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THE OXFORDSHIRE POND SURVEY

A Report to the World Wide Fund for Nature (WWF-UK)

Volume 1

Pond Action

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SUMMARY

Introduction

This report describes the results of the Oxfordshire Pond Survey (OPS), initiated by Pond Action in 1988 and core funded by the World Wide Fund for Nature (WWF-UK).

The aim of the survey was to describe the physical, chemical and biological characteristics of ponds in Oxfordshire and to use this information to improve our current understanding of pond wildlife and pond conservation techniques.

The report has four main sections. Chapter 2 describes the basic physical and chemical features of ponds in Oxfordshire (size, chemistry, associated land use, geology, etc.). Chapter 3 describes the wildlife recorded during the survey and the importance of Oxfordshire ponds as a wildlife resource. Chapter 4 describes the influence that environmental factors have on the conservation value of ponds. Chapter 5 describes the result of computer-based ordination and classification used to identify pond community types and the environmental factors which appear to shape those communities.

Physical and chemical results

Of the Oxfordshire ponds surveyed, 141 different physical and chemical features were recorded, describing the size, depth, sediment accumulation, age, water source, surrounding land use, geology and chemistry.

The ponds surveyed varied in size from 27m^2 (0.0027 ha) to 7490m^2 (0.75 ha). All were relatively shallow, with an average depth of only 0.77m. The deepest part of any of the ponds surveyed was 3.00m. Larger ponds were more likely to be fed by springs and streams than by groundwater. Water levels of ponds on clay substrates tended to fluctuate more than those of ponds in areas of limestone geology.

The amount of sediment accumulated in ponds varied widely: the average depth of accumulated sediment was only 0.3m, but the deepest sediment accumulation was 1.9m. The depth of sediment was correlated with the percentage of the pond which was overhung by trees, presumably reflecting the accumulation of leaf litter. Ponds which had been managed, or were recently created, had significantly less accumulated sediment.

Chemically, the ponds were mostly highly calcareous. Very few ponds had soft water (i.e., low concentrations of dissolved ions) and none could be considered acidic. This reflects the fact that Oxfordshire has virtually no acid strata being dominated by chalk, clay and limestone. Of the chemical determinands measured, only one, nitrate, is commonly regarded as a pollutant. Nitrate levels in ponds were very variable, ranging from undetectable (less than 0.005mg/l) to 34mg/l, indicative of severe nitrate pollution. Of considerable interest was the finding that ponds with inflows had significantly higher nitrate concentrations than those without.

Wildlife of Oxfordshire ponds

A large number of wetland plants and invertebrates were recorded during the survey, demonstrating the considerable conservation resource which ponds represent.

From only 34 ponds surveyed in 1989/90, 119 vascular wetland plant species were recorded (approximately 40% of those occurring in Britain). The average number of plant species per pond was 17, a higher number than has been found in other, similar, pond surveys. We do not know whether this is because the Oxfordshire ponds had more species or were more thoroughly surveyed. In addition to the wide range of plants recorded, a large number were uncommon (19% of the emergent species and 61% of the aquatic species). This may reflect the fact that wetland habitats are generally scarce in Britain. The particularly high percentage of uncommon aquatic plants (i.e., submerged and

floating species) perhaps indicates that unpolluted water, the habitat of the many truly aquatic species, is an even scarcer habitat.

A total of 231 aquatic macroinvertebrate species was recorded from the 34 ponds in 1989/90. This represented over 30% of the British list in those groups covered by the survey. When the records for 1988 are added to those for the 34 ponds, a total of 256 species (35% of the British list) was recorded. That the records from the extra sites added so few extra species suggests that the 34 ponds did, indeed, fairly represent the range of pond types in the county.

A large number of the invertebrate species recorded during the work were either Local, Nationally Notable or Red Data Book species: from the 34 ponds, 58 species fell into one of these three categories. Particularly of note was the discovery of Britain's rarest aquatic invertebrate, *Myxas glutinosa* (Glutinous Snail), which it had been feared was extinct in Britain. This species/site is now the focus of an English Nature 'Recovery' programme.

Factors affecting the conservation value of ponds

A major aim of the study was to investigate the relationships between environmental factors and the conservation value of the ponds. Conservation value was assessed in two ways: (a) in terms of species number (numbers of species of aquatic and emergent plants and macroinvertebrates); and (b) in terms of the *quality* of the plant and invertebrate community (the number and proportion of uncommon species). Quality was measured objectively using a Species Rarity Index (SRI) developed by Pond Action for this study.

Pond area

More plant species were recorded in large ponds than smaller ponds. Deep ponds also supported more *aquatic* plant and more invertebrate species than shallow ponds. Numbers of *emergent* plant species were not related to pond depth. Interestingly, neither depth nor area were correlated with the *quality* of plant and invertebrate communities, suggesting that small ponds are just as likely to support uncommon species as large ponds.

Shade

In general there were fewer species of aquatic plants and invertebrates in ponds heavily overhung by trees and shrubs. However, perhaps surprisingly, shade did not appear to influence the *quality* of the emergent plant or invertebrate communities. This suggests that the traditional view that shading reduces the conservation value of ponds may be an oversimplification, and that although shaded ponds may support fewer species, they can still be of high conservation value. In addition, it should be noted that many of the species characteristic of shaded ponds (such as Diptera) were not included in the OPS.

Age

There was little evidence from the OPS that older ponds were more valuable wildlife habitats (either in terms of species number or quality). This may reflect (a) the fact that many of the relatively new ponds surveyed were in contact with ancient wetland habitats (for example, river valley ponds); and (b) that new ponds may provide a disturbed environment exploited by large numbers of opportunistic species. In addition, few of the ponds in the OPS were thought to be more than a few hundred years old.

Inflows

There was strong evidence that the presence of an inflow to a pond reduced the quality of the invertebrate community, although numbers of species were not affected. This may be due to inflows bringing nutrients, pesticides or other pollutants into ponds (for example, nitrate levels were higher in ponds with inflows). There was no evidence that inflows affected the plant community.

Surrounding land use

There was a clear indication from the results that land use is an important influence on the conservation value of ponds. In particular, ponds in areas of fen, marsh or unimproved grassland had greater numbers of invertebrate species, as well as more uncommon invertebrates. Interestingly, although ponds in areas of semi-natural land often supported more uncommon plants, the total number of plant species was generally not correlated with land use factors. This may suggest that there is a suite of common wetland plants tolerant of a wide range of conditions, and a small number of rarer species much less tolerant of intensive land use practices.

Overall, results of the study suggested that many of the factors traditionally believed to influence pond conservation value (for example, pond area, shade, sediment) primarily affect *numbers* of species. In Oxfordshire ponds these factors seemed to have little effect on the proportion of *uncommon* species, which seem more affected by water quality and surrounding land use.

Classification of pond communities

Pond communities were analysed using the ordination programme DECORANA and the classification programme TWINSPAN.

Classification suggested that the *aquatic* plant communities of Oxfordshire ponds could be represented by four main types: (a) nutrient enriched sites with relatively common plant species; (b) older sites with high numbers of aquatic plant species and low alkalinity; (c) sites with a predominantly gravel water source; and (d) unenriched alkaline fen ponds in limestone/sandstone catchments. Ordination analysis indicated that the major environmental variables to be associated with aquatic plant community type were nutrient enrichment and geology. Alkaline fen aquatic communities appeared to show greater differences from all other types of aquatic plant community.

Classification suggested that *emergent* plant communities of the ponds could be represented by three main types: (a) ponds in limestone/sandstone catchments, often in deciduous woodland and stocked with fish; (b) small, shallow ponds in clay catchments in lowland areas, and (c) ponds in a geology of gravels, often with fen and marsh in the vicinity and with above average aquatic plant rarity and invertebrate richness. The major environmental variables affecting or associated with emergent plant community type were shown by ordination analysis to be geology (especially gravels and clays), surrounding land use (especially fens, marshes and unimproved grassland), and age.

Classification suggested that the *macroinvertebrate* communities of ponds could be broadly represented by four main types: (a) fishponds in limestone geology, stream-fed, permanent and often wooded; (b) permanent sites in gravel geology, often with other open water and wood and scrub nearby; (c) less permanent ponds in clay catchments, often on floodplain and of intermediate size; and (d) less permanent, small shallow ponds, groundwater-fed and in a geology with a relatively high amount of sandstone. The major environmental variables affecting or associated with macroinvertebrate community type were shown to be permanence and, to a lesser extent, geology. In more temporary sites, water beetle species represented a higher percentage of the fauna, whilst the more permanent sites had larger numbers of, and higher percentages of, dragonflies, mayflies, leeches and caddisflies.

There was little correlation between the results of the three classifications, possibly reflecting the variety of factors which affect pond communities.

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CHAPTER 1

INTRODUCTION

1.1 Content and scope

This report describes the results of the Oxfordshire Pond Survey (OPS), initiated by Pond Action in 1988, and core funded by Word Wide Fund for Nature (WWF-UK).

The aim of the survey has been to describe the physical, chemical and biological characteristics of ponds in Oxfordshire, and to use this information to improve our current understanding of pond wildlife and pond conservation techniques. A brief history of the OPS is given in Appendix 1, Section A1.1.

1.2 Background

Ponds are widely perceived as being important habitats for wildlife - yet any search of ecological literature rapidly shows that very little information about the conservation value of pond communities is available.

It is equally clear that, although ponds are very popular and approachable places for wildlife management, there is a marked lack of evidence to indicate the value and success of pond management work. For example, do heavily shaded ponds generally benefit from selective marginal tree-felling, or do they already support a distinctive community in need of protection? Similarly, are ponds which are 'choked' by silt or wetland vegetation in urgent need of dredging or do they in fact support valuable wetland species characteristic of late pond succession?

Without such information it is very difficult to adequately manage and protect Britain's ponds - we cannot easily identify high value pond communities with any certainty, and it is difficult to prescribe detailed management regimes which will assure beneficial results. At worst, lack of information may not only waste scarce money and resources in inappropriate works but may cause irreparable damage to high value and vulnerable pond wildlife communities.

Much research on ponds is required in order to produce answers to all these problems. The aim of the work presented here is to begin this process by looking at the relationship between ponds, pond communities and pond conservation value in selected ponds within a single English county. Wider requirements for a pond classification over Britain as a whole are being addressed by a national pond survey, which is currently being undertaken by Pond Action and will be completed in 1994.

1.3 Content of the report

The report is broadly divided into four sections: Chapter 2 describes the physical and chemical parameters of the ponds in the OPS, and the significant relationships between these variables. Remaining chapters describe the wildlife recorded during the survey, together with the relationship between wildlife and the physical characteristics of the ponds. This includes the use of computer techniques to classify and ordinate the data (Chapter 5), and a numerical assessment of the conservation value of the ponds.

The methods used to sample and analyse the OPS data have been described very briefly in the main text. More detailed descriptions are given in relevant appendices, together with the raw physical, chemical and biological data.

1.4 Surveys undertaken

The report includes information about two data sets. The first, larger, data set (133 ponds) was gathered in 1988 and was largely limited to macroinvertebrates, with some associated physico-chemical data (mainly water chemistry). The second, smaller, data set (34 ponds) was gathered in 1989/90 and was much more detailed, including information about physical and chemical variables and a survey of wetland plants at each pond.

