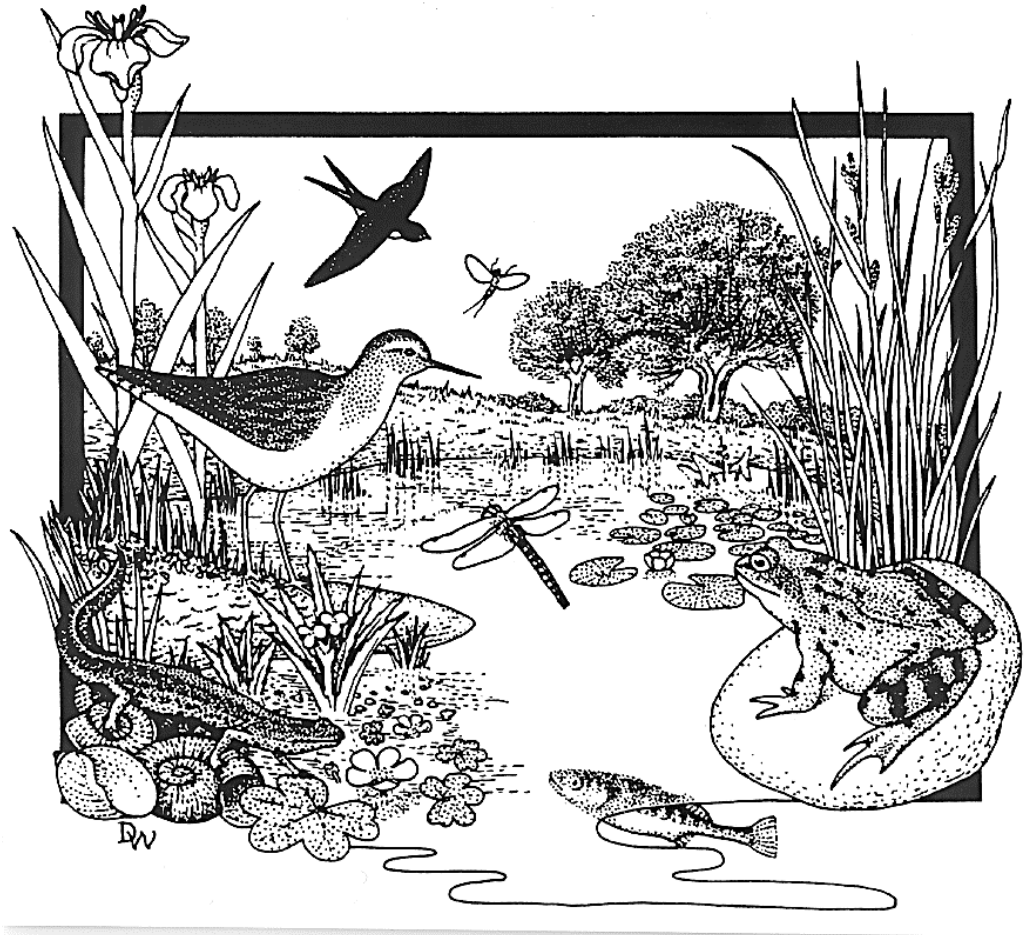
Appraisal of Amberley Wild Brooks aquatic invertebrate, wetland plant and water chemistry monitoring data

Final Report



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Appraisal of Amberley Wild Brooks aquatic invertebrate, wetland plant and water chemistry monitoring data

Summary

This report reviews and evaluates data from Amberley Wild Brooks, West Sussex, describing water quality, aquatic macroinvertebrates and wetland plant assemblages in the Amberley ditches. The report provides information on the condition of the Amberley Wild Brooks SSSI, and also on part of the Arun Valley SPA and Ramsar site.

The relatively limited invertebrate information available shows that Amberley supports rich aquatic invertebrate assemblages, including BAP and RDB invertebrate species. There is, however, an indication that overall invertebrate species richness is lower at Amberley than in other southern England grazing marsh ditch systems. Botanically, the Amberley ditches are outstanding: both rich in wetland plants and supporting nationally important populations of RDB and BAP species.

Existing monitoring programmes currently provide rather little information about biological trends at Amberley. No overall assessments of trends in the biological quality of the site are possible, either for plants or invertebrates, although it is obvious that the site is still a high quality location. Monitoring of BAP molluscs, particularly *Anisus vorticulus* (Little Whirlpool Ram's-horn Snail) has provided information on very short timescale trends.

The fact that the existing programmes of biological monitoring provide little long-term trend information is because:

(i) So far, monitoring programmes implemented have been of short duration

(ii) Survey methods have varied or lacked a standard, quality controlled, methodology.

Water quality monitoring, in contrast, provides important trend information at Amberley. In particular, there is evidence of an approximate doubling in orthophosphate phosphorus concentrations since 1996. This increase has occurred despite measures on and around Amberley Wild Brooks to reduce nutrient inputs. Total oxidised nitrogen concentrations are generally above levels regarded as 'natural' background levels, but no trends, either increasing or decreasing, are evident since 1996. There is also evidence of localised water quality deterioration, possibly as a result of small sewage effluent sources.

Given that good water quality is likely to be the most important environmental factor in maintaining the biological quality and special interest of Amberley, these results are worrying.

We recommend that a more detailed study of ditch hydrology and catchment nutrient sources is undertaken and that careful attention is paid to monitoring the biota likely to be most sensitive to water quality deterioration.

In the light of the results of these studies we anticipate that it will be necessary to identify further methods for reducing nutrient inputs to the Amberley ditch system.

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Appraisal of Amberley Wild Brooks aquatic invertebrate, wetland plant and water chemistry monitoring data

1. Introduction

Amberley Wild Brooks grazing marshes in West Sussex are well known for their rich aquatic flora and fauna, including many uncommon and rare species. Since 1996, a number of studies have been carried out at the site to collect data on macroinvertebrates, macrophytes and a range of physico-chemical variables.

This report, which was commissioned by the Environment Agency and the RSPB, and written by the Ponds Conservation Trust: Policy & Research, provides a summary of data describing the ecological quality of Amberley Wild Brooks including:

- Analysis of historical water chemistry data
- Analysis of species-level Environment Agency macroinvertebrate data from 1999
- Analysis of Environment Agency 2003 datasets (macroinvertebrates, water chemistry, diatoms and Mean Trophic Rank data)
- Provision of a summary of the results and conclusions of historical biological survey reports, and a review these in the light of recent monitoring data
- Conclusions on the ecological quality of the site including information on trends and the status of rare species.

2. Study area

Amberley Wild Brooks[1] (TQ01) is a large area of lowland grazing marshes covering 323 ha in the floodplain of the River Arun (West Sussex). The site is part of a complex of grazing marshes of high nature conservation importance between Pulborough and Arundel. Amberley is designated as a Site of Special Scientific Interest (SSSI), as are the adjacent Pulborough Brooks and Waltham Brooks both to the north of Amberley. Together these sites comprise the Arun Valley Ramsar site and Arun Valley Special Protection Area (SPA). Of the 323 ha of the Amberley Wild Brooks SSSI, 81 ha are owned by the Sussex Wildlife Trust and 86 ha by the RSPB. The remainder of the area is in private ownership. The RSPB has also recently purchased a further 36 ha of the Brooks outside the SSSI boundary.

Landuse on Amberley Wild Brooks is mainly unimproved and semi-improved grassland drained by an extensive network of ditches, with weed cutting and desilting on a range of rotations. Water levels in the larger drains are managed by the Environment Agency under the provisions of the Amberley Wild Brooks Water Level Management Plan (NRA 1995). Water levels in smaller drains are under the control of individual land owners.

[1]Note that Wild Brooks is sometimes spelt 'Wildbrooks'. Wild Brooks is used in this report, following the spelling given by the Ordnance Survey.

The surface geology of Amberley comprises river alluvium (deep Fladbury clays and light silts), loamy river terrace deposits and peat, the latter particularly to the north and north east of the Brooks. Amberley is notable for its unusual chemical gradient, which ranges from calcareous springs in the south to raised peat bog in the north. This has encouraged the development of a diverse flora, which purportedly includes about 80% of the known aquatic plant species in the UK (English Nature, 2000).

3. Summary of data available

A summary of the main datasets reviewed and analysed in this report is given in Table 1. The location of the ditches sampled by the Environment Agency is given in Appendix 1 and 2. Further details on data types and sources are given in relevant sections.

Table 1. Summary of the information available on Amberley Wild Brooks

Date	Samples	Season	Methods	Data from
Invertebrates				
2003	4	Summer	Environment Agency (1999a), standard 3-minute sample	Environment Agency
1999	15	8 spring, 7 autumn some sites repeated	Environment Agency (1999a), standard 3-minute sample	Environment Agency
1999	18	Summer	Mollusc sieve sample	Watson (2002)
1999	1	May and November 1998	Mollusc sieve sample	Willing (1999a)
1998	1	May and October 1999	Mollusc sieve sample	Willing (1999b)
1997	50	Summer	Mollusc sieve sample	Willing and Killeen (1998)
1996	21	Summer	Mollusc sieve sample	Killeen and Willing (1997)
Macrophytes				
2003	5[1]	Summer	Environment Agency standard for MTR, 100 m ditch length (Holmes *et al.,* 1999)	Environment Agency
1999	20	Summer	Standard 20 m ditch length (Alcock and Palmer, 1985)	Watson (2002)
1998	All ditches	Summer	Whole ditch (variable length)	Abraham (1998)
Water quality				
1996 - 2003	634	All seasons. Up to 143 samples per year, decreasing to 18 in 2003.	Water chemistry for a wide range of determinands (Appendix 4)	Environment Agency
2003	4	Summer	Diatoms for Trophic Diatom Index (Environment Agency, 1999)	Environment Agency

[1] Data used for calculating the Mean Trophic Rank (MTR) score.

4. Aquatic invertebrates

4.1 Data sources

4.1.1 Main datasets

For the present review, data describing aquatic invertebrates recorded from Amberley Wild Brooks have been derived from three main sources:

(i) Surveys of ditch macroinvertebrate assemblages undertaken by the Environment Agency between spring 1999 and summer 2003.

(ii) Surveys of aquatic molluscs undertaken for work relating to the UK BAP species, particularly the Little Whirlpool Ram's-horn snail (*Anisus leucostoma*), and the Red Data Book pea mussel *Pisidium pseudosphaerium*.

(iii) Surveys of other aquatic invertebrate groups undertaken either as part of individual national recording schemes or special site studies, particularly for aquatic beetles, dragonflies and Diptera. Summaries of the results of these dispersed datasets are available in Abraham *et al*. (1997). In addition, summary information on water beetle assemblages prior to 1992 is summarised in Foster and Eyre (1992).

4.1.2 Survey methods

4.1.2.1 Environment Agency ditch surveys

All Environment Agency ditch survey samples were collected by Environment Agency staff using a standard 3-minute hand net sampling method. Samples were preserved in 4% formalin for subsequent processing. Laboratory sorting and identification was carried out by contractors following standard Environment Agency procedures for river sampling (Environment Agency 1999a).

Eight ditches were sampled in spring 1999 (March, April, May) and seven in autumn 1999 (September, October, November). Six ditches were sampled both in spring and autumn 1999. Four new ditch sites were sampled in 2003. All macroinvertebrate groups were recorded to species except for Diptera and *Pisidium* spp. (Table 2).

4.1.2.2 Surveys of aquatic molluscs

Aquatic mollusc surveys have generally been undertaken using a methodology developed by mollusc specialists. In this technique animals are collected using a metal kitchen sieve (mesh size 0-5-1mm) attached to a pole. Samples are collected 'from the interface between the sediment and the aquatic vegetation' to ensure collection of both sediment dwelling bivalves and mainly plant dwelling gastropods (Willing and Killeen 1998). At each site 10 scoopfuls are collected. Sample processing methods vary slightly depending on the study, but at Amberley samples were bulk preserved in 80% alcohol, washed in the laboratory over 0.5 mm mesh sieves and then sorted in white trays to remove animals. 'Smaller samples' were inspected using a binocular microscope.

Surveys undertaken by Alisa Watson as part of her PhD work on rare freshwater molluscs used a similar sampling method.

Table 2. Major macroinvertebrate groups identified in Environment Agency sampling programmes

Tricladida	Flatworms (adult and juvenile stages)
Gastropoda	Water snail (adult and juvenile stages)
Bivalvia (except *Pisidium* sp.)	Bivalves (adult and juvenile stages)
Hirudinea	Leeches (adult and juvenile stages)
Amphipoda and Isopoda	Water shrimps and slaters (adult and juvenile stages)
Ephemeroptera	Mayflies (larvae)
Plecoptera	Stoneflies (larvae)
Odonata	Dragonflies and damselflies (larvae)
Hemiptera	Water bugs (adults only)
Coleoptera	Water beetles (adults only)
Megaloptera	Alderflies
Trichoptera	Caddis flies
Lepidoptera	Aquatic moths (larvae)

4.1.2.3 Surveys of other aquatic invertebrate groups (dragonflies, water beetles, water bugs).

Water beetle and water bug surveys were carried out using a field search method in which a pond net is passed through aquatic vegetation approximately 10 times. No information is given in Abraham *et al*. (1997) about the sample processing methods or time spent at each site. However, normally in this method, invertebrates are removed from vegetation in the field, inspected either in a white tray or on a plastic sheet, and identified on site or preserved for subsequent identification in the laboratory.

No specific information is available about dragonfly recording methods but it is likely to have been primarily based on observations of adults.

4.2 Results of 1999 and 2003 Environment Agency macroinvertebrate surveys

4.2.1 Species richness

Overall, a total of 107 macroinvertebrate species were recorded in 1999 and 2003 Environment Agency surveys from 19 ditches (Appendix 3). This represent c.15% of the aquatic macroinvertebrate species found in the UK, in the groups surveyed.

The average number of macroinvertebrates species recorded per site was 20, with a range of 4 to 33 species. The ditches sampled by the Agency in 2003 generally supported a greater number of species, with a mean species of 27 compared to 19 species for 1999 samples. Note, however, that 2003 data come from completely different sites to 1999 data so should not be taken to indicate that there was an increase in species richness between the two surveys.

The Environment Agency macroinvertebrate data were compared with compatible ditch datasets England and Wales collected by the Ponds Conservation Trust as part of a recent DEFRA project defining the characteristics of UK aquatic habitats (PCTPR, Cranfield University and ADAS 2003).

Amberley lies within UK agricultural landscape class 1, river valley floodplains. Analysis of UK ditch data indicates that ditch systems in this landscape class, and in Landscape Class 2 (fenland and warpland) are generally highly species rich. Most of Britain's well-known grazing marsh drainage ditch systems (e.g. Somerset Levels, Pevensey, North Kent etc) fall within landscape class 2. Figure 1 shows the extent of landscape classes 1 and 2 in Britain as a whole. Note that LC1 is hard to see on the main map because it is generally represented by very narrow threads running along river valleys. Figure 2 shows an enlargement of the landscape classification for the Amberley area.

Landscape Classes 1 and 2 typically support around 30 species in a standard 3 minute sample in *impacted* environments (Figure 3). The 1999 Amberley samples are therefore somewhat below the expected values. This is perhaps surprising considering that ditches at Amberley are generally considerably less impacted by pollutants than those in the 'ordinary' countryside. The 4 sites surveyed in 2003 had values somewhat closer to the average.

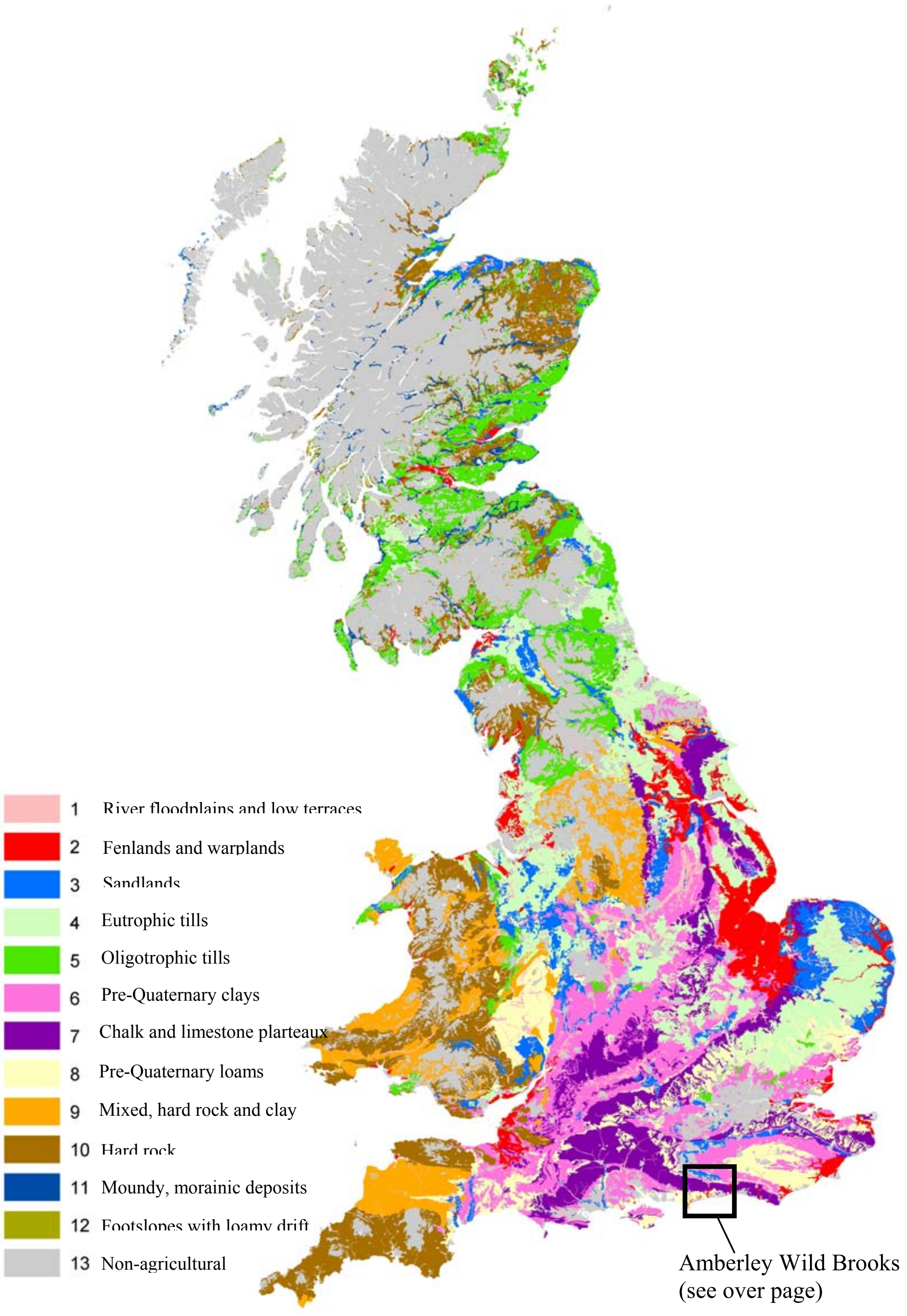

Figure 1. Distribution of agricultural landscape classes in England, Scotland and Wales.

Light pink areas are Landscape Class 1, river valley floodplains and low terraces. Note that most species rich freshwater grazing marsh ditch systems in Britain are in Landscape Class 2 (red).

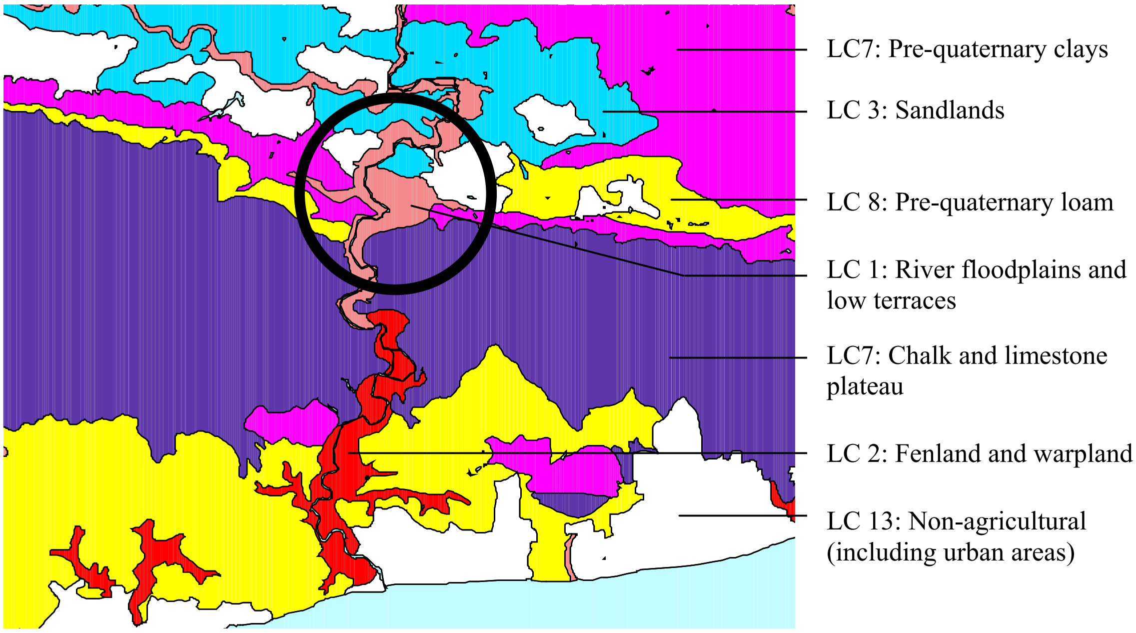

Figure 2. Detail of agricultural landscape classes around Amberley Wild Brooks.

