in the lower Thames, this species is not yet present in the reaches affected by the transfer and it is possible that it will colonise the upper reaches of the Thames at a greater rate than would have occurred naturally by upstream migration of Thames stock.

Few eels are found in the upper Thames and these may be transferred although the bulk of the transfers occur outside the main migration period for elvers in the Severn. It is reported that some stocking of elvers from the Severn has already taken place in the upper Thames so the transfer of this species is unlikely to be a problem.

2.7 Mitigation

It is not an objective of the current study, as set out in the Schedule 1, Project Specifications to recommend mitigation procedures to minimise the impacts of the release of Severn water into the Thames. Nevertheless, here, as in other chapters, brief recommendations are set out for completeness.

A review of the literature on the impacts of inter-basin water transfer is set out in Mann & Bass (1995) including assessments of the likely impacts on fish.

2.7.1 Flow effects

Stored Severn water should be released in stages so that the flow increase is gradual, even at the lowest point in the river. This is particularly important in the summer when the young of the year are small. Staged releases will allow fry to detect changes and move into sheltered areas to avoid washout. The Environment Agency is about to undertake an R&D study on the swimming speeds of fish and the effects of in river structures on washout and disrtibution of coarse fish (W2C(96)1). This will provide information on the rate of increase in flow that is not deleterious to fish.

2.7.2 Sediments and turbidity

Mitigation can be acheived by allowing the sediment from the transferred water to settle before release into the Thames. There may be some local redistribution of sediment but this should be no more than is expected following natural increased discharge regimes, ie floods, and fish are able to cope with such changes.

2.7.3 Temperature

This is not expected to be a problem as the temperature of the released water is expected to be similar to the temperature of the Thames.

2.7.4 Chemical effects

The transferred water should be well aerated prior to release into the Thames to ensure that high concentrations of DO are maintained. DO levels in the released water should be monitored.

2.7.5 Disease

Most common fish diseases are already present in the Thames and the probability of transfer of a major problem is low. A check should be kept on the incidence of disease in the Severn to ensure that water is not transferred during any major outbreak of fish disease. If this is unavoidable, steps will need to be taken to sterilise the water if this is not already done. Environment Agency (Thames Region) should liaise with Midlands Region to be kept informed of any serious outbreak of fish disease prior to or during water transfer.

2.7.6 Transfer of biota

This is a high probability. Fish can be transferred as eggs or very young larvae and it is unlikely that any practical mesh size can avoid this. Careful positioning of the intake pipe can reduce this probability. If the intake pipe is in a fast flowing area, the chances of entrainment by eggs or fish larvae will be relatively low.

2.8 Future sampling strategy

The normal expectation is that any changes in fish population structure will become evident at the fry stage first. For this reason, the surveys of fry and juvenile fish already being carried out annually for South West Oxfordshire Reservoir Proposal should be continued.

Further, as abundance and year class strength is largely determined from factors impinging on the fry, factors affecting fry survival should be examined. Thus surveys of larval and juvenile habitat should be carried out to ensure that these areas are conserved. In addition, studies on the food availability, feeding and growth of fry should be maintained.

In order to more closely monitor the immediate impacts of Severn-Thames transfer, similar fry and juvenile fish studies should be initiated in the reaches most likely to be affected, including a control reach. Recommended reaches are: 10, St John's (control); 11, Buscot (downstream of the augmentation point); 12, Grafton and 15, Shifford. The first sampling should be undertaken prior to the implementation of the transfer scheme.

2.9 Bibliography

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3 MACRO-INVERTEBRATES

3.1 Introduction

Existing macro-invertebrate data were sought in the published and "grey" literature and clearance was then gained for their use in connection with this study and subsequent use by the Environment Agency.

The principal data-suppliers were the Environment Agency and the Institute of Freshwater Ecology. The data held by the Agency were supplied by John Steel, Les Ruse, Julie Jefferies and Paul Logan. The Institute of Freshwater Ecology made available data collected during *the development of the software package, RIVPACS.*

Wherever available a standard set of environmental data were sought for each macro-invertebrate sample.

3.2 Methods

3.2.1 Classification of reaches

To examine spatial zonation of the data, the section of the river between St John's and Caversham Lock was partitioned into 24 inter-lock reaches numbered from 10 (St John's to Buscot) to 32 (Mapledurham to Caversham). Reaches were named by the lock at their upper limit. (Table 3.1).

Samples collected at a particular lock, usually within the lock cut, were ascribed to the reach upstream (e.g. samples taken at Buscot Lock were assigned to St John's reach).

3.2.2 Environmental data

Environmental data fell into two categories.

The first was site measured time variant data and these included:

- water width (m)
- mean depth (cm)
- mean substratum cover by boulders and clay (%)
- mean substratum cover by pebbles and gravel (%)
- mean substratum cover by sand (%)
- mean substratum cover by silt and clay (%)
- mean annual total alkalinity for the year of sampling (mg l^{-1} $CaCO_3$)

Published values for these variables were scrutinised for obvious errors and these were amended. All values were converted to thestandard units of measurement given in this section of the report.

Table 3.1 **Reach names, numbers and geographic limits, as used in this study and the accompanying data-base**

Reach name	No.	Upper limit	Lower limit
St John's	10	St John's Lock	Buscot Lock
Buscot	11	Buscot Lock	Grafton Lock
Grafton	12	Grafton Lock	Radcot Lock
Radcot	13	Radcot Lock	Rushey Lock
Rushey	14	Rushey Lock	Shifford Lock
Shifford	15	Shifford Lock	Northmoor Lock
Northmoor	16	Northmoor Lock	Pinkhill Lock
Pinkhill	17	Pinkhill Lock	Eynsham Lock
Eynsham	18	Eynsham Lock	King's Lock
King's	19	King's Lock	Godstow Lock
Godstow	20	Godstow Lock	Osney Lock
Osney	21	Osney Lock	Iffley Lock
Iffley	22	Iffley Lock	Sandford Lock
Sandford	23	Sandford Lock	Abingdon Lock
Abingdon	24	Abingdon Lock	Culham Lock
Culham	25	Culham Lock	Clifton Lock
Clifton	26	Clifton Lock	Day's Lock
Day's	27	Day's Lock	Benson Lock
Benson	28	Benson Lock	Cleeve Lock
Cleeve	29	Cleeve Lock	Goring Lock
Goring	30	Goring Lock	Whitchurch Lock
Whitchurch	31	Whitchurch Lock	Mapledurham Lock
Mapledurham	32	Mapledurham Lock	Caversham Lock

The second category of environmental data was time invariant data which included variables:

- national grid reference (12 character numeric)
- altitude (m)
- slope (m km^{-1})
- discharge (annual mean flow category)
- distance from source

These values were all re-calculated from source maps to ensure consistency in the data-set. This eliminated situations in which published distance from source of a site was less than another site upstream of it or the altitude of the downstream site was greater than the upstream .

3.2.3 Macro-invertebrates

The macro-invertebrate data obtained from published documents, the "grey" literature and the Environment Agency's and IFE's own data-bases were collected between 1977 and 1995. Samples were identified to a variety of different taxonomic levels by people with differing levels of experience and expertise.

Very few specimens were available for checking and the identities of the people processing the samples was rarely known. On the basis of the authors' knowledge of previous work by the organisations collecting the data, or from the IFE's quality auditing of external organisations sample processing and identification skills, each sample for which taxon lists were held was ascribed a Quality Control (QC) level. These fell into three categories:

- novice
- average
- expert

QC levels varied within an organisation. Thus samples collected by the FBA for RIVPACS were identified by permanent staff and they were categorised as "expert". The samples collected by the FBA under commission to Thames Water Authority were identified by inexperienced students and subject to checking by FBA staff. These were categorised as "average".

Where specimens were still held, the identity of some of the rarer or more unusual specimens was checked by experienced IFE personnel with the Natural History Museum's IdQ qualification in species level identification.

Over the two decades for which data were obtained there have been many changes in the nomenclature of aquatic macro-invertebrates, new species have been discovered and, in some cases, what was thought to be a single species has since been sub-divided into two distinct species. Before entering macro-invertebrate data in the data-base, each taxon list was checked by an IFE expert and all identifications were standardised to the nomenclature in current use. The standard applied was the revised "Maitland" coded checklist of animals found in freshwater in Great Britain (Biological Dictionary Determinand Working Group 1989) as currently updated for pending re-issue.

3.2.4 The data-base

A relational data-base was developed to hold the macro-invertebrate and macrophyte data and accompanying environmental information. Development was in Microsoft Access Version 2.0.

Data were entered at sample level. Each sample was identified by the following parameters:

• reach name	as per table 3.1
• reach ID	as per table 3.1
• site name	as given in the data source document
• site ID	allocated by IFE and standard for a given grid reference
• sample year	as given in the source document
• season ID	1 = spring (February - May) 2 = summer (June - August) 3 = autumn (September - January)
• sample date	as given in the source document
• sample ID	a counter allocated by IFE
• subsidiary ID	an identification code for the data collecting organisation
• subsidiary code	the sample identifier given in the source document

Where the taxon list represented a summation of the results of more than one collection, such as some of the supplied chironomid pupal exuviae data, no date could be assigned to the sample. Where the taxon list was only available as a combination of taxon lists from collections taken in more than one year, such as some of the supplied exuvial data, the first year of the period of collection was assigned to that sample.

The subsidiary code was included in order that data-base entries could be cross-referenced to the source document.

Environmental data were entered in the data-base as numeric values, categories or, in the case of grid references, character strings.

Macro-invertebrate data were entered using the hierarchical, eight digit codes given in the revised coded checklist of British freshwater animals (Biological Dictionary Determinand Working Group 1989) supplemented by the eight character alpha-numeric codes used in RIVPACS III to signify taxon aggregates (Environment Agency 1997).

Where known, the abundances of individual taxa within a sample were also entered in the data-base. In some instances absolute numbers were not provided in the source document but categories of abundance were given. Category definitions varied between sources and so each an abundance system code was attached to each sample with details of each system available for cross-reference in a look-up table within the data-base.

Additional fields were created within the data-base structure to carry the following biotic indices for each appropriate sample:

- Biological Monitoring Working Party (BMWP) score
- number of scoring taxa
- Average Score Per Taxon (ASPT)

The structure and functionality of the data-base is shown in its entity-relationship diagram (Figure 3.1).

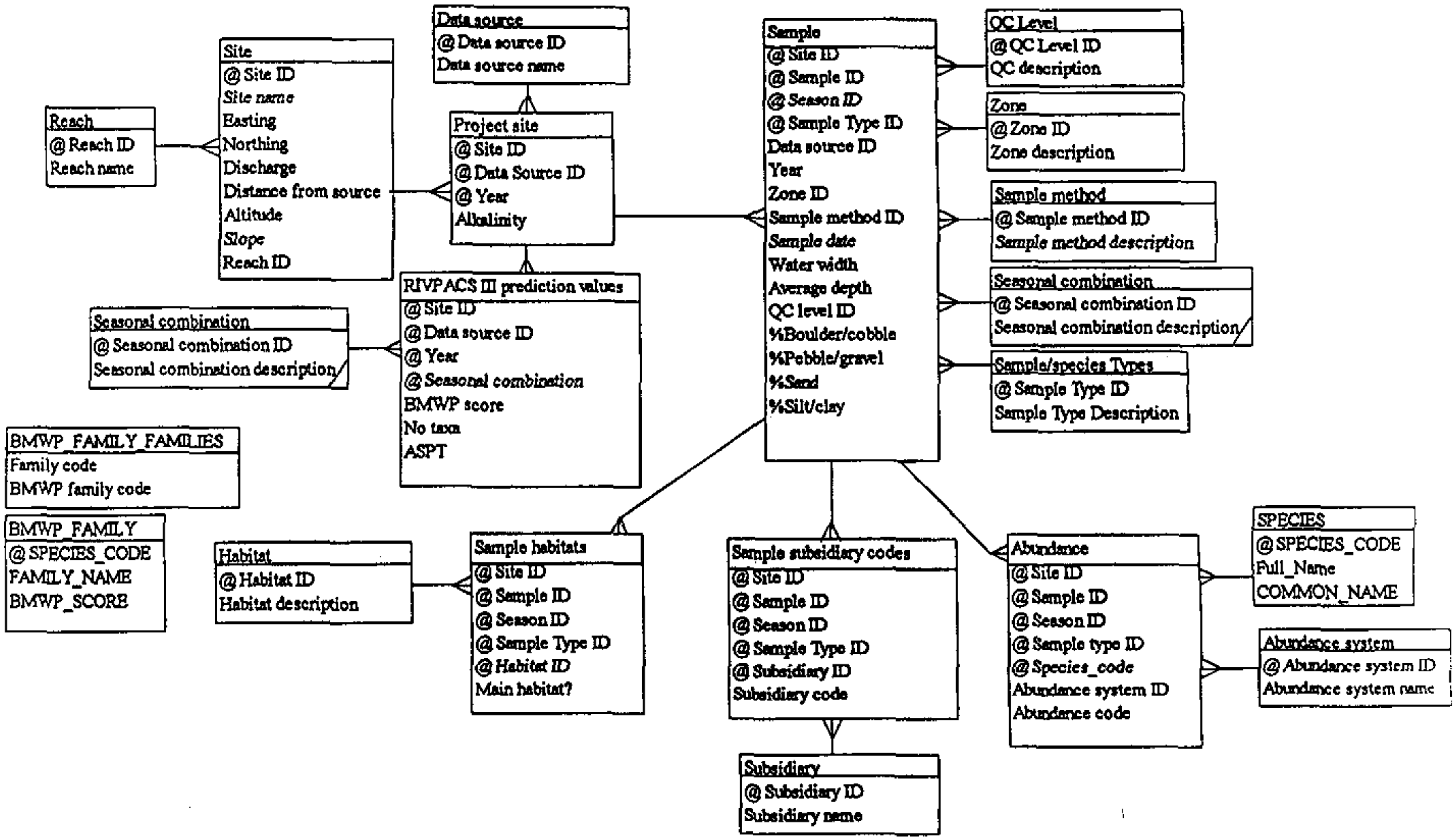


Figure 3.1 An entity-relationship diagram showing the structure of the macro-invertebrate and macrophyte data base

3.3 Results

3.3.1 Numbers of samples

A total of 379 samples from six different sources were entered in the data-base (Table 3.2).

Table 3.2 The numbers, sources and periods covered by samples entered in the data-base

Data-source	Subsidiary ID	Period covered	No. of -samples
Samples collected by the FBA as a baseline study of the middle reaches of the River Thames prior to possible earlier plans for a Severn-Thames water transfer scheme.	FBA - with subsidiary codes 6911..	1977	190
Chironomid pupal exuviae samples collected by Les Ruse (Environment Agency - Thames Region)	LR	1977-94	42
Routine monitoring samples collected by the Environment Agency (EA), the National Rivers Authority (NRA) or the Water Authority (WA) Thames Region.	WA/NRA/EA	1980-95	110
Samples collected by the Freshwater Biological Association (FBA) as part of its RIVPACS development programme.	FBA - with subsidiary codes FBA77..	1984	18
Samples collected by an un-named consultant as part of the Oxford Structures Plan investigations.	RPS	1992	7
Samples collected by Pond Action as part of the South-West Oxfordshire Reservoir Development Study (SWORDS)	PA	1992	12
		TOTAL	379

A full list of samples, their identifiers and their environmental descriptors are provided in Appendix 3.1. The reaches sampled or specific samplig locations are shown in Figures 3.2 to 3.7.

3.3.2 Numbers of taxa

A total of 487 taxa ("species") were recorded within the study reach (Appendix 3.2). However many of these categories are overlapping. Thus the list includes each of Erpobdellidae, *Erpobdella* sp. and *Erpobdella octoculata* from one data source or another. In this example only *Erpobdella octoculata* is included in the calculation of total numbers of taxa present. When overlapping records and micro-crustacea are excluded the list was reduced to 349 "species".

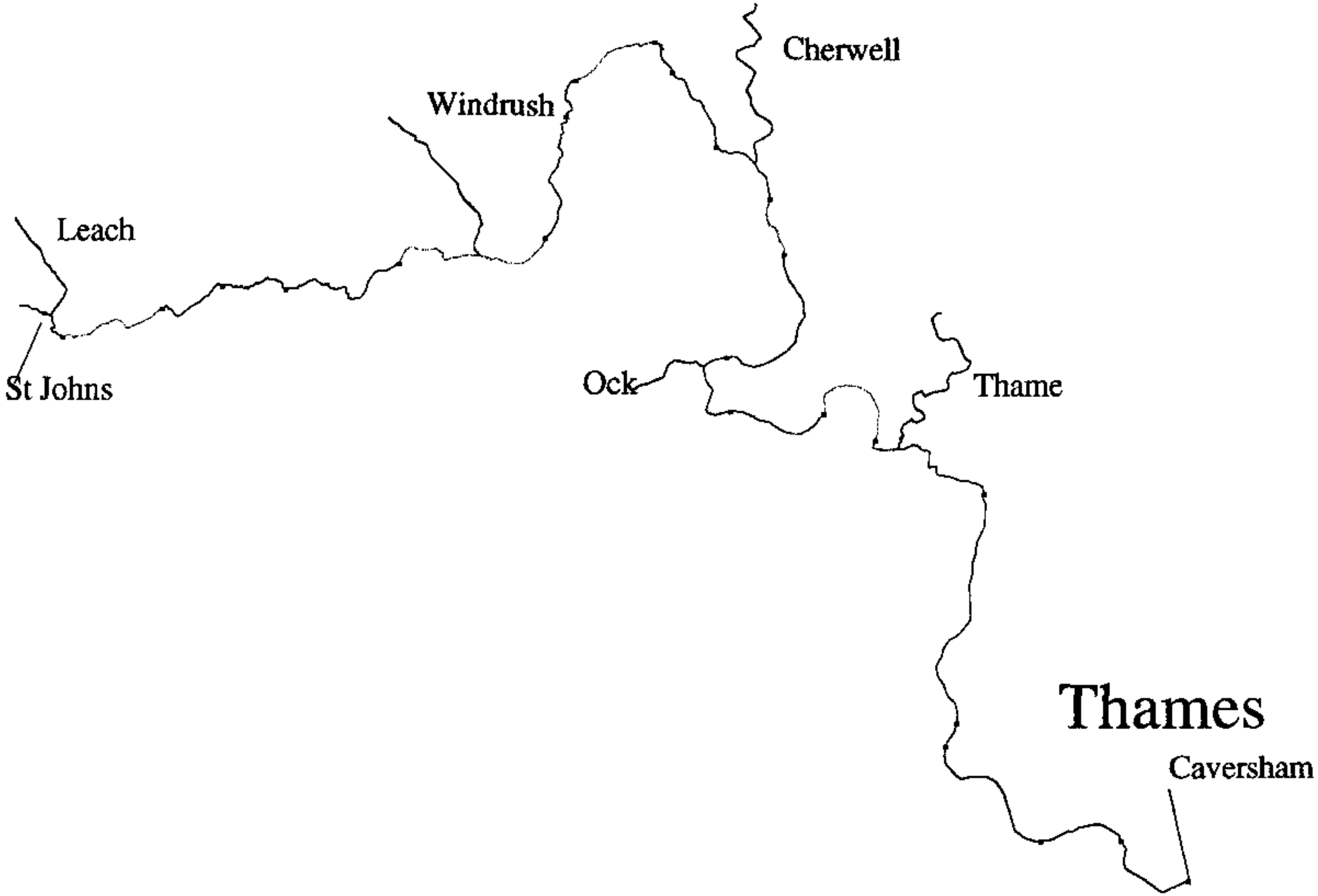


Figure 3.2 **The location of the sampling reaches surveyed for macro-invertebrates and macrophytes in 1977 by the Freshwater Biological Association. Reaches highlighted in green indicate general macro-invertebrate and macrophyte sampling. Reaches shown in plum indicate additional, habitat-specific macro-invertebrate sampling**

Figure 3.3 **The location of the sampling reaches (shown in green) surveyed for chironomid pupal exuviae between 1977 and 1994 by Les Ruse**

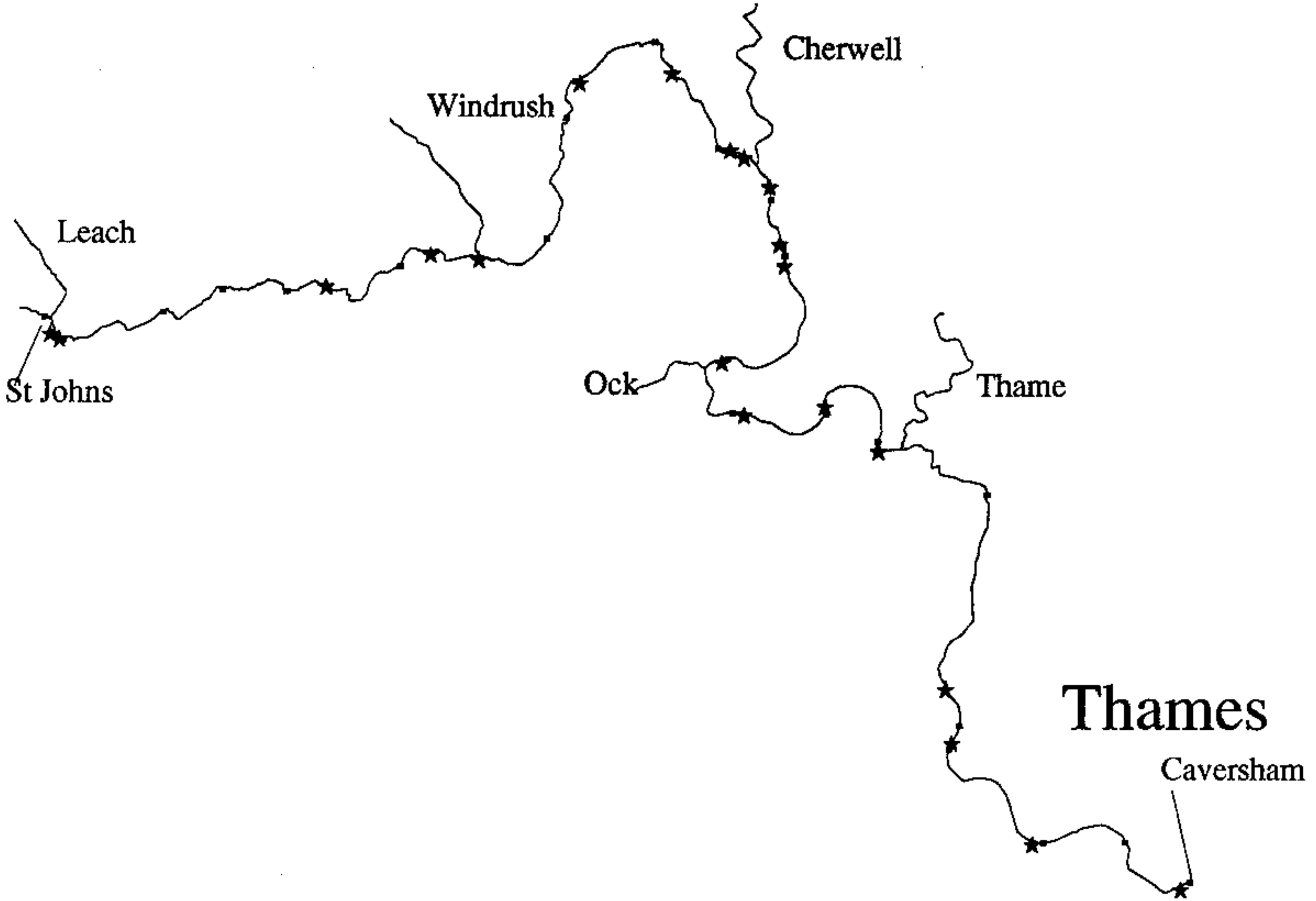


Figure 3.4 **The location of the sites (shown as green stars) sampled by Thames Water/National Rivers Authority/Environment Agency between 1980 and 1995 as part of their routine monitoring programmes**