CHAPTER 2

PHYSICAL AND CHEMICAL RESULTS

2.1 Introduction

In total, 141 physical and chemical parameters were measured or assessed for the Oxfordshire Pond Survey. This included information about both the pond itself (e.g., size, depth, water chemistry) and about the surrounds (e.g., land use, geology, water source). A full list of the variables, together with the raw data, is given in Appendix 1, Table A1.9. The methods used to measure or derive variables are described in Appendix 1, Section 1.2.

This chapter describes the physical and chemical characteristics of the ponds and indicates where these variables were significantly interrelated. Most correlations relate to the main 34 ponds data set, but where additional information from the larger 133 ponds data set has been available (particularly water chemistry and land designation), this is mentioned in the relevant sections. Correlations between variables and wildlife parameters are given in Chapters 4 and 5.

2.2 Methods and results

The results of correlating the most important physico-chemical variables are presented below. Variables were correlated using Spearman's rank correlation and the null hypothesis (there is no correlation) was assessed. More details of statistical methods are given in Appendix 5.

2.2.1 Pond Area

Pond area was measured as total pond area (i.e., pond area at maximum water levels, see Appendix 1, Section A1.2.1). Water area was also measured, but as this is a highly seasonal variable, *pond* area was used in preference when calculating size-related parameters (e.g., percentage area overhung by trees and shrubs). The one exception to this was the estimation of the turnover (water volume/inflow volume) of the pond, since inflow volume is also typically highly seasonal (see Section 2.2.6).

Table 2.1 Pond Area

	Total pond area	Water area
Minimum	0.0027 ha	0.0025 ha
Maximum	0.7490 ha	0.749 ha
Average	0.1739 ha	0.1537 ha
Pond circumference	++++++	++++++
Maximum dimension	++++++	++++++
maximum total depth	+++	+++
Mean total depth	+++	+++
Mean water depth	+++	+++++
Maximum water depth	+	+++
Index of shore complexity	------	------
Area of pond overhung	+++	+++
Area of water overhung	+	+++
Area of pond margin overhung	++	+++
Area of water margin overhung	+	+++
Water source: stream	ns	+
Nitrite	+	+++

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

The ponds in the OPS varied from little more than the area of a garden pond (0.0027 ha, or less than 5m x 6m) to a maximum of 0.75 ha. The average size of ponds was 0.17 ha (i.e., approximately 40m x 40m).

Correlations between pond area and the other physical and chemical parameters indicate that area was most significantly correlated with other size variables, such as pond circumference and total pond depth. In addition area was correlated with both total depth and water depth, suggesting that, not surprisingly, larger ponds were generally deeper than smaller ponds.

In general, larger ponds also had a greater *total* area overhung by trees and shrubs. They did not, however, have a greater *percentage* of shade than smaller ponds (see Section 2.2.5). Size was relatively weakly correlated with nitrite (though not nitrate) and with the presence of stream inflow.

There was a strong negative relationship between pond area and shoreline complexity (i.e., pond margin/pond area), implying that large ponds generally have a more simple shape than smaller ponds. This may reflect, for example, the effect of a number of large simply-shaped fish ponds in the data set. However, the strength of the relationship may also be partly an artefact of the mapping technique used, since small ponds were usually mapped at a larger scale, where the detail of pond shape is more easily drawn and measured.

2.2.2 Total pond depth

Pond depth was measured along two perpendicular transects using graduated poles (see Appendix 1, Section A1.2.2). Total pond depth refers to the original depth of the pond before any infilling of sediment occurred, and was calculated as water depth plus sediment depth.

Table 2.2 Total Pond Depth

	Maximum total depth	Mean total depth
Minimum	0.36m	0.26m
Maximum	3.00m	2.43m
Average	1.48m	1.07m
Pond area	+++	++
Pond circumference	+	++
Maximum dimension	+	++
Index shore complexity	---	-----
Maximum water depth	++++++	++++++
Mean water depth	++++++	++++++
Maximum sediment depth	++	++
Mean sediment depth	++	+++
Permanence	+	+
Pond area overhung	+	+
Water source: stream	+	+
Nitrite	+	+
pH		
Alkalinity	ns	-
Pond age	+	ns
Disturbance	--	--

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

The average total depth of ponds in the survey was just over 1m, but depths ranged from a maximum of between 3m and 0.36m to a mean per pond of between 2.43 and 0.26m.

Not surprisingly, total pond depth correlated positively with water depth, sediment depth and degree of permanence. It also correlated with other area-related variables, such as nitrite, the presence of a stream inflow, and the area of the pond which was overhung by trees and shrubs.

More interestingly, pond depth correlated negatively with recent disturbance by man (i.e., creation or severe management). This may be because shallow ponds are easier to dig out or dredge than large, deep ponds.

2.2.3 Water depth and permanence

Pond water depth and pond permanence are clearly related variables, but whereas pond water depth is relatively easy to quantify, the extent to which a pond dries out is generally a more subjective judgement. For the purposes of the

Table 2.3 Water Depth and Permanence

	Max. water depth	Mean water depth	Permanence
Minimum	0.15m	0.07m	
Maximum	2.30m	1.74m	
Average	1.13m	0.77m	
Pond area	+	+++	ns
Pond circumference	+	++	ns
Maximum dimension	+	+	ns
Index of shoreline complexity	--	---	ns
Total pond depth	ns	ns	+
Mean water depth	ns	ns	+
Pond area overhung	ns	ns	+
Water area overhung	ns	ns	+
% of pond area overhung	ns	-	ns
Water source: inflow present	ns	ns	+++
Water source: inflow volume	ns	ns	+
Water source: stream	+	+	+
Water source: spring	ns	ns	+
Water source: surfacewater	ns	ns	-----
Geology of water source: clay	ns	ns	-
Geology of water source: limestone	ns	ns	++
Calcium	ns	ns	+
pH	ns	ns	+
Nitrite	ns	+	ns
Nitrite/conductivity	+	+++	ns
Alkalinity	-	-	ns
Ponds and lakes - 25m	-	-	ns
Ponds and lakes - 100m	-	-	ns
Ponds and lakes - total	---	--	ns
SSSI + LNR	+	+	ns
Altitude	+	ns	ns
DOME (eutrophication)	+	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

OPS, permanence was ranked for each site on a score of 1-4 (with low scores indicating a tendency to dry out and higher scores indicating a greater degree of permanence).

The average water depth in the ponds surveyed was 0.77m, but maximum water depths ranged from as little as 0.15m to a maximum of 2.30m. Two ponds in the data set were truly temporary ponds, drying more or less every year; a further four were known to dry, relatively regularly, in dry years.

The relationships between water depth and other variables were similar to those for pond size and total depth (see Tables 2.1 and 2.2), with positive correlations between area, pond circumference, pond depth, stream water source and nitrate levels, and negative associations with shoreline complexity. Not surprisingly, increasing permanence directly correlated with water depth, but there was no relationship with area.

More interestingly, there was a negative relationship between water depth and the percentage of tree cover, indicating that ponds with shallow water were generally more overhung by trees and shrubs than deeper ponds. This may be linked with the relationship between trees and sediment depth (see Section 2.2.5), which suggests that shaded ponds also had greater depths of sediment.

Deeper ponds were more likely to be protected on SSSIs and Local Nature Reserves (LNRs) than shallow ponds, but, as Chapter 4 shows, these protected ponds were not necessarily of higher conservation value for wildlife.

Pond permanence was positively associated with the presence of inflows, especially streams or springs. In contrast there was a strong negative correlation between both permanence and clay substrates and surfacewater sources. The latter two factors would be expected to be linked, since ponds in clay catchments are typically characterised by a high degree of surface runoff and little groundwater influence. Evidence of lower calcium and pH levels in temporary ponds (see Table 2.3) almost certainly also reflects this predominantly surfacewater origin, with water chemistry relatively less modified from precipitation. Note that chemical samples were taken in spring before any effects of drying out of the ponds could occur.

2.2.4 Sediment depth

The average sediment depth in the ponds surveyed was approximately 0.3m, but depths ranged from negligible (0.05m) to 1.9m.

There was no relationship between sediment depth and water depth, but sediment depth correlated quite strongly with total pond depth (i.e., sediment depth plus water depth). Sediment depth also correlated with both the *percentage* and the *area* of the pond which was overhung by trees, perhaps indicating that heavily shaded ponds accumulate sediments more rapidly than unshaded ponds.

It might be expected that there would be a correlation between sediment depth and pond age. However, this is only shown, weakly, for *maximum* sediment depths. This may be because of other confounding effects, such as differing rates of sediment accumulation between ponds or, perhaps, pond management/dredging of some sites.

2.2.5 Tree cover

Tree cover was measured in two ways: (i) as the *area* of each pond that was directly overhung by trees or shrubs (in m^2) and (ii) as the *percentage* of tree cover. The percentage of overhang for individual ponds varied from 0-66% (average 11%). The total area tree cover varied from 0 to 0.054 ha (average 0.012 ha).
As would be expected, the *area* of tree cover was strongly correlated with pond size (since larger ponds clearly have a greater potential shade area than smaller ponds). However, pond area did not significantly correlate with the *percentage* of tree cover. Other co-correlates of pond area (such as shore complexity and inflow) were also only significantly associated with the *area* (not percentage) of pond which was overhung. These are, therefore, more likely to be an artefact rather an indication of an important link with shade itself.

In the previous sections (2.2.3 and 2.2.4), it was noted that the percentage of tree cover was positively correlated with sediment depth and negatively associated with mean water depth. Tree cover was not, however, related to total depth.

Table 2.4 Sediment Depth

	Max. sediment depth	Mean sediment depth
Minimum	0.05m	0.02m
Maximum	1.90m	1.16m
Average	0.54m	0.30m
Maximum total depth	++	++
Maximum total pond depth	++	++
Mean total pond depth	++	+++
Pond area overhung	++	++
% of pond area overhung	++	+
Pond age	+	ns
Disturbance	--	---
Turbidity	+	+
Unimproved grassland - 5m	-	---

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

Table 2.5 Tree Cover

	% Pond area overhung	Total pond area overhung
Minimum	0%	0 ha
Maximum	66.0%	0.054 ha
Average	11.1%	0.012 ha
Pond circumference	ns	+++
Pond area	ns	+++
Maximum dimension	ns	+++
Index of shore complexity	ns	---
Maximum total pond depth	ns	+
Mean total pond depth	ns	+
Maximum water depth	ns	ns
Mean water depth	-	ns
Maximum sediment depth	++	++
Mean sediment depth	+	++
Inflow present	ns	+
Surrounding geology: limestone	ns	+
Surrounding geology: clay	ns	-
Geology of water source: sandstone	ns	+
Geology of water source: limestone	ns	+
Geology of water source: gravel	-	ns
Nitrate	ns	+
Unimproved grassland - 5m	---	-----
Pond age	ns	+

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

It seems likely, therefore, that ponds which are heavily shaded by trees accumulate more sediment (or fill up more quickly) than unshaded ponds. This, in turn, reduces the depth of water in the ponds. Such a tendency would, indeed, be expected, since fallen tree leaves are likely to be a major source of organic input into many ponds. In addition, fallen leaves are largely composed of refractory material, which, once shed into water, breaks down relatively slowly, potentially increasing sedimentation rates compared with other types of organic input.