Amberley, which lies in Landscape Class 1 (pink), is circled.

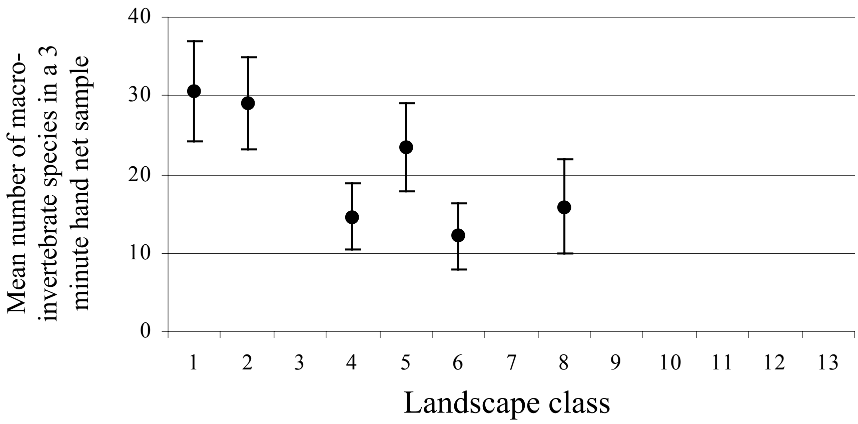

Figure 3. Mean macroinvertebrate species richness in UK ditch systems.

Provisional estimates from the DEFRA Aquatic Habitats of the UK Agricultural Landscape project. Differences between landscapes are statistically significant.

4.2.2 Uncommon species

Species Rarity Index (SRI) scores were calculated for the Environment Agency samples (Table 3) following standard PCTPR methods. SRIs were derived in the following manner: (i) all species present were given a numerical value depending on rarity/threat (Appendix 3) (ii) the rarity/threat values of all species in each sample were summed to give a Species Rarity Score (iii) the Species Rarity Score was divided by the number of species recorded to give the SRI.

The findings indicate that 1999 samples were generally of relatively low nature conservation value, with most samples in the 'Low' value category on a four point scale ('Low', 'Moderate', 'High', 'Very High' value). In 2003 two of the four samples collected fell into the 'Very High' value category (Table 3).

Table 3. Numbers of samples in each of four Species Rarity Index categories for Environment Agency samples collected at Amberley Wild Brooks

Conservation value	1999 samples	2003 samples
Low (SRI = 1.00)	12	1
Moderate (SRI = 1.01 – 1.19)	2	1
High (SRI = 1.20 – 1.49)	1	0
Very High (SRI = 1.50 and above)	0	2
Total number of samples	**15**	**4**

In terms of individual species, in the 1999 Environment Agency samples a total of three uncommon species were recorded (Table 4 and 5). The nationally scarce water beetle *Peltodytes caesus* was recorded from three ditches, twice in spring samples (sampling point 6 and 7, see Appendix 1) and once in autumn (sampling point 9). The species has previously been recorded at Amberley, but there are no details of the records (Callaway 1997). Two local species were also recorded at the same sampling point (sampling point 6), the Water Stick Insect (*Ranatra linearis*) and the leech *Trocheta subviridis*.

Two uncommon species were recorded in the 2003 surveys, neither of which were recorded in 1999 (Tables 4 and 5). The RDB2 snail *Anisus vorticulus* was found in one ditch in 2003 (sampling point 15). This ditch is outside the area defined by Willing and Killeen (1998) as the *A. vorticulus* stronghold at Amberley Wild Brooks, which is on the central-western side of the Brooks (e.g. Abraham's ditches 153, 158, 159, 160, 162 and 163). The snail was not, however, recorded from Environment Agency sampling points 3 and 13, which *are* at the edge of the *A. vorticulus* stronghold. One local species was also recorded in 2003, the leech *Hemiclepsis marginata*.

Table 4. RDB and Nationally Scarce species recorded at Amberley Wild Brooks

Species	Status	Year last recorded
Anisus vorticulus	RDB2	2003
Peltodytes caesus	Nationally Scarce	1999
Libellula fulva[1]	RDB3	TO BE ADDED
Brachytron pratense	Nationally Scarce	TO BE ADDED
Gomphus vulgatissimus[1]	Nationally Scarce	TO BE ADDED
Cordulia aenea	Nationally Scarce	TO BE ADDED
Hemiclepsis marginata	Local	2003
Ranatra linearis	Local	1999
Trocheta subviridis	Local	1999

[1]*L. fulva* and *G. vulgatissimus* are known form the R. Arun alongside Amberley Wild Brooks; it is not known whether either species breeds in ditches on the site.

Table 5. Summary of status and habitat requirements for uncommon invertebrates

Anisus vorticulus Little Whirlpool Ram's-horn Snail (RDB2 Critically Endangered)	*A. vorticulus* generally lives in clean, often calcareous water, in well-vegetated marsh drains, usually in association with a rich macroinvertebrate and macrophyte assemblage, often including other uncommon water snail species such as *Segmentina nitida*, *Valvata macrostoma* and *Pisidium pseudosphaerium* (Kerney 1999). Of those, only the latter has been recorded at Amberley Wild Brooks (see text for additional information).
Pisidium pseudo-sphaerium A pea mussel (RDB3)	*P. pseudosphaerium* is generally found in clear, clean water with a dense vegetation cover and a rich organic bottom (Kerney, 1999). Indeed, Watson (2002) found at Amberley that *P. pseudosphaerium* is generally recorded in ditches with slightly elevated Biological Oxygen Demand (BOD), and relatively low calcium and nutrient concentrations. This species also requires a high floating vegetation cover, and frequently occurs with *Valvata macrostoma* and *Anisus vorticulus*. In terms of management, de-silting is likely to be detrimental as bivalves are usually sediment dwelling.
Peltodytes caesus A haliplid water beetle (Nationally Scarce)	*P. caesus* has previously been recorded at Amberley, but there are no details of the records. This species is confined to lowland slow-moving drains and ponds with permanent waters, and it is always found in base-rich conditions and usually in association with soft, muddy bottoms. The decline of this species is associated with habitat loss and eutrophication, and in particular the conversion of grazing fens to arable land (Foster, 2000).

Table 6. Summary of status and habitat requirements for uncommon invertebrates

Hydrophilus piceus, Great Silver Water Beetle (Near Threatened = RDB3),	*H. piceus* is largely confined to drains in coastal levels. Those specially favoured are densely vegetated with plants such as ivy-leaved duckweed (*Lemna trisulca)* and fringed by common reed (*Phragmites australis*). *H. piceus* is a summer breeder (larvae reported from mid-May to the beginning of August in the Netherlands). In the Somerset Levels adults are found mainly in ditches that have been recently cleared, whereas larvae occur in densely vegetated ditches (Foster 2000).
Hydraena testacea A scavenger beetle (Nationally Scarce)	*H. testacea* is found in stagnant water in association with a well-developed marginal vegetation line, but it also occurs in slow-moving water in canals and streams, being found in the moist zone just above the main water line. The seasonal occurrence of adults is strongly bimodal, with peaks in June and September (Foster 2000).
Enochrus ochropterus A scavenger beetle (Nationally Scarce)	*E. ochropterus* is typical of mesotrophic mires, including small base-enriched sections of other nutrient poor bogs, base-flushed peat cuttings and mossy duneslack and oxbow pools. It can occur in fen carr and appears to be particularly common in litter zones or where mosses are decaying after trampling. Adults feed on algae and decaying plants whereas the larvae are predaceous.
Brachytron pratense Hairy Dragonfly (Nationally Scarce)	*B. pratense* breeds in mesotrophic ponds and lakes, including mature gravel pits, canals, ditches and marshy fens where there is plenty of tall emergent vegetation.
Cordulia aenea The Downy Emerald (Nationally Scarce)	*C. aenea* breeds on well-vegetated mesotrophic neutral to mildy acid ponds, lakes and canals, often where there are shallow sheltered bays with trees and bushes overhanging the water margin. Records of this species have not been confirmed recently.

4.2.3 Community classification and ordination

TWINSPAN analysis[2] of the 1999 and 2003 Environment Agency macroinvertebrate data showed that the season and year in which the samples were collected was the most important factor influencing assemblage composition (Figure 4). Four TWINSPAN groups were identified:

- Group 1: samples collected in spring 1999 , and defined by the occurrence of the water scorpion (*Nepa cinerea*), duck leeches (*Theromyzon tessulatum*) and the Ram's-horn (*Planorbis planorbis*).
- Group 2: spring 1999 samples plus sampling point 5 (sampled autumn 1999).
- Group 3: samples collected in autumn 1999.
- Group 4: all the samples collected in summer 2003.

The results of DECORANA[4] ordination showed a similar pattern. Group 1 was poorly defined, with the samples rather dissimilar to each other (Figure 5).

Canonical Correspondence Analysis (ter Braak and Smilauer 2002) indicated that patterns in macroinvertebrate assemblage composition were related to pH. No other environmental variables showed significant relationships with assemblage composition although this may have been because the data set was too small for general patterns to be apparent.

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[2]TWINSPAN analyses were undertaken using the Community Analysis Package v2.0 (Pisces Software).

Overall the multivariate analysis indicated that invertebrate assemblages in different parts of the ditch network were rather similar to each other. The 1999 samples were separated according to season of sampling. The 2003 samples, which were from four previously unsampled locations, could have differed either for this reason or because of the year of sampling,

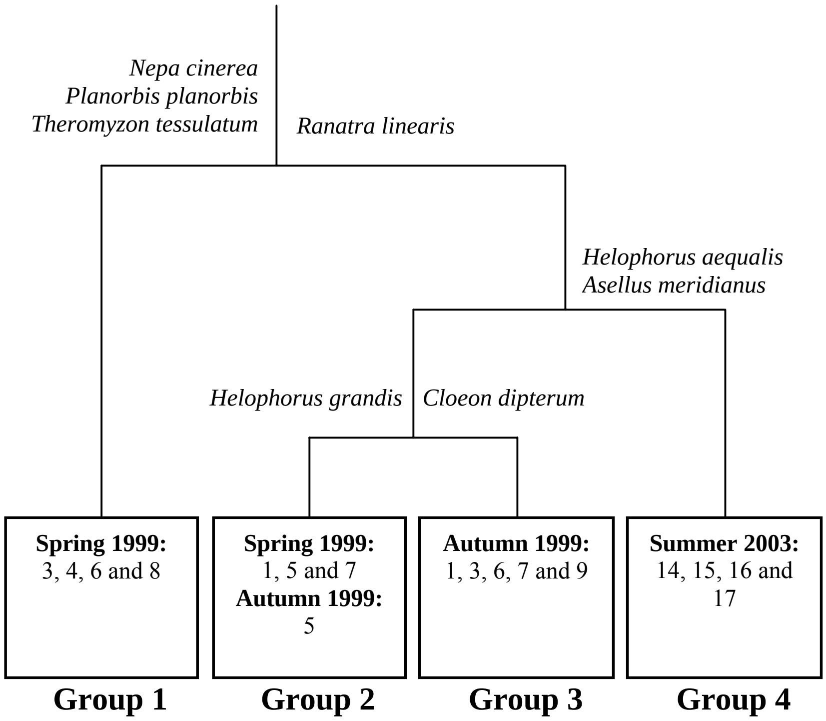

Figure 4. TWINSPAN classification of 1999 and 2003 Environment Agency macroinvertebrate samples

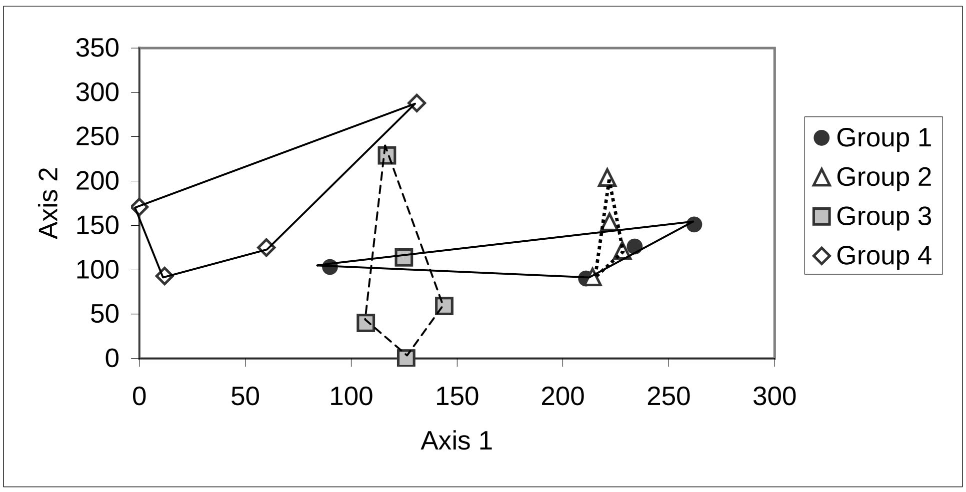

Figure 5. DECORANA ordination of 1999 and 2003 Environment Agency macroinvertebrate samples

4.3 Surveys of dragonflies, water beetles and water bugs

Historical data describing the occurrence of water beetles and water bugs at Amberley are based on surveys of seven ditches in 1989 and 1990 (Hodge 1990), and on summary reports in Callaway (1997). The Lower Arun Valley survey (Abraham 1997) did not carry out macroinvertebrate surveys at Amberley.

Hodge (1990) recorded a total of 31 water beetle species including one Red Data Book species, the Great Silver Water Beetle, *Hydrophilus piceus*, and two Nationally Scarce species *Hydraena testacea* and *Enochrus ochropterus* (Tables 4 and 5).

Foster and Eyre (1992) classified samples from Amberley Wild Brooks within a group of rich fen ditches and ponds. For the site as a whole they reported a total of 29 species including only 1 nationally scarce species. This is a relatively unexceptional fauna compared to sites such as Pevensey or the Lewes Levels which were also investigated in the same analysis. However, it should be noted that no information is available on the amount of sampling effort undertaken (and effort probably varied greatly between sites), or on the exact methodology used.

Amberley is well-known for its populations of *Brachytron pratense* (Hairy Dragonfly) in the ditch system and, in the adjacent river, *Libellula fulv*a (Scarce Chaser Dragonfly) and *Gomphus vulgatissimus* (Club-tailed Dragonfly). Although *Libellula fulva* larvae have not been recorded from the Amberley ditches this habitat may also be used for breeding. No further data are available on the occurrence of *Gomphus vulgatissimus* in the Amberley ditches. *Cordulia aenea* (the Downy Emerald) has also been recorded at Amberley (Callaway 1997) but no information is available on the specific location(s) at which the species was recorded.

The publicly accessible areas of the National Biodiversity Network (NBN 2004) lists 17 species of dragonfly for Amberley. Post-1990 records are held in a private area which was not accessed for this review.

No Nationally Scarce or Red Data Book water bugs have been recorded at Amberley. Abraham (1997) does not provide any specific data on the water bugs recorded, apart from noting the occurrence of the nationally local Water Stick Insect (*Ranatra linearis*).

4.4 Aquatic mollusc surveys

4.4.1 Species richness and communities

Amberley Wild Brooks supports a rich molluscan assemblage typical of river floodplains and grazing marshes. From 1996 to 1999, molluscan surveys using comparable methods recorded on average 16 water snail species and nine bivalves (Appendix 3). Killeen and Willing (1997), however, noted that the molluscan fauna of Amberley Wild Brooks is relatively poor compared to other *high quality* grazing marshes in southern England (Table 6). They noted the absence of the common species *Bathyomphalus contortus* and *Armiger crista* and the more local *Bithynia leachii*, as well as rare species which are characteristic of grazing marshes (e.g. *Segmentina nitida*, *Valvata macrostoma*). Although *B. contortus* and *A. crista* were subsequently recorded (Watson 2002) the other species (*B. leachii*, *S. nitida*, *V. macrostoma*) may never have occurred at Amberley (Kerney 1999).

Comparison of standard Environment Agency 3-minute hand net samples from Amberley Wild Brooks and Pevensey Levels generally supports the statement made by Killeen and Willing (1997). Thus standard Environment Agency samples from Pevensey had a mean of 11 gastropod mollusc species/sample compared to less than half this number (4 species/sample) at Amberley (Table 7).

Table 7. Comparative species richness of water snail assemblages in Environment Agency samples from at Amberley Wild Brooks and Pevensey Levels

	Number of mollusc species recorded in 3-minute hand net samples
Amberley Wild Brooks	4.05 (n = 19)
Pevensey Levels	11.53 (n = 30)

Killeen and Willing (1997) suggested that, for snails, the reduced species richness may relate either to the relative isolation of the area or to the apparently variable chemistry, with areas of relatively low pH. The former (isolation) seems a plausible possibility, considering the relatively small size of the site: Amberley Wild Brooks is approximately 1/10th the area of Pevensey Levels, for example.

4.4.2 Uncommon species

4.4.2.1 Anisus vorticulus (Little Whirlpool Ram's-horn Snail) RDB1

Anisus vorticulus is a Red Data Book and UK BAP species. It is declining throughout its central and southern European range. In Britain it is known from the lower Arun Valley, the Pevensey Levels, the Waveney Valley in Suffolk and the Halvergate Marshes in Norfolk (Table 8).

Anisus vorticulus was rediscovered at Amberley Wild Brooks in 1996 (Killeen and Willing 1997) and has subsequently been recorded in the Arun valley from Pulborough Brooks, North Stoke marshes and near Houghton Bridge. At Amberley the snail is known from a rather localised area in the centre-west of the site (Willing and Killeen 1998; Watson 2002) with two other isolated populations (Ditch 18 of Willing and Killeen 1998, and sampling point 15 of the 2003 Environment Agency survey).

Although localised the Amberley population is relatively large with the peak recorded count (303 individuals in a sample) greater than any other site (Table 8).

Table 8. Summary of British sites for *Anisus vorticulus*

Site	Number of ditches in which *A. vorticulus* recorded Proportion of total ditches surveyed with *Anisus vorticulus* is shown in parentheses.		
	1996 (Killeen and Willing 1997).	**1997 (Willing and Killeen 1998).**	**1999 (Watson 2002)**
Lower Arun Valley			
- Amberley Wild Brooks, West Sussex	3 (14%)	7 (14%)	3 (9%)
- Pulborough Brooks, West Sussex	No data	3 (38%)	3 (30%)
- North Stoke	No data	2[3]	2[5]
- Timberley/Houghton	No data	1[5]	1[5]
Pevensey Levels, East Sussex	4 (10%)	No data	3 (9%)
Norfolk			
- Halvergate Marshes, Norfolk	No data	6 (29%)	No data
Suffolk			
- Castle Marshes, Suffolk	No data	2 (20%)	No data
- Carlton Marshes, Suffolk	7 (64%)	9 (75%)	No data
- North Cove, Suffolk	2 (20%)	8 (62%)	No data

Table 9. Peak counts for *Anisus vorticulus* at its British locations

	Maximum count	**Date**
Lower Arun Valley		
- Amberley Wild Brooks, West Sussex	303	27/9/97
- Pulborough Brooks, West Sussex	153	19/9/98
- North Stoke	6	7/9/97
- Timberley/Houghton	2	7/9/97
Pevensey Levels, Kent	266	May/Sept 1999
Halvergate Marshes, Norfolk	165	23/9/97
Suffolk		
- Castle Marshes, Suffolk	5	23/6/97
- Carlton Marshes, Suffolk	133	Sept 1997
- North Cove, Suffolk	48	Apr 1997

Sources: Killeen and Willing (1997), Willing and Killeen (1998), Watson (2002).

[3]No other ditches in these locations supported *A. vorticulus* so a value for percentage occupancy is not appropriate.

Habitat requirements of *Anisus* can now be reasonably reliably inferred from the studies undertaken by Willing and Killeen (1998) and Watson (2002). Of over-riding importance is the need for good water quality: all existing populations exist more or less entirely in areas of exceptionally good water quality which is a prerequisite for long term survival of *A. vorticulus* in Britain.

Apart from clean water *A. vorticulus* has the following requirements in terms of ditch management:

- **Physical characteristics of ditches**. *A. vorticulus* has been recorded in ditches of narrow to medium width (1.3 - 3m) and of a variety of depths. Probably more important than the precise physical dimensions of the ditches is the presence of shallow marginal areas, created either by poaching or natural infilling. Shallow areas, which warm up more quickly and generally have higher temperatures than deeper water, may be important as breeding areas for the snail.
- **Hydrology**. *A. vorticulus* shows poor ditch-to-ditch colonisation if there are no direct connection between ditches. Indeed, many suitable ditches show no records of supporting the species. It is therefore likely that flooding is important in helping the species disperse. For example, Pulborough Brooks experiences more frequent inundations and a higher proportion of ditches support *A. vorticulus* (although it should be noted that the total number of sites at Pulborough is smaller than at Amberley).
- **Management regime**. Ditches need to be managed on a 5 to 10 year rotation to maintain shallow, well-vegetated conditions. Willing (1999b) recorded only one juvenile *A. vorticulus* from a ditch which had been completely cleared one year earlier by a contractor misunderstanding instructions. In contrast, recovery was good for other species, and the total number of other molluscs (snail and bivalve) had increased from 14 to 20 species.
- **Surrounding landuse**. *A. vorticulus* is usually recorded from ditches with unimproved or semi-improved grassland as the main surrounding landuse. This is probably linked to the provision of suitable disturbance by livestock, but also to high water quality.