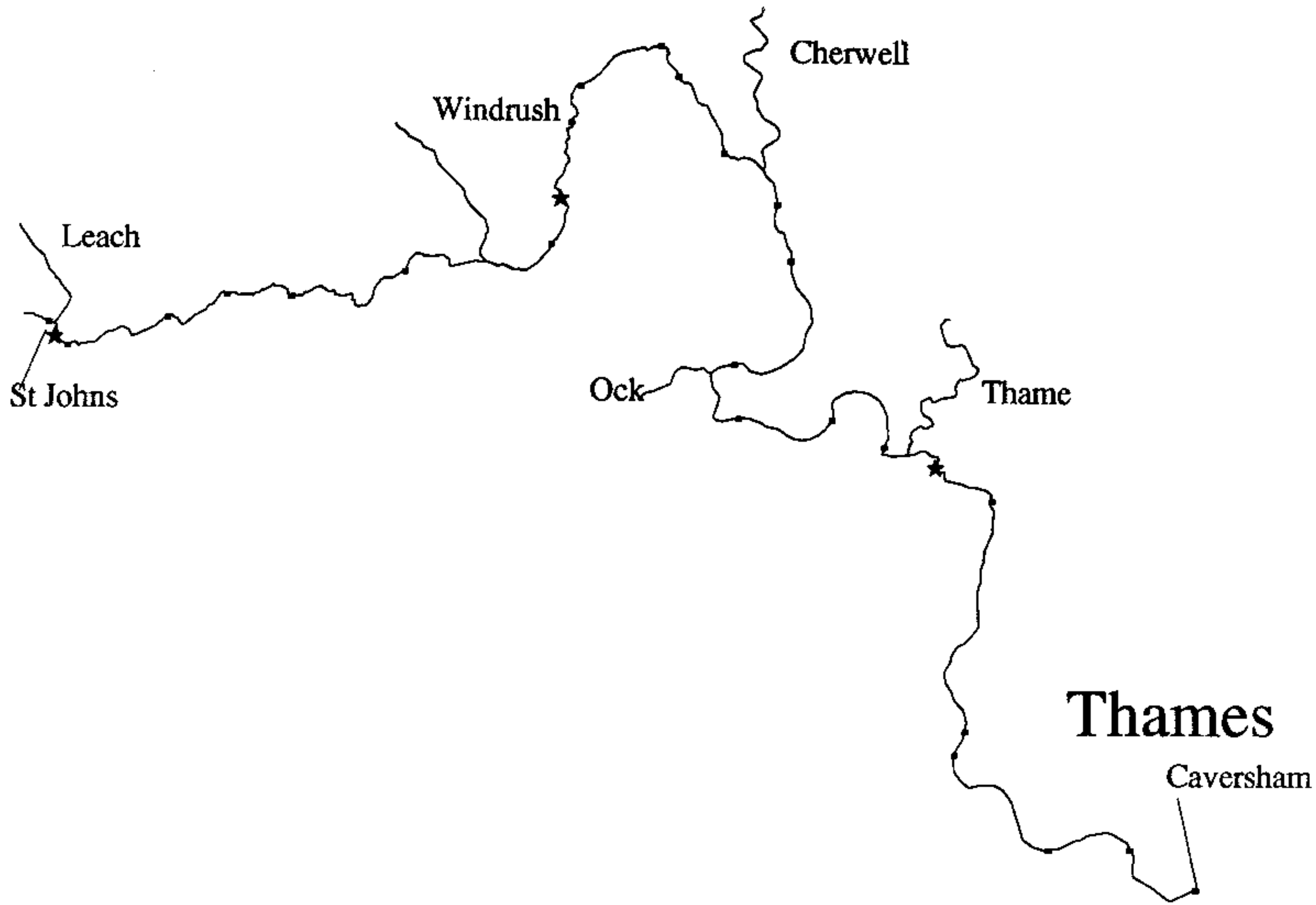


Figure 3.5 The location of the sites (shown as green stars) sampled by the Freshwater Biological Association in 1984 for inclusion in RIVPACS

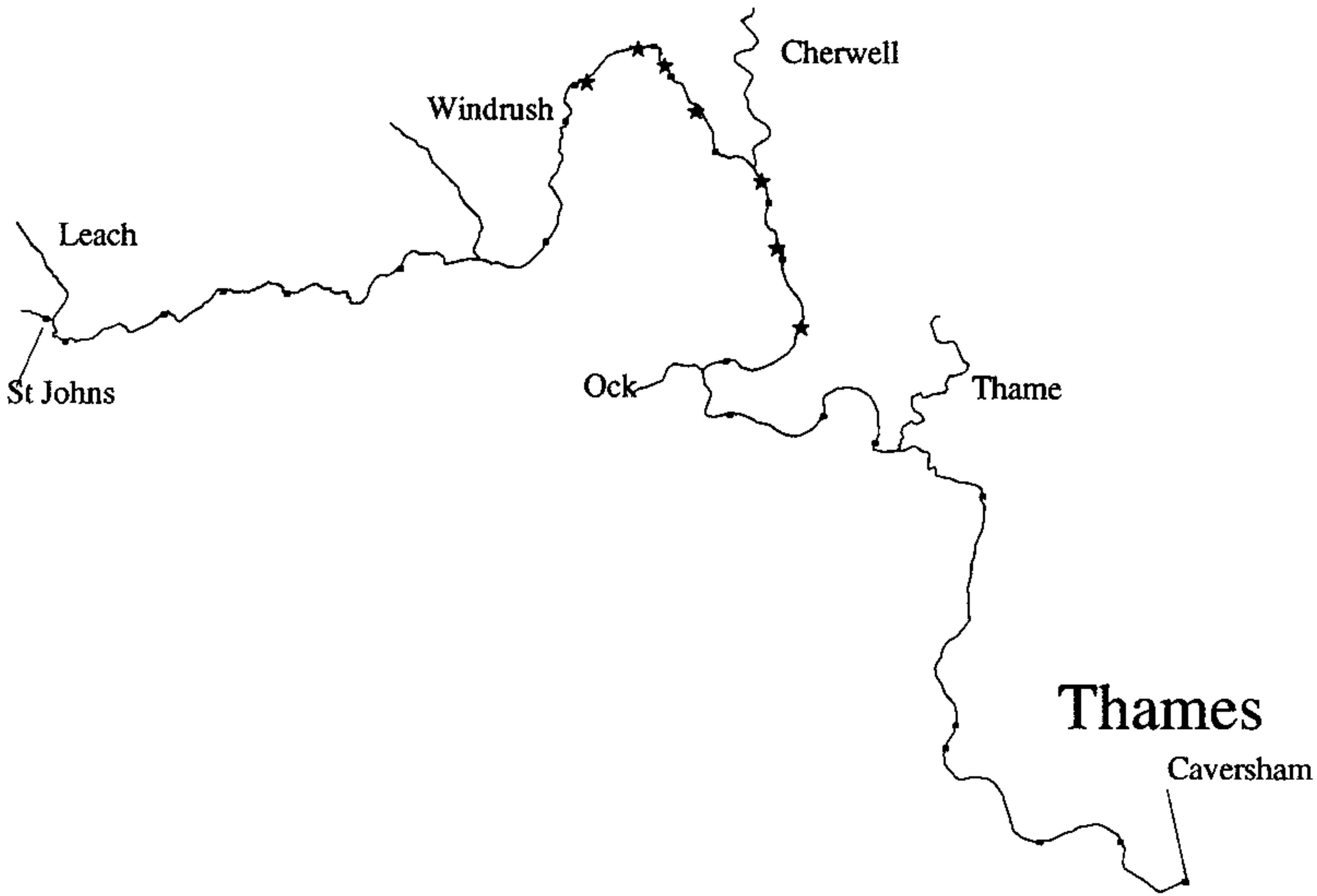


Figure 3.6 **The location of the sites (shown as green stars) sampled by an un-named consultant in 1992 in connection with the Oxford Structures Plan**

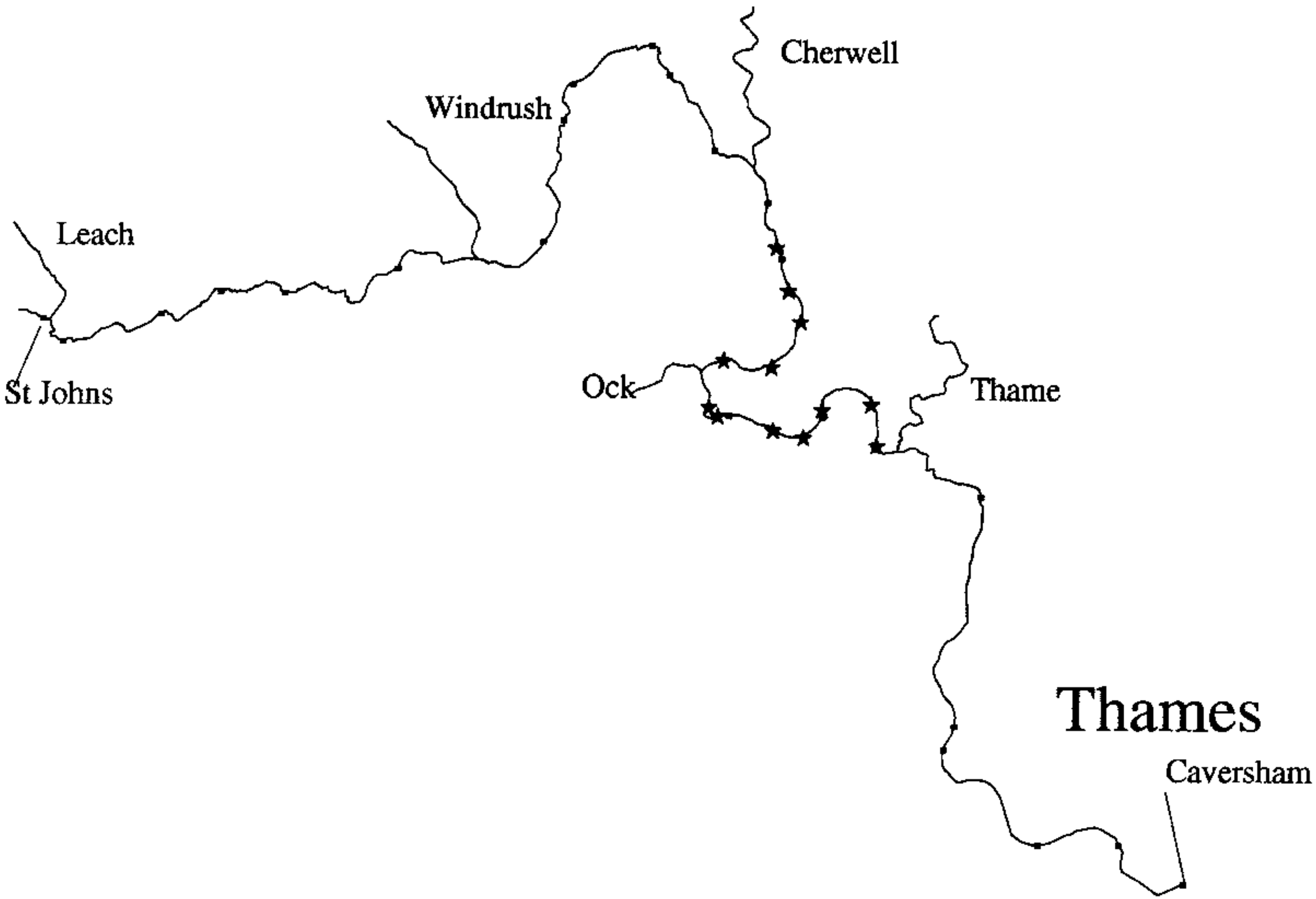


Figure 3.7 The location of the sites (shown as green stars) sampled by Pond Action in 1992 in connection with SWORDS

No comparable information is available for other sections of river because it is rare for groups such as the Sphaeriidae, Oligochaeta, Hydracarina and Chironomidae to all be so fully identified and few river reaches have been so thoroughly sampled over an equivalent period. Nevertheless, the extent of the list is clearly indicative of a rich and diverse macro-invertebrate fauna.

One hundred families of macro-invertebrates are represented in the full taxon list (Table 3.3, Appendix 3.3) of which 65 are BMWP taxa. The best represented groups are Diptera with 96 taxa, including 88 different forms of Chironomidae (non-biting midges), Trichoptera with 43 taxa Coleoptera with 40. Twenty-eight species of Gastropoda are present, including 27 (61%) of the 44 obligate aquatic species, and 15 (54%) of the 28 species of Lamellibranchia.

Table 3.3 **The numbers of families (BMWP families in parentheses) and "species" (i.e taxa identified to the best achievable, non-overlapping level) present in each major taxonomic group in the full study section of the Thames.**

Taxonomic group	Number of taxa	
	Families	"Species"
Porifera (sponges)	1 (0)	1
Coelenterata (hydras)	1 (0)	1
Platyhelminthes (flatworms)	3 (2)	6
Nemertea (nemertine worms)	1 (0)	1
Nematoda (nematodes)	1 (0)	1
Ectoprocta	1 (0)	1
Gastropoda (snails)	11 (9)	28
Lamellibranchia (clams and mussels)	2 (2)	15
Oligochaeta (true worms)	5 (1)	27
Hirudinea (leeches)	3 (3)	10
Hydracarina (water mites)	10 (0)	20
Branchiura (fish lice)	1 (0)	1
Isopoda (water slaters/water hog louse)	1 (1)	2
Amphipoda (freshwater shrimps)	3 (2)	3
Ephemeroptera (mayflies)	5 (5)	17
Plecoptera (stoneflies)	3 (3)	3
Odonata (dragonflies and damselflies)	6 (6)	12
Hemiptera (water bugs)	9 (9)	17
Coleoptera (water beetles)	8 (5)	40
Megaloptera and Neuroptera (alder flies)	2 (1)	4
Trichoptera (caddis flies)	15 (13)	43
Diptera (true flies)	8 (3)	96
TOTALS	100 (65)	349

The breakdown of number of BMWP families by reach shows a number of apparent disparities (Table 3.4) but most of these are a function of the number and type of samples taken.

Table 3.4 The number of samples collected and BMWP taxa recorded from each study reach. No samples are held for reaches 28 (Benson) and 31 (Whitchurch).

Reach name	Number of samples	Number of BMWP families
St John's	31	50
Buscot	32	32
Grafton	2	25
Radcot	2	19
Rushey	3	27
Shifford	40	43
Northmoor	17	43
Pinkhill	11	23
Eynsham	40	47
King's	17	52
Godstow	3	27
Osney	10	46
Iffley	49	50
Sandford	21	55
Abingdon	4	47
Culham	7	46
Clifton	50	49
Day's	8	43
Cleeve	4	32
Goring	22	48
Mapledurham	6	37

However the data presented in Table 3.3 do suggest that the Buscot and Pinkhill reaches are taxon-poor. The numbers of BMWP families recorded in these reaches are 32 and 23 respectively, which are conspicuously lower than the mean (48.3) and range (43 - 55) of BMWP families found in all other reaches sampled on ten or more occasions.

The Pinkhill situation is easily explicable. Nine of the eleven samples are pupal exuviae samples which only include the BMWP family Chironomidae. Only two samples contribute to the general BMWP reach listing. The situation at Buscot is less clear. All samples were taken in the 1977 FBA survey, a phenomenon which applied to no other reach. However, two other reaches where 1977 survey samples predominated; Shifford (43) and Eynsham (47) had considerably more taxa than Buscot.

One possibility, which has not been checked, is that Buscot had been recently dredged in 1977 and was taxon depauperate on that account. Alternatively, the fauna may have been impacted by the severe drought followed by flooding which characterised the preceding twelve months. Given that the augmentation water will enter the Thames just upstream of Buscot Weir the possibility that this reach is, or has been taxon-poor and that no data are available since 1977 are important considerations for future monitoring strategies.

3.3.3 Measures of ecological quality

The ecological quality, or biological condition, of a river is commonly represented by biotic indices, of which the most commonly used, particularly within the Environment Agency, is the BMWP score system (Armitage *et al.* 1983).

It is now common practice to use the software package RIVPACS (Wright *et al.* 1993) to index a site by comparing its observed index values with those predicted by RIVPACS. The ratio of observed to expected values is termed the Ecological Quality Index or EQI.

Both observed and expected values are available for the three sites sampled by the FBA as part of their RIVPACS development programme (Table 3.5).

Table 3.5 The observed and expected three seasons combined BMWP index values and their resultant Ecological Quality Index (EQI) values for three sites sampled by the FBA in 1984 as part of the RIVPACS development programme. Assessments made using RIVPACS III. SCR = BMWP score, TAXA = number of scoring taxa, ASPT = average score per taxon.

Site name and reach number	Observed index values			Expected index values			EQI's		
	SCR	TAXA	ASPT	SCR	TAXA	ASPT	SCR	TAXA	ASPT
Malthouse (reach 10)	223	38	5.87	194	34.9	5.87	1.15	1.09	1.06
Bablock Hythe (reach 16)	231	41	5.63	185	33.9	5.63	1.25	1.21	1.03
Shillingford (reach 27)	235	42	5.60	184	33.6	5.60	1.28	1.25	1.03

The observed and expected index values for the three sites indicate that the ecological quality of these sites was good at the time of sampling in 1984. Indeed the EQI values of above unity for all three BMWP indices; BMWP score, number of taxa and ASPT, indicate that the river is a particularly good representative of its type.

The consistency of expected BMWP index values along the study section is known to extend as least as far as Runnymede (expected: score = 184, taxa = 33.7 and ASPT 5.44). This allows the observed index values of individual samples to be assessed rapidly without full recourse to RIVPACS predictions, particularly as the full suite of environmental data required for RIVPACS predictions is not always available.

The expected values cited above are for three seasons combined data. Equivalent single season mean values for the study reach are: BMWP score - 128, number of taxa - 24.9 and ASPT - 5.13.

On the basis of the 5M classification system used by the NRA for assessing the ecological quality of samples collected for the 1990 River Quality Survey (RQS), the only survey for which single season bands are available (Clarke *et al.* 1992) a highest quality, band A, site has an EQI of no less than 0.62 (BMWP score), 0.67 (number of taxa) and 0.84 (ASPT). In order to achieve band A status (*sensu* the 1990 RQS) the Thames samples would therefore need to have minimum observed index values of 79 (score), 17 (taxa) and 4.31 (ASPT). Similar minimum values can be set for lower bands of succeedingly poorer quality (Table 3.6).

Table 3.6 Minimum, approximate observed BMWP index values that need to be obtained for single season Thames samples (St John's Lock to Caversham Lock section) in order to reach each of three different bands of ecological quality.

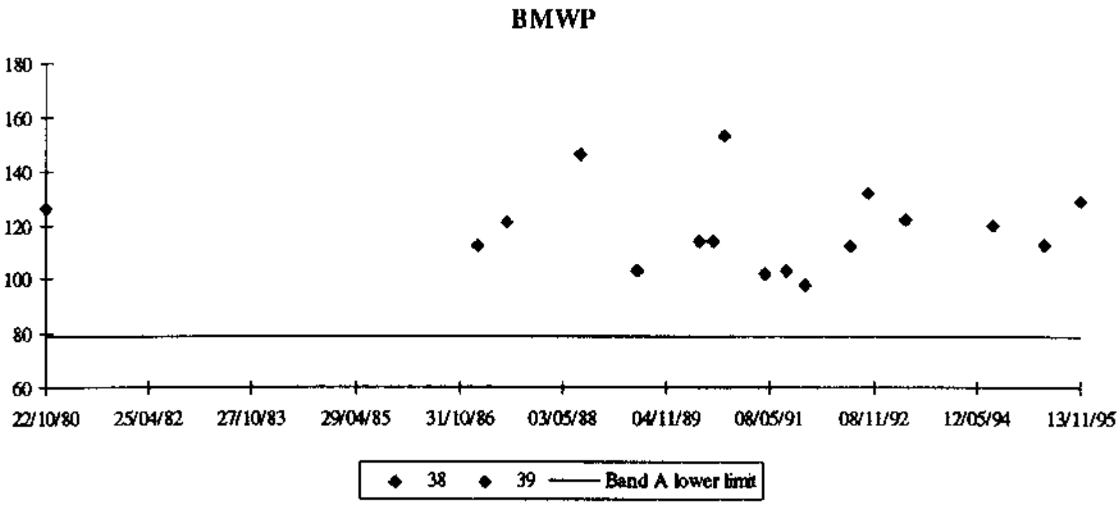
Ecological quality band	Minimum observed index value needed in order to attain the band		
	BMWP score	Number of taxa	ASPT
A - "good"	79	16	4.31
B - "fair"	31	8	3.49
C - "poor"	1	0	2.67
D - "bad"	0	No band	0.00

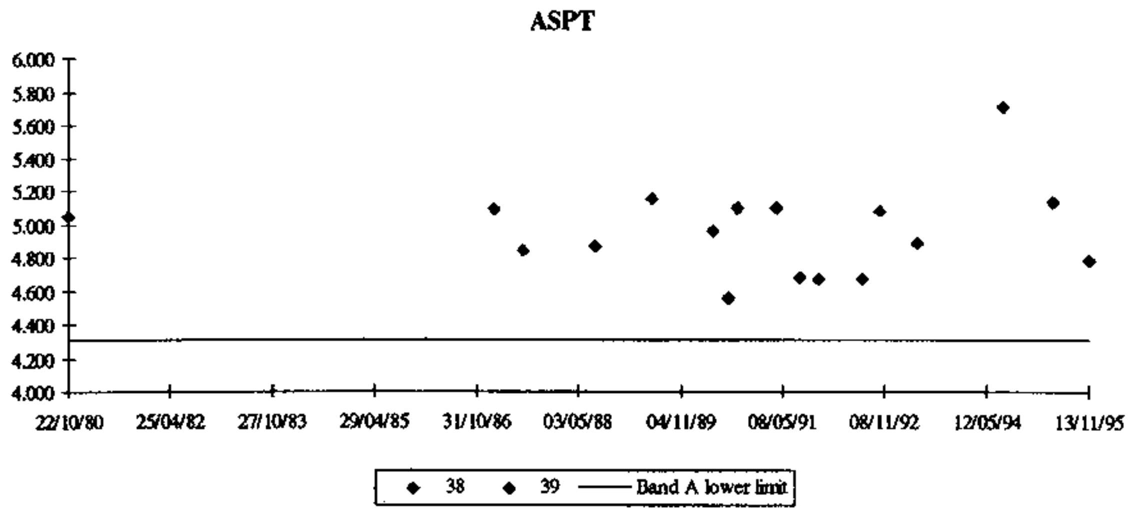
As a result of the inherent variation in collecting biological data the band widths for BMWP score and number of taxa are necessarily broad in order to have a high degree of certainty about the accuracy of the band allocation. The most effective and discriminating index is based upon the ASPT since these values are less dependant on sampling effort and efficiency (Armitage et al 1983).

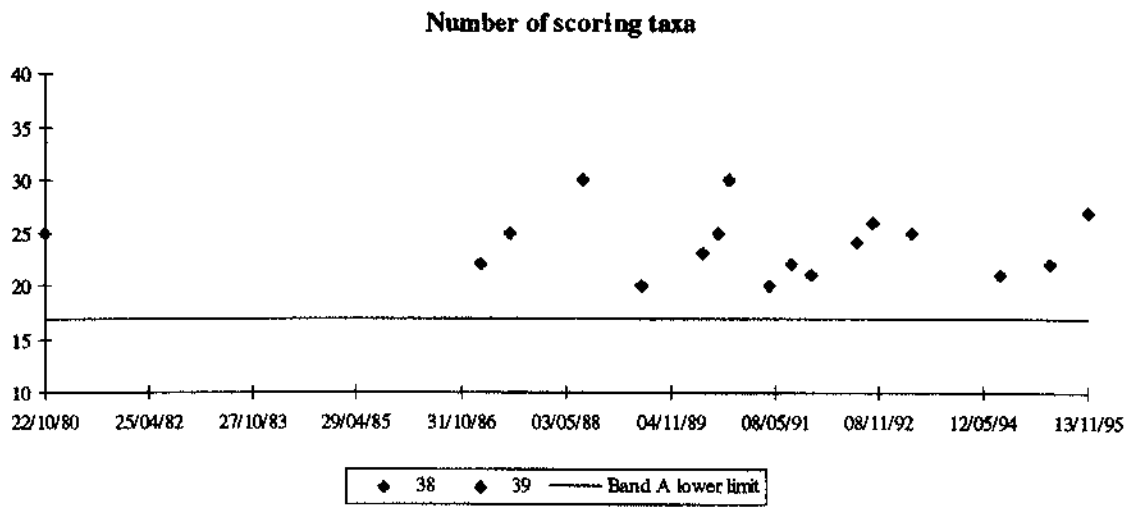
The observed values for all samples in the data-set are given in Appendix 3.4. The water industry samples (subsidiary ID: WA/NRA/EA) were collected specifically for monitoring the ecological quality of the rivers.

The sample index values of each site inevitably vary between years (Figures 3.8 - 3.19) but almost always remain within the best quality band A in each reach sampled by the Environment Agency and its predecessors.