The positive associations between tree cover and limestone catchments are almost certainly related to the occurrence of shaded fish ponds and fen pools, both of which favour the limestone areas of Oxfordshire.

2.2.6 Water source

Pond water source was assessed in terms of the presence and volume of any inflow, inflow type (i.e., ditch, stream, spring, flood) and the degree to which the pond was fed by groundwater or surface water. Together, these water sources correlated with a wide range of environmental variables (see Table 2.6). Inflow volume assessments are discussed in Appendix 1, Section A1.2.

Ponds with an inflow

The most significant correlations with inflow were the strong positive associations between the presence of an inflow and pond nitrate levels. This relationship was not shown to be statistically significant for most individual water sources alone (e.g., streams or springs), although there *was* a weak correlation with ditches. Almost certainly the latter correlation was because, in this data set, ditches tended to drain intensive farmland fertilized by nitrate. Ponds with inflow ditches also had relatively high eutrophication ratings (see Section 2.2.11).

Ponds with some kind of inflow were significantly older than other types of pond. This is likely to be linked with the inclusion of old stream-fed ponds and fish ponds in the data set. Not surprisingly, ponds fed by springs and streams were associated with limestone and sandy-limestone lithologies. They were also more likely to be partly overhung by trees and to be found in areas of wood or scrub.

Ponds with a floodwater input were significantly associated with low altitudes and unimproved grasslands. Both correlates are likely to reflect the association between flooding and river flood-meadows.

Groundwater- and surfacewater-fed ponds

The positive relationship between groundwater and gravels, and the strong negative link between groundwater source and nitrate are important, since they suggest that in Oxfordshire gravel-fed groundwaters may be generally less nutrient-enriched, and probably, therefore, less polluted than other water sources.

Groundwater ponds also tended to be younger and to be located outside areas of woodland; in consequence they were also relatively unshaded. The significant negative link between groundwater and altitude (see Table 2.6) may, like looding, reflect the increasing likelihood of groundwater occurring near-surface at lower altitudes, e.g., on river flood plains.

Ponds which were mainly fed by surfacewater were more likely to be temporary, presumably because they are more susceptible to the effects of climate variations, particularly high summer temperatures.

Table 2.6 Water Source

	Inflow present	Inflow volume	Inflow stream	Inflow spring	Inflow ditch	Inflow flood	Surface water	Ground water
Altitude	ns	ns	+	ns	ns	---	ns	-
Pond age	++	+++	+	ns	ns	ns	ns	---
Turbidity	ns	-	ns	---	ns	ns	ns	ns
DOME (eutrophication)	ns	ns	ns	ns	+	ns	ns	ns
Mean water depth	+	+	+	ns	ns	ns	ns	ns
Total depth	+	+	+	ns	ns	ns	ns	ns
Permanence	+++	+	+	+	ns	ns	----	ns
Pond area overhung	+	+	ns	ns	ns	ns	ns	ns
Water area overhung	+	+	+	ns	ns	ns	ns	-
% of water area overhung	ns	ns	ns	ns	ns	ns	ns	-
Surrounding geology: gravel	ns	ns	-	-	+	ns	ns	+
Surrounding geology: lst.	ns	ns	+	ns	ns	ns	ns	ns
Surrounding geology: clay	ns	ns	-	ns	ns	+	ns	ns
Geol. of water source: sst.	+++	ns	+	+++	ns	ns	ns	---
Geol. of water source: gr.	---	-	-	-	ns	ns	ns	++++++
Geol. of water source: lst.	+++	+	+++	++++++	ns	ns	ns	ns
Nitrate	+++++	+++++	ns	ns	+	ns	ns	---
Nitrite	ns	ns	ns	ns	ns	+	ns	ns
Calcium	ns	ns	ns	ns	ns	ns	-	ns
Alkalinity	+	++	ns	ns	ns	ns	ns	ns
Conductivity	ns	+	ns	ns	ns	ns	ns	ns
Deciduous woodland-5m	+	ns	+++	+	ns	ns	ns	ns
Deciduous woodland-25m	ns	ns	++	ns	ns	ns	ns	ns
Deciduous woodland-100m	+	ns	++	+	ns	ns	ns	-
Deciduous woodland-total	+	ns	+++	ns	-	-	ns	-
Wood and scrub-5m	ns	ns	+++	++	ns	ns	ns	ns
Wood and scrub-100m	ns	ns	+	+++	ns	ns	ns	ns
Wood and scrub-total	ns	ns	++	++++	ns	ns	ns	-
Unimproved grassland-25m	--	ns	ns	ns	ns	+	ns	ns
Unimproved grassland-100m	--	-	-	ns	ns	+++	ns	ns
Unimproved grassland-total	ns	ns	ns	ns	ns	+	ns	ns
Semi-natural-25m	ns	ns	ns	+	ns	ns	ns	ns
Semi-natural-100m	ns	ns	ns	+	-	ns	+	ns
Semi-natural-total	ns	ns	ns	+	ns	ns	+	ns
Improved grassland-5m	ns	ns	ns	-	ns	ns	ns	ns
Improved grassland-25m	ns	ns	ns	-	ns	ns	ns	ns
Arable-5m	ns	ns	ns	ns	++	ns	ns	ns
Arable-total	ns	ns	ns	ns	ns	ns	-	ns
Disturbed-25m	ns	ns	ns	-	+	ns	ns	ns
Disturbed-100m	ns	ns	ns	-	+	ns	-	ns
Disturbed-total	ns	ns	ns	-	ns	ns	-	ns
LNR	ns	ns	ns	ns	ns	ns	ns	ns
SSSI	ns	ns	ns	ns	ns	ns	+	ns
SSSI+LNR	ns	ns	ns	ns	ns	+	+	ns

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

2.2.7 Land protection and designation

34-pond data set

About a third of the ponds surveyed for the OPS in 1989/90 were located on Sites of Special Scientific Interest (SSSIs). A further four were designated as LNRs.

As Table 2.7.1 shows, ponds which were located on SSSIs were most strongly correlated with landuse factors. Not surprisingly, there were consistently positive correlations with semi-natural landuse (especially unimproved

Table 2.7.1 Land Designation (34-Pond Data Set)

	SSSI	LNR	SSSI + LNR
Maximum water depth	-	ns	ns
Water source: surfacewater	+	ns	+
Water source: flood	ns	ns	+
Surrounding geology: gravel	--	ns	---
Surrounding geology: clay	ns	-	ns
Geology of water source: gravel	--	ns	--
Geology of water source: sandstone	ns	+	ns
Sulphate	ns	ns	-
Scrub-100m	+	ns	+
Scrub-total	ns	ns	+
Wood and scrub-25m	ns	+	+
Wood and scrub-100m	+	ns	+++
Wood and scrub-total	ns	+	+
Unimproved grassland-25m	+++	ns	+
Unimproved grassland-100m	+++	ns	+++
Unimproved grassland-total	++	ns	+
Semi-natural-5m			+++
Semi-natural-25m	+++++	ns	+++++
Semi-natural-100m	++++++	ns	++++++
Semi-natural-total	++++++	ns	++++++
Arable-25m	ns	ns	-
Improved grassland-5m	-	ns	---
Improved grassland-25m	---	ns	----
Improved grassland-100m	--	ns	-----
Improved grassland-total	--	ns	-----
Parks and gardens-5m	ns	ns	-
Parks and gardens-25m	-	ns	ns
Parks and gardens-100m	-	ns	-
Parks and gardens-total	--	ns	---
Urban-25m	--	ns	-
Urban-100m	---	ns	-
Urban-total	-	ns	-
Urban and roads-25m	-	ns	ns
Urban and roads-100m	--	ns	ns
Disturbed-5m	-	ns	---
Disturbed-25m	-----	ns	-----
Disturbed-100m	-----	ns	-----
Disturbed-total	-----	ns	------

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

grassland and scrub) in the surrounds. The reverse was also true, with strong negative correlations between ponds on SSSIs and disturbed-ground categories (particularly improved grassland and urban areas).

Ponds on SSSIs were often located in limestone areas; no doubt because of the perceived need to protect relatively uncommon calcareous habitats such as marl ponds (e.g., Wychwood) and fens (e.g., Dry Sandford and Cothill). There were also positive correlations between pond protection and ponds fed by flood and surface water sources. This probably (at least partly) relates to the location of ponds on flood plain SSSIs such as Otmoor.

Ponds located within LNRs (which were not SSSIs) were much more poorly correlated with most environmental variables other than woodland and scrub. This may reflect the number of sites in this category in the database.

133-pond data set

Note that only chemical parameters are available for correlation with the 1988 data.

Of the ponds surveyed for the OPS in 1988, 23 were located on SSSIs, and ten on LNRs which were not also classified as SSSIs. In total, therefore, about a quarter were on protected landuse.

As Table 2.7.2 shows, ponds on protected landuse are likely to have lower nitrate levels and higher sodium levels than other ponds in the database. Lower nitrate levels are to be expected as these sites are likely to be more protected from intensive agriculture than other sites. The correlation with sodium ion concentration is weaker and is less easily explained.

Table 2.7.2 Land Designation (133-Pond Data Set)

	SSSI	LNR	SSSI + LNR
Sodium	ns	ns	+
Nitrate	-	ns	—

+ = positive correlation, - = negative correlation, ns = not significant.
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001.
Correlations have been adjusted for ties.

2.2.8 Altitude

See Table 2.8. There is relatively little altitude variation in Oxfordshire, and this is reflected in the range of altitudes seen in the OPS (55m to 168m). Generally, correlations with altitude reflect the association of different types of pond with different types of geomorphology. In particular, the tendency for stream-fed fish ponds to occur in wooded catchments in the Chilterns is reflected in positive correlations between altitude and parameters such as stream inflow, shade and wooded surrounds. In contrast, negative correlations with altitude almost certainly reflect the occurrence of river valley ponds dominated by clay or gravel substrates and mostly fed by groundwater.

2.2.9 Pond age and pond disturbance

See Table 2.8. Except for new ponds, it was very difficult to establish the exact age of the majority of ponds. Ponds were therefore placed in one of three relatively broad age categories. These were: <7 years, 8-114 years and >114 years.

The main difficulty with using pond age as a correlate was that some of the oldest ponds had also been drastically managed (e.g., cleared and dredged) in the previous five years. In order to look independently at the possible effects of this, managed ponds were put in a disturbed category, together with very new ponds created in the last seven years. These were correlated independently against other variables.

Age correlated positively, though rather weakly, with a number of size variables such as maximum pond dimension, the presence of stocked fish, and presence of an inflow. This almost certainly reflects the inclusion of several old, deep, stream-fed fish ponds in the OPS data set. Linked with this, the significant correlation with other ponds in the vicinity probably reflects the tendency for fish ponds to occur, in series, down river valleys. Positive correlations with nitrate almost certainly result from the presence of inflows in these ponds (see Section 2.2.6).

Ponds which were created or disturbed within the seven years prior to the OPS showed many of the opposite trends to older ponds. Many were shallow, almost certainly because shallow ponds are cheaper and easier to create or manage. The association with nearby rivers may be because new ponds have more frequently been created in areas of high water tables adjacent to streams and rivers.