4.4.2.2 Pisidium pseudosphaerium (a pea mussel) RDB3

Pisidium pseudosphaerium is a Red Data Book species (category 3: rare) and a Biodiversity Action Plan bivalve species. This species was recorded in all surveys specifically concerned with molluscs but not in those carried out by the Environment Agency in 1999 and 2003. This may have been due to differences in methodology. For specific mollusc surveys, samples were either preserved in alcohol or frozen; in contrast, the Environment Agency samples were preserved in formalin which is mildly acid and dissolves mollusc shells. This may have made it more difficult to recognise *P. pseudosphaerium* in the Agency samples.

Overall, *P. pseudosphaerium* is the commonest bivalve recorded at Amberley Wild Brooks, and it occurs in 45% of ditches in the Arun Valley, a population stronghold (Killeen and Willing 1997). Although *P. pseudosphaerium* is probably not as rare as the records suggest (Kerney 1999), the species must nevertheless be considered at risk due to its relict distribution and poor power of dispersal. Habitat requirements for *P. pseudosphaerium* are summarised in Table 5.

4.5 Long-term trends in macroinvertebrate community and species data

Existing monitoring programme have not yet provided any information on general trends in invertebrate populations at Amberley Wild Brooks. This is mainly because of the lack of standard methods (there is still no defined standard method for ditches) and, more recently, because of changes in sampling locations.

Short term trends in the occurrence of *Anisus vorticulus* between 1997 and 1999 indicate that populations were essentially stable, but no further monitoring has been undertaken to assess trends subsequently. A similar pattern is apparent for *Pisdium pseudosphaerium*. No data on long term trends in other uncommon invertebrates are available.

5. Macrophytes

5.1 Main data sources and methods used

Data for the current review were derived from the following sources:

(i) Historic wetland plant records for Amberley Wild Brooks as a whole, summarised in the RSPB management plan covering the Sussex Wildlife Trust Nature Reserve area of the marshes (Callaway 1997).

(ii) Limited plant data were gathered by Willing and Killeen (1998) during their mollusc surveys. No information is given on the methods used for these surveys.

(iii) The comprehensive plant survey of the Amberley ditches undertaken by Frances Abraham in summer 1998 (Abraham 1998). This provides a total species list for the site, together with species lists for the full length of individual ditches. Data were collected by walking the banks with periodic grapnelling into the ditch channel. The survey used Alcock and Palmer's list of wetland macrophytes as a base list (Alcock and Palmer 1985).

(iii) Twenty ditches were surveyed for macrophytes in 1999 as part of Alisa Watson's PhD on the ecology of uncommon snails. These data have not been published but are available as an Excel data sheet (Alisa Watson *pers. comm*. 2002). Her survey was undertaken using English Nature's standard method which records all macrophyte species present in a 20 m ditch length (Alcock and Palmer 1985).

(iv) The most recent plant data for the Wild Brooks were collected in summer 2003 by the Environment Agency. Only five ditch lengths were surveyed, with the main aim being to assess the nutrient status of those ditches using MTR (Mean Trophic Rank). All surveys were of 100m ditch sections.

In addition to records of ditch plant assemblages, more detailed surveys have been undertaken on an annual basis (1998 – 2003) for the BAP species *Tolypella prolifera* (Great Tassel Stonewort). These surveys are now co-ordinated by P Williams (PCTPR) on behalf of Plantlife. To date, searches have been limited to a single ditch on the south edge of the Brooks. They were undertaken by wading the ditch: a method which is more effective for surveillance of submerged aquatic plants than bankside surveys (Williams and Stewart 2002).

5.2 Overview of survey findings (pre 1997-2003)

In the Amberley Wild Brooks surveys reviewed for this report, the total number of wetland plants species recorded was 147. This is approximately one third of Britain's wetland plants[4]. The full list of species is given in Appendix 4.

The total number of plant species believed to be extant at the site includes four Red Data Book and at least three Nationally Scarce species (Table 9). A summary of the status and habitat requirements of the RDB species is given in Table 10. In addition to the above, the Wild Brooks ditches support at least 28 species which can be considered "locally

[4] As defined by the PCTPR British wetland plant list.

uncommon"[5] at a national level. At regional level, Abraham (1998) notes 16 species that are regionally rare or local within Sussex.

Table 10. Summary of Red Data Book and Nationally Scarce plants recorded in ditches on Amberley Wild Brooks

Species	Pre-1997 (Callaway 1997)	Killeen and Willing 1997 (n=20)	Abraham 1998 (n=215)	Watson 1999 (n=20)	EA 2003 (n=5)	*T. prolifera* BAP 1998-2003 (n=1)
RDB						
Leersia oryzoides (EN) BAP	•	•	•			
Tolypella prolifera (EN) BAP[1]						•
Carex vulpina (VU) BAP	•		•			
Potamogeton acutifolius (VU)	•	•	•	•		•
Nationally Scarce						
Oenanthe silaifolia	•		•			
Potamogeton compressus (BAP)[2]	•[2]					
Potamogeton filiformis[2]	•[2]					
Sium latifolium	•	•	•	•		
Wolffia arrhiza	•		•			

[1]Recently reclassified (N. Stewart *in litt.*). [2]Record not confirmed (see text).

[5] 'Locally uncommon' or "local" species are defined in this report as species recorded from less than one third of all 10x10 km^2 in the British Isles.

Table 11. Summary of status and habitat requirements for Red Data Book plants

Leersia oryzoides Cut Grass (Critically Endangered)	*National status*: only four extant UK sites, of which Amberley holds the only sizeable population. *Status in Amberley*: recorded from 12.5% of ditches in the Brooks. *General habitat:* seasonally inundated margins of drainage ditches and ponds on nutrient-rich mud. Must have good water quality in adjacent ditches. Prefers open disturbed communities. Colonises bare mud provided by dredging. Monitoring of the species at Amberley Wild Brooks over the last 15 years shows that it grows best on banks of managed, clean-water ditches that are grazed and trampled by cattle *Threats:* pollution, especially enrichment, declines in traditional management of ditches and areas of grazing marsh. No evidence of recent BAP monitoring.
Tolypella prolifera Great Tassel Stonewort (Critically Endangered)	*National status*: nine extant UK sites, still in decline. One ditch currently known on Amberley Wild Brooks, but appropriate searches may well find others. *Status in Amberley*: Known from one ditch on the south edge of the Brooks. Not seen since 2000, despite annual monitoring in last 5 years as part of BAP surveillance. Quite likely to be present in other ditches on the south and eastern edges of the Brooks. *General habitat:* An aquatic annual of high quality calcareous mesotrophic waters. It requires submerged areas of bare mud and is particularly characteristic of recently dredged ditches, often those grazed and poached by cattle. *Threats:* The main threat is water quality pollution, especially enrichment. Also competition from invasive alien aquatic species (see Section 5.3.5) and possibly declines in the area of grazing marsh.
Carex vulpina Fox Sedge (Vulnerable)	*National status*: believed to be extant at 15 10 x 10 km squares in the UK. *Status in Amberley*: recorded from one ditch top on the southern edge of the Brooks c.1988. No evidence of recent BAP monitoring. *General habitat:* wet ditches and pond sides, often associated with calcareous soils. *Threats:* drainage, drought, ditch clearance. The plant's relationship with shade is uncertain.
Potamogeton acutifolius Sharp-leaved Pondweed (Vulnerable)	*National status*: extant at 13 10 x 10 km squares in the UK, still believed to be undergoing a long-term decline. Amberley Wild Brooks holds the most important population in the UK. *Status in Amberley:* occurs frequently (c.50% of ditches in 1998*). General habitat:* shallow, species-rich calcareous ditches. Requires high quality, mesotrophic or meso-eutrophic waters. *Threats:* water quality pollution, especially eutrophication, habitat destruction, conversion of grazing lands to arable.

Sources: Abraham (1998), Wigginton (1999), Williams and Stewart (2002), BAP 2002 reports: http://www.ukbap.org.uk/asp/2002

5.3 Review of available survey data

5.3.1 1997 RSPB review

The 1997 RSPB management plan summarises historical plant records for Amberley Wild Brooks and no details of the date or location of records are given. The report notes the presence of "some 86 species of aquatic flora (56% of the British list)". However the source of the "British list" is not given[6], so, this species total cannot be compared with later surveys.

The RSPB report includes the following wetland species as being recorded historically from the Brooks. The majority of these are abstracted from the SSSI notification for the Brooks:

- All five species of water-cress
- All three native water milfoils
- Six out of seven species of water-dropwort
- Fourteen out of 21 species of *Potamogeton*
- All five species of duckweed

The following Rare and Nationally Scarce wetland species are also listed: *Leersia oryzoides* (Cut Grass), *Potamogeton acutifolius* (Sharp-leaved Pondweed), *Carex vulpina* (Fox Sedge), *Potamogeton compressus* (Grass-wrack Pondweed), *Potamogeton filiformis* (Slender-leaved Pondweed) and *Oenanthe sialifolia* (Narrow-leaved Water-dropwort) and *Sium latifolium* (Greater Water-parsnip).

Of these, the records for *P. compressus* and *P. filiformis* are presumed to be of dubious authenticity, since neither are included as recent or historic (pre-1970) records in UK distribution maps and descriptions for the species' (Stewart *et al*. 1994, Preston 1995, Preston *et al*. 2002). The same holds true for records of the "locally uncommon" aquatic *Oenanthe fluviatile* (River Water-dropwort) which is listed Callaway's report, but not shown as present in the recent atlas (Preston *et al*. 2002).

Tim Callaway's list also includes two uncommon plant species: *Potamogeton trichoides* (Hairlike Pondweed) and *Myriophyllum verticillatum* (Whorled Water-milfoil) which, listed as Nationally Scarce, are now known from >100 10 x 10 km squares (Preston 2002). The list also includes the wetland species *Thelypteris palustris* (Marsh Fern) (NS) which is associated with fen areas rather than ditches on the Brooks. Other scarce plants listed are: *Persicaria minor* (Small Water-pepper), *Hydrocharis morsus-ranae* (Frogbit), *Utricularia vulgaris* (presumably *s.l.*) (Greater Bladderwort), *Alisma lanceolatum* (Narrow-leaved Water-plantain) and *Rumex palustris* (Marsh Dock).

5.3.2 1997 plant data collected as part of mollusc surveys

Willing and Kileen (1998) Recorded a total of 66 plant species in their mollusc survey of 20 ditches. This included the three most widespread of the RDB and Scarce plant

[6] Standard British wetland plant lists typically include over 400 species so, the "list" referred to presumably omits many wetland marginal species.

species present on the Brooks: *Leersia oryzoides*, *Potamogeton acutifolius and Sium latifolium*). Twelve local plant species were also recorded (see Appendix 4).

5.3.3 1998 Abraham's comprehensive ditch survey

Frances Abraham's comprehensive ditch macrophyte survey carried out in 1998, recorded 133 wetland plant species for the Brooks as a whole (Appendix 4). The richest ditches (with more than 40 species recorded) were generally located in two areas: (i) north-south aligned ditches on the west side of the Brooks immediately north of the river (ii) ditches on the eastern edge of the Brooks, mainly aligned east-west. It was noted, however, that ditches in the southern quadrant of the Brooks were mainly in late succession and would need to be surveyed after de-silting, to properly assess their value (see, for example, Section 5.3.6).

5.3.3.1 Plant assemblages

Abraham's study showed that Amberley Wild Brooks supported macrophyte species typical of (i) soft, peaty water and (ii) calcareous, more mesotrophic or eutrophic waters. Assemblages recorded in softer waters typically included *Potamogeton polygonifolius* (Bog Pondweed), *Utricularia australis* (Bladderwort), *Menyanthes trifoliata* (Bog-bean) and *Potentilla Palustris* (Marsh Cinquefoil). Assemblages more typical of mesotrophic and eutrophic waters included *Potamogeton acutifolius* (Sharp-leaved Pondweed), *Potamogeton lucens* (Shining Pondweed), *Berula erecta* (Lesser Water-parsnip), *Hydrocharis morsus-ranae* (Frog-bit), *Groenlandia densa* (Opposite-leaved Pondweed) and *Lemna trisulca* (Ivy-leaved Duckweed).

5.3.3.2 Uncommon plants

Abraham's study recorded three of the four Red Data Book plants believed to be extant at the Brooks. Of these, the calcicole P*otamogeton acutifolius* (Sharp-leaved Pondweed) was the most widespread. It was recorded from almost 40% of the ditches, and was particularly common within: (i) a central band, running west to east across the site, and (ii) in the south-west corner of the Brooks. *Leersia oryzoides* (Cut Grass) was recorded from 27 ditches (12.5%) mainly located along the western edge and in the north-eastern corner of the Brooks. *Carex vulpina* (Fox Sedge) was not recorded during the survey itself and strictly, is associated with the bank top of a ditch, rather than the ditch itself. However, Abraham notes that the species was known to be still present at its site on the southern edge of the Brooks, at the time of the 1998 survey. The fourth RDB species, *Tolypella prolifera* (Great Tassel Stonewort) was not recorded during the 1998 survey. However, in 1998 its last known ditch on the Brooks was probably in too late a successional stage for it to be seen (N. Stewart *pers. comm.*).

Three Nationally Scarce species were noted by Abraham. *Sium latifolium* (Great Water-parsnip) was present as an occasional species at the site, particularly beside the larger ditches. *Wolffia arrhiza* (Rootless Duckweed) was recorded from one ditch on the south-west corner of the Brooks, though since the species is easily overlooked it may be more widespread. *Oenanthe silaifolia* (Narrow-leaved Water-dropwort) was not recorded directly, because the survey was undertaken too late in the season to be optimal. However, Abraham notes that it was known to be present in a number of ditches in 1998.

5.3.3.3 *Introduced species*

Abraham recorded four potentially invasive introduced species in her survey. Of these, the two naturalised *Elodea* species were the most common: *Elodea nuttallii* (Nuttall's Pondweed) was present in almost half of the Amberley ditches (47%), and *Elodea Canadensis* (Canadian Pondweed) in over a quarter (28%). The floating-leaved aquatic *Lemna minuta* (Least Duckweed) was recorded from almost 10% of the sites. The fourth invasive, the marginal plant *Impatiens glandulifera* (Indian Balsam), was recorded from a single ditch.

5.3.4 *Alisa Watson's PhD 1999*

Plant data gathered by Watson from 20 m lengths of 20 ditches in 1999 recorded a total of 66 species. Because the ditch lengths surveyed were shorter than in Abraham's survey the species lists cannot be directly compared. The average number of species per ditch length in Watson's survey was 19, with a range of 7 to 30 species. The survey recorded two uncommon species *Potamogeton acutifolius* (RDB VU) and *Sium latifolium* (Nationally Scarce). Ten local species were also found. All the rare, scarce and local species were also recorded in Abraham's survey the year before.

5.3.5 *Environment Agency MTR survey 2003*

The most recent plant data for the Wild Brooks were gathered from five ditches surveyed in summer 2003 by the Environment Agency for Mean Trophic Rank (MTR) surveys.

A total of 32 plant species were recorded from the five sites. Of these, seven species were locally uncommon; all had been recorded in previous surveys with the exception of the local *Ranunculus trichophyllus* (Thread-leaved Water-crowfoot). On average, ditch lengths supported 16 macrophyte species, with a range of 8 to 22 species. The most species-poor ditch was temporary and only supported emergent taxa. The 100 m ditch lengths, used for the MTR survey are shorter than in Abraham's 1998 survey, and longer than the 20 m lengths surveyed by Watson in 1999. The data are, therefore, not directly comparable with either survey.

5.3.6 *Tolypella prolifera surveys*

Great Tassel Stonewort is an aquatic plant species that has been recorded sporadically from Amberley Wild Brooks ditches since 1900. The Wild Brooks is one of nine extant sites for the stonewort, and there are also a number of recent records from North and South Stoke further down the Arun valley. Most historical records for the *T. prolifera* at Amberley Wild Brooks are poorly located, but in 1985 the species was recorded from a ditch at the southern edge of the marshes (TQ0313). Following experimental clearance of this ditch in winter 1998/1999 instigated by Plantlife and RSPB, seventeen *T. prolifera* plants were found scattered over a 50 metre length of the southern section of the ditch very close to its previous location (Stewart and Pankhurst 2000). Surveys the following year (2000) recorded only one plant. Additional experimental management was undertaken in the ditch in winter 2000/2001 to investigate the management regimes likely to best promote *T. prolifera* growth. This included three de-silting and/or weed cutting treatments. The results were disappointing but instructive: in the following years (2001-2003) all ditch treatments were completely dominated by dense stands of the alien species *Elodea nuttallii*, and *T. prolifera* was not recorded (Williams and Stewart 2002). The competition threat to *T. prolifera* from *Elodea* is clear. It may, therefore, be advisable that the ditch is dredged on a long rotation basis, so that the abundance of *Elodea* propagules declines in the ditch before open water conditions are re-established[7] (Williams and Stewart 2002, Williams 2004).

The true current distribution of *T. prolifera* at Amberley Wild Brooks is still not known. Surveys around other extant sites for this species in the Somerset Levels and Cambridgeshire fens in the last 5 years have, for example, shown the plant to occur over a much wider range of ditches than previously realised. In Amberley, ditches supporting common associates of *T. prolifera* (e.g. *Groenlandia densa, Potamogeton acutifolius, P. trichoides*) have been recorded elsewhere on the Brooks, particularly on the southern and eastern margins. So the likelihood of it being present here in additional ditches here seems quite high (Williams 2004). Surveys undertaken by wading ditches the year after clearance would be required to confirm its presence.

5.4 Trends seen from pre 1997 to 2003 macrophyte data

Differences in the length of sections used to survey ditches in the last five years preclude any clear conclusions about change over time in macrophyte species richness and rarity at Amberley Wild Brooks. Thus, for example, in the ditch at TQ043145 Abraham recorded the uncommon species: *L. oryzoides*, *P. acutifolius* and *S. latifolium* in 1998. None of these species were recorded by the Environment Agency in 2003 (point 15, New2), but this is likely to be due to the shorter length of the Agency's 2003 survey rather than to disappearance of species.

It is worth noting that other factors are also an influence on the ditch species recorded at the Brooks, making plant trend data generally difficult to interpret. Specifically:

(i) Ditch successional state which considerably influences the number of submerged and floating-leaved species present in any year.

(ii) The method used for surveys i.e. bank-side searches or in-ditch wading which can influence the number of aquatic species recorded.

(iii) "Natural" variations: recent monitoring of *T. prolifera* ditches in N Stoke has, for example, shown that even ditches with a regular annual weed cutting regime can show considerable differences in the richness and rarity of ditch floras present year to year. The causes of these differences are unknown but may relate to variation in temperature, rainfall or water quality (Williams 2004).

Overall the best trend data currently available for the Brooks are between Abraham's comprehensive survey in 1998 and the pre-1998 data. Thus, Callaway (1997), quoting the SSSI notification, reported that all three native species of water milfoils were present at Amberley Wild Brooks. Abraham (1998), in contrast, recorded only *Myriophyllum spicatum* (Spiked Water-milfoil). She suggested that the absence of the calcicole species *M. verticillatum* (Whorled Water-milfoil) may be due to a reduction in the inflow of calcareous water from the chalk downs due to over-abstraction. Other possible explanations are increases in ditch nutrient status and/or ditch succession.

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[7] *Elodea nuttallii* is an aquatic that does not set seed in Britain, but propagates by over-wintering turions near to the sediment-water interface.

Other apparent discrepancies between Abraham's 1998 and pre-1998 data include the absence in 1998 of species such as *Thelypteris palustris* (Marsh Fern), *Osmunda regalis* (Royal Fern) and *Rumex palustris* (Marsh Dock). In some cases this may result from the limited availability of locational data for earlier records. Thus wetland species noted for the Brooks as a whole may not have been present in the ditches in the 1998 survey because they are associated with wet meadow areas. This is certainly the case for *Thelypteris palustris* (Marsh Fern), which Abraham noted as present in many grassland areas. It may also be the case with other local species. Further investigation of the early records for these species would be required to elucidate this.

5.5 Conclusions and recommendations

The persistence of rare species associated with the ditches in Amberley Wild Brooks, particularly the RDB species *Tolypella prolifera*, *Leersia oryzoides* and *Potamogeton acutifolius* is likely to be dependent on the continuation of:

(i) Good water quality in the ditches, particularly calcium rich mesotropic waters relatively unpolluted by nutrients in the non-peaty areas of the Brooks, and

(ii) Stock grazing and poaching of ditch margins

Ongoing assessment of water chemistry and MTR will partially address these issues, especially if measures are taken to stabilise or reduce nutrient loading. However, understanding of water quality alone may be insufficient to protect these species in the long term. The spread of invasive plant species such as *Elodea nuttallii* and *Lemna minuta* may, in particular, have the potential to compound impacts from water quality change. Land use changes also have the potential to impact the species, particularly if poaching and grazing of ditch margins are reduced, or ditch rotation practices are changed unfavourably.

To address these issues directly it would be advisable to continue annual MTR surveys at fixed locations and, in addition, undertake the following:

- Regular (annual or biannual) surveillance monitoring of key species, especially RDB and Scarce plants, and invasive aquatics.
- Periodic (e.g. 5 yearly) re-survey of all, or a proportion, of Abraham's full-length ditch surveys. Some or all of these ditch sections should also be surveyed using the standard 20 m length method (Alcock and Palmer 1985) to facilitate broader comparisons with other locations.

6. Water quality

6.1 Data sources

The present review of water quality focuses on the sampling programme undertaken by the Environment Agency since 1996 as part of the implementation of the Amberley Wild Brooks Water Level Management Plan. For this monitoring programme water chemistry samples have been collected from 17 sampling points from 1996 to 2003 for the determinands listed in Table 12. Samples were initially collected monthly but latterly (post 2000) have been collected only in the summer and early autumn (Table 13). In total, approximately 650 water samples were collected giving about 12,000 individual measurements.