TH10 - ST JOHN'S

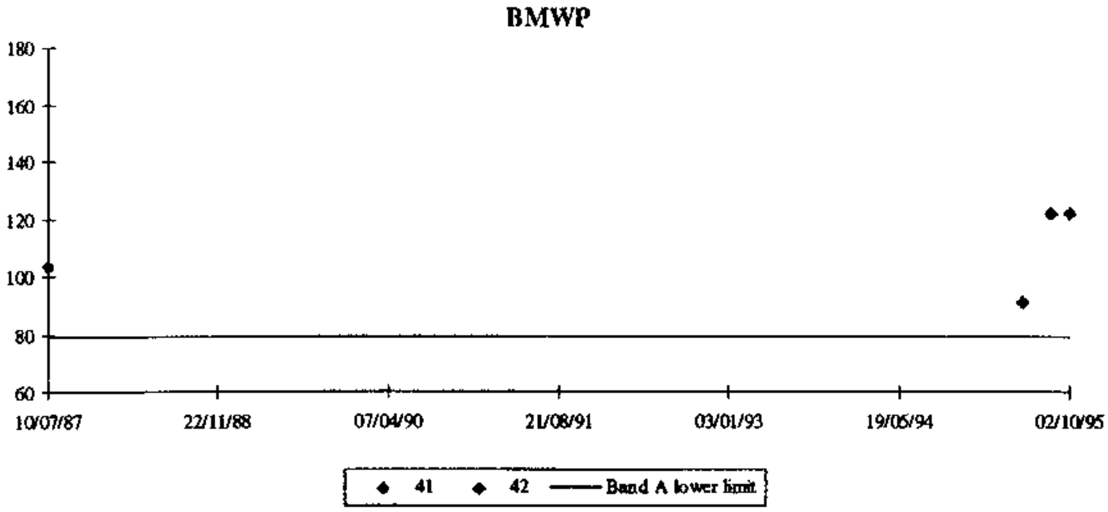


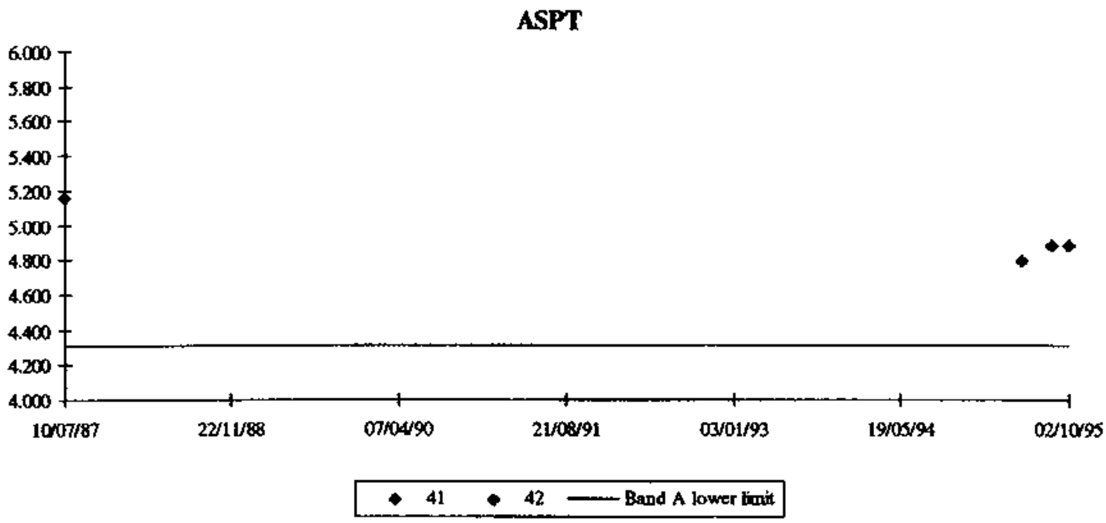


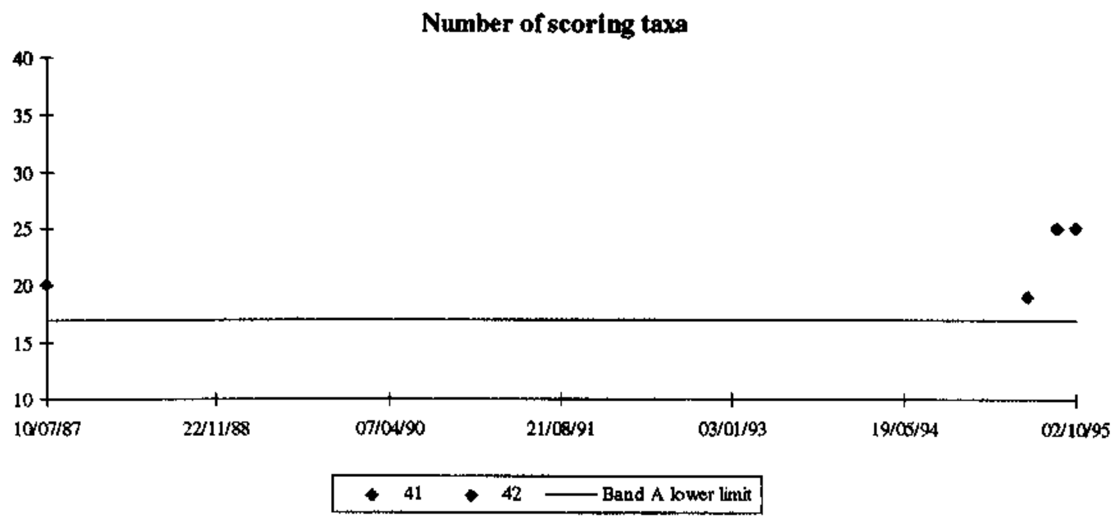


3.8 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the St John's reach (TH10)

TH15 - SHIFFORD



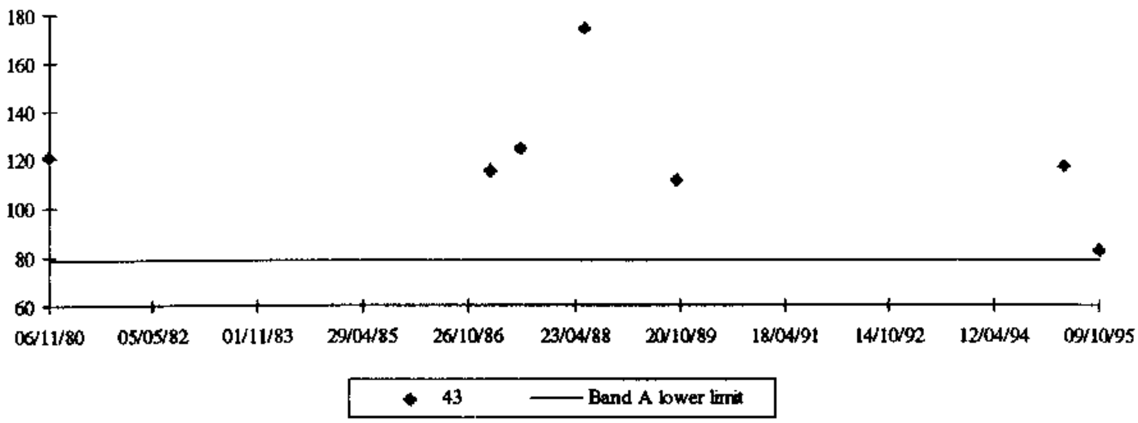




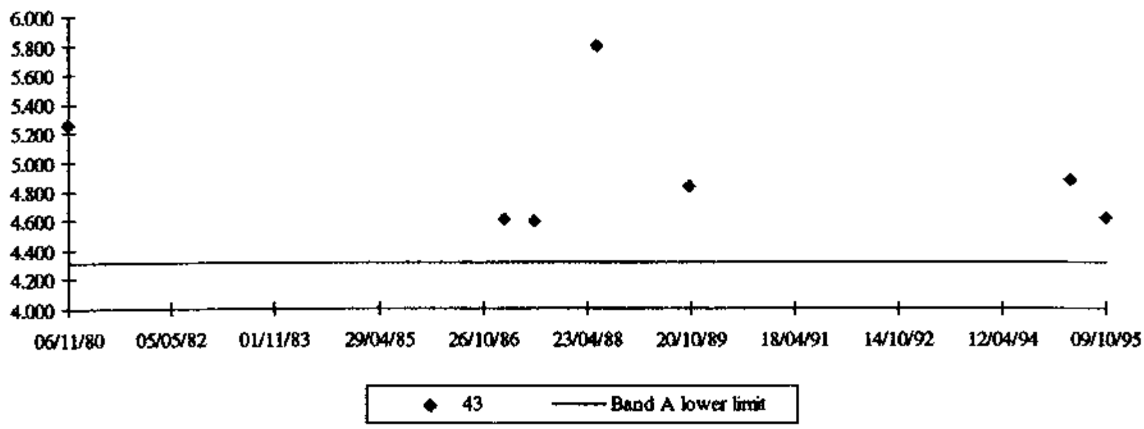
3.9 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Shifford reach (TH15)

TH18 - EYNSHAM

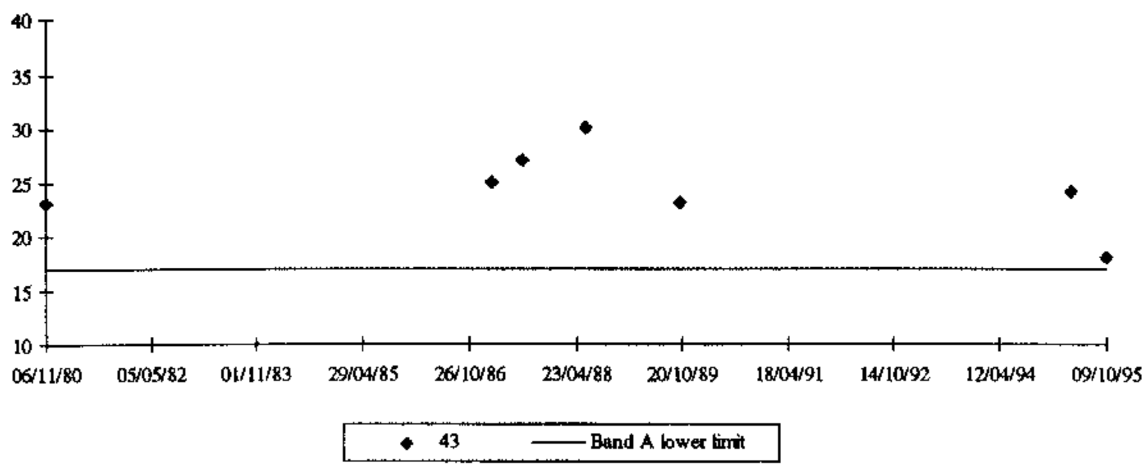
BMWP



ASPT

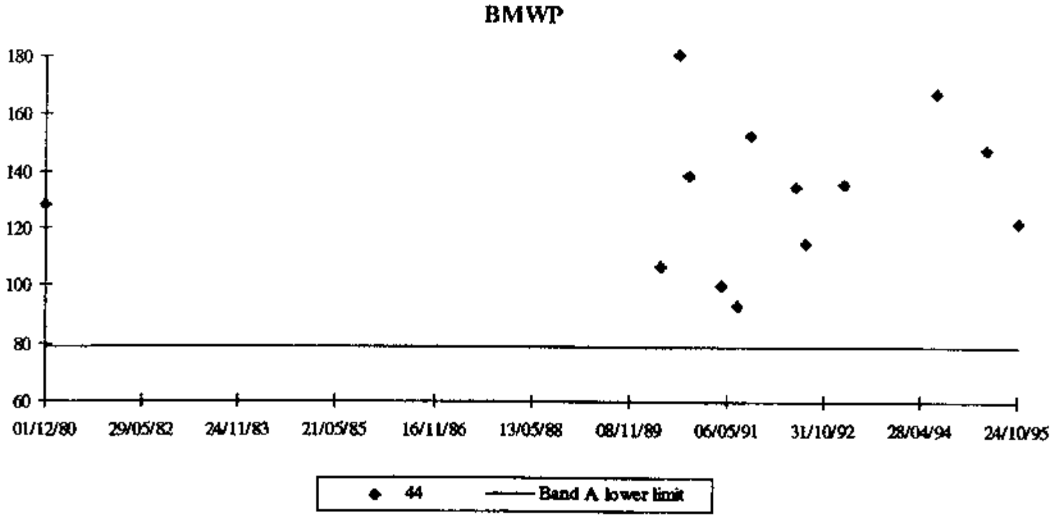


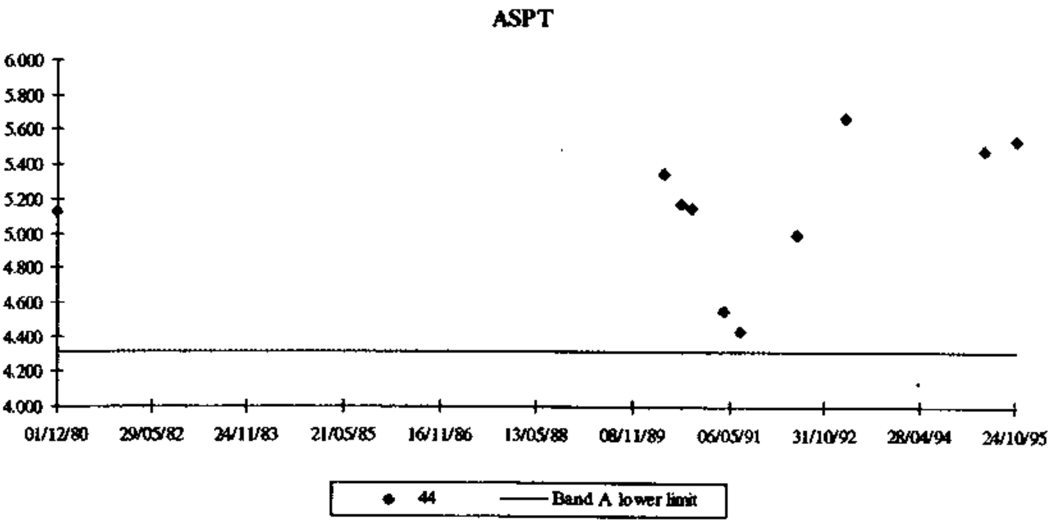
Number of scoring taxa

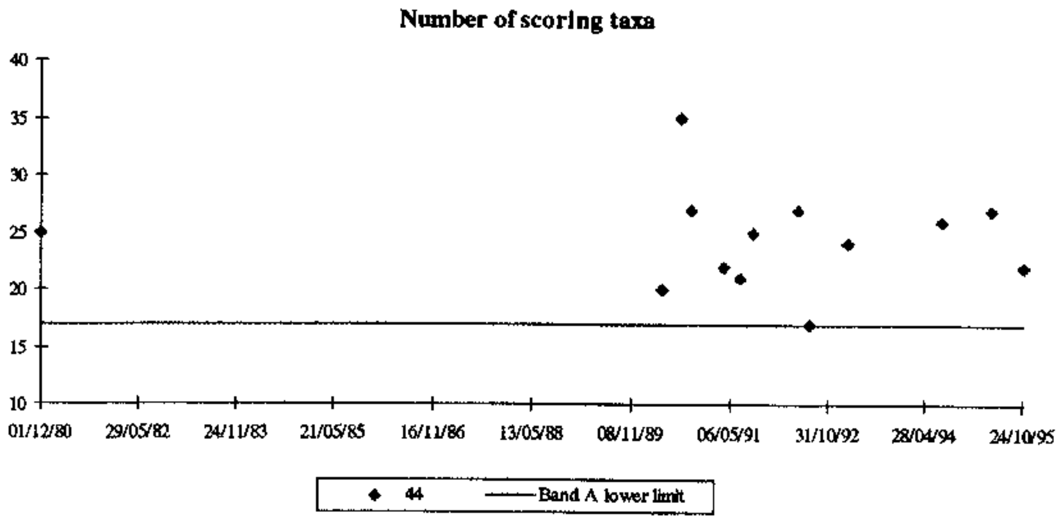


3.10 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Eynsham reach (TH18)

TH19 - KING'S

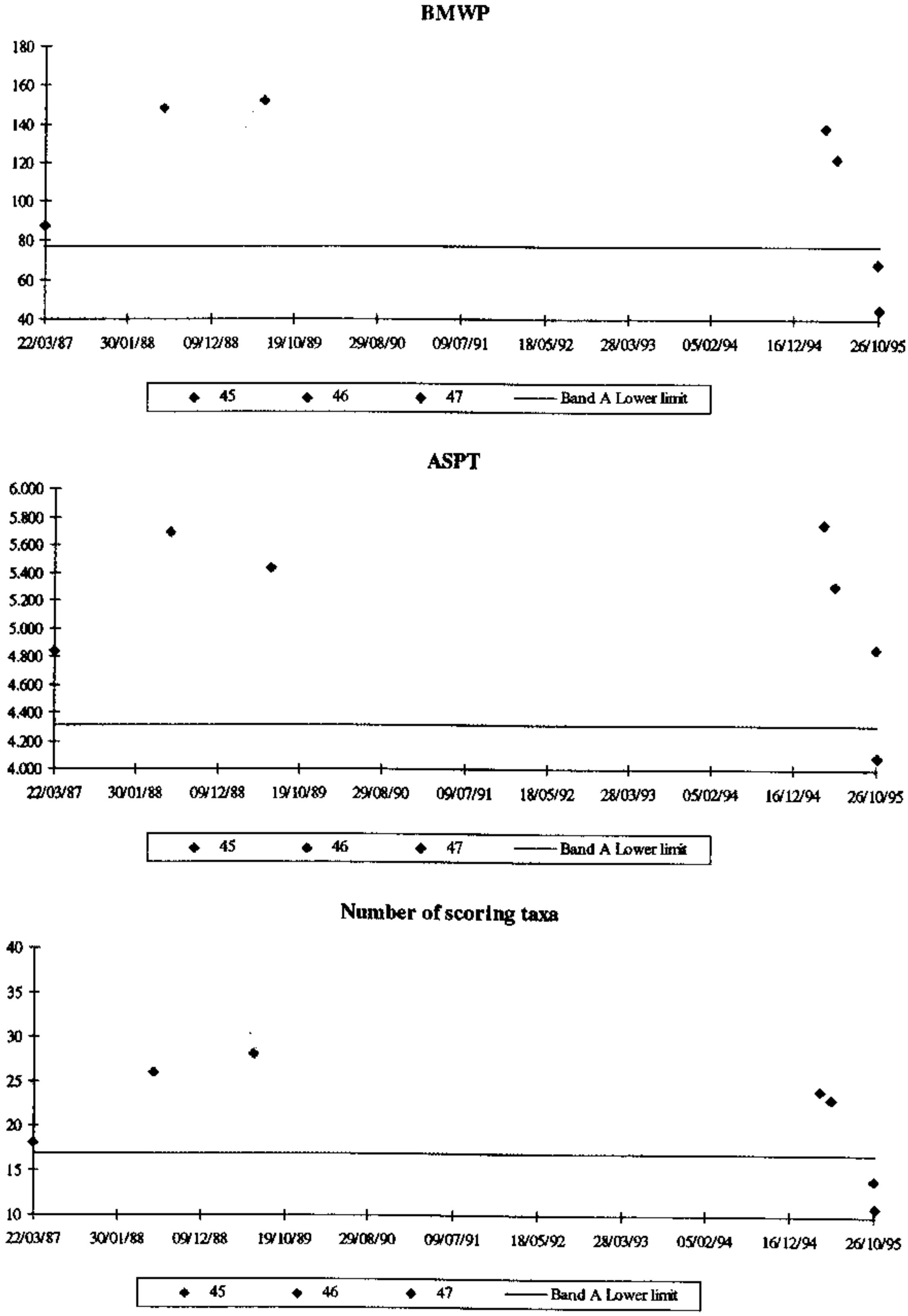






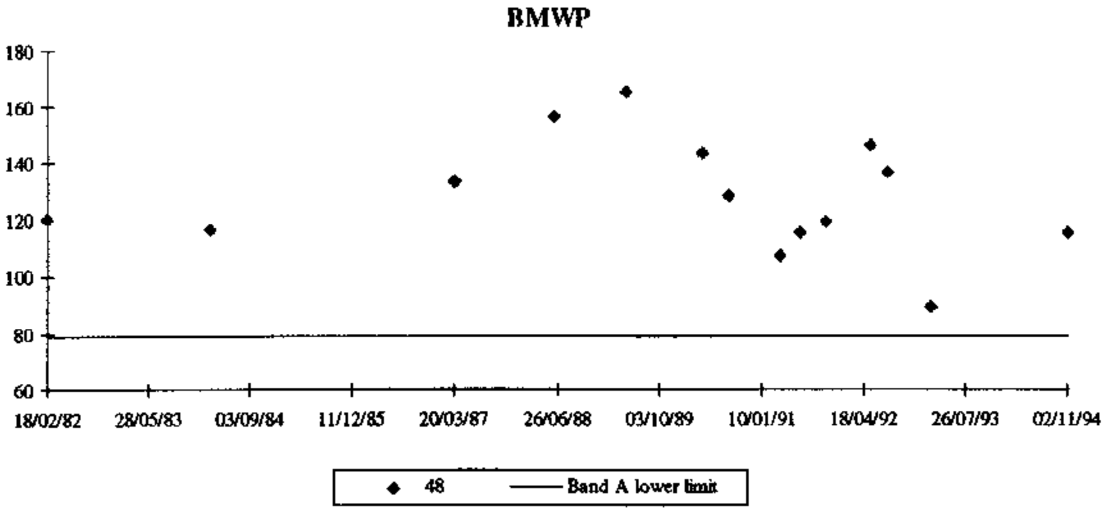
3.11 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the King's reach (TH19)

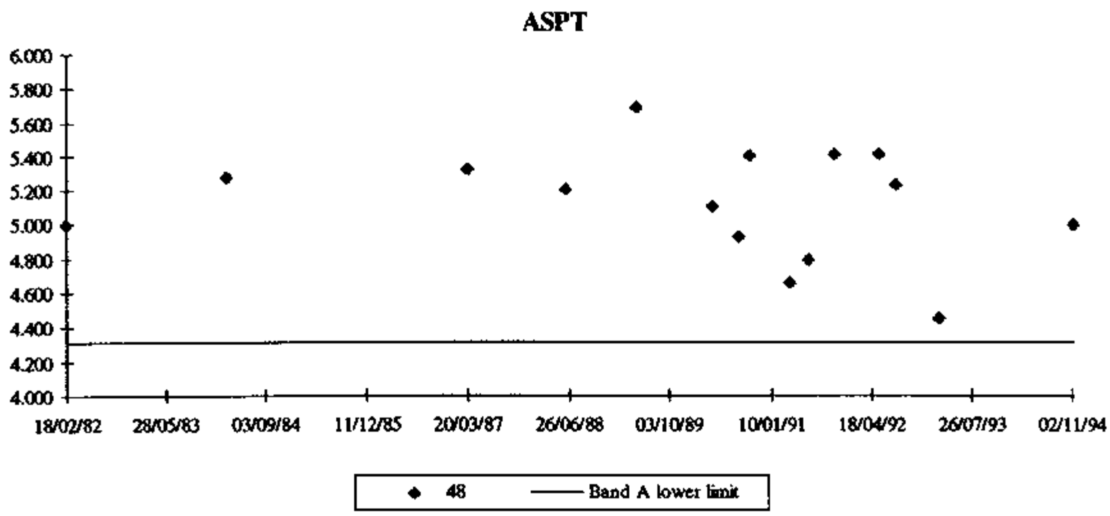
TH21 - OSNEY

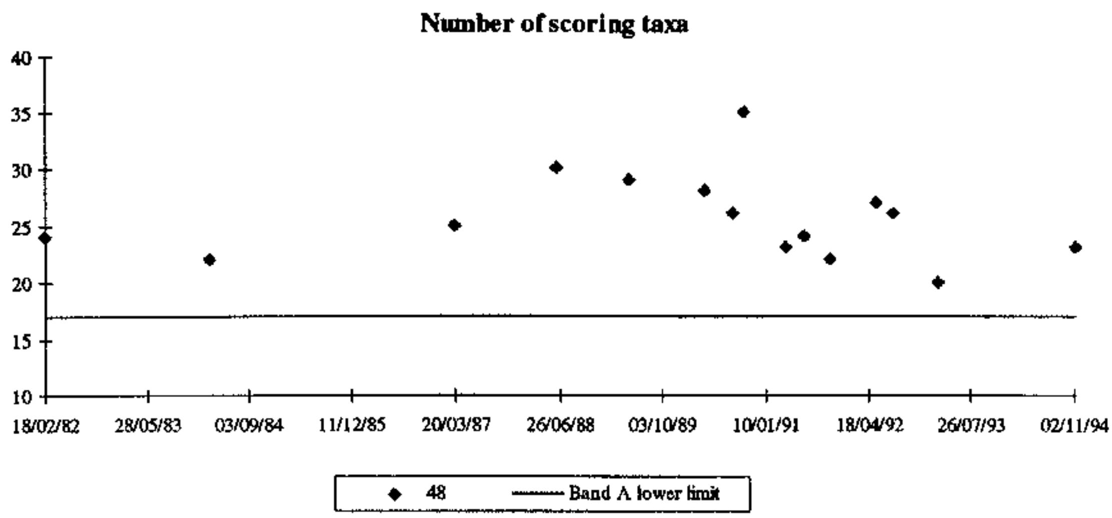


3.12 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Osney reach (TH21)