2.2.10 Turbidity

See Table 2.8. Not surprisingly, pond turbidity was positively associated with clay lithologies and this was in turn associated with grazing and river valleys. The clearest water was strongly associated with spring-fed limestone catchments and calcareous fens.

2.2.11 DOME code (eutrophication)

See Table 2.8. DOME codes are based on the tolerance of aquatic plant species to different levels of waterbody enrichment (i.e., Dystrophic, Oligotrophic, Mesotrophic, Eutrophic). They therefore give an estimation of waterbody nutrient status. High and low DOME scores indicate, respectively, relatively high and low nutrient status.

DOME scores correlated positively with a number of chemical determinands including sulphate and nitrite. They also correlated with turbidity and clay lithologies, probably reflecting the effect of limited light on the submerged plant community. The lowest scores (i.e., water with the lowest nutrient status) were associated with calcareous fen communities.

2.2.12 Grazing

See Table 2.8. Ponds with margins grazed by cattle tended to be located on unimproved flood meadows, particularly within the clay vales. Grazed ponds were predominantly fed by surfacewater and they showed a marked propensity to dry out.

Table 2.8 Other Physical Variables

	Altitude	Age	Disturbed	Turbidity	DOME	Grazing
Maximum dimension	ns	+	ns	ns	ns	ns
Maximum total depth	ns	+	--	ns	ns	ns
Mean total depth	ns	ns	--	ns	ns	ns
Maximum water depth	+	ns	ns	ns	+	ns
Maximum sediment depth	ns	+	--	+	ns	ns
Mean sediment depth	ns	ns	---	+	ns	ns
Permanence	ns	ns	ns	ns	ns	----
Pond area overhung	ns	+	ns	ns	ns	-
Water source: inflow present	ns	++	ns	ns	ns	-
Water source: inflow volume	ns	+++	ns	-	ns	-
Water source: stream	+	+	ns	ns	ns	ns
Water source: spring	ns	ns	ns	---	ns	ns
Water source: ditch	ns	ns	ns	ns	+	ns
Water source: flood	---	ns	ns	ns	ns	++
Water source: surfacewater	ns	ns	ns	ns	ns	+++++
Water source: groundwater	-	---	ns	ns	ns	ns
Surrounding geology-gravel	-	ns	ns	ns	ns	ns
Surrounding geology-lst.	++	ns	ns	ns	-	ns
Surrounding geology-clay	--	ns	ns	ns	+	ns
Geol. all water sources-sst.	+	ns	ns	ns	ns	ns
Geol all water sources-gravel	ns	-	ns	ns	ns	ns
Geol all water sources-lst.	+	ns	ns	-----	ns	---
Geol all water sources-clay	ns	-	ns	+	ns	++
Ca	ns	ns	ns	ns	ns	--
Na	--	ns	ns	ns	ns	ns
SO_4	ns	ns	ns	ns	+	ns
NO_3	ns	++	ns	ns	ns	ns
NO_2	ns	ns	ns	ns	+	ns
Cl	ns	ns	ns	ns	ns	-
NO_2/cond	ns	ns	ns	ns	+	ns
Alk.	ns	ns	ns	ns	ns	-
Cond.	ns	ns	ns	ns	ns	--
Grazing	ns	ns	ns	+	ns	X
Fish present	ns	+++	ns	ns	ns	ns
Fish stocked	+++	+	+	ns	ns	ns
Ducks present	ns	ns	ns	ns	ns	ns
Altitude	X	ns	ns	ns	ns	ns
Pond age	ns	X	-----	ns	ns	ns
Disturbance	ns	-----	X	ns	ns	ns
Turbidity	+	ns	ns	X	+	+
DOME (eutrophication)	ns	ns	ns	+	X	ns
SSSI+LNR	ns	ns	ns	ns	ns	+
Deciduous woodland-25m	+	ns	ns	ns	ns	ns
Deciduous woodland-100m	+	ns	ns	ns	ns	ns
Deciduous woodland-total	+	ns	ns	ns	ns	ns
Wood and scrub-100m	ns	ns	ns	-	ns	ns

(cont.)

Table 2.8 (cont.)

	Altitude	Age	Disturbed	Turbidity	DOME	Grazing
Wood and scrub-total	ns	ns	ns	-	ns	ns
Ponds and lakes-25m	ns	+	ns	ns	ns	ns
Ponds and lakes-100m	ns	+	ns	ns	ns	ns
Ponds and lakes-total						
Fen, marsh and bog-100m	ns	ns	ns	ns	---	ns
Unimproved grassland-5m	ns	ns	ns	ns	ns	+++
Unimproved grassland-25m	ns	ns	ns	ns	ns	+++
Unimproved grassland-100m	ns	ns	ns	ns	ns	++++
Unimproved grassland-total	ns	ns	ns	ns	ns	+++
Semi-natural-100m	ns	ns	ns	ns	ns	+
Semi-natural-total	ns	ns	ns	ns	ns	+
Parks and gardens-25m	ns	ns	ns	ns	ns	ns
Parks and gardens-100m	ns	ns	-	+	ns	ns
Parks and gardens-total	ns	ns	ns	+	ns	ns
Urban-25m	ns	ns	-	+	ns	ns
Urban-100m	ns	ns	-	ns	ns	ns
Urban-total	ns	ns	--	ns	ns	ns
Urban and roads-25m	ns	ns	-	+	ns	ns
Urban and roads-100m	ns	ns	ns	+	ns	ns
Urban and roads-total	ns	ns	-	ns	ns	ns
Disturbed land-25m	ns	ns	ns	+	ns	-
Disturbed land Total	ns	ns	ns	ns	ns	-
Ponds and lakes-250m	+	ns	ns	ns	ns	ns
Ponds and lakes-500m	ns	+	ns	ns	ns	ns
Rivers-250m	ns	ns	+	-	ns	-
Rivers-500m	---	--	++	ns	ns	--
Rivers-total	---	-	++	---	ns	---
Ditches-10m	-	ns	ns	ns	ns	ns
Ditches-250m	--	-	ns	ns	ns	ns
Fen marsh and bog-10m	ns	ns	ns	ns	-	ns
Fen marsh and bog-250m	ns	ns	ns	-	--	ns
Fen marsh and bog-total	--	ns	ns	-	--	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

2.2.13 Water chemistry (1989/90)

The main chemical determinands measured for the OPS were calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), sulphate (SO_4), nitrate (NO_3), nitrite (NO_2), chlorine (Cl), pH, alkalinity and conductivity. The methods which were used to sample and analyse these determinands are described in Appendix 4, Section A4.1.

Intercorrelations between the chemical variables are given in Table 2.9.1. Correlations between chemical and physical variables are given in Table 2.9.2

Table 2.9.1 Chemistry: Intercorrelations of Chemical Determinands (1989/90)

	Ca	Mg	K	Na	SO_4	NO_3	NO_2	Cl	Alk.	Cond.	pH
Minimum	5.2	0.8	0.7	2	2	<0.005	<0.005	4.5	0.5	71	6.5
Maximum	145	13.4	49	51	50	14	0.08	75	6.0	984	8.9
Average	90	4.6	6	17	15	3.0	0.01	33	3.5	568	8.0
Mode	86	1.8	3	13	7	0.01	<0.005	24	2.5	670	8.1

All mg/l except alkalinity (milliequivalent/l), conductivity (µSiemens/cm) and pH (not units)

Ca	X										
Mg	+	X									
K	ns	+++	X								
Na	+++	+++++	++	X							
SO_4	ns	ns	ns	+	X						
NO_3	++	ns	ns	ns	ns	X					
NO_2	ns	ns	ns	ns	ns	+++	X				
Cl	ns	ns	ns	+++	++++	ns	ns	X			
Alk.	+++	ns	ns	+++	+	ns	ns	++	X		
Cond.	+++++	ns	ns	++++	+++++	++	ns	++++++	++++++	X	
pH	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	X

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties

Water chemistry intercorrelations

The values for calcium, magnesium and sodium were intercorrelated, as were those of sodium, chloride and sulphate. Nitrate and nitrite correlated with each other, but with few other determinands.

Conductivity and alkalinity correlated positively with all determinands except magnesium, potassium and nitrite. pH correlated with none of the other chemical determinands measured.

Correlations between water chemistry and physical variables

Correlations between water chemistry and landuse were generally only weakly significant, but they showed fairly consistent trends, with higher determinand concentrations in ponds located within areas of disturbed landuse, and generally lower levels in semi-natural areas. Other correlations such as the highly significant relationship between nitrate and water sources have already been mentioned (see Section 2.2.6). A few correlations are rather inexplicable and are more probably due to inter-correlations with other variables. The relationship between nitrate and pond shade, for example, may reflect the tendency for shaded ponds to have inflows (see Tables 2.5 and 2.6). The relationships between nitrite or alkalinity and pond depth are less amenable to interpretation.

2.2.14 Water chemistry - 1988 data

Water samples from most of 133 sites (127) visited in 1988 for the OPS were analysed for calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), sulphate (SO_4), nitrate (NO_3), nitrite (NO_2), chlorine (Cl), pH, alkalinity and conductivity. The methods which were used to sample and analyse these determinands are described in Appendix 4, Section A4.1. Intercorrelations between the chemical variables are given in Table 2.10. Correlations between water chemistry and land designation are given in Table 2.7.2.

Table 2.9.2 Chemistry (1989/90)