In addition a more limited range of data have been collected in studies on molluscs by Willing and Killeen (1998), Willing (1999a) and Watson (2002). Typically these have been concerned with assessing the habitat requirements of *Anisus vorticulus* and other molluscs and are not considered further here.

Table 12. List of chemical determinands recorded by the Environment Agency

pH	Conductivity
Turbidity	Temperature
Dissolved oxygen % saturation	Biochemical oxygen demand
Total organic carbon	Ammonia (total)
Total oxidised nitrogen	Ammonia (un-ionised)
Nitrite	Suspended solids
Nitrate	Total hardness
Chloride	Orthophosphate phosphorus
Magnesium	Calcium
Manganese	Chlorophyll a
Iron (total and dissolved)	

Table 13. Months during which water samples were collected at Amberley Wild Brooks during 1996-2003

	1996	1997	1998	1999	2000	2001	2002	2003
Jan								
Feb			●					
Mar				●				
Apr	●	●		●				
May	●	●	●	●			●	
Jun	●			●	●			●
Jul	●	●	●		●	●	●	●
Aug	●	●	●		●	●	●	●
Sep	●	●	●	●	●	●	●	●
Oct	●	●					●	
Nov	●			●				
Dec	●			●				

In addition to chemical sampling, the Environment Agency has also initiated surveys using biological measures of nutrient status. These are:

(i) **Mean Trophic Rank (MTR)**. MTR indices were calculated for five sampling points in 2003. Macrophyte surveys were carried out by contractors using the standard Environment Agency method (100m ditch length) (Holmes *et al*., 1999).

(ii) **Trophic Diatom Index (TDI)**. TDI scores were calculated for the five sampling points used for MTR. However, as one site was dry TDIs were only calculated for four sites. The samples were collected by Environment Agency staff, and processed by contractors following standard procedures (Environment Agency, 1996).

6.2 Water sample analysis results 1996 to 2003

6.2.1 Nutrients

6.2.1.1 Orthophosphate phosphorus

Orthophosphate phosphorus concentrations for the Brooks generally indicate water of exceptionally high quality for southern England. The overall mean orthophosphate phosphorus concentration was 51 µg/l (range 33 -128 µg/l) which is close to the mesotrophic/eutrophic border and is clearly indicative of the generally high quality of water at Amberley.

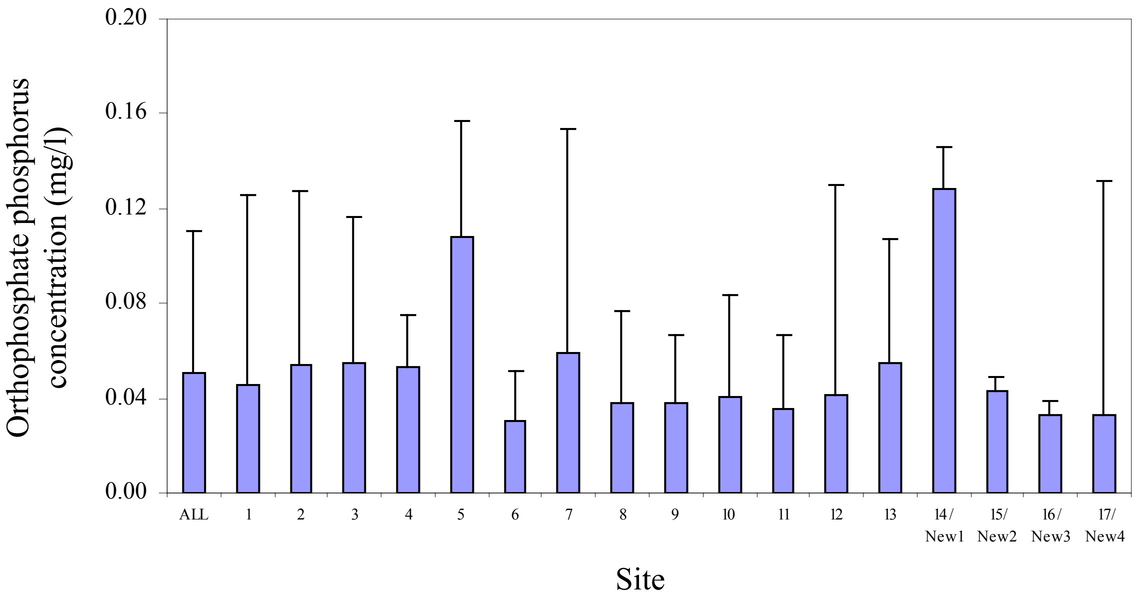

Figure 6. Orthophosphate phosphorus concentrations in Amberley Wild Brooks ditches: site mean concentrations 1996-2003

Differences between sites were statistically significant. Two sites (5 and 14/New1) on the eastern margin of the site stand out as having high (probably hypertrophic) phosphorus concentrations. This may be related to small sewage effluent discharges on the eastern side of the Brooks.

More worryingly, there was a highly significant ($p < 0.001$) increase in mean orthophosphate phosphorus concentrations over the eight years of the monitoring programme. Overall, orthophosphate P concentrations roughly doubled over this time. This trend remained evident even when the exceptionally high year of 2003 was removed from the analysis.

More detailed analysis of individual sampling locations indicates that six of the 13 sites (3, 4, 5, 7, 10, 13) showed significant increases in orthophosphate phosphorus concentrations between 1996 and 2003 (Table 13 and Figure 7). Appendix 6 shows the trend with time at individual sites. It is also clear that for samples taken at the same time of year, sites surveyed later in the sampling programme have higher phosphorus concentrations than those collected earlier. Comparisons of the same months in 1996/7 and 2002/3 showed significant differences in 9 out of 13 possible comparisons (see legend of Figure 7).

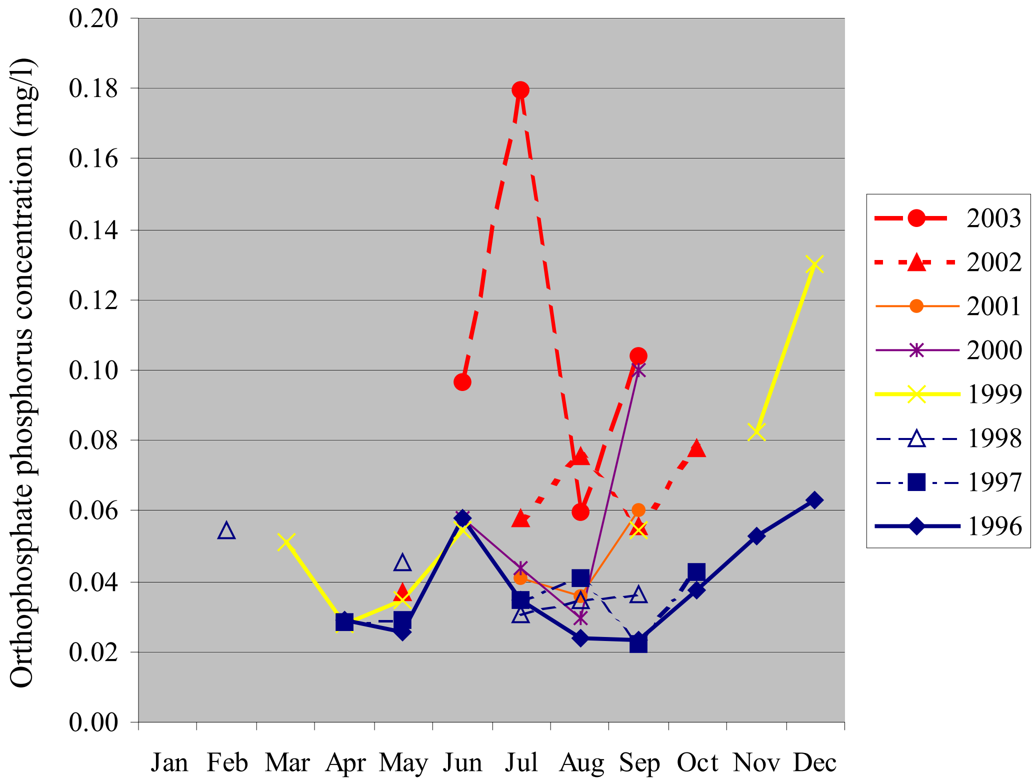

Figure 7. Mean monthly orthophosphate phosphorus concentrations at Amberley Wild Brooks, 1996 – 2003.

Significance levels (p values) for pairwise comparisons between 1996 and 1997 vs 2002 and 2003 mean orthophosphate phosphorus concentrations, Mann-Witney U test.

2002	June	July	August	September
1996	No data	0.032*	0.001***	0.001*
1997	No data	0.078 (ns)	0.181 (ns)	0.004**

2003	June	July	August	September
1996	0.123 (ns)	0.027*	0.012*	0.011*
1997	No data	0.011*	0.4 (ns)	0.007**

Table 14. Summary of statistical analysis of relationship between date and orthophosphate phosphorus concentration in 13 sites on Amberley Wild Brooks

Site	n	Spearman R		p
1	51	0.154885	1.097440	0.277813
2	48	0.222278	1.546246	0.128898
3	**51**	**0.529806**	**4.372791**	**0.000064**
4	**50**	**0.449492**	**3.486205**	**0.001058**
5	**46**	**0.313825**	**2.192438**	**0.033681**
6	44	0.063948	0.415278	0.680053
7	**48**	**0.364220**	**2.652452**	**0.010929**
8	49	0.200337	1.401863	0.167526
9	49	0.145551	1.008591	0.318335
10	**50**	**0.292441**	**2.118715**	**0.039316**
11	48	0.069993	0.475881	0.636412
12	48	0.097469	0.664231	0.509858
13	**52**	**0.569451**	**4.898427**	**0.000011**

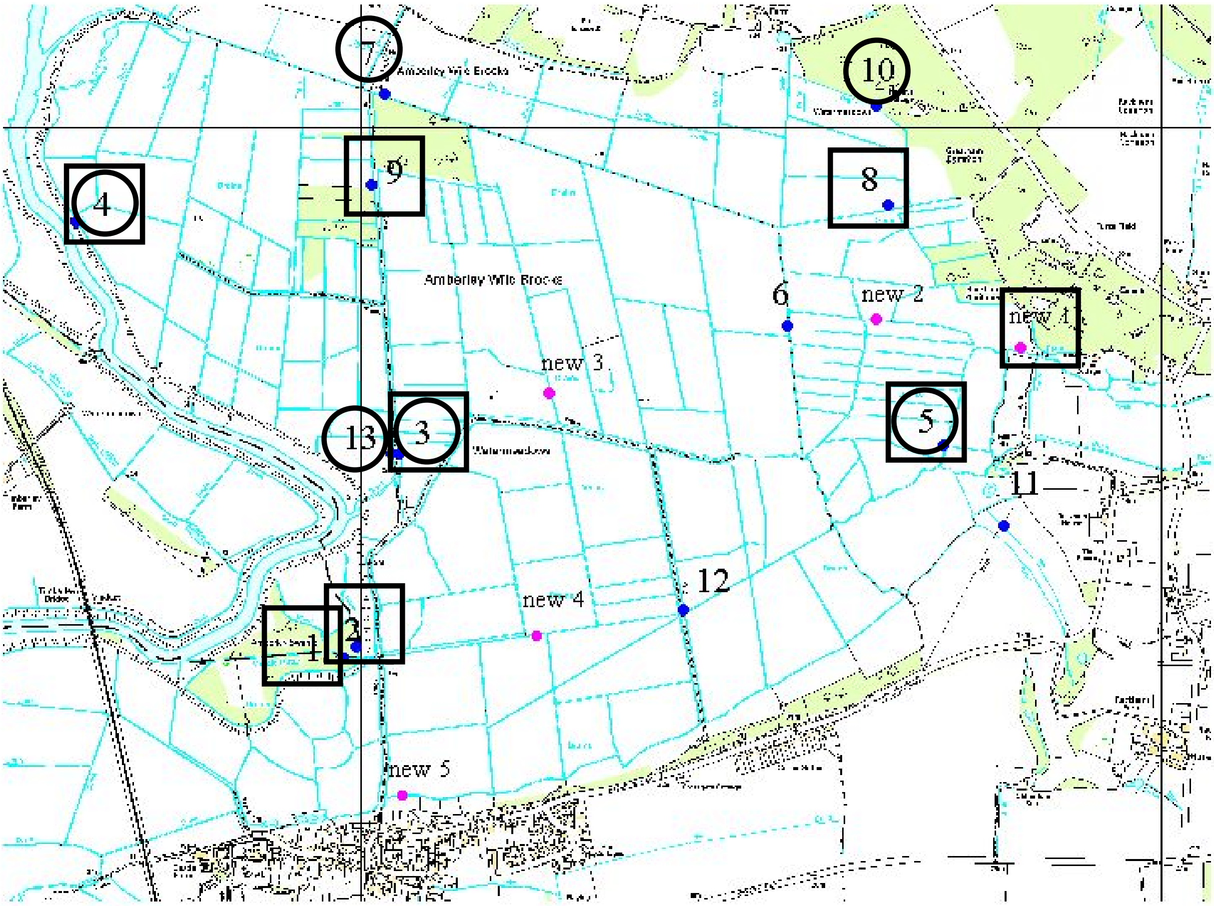

Figure 8. Location of sampling sites showing increases in orthophosphate phosphorus concentrations between 1996 and 2003.

Circles show sites with significant increases in PO_4-P; squares indicate above ‘minimally impaired’ total oxidised nitrogen levels.

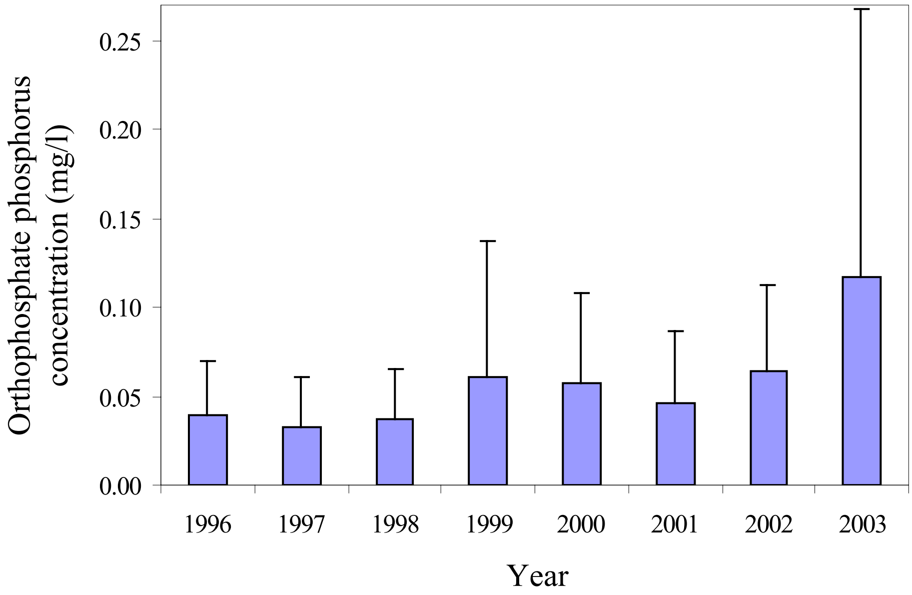

Figure 9. Annual mean orthophosphate phosphorus concentrations in Amberley Wild Brooks ditches: 1996-2003

6.2.1.2 Nitrogen

The overall mean total oxidised nitrogen (TON) concentration for the Brooks samples was 1.95 mg/l, roughly double the level that is typical of minimally impaired natural waters in lowland Britain. Approximately half of the sites had TON concentrations which were above this 'unpolluted' background level, suggesting that the Brooks may be in danger of experiencing water quality impacts from nitrogen. Sites with elevated TON concentrations are shown in Figure 10. Although concentrations of nitrogen are high there is no indications of any post-1996 increases in concentrations.

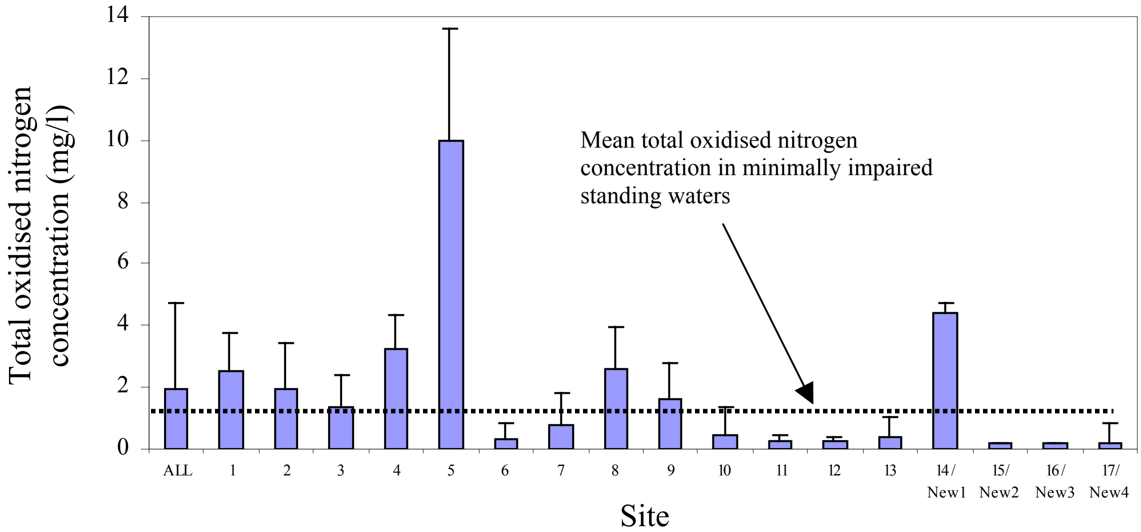

Figure 10. Mean total oxidised nitrogen concentrations in Amberley Wild Brooks ditches: 1996-2003

There were statistically significant ($p<0.001$) variations in total oxidised nitrogen (TON) concentrations between ditches. Site 5 had much higher average concentrations of nitrogen than other sites, perhaps reflecting the influence of small sewage effluent discharges on the eastern side of the site.

6.2.2 pH, calcium and hardness

Between 1996 and 2003, ditches at Amberley Wild Brooks were generally circum-neutral, with a mean pH of 7.2 (range 6.8 - 8.1) (Appendix 5). Dissolved calcium concentrations were, on average, relatively low with a mean of 62 mg/l (range 22 – 155 mg/l).

There were statistically significant differences in mean pH across the site, as might be expected from known hydro-geological characteristics of Amberley. Sites 6 and 9 were the most acid and Sites 2, 4 and 5 the most alkaline (Figure 11). Calcium concentrations and hardness also differed significantly between sites, with particularly high values at Site 5.

Calcium concentrations of less than about 25 mg/l can be regarded as fairly low although probably unlikely to create significant stress for calcium requiring taxa such as molluscs. Thus Site 6 had the lowest mean calcium concentration (22.2 mg/l) and the equal highest number of mollusc species (eight). For the sites with Environment Agency water quality data there was no obvious relationship between calcium concentrations and mollusc species richness or abundance.

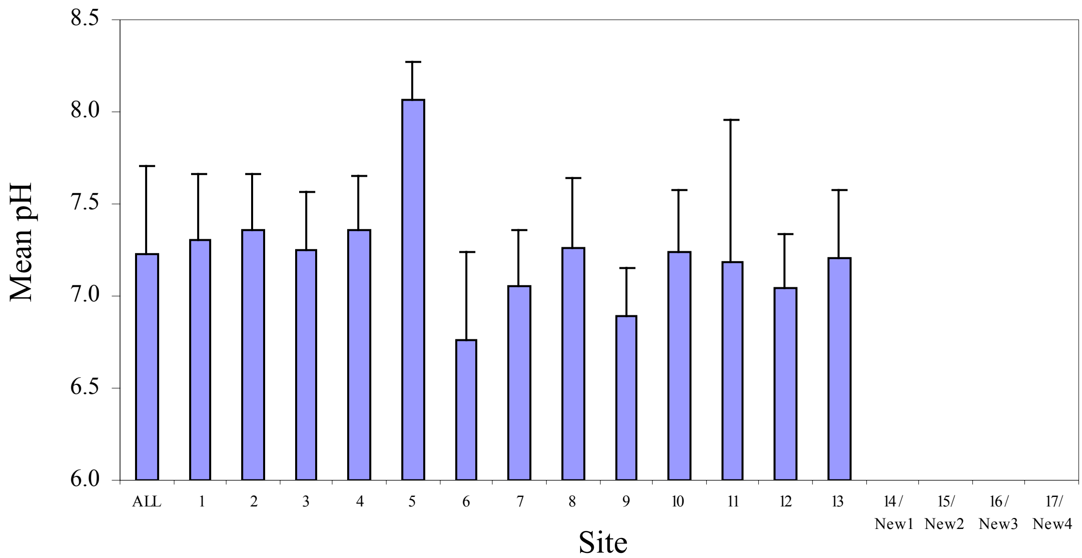

Figure 11. Mean pH in Amberley Wild Brooks ditches: 1996-2003

Perhaps surprisingly pH showed a slight but statistically significantly decrease across the site as a whole between 1996 and 2003 (Figure 12) ($p<0.001$, Spearaman's coefficient of rank correlation). It is not immediately obvious what the cause(s) of this trend might be but they may be related to the suggestion by Abraham (1998) that there is less calcium rich water entering the site due to increased water abstraction. However, there was no long-term trend in calcium concentrations or hardness (Figures 13 and 14).