TH22 - IFFLEY

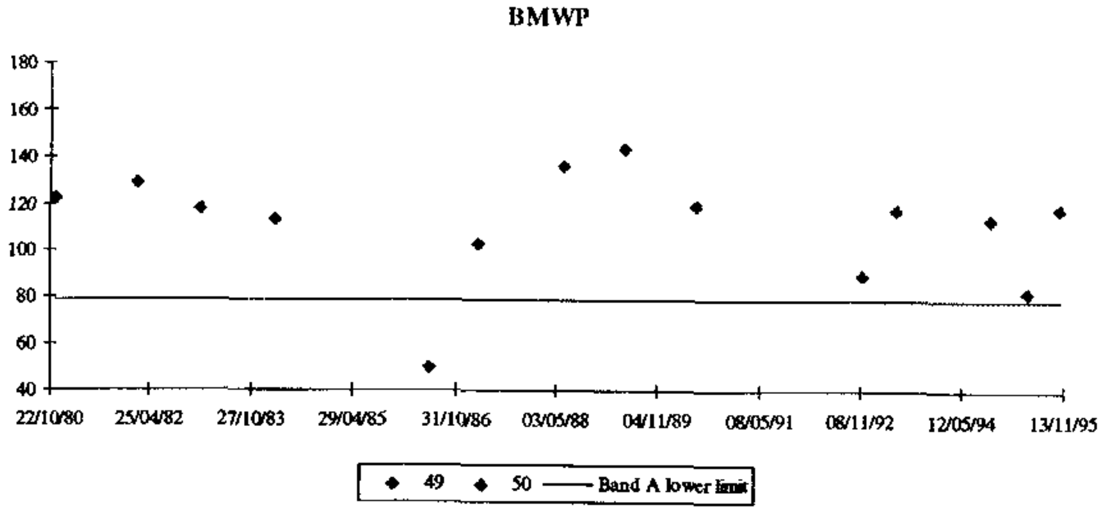


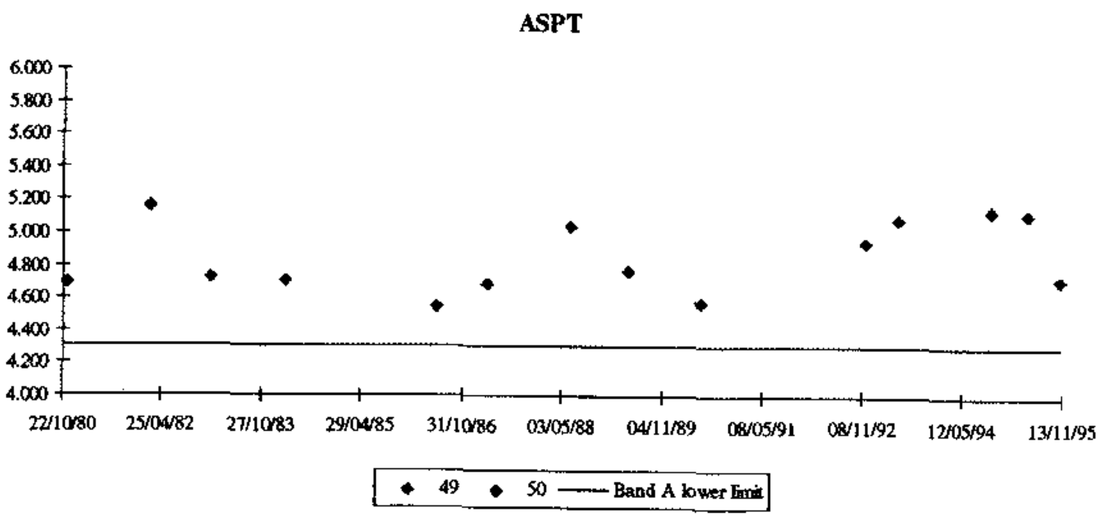


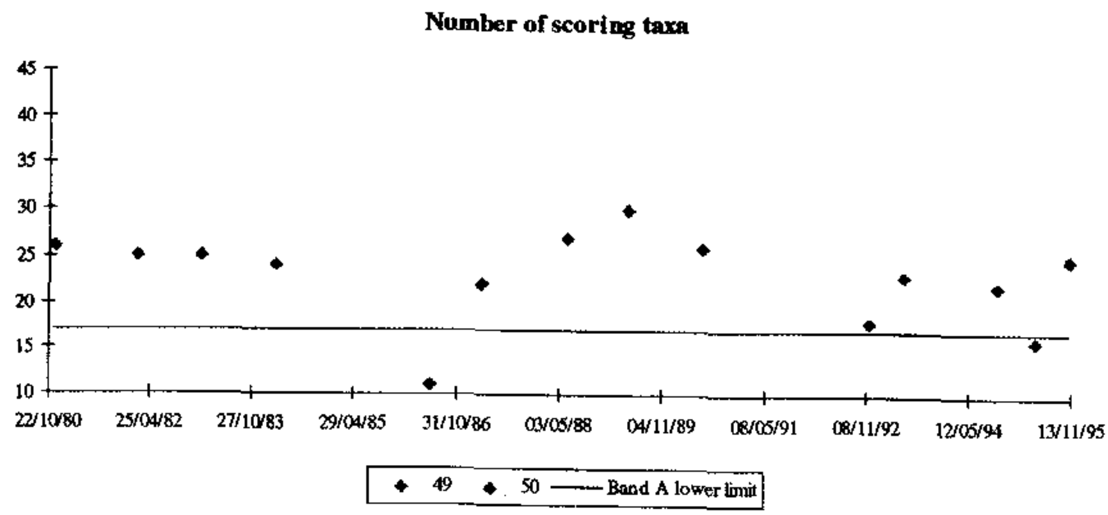


3.13 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Iffley reach (TH22)

TH23 - SANDFORD

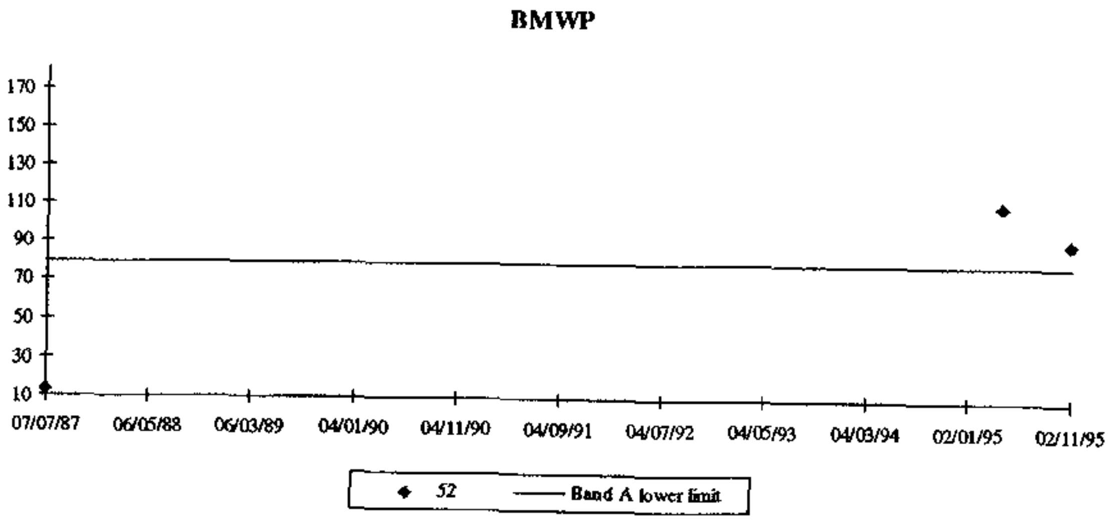


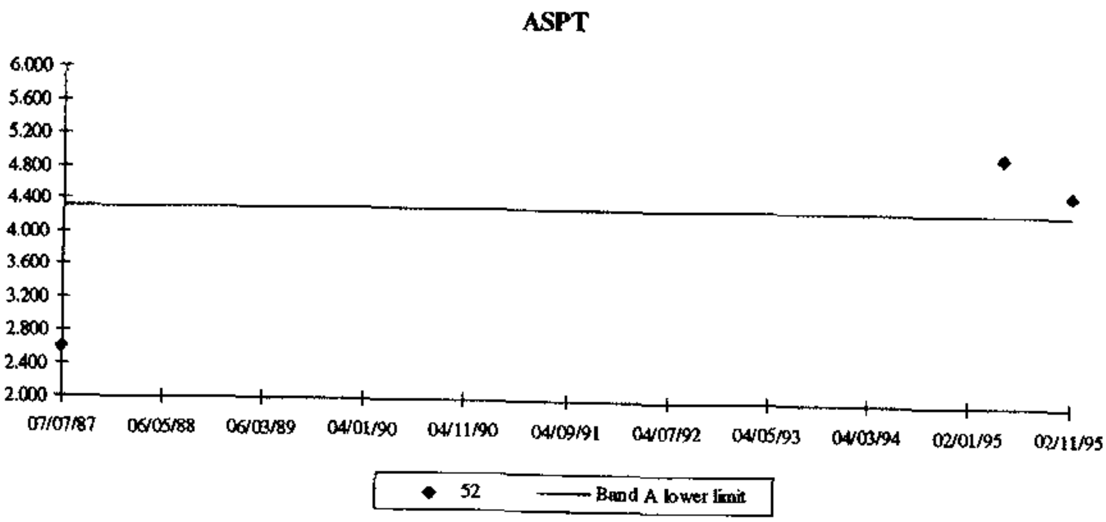


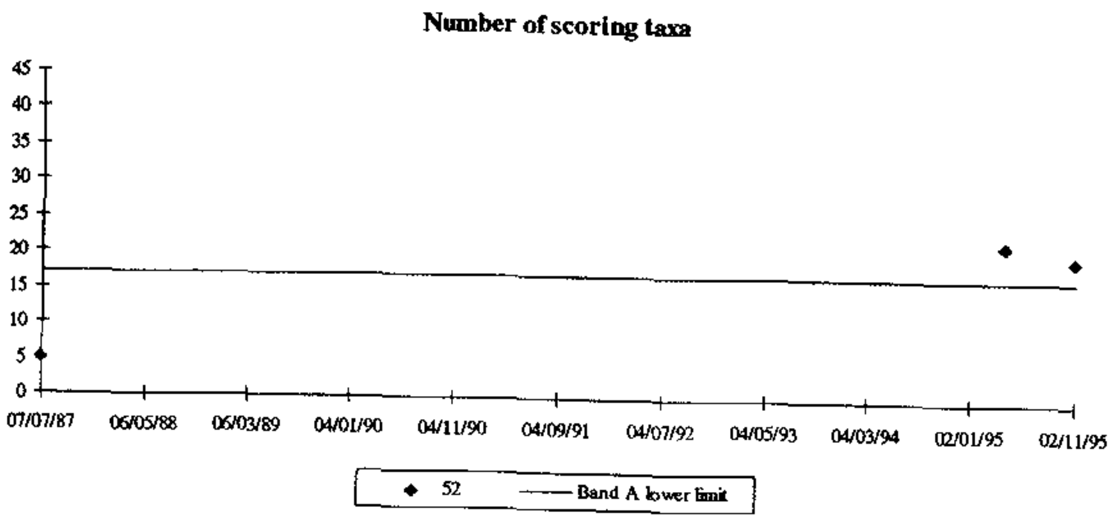


3.14 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Sandford reach (TH23)

TH25 - CULHAM



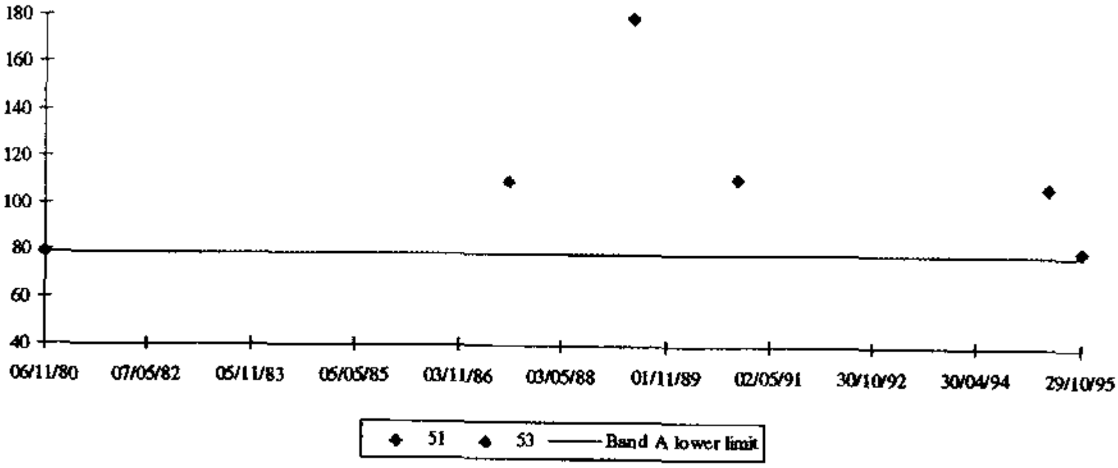




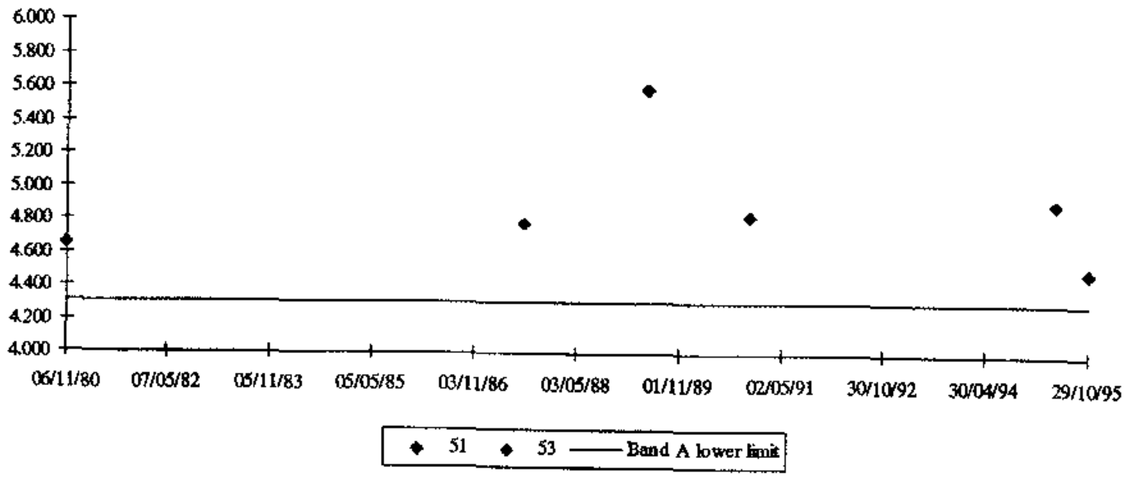
3.15 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Culham reach (TH25)

TH26 - CLIFTON

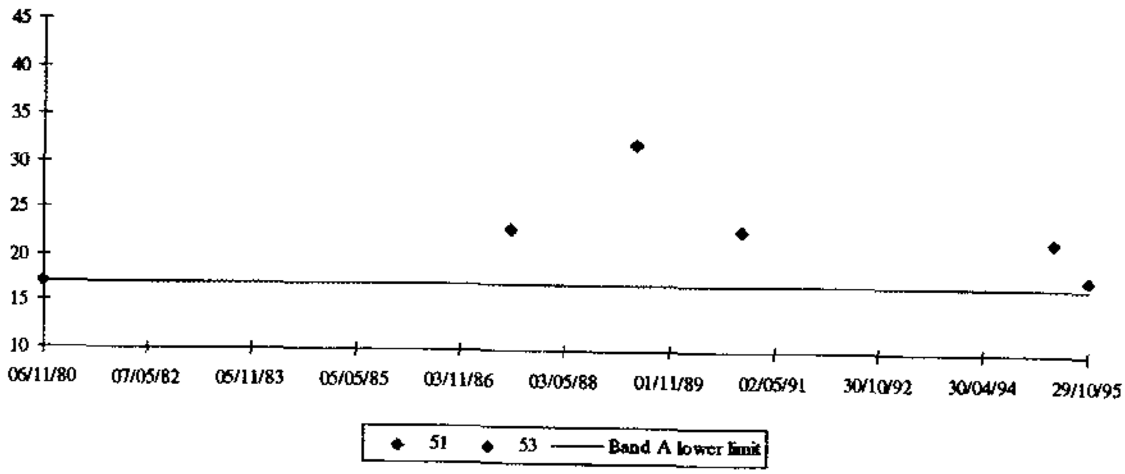
BMWP



ASPT



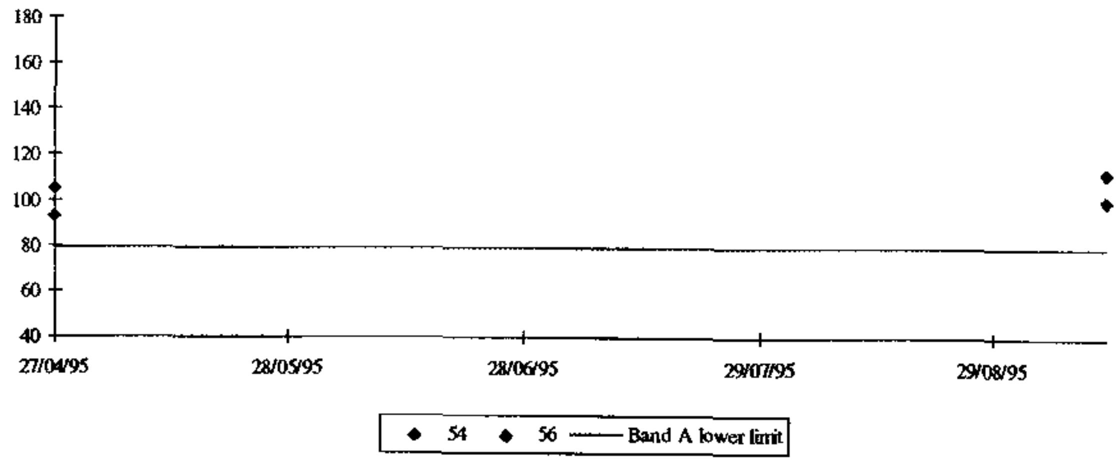
Number of scoring taxa



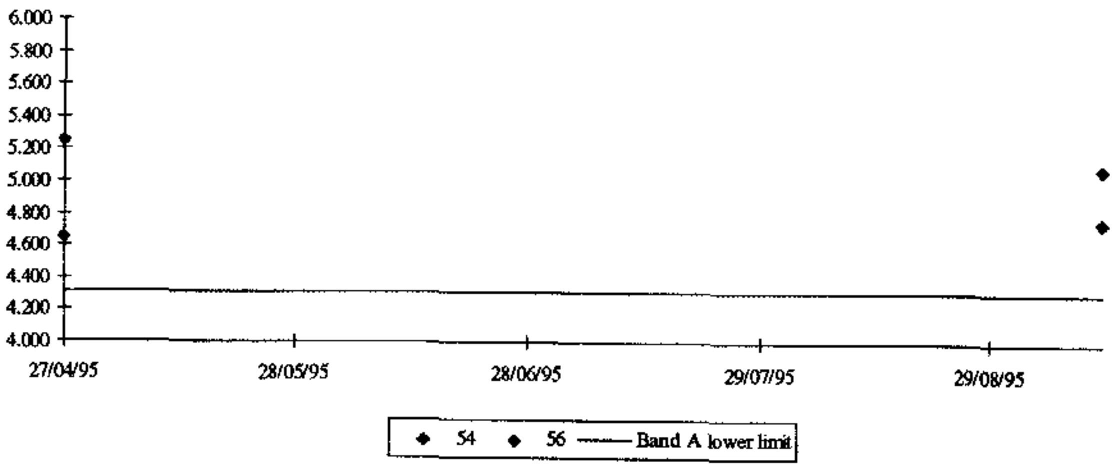
3.16 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Clifton reach (TH26)

TH28/TH29 - BENSON (54) / CLEEVE (56)

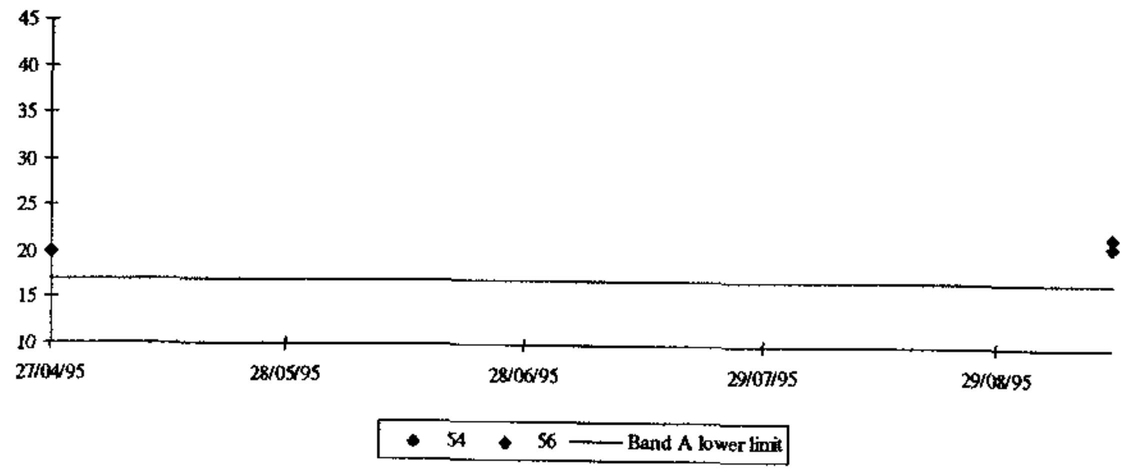
BMWP



ASPT



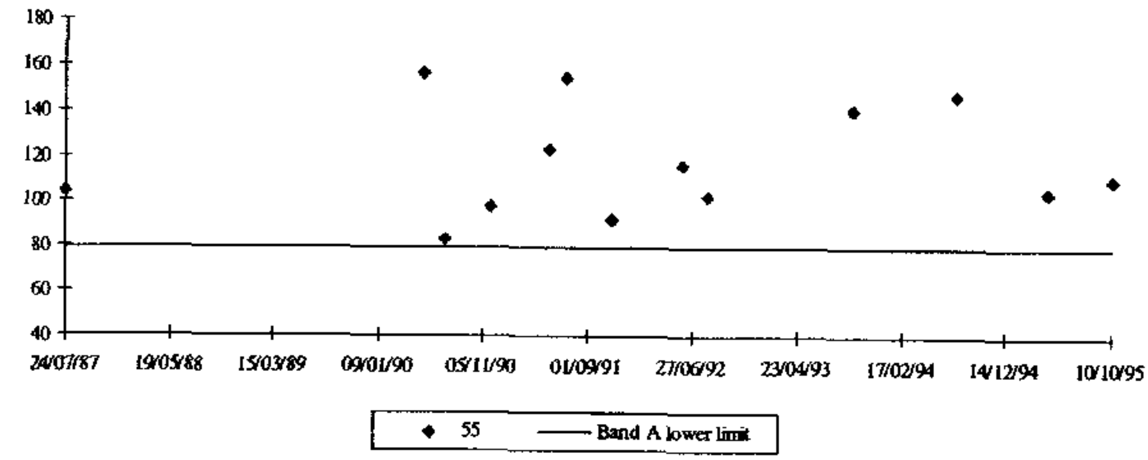
Number of scoring taxa



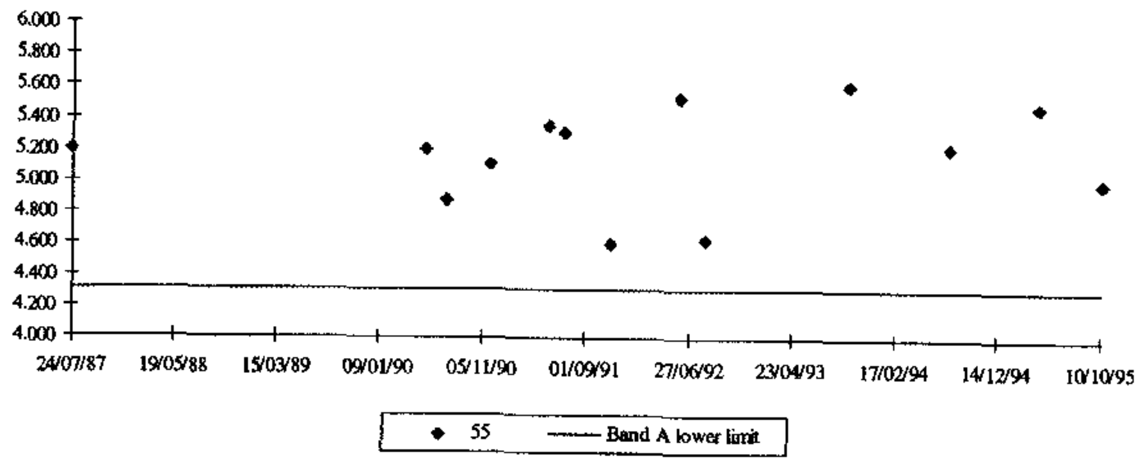
3.17 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Benson and Cleeve reaches (TH28 & TH29)