	Ca	Mg	K	Na	SO4	N03	NO2	Cl	Alk.	Cond.	pH
Pond area	ns	ns	ns	ns	ns	ns	+	ns	ns	ns	ns
Pond circumference	ns	ns	ns	ns	ns	ns	+	ns	ns	ns	ns
Maximum dimension	ns	ns	ns	-	ns	ns	+	ns	ns	ns	ns
Mean pond depth	ns	ns	ns	ns	ns	ns	+	ns	-	ns	+
Maximum pond depth	ns	ns	ns	ns	ns	ns	+	ns	ns	ns	ns
Mean water depth	ns	ns	ns	ns	ns	ns	+	ns	-	ns	ns
Maximum water depth	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	ns
Maximum sediment depth	ns	ns	+	ns	ns	ns	ns	ns	ns	ns	ns
Pond area overhung	ns	ns	ns	ns	ns	+	ns	ns	ns	ns	ns
Pond margin overhung	ns	ns	ns	ns	ns	+	ns	ns	ns	ns	ns
Permanence	+	ns	ns	ns	ns	ns	ns	ns	ns	ns	+
Altitude	ns	ns	ns	--	ns	ns	ns	ns	ns	ns	ns
Age	ns	ns	ns	ns	ns	++	ns	ns	ns	ns	ns
Turbidity	ns	ns	+	ns	ns	ns	ns	ns	ns	ns	ns
DOME (eutrophication)	ns	ns	ns	ns	+	ns	+	ns	ns	ns	ns
Water source: inflow present	ns	ns	ns	ns	ns	+++++	ns	ns	+	ns	ns
Water source: inflow vol.		ns	ns	ns	ns	ns	+++++	ns	ns	++	+
Water source: stream	ns	ns	ns	-	ns	ns	ns	-	ns	ns	ns
Water source: ditch	ns	ns	ns	ns	ns	+	ns	ns	ns	ns	ns
Water source: flood	ns	ns	ns	ns	ns	ns	+	ns	ns	ns	ns
Water source: surface	ns	ns	ns	ns	ns	---	ns	ns	ns	ns	ns
Water source: ground	-	-	ns	ns	ns	ns	ns	ns	ns	ns	ns
Surrounding geology: sst.	ns	ns	+	ns	--	ns	ns	ns	ns	ns	ns
Surrounding geology: gr.	ns	ns	ns	ns	++	ns	ns	+++	ns	+	ns
Surrounding geology: lst	ns	ns	---	ns	---	ns	ns	ns	ns	ns	ns
Surrounding geology: clay.	ns	ns	ns	ns	+	ns	ns	ns	ns	ns	ns
Geol. of water source: grav.	ns	ns	ns	ns	ns	-	ns	ns	ns	ns	+
Geol. of water source: lst.	ns	ns	ns	ns	ns	-	ns	ns	ns	ns	+
Geol. of water source: clay	ns	ns	ns	ns	ns	+	+	ns	ns	ns	-
SSSI+LNR	ns	ns	ns	ns	-	ns	ns	ns	ns	ns	ns
Deciduous woodland-25m	ns	-	ns	---	ns	ns	ns	ns	ns	ns	ns
Deciduous woodland-100m	ns	ns	ns	-	ns	ns	ns	ns	ns	ns	ns
Deciduous woodland-total	ns	ns	ns	-	ns	ns	ns	ns	ns	ns	ns
Unimproved grassland-5m	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	-
Unimproved grassland-25m	ns	ns	ns	ns	ns	ns	ns	-	ns	ns	ns
Unimproved grassland-total	ns	ns	ns	ns	ns	ns	ns	-	ns	ns	ns
Ponds and lakes-25m	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	ns
Ponds and lakes-100m	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	+
Ponds and lakes-total	ns	ns	ns	ns	ns	ns	ns	ns	-	ns	+
Fen, marsh and bog-25m	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fen, marsh and bog-100m	ns	ns	ns	ns	ns	ns	-	ns	ns	ns	ns
Semi-natural-100m	ns	ns	ns	ns	-	ns	-	ns	ns	ns	ns
Improved grassland-100m	ns	ns	-	ns	ns	ns	ns	ns	ns	ns	ns
Parks and gardens-5m	-	ns	ns	ns	+	+	+++	ns	ns	ns	ns
Parks and gardens-25m	ns	ns	ns	ns	ns	ns	+	ns	ns	ns	ns
Urban and roads-5m	-	ns	ns	-	ns	ns	ns	ns	ns	ns	ns
Urban and roads-25m	ns	ns	+	ns	ns	ns	ns	ns	ns	ns	ns
Urban and roads-100m	ns	+	+++	+	ns	ns	ns	ns	ns	ns	ns
Urban and roads-total	ns	ns	+++	ns	ns	ns	ns	ns	ns	ns	ns
Total urban-100m	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Total urban-100m	ns	ns	+	ns	ns	ns	ns	ns	ns	ns	ns
Disturbed-100m	ns	ns	ns	ns	ns	ns	ns	+	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

Water chemistry intercorrelations

The results of the cross-correlations are similar to those seen with the 1989/90 subset, except that the correlations tend to be stronger and, as a result, some correlations appear which did not appear in the smaller subset. With the exceptions of pH and potassium, most determinands are cross-correlated with several others. pH is only correlated (weakly) with sulphate and chloride levels. Potassium is only correlated, though very strongly, with sodium.

Table 2.10 Chemistry: Intercorrelations of Chemical Determinands

	Ca	Mg	K	Na	SO_4.S	NO_3.N	NO_2.N	Cl	Alk.	Cond.	pH
Minimum	4.6	<0.25	<0.5	2.2	1.2	<0.005	<0.005	1.81	0.5	71	6.5
Maximum	287	18	66	285	101	34	0.20	101	8.0	1406	9.43
Average	92	5.0	7.6	18	17	4.4	0.015	32	3.4	573	8.0
Mode	101	2.5	<0.5	14	13	.015	0.05	21	3.5	593	8.0

All mg/l except alkalinity (milliequivalents per litre), conductivity (µSiemens/cm) and pH (no units)

Ca	X										
Mg	+	X									
K	ns	++++++	X								
Na	++	++++++	++++++	X							
SO_4.S	++++	++	ns	++++++	X						
$N0_3$.N	++++++	ns	+	+	ns	X					
NO_2.N	+++++	ns	ns	ns	+	++++++	X				
Cl	++	+++++	ns	++++++	++++++	ns	ns	X			
Alk.	++++++	ns	ns	++++++	+	++	ns	+++	X		
Cond.	++++++	++	ns	++++++	++++++	++++++	+++	++++++	++++++	X	
pH	ns	ns	ns	ns	+	ns	ns	+	ns	ns	X

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

Levels of the chemical determinands in Oxfordshire ponds

The levels of chemical determinands show that most of the Oxfordshire ponds visited were highly calcareous. Very few of the ponds (and very few ponds in Oxfordshire) have soft water and none of the ponds could be considered to be acidic.

Only one of the determinands measured (nitrate) is considered to be a pollutant. Defining what constitutes pollution for a naturally occurring chemical is a matter of judgment. Levels of nitrate in still waters tend to be much lower than in flowing waters, and in many cases levels in excess of 0.1mg/l might be considered to be pollution. This lower level, however, could not be applied to sites with a substantial inflow. The only legal definitions of nitrate pollution levels were defined several years ago in order to prevent the problems of methaemoglobinaemia and a presumed link between nitrates and cancer. The mandatory and guideline levels of the European Union (EU) of 11.7 and 5.85 mg/l nitrate nitrogen and the World Health Organisation (WHO) level of 10mg/l, should be considered to indicate gross nitrate pollution in ponds.

Figure 2.1 shows a histogram of nitrate concentrations in the 127 ponds surveyed for the OPS. The WHO, EEC mandatory limit, and EEC guideline limits are also shown on the figure. As can be seen from the figure, 22 (17%)

are above the EU mandatory limit, 23 (18%) above the WHO limit, and 35 (28%) above the EU guideline limit. All these ponds have nitrate limits well above any natural level and should be considered to be polluted. In addition, many of the other ponds in the data set are also well above a natural, pristine level of nitrate, though it is difficult to estimate quite how many.

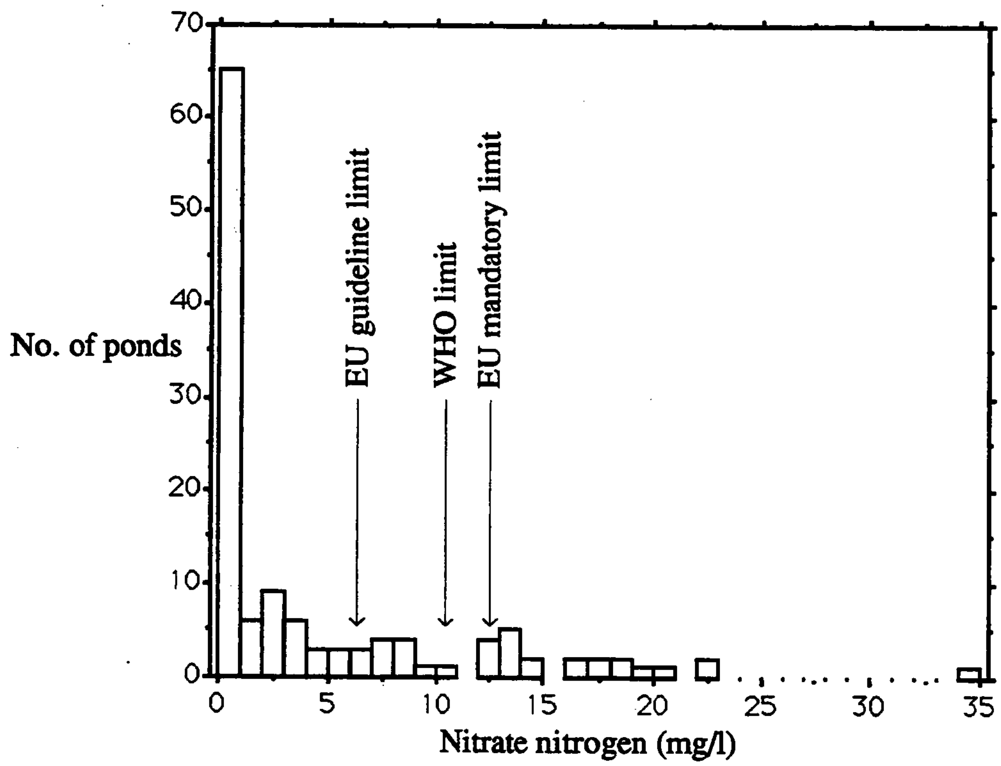


Figure 2.1 Frequency Histogram of Nitrate in Oxfordshire Ponds

CHAPTER 3

WILDLIFE OF OXFORDSHIRE PONDS

3.1 Introduction

This chapter describes the wildlife recorded from the ponds in the main Oxfordshire data set of 34 ponds. Additional information is also given about the macroinvertebrates recorded from the larger data set (i.e., 133 ponds), in Section 3.5.

Wildlife is described in three main sections: plants, macroinvertebrates of the 34 ponds, and macroinvertebrates of the 133 ponds. Brief accounts of the factors associated with the presence of fish and ducks is given in Sections 3.6 and 3.7. A brief account of the methods used for species recording are given at the beginning of each section. More detail is given in Appendices 2 and 3. Definitions of terms used to define wildlife in this section (e.g., wetland plants, aquatic plants) are given in the Glossary. Correlations between wildlife and physiochemical parameters are discussed in the following chapter.

3.2 Wildlife recorded from Oxfordshire ponds

A wide range of wetland wildlife was recorded during the Oxfordshire Pond Survey: from only 34 ponds, a total of over 300 species of wetland plants and macroinvertebrates was recorded. Amongst the uncommon species found were *Myxas glutinosa* (an aquatic snail which was thought to be extinct in Britain), and over 90 other uncommon invertebrates and plants (see Table 3.1). In total, this information serves to underline the considerable importance of ponds as habitats protecting wetland wildlife.

Table 3.1 Summary of the Species Recorded from 34 Oxfordshire Ponds

	Plants			Invertebrates
	Aquatic	Emergent	Total	
Number of species				
Total no. of spp. recorded	36	82	118	231
Mean no. of spp. per pond	4.4	13.3	17.7	56
Range of spp. per pond	0-11	1-33	1-44	13-79
Uncommon species				
Total no. of local spp.	20	16	36	32
Total no. of NNB spp.	2	0	2	24
Total no. of NNA spp.	0	0	0	1
Total no of RDB3 spp.	0	0	0	2
Total no of RDB2 spp.	0	0	0	0
Total no of RDB1 spp.	0	0	0	1
Protected species*	0	0	0	2
Average no. of uncommon spp. per pond	1.18	1.14	2.32	6.4
Range of uncommon spp. per pond	0-6	0-5	0-9	0-12

* Species currently protected under the Wildlife and Countryside Act.

3.3 Wetland plants

3.3.1 Recording wetland plant species

The wetland plant species present at each pond were recorded during Summer 1989. The sites were revisited and the species lists checked for a second time during Summer 1991. At each pond a list of all wetland plant species growing within the outer edge of the pond was compiled. Plants which were included as 'wetland species' were defined by the Pond Action Wetland Plant List (see Appendix 2, TableA 2.1).