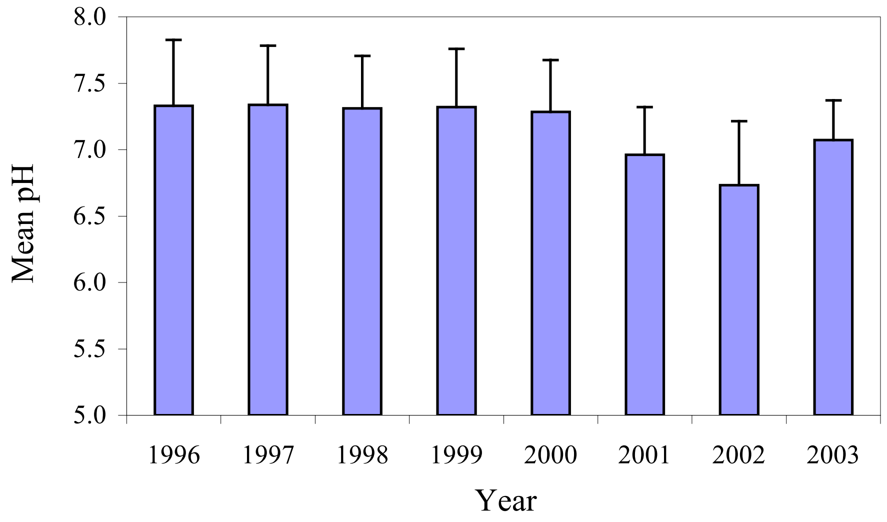

Figure 12. Annual mean pH in ditches on Amberley Wild Brooks

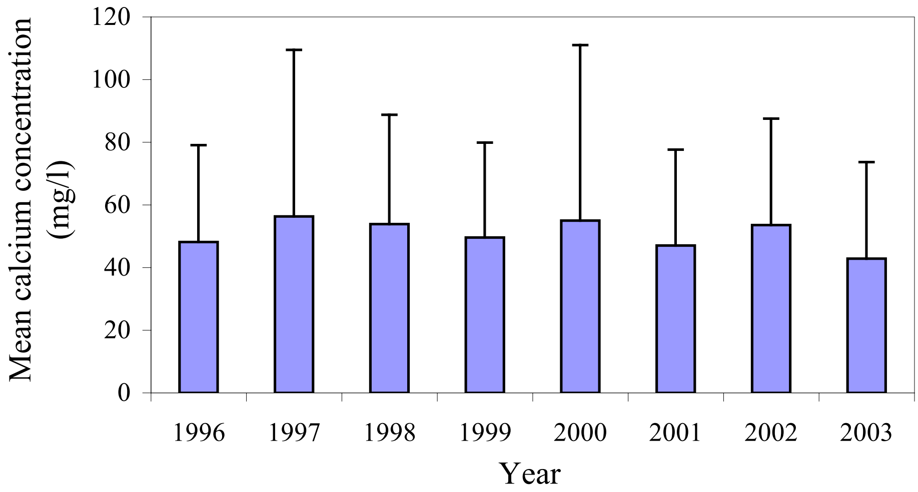

Figure 13. Annual mean calcium concentration in ditches on Amberley Wild Brooks

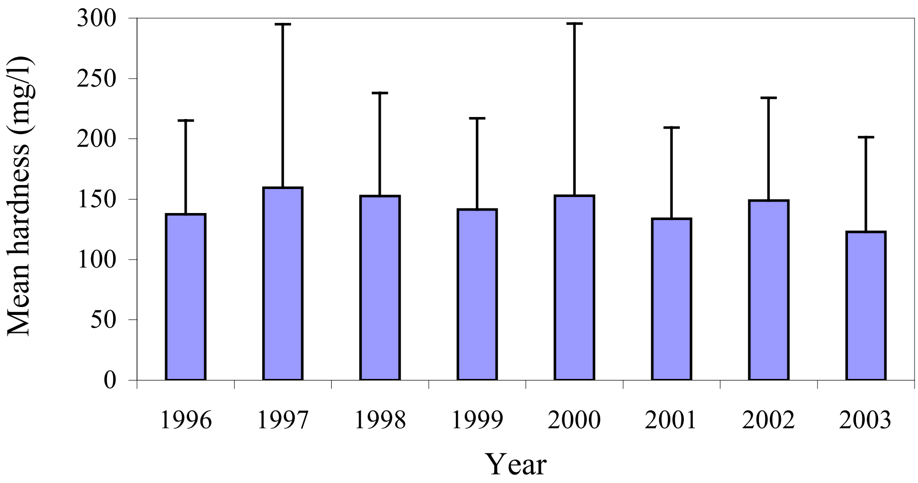

Figure 14. Annual mean hardness in ditches on Amberley Wild Brooks

6.2.3 Other determinands

6.2.3.1 Long-term trends

Significant long-term increases were seen in water temperature and iron across the site as a whole. There was a significant decline in magnesium concentrations. Other determinands showed no long-term trends or had insufficient data for an assessment to be made (Table 15).

Table 15. Summary of long-term water quality trends at Amberley Wild Brooks

Determinand	Long-term trend
Temperature	Increasing
Orthophosphate phosphorus	Increasing
Iron (dissolved)	Increasing
pH	Decreasing
Magnesium	Decreasing
Calcium	No change
Total hardness	No change
Turbidity FTU	No change
Dissolved oxygen % saturation	No change
Biochemical oxygen demand	No change
Total organic carbon	No change
Ammonia (total)	No change
Total oxidised nitrogen	No change
Ammonia (un-ionised)	No change
Suspended solids	No change
Chloride	No change
Manganese	No change
Iron (total)	No change
Conductivity	Sampling started in 2003
Chlorophyll a	Sampling started in 2003

There is a strong possibility that apparent temperature changes are an artefact of the sampling programme structure (Figure 15). At the beginning of the sampling programme samples were collected throughout the year, including winter, whereas in the latter half of the programme sampling has been confined more to spring, summer and autumn. This probably accounts for the apparent increase in the temperature of water samples.

The reason(s) for the trend in magnesium concentrations may relate to the general reduction in pH, perhaps because of increased abstraction. The increase in dissolved iron could have been caused by a reduction in pH as metals are generally more soluble in acid water (Bronmark and Hansen 1998).

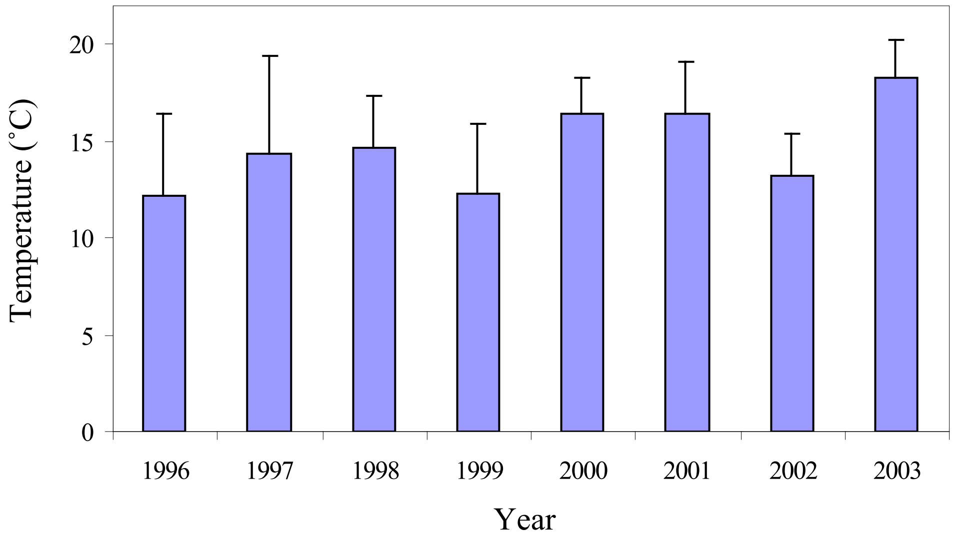

Figure 15. Annual mean temperature in ditches on Amberley Wild Brooks

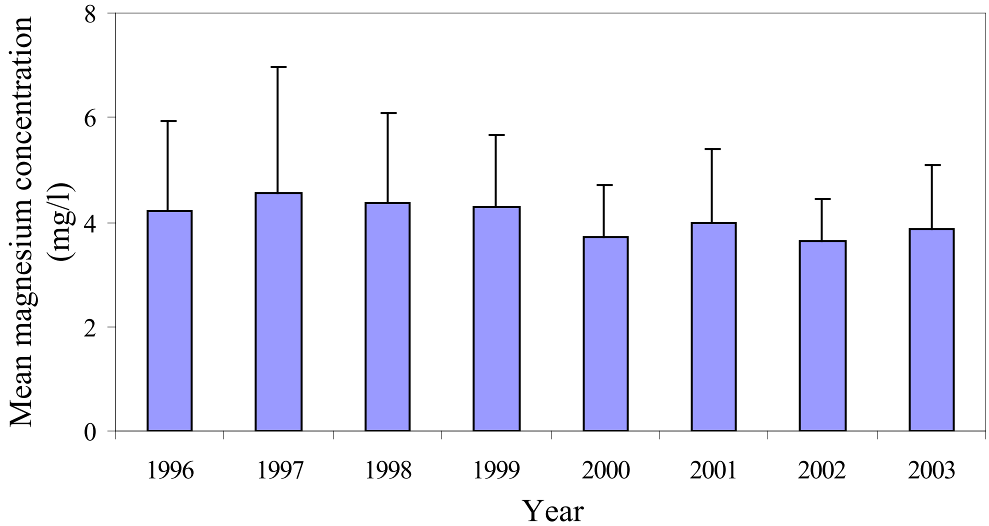

Figure 16. Annual mean magnesium concentration in ditches on Amberley Wild Brooks

6.2.3.2 Variation within the site

In addition to the trends apparent across the whole site there were significant within-site variations in ditch water quality. Potentially of concern were elevated concentrations of total ammonia, total organic carbon and suspended sediments, lower dissolved oxygen concentrations and increased turbidity. The sites at which these potentially stressful water quality parameters were at their highest were grouped towards the south east side of the Brooks (specifically Sites 5, 6, 11 and 12 – see Appendix 2). This may be an indication of the effect of small private sewage effluent discharges on the Amberley ditch systems.

Table 16. Sites with potentially stressful, levels of ammonia, total organic carbon, suspended sediments, dissolved oxygen, turbidity and biochemical oxygen demand

Site	Ammonia (highest)	Total organic carbon (highest)	Suspended sediments (highest)	Dissolved oxygen (lowest)	Turbidity (highest)	Biochemical oxygen demand (highest)
Site 5			•		•	•
Site 6	•	•			•	•
Site 11	•	•			•	•
Site 12				•	•	•

6.3 Mean Trophic Rank (MTR)

The Mean Trophic Rank for the five locations surveyed in 2003 ranged from 33 to 41. These data suggest that the sites surveyed are naturally eutrophic and, therefore, at risk of further eutrophication (Holmes *et al*. 1999). The relatively high macrophyte species richness (>20 species) in two of the ditches surveyed (15/New 2 and 17/New 4) suggests that, using the criteria of Holmes *et al*. (1999), these ditches are relatively little impacted by eutrophication at present. As only 1 year of sampling data are available it is not yet possible to make any comments on trends in ditch quality based on MTR data. Holmes *et al.* (1999) recommend that a minimum of one survey per year for three years should be carried for MTR assessments.

6.4 Trophic Diatom Index (TDI)

The Trophic Diatom Index scores for the four locations surveyed in 2003 at Amberley Wild Brooks ranged from 40 to 47. The percentage of taxa tolerant of organic pollution ranged from 19% to 25%. These results suggest that the four ditches surveyed are relatively free of organic pollution (Environment Agency, 1996). At present it is not possible to make comments about trends because data are available only for 2003. It is generally recommended that two samples per year are collected for most monitoring purposes using the TDI approach (Environment Agency, 1996).

6.5 Conclusions

6.5.1 Water quality trends

Water quality monitoring data reveal important, and worrying, trends in orthophosphate phosphorus concentrations at Amberley. Approximately half of the stations monitored are showing significant increases in phosphate concentration since 1996. Over the site as a whole, mean orthophosphate phosphorus concentrations have approximately doubled in this time. In addition, total oxidised nitrogen concentrations are considerably above natural background levels. Given the sensitivity of the site to nutrient levels, especially of phosphorus, these changes require both further investigation, action to prevent further increases and, if possible, reduction to at least 1996 levels .

In addition to site-wide trends, four sites in the south-east corner of the Brooks appear to have elevated concentrations of ammonia, suspended sediments, turbidity and total organic carbon. The lowest dissolved oxygen concentration was also recorded in this area. These observation suggest that this part of Amberley Wild Brooks may be experiencing localised impacts from small sewage effluent sources.

Considering the implementation of the water quality monitoring programme more generally, some refinements are advisable. The programme initially began with year round sampling but more recently sampling has been focussed on the summer and early autumn. Although the total number of samples collected has remained approximately constant, an important consequence of this change is that between-year comparisons are now less reliable, reducing the value of what is otherwise a very good chemical monitoring programme.

6.5.2 Recommendations

Although there appears to be a very worrying trend in orthophosphate phosphorus concentrations, absolute concentrations still remain relatively low. Probably because of this there have, so far, been few, if any, obvious signs of nutrient enrichment affecting the Amberley ditches. However, given the extreme difficulty of managing nutrient enriched systems once that enrichment has occurred, every effort should be made now to prevent the situation from becoming worse.

To this end we make the following recommendations:

Recommendation 1. There is an urgent need for a more detailed description of the hydrology and nutrient budgets of the Amberley ditch system. In particular, there is a need to:

(i) identify the main water sources for the site

(ii) describe the main catchment nitrogen and phosphorus sources, and

(iii) estimate the rate at which nutrients enter and leave the system.

The balance between internal supply (i.e. from the grasslands of the Brooks themselves) and outside sources is likely to be critical in this respect. Establishing water and nutrient budgets for the site is an essential precursor to the development of a programme of measures (Recommendation 2) to ensure no further deterioration in water quality and, if possible, reversal of the current apparent trends.

Related to this, it is also necessary to ensure that there is biological monitoring of the most nutrient sensitive plants and animals found in the ditches. This monitoring should comprise a combination of species specific studies (e.g. studies of plants known to be particularly sensitive to nutrients, such a *Tolypella prolifera*) and standard plant and invertebrate surveys to keep an overall check on the quality of the site. For vegetation surveys it would be desirable to establish survey stations where the standard Alcock and Palmer (1985) plant survey method is used, in addition to other methods (i.e. whole ditch and 100 m MTR plant surveys).

Recommendation 2. In the light of the investigation outlined above establish a programme of further measures to reduce as far as possible the levels of nutrients entering the system.

These are likely to involve further application of land management initiatives and rigorous control of point sources of nutrients.

7. Conclusions

7.1 Introduction

The ditch system at Amberley Wild Brooks is one of a relatively small number of mainly coastal grazing marsh sites in lowland England which combine exceptionally good water quality with a long history as wetland environments. These systems are widely recognised as being of exceptional nature conservation interest particularly for the wetland plant and invertebrate assemblages they support. Of particular importance in these systems is the occurrence of large areas of relatively unpolluted water, with near natural nutrient concentrations and probably relatively low levels of exposure to pesticides. Collectively they represent an extremely scarce and vulnerable resource in lowland Britain.

The corollary of this is that protection of existing high quality grazing marsh sites, particularly from water quality degradation and inappropriate habitat management, is of prime importance. Given the intensity of land management surrounding these areas this is likely to prove a challenging task for the future.

7.2 Quality of the aquatic invertebrate assemblages

There has been a relatively limited amount of aquatic invertebrate survey work undertaken at Amberley making it difficult to assess the overall importance of the site for invertebrates in relation to other areas. This difficulty is compounded by the lack of compatible survey data generally from other high quality ditch systems.

Despite this lack of data it is clear that Amberley supports an important invertebrate assemblage. Three Red Data Book aquatic invertebrate species have been recorded over the last 13 years at Amberley: the Great Silver Water Beetle (*Hydrophilus piceus*), the Little Whirlpool Ram's-horn Snail and the pea mussel *Pisidium pseudosphaerium*. It is not known whether *H. piceus* still occurs at Amberley. In addition 10 nationally scarce water beetles and dragonflies have also been recorded.

More generally the existing data indicate that:

(i) Amberley supports a rich invertebrate fauna compared to the 'ordinary' countryside;

(ii) The site may be slightly less species rich in invertebrate terms than other SSSI grade grazing marshes (e.g. Pevensey Levels, Somerset Levels). However, available data are generally too limited to enable this to be more than a tentative conclusion pending the establishment of more reliable sampling programmes

(iii) Amberley is an important location in Britain for the Little Whirlpool Ram's-horn snail with some of the highest individual population counts of this species.

(iv) The relatively limited amount of survey work undertaken at Amberley compared to some other sites suggests its importance for invertebrates may be underestimated.

7.3 Quality of macrophyte assemblages

The flora of the Amberley Wild Brooks ditches is both species-rich and includes nationally important populations of rare wetland plants. The flora includes four RDB species, two of which are Critically Endangered. One of these species, *Tolypella* *prolifera*, has not yet been adequately searched for at Amberley, and may well be more widespread than its current known locality.

Differences in the length of sections used for plant surveys in the last five years prevent any clear conclusions about change over time in macrophyte species richness and rarity at Amberley Wild Brooks. There is a hint that *Myriophyllum verticillatum*, and possibly other local species, may have been lost from the site prior to 1997, possibly due to water quality deterioration. However, poor locational data, together with issues around ditch successional state, make this difficult to assert with confidence.

It is, however, possible to assess the main threats to rare and uncommon species extant at the site based on both their known habitat requirements and threats to the species nationally. This suggests the following conclusions:

- *Water quality*: for at least three of the four RDB species *(Leersia oryzoides, Tolypella prolifera, Potamogeton acutifolius)* maintenance of good water quality relatively low in nutrients (in what are currently borderline mesotrophic/eutrophic ditches), is likely to be critical to sustaining these species at Amberley Wild Brooks in the long term.

- *Alien aquatic species*, particularly *Elodea nuttallii* and *Lemna minuta*, are known threats *Tolypella prolifera* and probably also *Potamogeton acutifolius*. The domination of aquatic aliens in ditches is likely to increase with increasing nutrient levels, compounding detrimental impacts of enhanced nutrient levels.
- *Cattle grazing*: at least moderate levels of grazing and poaching of ditch margins are likely to be important for maintaining species such as *Leersia oryzoides* and *Tolypella prolifera,* which require areas of bare ground within or adjacent to ditches.
- *Ditch management regimes* may also be critical for some species. *Potamogeton acutifolius* and, particularly, *Tolypella prolifera* are species of early succession ditches. For these species it is important to ensure that the early succession phase is maintained in ditches (rather than, for example, undertaking "conservation" de-silting or weed cutting of half the channel). Dredging periodicity may also be important, since, as shown by the recent *T. prolifera* experiments, if clearance is too frequent, this may promote the growth of alien aquatics such as *E. nuttallii*.