TH30 - GORING

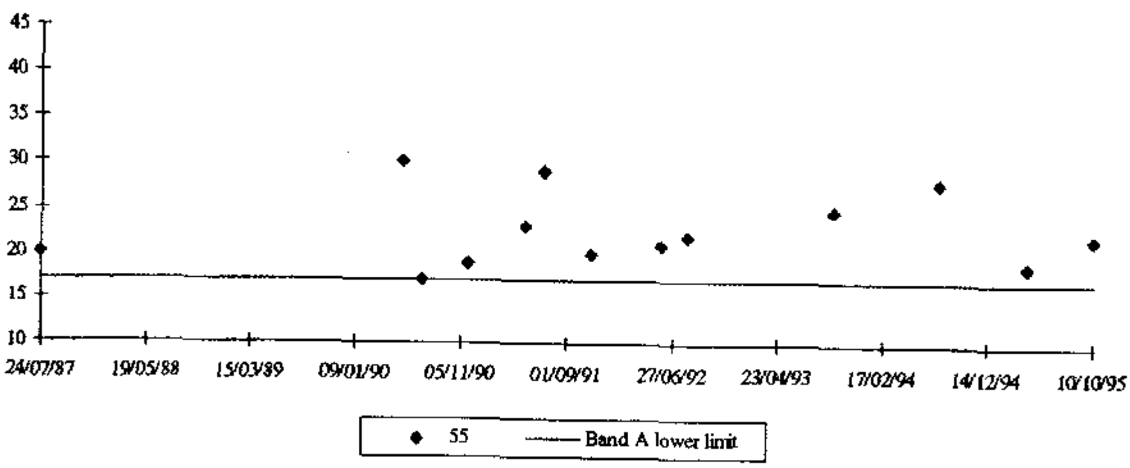
BMWP



ASPT



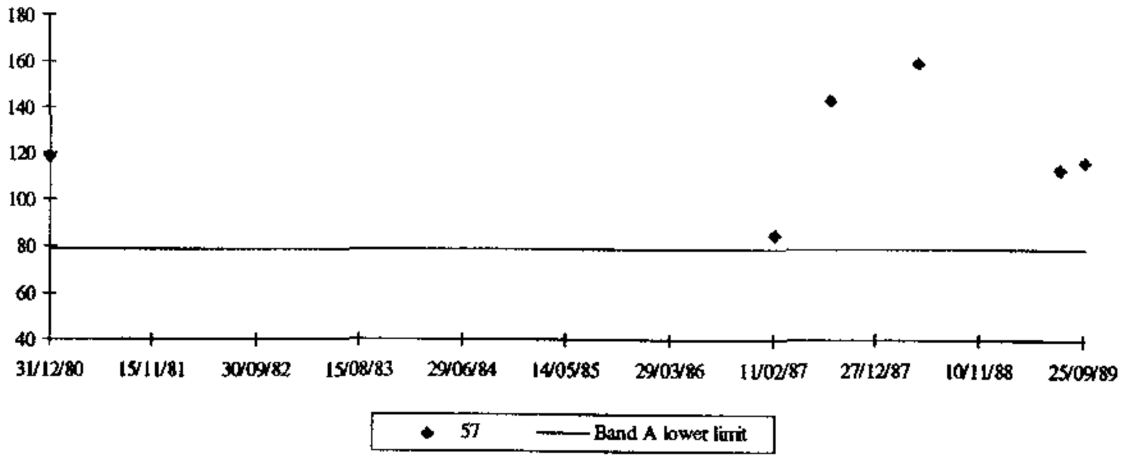
Number of scoring taxa



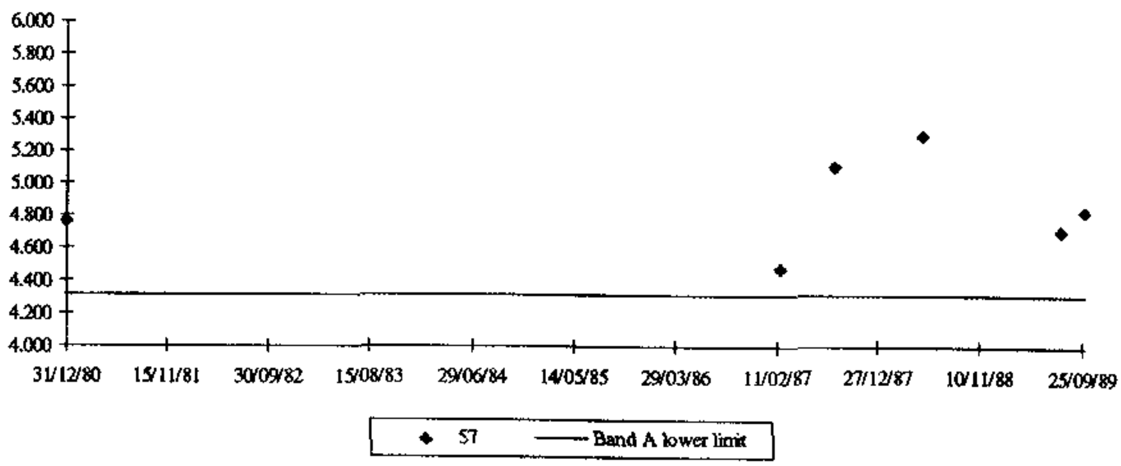
3.18 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Goring reach (TH30)

TH32 - MAPLEDURHAM

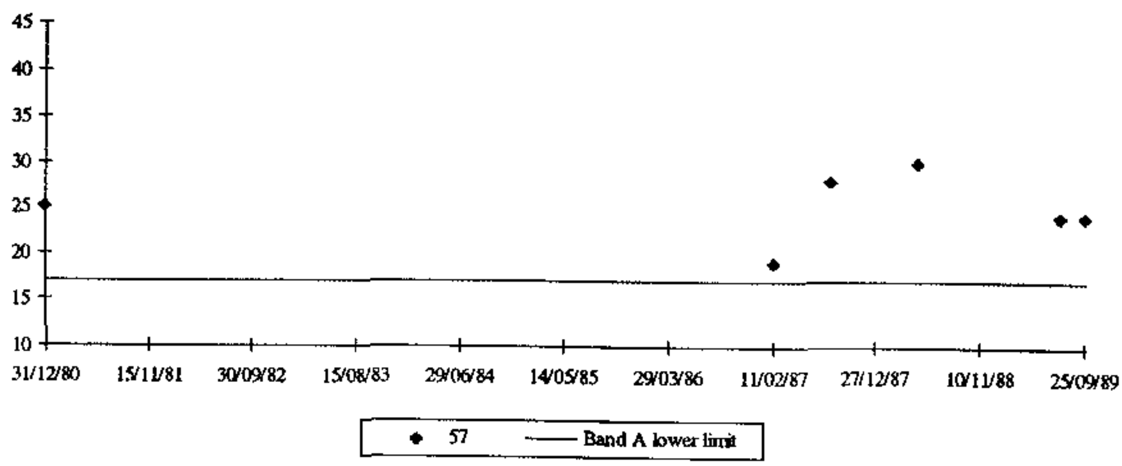
BMWP



ASPT



Number of scoring taxa



3.19 The BMWP index values (BMWP score, ASPT and number of taxa) for all macro-invertebrate samples collected by the Thames Water Authority and the NRA Thames Region in the Mapledurham reach (TH32)

Of the 110 water industry monitoring samples only two fail to meet the band A standard; Donnington Bridge, Oxford , Reach 21, 2-11-95 (4.09 - band B) and Sutton Bridge, Culham, Reach 25 (2.60 - band D).

The Donnington sample also attained band B only, for both BMWP score (45) and number of taxa (11). A further sample from Folley Bridge, in the same reach, collected on 30-10-95 was also band B for score (68) and number of taxa (14) although it was band A for ASPT (4.86). On each sampling occasion mild environmental stress is indicated.

The Sutton Bridge sample was classified as band C for both BMWP score (13) and number of taxa (5). The reasons for this poor ecological quality have not been made known to the authors but possible reasons include an acute pollution incident or inappropriate choice of sampling location.

No water industry samples were taken from the Buscot reach where poor species diversity was indicated from the FBA survey data (see section 3.3.3). Examination of the ASPT values for the upstream samples taken during the IFE survey is also informative. These upstream samples comprised the aggregate faunal lists from nine separate samples of which three were taken in each of marginal, midstream and vegetation zones. Comparable composite samples were taken from each reach from St John's Lock (Reach 10) to Day's Reach (Reach 27). The ASPT value for the Buscot site was 4.174 (band B if it were a RIVPACS-compatible sample). The equivalent samples from all the other 17 reaches were each band A with a range of 4.43 - 5.40 and a mean of 4.97.

Again the Buscot site is indicated to have been of less than good ecological quality in 1977 and the absence of any more recent information is a significant deficiency in the light of the proposed water transfer.

3.3.4 Taxa with specific habitat requirements

An objective of this study (see section 1.2) is to identify any particular autecological requirements of important component species of the fauna. It is outside the scope of the study to detail the precise requirements of the many taxa of invertebrates present. Therefore, the approach adopted is to consider the habitat preferences of all taxa present in the study sectio in relation to four factors:

- longitudinal zonation
- transverse zonation
- substratum requirements
- macrophyte/macro-invertebrate relationships

Longitudinal zonation

The distribution of individual taxa by reach is shown in Appendices 3.4 ("species") and 3.5 (families).

Most taxa are either distributed over the full length of the study section or confined to too few reaches to make meaningful assessments of their longitudinal distribution patterns but many do appear to show upstream or downstream preferences. In order to distinguish those taxa which may be exhibiting longitudinal zonation a simple comparison of frequency of occurrence in the upper and lower portions of the study section was applied.

The cut-off point between the upper and lower stretches was the lock at Iffley. This was almost equivalent to upstream and downstream of the confluence with the Cherwell although some sites in the Osney reach were downstream of this point. Reaches considered excluded those not sampled during the 1977 FBA survey in order to ensure that equivalent levels of identification were considered. This resulted in 12 reaches being included in the upper stretch and six in the lower.

Frequency of occurrence was calculated at reach level and not at sample level (i.e in the upper stretch, say, in what proportion of reaches, out of 12, did a taxon occur).

The number of reaches per stretch were too small to allow the reliable application of statistical tests of differences in frequencies. Thus, a simpler, arbitrary procedure was applied. In order to be considered to have substantially different frequencies of occurrence, the following criteria were established:

- the taxon must occur in at least half the reaches in its preferred stretch
- the taxon must occur twice as frequently in its preferred stretch as its non-preferred

For all taxa meeting these criteria, a simple preference index was derived from the following formula:

$$\frac{\text{\% frequency of occurrence in one stretch}}{\text{\% frequency of occurrence in the other stretch}}$$

For the purposes of calculating preference index values only, a small increment of 0.1 was added to the number of occurrences per taxon per stretch prior to calculating frequencies of occurrence. This was to avoid divisions by zero in calculating the preference index.

Taxa meeting the two criteria above will have a preference index ≥2 in order to be considered as having substantially different frequencies of occurrence in the two reaches. These taxa are considered to have notable association with their preferred reach.

Although the samples analyzed included the chironmid pupal exuviae collections, too few sites were sampled to allow the taxa of exuviae identified to meet the first criterion of notable association. Therefore, no chironomid taxa could be included in Table 3.7 on the basis of exuviae sampling alone.

Only ten taxa appeared to be relatively common in the upper stretch (St John's to Iffley Lock) but relatively rare or absent in the lower stretch (Iffley to Benson's Lock) (Table 3.7).

Table 3.7 Taxa substantially more frequent upstream than downstream of Iffley Lock

Species name	Frequency of occurrence u/s Iffley Lock	Frequency of occurrence d/s Iffley Lock	Preference Index
Hygrobates (Hygrobates) fluviatilis (Ström)	75.00	0.00	45.50
Polypedilum (Polypedilum) sp.	83.33	16.67	4.59
Lebertia (Pilolebertia) inaequalis (Koch)	58.33	16.67	3.23
Spongillidae	50.00	16.67	2.77
Pisidium nitidum Jenyns	50.00	16.67	2.77
Cloeon simile Eaton	50.00	16.67	2.77
Ephemerella ignita (Poda)	50.00	16.67	2.77
Hydroptila sp.	91.67	33.33	2.64
Rheotanytarsus sp.	83.33	33.33	2.40
Microtendipes sp.	75.00	33.33	2.17

In contrast many more taxa appeared to have a substantially higher frequency of occurrence in the lower stretch (Table 3.8).

Table 3.8 Taxa substantially more frequent downstream than upstream of Iffley Lock.

Species name	Frequency of occurrence u/s Iffley Lock	Frequency of occurrence d/s Iffley Lock	Preference Index
Physa acuta group	0.00	83.33	102.00
Hippeutis complanatus (L.)	0.00	83.33	102.00
Erythromma najas (Hansemann)	0.00	83.33	102.00
Nepa cinerea L.	0.00	83.33	102.00
Phryganea bipunctata Retzius	0.00	83.33	102.00
Aeshna cyanea (Müller)	0.00	66.67	82.00
Noterus clavicornis (Degeer)	0.00	66.67	82.00
Viviparus contectus (Millet)	0.00	50.00	62.00
Hydrometra stagnorum (L.)	0.00	50.00	62.00
Haliplus immaculatus Gerhardt	0.00	50.00	62.00
Laccobius (Laccobius) minutus (L.)	0.00	50.00	62.00
Lype reducta (Hagen)	0.00	50.00	62.00
Lymnaea auricularia (L.)	8.33	83.33	9.27
Limnesia (Limnesia) undulata (Müller)	8.33	83.33	9.27
Laccophilus hyalinus (Degeer)	8.33	83.33	9.27
Cyrnus flavidus McLachlan	8.33	83.33	9.27
Mystacides longicornis (L.)	8.33	83.33	9.27
Branchiura sowerbyi Beddard	8.33	66.67	7.45
Unionicola (Pentatax) aculeata (Koenike)	8.33	66.67	7.45
Notonecta glauca L.	8.33	66.67	7.45
Haliplus lineatocollis (Marsham)	8.33	66.67	7.45
Enchytraeidae	8.33	50.00	5.64
Enallagma cyathigerum (Charpentier)	8.33	50.00	5.64
Hyphydrus ovatus (L.)	8.33	50.00	5.64
Helophorus (Atracthelophorus) brevipalpis Bedel	8.33	50.00	5.64
Ecnomus tenellus (Rambur)	8.33	50.00	5.64
Anodonta cygnea (L.)	16.67	83.33	4.86
Glossiphonia heteroclita (L.)	16.67	83.33	4.86
Gerris (Gerris) lacustris (L.)	16.67	83.33	4.86
Calopteryx splendens (Harris)	25.00	100.0	3.94
Haliplus fluviatilis Aubé	25.00	100.0	3.94
Tinodes waeneri (L.)	25.00	100.0	3.94
Valvata cristata Müller	16.67	66.67	3.90
Oecetis lacustris (Pictet)	16.67	66.67	3.90
Bathyomphalus contortus (L.)	25.00	83.33	3.29
Theromyzon tessulatum (Müller)	25.00	83.33	3.29
Anisus vortex (L.)	33.33	100.0	2.98
Acroloxus lacustris (L.)	33.33	100.0	2.98
Ischnura elegans (Van der Linden)	33.33	100.0	2.98
Mystacides nigra (L.)	33.33	100.0	2.98
Stictotarsus duodecimpustulatus (Fabricius)	16.67	50.00	2.95
Endochironomus sp.	16.67	50.00	2.95
Agraylea multipunctata Curtis	25.00	66.67	2.65
Lymnaea stagnalis (L.)	33.33	83.33	2.49
Planorbis carinatus Müller	33.33	83.33	2.49
Platycnemis pennipes (Pallas)	33.33	83.33	2.49
Valvata piscinalis (Müller)	41.67	100.0	2.39
Physa fontinalis (L.)	50.00	100.0	2.00
Gyraulus albus (Müller)	50.00	100.0	2.00
Piscicola geometra (L.)	41.67	83.33	2.00
Ceratopogonidae	41.67	83.33	2.00
Stylodrilus heringianus Claparède	33.33	66.67	2.00
Tubifex tubifex (Müller)	33.33	66.67	2.00
Potamonectes depressus (Fabricius)	33.33	66.67	2.00
Armiger crista (L.)	25.00	50.00	2.00
Sphaerium lacustre (Müller)	25.00	50.00	2.00
Argulus sp.	25.00	50.00	2.00
Micronecta (Micronecta) poweri (Douglas & Scott)	25.00	50.00	2.00
Haliplus ruficollis (Degeer)	25.00	50.00	2.00
Halesus radiatus (Curtis)	25.00	50.00	2.00
Harnischia sp.	25.00	50.00	2.00

The taxa with downstream preference indices ≥2 include 15 species of Mollusca (35% of the total number of mollusc "species" recorded in this stretch), four Oligochaeta (15% of oligochaete taxa in the stretch), three Hirudinea (30%), two Hydracarina (10%), one Crustacean (17%), six Odonata (50%), five Hemiptera (29%), eleven Coleoptera (27%), nine Trichoptera (21%) and three Diptera (3%). There were no Ephemeroptera or Plecoptera in the list.

The family Gomphidae as a whole also had a notable downstream preference index. This family was excluded from the table because it was not one of the 349 standard taxa but can only have represented the species *Gomphus vulgatissimus* (L.), a taxon with the conservation status of Nationally Scare (formerly Nationally Notable).

None of the other taxa with notable upstream or downstream associations have special conservation status Section 3.3.5.

The same analyses used to examine zonation at species level was also performed on family data. This allowed three further downstream reaches to be included in the analyses because data from all samples could be compared at a consistent level of identification.

All families with preference indices >1.1 are listed (Table 3.9 - upstream, Table 3.10 - downstream) so that the trends for each are shown. Only one taxon had a notable upstream preference. This was Spongillidae which is a standard (i.e. non-overlapping) taxon also appearing in Table 3.7.

Table 3.9 The numbers and frequencies of occurrence of all families with a preference index for the upstream stretch of >1.1. Families which meet the two criteria of notable association with the upstream section (n ≥ 6 and preference index ≥ 2.00) are in bold.

Family name	Occurrences (out of 12)	Frequency (%)	Preference index
Sisyridae	3	26	232.50
Tetrastemmatidae	1	9	82.50
Leptophlebiidae	1	9	82.50
Perlodidae	1	9	82.50
Dryopidae	1	9	82.50
Rhyacophilidae (incl. Glossosomatidae)	1	9	82.50
Lepidostomatidae	1	9	82.50
Ephydridae	1	9	82.50
Spongillidae	**6**	**51**	**4.53**
Ectoprocta	5	43	1.90
Nematoda	12	100	1.81
Leuctridae	4	34	1.53
Aphelocheiridae	4	34	1.53
Naididae	8	68	1.51
Tanytarsini	10	84	1.51
Tubificidae	12	100	1.51
Prodiamesinae	11	93	1.39
Lumbriculidae	12	100	1.29
Tanypodinae	12	100	1.29
Orthocladiinae	12	100	1.29
Chironomini	12	100	1.29
Goeridae	5	43	1.27
Diamesinae	6	51	1.14

Four families had notable downstream preferences (Table 3.10). These were Gomphidae, as noted above, together with Hydrometridae, Notonectidae and Gyrinidae.

Table 3.10 The numbers and frequencies of occurrence of all families with a preference index for the downstream stretch of >1.1. Families which meet the two criteria of notable association with the upstream section (n ≥ 4 and preference index ≥ 2.00) are in bold.

Family name	Occurrences (out of 9)	Frequency (%)	Preference index
Hydridae	3	33	40.13
Heptageniidae	3	33	40.13
Muscidae	3	33	40.13
Empididae	2	22	26.80
Succineidae	1	11	13.47
Libellulidae	1	11	13.47
Mesovelidae	1	11	13.47
Naucoridae	1	11	13.47
Chrysomelidae	1	11	13.47
Sericostomatidae	1	11	13.47
Gomphidae	**6**	**67**	**7.28**
Enchytraeidae	3	33	3.65
Nepidae	5	56	3.18
Hydrometridae	**6**	**67**	**2.58**
Notonectidae	**6**	**67**	**2.58**
Gyrinidae	**6**	**67**	**2.58**
Dendrocoelidae	2	22	2.44
Tipulinae	2	22	2.44
Gerridae	6	67	1.95
Ceratopogonidae	7	78	1.83
Piscicolidae	8	89	1.75
Aeshnidae	4	45	1.72
Calopterygidae	9	100	1.69
Platycnemididae	6	67	1.57
Tipulidae	6	67	1.57
Coenagriidae	8	89	1.50
Valvatidae	9	100	1.48
Physidae	9	100	1.48
Corophiidae	9	100	1.48
Ephemeridae	9	100	1.48
Lymnaeidae	9	100	1.32
Planorbidae	9	100	1.32
Erpobdellidae	9	100	1.32
Limnephilidae	9	100	1.32
Elmidae	8	100	1.32
Molannidae	9	89	1.32
Psychomyiidae (incl. Ecnomidae)	8	89	1.32
Viviparidae	7	78	1.32
Argulidae	3	33	1.29
Brachycentridae	2	22	1.28
Taeniopterygidae	1	11	1.22
Nemouridae	1	11	1.22
Veliidae	1	11	1.22
Tabanidae	1	11	1.22
Ancylidae (incl. Acroloxidae)	9	100	1.19
Phryganeidae	8	89	1.17

The following families have a preference index in the range 1 - 1.0:

> Planariidae (incl. Dugesiidae), Neritidae, Hydrobiidae (incl. Bithyniidae), Sphaeriidae, Unionidae, Lumbricidae, Glossiphoniidae, Asellidae, Gammaridae (incl. Crangonyctidae & Niphargidae), Baetidae, Ephemerellidae, Caenidae, Corixidae, Haliplidae, Dytiscidae (incl. Noteridae), Hydrophilidae (incl. Hydraenidae), Sialidae, Polycentropodidae, Hydropsychidae, Leptoceridae and Simuliidae.

As stated above the derivation of preference indices is not a statistical test. With so few reaches considered in each stretch, it is entirely possible that any apparent notable preference for either upstream or downstream locations is a matter of chance. The analysis must be regarded as indicative rather than definitive.

Transverse zonation

Examination of transverse zonation patterns is based on the downstream sampling phase of the FBA's 1977 survey. In this phase five reaches (Buscot -11, Shifford - 15, Eynsham - 18, Iffley - 22 and Clifton - 26) were studied in particular detail with separate sampling and analysis of samples collected in three distinct zones; in macrophyte-free marginal areas, in mid-channel and directly from vegetation. Marginal and vegetation samples were collected by pond-netting and mid-channel samples by airlift.

Ten samples were taken from each zone in each reach with an additional four vegetation samples collected from the Shifford reach. Thus fifty samples were collected from each of the margin and mid-channel zones and 54 from vegetation.

The most species-rich zone was the vegetation with 118 distinct, standard taxa occurring in samples collected from this source. This compared with 105 from the margins and 92 from mid-channel. Full lists of frequencies per zone are given in Appendix 3.5.

The odds of any given taxon appearing in any one sample are much less than its chances of appearing in the reach as a whole. Therefore the overall frequency of occurrence criterion for notability of association with a particular zone was relaxed. In this instance a taxon was considered to have a notable affinity with a zone if it:

- occurred in 20% of all samples within the zone
- occurred in twice as many samples in that zone as either of the other two zones

Additionally a taxon was considered to have an affinity for a particular zone if it:

- occurred in 10% of all samples within the zone
- occurred in neither of the other two zones.

When these criteria were applied only two taxa, each chironomids in the tribe Chironomini appeared to have notable association with marginal samples (Table 3.11).

Table 3.11 **Taxa substantially more frequent in marginal samples than in either of the other two zones.**

Species name	Frequency of occurrence per zone Margin	Mid-channel	Vegetation
Dicrotendipes (Limnochironomus) sp.	78.0%	38.0%	35.2%
Glyptotendipes sp.	32.0%	14.0%	1.9%

Similarly, very few taxa had notable affinities with mid-channel samples (Table 3.12). The four which met one or other of the two sets of qualifying criteria included two Chironomini, nematode worms and the freshwater mussel *Unio tumidus*.

Table 3.12 **Taxa substantially more frequent in mid-channel samples than in either of the other two zones.**

Species name	Frequency of occurrence per zone Margin	Mid-channel	Vegetation
Chironomus sp.	34.0%	70.0%	5.6%
Nematoda	16.0%	60.0%	3.7%
Unio tumidus Philipsson		14.0%	
Cryptotendipes sp.		14.0%	

Part of the reason why so few taxa have notable affinities with the marginal or mid channel samples alone is that several taxa rarely occurring on vegetation are present with similar frequencies in both the other two zones that are sampled at the stream-bed.

When marginal and mid-channel samples are considered together, fifteen taxa meet at least one of the sets of criteria for notable association with a particular zone (Table 3.13). These included two taxa, Nematoda and *Chironomus* sp., which are particularly associated with mid-channel (Table 3.12) and one, *Glyptotendipes* sp., that is associated with the margin (Table 3.11).