Plant abundance was recorded by plotting the distribution of major stands of wetland vegetation on to a base map of the pond. The data was abstracted from the maps to give the percentage abundance of plants in three categories: emergent, submerged, and floating-leaved.

Uncommon plant species (i.e., species which have relatively restricted distribution in Britain) have been divided into five groups. In ascending degree of rarity order, these are: local, NNB, NNA, RDB3, RDB2 and RDB1. Definitions of each of these terms are given in Appendix 6, Table A6.3.

3.3.2 Number of wetland plant species

A total of 118 wetland plant species was recorded from the 34 ponds. The number of wetland species recorded from individual ponds ranged from one to 44, and the average per pond was 17 (see Table 3.1).

The minimum number of *emergent* plant species recorded from any pond was one, the maximum was 33. However, most ponds (about 90%) supported fewer than 20 emergent species (see Figure 3.1). The average number of emergent species recorded per pond was 13.3.

Aquatic species (including both submerged plants and those with floating leaves) were much less common than the emergent herbs and grasses. The average number of species in the data set was 4.4 per pond, but some sites supported no aquatic species, and only about 20% supported more than six. The three richest ponds (Kennington, Central and Wychwood 3) each supported 11 aquatic species.

Correlation shows that the number of aquatic and the number of marginal species recorded from each pond were positively correlated ($p=<0.05$), and this is discussed in Chapter 4.

3.3.3 Wetland plant cover

The cover of wetland plants was assessed in three broad categories: emergent, floating, and submerged-leaved plants.

Emergent plant cover varied between 0% and 81% with an average of 21.5%. The average extent of floating-leaved cover was relatively low (only 14.5%), but the range was large, varying from 0% to almost total cover (97%). The latter was caused by rafts of duckweed at Little Wittenham Lower Pond. The abundance of submerged plants varied between 0% and 61%, with an average of 20.5%. Total cover (calculated by summing the cover in individual categories) varied between 0 and 120% with an average of 56%.

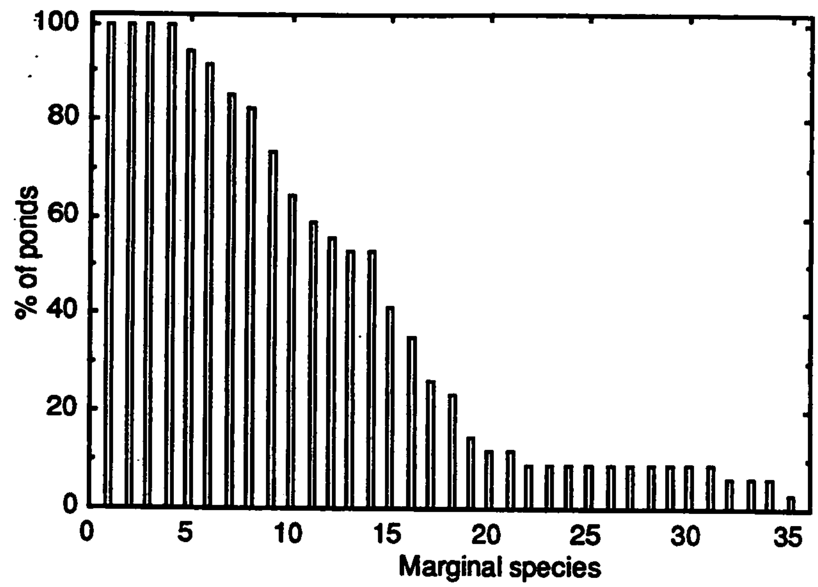
3.3.4 Uncommon wetland plant species

A surprisingly large number of uncommon wetland plant species were recorded during the OPS. These are listed in Table 3.2, together with their rarity status and the number of sites from which they were recorded. As would be expected, most uncommon species were of 'local' conservation value. However, two rather more uncommon plants were also recorded; both of these were pondweeds. The first, Fen Pondweed (*Potamogeton coloratus*), has NNB status; the second, Long-stalked Pondweed (*Potamogeton praelongus*) is believed to have declined considerably in recent years due to eutrophication (Rich, 1989) and almost certainly now deserves NNB status.

Overall, 19.5% of the emergent plant species recorded during the OPS fell into the category of 'uncommon species'. More notably, well over half (61%) of the *aquatic* plant species were deemed uncommon in some way. This may, in part, reflect a general under-recording of aquatic species (making them seem more uncommon than they really are); however, it is also likely to reflect the paucity of unpolluted freshwater habitats in Britain.

Most uncommon plant species (80%) were recorded from only one or two sites. The exception was Great Pond Sedge (*Carex riparia*), which was recorded from approximately a third of the ponds (12 sites). It should be noted, however, that *Carex riparia* only just merits 'local' status, using the criteria given in Appendix 6.

1. **Marginal plants: Numbers of species recorded from Oxfordshire ponds**



2. **Aquatic plants: Numbers of species recorded from Oxfordshire ponds**

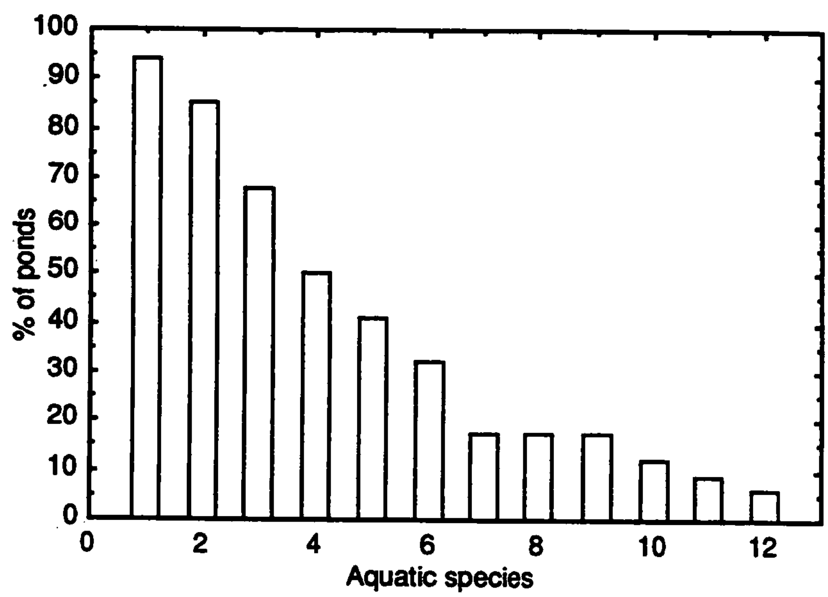


Figure 3.1 Numbers of Species of Wetland Plants Recorded from Oxfordshire Ponds

Table 3.2 Uncommon Wetland Plants

Species	English name	Number of sites recorded
Nationally Notable B species		
Potamogeton coloratus	Fen Pondweed	2
Potamogeton praelongus	Long-stalked Pondweed	1
Local aquatic species		
Callitriche hamulata	Intermediate Water-starwort	2
Callitriche obtusangula	Blunt-fruited Water-starwort	1
Ceratophyllum demersum	Rigid Hornwort	4
Hippuris vulgaris	Mare's Tail	4
Hottonia palustris	Water-violet	2
Hydrocharis morsus-ranae	Frogbit	2
Lemna gibba	Fat Duckweed	1
Lemna polyrhiza	Greater Duckweed	1
Oenanthe fluviatilis	River Water-dropwort	1
Potamogeton berchtoldii	Small Pondweed	7
Potamogeton crispus	Curled Pondweed	2
Potamogeton lucens	Shining Pondweed	2
Potamogeton pectinatus	Fennel Pondweed	1
Potamogeton pusillus	Lesser Pondweed	2
Ranunculus peltatus	Pond Water-crowfoot	2
Ranunculus trichophyllus	Thread-leaved Water-crowfoot	3
Sagittaria sagittifolia	Arrowhead	1
Utricularia vulgaris	Greater Bladderwort	1
Zannichellia palustris	Horned Pondweed	1
Local emergent species		
Butomus umbellatus	Flowering-rush	1
Calamagrostis epigejos	Wood Small-reed	1
Carex riparia	Greater Pond-sedge	12
Epilobium tetragonum	Square-stalked Willow-herb	1
Epipactis palustris	Marsh Helleborine	1
Eriophorum latifolium	Broad-leaved Cottongrass	1
Juncus subnodulosus	Blunt-flowered Rush	2
Lysimachia nummularia	Creeping Jenny	5
Lysimachia vulgaris	Yellow Loosestrife	1
Lythrum portula	Water-purslane	1
Oenanthe aquatica	Fine-leaved Water-dropwort	4
Oenanthe fistulosa	Tubular Water-dropwort	1
Ranunculus lingua	Greater Spearwort	1
Rorippa amphibia	Great Yellow-cress	1
Schoenoplectus lacustris	Common Club-rush	4
Schoenus nigricans	Black Bog-rush	2

3.3.5 Comparison with other studies

A number of other studies are available with which the results of the OPS can be compared. The most comprehensive of these studies have been reviewed and, where necessary, modified so that species lists are directly comparable with the OPS wetland plant recording list.

The results, presented in Tables 3.3 and 3.4, show that the number of species recorded from Oxfordshire was consistently higher than most other studies, particularly when the number of ponds surveyed is taken into account. This is likely to be because the OPS contained a relatively high proportion of sites located on SSSIs, LNRs or within other areas of seminatural landuse, and adds to the evidence that ponds located in seminatural areas are richer in species and more likely to support uncommon species than ponds in the wider countryside.

3.4 Aquatic macroinvertebrates of the 34 Oxfordshire ponds

3.4.1 Methods

Aquatic macroinvertebrate samples were collected from each pond using a hand-net. The sampling was time-limited, with a three-minute sampling period allocated to each pond. This time period was split equally between the different microhabitats identified in the pond (e.g., gravel bottom, earth banks, plant communities of different compositions etc.). Typically, between three and eight microhabitats were sampled in each pond. Samples were taken to the laboratory where macroinvertebrates were removed for identification and counting.

Dates of aquatic macroinvertebrate sampling are given in Appendix 1, Table A1.1, and a more detailed account of sampling and sorting methodology is given in Appendix 3, Section A3.1. A list of the invertebrate taxa which were systematically recorded and identified to species level is given in Appendix 3, Table A3.1. Further details about the choice and use of macroinvertebrate survey techniques are given in Appendix 3.

3.4.2 Results of macroinvertebrate surveys

The following section discusses the result of the main data set of 34 ponds. This includes the data from 128 samples (triplicate samples taken in 1989 and a single invertebrate sample taken in 1990). Full lists of all species of macroinvertebrates recorded during these surveys are given in Appendix 3, Table A3.6. A summary of the numbers of species of invertebrates within the major groups recorded is given in Table 3.5, together with the percentage of the British fauna which these numbers represent. In addition, the number (and percentage) of species in each of the groups which are likely to be found in *still* freshwater habitats alone has been estimated from studies of the literature.