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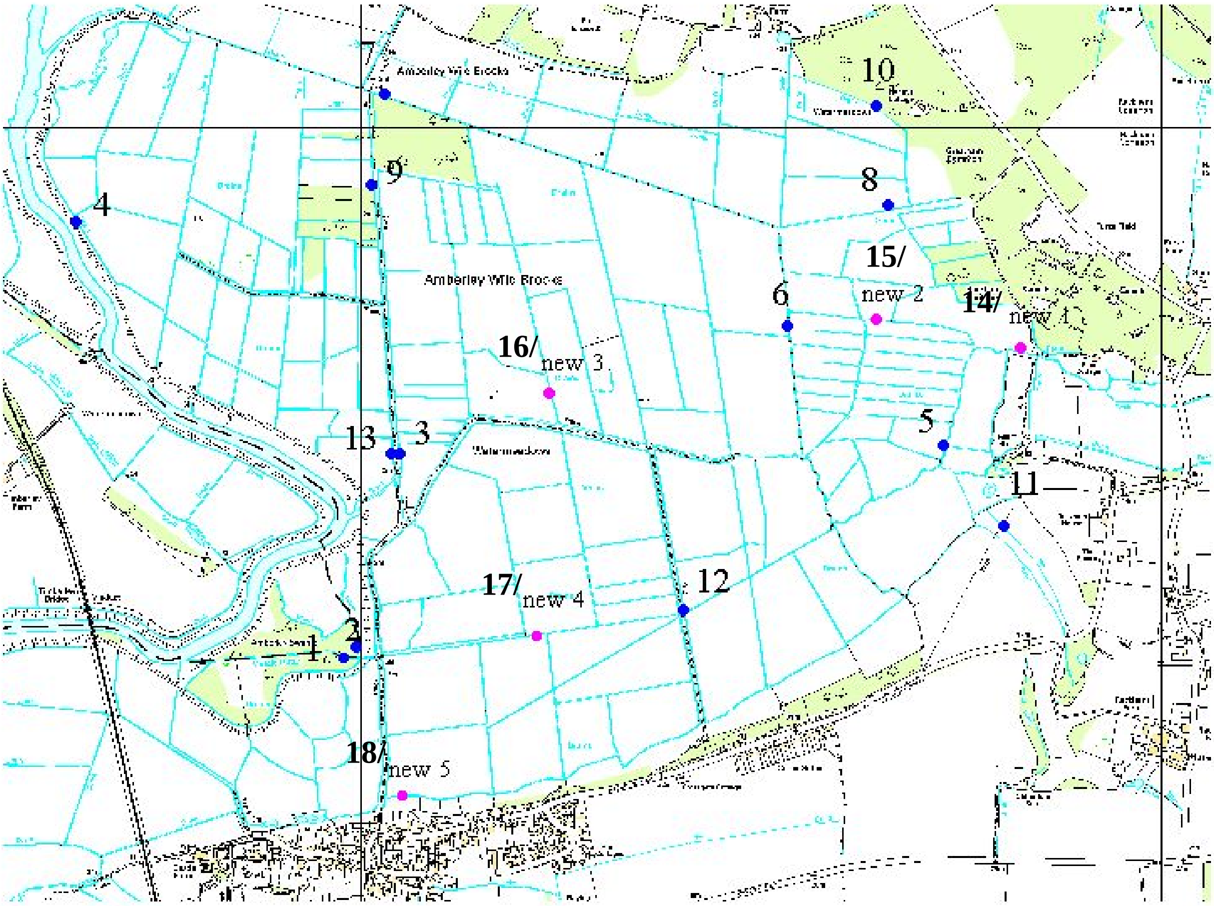
Appendix 1. Ordnance survey grid references for the sampling location of the 1996-2003 Environment Agency monitoring programme at Amberley Wild Brooks

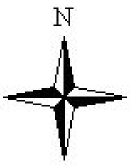
Site No.	Name	Ordnance survey grid reference	Other names
1	Middle Gutter Ditch	TQ02951368	
2	Middle Gutter Ditch	TQ02981371	
3	Lower wild brook stream	TQ03111418	
4	Western low brook ditch	TQ02281476	
5	Upper wildbrook stream	TQ04461420	
6	Smooth Ditch	TQ04061450	
7	Smiths Ditch	TQ03051508	
8	Watermeadows	TQ04311480	
9	Iron site	TQ03031485	
10	Sphagnum site	TQ04281506	
11	SE ditch	TQ04601400	
12	Middle ditch	TQ03811379	
13	Central low brook ditch west	TQ03071418	
14	Rackham Mill drain	TQ 0462 1444	NEW1
15	Unnamed tributary of Smooth Ditch	TQ 0431 1451	NEW2
16	Pound Piece ditch (water meadows)	TQ 0346 1436	NEW3
17	Middle Gutter Ditch (east)	TQ 0341 1372	NEW4
18	Wey-South path (south)	TQ 0209 1333	NEW5

Appendix 2. Map showing the sampling locations for the 1996-2003 Environment Agency monitoring programme at Amberley Wild Brooks



Historical sites

New 2003 sites



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Appendix 3. Summary of macroinvertebrate species data at Amberley Wild Brooks

Reference		Killeen and Willing (1997)	Abraham et al. (1997)	Callaway (1997)	Willing and Killeen (1998)	Willing (1999)	Willing (1999)	Watson (2002)	EA 1999	EA 2003
Survey year		**1996**	**1997**	**n/a**	**1997**	**1998**	**1999**	**1999**	**1999**	**2003**
Type of survey		**Mollusc search**	**Field search**	**n/a**	**Mollusc search**	**Mollusc search**	**Mollusc search**	**Mollusc search**	**3-min**	**3-min**
No of sampling stations	**Status[1]**	**21**	**9**	**n/a**	**50**	**1**	**2**	**18**	**15**	**4**
Flatworms										
Dendrocoelum lacteum	Common								+	
Dugesia polychroa	Common									+
Dugesia polychroa grp	Common								+	
Polycelis tenuis grp	Common								+	
Polycerlis felina	Common								+	
Water snails										
Acroloxus palustris	Common	+						+		
Anisus leucostoma	Common				+				+	
Anisus vortex	Common	+			+	+	+	+	+	+
Anisus vorticulus	RDB2	+		+	+	+	+			+
Armiger crista	Common							+		
Bathyomphalus contortus	Common						+			
Bithynia tentaculata	Common	+			+	+	+	+	+	+
Gyraulus albus	Common	+			+		+	+	+	+
Hippeutis complanatus	Common	+			+	+		+	+	+
Lymnaea palustris	Common	+			+	+	+	+	+	+
Lymnaea peregra	Common	+			+	+	+	+	+	+
Lymnaea stagnalis	Common	+			+	+	+	+	+	
Lymnaea truncatula	Common				+					
Physa group	Common								+	+
Physa fontinalis	Common	+			+	+	+	+		
Planorbarius corneus	Common	+			+	+	+	+	+	
Planorbis carinatus	Common	+			+			+		
Planorbis planorbis/carinatus	Common	+			+	+	+		+	+
Potamopyrgus antipodarum	Common	+			+			+	+	
Valvata cristata	Common	+			+	+	+	+	+	+
Valvata piscinalis	Common	+			+	+	+	+	+	+
Bivalves										
Musculium lacutris	Common				+		+	+		+
Pisidium castertanum	Common	+								
Pisidium henslowanum	Common							+		
Pisidium hibernicum	Common	+			+		+	+		
Pisidium milium	Common	+			+	+	+	+		
Pisidium nitidum	Common	+			+	+	+	+		
Pisidium obtusale	Common	+			+	+	+	+		
Pisidium pseudosphaerium	RDB3	+			+	+	+	+		
Pisidium pulchellum	local	+			+	+	+			
Pisidium subtruncatum	Common	+			+		+	+		
Pisidum personatum	Common							+		
Sphaerium corneum	Common	+			+	+	+	+		+

Reference		Killeen and Willing (1997)	Abraham et al. (1997)	Callaway (1997)	Willing and Killeen (1998)	Willing (1999)	Willing (1999)	Watson (2002)	EA 1999	EA 2003
Leeches										
Erpobdella octoculata	Common								+	+
Erpobdella testacea	Common								+	+
Glossiphonia complanata	Common								+	+
Helobdella stagnalis	Common								+	+
Hemiclepsis marginata	Local									+
Piscicola geometra	Common								+	+
Theromyzon tessulatum	Common								+	+
Trocheta subviridis	Local								+	
Shrimps and slaters										
Asellus aquaticus	Common								+	+
Asellus meridianus	Common								+	+
Crangonyx pseudogracilis	Common								+	+
Gammarus pulex	Common									+
Mayflies										
Baetis rhodani	Common									+
Baetis vernus	Common									+
Caenis horaria	Common								+	
Caenis robusta	Common								+	
Cloeon dipterum	Common								+	+
Leptophlebia marginata	Common									+
Dragonflies										
Aeshna cyanea	Common								+	
Brachytron pratense	NS			+						
Coenagrion puella group	Common									+
Cordullia aenea	NS			+						
Enallagma cyathigerum	Common								+	
Ischnura elegans	Common								+	
Lestes sponsa	Common								+	+
Libellula fulva	RDB3			+						
Pyrrhosoma nymphula	Common								+	
Sympetrum striolatum	Common									+
Water bugs										
Corixa punctata	Common								+	+
Gerris lacustris	Common								+	
Hesperocorixa linnei	Common								+	+
Hesperocorixa moesta	Common								+	
Hesperocorixa sahlbergi	Common								+	+
Ilyocorus cimicoides	Common								+	
Nepa cinerea	Common									+
Notonecta glauca	Common								+	+
Plea leachi	Common								+	
Ranatra linearis	Local		+						+	
Sigara dorsalis	Common								+	
Sigara falleni	Common								+	+
Sigara fossarum	Common								+	+
Sigara nigrolineata	Common								+	

Reference		Killeen and Willing (1997)	Abraham et al. (1997)	Callaway (1997)	Willing and Killeen (1998)	Willing (1999)	Willing (1999)	Watson (2002)	EA 1999	EA 2003
Water beetles										
Agabus bipustulatus	Common								+	
Agabus paludosus	Common								+	
Agabus sturmii	Common								+	+
Anacaena limbata	Common								+	
Anacaena lutescens	Common								+	
Brychius elevatus	Common									+
Colymbetes fuscus	Common								+	
Dytiscus sp larvae	Common								+	
Enochrus coarctatus	Common		+							
Enochrus testaceus	Common		+							
Enochrus ochropterus	LRnsB		+	+						
Graptodytes pictus	Common		+						+	+
Haliplus fulvus	Common								+	
Haliplus immaculatus	Common									+
Haliplus lineatocollis	Common								+	+
Haliplus ruficollis	Common								+	+
Hydrophilus piceus	LRnt		+							
Helophorus aequalis	Common								+	
Helophorus brevipalpis	Common								+	+
Helophorus grandis	Common								+	
Helophorus minutus	Common								+	+
Hydraena riparia	Common									+
Hydraena testacea	LRnsB		+							
Hydrobius fuscipes	Common								+	
Hydroporus palustris	Common								+	+
Hydroporus pubescens	Common								+	+
Hydroporus striola	Common								+	
Hygrobia hermani	Common								+	
Hygrotus inaequalis	Common								+	
Hygrotus versicolor	Common		+						+	
Hyphydrus ovatus	Common								+	+
Ilybius fuliginosus	Common								+	
Lacobius biguttatus	Local		+							
Laccophilus minutus	Common		+							
Laccophilus hyalinus	Common								+	
Nebioporus depressus elegans	Common									+
Nebioporus elegans	Common								+	
Noterus clavicornis	Common								+	
Octhebius dilatatus	Common								+	
Peltodytes caesus	LRnsB			+					+	
Porhydrus lineatus	Local		+							
Stictotarsus duodecimpustulatus	Common								+	
Suphrodytes dorsalis	Common		+							
Alderflies										
Sialis lutaria	Common								+	+

Reference		**Killeen and Willing (1997)**	**Abraham et al. (1997)**	**Callaway (1997)**	**Willing and Killeen (1998)**	**Willing (1999)**	**Willing (1999)**	**Watson (2002)**	**EA 1999**	**EA 2003**
Caddis flies										
Anabolia nervosa	Common								+	
Athripsodes sp	Common								+	
Holocentropus sp	Common								+	
Hydroptila sp	Common								+	
Leptoceridae sp	Common									+
Limnephilus lunatus	Common								+	+
Limnephilus marmoratus grp	Common								+	
Phryganea bipunctata	Common								+	
Triaenodes bicolor	Common								+	+
Moths										
Paraponyx stratiotes	Common								+	

[1] Conservation status: leeches (??), dragonflies (Merritt *et al*. 1996), water beetles (Foster 2000)

Appendix 4. Summary of macrophyte species data from Amberley Wild Brooks

Reference	**English name**	**National status**	**Willing and Killeen (1998)**	**Abraham (1998)**	**Watson (2002)**	**EA 2003**
Survey year			**1997**	**1998**	**1999**	**2003**
Number of ditch length			**50**	**All ditches**	**20**	**5**
Latin name						
Submerged species						
Callitriche obtusangula	Blunt-fruited Water-starwort	local		+		+
Callitriche platycarpa	Various-leaved Water-startwort	local		+		
Callitriche sp.	Water-starwort species	n/a	+	+	+	
Callitriche stagnalis	Common Water-starwort	common		+		
Ceratophyllum demersum	Rigid Hornwort	common	+	+	+	+
Ceratophyllum submersum	Soft Hornwort	local			+	
Chara globularis	Fragile Stonewort	frequent		+		
Chara sp.	*Chara* species	n/a	+			
Chara virgata	Delicate Stonewort	frequent		+		
Chara vulgaris var. *longibracteata*	Common Stonewort variety	frequent		+		
Chara vulgaris var. *vulgaris*	Common Stonewort variety	frequent		+		
Charophyta	Stonewort species	n/a			+	
Elodea canadensis	Canadian Pondweed	introduced	+	+	+	+
Elodea nuttallii	Nuttall's Pondweed	introduced	+	+	+	+
Groenlandia densa	Oppositve-leaved Pondweed	local	+	+	+	
Myriophyllum spicatum	Spiked Water-milfoil	common		+		
Nitella flexilis agg.	Smooth Stonewort group	common		+		
Nitella opaca	Dark Stonewort	local		+		
Oenanthe aquatica	Fine-leaved Water-dropwort	local	+	+		
Potamogeton acutifolius	Sharp-leaved Pondweed	RDB2	+	+	+	
Potamogeton berchtoldii	Small Pondweed	common		+		+
Potamogeton crispus	Curled Pondweed	common		+		
Potamogeton lucens	Shining Pondweed	local	+	+	+	+
Potamogeton pectinatus	Fennel Pondweed	common		+		
Potamogeton perfoliatus	Perfoliate Pondweed	local		+		
Potamogeton pusillus	Lesser Pondweed	local		+		
Potamogeton sp.	Pondweed species	n/a			+	
Potamogeton trichoides	Hairlike Pondweed	local	+	+		+
Ranunculus circinatus	Fan-leaved Water-crowfoot	local	+	+		
Ranunculus sp.	Water-crowfoot species	n/a			+	
Ranunculus trichophyllus	Thread-leaved Water-crowfoot	local				+
Sagittaria sagittifolia	Arrowhead	local	+	+	+	+
Sparganium emersum	Unbraned Bur-reed	common	+	+	+	+
Utricularia australis	Bladderwort	local		+		
Utricularia sp.	Bladderwort species	n/a	+			
Floating-leaved species						
Hydrocharis morsus-ranae	Frog-bit	local	+	+	+	+
Lemna gibba	Fat Duckweed	local		+		
Lemna minor	Small Duckweed	common	+	+	+	+
Lemna minuta	Lesser Duckweed	introduced	+	+	+	
Lemna trisulca	Ivy-leaved Duckweed	common	+	+	+	+

Reference	English name	National status	Willing and Killeen (1998)	Abraham (1998)	Watson (2002)	EA 2003
Nuphar lutea	Yellow Water-lily	common		+		
Persicaria amphibia	Amphibious Bistort	common		+	+	+
Potamogeton natans	Broad-leaved Pondweed	common	+	+	+	+
Potamogeton polygonifolius	Bog Pondweed	common		+		
Riccia fluitans	A floating liverwort	local	+	+		
Spirodela polyrhiza	Greater Duckweed	common	+	+	+	+
Wolfia arrhiza	Rootless Duckweed	NS		+		
Emergent/marginal species						
Achillea ptarmica	Sneezwort	common		+		
Agrostis stolonifera	Creeping Bent	common		+	+	
Alisma lanceolatum	Narrow-leaved Water-plantain	local		+	+	
Alisma plantago-aquatica	Water-plantain	common	+	+	+	+
Alopecurus geniculatus	Marsh Foxtail	common		+		
Angelica sylvestris	Wild Angelica	common	+	+		
Apium nodiflorum	Fool's-water-cress	common	+	+		+
Baldellia ranunculoides	Lesser Water-plantain	local		+		
Berula erecta	Lesser Water-parsnip	common	+	+	+	+
Bidens cernua	Nodding Bur-marigold	local	+	+	+	
Bidens tripartita	Trifid Bur-marigold	local		+		
Butomus umbellatus	Flowering-rush	local		+		
Caltha palustris	Marsh-marigold	common	+	+		
Cardamine pratensis	Cuckooflower	common		+	+	
Carex acuta	Slender Tufted-sedge	local		+		
Carex acutiformis	Lesser Pond-sedge	common		+		+
Carex hirta	Hairy Sedge	common		+		
Carex otrubae	False Fox-sedge	common		+	+	
Carex paniculata	Greater Tussock-sedge	common	+	+		
Carex pseudocyperus	Cyperus Sedge	common	+	+	+	
Carex riparia	Greater Pond-sedge	common		+	+	
Carex rostrata	Bottle Sedge	common		+		
Carex sp.	Sedge species	n/a		+	+	
Carex versicaria	Bladder Sedge	local		+		+
Carex vulpina	Fox Sedge	RDB2		+		
Catabrosa aquatica	Whorl-grass	local		+		
Cirsium palustre	Marsh Thistle	common		+		
Deschampsia cespitosa	Tufted Hair-grass	common	+	+		
Elocharis palustris	Common Spike-rush	common		+	+	+
Epilobium hirsutum	Great Willowherb	common	+	+		
Epilobium obscurum	Short-fruited Willowherb	common		+		
Epilobium palustre	Marsh Willowherb	common		+	+	
Epilobium parviflorum	Hoary Willowherb	common		+		
Epilobium sp.	Willowherb species	n/a		+		
Epilobium tetragonum	Square-stalked Willowherb	common			+	
Equisetum fluviatile	Water Horsetail	common	+	+	+	+
Equisetum palustre	Marsh Horsetail	common		+		
Eupatorium cannabinum	Hemp-agrimony	common		+		
Filipendula ulmaria	Meadowsweet	common	+	+	+	
Galium palustre	Common Marsh-bestraw	common	+	+	+	
Glyceria declinata	Small Sweet-grass	common	+	+		

Reference	English name	National status	Willing and Killeen (1998)	Abraham (1998)	Watson (2002)	EA 2003
Glyceria fluitans	Floating Sweet-grass	common	+	+	+	
Glyceria maxima	Reed Sweet-grass	common	+	+	+	+
Glyceria notata	Plicate Sweet-grass	common	+	+		
Glyceria sp.	Sweet-grass species	n/a		+		
Hydrocotyle vulgaris	Marsh Pennywort	common		+	+	
Hypericum tetrapterum	Square-stalked St Johns-wort	common		+	+	
Impatiens glandulifera	Indian Balsam	introduced		+		
Iris pseudacorus	Yellow Iris	common	+	+		+
Juncus acutiflorus	Sharp-flowered Rush	common		+	+	
Juncus articulatus	Articulated Rush	common	+	+	+	
Juncus bufonius	Toad Rush	common		+		
Juncus effusus	Soft Rush	common	+	+	+	
Juncus inflexus	Hard Rush	common	+	+		
Leersia oryzoides	Cut-grass	RDB1	+	+		
Lotus pedunculatus	Greater Bird's-foot-trefoil	common	+	+	+	+
Lychnis flos-cuculis	Ragged-robin	common		+		
Lycopus europaeus	Gipsywort	common	+	+	+	
Lysimachia nummularia	Creeping-jenny	common	+	+	+	
Lysimachia vulgaris	Yellow Loostrife	common	+	+		
Lythrum portula	Water-purslane	common			+	
Lythrum salicaria	Purple Loostrife	common	+	+		
Mentha aquatica	Water Mint	common	+	+	+	
Mentha x verticillata	Water Mint hybrid	common	+	+		
Menyanthes trifoliata	Bogbean	common		+		
Myosotis laxa	Tufted Forget-me-not	common	+	+		
Myosotis scorpioides	Water Forget-me-not	common	+	+	+	
Myosotis secunda	Creeping Forget-me-not	common		+		
Myosoton aquaticum	Water Chickweed	common		+		
Oenanthe crocata	Hemlock Water-dropwort	common		+		+
Oenanthe fistulosa	Tubular Water-dropwort	local	+	+	+	
Oenanthe silaifolia	Narrow-leaved Water-dropwort	NS		+		
Persicaria hydropiper	Water-pepper	common	+	+	+	
Persicaria minor	Small Water-pepper	local	+	+		
Phalaris arundinacea	Reed Canary-grass	common	+	+	+	
Phragmites australis	Common Reed	common		+	+	+
Potentilla erecta	Tormentil	common			+	
Potentilla palustris	Marsh Cinquefoil	common		+		
Pulicaria dysenterica	Common Fleabane	common		+		
Ranunculus flammula	Lesser Spearwort	common	+	+	+	+
Ranunculus sceleratus	Celery-leaved Buttercup	common	+	+	+	
Rorippa amphibia	Great Yellow-cress	local			+	
Rorippa nast.aquat./offic.	Water-cress	common		+		+
Rorippa palustris	Marsh Yellow-cress	common		+		
Rorippa sp.	Yellow-cress species	n/a		+		
Rorippa sylvestris	Creeping Yellow-cress	common		+	+	
Rumex hydrolapathum	Water Dock	common	+	+	+	
Schoenoplectus lacustris	Common Club-rush	local		+	+	
Scorphularia auriculata	Water Figwort	common		+		
Scutellaria galericulata	Skullcap	common	+	+	+	

Reference	English name	National status	Willing and Killeen (1998)	Abraham (1998)	Watson (2002)	EA 2003
Senecio aquatica	Marsh Ragwort	common	+	+		
Sium latifolium	Greater Water-parsnip	NS	+	+	+	
Solanum dulcamara	Bittersweet	common		+	+	
Sparganium erectum	Branched Bur-reed	common	+	+	+	+
Stachys palustris	Marsh Woundwort	common	+	+	+	
Stellaria palustris	Marsh Stitchwort	local	+	+		
Stellaria uliginosa	Bog Stitchwort	common		+		
Symphytum officinale	Common Comfrey	common		+		
Typha latifolia	Bulrush	common		+	+	
Valeriana officinalis	Common Valerian	common		+		
Veronica anagallis-aquatica	Blue Water-speedwell	common		+		
Veronica beccabunga	Brooklime	common		+		
Veronica catenata	Pink Water-speedwell	common	+	+		+
N.B. National conservation status from Wigginton (1999), NS=Nationally Scarce						

Appendix 5. Summary of water chemistry data for the 1996-2003 Environment Agency monitoring programme (per year and per site)

1996

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		18	16.8	61.4	3.0	8.0
SD	0.5		33	24.2	24.8	3.1	9.2
Min	5.9		1	3.0	3.2	1.0	1.0
Max	9.9		192	210.0	131.0	24.7	62.0
No of readings	114	0	114	114	114	114	114
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.099	2.18	2.17	0.024	0.039	137.7	48.1
SD	0.155	3.24	3.24	0.018	0.030	77.6	31.0
Min	0.030	0.20	0.20	0.004	0.020	36.4	8.0
Max	1.000	19.40	19.40	0.077	0.150	428.0	162.0
No of readings	114	114	114	114	114	114	114
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	30.3	4.2	0.21	0.95	4.16	12.2	
SD	9.4	1.7	0.21	2.48	21.80	4.2	
Min	14.0	1.7	0.01	0.05	0.14	3.3	
Max	68.0	11.4	1.56	20.00	230.00	19.5	
No of readings	114	114	114	114	114	114	0