Table 3.13 **Taxa substantially more frequent in margin and mid-channel samples than in vegetation samples.**

Species name	Frequency of occurrence per zone Margin/Mid-channel	Vegetation
Cyrnus trimaculatus (Curtis)	55.0%	13.0%
Lumbriculidae	54.0%	9.3%
Chironomus sp.	52.0%	5.6%
Potamothrix moldaviensis (Vejdovsky & Mràzek)	49.0%	20.4%
Psammoryctides barbatus (Grube)	40.0%	11.1%
Cladotanytarsus sp.	39.0%	3.7%
Nematoda	38.0%	3.7%
Limnodrilus hoffmeisteri Claparède	38.0%	9.3%
Procladius sp.	32.0%	14.8%
Cryptochironomus sp.	32.0%	9.3%
Prodiamesa olivacea (Meigen)	27.0%	11.1%
Glyptotendipes sp.	23.0%	1.9%
Macropelopia sp.		14.0%
Unio pictorum (L.)		13.0%
Polypedilum (Polypedilum) sp.		11.0%

Twenty taxa had notable associations with the vegetation zone (Table 3.14). This was many more than with either the marginal or mid-channel zones. The 20 taxa were dominated by two groups; Mollusca (five taxa) and Ephemeroptera, (six taxa, of which five were baetids). Each of these groups include epiphytic algae amongst their main food items.). Also represented were Oligochaeta and Hemiptera with two taxa each and Isopoda, Amphipoda, Coleoptera, Trichoptera and Chironomidae (Tanypodinae) with one each. Whereas *Cyrnus trimaculatus* was associated with stream-bed samples, the closely related *Polycentropus* sp. (the standard level of identification for this set of samples) had closer affinities with vegetation.

Table 3.14 Taxa substantially more frequent in vegetation samples than in either of the other two zones.

	Frequency of occurrence per zone		
Species name	Margin	Mid-channel	Vegetation
Procloeon bifidum Bengtsson	18.0%		74.1%
Asellus aquaticus (L.)	28.0%	26.0%	61.1%
Stylaria lacustris (L.)	6.0%		46.3%
Baetis scambus group	4.0%		42.6%
Lymnaea peregra (Müller)	16.0%	2.0%	37.0%
Dytiscidae	10.0%		37.0%
Gammarus pulex (L.)	12.0%	2.0%	29.6%
Cloeon dipterum (L.)	6.0%		25.9%
Baetis vernus Curtis	4.0%		24.1%
Sigara (Sigara) sp.	2.0%		24.1%
Caenis luctuosa group	6.0%	24.0%	11.1%
Aulodrilus pluriseta (Piguet)	8.0%		22.2%
Bithynia leachii (Sheppard)	6.0%	2.0%	20.4%
Gyraulus albus (Müller)	4.0%	4.0%	20.4%
Polycentropus sp.	4.0%		20.4%
Acroloxus lacustris (L.)			18.5%
Cloeon simile Eaton			18.5%
Physa fontinalis (L.)			16.7%
Sigara (Subsigara) falleni (Fieber)			14.8%
Thienemanniella sp.			14.8%

Habitat preferences

In the downstream phase of the 1977 FBA's 1977 survey, where transverse zonation patterns were examined (see Transverse zonation above), the precise habitat type from which samples were taken was noted. These were grouped into ten categories of these representing different dominant substratum particle sizes and macrophyte growth forms (Table 3.15).

Different numbers of samples were taken from each habitat type. Two habitat types, sand and pebbles/stones, although known to occur as a substratum type in a sample, were never dominant. Four others; silt, bedrock/concrete, detritus/organic matter and submerged vegetation, occurred too infrequently to be considered. Analyses were based on the four remaining types; clay, gravel, emergent vegetation and floating vegetation.

Table 3.15 **The ten different habitat types sampled and the number of samples collected from each.**

Dominant substratum type	Numbers of samples
Clay	34
Silt	5
Sand	0
Gravel	49
Pebbles/stones	0
Bedrock/concrete	3
Detritus/organic matter	5
Emergent vegetation	31
Submerged vegetation	4
Floating vegetation.	17

The full lists of frequencies of each taxon on each habitat type are given in Appendix 3.6).

In considering habitat preferences, the same two sets of affinity criteria were adopted as for the transverse zonation analyses. However a third criterion was also applied to allow for the possible association of any given taxon with any two habitat types. In this instance a taxon was considered to have a notable affinity with a habitat if it:

- occurred on a particular habitat with twice the frequency with which it occurred in all sample types from all habitats.

This criterion is akin to the preference index used to examine longitudinal zonation.

The taxa with notable associations with clay (Table 3.16) and gravel (Table 3.17) substrata effectively replicated the patterns of association revealed for margin (Table 3.11) and mid-channel (Table 3.12) samples, reflecting the differences between the clay banks and the predominantly pea-gravel substratum of the midstream zone.

Those taxa associated with clay (Table 3.16) included both the two Chironomini with marginal affinities together with *Microtendipes* sp., a third member of the same tribe.

Table 3.16 **Taxa particularly associated with samples taken from clay substratum (Grav = gravel, Emerg = emergent vegetation, Float = floating vegetation, Pref index = preference index).**

	Clay	Grav	Emerg	Float	Pref index
Dicrotendipes (Limnochironomus) sp.	88%	41%	29%	35%	1.76
Glyptotendipes sp.	38%	16%	3%	0%	2.46
Microtendipes sp.	21%	14%	3%	0%	2.03

Taxa associated with gravel (Table 3.17) included all those associated with mid-channel together with the mayfly species aggregate *Caenis luctuosa* group.

Table 3.17 Taxa particularly associated with samples taken from gravel substratum.

	Clay	Grav	Emerg	Float	Pref index
Nematoda	15%	55%	6%	0%	2.04
Unio tumidus Philipsson	0%	14%	0%	0%	3.02
Caenis luctuosa group	9%	20%	10%	6%	1.68
Chironomus sp.	29%	67%	6%	0%	1.88
Cryptochironomus sp.	21%	45%	6%	12%	1.95

A much broader range of taxa are associated with the two macrophyte growth forms, of which twelve have notable affinities with emergent vegetation. These are dominated by isopod and amphipod crustaceans (three species) and baetid mayflies (four taxa). The list also includes one mollusc species, two oligochaete species and one family of beetles.

Table 3.18 Taxa particularly associated with samples taken from emergent vegetation substratum.

	Clay	Grav	Emerg	Float	Pref index
Bithynia tentaculata (L.)	18%	4%	42%	41%	2.00
Acroloxus lacustris (L.)	0%	0%	29%	0%	4.77
Stylaria lacustris (L.)	9%	0%	42%	47%	2.39
Aulodrilus pluriseta (Piguet)	6%	0%	32%	6%	3.41
Asellus aquaticus (L.)	26%	24%	77%	29%	2.01
Crangonyx pseudogracilis Bousfield	26%	12%	58%	18%	2.26
Gammarus pulex (L.)	15%	2%	29%	24%	2.05
Baetis vernus Curtis	6%	0%	23%	24%	2.39
Baetis scambus group	6%	0%	45%	47%	2.78
Centroptilum luteolum (Müller)	47%	2%	90%	65%	2.27
Procloeon bifidum Bengtsson	24%	0%	81%	59%	2.59
Dytiscidae	9%	2%	45%	24%	2.78

Even more taxa, 22, were associated with floating vegetation. Molluscs (four taxa), baetid mayflies (four taxa), corixid water-bugs (three taxa) and chironomids (seven genera) were particularly well represented.

The baetids included two taxa, *Baetis vernus* and *Baetis scambus* group with affinities with both emergent and floating vegetation on the basis of preference indices >2 for both substrata. In the same category of dual preferences was the oligochaete, *Stylaria lacustris*. In all three instances their association was slightly higher with floating vegetation.

Other taxa with notable associations with floating vegetation were one leech, *Theromyzon tessulatum* which is sanguivorous on water-fowl and two species of polycentropodid caddis. The affinity of *Polycentropus* sp. with the vegetation zone was noted earlier (Table 3.13). The association of the other polycentropodid, *Cyrnus flavidus*, with floating vegetation contrasts with *C. trimaculatus* which was associated with stream-bed samples (Table 3.14), suggesting habitat partitioning amongst these co-geners.

Table 3.19 Taxa particularly associated with samples taken from floating vegetation substratum.

	Silt	Grav	Emerg	Float	Pref index
Physa fontinalis (L.)	0%	0%	10%	24%	3.87
Physa acuta group	0%	0%	0%	12%	8.71
Lymnaea peregra (Müller)	18%	2%	19%	59%	3.48
Gyraulus albus (Müller)	3%	6%	10%	24%	2.68
Stylaria lacustris (L.)	9%	0%	42%	47%	2.68
Theromyzon tessulatum (Müller)	3%	2%	3%	24%	4.35
Baetis vernus Curtis	6%	0%	23%	24%	2.49
Baetis scambus group	6%	0%	45%	47%	2.90
Cloeon dipterum (L.)	3%	0%	19%	35%	3.26
Cloeon simile Eaton	0%	0%	6%	35%	5.80
Sigara (Sigara) sp.	3%	0%	13%	41%	4.69
Sigara (Subsigara) distincta (Fieber)	0%	0%	0%	12%	8.71
Sigara (Subsigara) falleni (Fieber)	0%	0%	10%	24%	4.97
Cyrnus flavidus McLachlan	0%	0%	0%	18%	8.71
Polycentropus sp.	6%	0%	10%	35%	4.35
Nanocladius sp.	0%	0%	0%	12%	8.71
Orthocladius sp.	21%	6%	6%	29%	2.18
Corynoneura sp.	0%	0%	0%	12%	8.71
Chironomus sp.	29%	67%	6%	0%	1.88
Cryptochironomus sp.	21%	45%	6%	12%	1.95
Cryptotendipes sp.	0%	10%	0%	0%	2.16
Rheotanytarsus sp.	15%	18%	19%	47%	2.40

Macrophyte/macro-invertebrate relationships

The final form of habitat preference that can be examined is that of associations of particular macro-invertebrates with particular macrophytes. This analysis relies upon the same downstream sampling programme from the FBA's 1977 survey.

In this instance, the frequencies with which particular macro-invertebrate taxa occurred in samples where a given macrophyte was present, as the dominant <u>or</u> non-dominant species, were calculated. For the purposes of the analysis, separate analyses were performed for each of the three macrophyte growth forms used in previous analyses.

Full frequency listings are presented in Appendices 3.7 (emergent taxa), 3.8 (submerged taxa) and 3.9 (floating taxa).

In detailed analyses, only those macrophytes occurring in five or more samples were considered. No submerged species met this criterion and were thus excluded.

Only three emergent taxa were sufficiently common to be considered; *Scirpus lacustris* (16 records), *Sparganium erectum* (7) and *Phragmites australis* (5). Where either of the first two taxa only occurred in the submerged growth form these were excluded from consideration in the analysis of emergent taxa.

The criteria for notability of association with a particular macrophyte species were the same as were adopted for the transverse zonation. An additional criterion was applied because of the low numbers of samples available for some macrophyte species. This was so that no taxon was considered notable if it occurred in fewer than three samples from the macrophyte on which it was most common:

The effect of this was that a taxon had to occur in at least 60% of *Phragmites australis* samples to be eligible for notable association with that taxon, 43% of *Sparganium erectum* samples or 19% of *Scirpus lacustris* samples.

Only four notable associations were detected, according to the criteria applied (Table 3.20). Three associations were with *Sparganium erectum* and the other was with *Phragmites australis*. None of these associations was based on more than four occurrences on the "preferred" macrophyte and it is concluded that too few samples were taken on each species to draw meaningful conclusions.

Table 3.20 Macro-invertebrate taxa which have notable associations with either *Scirpus lacustris*, *Sparganium erectum* or *Phragmites australis* amongst emergent macrophytes. Notable associations are shown in bold in the table.

	Scirpus lacustris	*Phragmites australis*	*Sparganium erectum*
Aulodrilus pluriseta (Piguet)	19%	20%	**43%**
Helobdella stagnalis (L.)	19%	0%	**57%**
Gammarus pulex (L.)	19%	20%	**43%**
Hydroptila sp.	6%	**60%**	14%

Amongst floating macrophytes, only two species were sampled on at least five occasions; *Nuphar lutea* (ten samples) and *Potamogeton pectinatus* (seven samples).

In view of the fact that only two macrophyte species were being compared, the criteria applied were those used earlier to compare upstream and downstream sections in the longitudinal zonation. These were that :

- the taxon must occur in at least half the samples from its preferred macrophyte
- the taxon must occur twice as frequently in samples from its preferred macrophyte as in samples from its non-preferred

On this basis, only one taxon, *Polycentropus* sp, was identified as having an apparent preference for *Nuphar lutea* (Table 3.21). It is assumed that this is because this broader-leaved plant species offered a more suitable platform for the caddis's spun net.

In contrast, eleven taxa had an apparent preference for *Potamogeton pectinatus* (Table 3.21), including two of the three taxa of *Sigara* recorded in the river and both of the two *Cloeon* species.

The differences in frequencies of the taxa listed in Table 3.21 provide a firmer basis for interpreting real preferences than those taxa listed in Table 3.20 for emergent taxa. The realibility of this interpretation would have been better for more intensive sampling.

Table 3.21 Macro-invertebrate taxa which have notable associations with either *Nuphar lutea* or *Potamogeton pectinatus* amongst floating macrophytes. Notable associations are shown in bold in the table.

	Nuphar lutea	*Potamogeton pectinatus*
Sphaerium corneum (L.)	10%	**71%**
Asellus aquaticus (L.)	10%	**57%**
Cloeon dipterum (L.)	0%	**86%**
Cloeon simile Eaton	10%	**71%**
Sigara (Sigara) sp.	0%	**100%**
Sigara (Subsigara) falleni (Fieber)	0%	**57%**
Dytiscidae	0%	**57%**
Polycentropus sp.	**50%**	14%
Cricotopus sp.	50%	**100%**
Orthocladius sp.	10%	**57%**
Polypedilum (Pentapedilum) sp.	10%	**57%**

3.3.5 Taxa of conservation importance

Fourteen species with conservation status occurred in one or more samples taken from the study reach (Table 3.22). Full details of the occurrences of each of these taxa are given in Appendix 3.10.

Table 3.22 Taxa with national conservation status which are known to occur in the study section.

TAXON	STATUS	REACHES FOUND
Gyraulus acronicus (Ferrusac)	RDB2	23
Pisidium moitesserianum Paladihle	Nb	16, 27
Pisidium supinum Schmidt	Nb	10,11,14,15,16,18, 19,20,
Heptagenia fuscogrissea (Retzius)	N	27
Gomphus vulgatissimus (L.)	N	16,26,27,30
Haliplus laminatus Schaller	Nb	25
Gyrinus distinctus Aubé	RDB3	27
Gyrinus urinator Illiger	Nb	10,22
Anacaena bipustulata (Marsham)	Nb	22
Laccobius (Macrolaccobius) sinuatus Motschulsky	Nb	22,26
Oulimnius major (Rey)	Na	19
Sialis nigripes (Pictet)	Nb	10,11,16,18
Ceraclea senilis (Burmeister)	N	23,30
Leptocerus lusitanicus (McLachlan)	RDB2	30

The conservation categories listed in Table 3.22 are as follows:

RDB2 (Vulnerable)

Taxa believed likely to move into the Endangered (RDB1) category in the near future. Included are taxa of which most or all of the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations which have been seriously depleted and whose ultimate security is not yet assured; and taxa with populations that may still be abundant but are under threat from serious adverse factors throughout their range.

RDB3 (Rare)

Taxa with small populations which are not at present Endangered or Vulnerable, but are at risk. These taxa are usually localised within restricted geographical areas or habitats or are thinly scattered over a more extensive range. Usually, such taxa are not likely to exist in more than fifteen 10km squares of the National Grid. This criterion may be relaxed where populations are likely to exist in over fifteen 10km squares but occupy small areas of especially vulnerable habitat.

N (Nationally Scarce - formerly Nationally Notable)

Taxa which do not fall within RDB categories 1-3 but which are none-the-less uncommon in Great Britain and thought to occur in fewer than a hundred 10km squares of the National Grid.

In some cases the Scarce/Notable category is sub-divided into classes Na and Nb which are defined as follows

- Na Nationally Scarce taxa known to occur in thirty or less 10km squares of the National Grid

- Nb Nationally Scarce taxa known to occur in more than thirty but less than a hundred 10km squares of the National Grid

Brief details of the national distribution, habitat preferences and ecology of each taxon are given in the following text, together with information on two other unusual taxa, *Branchiura sowerbyii* Beddard and *Boreobdella verrucata* (Müller), from groups which are not generally ascribed conservation status.

Gyraulus acronicus (Ferrusac)

There remains some doubt about the identity of this species compared to specimens bearing the same name in other parts of Europe. In Britain, the species is restricted to the Thames between Oxford and Marlow and to a few of its tibutaries, including the Lodden (Bratton 1991). In the Thames, it lives in backwaters and quiet stretches on weeds and stones. Even in the Thames, this species is rarely captured alive, although empty shells are more commonly found, as was the case for the records contributing to the data-base in this study (Pond Action 1992). Kerney (in Bratton 1991) considers that its main threats are water pollution or gross habitat disturbance and states that "a serious pollution incident in the Upper Thames would probably destroy most of the population".

Pisidium moitesserianum Paladihle

The distribution range of this taxon is quite extensive for a species with national conservation status. Ellis (1978) defines its range as most of the more central and western parts of England south from Yorkshire. Its eastern range extends to Norfolk and its western range to Cornwall. It is listed as occurring in lakes, rivers and canals but its assumed riverine distribution is larger, slower-flowing watercourses. Ellis (1978) gives no information on the ecology of this species.

Pisidium supinum Schmidt

According to Ellis (1978), *P. supinum* inhabits large slow flowing rivers in England North to Yorkshire. He gives no information on the ecology of this species.

Branchiura sowerbyii Beddard

The origins of this species in Britain are unclear. It was once thought to have been introduced from the Far East (Stephenson 1930) although Brinkhurst and Jamieson (1971) have postulated that it occurs naturally in Britain but only becomes abundant in the presence of thermal pollution. The first known British record was from the Royal Botanical Society's Gardens at Kew but this species has often been recorded in the Thames, particularly downstream of heated effluent outlets (Aston 1966) such as downstream of the "Dreadnought" reach at Reading.

Boreobdella verrucata (Müller)

Elliott and Tullett (1982) record this species as rare, with just two English records. Since then, the Institute of Freshwater Ecology have recorded this specimen from two further sites on the Thames and one on the lower Tent. In the rest of Europe it has been found in lakes and slow flowing streams and rivers. It feeds on molluscs and to carries young in June and July. However, little else is known about its ecology (Elliott and Mann 1979).

Heptagenia fuscogrissea (Retzius)

The distribution of this taxon is given by Bratton (1990) as the Thames, the Kennet and Avon Canal, minor channels of the River Nene, the Derwent, West Beck and River Hull in Yorkshire and a small stream at Mochrum in Galloway. In addition to three records from the Thames, the Institute of Freshwater Ecology have also captured this taxon at two sites on the Yorkshire Derwent and from seven sites in Scotland, principally on the River Cree. The preferred habitat is on the stony substratum. It also occurs amongst the vegetation of calcareous rivers (Bratton 1990), although it is known to be tolerant of acidification. Amongst the threats to this species, Bratton (1990) lists industrial and urban development and the concomitant risks of pollution, river engineering works which increase flow rates but eliminate side channels, pollution from fish farms and low flows. Increased siltation also poses a threat, including that arising from afforestation. He recommends that the vegetation of river margins and banks should be managed to ensure the presence of shelter for the adult stages of this species.

Gomphus vulgatissimus (L.)

This species is confined to seven river systems in southern Britain (Merritt, Moore and Eversham 1966). These are the Thames, Arun, Dee (Wales), Severn, Wye, Twyi and Teifi. It has disappeared from several other rivers in Southern Britain in the last thirty years. Its preferred habitat is silty and muddy substrata in unpolluted rivers of moderate to slow speed. The larvae take at least three years to develop. According to Merritt, Moore and Eversham (1966), this species is vulnerable to pollution and to the increased use of rivers by pleasure boats whose wash can dislodge and drown large numbers of emerging adults in May.

Haliplus laminatus Schaller

According to Balfour-Browne (1939), this species occurs as far north as Northumberland, as far east as east Norfolk and as far west as Somerset. Friday (1988) states it is most widespread in East Anglia. Its preferred habitat is given in both sources as rivers, canals and silt ponds. Neither give details of its ecology.

Gyrinus distinctus Aube

This species was formerly known as *Gyrinus colymbus*. It occurs mainly in lakes and drains, with occasional records throughout the British Isles (Balfour-Browne 1950, Friday 1988).

Gyrinus urinator Illiger

Like the previous species, isolated specimens of this species have been taken throughout the British Isles but nowhere is it widespread. Its preferred habitat is lowland rivers (Balfour-Browne 1950, Friday 1988) Amongst the gyrinids, it is unusual for the longer periods that it spends beneath the surface than most other British species (Balfour-Browne 1939).

Anacaena bipustulata (Marsham)

A. bipustulata is most frequently recorded in the south and west of England and in Wales although there are also northern English records. It inhabits streams, rivers and quarry pits (Friday 1988).

Laccobius (Macrolaccobius) sinuatus Motschulsky

Occasional specimens of this species are taken throughout England and Wales where it is most commonly found in slow flowing drains and new ponds.

Oulimnius major (Rey)

Most records of this species are from the south west, south east and Anglian regions of England, with occasional records from Wales. The taxon is most commonly found in fen drains and slow flowing lowland rivers (Friday 1988). The taxon was recorded in Britain for the first time in 1980 in the River Teme, Worcestershire (Parry 1980). Records held by the Institute of Freshwater Ecology are mainly from watercourses with silty substrata (Furse et al 1986).

Sialis nigripes (Pictet)

The first British records of this species were in the mid-1970s (Barnard 1977). Records of this species are becoming increasingly common now that a good key is available (Elliott 1996). These range from southern England to Scotland and Ireland. It tends to occur most commonly in calcareous rivers, streams and lakes (O'Connor and O'Grady 1990). It may have particular affinities with *Scirpus lacustris* and other emergent macrophytes since it is known to place its eggs on the dead stems of these species above the water-line (Kaiser 1961, Fozard and Clelland 1981). Little is known of the life history of this species although the flight period appears to be May and June (Elliott 1996).

Ceraclea senilis (Burmeister)

Wallace (1991) cites records of this species in nine counties in south east England and East Anglia, together with confirmed records for Nottinghamshire and Galloway and unconfirmed records for the River Tent in Staffordshire and the River Doon in Ayrshire. The larvae live in slow-flowing rivers, with a variety of substratum types, where it feeds on sponges (wallace 1991).

Leptocerus lusitanicus (McLachlan)

The only confirmed British records cited by Wallace (1991) are from the Thames at Day's Lock and from the River Thame at Dorchester, with an adult specimen also taken from Shiplake, near Henley. The data-base record for the current study is from Whitchurch Weir in 1990 (Blackburn *et al.* 1995). The confirmed specimens referred to by Wallace (1991) were found on tree roots. Wallace (1991) gives no information on the ecology of this species. The fact that this species is largely confined to the Thames means that it is particularly vulnerable to loss of ecological quality in this river system. Its occurrence on tree roots implies that the marginal zones, possibly near the water-line, are particularly important.

3.4 Mitigation

A review of the literature on the impacts of inter-basin water transfer is set out in Mann & Bass (1995), including assessments of the likely impacts on macro-invertebrate assemblages.

3.4.1 Discharge

The recommendations made in the fish section of this report also hold for macro-invertebrates. Most macro-invertebrate species are resilient to gradual change because this is the normal seasonal and annual pattern. Sudden changes in discharge are more likely to have a deleterious effect, particularly upon those species living at the waters' edge, including those associated with marginal and floating macrophytes, which are themselves susceptible to the impacts of rapid flow changes.

3.4.2 Sediment

Increased sediment loads and turbidity could have a range of direct and indirect impacts on aquatic macro-invertebrates. The accumulation of fines may impact habitat diversity and quality directly on river bed or indirectly through its impact on plants. Sediments may also bind potentially harmful chemicals within the sediment. Whereas most macro-invertebrate species are more likely to be disadvantaged than favoured by increased siltation and turbidity, some filter-feeding species are likely to benefit.

Indirect effects on macrophytes, which act as habitats for invertebrates, include a reduction in production due to light attenuation from increased turbidity and the deposition of silt on stem and leaf surfaces. Siltation of marginal zones may favour some plant species through the provision of a favourable rooting substratum but this material may be more susceptible to the eroding impact of wave action and the plants more susceptible to wash-out.