Number of all aquatic macroinvertebrates

A total of 231 aquatic macroinvertebrate species was recorded in the 34 Oxfordshire ponds surveyed. Within the groups which were identified to species level this represents approximately 35% of the British freshwater fauna as a whole and approximately 44% of those species which are likely to be found in *still* freshwater (i.e., excluding obligate brackish and running water species). Individual Oxfordshire ponds yielded from between 13 and 79 species per site. The number of species within individual three-minute samples also varied considerably, from two species in Towersey Duck Pond in 1990 (which had recently suffered an oil spillage) to 60 in Kennington Pit in 1990.

A wide variety of pond types were surveyed in Oxfordshire, from large valley-fishponds to small temporary ponds. Nevertheless, the absence of any acidic, upland or coastal sites from the survey will have effectively limited the range of invertebrates which were likely to be found. That 35% of the British list was recorded from only 34 ponds in what is a relatively small county, gives a good indication of the conservation resource which Oxfordshire ponds represent.

Table 3.3 Number of Plant Species Recorded from Oxfordshire and Other Ponds

	Number of ponds	All species: average	All species: range	Aquatic spp: average	Aquatic spp: range	Marginal spp: average	Marginal spp: range
Oxfordshire Pond Survey	36	17.7	1-44	4.4	0-11	13.3	1-33
Dorset (Friday, 1988)	16	8	2-15	3	1-7	5	1-9
Cheshire* (Brian *et al.* ,1987)	153	9	0-23	2	-	7	-
Clwyd* (Day ,1981)	406	14	0-30	2.5	-	11.5	-
Milton Keynes* (Ridge and Furniss, 1985)	117	7.5	-	1.5	-	6	-

Table 3.4 Number of Uncommon Plant Species Recorded from Ponds in Oxfordshire and Other Areas

	Number of ponds	Number of species	Number of local species	Number of NNB species	Number of NNA species
Oxfordshire Pond Survey	36	118	36	2	0
Dorset (Friday, 1988)	16	31	4	0	0
Cheshire* (Brian *et al.*, 1987)	153	79	15	0	1
Clwyd* (Day, 1981)	406	114	26	1	2
Milton Keynes* (Ridge and Furniss, 1985)	117	89	11	1	0

* Species lists have been adapted to correspond to those of National Pond Survey (Pond Action).

Table 3.5 Number of Species of Macroinvertebrates in Major Groups Recorded from 34 Oxfordshire Ponds

Group		Local	Notable b	Notable a	RDB 3	RDB 2	RDB 1	OPS Total	UK Total	% UK Total	Pond*1 Total	%Pond*1 Total
Flatworms	(Tricladida)	1	-	-	-	-	-	7	12	58	10	70
Snails	(Gastropoda)*2	1	-	-	-	-	1	26	44	59	36	72
Leeches	(Hirudinea)	3	-	-	-	-	-	8	16	50	14	57
Spiders	(Araneae)	-	-	-	-	-	-	1	1	100	1	100
Shrimps/slaters	(Malacostraca)	-	1	-	-	-	-	5	41	12	14	36
Mayflies	(Ephemeroptera)	2	-	-	-	-	-	6	49	12	18	33
Stoneflies	(Plecoptera)	1	-	-	-	-	-	3	34	9	10	30
Dragonflies	(Odonata)*3	1	-	-	-	-	-	10	45	22	35	29
Bugs	(Hemiptera)	9	-	-	-	-	-	32	63	51	61	52
Beetles	(Coleoptera)*4	10	23	1	2	-	-	99	273	36	226	44
Alderflies	(Megaloptera)	-	-	-	-	-	-	1	3	33	1	100
Caddisflies	(Trichoptera)*5	4	-	-	-	-	-	33	168	20	90	37
TOTAL		32	24	1	2	-	1	231	742	31	529	44

Unless otherwise stated, the definition of which species are 'aquatic' in any group follows Maitland (1977)

*1 Species possibly found in ponds (e.g., excludes obligate brackish and running water species).
*2 Aquatic Gastropoda are as defined in Macan (1975).
*3 The two species *Coenagrion puella* and *Coenagrion pulchellum* are inseparable as larvae.
*4 Aquatic Coleoptera are limited to those described in Friday (1988).
*5 Excluding the Hydroptilidae which are rarely identifiable as larvae.

Flatworms

Seven species of flatworm were recorded from the 34 ponds. This represents approximately 70% of the British freshwater fauna but, in fact, includes all the species likely to be recorded from Oxfordshire ponds. The maximum number of flatworms recorded from a single pond was five species from Wroxton Bottom Pond. The most widespread of the flatworms in the data set were *Polycelis tenuis* and *Polycelis nigra*, found at 16 and 15 sites respectively.

Snails

Snails are well represented in the Oxfordshire survey with a total of 26 species recorded. This represents approximately 59% of British aquatic snails and about 72% of the British stillwater snail fauna. Of the snail species which are absent, many are brackish water or exclusively riverine species. The relatively large number of species is likely to be related to the presence of the Thames corridor: an area noted for the richness of its snail fauna. Some ponds had exceptionally rich snail faunas. This was particularly true of larger, deeper sites such as Kennington Pit (a deep gravel pit on the Thames flood plain) which had 19 species of snail, including the very rare (RDB 1) Glutinous Snail (*Myxas glutinosa*).

Six species of snail occurred widely in the survey (i.e., they were recorded in over 50% of the sites). The Wandering Snail (*Lymnaea peregra*) was particularly common, being recorded from 85% of the 34 sites. Four species of snail were found at one site alone.

Leeches

Sixteen species of leech occur in Britain. All are amphibious or aquatic and most (14) are quite likely to occur in ponds at some time. The eight species recorded during the OPS represent 50% of the total freshwater fauna. The most widespread leeches were *Glossiphonia complanata* and *Helobdella stagnalis*, both found in 23 of the 34 sites. Individual ponds supported up to eight species of leech, with Kennington Pit again the richest site.

Malacostracan crustaceans (shrimps, slaters and crayfish)

Very few species of the malacostracan crustaceans were found during the survey of the 34 ponds, a reflection of the brackish and sometimes subterranean nature of the habitats of many of this group. The five species recorded represent about 36% of the species likely to be found in freshwater. Four of these five species were widespread, being recorded from between 53% and 71% of the sites. The fifth species, our native crayfish, *Austropotamobius pallipes*, was recorded from only one site (Wroxton Bottom Pond). *A. pallipes* is now a protected species under the Wildlife and Countryside Act.

Mayflies

The mayflies are poorly represented in the OPS database, but this is largely because the majority of species are riverine. Of the 49 British mayflies, only 18 are ever likely to be found in still water habitats and, of these, several are largely confined to upland sites. The six species recorded from the 34 OPS ponds actually represent most of the species which are likely to live in lowland still freshwaters. Individual ponds supported up to five of these six species, with the richest site being a medium-sized gravel pit (Milton pools, Pond A).

The most widespread mayfly in the survey was the Pond Olive (*Cloeon dipterum*), which was recorded from 32 of the 34 ponds. This was the second most widespread species of invertebrate recorded during the OPS.

Stoneflies

Only three of the 34 British species of stonefly were recorded during the survey. Again, this was because the stoneflies are a predominantly riverine group, and it is unlikely that more than three species of stonefly would ever be recorded from lowland ponds. Individual ponds supported up to two of these three species (Wychwood Pond 2 and Lashford Lane).

The commonest of the stoneflies was *Nemoura cinerea*, a genuinely still-water animal, although this was still only present in five of the 34 ponds.

Dragonflies (dragonflies and damselflies)

Dragonflies and damselflies are relatively poorly represented in the OPS database, with the 10 species recorded representing only about 29% of those species likely to be recorded from still water in Britain. Reasons for this are likely to be twofold: (i) the best dragonfly assemblages tend to occur in more acidic waters, or large wetland complexes (e.g., the Cotswold Water Park); and (ii) some species of dragonfly are very difficult to find as larvae.

Individual ponds supported up to seven species of damselfly and dragonfly with the two richest sites both large, deep ponds with good water quality (Wroxton Bottom Pond and Kennington Pit).

Three dragonflies were found to be widespread in Oxfordshire ponds. These were: the Blue-tipped Damselfly (*Ischnura elegans*), the Azure Damselfly (*Coenagrion puella*), and the Large Red Damselfly (*Pyrrhosoma nymphula*). All were recorded from 20 or more sites. True dragonflies appeared to be less widespread, with the commonest, The Southern Hawker (*Aeshna cyanea*), being recorded from just over a third of the ponds (12 sites).

Bugs

Most of the aquatic bugs are still-water species and they were therefore particularly well represented in the 34 ponds.

In total, 51% of the British list (32 species) were recorded. Many of the remaining species were those largely confined to upland or acidic sites. Individual ponds supported up to 17 species of bug.

Five species of water bug were found to be widespread in the survey ponds (i.e., recorded from more than half of the 34 sites). One species was particularly common: a lesser water boatman, *Sigara dorsalis*, which was recorded from 29 sites and was the third most widespread invertebrate in the data set.

Beetles

Water beetles are a very diverse group, and ponds can provide an important habitat for them - over 80% of the aquatic species are likely to occur in still freshwater habitats. It is, therefore, not surprising that water beetles represented by far the most diverse group in the OPS data set. A total of 99 species were recorded from the 34 ponds, which was approximately 44% of *all* the invertebrate species recorded during the survey. Individual ponds supported up to 39 beetle species, with the richest site being Asham Meads, a small floodplain field-pond with grassy edges.

Beetles were also the most *widespread* invertebrate group recorded from the ponds, with 11 species recorded from over half the ponds in the survey. The hydrophilid beetle, *Helophorus brevipalpis* ,was recorded from all but one of the ponds, and was the most widespread invertebrate recorded in the survey.

Alderflies

There are only three species of alderfly in Britain, and two of these are exclusively riverine. The remaining species (*Sialis lutaria*) is more of a generalist which can live in both still and running waters. This species was recorded from 27 of the 34 ponds and was the sixth most common invertebrate recorded during the survey.

Caddisflies

In total, 33 species of caddisfly were recorded during the OPS - approximately 20% of the British fauna and 37% of the species likely to be found in still freshwater. The relatively low percentage of the fauna recorded is likely to partly reflect the restriction of many caddisflies to riverine, upland and acidic waters. But in addition, many species are adapted to very temporary waters and often emerge very early in the year (at the beginning of March in many cases). This means that the OPS surveys will inevitably have missed some of the species which emerge at this time. Individual ponds were shown to support up to 13 species of caddis, with the greatest number being found in a relatively large spring-fed pond (Little Wittenham Upper Pond).

Only one caddisfly species was particularly widespread in the 34 pond data set: the limnephilid, *Limnephilus lunatus*, which was present in 22 ponds.

3.4.3 Uncommon macroinvertebrate species

Just over a quarter (26%) of the invertebrate species recorded from the 34 ponds were uncommon (i.e., local, notable or Red Data Book). These species are listed in Table 3.6, and details of their national distribution status are given in Appendix 3.6.

Numbers of local, notable and RDB species in individual ponds varied from 12 in Central Pond down to none in two ponds (Kingston Bagpuize Ditch Pond and Towersey Duck Pond).

Most of the uncommon species (53.5%) were recorded from only one site but there were a number of notable exceptions, including the local haliplid beetle, *Haliplus obliquus*, which was recorded from 16, sites and the Nationally Notable B hydrophilid beetle, *Helochares lividus*, present in seven sites.