1997

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		90	134.0	63.9	5.1	8.9
SD	0.4		547	890.3	32.2	10.4	10.0
Min	6.1		1	3.0	2.2	1.0	1.5
Max	8.9		5400	8770.0	125.2	102.0	43.9
No of readings	99	0	98	98	100	99	99
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.074	1.74	1.72	0.023	0.033	159.5	56.4
SD	0.085	2.80	2.79	0.020	0.028	135.4	53.2
Min	0.030	0.20	0.20	0.004	0.010	46.4	11.0
Max	0.533	18.00	18.00	0.133	0.149	972.0	375.0
No of readings	99	99	99	99	99	98	98
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	29.7	4.5	0.56	1.13	5.36	14.3	
SD	8.8	2.4	1.11	2.41	10.25	5.1	
Min	12.0	2.2	0.01	0.03	0.08	3.1	
Max	70.2	14.3	8.70	16.60	61.00	25.1	
No of readings	99	98	98	98	98	101	0

1998

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		23	26.2	48.3	3.3	9.6
SD	0.4		28	35.0	31.1	2.4	10.6
Min	6.3		1	3.0	1.0	1.0	1.3
Max	8.7		167	178.0	160.5	16.5	56.7
No of readings	104	0	104	104	104	104	104
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.096	2.05	2.03	0.026	0.037	152.7	53.9
SD	0.231	3.09	3.07	0.022	0.029	85.3	34.8
Min	0.030	0.20	0.20	0.004	0.010	60.8	15.3
Max	2.250	13.50	13.50	0.149	0.160	383.0	145.7
No of readings	104	104	104	104	104	104	104
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	29.9	4.4	0.43	1.63	4.53	14.7	
SD	7.2	1.7	0.69	3.11	8.00	2.7	
Min	12.9	2.3	0.02	0.02	0.04	7.3	
Max	42.2	10.8	3.96	14.70	66.32	21.8	
No of readings	104	104	104	104	104	104	0

1999

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		26	24.6	59.7	2.9	11.5
SD	0.4		49	53.9	29.3	2.1	10.0
Min	5.8		1	3.0	3.1	1.0	1.2
Max	8.5		364	569.0	132.8	16.7	55.5
No of readings	143	0	143	143	142	143	143
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.111	1.91	1.89	0.024	0.061	141.6	49.6
SD	0.193	2.54	2.53	0.027	0.077	75.6	30.3
Min	0.030	0.20	0.17	0.004	0.010	18.3	2.6
Max	1.580	14.40	14.40	0.268	0.559	406.0	154.0
No of readings	143	143	143	143	143	142	142
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	30.9	4.3	0.42	1.31	3.32	12.3	
SD	6.7	1.4	1.11	2.67	5.29	3.6	
Min	13.7	1.6	0.01	0.03	0.12	5.4	
Max	45.1	9.9	12.20	21.60	49.50	19.6	
No of readings	143	142	143	142	142	142	0

2000

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		21	24.3	70.7	3.6	13.0
SD	0.4		35	56.4	27.2	2.3	11.1
Min	6.7		1	3.0	8.2	1.0	1.7
Max	8.3		205	397.0	134.3	13.1	48.2
No of readings	52	0	52	52	52	52	52
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.059	2.01	1.98	0.030	0.058	152.8	55.0
SD	0.045	2.72	2.72	0.024	0.050	142.6	56.0
Min	0.030	0.20	0.17	0.004	0.010	45.8	10.2
Max	0.267	12.50	12.50	0.157	0.244	994.0	383.0
No of readings	52	52	52	52	52	51	51
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	26.5	3.7	0.47	1.03	3.41	16.4	
SD	8.0	1.0	0.75	1.25	6.22	1.8	
Min	7.6	2.3	0.01	0.03	0.10	13.0	
Max	40.5	8.8	3.84	4.53	40.60	22.5	
No of readings	52	51	51	52	51	52	0

2001

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.0		36	28.8	52.6	3.5	7.0
SD	0.4		91	61.9	24.0	4.8	5.6
Min	6.5		1	3.0	2.0	1.0	1.5
Max	8.0		520	366.0	126.1	20.6	27.5
No of readings	39	0	39	39	39	39	39
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.046	1.78	1.75	0.028	0.046	133.8	47.0
SD	0.019	2.37	2.36	0.042	0.041	75.5	30.7
Min	0.030	0.20	0.18	0.004	0.010	52.5	12.9
Max	0.093	10.70	10.70	0.271	0.221	388.0	149.0
No of readings	39	39	39	39	39	39	39
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	27.7	4.0	0.29	0.84	2.44	16.5	
SD	7.0	1.4	0.53	2.21	3.82	2.7	
Min	16.3	2.4	0.01	0.03	0.18	11.5	
Max	41.7	9.2	3.10	13.80	20.20	23.5	
No of readings	39	39	39	39	39	39	0

2002

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	6.7		25	23.1	65.1	2.9	8.8
SD	0.5		41	36.2	24.1	2.2	6.5
Min	5.9		1	3.0	4.8	1.0	1.1
Max	7.9		253	194.0	167.3	11.7	31.4
No of readings	65	0	65	65	65	65	65
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.073	1.98	1.97	0.017	0.064	148.9	53.6
SD	0.102	2.57	2.57	0.014	0.049	85.2	34.0
Min	0.030	0.20	0.19	0.004	0.020	66.6	17.3
Max	0.818	12.90	12.90	0.055	0.265	395.0	151.0
No of readings	65	65	65	65	65	65	65
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	31.0	3.7	0.40	1.32	3.74	13.2	
SD	9.0	0.8	0.61	3.87	7.78	2.2	
Min	16.6	2.2	0.01	0.03	0.15	7.9	
Max	61.5	6.2	2.86	30.80	49.60	17.4	
No of readings	65	65	65	65	65	65	0

2003

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.1	248	32	41.1	62.3	3.2	6.0
SD	0.3	54	42	91.2	18.4	2.8	7.8
Min	6.7	169	2	3.0	25.6	1.0	1.8
Max	7.8	313	137	377.0	91.6	11.0	36.5
No of readings	18	12	18	18	18	30	18
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.189	1.75	1.73	0.020	0.118	122.9	42.8
SD	0.436	2.01	2.00	0.015	0.151	78.4	30.8
Min	0.030	0.20	0.19	0.008	0.020	65.1	23.2
Max	1.680	6.89	6.85	0.064	0.668	413.0	157.0
No of readings	30	30	30	30	30	18	18
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	33.1	3.9	0.29	1.26	4.44	18.3	22.9275
SD	9.8	1.2	0.38	2.10	6.23	2.0	28.4729
Min	14.4	1.8	0.01	0.03	0.18	12.1	3.3
Max	51.8	7.8	1.72	7.77	21.60	20.6	101
No of readings	18	18	18	18	18	18	12

Sampling Point 1: Middle Gutter Ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		4.7	5.9	58.1	2.1	4.8
SD	0.4		4.4	4.3	28.3	1.1	3.2
Min	6.6		1.0	3.0	3.2	1.0	1.8
Max	8.0		21.0	22.0	134.3	6.0	16.3
No of readings	51	0	51	51	51	51	51
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.06	2.50	2.47	0.034	0.045	169.9	62.0
SD	0.04	1.23	1.23	0.037	0.080	45.0	17.6
Min	0.03	0.59	0.56	0.004	0.010	121.0	43.0
Max	0.19	6.59	6.55	0.268	0.559	317.0	120.0
No of readings	51	51	51	51	51	51	51
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	27.8	3.65	0.08	0.17	0.47	13.4	
SD	6.3	0.46	0.09	0.14	0.36	3.8	
Min	19.5	2.69	0.01	0.04	0.08	3.6	
Max	51.8	5.13	0.44	0.72	1.80	19.1	
No of readings	51	51	51	51	51	51	0

Sampling point 2: Middle Gutter Ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.4		7.4	11.7	54.5	2.2	5.4
SD	0.3		12.7	26.2	23.6	1.0	4.3
Min	6.7		1.0	3.0	10.0	1.0	1.9
Max	8.1		85.0	180.0	103.7	5.5	23.9
No of readings	48	0	48	48	48	48	48
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.07	1.95	1.92	0.030	0.054	195.7	72.2
SD	0.08	1.49	1.49	0.022	0.074	60.4	23.8
Min	0.03	0.20	0.19	0.004	0.010	121.0	43.0
Max	0.53	8.32	8.29	0.135	0.424	340.0	130.0
No of readings	48	48	48	48	48	48	48
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	29.5	3.70	0.13	0.24	0.78	13.2	
SD	7.1	0.44	0.15	0.44	1.23	3.8	
Min	19.8	2.71	0.01	0.03	0.04	3.6	
Max	51.9	5.06	0.64	3.05	7.89	18.9	
No of readings	48	48	48	48	48	48	0

Sampling point 3: Lower wild brook stream

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		13.8	12.1	62.1	2.1	8.0
SD	0.3		8.1	7.7	22.0	0.9	5.8
Min	6.3		3.0	3.0	19.2	1.0	1.9
Max	8.0		39.6	36.0	108.4	5.6	30.8
No of readings	51	0	51	51	51	51	51
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.10	1.35	1.32	0.024	0.055	116.4	40.5
SD	0.13	1.06	1.05	0.015	0.062	21.7	8.0
Min	0.03	0.20	0.18	0.007	0.010	60.3	20.0
Max	0.93	5.22	5.14	0.081	0.296	174.0	62.2
No of readings	51	51	51	51	51	51	51
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	26.0	3.73	0.23	0.75	1.85	14.2	
SD	4.1	0.75	0.30	0.94	1.43	4.3	
Min	14.5	2.50	0.05	0.15	0.46	3.4	
Max	39.7	6.30	2.21	6.22	9.26	21.7	
No of readings	51	51	51	51	51	51	0

Sampling point 4: Western low brook ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.4		8.2	10.9	77.0	2.5	5.9
SD	0.3		9.6	10.1	27.4	1.1	3.7
Min	6.2		2.0	3.0	10.5	1.0	1.0
Max	8.0		62.0	57.5	132.8	5.7	22.0
No of readings	50	0	50	50	51	50	50
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.06	3.27	3.24	0.030	0.053	149.2	54.3
SD	0.03	1.08	1.08	0.013	0.022	28.3	11.3
Min	0.03	0.20	0.19	0.004	0.018	95.7	31.3
Max	0.12	8.40	8.37	0.069	0.115	283.0	106.0
No of readings	50	50	50	50	50	50	50
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	25.7	3.28	0.12	0.34	0.97	13.7	
SD	2.8	0.43	0.33	0.51	1.48	2.7	
Min	20.0	2.40	0.01	0.05	0.12	6.9	
Max	35.0	4.40	1.73	2.92	8.91	18.3	
No of readings	50	50	50	50	50	51	0

Sampling point 5: Upper wildbrook stream

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	8.1		190.7	323.3	85.6	5.4	4.4
SD	0.2		793.6	1288.0	18.0	14.7	4.5
Min	7.5		3.9	5.7	31.7	1.0	1.9
Max	8.3		5400.0	8770.0	167.3	102.0	31.0
No of readings	46	0	46	46	46	46	46
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.06	9.98	9.95	0.046	0.108	407.3	155.2
SD	0.04	3.60	3.63	0.039	0.049	142.2	54.7
Min	0.03	0.83	0.79	0.011	0.040	324.0	122.0
Max	0.27	19.40	19.40	0.271	0.271	994.0	383.0
No of readings	46	46	46	46	46	45	45
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	37.1	4.73	0.37	0.04	4.73	13.2	
SD	6.2	1.55	0.98	0.02	12.61	3.4	
Min	31.0	3.56	0.01	0.02	0.10	4.8	
Max	68.0	11.90	4.50	0.17	61.00	20.2	
No of readings	46	45	46	46	45	46	0

Sampling point 6: Smooth ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	6.8		58.5	27.9	61.6	5.5	17.9
SD	0.5		58.5	25.3	32.0	5.0	7.4
Min	5.9		3.7	3.0	6.5	1.0	3.1
Max	7.9		253.0	113.0	160.5	20.9	35.0
No of readings	44	0	44	44	45	44	44
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.20	0.34	0.33	0.019	0.031	79.2	22.2
SD	0.23	0.54	0.53	0.013	0.020	27.5	9.7
Min	0.03	0.20	0.18	0.004	0.010	36.4	8.0
Max	0.82	3.25	3.22	0.058	0.105	170.0	54.8
No of readings	44	44	44	44	44	44	44
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	39.2	5.77	0.28	3.31	13.01	14.9	
SD	6.6	1.49	0.21	3.30	33.81	4.5	
Min	20.9	3.02	0.02	0.14	0.50	5.4	
Max	61.0	10.30	1.01	16.60	230.00	23.5	
No of readings	44	44	44	44	44	45	0

Sampling point 7: Smiths Ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.1		20.7	20.7	60.3	3.4	10.1
SD	0.3		15.5	30.8	23.3	2.3	6.4
Min	6.1		3.0	3.0	26.3	1.0	1.1
Max	7.8		63.5	208.0	114.2	13.4	25.2
No of readings	48	0	47	48	48	48	48
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.10	0.75	0.73	0.023	0.059	97.8	32.6
SD	0.10	1.05	1.04	0.015	0.095	27.2	9.3
Min	0.03	0.20	0.18	0.004	0.010	49.5	17.0
Max	0.45	6.39	6.33	0.064	0.668	200.0	63.0
No of readings	48	48	48	48	48	48	48
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	27.4	3.99	0.30	1.07	3.25	14.6	
SD	5.7	1.35	0.41	1.05	3.87	4.4	
Min	14.4	1.61	0.01	0.11	0.27	3.7	
Max	44.7	10.30	2.82	6.20	26.00	24.2	
No of readings	48	48	48	47	48	48	0

Sampling point 8: Watermeadows

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.3		12.3	23.5	67.3	3.6	5.8
SD	0.4		14.2	36.7	24.6	2.7	5.0
Min	5.9		1.5	3.0	20.1	1.0	1.9
Max	8.1		72.0	191.0	125.2	17.0	30.0
No of readings	49	0	49	49	49	49	49
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.07	2.61	2.57	0.033	0.038	162.7	59.0
SD	0.07	1.32	1.32	0.029	0.039	63.2	24.5
Min	0.03	0.20	0.19	0.004	0.010	90.4	31.2
Max	0.40	6.47	6.41	0.157	0.180	387.0	145.0
No of readings	49	49	49	49	49	49	49
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	25.9	3.68	0.22	0.24	1.26	13.5	
SD	5.0	0.59	0.39	0.25	1.71	3.7	
Min	18.1	2.88	0.02	0.05	0.19	4.6	
Max	43.3	6.00	2.55	1.11	10.40	19.8	
No of readings	49	49	49	49	49	49	0

Sampling points 9: Iron site

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	6.9		16.2	27.3	49.4	3.3	3.1
SD	0.3		19.1	30.0	29.4	2.4	3.2
Min	6.0		1.2	3.0	3.1	1.0	1.2
Max	7.3		99.5	161.0	121.8	11.7	20.0
No of readings	49	0	49	49	49	49	49
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.07	1.63	1.61	0.023	0.038	90.2	30.2
SD	0.06	1.14	1.14	0.022	0.028	6.7	2.6
Min	0.03	0.20	0.20	0.004	0.010	78.5	26.0
Max	0.25	5.50	5.49	0.149	0.127	110.0	38.0
No of readings	49	49	49	49	49	49	49
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	35.7	3.56	0.74	0.82	3.55	13.0	
SD	3.6	0.23	1.33	1.95	5.29	2.8	
Min	25.2	2.95	0.06	0.03	0.13	3.1	
Max	42.0	4.16	8.70	11.60	27.00	18.8	
No of readings	49	49	49	49	49	49	0

Sampling point 10: Sphagnum site

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.2		64.8	30.3	55.8	5.5	31.0
SD	0.8		76.5	31.9	36.3	4.7	13.6
Min	5.8		4.1	3.0	2.2	1.4	1.6
Max	9.9		364.0	146.0	131.0	24.7	62.0
No of readings	48	0	48	47	46	48	48
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.24	0.25	0.24	0.022	0.035	100.8	27.3
SD	0.46	0.20	0.20	0.018	0.031	34.1	10.1
Min	0.03	0.20	0.17	0.004	0.010	18.3	2.6
Max	2.25	1.40	1.33	0.067	0.154	171.0	54.0
No of readings	48	48	48	48	48	46	46
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	34.2	7.96	0.25	4.15	10.77	15.0	
SD	10.0	2.61	0.28	4.28	9.30	4.6	
Min	16.3	2.74	0.01	0.20	0.52	5.0	
Max	70.2	14.30	1.35	20.00	49.50	25.1	
No of readings	48	46	46	47	46	47	0

Sampling point 11: SE ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.2		64.8	30.3	55.8	5.5	31.0
SD	0.8		76.5	31.9	36.3	4.7	13.6
Min	5.8		4.1	3.0	2.2	1.4	1.6
Max	9.9		364.0	146.0	131.0	24.7	62.0
No of readings	48	0	48	47	46	48	48
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.24	0.25	0.24	0.022	0.035	100.8	27.3
SD	0.46	0.20	0.20	0.018	0.031	34.1	10.1
Min	0.03	0.20	0.17	0.004	0.010	18.3	2.6
Max	2.25	1.40	1.33	0.067	0.154	171.0	54.0
No of readings	48	48	48	48	48	46	46
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	34.2	7.96	0.25	4.15	10.77	15.0	
SD	10.0	2.61	0.28	4.28	9.30	4.6	
Min	16.3	2.74	0.01	0.20	0.52	5.0	
Max	70.2	14.30	1.35	20.00	49.50	25.1	
No of readings	48	46	46	47	46	47	0

Sampling point 12: Middle ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.0		42.6	39.3	39.8	5.2	15.1
SD	0.3		54.2	42.3	27.5	3.7	6.8
Min	6.3		2.0	3.4	1.0	1.0	4.9
Max	7.8		296.0	196.0	116.8	18.6	43.2
No of readings	48	0	48	48	48	48	48
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.10	0.23	0.22	0.008	0.042	162.6	60.2
SD	0.31	0.19	0.19	0.005	0.088	51.4	21.0
Min	0.03	0.20	0.18	0.004	0.010	65.1	23.2
Max	1.68	1.53	1.51	0.024	0.589	340.0	131.2
No of readings	48	48	48	48	48	48	48
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	20.9	2.99	1.33	3.21	9.53	13.3	
SD	7.2	0.68	1.84	4.51	12.22	4.0	
Min	7.6	1.75	0.05	0.03	0.33	3.4	
Max	41.8	4.49	12.20	21.60	66.32	20.7	
No of readings	48	48	48	48	48	48	0

Sampling point 13: Central low brook ditch west

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean	7.2		11.6	10.4	55.0	2.4	6.7
SD	0.4		18.8	13.8	24.4	1.1	4.7
Min	6.1		1.0	3.0	15.5	1.0	1.5
Max	8.3		134.0	96.8	111.8	5.8	22.8
No of readings	52	0	52	52	52	52	52
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.06	0.41	0.41	0.011	0.055	89.6	29.3
SD	0.04	0.59	0.58	0.011	0.052	26.4	10.3
Min	0.03	0.20	0.18	0.004	0.010	70.6	22.0
Max	0.21	3.72	3.66	0.062	0.265	249.0	93.3
No of readings	52	52	52	52	52	52	52
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean	28.2	3.96	0.63	1.20	2.27	14.0	
SD	9.9	0.77	0.58	4.24	6.78	4.0	
Min	12.0	2.40	0.09	0.05	0.20	4.2	
Max	42.8	7.70	2.48	30.80	49.60	21.8	
No of readings	52	52	52	52	52	52	0

Sampling point 14: Rackham Mill drain

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean		309				1.2	
SD		4				0.3	
Min		305				1.0	
Max		313				1.5	
No of readings		3				3	
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.04	4.40	4.38	0.019	0.128		
SD	0.00	0.30	0.30	0.002	0.018		
Min	0.04	4.13	4.11	0.018	0.111		
Max	0.04	4.73	4.71	0.022	0.146		
No of readings	3	3	3	3	3		
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean							13.4
SD							11.8
Min							6.6
Max							27.1
No of readings							3

Sampling point 15: Unnamed tributary of Smooth Ditch

	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean		200				5.4	
SD		45				4.0	
Min		169				2.8	
Max		252				10.0	
No of readings		3				3	
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.06	0.20	0.19	0.008	0.043		
SD	0.05	0.00	0.00	0.000	0.006		
Min	0.03	0.20	0.19	0.008	0.040		
Max	0.12	0.20	0.19	0.008	0.050		
No of readings	3	3	3	3	3		
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^0C)**	**Chloro-phyll a**
Mean							56.9
SD							43.6
Min							13.9
Max							101.0
No of readings							3

Sampling point 16: Pound Piece Ditch (water meadows)