In summary, the impacts of increased sediment load and turbidity will vary according to the extent and quality of the sediment load and the macro-invertebrate taxa involved. Effects will not always be detrimental. Wherever possible, however, it is advisable to avoid any impacts in order to minimise environmental change. The most sensible course of mitigation is to make ample provision for sediments in the transferred water to settle in the holding lagoons before it is released into the Thames. Talbot *et al.* (1997) also recommend that residence time and aeration of water in the transfer pipe should be managed to prevent build up of sediment in the pipework and settlement ponds

3.4.3 Temperature

The temperature profile of the water is expected to show little change in response to the water transfer and is very unlike to extend the range of normal annual variation. No discernable impacts upon macro-invertebrates are expected and no specific mitigation measures are anticipated.

3.4.4 Water chemistry

Most macro-invertebrate taxa have a relatively broad range of tolerance to naturally occurring chemicals and no substantial impacts are expected from the differences in normal baseline chemistry of the Severn and Thames (Talbot *et al.* 1997). They also showed that both rivers appeared to be relatively free of micro-organic contamination.

It is assumed that the transferred water will be frequently tested at or just upstream of the point of abstraction from the Severn and in the settlement ponds in order to test for abnormal levels of potentially harmful substances in the Severn itself, or as a result of changes that occur in the transfer pipeline. It is also assumed that release will be suspended if abnormal and potentially harmful concentrations of such substances are detected.

Transferred water should be well oxygenated during the release process to avoid any possible impacts of low dissolved oxygen levels at the point of release.

3.4.5 Transfer of biota

It is feasible that specimens of macro-invertebrates may be transferred from the Severn to the Thames. However, in view of the efficient dispersal mechanisms of most species, the broad range of taxa in the Thames and additional taxa in its tributaries and the presence of few species in the Severn which are not already present in the Thames, transfer of macro-invertebrate taxa is not likely to be a problem.

The one possible exception is the zebra mussel, *Dreissena polymorpha* (Pallas), which occurs in the Severn. This taxon occurs in the lower Thames, certainly as far upstream as Reading (Institute of Freshwater Ecology unpublished records) but does not appear to have colonised the St John's to Caversham section of the river. This taxon is potentially a nuisance species with a propensity to clog the inlets and outlets of power stations and other industrial installations (Nalepa and Schloesser 1993).

Once established within a system a variety of more or less effective control mechanisms are available including oxidising chemicals (Klerks, Fraleigh and Stevenson 1993) and chlorination, surface coating, heat treatment, drying, water velocity and microsieves (Jenner and Janssen-Mommen 1993). Most of these techniques are designed to eradicate established populations in inlet and outlet pipes but some, including the use of microsieves have potential application during the transfer process if the threat of transfer is perceived to be significant Further sampling of Severn populations near the abstraction point may be necessary in order to evaluate the extent of that threat.

3.4.5 Transfer of disease

This is not considered to be an important issue.

3.5 Future Monitoring

The preceding analyses have shown that the ecological quality of the St John's Lock to Caversham Lock, as determined using RIVPACS III, is generally of a high standard. Almost all samples were classified in the top ecological quality class, biological band A, of the 5M system (Environment Agency 1977).

It has also been shown that a very diverse range of taxa have been found in this section and that many of the taxa have distinct habitat preferences.

The objective of the future monitoring programme should be to demonstrate that both the ecological quality of the river and the diversity of its macro-invertebrate assemblages are maintained during periods of flow augmentation from Severn-Thames transfer water or any other source. The following recommendations are based upon the implementation of the transfer scheme but may be modified, as necessary, to apply to alternative schemes such as the South West Oxfordshire Reservoir Development Scheme (SWORDS).

The recommendations take particular account of the low level of routine macro-invertebrate monitoring in the Buscot reach and those reaches immediately downstream of it. Another consideration has been the need for the monitoring scheme to be achievable within the staffing and financial resources available to the Agency.

3.5.1 Monitoring ecological quality

In order to demonstrate that the ecological quality of the study section of the river remains within the normal temporal range, routine monitoring using established sampling techniques (Environment Agency 1997) should be maintained at all current sites (i.e sampled in 1994 and or 1995) with an existing time series of data of at least five years Table 3.23. Single samples should be collected in spring and autumn of each year.

Table 3.23 Sites where routine monitoring should be maintained each spring and autumn

Reach no.	Agency site name	Agency sample number	First sampled
Reach 10	St John's	(PUTR.0107)	1987
Reach 18	Water Intake, Swinford	(PTHR.0114)	1980
Reach 19	Trout Inn Godstow	(PTHR.0110)	1980
Reach 22	Top of Sandford Lock Cut	(PTHR.0109)	1982
Reach 23	Abingdon Weir	(PTHR.0077)	1980
Reach 30	Whitchurch Weir	(PTHR.0115)	1990

In addition, routine monitoring needs to be instigated in the Buscot reach (Reach 11) as matter of urgency. No sampling has been undertaken in this reach since 1977 when there were indications of environmental stress. Contributary factors may have included the drought and following floods over the previous twelve months. It is imperative that new baseline conditions are established prior to the operation of the water transfer scheme.

The routine monitoring point PUTR.0107 can act as an upstream control point for monitoring the impact of augmentation. It is recommended that two sampling sites are established in the Buscot reach, one between 0.5 and 1km downstream of the augmentation release point and the other near the bottom of the reach.

In order to monitor whether any impacts detected in the Buscot reach during years of augmentation persist downstream, it is further recommended that routine sites are also established in Grafton (12) and Shifford (15) reaches. This will fill the existing gap in the sampling network between St John's (PUTR.0107) and Swinford (PTHR.0114).

3.5.2 Monitoring faunal diversity

In order to demonstrate that faunal diversity is maintained during years of augmentation, it is recommended that a regular habitat specific sampling programme is established with faunal identification at species level.

The FBA survey procedures (Furse 1978) present a pattern for the sampling procedures. In that survey thirty samples were collected in each study reach; ten in the margin, ten from vegetation and ten from mid-channel samples. Marginal and vegetation samples were collected by 30 seconds of active pond-netting whilst midstream samples were collected by airlift sampler (Mackey 1972) and were based on single 15 second blasts of air. The precise details of air-lift sampling will vary according to the design of sampler used. Providing a boat is readily available on site, collection of a given set of thirty samples should take no more than two days.

It is recommended that this sampling regime is undertaken at five yearly intervals and in all years in which the augmentation scheme is operated.

It is further recommended that this habitat specific sampling programme should be implemented in the St John's, Buscot, Grafton and Shifford reaches. This will establish an upstream control reach (St John's), two reaches most likely to be impacted by the augmentation (Buscot and Grafton) and a downstream control reach (Shifford). It will also offer a measure of comparability with 1977 when both the Buscot and Shifford reaches were sampled in this way.

In order to limit the time needed to analyze the samples collected, it is recommended that no detailed identifications be made of the following groups; Oligochaeta, Hydracarina and Chironomidae. It is further recommended that external specialist identification of Sphaeriidae is contracted in order to determine whether taxa of national conservation status are present (Table 3.22).

The habitat specific sampling should ideally be co-ordinated with the macrophyte sampling programme recommended in the following chapter but consideration may need to be given to a rolling programme, with sampling effort divided between two years, where resource limitations make this desirable.

3.5.3 Monitoring taxa of conservation importance

Regular sampling programmes to monitor the presence of taxa with national conservation status is not recommended because the process itself may impact upon the taxa being monitored.

Instead it is recommended that sub-sets of routine monitoring samples be identified to species level either internally or by contracting out to specialist organisations.

3.5.4 Other recommendations

It is recommended that the time series of BMWP index values held for many sites (Table 3.23) is examined in relation to discharge levels over the same period to determine whether there are any statistical relationships between the two sets of values and any indications of critical discharge levels associated with loss of ecological quality.

It is recommended that steps are taken to establish the status of *Dreissena polymorpha* populations in the Severn and any remedial steps that may be necessary to prevent inter-basin transfer.

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4 MACROPHYTES

4.1 Introduction

Existing macrophyte records were sought from the same sources as the macro-invertebrate data (see section 3.1).

The only available data-set of any detail was that collected during the FBA's 1977 survey (Furse 1978). In this study frequency data were collected for all observable aquatic macrophytes between St John's Lock and Benson's Lock (Figure 3.2).

Monitoring was undertaken from a moving vessel travelling at an approximately constant speed of 7km h^{-1}. Data were collected moving downstream and expressed as frequencies of occurrence per sampling unit for each inter-lock reach. A sampling unit comprised two minutes of travel (approximately 250m). Successive sampling units were from alternate banks since only those macrophytes on one bank could be identified at a time and between bank differences needed to be eliminated.

The only other data source was River Corridor Surveys undertaken for the Environment Agency in 1992 by Ecosurveys Limited and River Habitat Surveys undertaken by IFE as part of the current contract.

Two River Corridor surveys were undertaken by Ecosurveys Ltd between May and August (Ecosurveys Ltd 1992a, 1992b). One survey covered the section between Eynsham and Sandford and the other the section between Abingdon and Benson Locks. Sampling was undertaken according to the standard NRA and English Nature methodology operating at that time and included the main river and side channels. Watercourses were divided into 500m lengths and, in the Thames, aquatic macrophytes were recorded from a boat.

Data on the IFE surveys are presented elsewhere (Bass & Collett, 1997)

4.2 Methods

The FBA data were stored in the same relational data-base using the same system of reach classification as for the macro-invertebrates. Confirmation of identifications were often made in the field by the specialist botanist Sylvia Haslam, then of Cambridge University, who was present on the research vessel during the sampling of several of the upper reaches.

The results were less complex than many macro-invertebrate samples and were not supported by extensive environmental or habitat data.

Conversely the Ecosurveys data were too complex for inclusion in the data-set and the user is referred to the original documents (Ecosurveys Ltd 1992a, 1992b) where individual maps of each 500m length are presented. The executive summaries and key supporting tables and figures from these reports are given in Appendix 4.1.

4.3 Results

The longitudinal frequency distribution of all macrophytes recorded during the FBA 1977 survey are given in Figure 4.1.

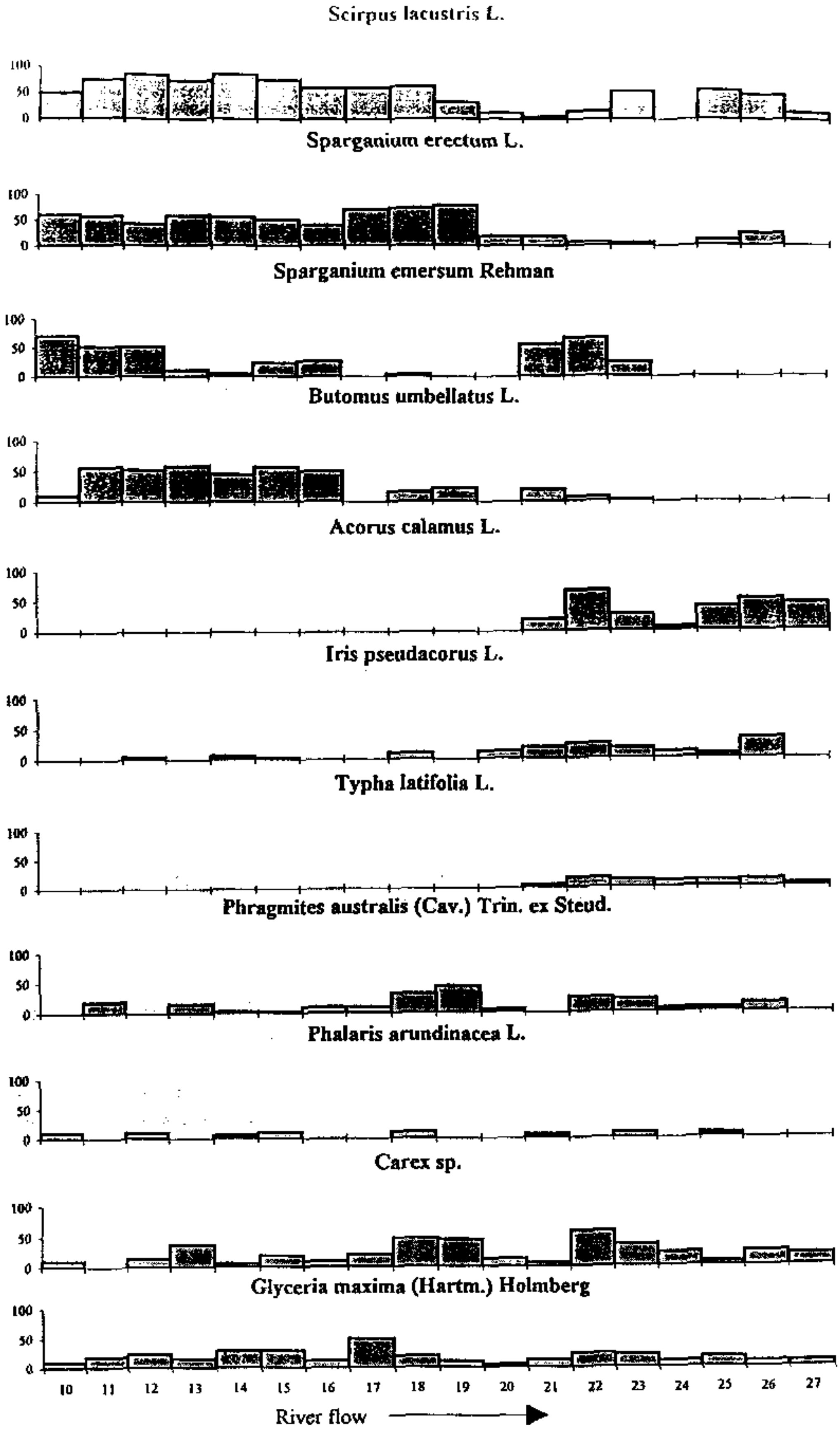

Figure 4.1 A histogram of the frequency of occurrence of twenty macrophyte taxa in each of eighteen inter-lock reaches from 10 (St John's to Buscot) to 26 (Clifton to Day's). Frequencies determined by presence or absence of sightings during fixed time periods of downstream boat travel at a constant speed.

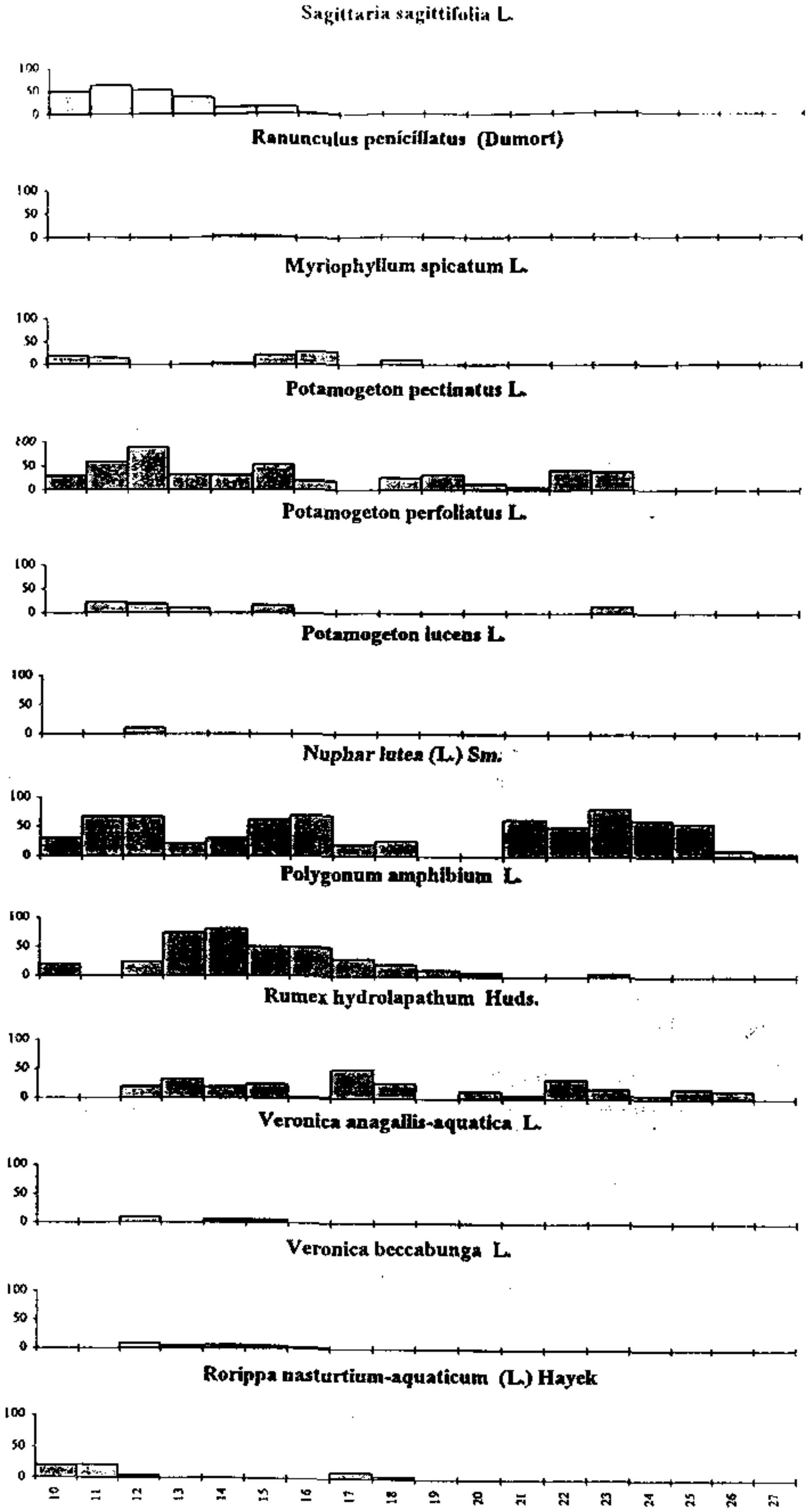

Figure 4.1 (continued) A histogram of the frequency of occurrence of ten macrophyte taxa in each of eighteen inter-lock reaches from 10 (St John's to Buscot) and 26 (Clifton to Day's). Frequencies determined by presence or absence of sightings during fixed time periods of downstream boat travel at a constant speed.

Some taxa were distributed over the study section of the river. However, many others showed evidence of longitudinal zonation. The break point in the zonation of many taxa was at, or about, Godstow Lock, upstream of Oxford.

Taxa which were more frequent in, or confined to, the St John's to Godstow section included *Sparganium erectum*, *Sparganium emersum*, *Sagittaria sagittifolia*, *Myriophyllum spicatum*, *Potamogeton pectinatus*, *P. perfoliatus* and *Rumex hydrolapathum*. The reed *Butomus umbellatus* showed a less marked tendency to be more frequent in the upper section.

Taxa which were more frequent in, or confined to the Godstow to Benson's Lock section included *Acorus calamus*, *Iris pseudacorus* and *Typha latifolia*.

4.4 Mitigation

Flowering plants, adapted to live wholly or partly in water, together with particular ferns, bryophytes and filamentous macro-algae, comprise the macrophytic element. Most natural macrophytic stands also have numerous species of micro-algae, micro-organisms and invertebrate in close association. Macrophytic vegetation is usually classified by life-form (submerged-rooted, emergent, floating-leaved free-floating, etc) and all main types are represented in the totality of river habitats (Fox, 1992): physical features of the channel and of the water flow predominate. The main courses of much of the Severn and long reaches of the Thames are amenable to the growth of flow-tolerant macrophytes; side arms, backwaters, weir leats may support many more less flow-tolerant species.

The main concerns arising from the proposed transfer are the passage of seeds, turions or other propagules, the opportunity for spawning vigourous novel hybrids and for the carriage of pathogenic organisms from one to the other. Without detailed knowledge of the fluvial flora of either catchment or a sound grounding in the strains represented therein, it is not possible to predict any particular event dependent on the proposed transfer. The proponents do need to be aware of the small risk of a virulent, invasive spread of a new hybrid, or of a die-back of existing flora through the introduction of a new strain of pathogen.

4.5 Future Monitoring

Macrophytes should be monitored in the four reaches selected for habitat-specific macro-invertebrate sampling: a control site in Reach 10 (St John's) and impact/recovery sites in reaches 11 (Buscot), 12 (Grafton) and 15 (Shifford). Two sampling sites should be established in the Buscot reach, one between 0.5 and 1km of the release point for Severn water and the other at the bottom of the reach.

All these sites should be at or near the existing or recommended routine macro-invertebrate sampling sites in order that results can be cross-referenced. Each of the four reaches is also recommended for habitat-specific macro-invertebrate sampling, again facilitating cross-comparisons.

The recommended sampling methodology is the Mean Trophic Rank (MTR) method which is being developed as a standard procedure within the Agency (Newman *et al.*, in preparation). MTR is based on the presence and abundance of aquatic macrophytes and uses a simple scoring system to derive a single index to describe the trophic status of a site. Sampling should be on an annual basis.

If resouces permit, then it is recommended that the survey procedures adopted by IFE, in 1977 namely frequency of occurrence data using timed intervals of downstream boat travel, (Furse, 1978) are repeated before the first release of augmentation water and thereafter at five-yearly intervals to co-incide with the habitat-specific macro-invertebrate sampling. The section of river covered should, at a minimum, be from St. John's to Day's Lock. This builds on the baseline established in 1977 and provides data pertinent to both the Severn-Thames transfer and the South Oxfordshire Reservoir Project.

All data should be stored in a relational database.

4.6 Bibliography

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5 PLANKTON

5.1 Introduction

The objectives of this review of planktonic data were

- to obtain existing information on phytoplankton and zooplankton in the study reach between St John's Lock and Caversham Lock

- to collate these in a series of tables and computer files, thus drawing the sources of key information together in a single bound report

- to comment on the significance of the data for the proposed Severn-Thames water transfer

- to identify an appropriate monitoring programme which will enable the impacts of any future water transfer upon phytoplankton and planktonic animals to be evaluated

The principal source of information was Environment Agency studies (Ruse and Hutchings 1996, Ruse and Love 1997). Raw data were supplied to the authors by Alison Love (Environment Agency - Thames Region).

In this chapter the data holdings are listed, the potential impacts of the proposed transferaddresses possible biotic consequences of inter-basin transfers of river water relevant to phyto-plankton and planktonic animals.

5.2 Data files

Available data were drawn together in the form of a series of files, prepared in Microsoft Access, which are held by both the Institute of Freshwater Ecology (IFE) and the Environment Agency, Thames Region. The file names and their contents are as follows:

File SWNOS

Contains 10160 lines of information, giving counts (in cells ml^{-1}) of all taxa present in each of 237 numbered water samples. Species data are stored in file SWTAX described below.

File SWORDS

Contains 72 lines of information, giving chlorophyll *a* concentrations ($\mu g\ ml^{-1}$) at four sites including Abingdon (SU 506 970) and Caversham (SU 720 741) within the review section (Figure 5.1). Data are held for 18 fortnightly occasions between 10 January and 18 September, 1996.

File SWSAM

Contains 854 lines of information referring to a series of surveys carried out at approximately fortnightly intervals between August 1992 and September 1996). Seven of the 12 sites for which data are held are within the current review section (Figure 5.1). These are: Newbridge (SP 403 014), Folly Bridge (SP 514 055), Abingdon (SU 506 970), Day's Lock (SU 568 935), Wallingford Bridge (SU 610 895), Goring Lock (SU 596 809) and Caversham Weir (SU 720 741). Entries are dated but not stored in chronological order within the data-base.