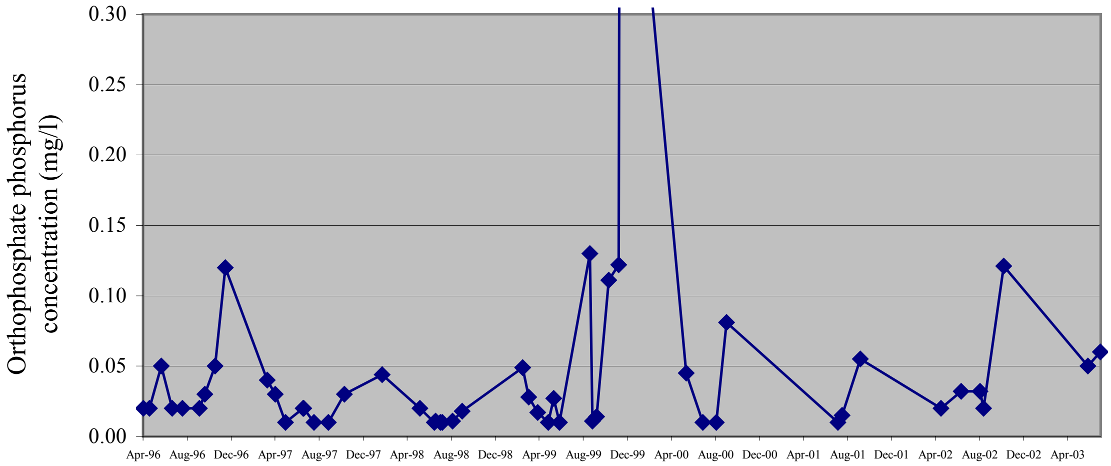
	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean		202				4.3	
SD		14				4.9	
Min		188				1.4	
Max		216				10.0	
No of readings		3				3	
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.03	0.20	0.19	0.010	0.033		
SD	0.01	0.00	0.00	0.003	0.006		
Min	0.03	0.20	0.19	0.008	0.030		
Max	0.04	0.20	0.19	0.013	0.040		
No of readings	3	3	3	3	3		
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^0C)**	**Chloro-phyll a**
Mean							16.1
SD							1.5
Min							15.1
Max							17.9
No of readings							3

Sampling point 17: Middle Gutter Ditch (east)

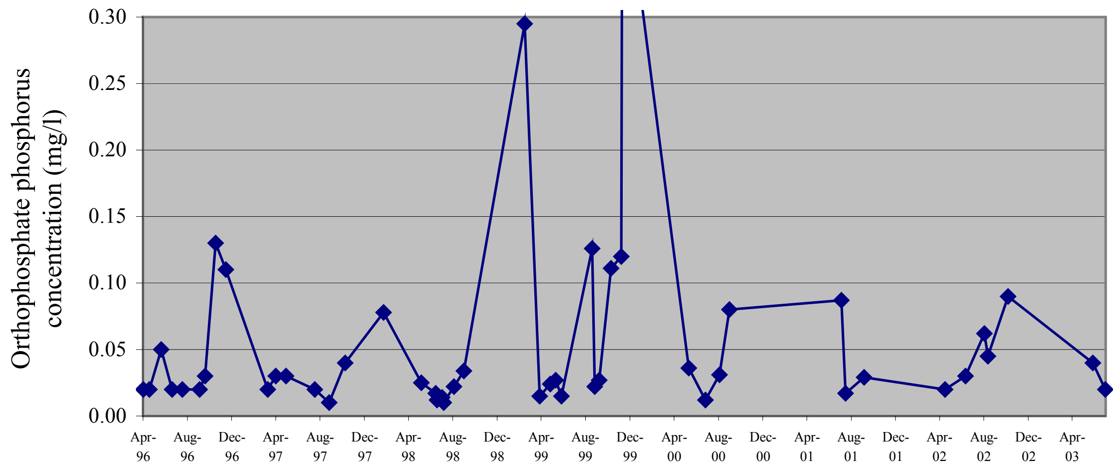
	pH	conductivity (µS/cm)	Turbidity (FTU)	Suspended solids (mg/l)	DO (% sat)	BOD (mg/l)	TOC (mg/l)
Mean		282				2.5	
SD		6				1.2	
Min		278				1.1	
Max		289				3.4	
No of readings		3				3	
	Ammonia-N (mg/l)	**TON (mg/l)**	**Nitrate (mg/l)**	**Nitrite (mg/l)**	**Ortho-phosphate-P (mg/l)**	**Hardness (mg/l)**	**Calcium (mg/l)**
Mean	0.08	2.78	2.76	0.026	0.087		
SD	0.07	0.65	0.65	0.007	0.099		
Min	0.03	2.11	2.08	0.020	0.020		
Max	0.16	3.40	3.38	0.034	0.200		
No of readings	3	3	3	3	3		
	Chloride (mg/l)	**Magnesium (mg/l)**	**Manganese (mg/l)**	**Iron dissolved (mg/l)**	**Iron (mg/l)**	**Temp (^{0}C)**	**Chloro-phyll a**
Mean							5.2
SD							3.0
Min							3.3
Max							8.7
No of readings							3

Appendix 6. Trends in orthophosphate phosphorus concentrations at individual sampling stations in Amberley Wild Brooks, 1996-2003

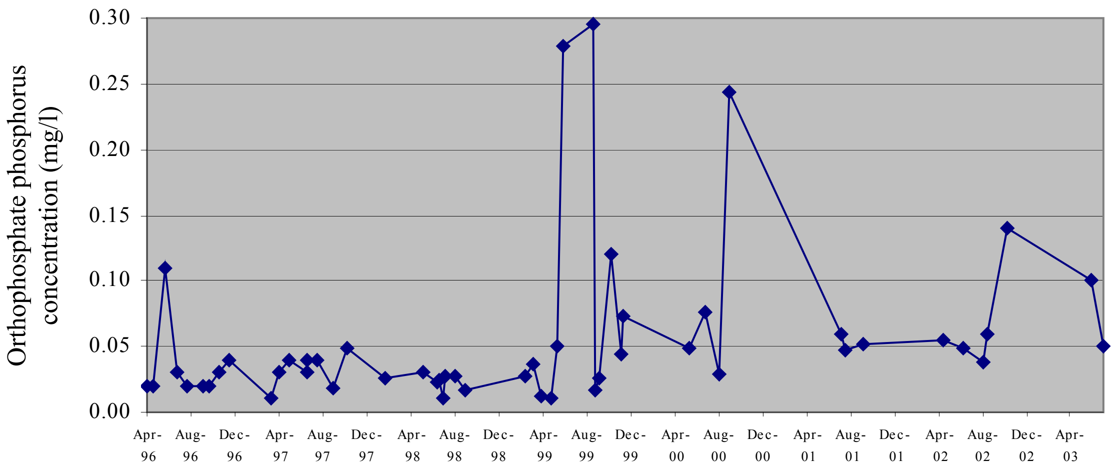
Site 1: No significant change.



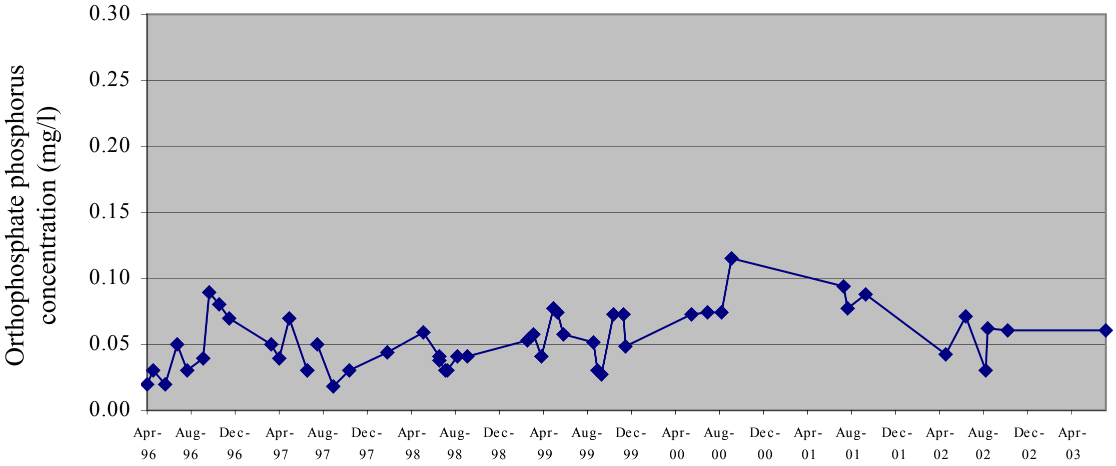
Site 2: No significant change.



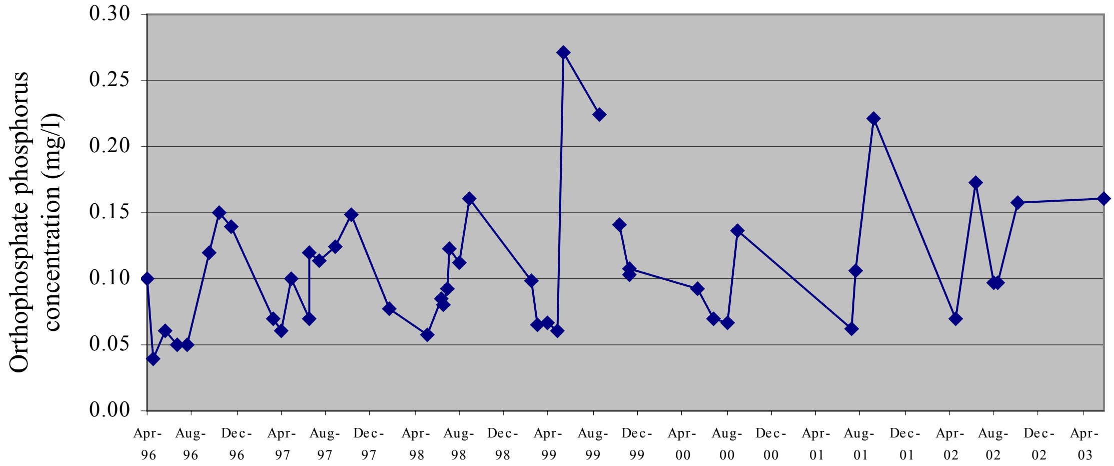
Site 3: Significant increase (Spearman R = 0.53; p < 0.001).



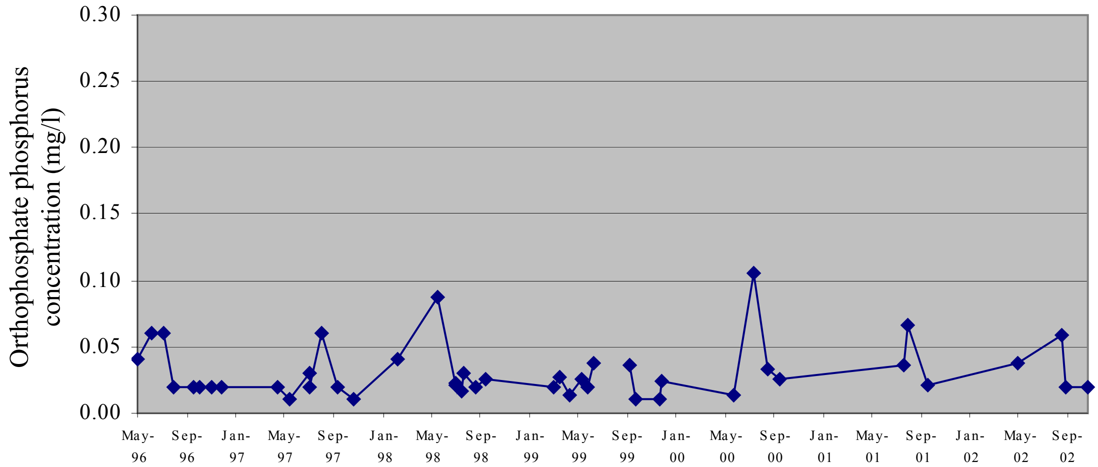
Site 4: Significant increase (Spearman R = 0.45; p < 0.01).



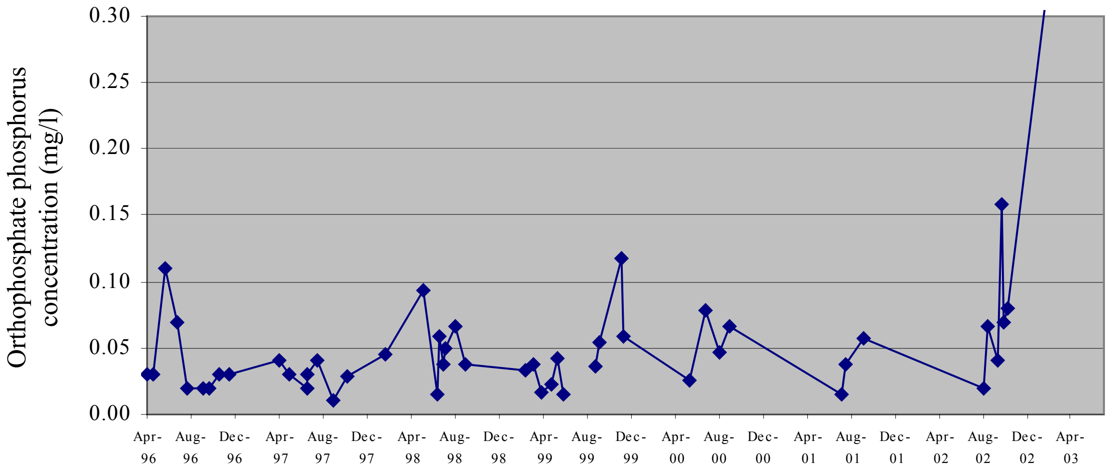
Site 5: Significant increase (Spearman R = 0.31; p < 0.05).



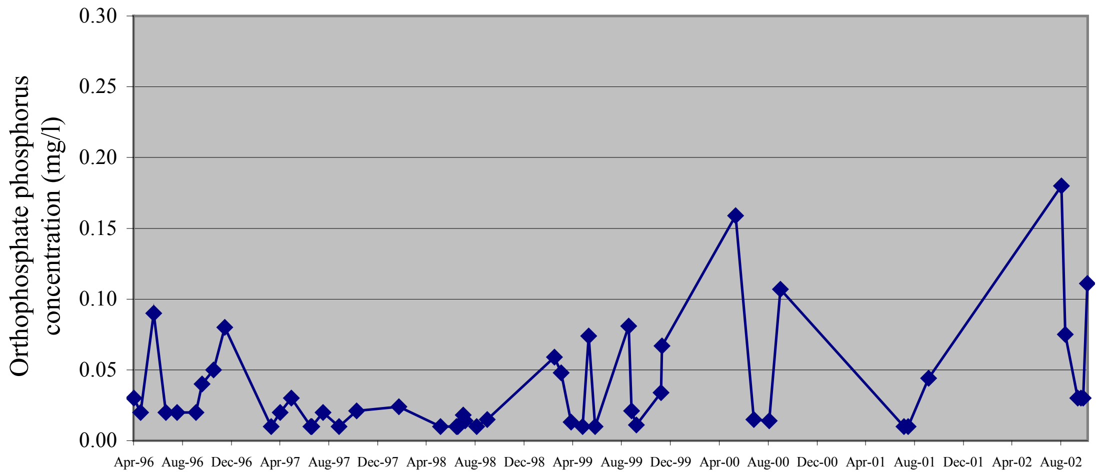
Site 6: No significant change.



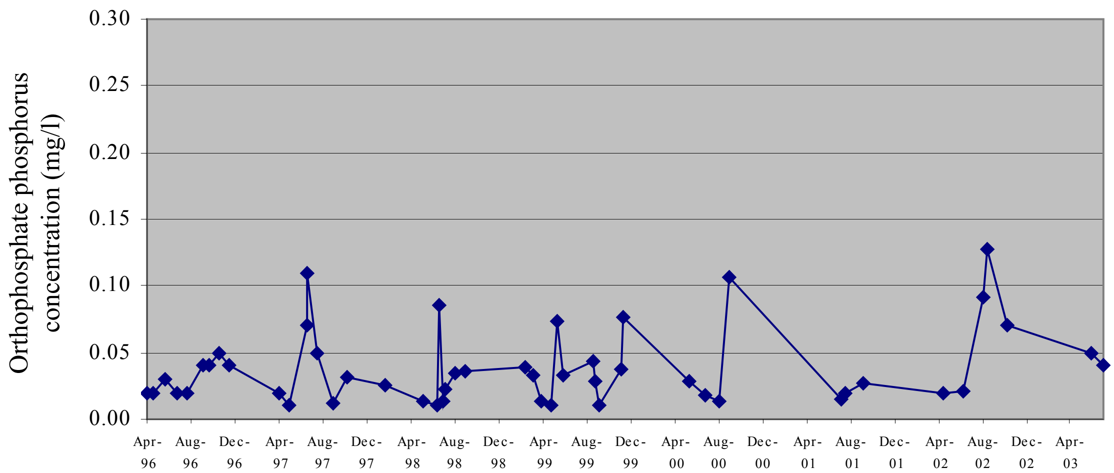
Site 7: Significant increase (Spearman R = 0.36; $p < 0.05$).



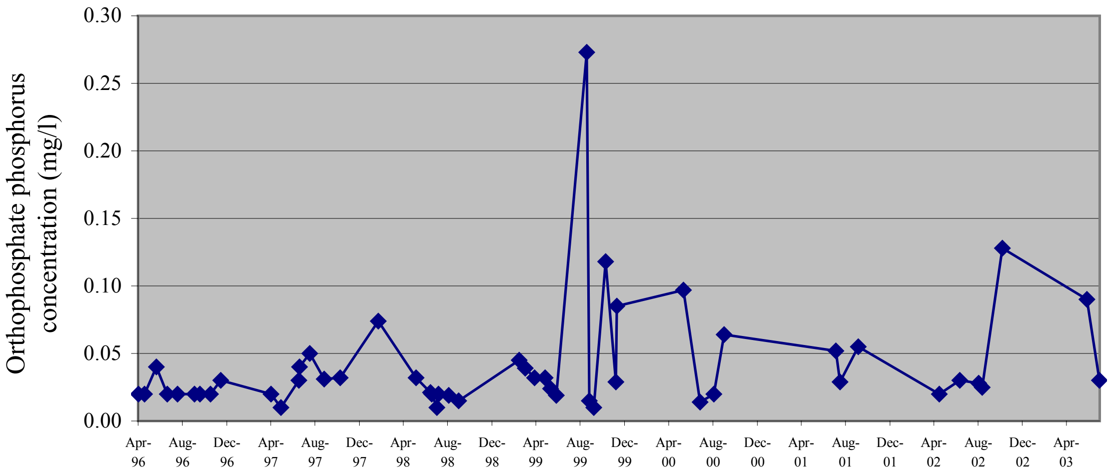
Site 8: No significant change



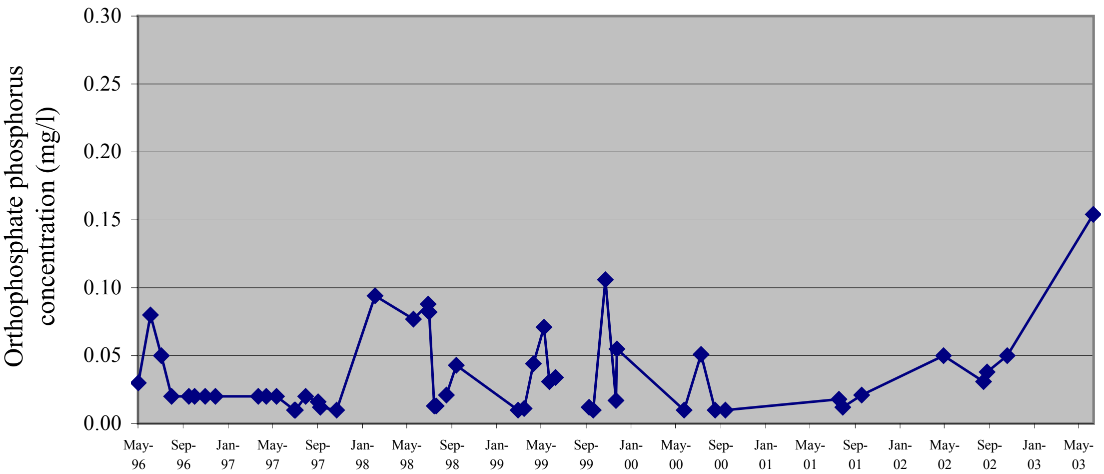
Site 9: No significant change



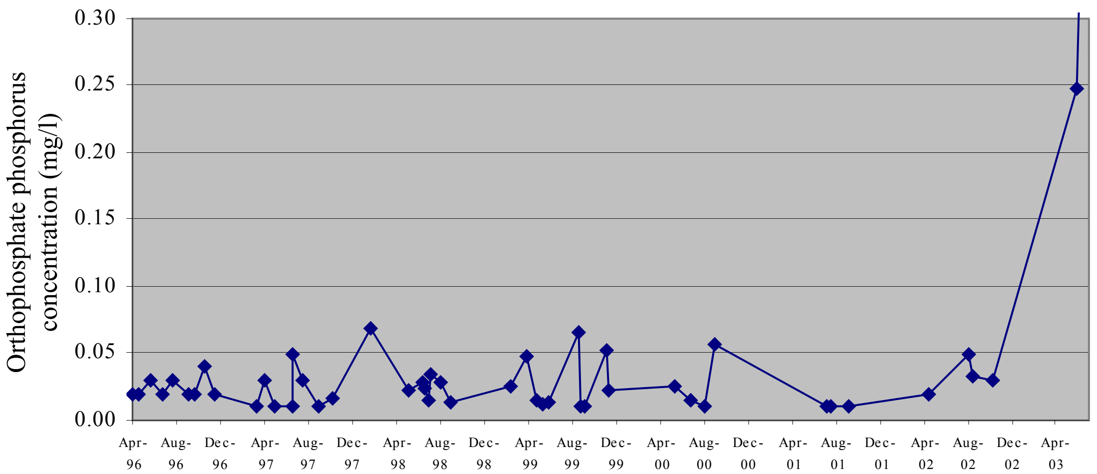
Site 10: Significant increase (Spearman R = 0.29; $p < 0.05$).



Site 11: No significant change



Site 12: No significant change



Site 13: Significant increase (Spearman R = 0.57; p < 0.001).