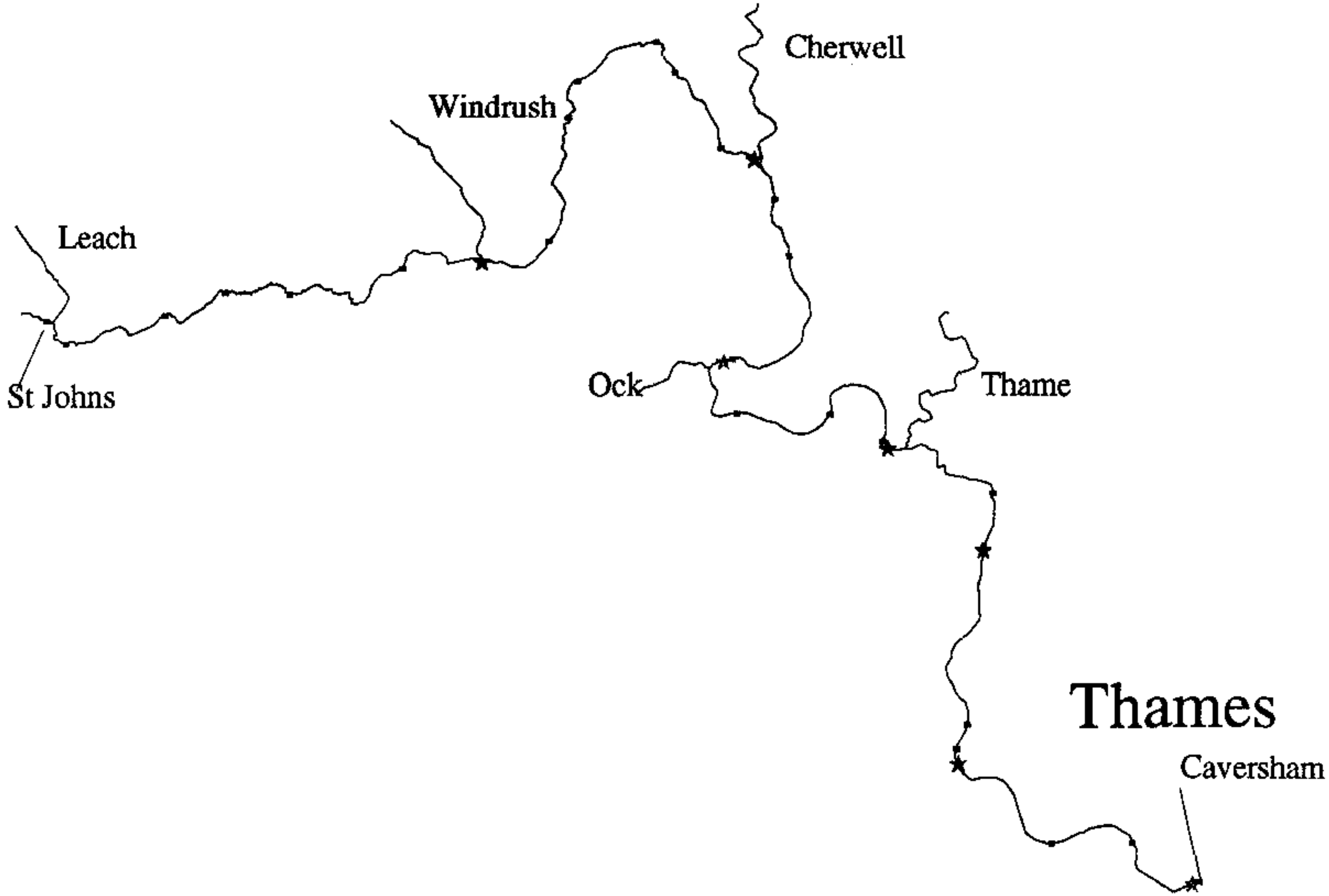

Figure 5.1 **The location of the seven sites sampled for chlorophyll *a* and/or phytoplankton and environmental data and held in data-files SWORDS and SWSAM in the Thames data-base. Sites sampled for chlorophyll *a*, phytoplankton and environmental data are shown as green stars. Sites only sampled for chlorophyll *a* are shown as plum stars. Red dots are locks.**

Determinands which are well covered in file SWSAM, with very few blanks or missing data, include: pH, BOD (mg l^{-1} O_2), temperature (°C), dissolved oxygen (% saturation), total organic (Kjeldahl) nitrogen (mg l^{-1}), nitrate-N (mg l^{-1}), nitrite-N (mg l^{-1}), ammonium-N (mg l^{-1}), orthophosphate-P (mg l^{-1}), total phosphate (mg l^{-1}), silicon (mg l^{-1} SiO_2), Secchi-disc reading (cm), discharge on sampled date (m^3 s^{-1}) and chlorophyll *a* concentration (µg l^{-1}).

The data-file also includes some useful interpretive terms: total sunshine hours in the previous 7 and 14 days, the discharge for the 10 days prior to sample collection and the N:P ratio.

The file also contains total algal cell counts per ml ("TOTCELLS M"). These are derived from counts in fields in a counting chamber of cells concentrated by sedimentation. The cell concentration is calculated from the actual count (not provided in the data-base) divided by the number of fields counted ("FIELDCOUNT"), multiplied by the number of fields per ml ("CELLFACT") and divided by the concentration of the sample ("SAMPCONC").

File SWSIT

Contains 22 lines bearing the identities of sampling sites along the Thames, and their National Grid References and distances from source (km). Only 12 of these stations are regularly specified in the SWORDS and/or SWSAM data-files.

File SWTAX

Contains 1741 lines of data, including the biological name and numeric coding assigned to each taxon recognised in the Water Data Unit dictionary compiled by Whitton *et al.* (1978).

The data held in these files are too extensive to present here in fully tabular form but the option exists to incorporate them in a linked data-base with that containing macro-invertebrate and macrophyte information.

5.3 Evaluation of the Potential Impacts of Severn-Thames Water Transfer

5.3.1 Phytoplankton

Most of the present ideas about how and why phytoplankton should grow, sometimes with conspicuous success, in unidirectionally-flowing rivers belong to a developing paradigm. Much of this was assembled by Welch (1952), drawing heavily on work by Butcher (1932) and Chandler (1937).

In a recent essay, Reynolds & Descy (1996) have critically reviewed the supposed mechanisms underpinning the fact that larger rivers, achieving fourth order, characteristically carry distinctive potamoplankton. River plankton is, indeed, surprisingly conservative in composition when compared (at least, at the level of genus) with lake and reservoir phytoplankton, and subject to broadly regular and predictable fluctuations in abundance. The reasons for this are partly related to the character of channels and their hydrology, and the opportunities they provide for planktonic algae to fulfil their growth requirements and divide. The relationship with length is in fact a function of the time of travel. The more divisions accommodated, the greater the population that can be achieved.

This generalisation is always subject to the dominance of physical conditions in rivers (transport, turbulence and turbidity) of rigourous selectivity: true potamoplankton has to be fast-growing, to be good light antenna and to be capable of maintaining an inoculum in the river at the times when conditions suppress growth. Small centric diatoms and attenuated pennate diatoms, each with an acknowledged capacity for meroplankty, and several genera of chlorococcales which can be maintained as epiphytes are thus conspicuous components of river plankton. Of course, many other species may occur, as chance introductions or colonists under conditions of low flows (among which cryptophytes and filamentous Cyanobacteria are often conspicuous; under prolonged flows almost any species, including of bloom-forming cyanobacteria, can be encountered). Thus, the plankton of rivers can be quite species-rich at times, yet, typically, diversity and equitability are low, centred about a core of species common to all (Reynolds, 1994).

Abundance and species composition in a given river changes in time. Low flow, warm water temperatures and high insolation in sinuous channels all promote growth; poor insolation, compounded by channel depth and high suspended sediment loads, depress it; growth is very restricted during high winter discharges. In most of the world's truly large rivers, in sixth-order channels and higher, depth and turbidity combine to prevent net phytoplankton growth throughout the year. Since no UK rivers exceed sixth order, we can accept a probability that the general expectation of enhanced downstream algal populations normally holds.

Another important feature of the predominantly physical regulation of phytoplankton in rivers is that the traditional view of the importance of chemical controls (through nutrients) and the anticipated intervention of biotic factors (chiefly grazing by zooplankton) do not apply, except under long, unaltered environmental conditions, such as persistent low flow. Prolonged residence, low water and high insolation drive the anabolic processes towards the capacities set by the nutrient inputs and provide the opportunity for the dynamics of planktonic and benthic consumers to catch up with an expanding resource. There is good evidence, revealed in Reynolds & Descy (1996), to the effect that grazing, by rotifers in particular, detracts from the biomass supported in large, regulated European rivers, especially towards the end of summer. The very high nutrient contents of most British rivers (Muscutt & Withers, 1996) determines that reductions in summer biomass at low summer discharges are more likely to be attributable eventually to grazing and not to nutrient limitation.

Summarising, rivers are capable of supporting large populations of phytoplankton, especially in their middle and lower reaches, and up to concentration-capacitities determined by light income (400 - 500 μg chlorophyll l^{-1}), as mediated primarily through flow.

The implications for the proposed transfer are that potentially high concentrations of fluvial algae will be transferred from the lower Severn to the upper Thames, at a point where, under present circumstances, algal populations may be often less concentrated. The mix of species would be similar to both (though not in the same proportions: cf. data for the two rivers summarised in Reynolds (1994; for more detailed species lists, cf. Reynolds & Glaister, 1993; Ruse & Hutchings, 1996) and eventually subject to the same powerful selective pressures operating in the middle and lower Thames. The (light-determined) carrying capacity will scarcely be altered, while the prospect of a more sustained base flow might marginally move downstream, the point at which it is achieveable. Any dilution or enhancement of the nutrient content is unlikely to alter greatly the fertility of the mixed water (as shown experimentally by Collie & Lund, 1980) or the ability of the nutrients to saturate the energy-limited carrying capacity of the algae.

No substantial risk to the algal quality of either river or abstracted water arises from the proposed transfer. Whatever may be the objections to such a transfer, the likely impact on the phytoplankton of the Thames is not one of them.

5.3.2 Zooplankton

Superficially, analogous deductions apply to the impact of the proposed transfer on zooplankton. In fact, the knowledge of what species are present or likely to be present in British rivers is less well-developed than that of the phytoplankton. The zooplankton comprises cladocerans, copepods, protists and rotifers, but it is the latter which are the most likely to be the most significant consumers of phytoplankton. They alone have the *in situ* population growth rates that can come close to those of the phytoplankton and which hold up despite unidirectional flow.

The principal species are of the genus *Brachionus* and there seems to be no good reason to suppose that the species differ significantly between the rivers.

Care must be taken, however, over the possible transfers of diseases, pathogens and parasite propagules associated with zooplankton, suspended benthos or similar sized particles.

5.4 Towards a monitoring strategy

An adequate basis for determining the effects of transfers of Severn water on the phytoplankton of the Thames could reasonably be established with a fortnightly programme of samples. The principal variables that require to be monitored are:

- the biomass of Severn phytoplankton transferred, sampled at or just above abstraction point and in the aqueduct at the point of discharge into the Thames
- the biomass of Thames phytoplankton at one site above the point of discharge
- the biomass of Thames phytoplankton 1-2 km below the point of discharge, after good integration has been allowed to take place, and
- the biomass of phytoplankton at stations approximately 5km (Buscot - Reach 11), 10km (Grafton - 12), 25km (Shifford - 15) and 50 km (Iffley - 22) further downstream.

Determinands should include cell counts (with biomass/bio-volume conversion). This is far superior to qualitative identification of the species making up the measured chlorophyll contents, although that is better than nothing.

Zooplankton could be enumerated from larger volumes of the same water.

The programme might start before the engineering work is implemented: some sort of "before" baseline is often very useful when supposedly novel consequences are investigated.

The itensity of sampling could be relaxed pragmatically, as the impact of the transfer became recognised.

It is assumed that discharges will continue to be monitored in the Severn and Thames, and that water temperature will continue to be logged. Pumping rates are also needed in some detail, in order to estimate the planktonic mass transferred. Analyses of nutrients beyond current routines are probably not justified.

5.5 Bibliography

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6 SUMMARY OF DATA SOURCES AND RECOMMENDATIONS FOR FUTURE MONITORING

On the following pages summary details are provided of the data sources consulted during this review (Table 6.1) and the major recommendations for future monitoring (Table 6.2).

Unless given in full in Table 6.1, references cited in this table are those listed in the respective chapters of the various taxonomic groups.

Table 6.1 Summary details of the sources of biological data considered during this review

FISH

Study	No. sites	Sections studied	Data collected and methods of collection.
EAU (1991a)	36	u/s Oxford to Day's Lock	Fry densities. Size at end of year one. Growth rates. Seine netting.
EAU (1991b)	Not known	Not known	Adult fish distribution. Method not known.
Duncan (1992a)	13 (all included in the 1991 EAU study)	Oxford to Day's Lock	Fry densities, overall and by micro-habitat type. Percentage composition by species and by age group, each also by micro-habitat. Most detailed sampling in Sutton Pools. Seine netting.
Duncan (1992b)	9	Sutton Pools	Fry densities, overall and by micro-habitat type. Percentage composition by species and by age group, each also by micro-habitat. Seine netting.
Hughes (1993)	5 reaches	Sandford Lock to Benson Lock	Adult fish densities by species by reach. Some breakdown of catch by mid-channel and margin. Comparison of electric fishing and hydroacoustic methodologies.
Hughes (undated) (1994?)	3 sections of 3-4 km 1 bank per section	Sandford Mill to Day's Lock	Fishing habits, methods, frequency, target species, experience. Current catch weight and species composition on day of survey. Personal interviews.
Hughes (1994)	5 reaches as per Hughes (1993)	Sandford Lock to Benson Lock	Adult fish densities by species by reach. Some breakdown of catch by mid-channel and margin. Age frequency and recruitment rates per species. Comparison of electric fishing & hydroacoustic methodologies.
Mann and Berrie (1994)	Two rivers	Thames Dreadnought Reach	Review of studies of coarse fish communities undertaken on the River Thames (Dreadnought Reach, Reading) during 1958-73 and the Great Ouse since 1988. Desk study with recommendations.

FISH (continued)

Study	No. sites	Sections studied	Data collected and methods of collection.
KES (1994a)*	14 (the same as in Duncan (1992a) + Abingdon Marina)	Oxford to Day's Weir	Juvenile fish densities, overall and by species and micro-habitats. Instantaneous rates of mortality and survival. Length weight conversions. Biomass (standing crop). Seine netting.
KES (1994b)**	14 (the same as in KES (1994a)	Oxford to Day's Weir	Juvenile fish densities, overall and by species and micro-habitats. Instantaneous rates of mortality and survival. Length weight conversions. Biomass (standing crop). Seine netting. Multiple regression analysis of fish habitat variables against fish densities.
Hughes (1994)	5 reaches as per Hughes (1993)	Sandford Lock to Benson Lock	Adult fish densities by species by reach. Some breakdown of catch by mid-channel and margin. Age frequency and recruitment rates per species. Parasitic infection rates. Comparison of electric fishing & hydroacoustic methodologies.
KES (1995)	14 (the same as in KES (1994a)	Oxford to Day's Weir	Juvenile fish densities, overall and by species and micro-habitats. Instantaneous rates of mortality and survival. Length weight conversions. Biomass (standing crop). Fish density/habitat variable relationships.Habitat preferences. Seine netting. Regression analyses.
Mann *et al.* (1995)	One	Abingdon	Between-species, between-habitats and between-season differences in fish diets. Comparison with data from the Great Ouse. Assessment of likely responses to change in flow regime. Seine netting.

* KES (1994a) = Kings Environmental Services (1994) *River Thames Juvenile Fish Survey 1993*. Volume 1 - Main Report. Volume 2 - Site Reports. Report to the National Rivers Authority Thames Region. *(not cited in main report)*

** KES (1994b) = Kings Environmental Services (1994) *River Thames Juvenile Fish Survey 1994*. Volume 1 - Main Report. Volume 2 - Site Reports. Report to the National Rivers Authority Thames Region. *(as cited in main report)*

MACRO-INVERTEBRATES

Study/Source	No. sites/samples	Sections studied	Data collected and methods of collection.
Furse *et al*. (1977) Upstream survey	18 reaches with 9 sampling locations per reach	Day's to St. John's Lock	"Species" presence/absence per reach. Sampling zone (margin, mid-channel or vegetation). Substratum characteristics. Timed pond-netting or standard number of air-lifts.
Furse *et al*. (1977) Downstream survey	5 reaches with a minimum of 30 distinct samples per reach.	Buscot Lock to Grafton Shifford to Northmoor Eynsham to Kings Iffley to Sandford Clifton to Day's Lock	Species presence/absence per sample and per reach. Samples distinguished by zone and substratum type. Timed pond-netting or standard number of air-lifts.
Ruse (unpublished) Data from 1977-94.	42 samples from 5 sites	Buscot, Newbridge, Swinford, Clifton Hampden and Whitchurch	Lists of chironomid species present as pupal exuviae. Absolute abundances and percentage composition of taxa in each sample Separate listings by taxonomic order and descending order of abundance. Percentage composition, by species and number of individuals also listed by sub-families or tribes and by trophic groups. A variety of biotic indices calculate, mainly diversity indices. Taxa divided into valency classes indicative of their tolerance to pollution. Samples or sites allocated to named ecological quality classes. Single samples or composite samples based on one or more year's collections. Surface netting.
Water Industry Routine Monitoring (1980 - 1985)	110 samples from 20 sites	St. John's Lock to Caversham Weir	Log. categories of abundance of BMWP families. BMWP index values of BMWP score, number of scoring taxa and average score per taxon (ASPT). Supporting environmental data, mainly .
Freshwater Biological Association (unpublished). RIVPACS samples, 1982.	6 samples from 3 sites.	Malthouse (near Buscot), Bablock Hythe and Shillingford.	Presence/absence of species and log. categories of abundance of all families. Separate margin and mid-channel sampling in each of spring, summer and autumn. Supporting environmental data, as required for RIVPACS predictions. Timed pond-netting of margins. Naturalists' medium dredging of mid-channel.

MACRO-INVERTEBRATES (CONTINUED)

Study/Source	No. sites/samples	Sections studied	Data collected and methods of collection.
Pond Action (1992)	12 sites	Top of Sandford Lock Cut to Day's Lock	Absolute abundance of most species with additional records of some taxa from other sources.. Presence/absence of all families. A single summer sample per site. Listings of rare, notable and local taxa recorded during the study. BMWP index values and ecological quality assessments. National Conservation Scores and index values for each site. Supporting environmental data, as required for RIVPACS predictions. Timed pond-netting plus additional records from Oxfordshire County Records Centre.
Oxford Structures Plan Investigations (unpublished) Sampling in 1992	7 sites	Swinford Water Works to Radley College Boathouse	"Species" level abundance categories. A single summer sample per site. BMWP index values. Supporting environmental data, as required for RIVPACS predictions. Timed pond-netting.

MACROPHYTES

Study/Source	No. sites/samples	Sections studied	Data collected and methods of collection.
Furse *et al.* (1977)	18 reaches. Continuous sampling.	St. John's to Day's Lock	Frequency of occurrence of macrophyte "species" per constant units of downstream travel (two minutes at constant speed). Consecutive units taken from alternate banks.
Ecosurveys (1992a) River Corridor	61 river corridor sections (500m), all on main river.	Benson to Abingdon Lock	Standard Environment Agency and English Nature methodologies. Some aquatic macrophyte information on the main river, with sampling by boat and from the bankside. River corridor quality assessment made using the London Ecology Unit River Reach Evaluation procedure. Extensive use of maps.
Phase 1	Thames floodplain	Benson to Abingdon Lock	Ecological land use survey using standard Environment Agency and English Nature methodologies. No information on aquatic plants in the main river channel.
Phase 2	16 sites but none on the main river	Benson to Abingdon Lock	Detailed NCC Phase 2 style botanical surveys of water level dependant habitats of conservation interest in the designated Thames floodplain. Sites included flushes, marshy pastures, swamps, open-water sites, wet woodlands and tall herb marshes. No nationally or regionally rare plants recorded.
Ecosurveys (1992a) River Corridor	148 river corridor sections (500m), 49 on main river	Eynsham to Sandford Lock	Standard Environment Agency and English Nature methodologies. Some aquatic macrophyte information on the main river, with sampling by boat and from the bankside. River corridor quality assessment made using the London Ecology Unit River Reach Evaluation procedure. Supporting desk study. Extensive use of maps. For examples of data collected see Appendix 4.1 of the current report.
Phase 1	Thames floodplain	Eynsham to Sandford Lock	Ecological land use survey as Ecosurveys 1992a (above). No information on aquatic plants in the main river channel.
Phase 2	34 sites but none thought to be on the main river	Benson to Abingdon Lock	Detailed Phase 2 botanical surveys of water level dependant habitats of conservation interest in the designated Thames flood-plain. Details as per Ecosurveys 1991a (above).

PHYTOPLANKTON

Study/Source	No. sites/samples	Sections studied	Data collected and methods of collection.
Environment Agency, Thames Region. File: SWORDS	2 sites	Abingdon and Caversham Weir	Chlorophyll a concentrations (ng ml^{-1}). 18 fortnightly sampling occasions between 10 January and 18th September, 1996.
Environment Agency, Thames Region. File: SWAM	7 sites	Newbridge to Caversham Weir	Data on a variety of chemical determinands, temperature, Secchi disc readings, flow, preceding weekly/fortnightly sunshine hours, chlorophyll a concentrations and total algal cells ml^{-1}. Approximately fortnightly sampling from August 1992 to September 1996.
Environment Agency, Thames Region File: SWNOS	237 samples	Not known	Counts (in cells ml-1) of major taxa of phytoplankton.

Table 6.2 Recommendations for future monitoring

Reach name (no.)	Fish	Macro-invertebrates	Macrophytes	Phytoplankton
St. John's (10) Upstream control reach	Undertake fry and juvenile fish surveys, including food availability, feeding and growth of fry, of the type currently being conducted downstream of Oxford for the South West Oxfordshire Reservoir Project. The first surveys to be conducted prior to the first year of augmentation of River Thames flow with water from the River Severn	Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0114 Undertake habitat-specific sampling of marginal, mid-stream and vegetation zones. Species-level identification. Frequency: five yearly with the first sampling prior to first year of augmentation (see Section 3.5.2 for more details)	Annual macrophyte surveys, at a single site, using Mean Trophic Rank (MTR) methodologies. The first survey should be prior to first year of augmentation Site location to be at or close to the routine macro-invertebrate monitoring site.	Fortnightly programme of routine sampling. Determinands should include biomass and cell counts with biomass/bio-volume conversion. First sampling prior to the first year of augmentation
Buscot (11) Reach containing the proposed release point for transferred Severn water	Undertake fry and juvenile fish surveys as per St. John's	Establish two new routine annual spring and autumn monitoring sites, one between 0.5km and 1km downstream of the augmentation release point and the other at the bottom of the reach Undertake habitat-specific sampling as per St. John's. Compare with 1977 baseline	Annual macrophyte surveys, at a two sites, using Mean Trophic Rank (MTR) methodologies. Site locations to be at or close to the routine macro-invertebrate monitoring site.Macrophyte mapping?	Fortnightly programme of routine sampling. The sampling location to be 1-2km downstream of the release point (i.e near the end of the reach).

Reach name (no.)	Fish	Macro-invertebrates	Macrophytes	Phytolankton
Grafton (12)	Undertake fry and juvenile fish surveys as per St. John's	Establish a new routine annual spring and autumn monitoring site Undertake habitat-specific sampling as per St John's.	Annual macrophyte surveys, at a single site, using Mean Trophic Rank (MTR) methodologies, as per St. John's	Fortnightly programme of routine sampling, as per St. John's
Radcot (13)				Fortnightly programme of routine sampling, as per St. John's
Rushey (14)				
Shifford (15)	Undertake fry and juvenile fish surveys as per St. John's	Establish a new routine annual spring and autumn monitoring site Undertake habitat-specific sampling as per St John's. Compare with 1977 baseline	Annual macrophyte surveys, at a single site, using Mean Trophic Rank (MTR) methodologies, as per St. John's	Fortnightly programme of routine sampling, as per St. John's
Northmoor (16)				
Pinkhill (17)				
Eynsham (18)		Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0114		
King's (19)		Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0110		
Godstow (20)				

Reach name (no.)	Fish	Macro-invertebrates	Macrophytes	Phytoplankton
Osney (21)	Continue, on an annual basis, the present series of surveys of fry and juvenile fish being conducted for the South West Oxfordshire Reservoir Project Studies on the food availability, feeding and growth of fry should be maintained			
Iffley (22)		Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0109		Fortnightly programme of routine sampling, as per St. John's
Sandford (23)		Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0077		
Abingdon (24)				
Culham (25)				
Clifton (26)				
Day's (27)				
Benson (28)				
Cleeve (29)				
Goring (30)		Maintain routine annual spring and autumn monitoring at Agency sample site PTHR.0115		
Whitchurch (31)				
Mapledurham (32)				

Reach name (no.)	Fish	Macro-invertebrates	Macrophytes	Phytoplankton
GENERAL	In the reaches most likely to be affected by the Severn-Thames transfer (and/or the South West Oxfordshire Reservoir Project) factors affecting fry survival should be examined. These include surveys of larval and juvenile habitat requirements to ensure that these areas are conserved.	Habitat-specific sampling may need to a rolling programme with sampling divided between two-years. It should be co-ordinated with the macrophyte sampling programme Regular sampling to monitor the status of conservation taxa not recommended but sub-sets of routine monitoring samples should be identified to species to check for rare taxa	If resouces permit, then it is recommended that the survey procedures adopted by IFE, namely frequency of occurrence data using timed intervals of downstream boat travel, (Furse *et al*. 1978) are repeated before the first release of augmentation water and thereafter at five-yearly intervals to co-incide with the habitat-specific macro-invertebrate sampling. The section of river covered should, at a minimum, be from St. John's to Day's Lock. All data should be stored in a relational database.	Information is also needed on the biomass of the plankton transferred from the River Severn. This should be sampled at, or just above the abstraction point and in the aqueduct at the point of discharge. It is assumed that flows and water temperatures in the Severn and Thames will continue to be logged. Pumping rates need to be known in detail, particularly during estimation of the biomass of phytoplankton being transferred. Analysis of nutrients beyond current routines are probably not justified. Zooplankton should be enumerated from larger volumes of water collected at the same time and locations as the routine phytoplankton samples