One very exceptional record came out of the Oxfordshire Pond Survey - this was the first live record of the Glutinous Snail (*Myxas glutinosa*), in Britain since 1951, when it was last seen in Windermere (Bratton, 1991). The species (which is scheduled under the Wildlife and Countryside Act) was previously thought to be extinct in Britain. It is

Table 3.6 Uncommon Macroinvertebrate Species of the 34 Ponds

SPECIES	No. of sites recorded
Endangered (RDB1) species	
GASTROPODA (snails)	
Myxas glutinosa	1
Rare (RDB3) species	
COLEOPTERA (beetles)	
Enochrus isotae	4
Gyrinus suffriani	1
Schedule 5 (protected) species	
DECAPODA (crayfish)	
Austropotamobius pallipes	1
Nationally Notable A species	
COLEOPTERA (beetles)	
Helophorus dorsalis	1
Nationally Notable B species	
COLEOPTERA (beetles)	
Agabus chalconatus	2
Anacaena bipustulata	7
Cercyon convexiusculus	5
Cercyon sternalis	1
Cercyon tristis	1
Cercyon ustulatus	1
Chaetarthria seminulum	1
Enochrus coarctatus	1
Enochrus melanocephalus	1
Enochrus ochropterus	1
Haliplus heydeni	1
Haliplus laminatus	4
Helochares lividus	7
Helophorus griseus	5
Helophorus nanus	2
Hydraena testacea	4
Hydroglyphus pusillus	3
Ilybius fenestratus	5
Limnebius nitidus	3
Limnebius papposus	5
Ochthebius bicolon	1
Peltodytes caesus	1
Riolus cupreus	1
Local species	
TRICLADIDA (flatworms)	
Dugesia lugubris	3
GASTROPODA (snails)	
Aplexa hypnorum	1
HIRUDINEA (leeches)	
Erpobdella testacea	14
Glossiphonia heteroclita	13
Hemiclepsis marginata	5
EPHEMEROPTERA (mayflies)	
Caenis robusta	8
Cloeon simile	3
PLECOPTERA (stoneflies)	
Nemoura erratica	1
ODONATA (dragonflies)	
Erythromma najas	6
HEMIPTERA (bugs)	
Corixa dentipes	1
Corixa panzeri	9
Cymatia bonsdorffi	1
Cymatia coleoptrata	6
Gerris argentatus	3
Mesovelia furcata	1
Micronecta scholtzi	3
Ranatra linearis	3
Sigara concinna	3
COLEOPTERA (beetles)	
Cercyon marinus	2
Copelatus haemorrhoidalis	4
Cymbiodyta marginella	5
Enochrus testaceus	11
Haliplus obliquus	16
Helophorus granularis	6
Hygrotus versicolor	2
Hydroporus memnonius	1
Laccobius biguttatus	3
Porhydrus lineatus	2
TRICHOPTERA (caddisflies)	
Beraeodes minutus	2
Ecnomus tenellus	1
Limnephilus decipiens	4

also listed as vulnerable in continental Europe where its numbers are declining rapidly due to deterioration in water quality (Collins and Wells, 1987). The record for the Glutinous Snail came from Kennington Pit, one of the richest of the ponds surveyed during the OPS. Interestingly, it was previously recorded in the vicinity of its current site earlier in the century, but there had been no positive records since 1920.

The Kennington Pit site is currently being established as a Local Nature Reserve and measures are being undertaken to protect *Myxas* under English Nature's Recovery Programme. This involves both detailed surveys at Kennington Pit to try and establish the size and exact location of the existing population and a series of further searches in ponds, ditches and streams in the near vicinity in order to establish whether other populations still survive in the area.

Other significant records include one for the Atlantic Stream Crayfish, *Austropotamobius pallipes* (from Wroxton Bottom Pond). This is a Schedule 5 protected species which is currently under threat from a fungal disease carried by two introduced crayfish (the Signal Crayfish, *Pacifastacus leniusculus* and, to a lesser extent, the Asian Crayfish, *Astacus leptodactylus*), both of which are currently expanding their British range at the expense of our native species (Goddard and Hogger, 1986).

The survey also brought the first county records of one of the lesser water boatman, *Arctocorisa germari*, and the second Oxfordshire records of two other uncommon lesser water boatman, *Sigara concinna*, and *Cymatia bonsdorfi*, (Campbell, 1990).

Finally, it was noted that the beetle fauna was of particularly high quality, with 10 local, 23 Nationally Notable B, one Nationally Notable A and two RDB3 (rare) species being recorded. The two rare species were a water scavenger beetle, *Enochrus isotae*, which is characteristic of semi-seasonal water bodies and a whirligig beetle, *Gyrinus suffriani*, a species of fen margins.

3.5 Aquatic macroinvertebrates of the 133 ponds

3.5.1 Methods

Methods were as described in Section 3.4.

3.5.2 Number of macroinvertebrate species recorded

The data presented in the following sections are the result of surveys of a total of 133 ponds (a total of 565 samples in all). Approximately 380,000 specimens were identified to species level during the course of the work. Full lists of all macroinvertebrate species are given in Appendix 3.7. A summary of the numbers of invertebrate species within the major groups recorded is given in Appendix 3, Table A3.7, together with the percentage of the British fauna which these numbers represent. The number of species in each of the groups which is likely to be found in still freshwater habitats has been estimated from studies of the literature, and the percentage of these species found in Oxfordshire ponds calculated.

All aquatic macroinvertebrates

A total of 256 aquatic macroinvertebrates was recorded in the 144-pond data set. This was only 25 species more than were recorded in the 34 pond survey (a 10% increase). Overall, the pattern seen from the 34 ponds, in terms of relative numbers of species in the major groups, remains relatively unchanged when the extra 99 ponds are added to the database.

Individual sites yielded from between 60 macroinvertebrate species in the richest site studied (Kennington Pit, 1990) and no species at all in the poorest site studied (a farmyard pond at Carrimer's Farm).

Of the 256 species recorded, 38 (15%) were found in only one site, and over half the species recorded were found in less than 10 sites. Only 11 of the 256 species were recorded from more than half of the ponds. The most ubiquitous

Table 3.7 Number of Species of Macroinvertebrates in Major Groups Recorded in the Oxfordshire Pond Survey (133 Ponds)

Group	Local	Notable b	Notable a	RDB 3	RDB 2	RDB 1	OPS Total	UK Total	% UK Total	Pond Total	%Pond Total
Tricladida	1	-	-	-	-	-	7	12	58	10	70
Gastropoda[*1]	2^{1}	1^{1}	-	-	-	1	28^{2}	44	64^{5}	36	78^{6}
Hirudinea	3	-	-	-	-	-	9^{1}	16	56^{6}	14	64^{7}
Araneae	-	-	-	-	-	-	1	1	100	1	100
Malacostraca	1	1^{1}	-	-	-	-	6^{1}	41	15^{3}	14	43^{7}
Ephemeroptera	2	-	-	-	-	-	7^{1}	49	14^{2}	18	39^{6}
Plecoptera	1	-	-	-	-	-	3	34	9	10	30
Odonata[*2]	1	1	-	-	-	-	11^{1}	45	24^{2}	35	31^{3}
Hemiptera	9	-	-	-	-	-	35^{3}	63	56^{5}	61	57^{5}
Coleoptera[*3]	11^{1}	31^{8}	2^{1}	2	-	-	112^{13}	273	41^{5}	226	50^{6}
Megaloptera	-	-	-	-	-	-	1	3	33	1	100
Trichoptera[*4]	5^{2}	-	-	-	-	-	36^{3}	168	21^{1}	90	40^{3}
TOTAL	36^{3}	34^{10}	2^{1}	2	-	1	256^{25}	742	35^{4}	529	48^{4}

Superscripts. Superscripts indicate the number of additional species (or percentage) compared to the 34-pond database. For example: 26^{5} indicates 26 species present, of which five are not also found in the 34 ponds.

Unless otherwise stated, the definition of which species are aquatic in any group is defined by the Department of the Environment list of animals found in freshwater in the United Kingdom.

[*1] Aquatic Gastropoda are as defined in Macan (1975).
[*2] The two species *Coenagrion puella* and *Coenagrion pulchellum* are inseparable as larvae.
[*3] Aquatic Coleoptera are limited to those described in Friday (1988).
[*4] Few species of the Hydroptilidae are identifiable as larvae and these were not covered.

Table 3.8 Frequency of the Most Widespread Species of Each of the Major Groups in the 133 Ponds

Group	Species' English name (where applicable)	Species' Latin name	No. of ponds
Flatworms	-	*Polycelis tenuis*	31
Snails	The Wandering Snail	*Lymnaea peregra*	98
Leeches	-	*Helobdella stagnalis*	91
Water slaters	-	*Asellus aquaticus*	95
Freshwater shrimps	-	*Cranngonyx pseudogracilis*	70
Crayfish	The Atlantic Stream Crayfish	*Austropotamobius pallipes*	2
Araneae	The Water Spider	*Argyroneta aquatica*	10
Mayflies	The Pond Olive	*Cloeon dipterum*	70
Stoneflies	An early brown	*Nemoura cinerea*	5
Dragonflies	The Southern Hawker	*Aeshna cyanea*	33
Damselflies	The Azure Damselfly	*Coenagrion puella*	61
Bugs	A lesser water boatman	*Sigara dorsalis*	71
Beetles	A water scavenger beetle	*Helophorus brevipalpis*	86
Caddisflies	-	*Limnephilus lunatus*	26
Alderflies	-	*Sialis lutaria*	27

species was the Wandering Snail, *Lymnaea peregra*, which was found in 98 ponds (74%). A species of water slater, *Asellus aquaticus*, and a leech, *Helobdella stagnalis*, were also very common (found in 95 and 91 ponds respectively). Table 3.8 shows which species were the most widespread in each of the major groups of macroinvertebrates.

3.5.3 Uncommon macroinvertebrate species

A total of 75 species of local, notable or Red Data Book (RDB) species was recorded during the survey of 133 ponds (see Table 3.9). This represented an increase of 15 species (25%) compared with the 34-pond data set. Of the species added to the list by the extra surveying, therefore, 60% were of local or higher status. Of particular note was the Nationally Notable A whirligig beetle, *Gyrinus bicolor*, which was recorded from Cassington Pit.

In addition to the record of *Myxas glutinosa*, mentioned previously, the record of the Smooth Ramshorn, *Gyraulus laevis*, from Bourton, is also unusual, being one of very few for the county (M P Kerney, pers. comm.).

The national distribution status of these and other uncommon species recorded during the survey are described in Appendix 3, Section 3.4.

3.6 Fish

Fish were recorded where observed or netted in the field. Species recorded included perch, pike, carp and three-spined stickleback. Of these, stickleback were by far the most widespread species, and usually the only fish found in small, shallow ponds.

The presence of fish correlates systematically with permanence and associated variables such as pond depth, pond area and clay water source (see previous sections). There were positive relationships between the presence of fish and the number of floating-leaved and total wetland plant species. This is likely to be the result of a combination of the paucity of aquatic plants in ponds which are temporary for part of the year, and generally lower species-richness in temporary ponds.

Ponds stocked with fish almost certainly had higher densities or biomass than unstocked ponds. Not surprisingly, stocked ponds were generally large and deep and tended to be associated with a stream inflow. They were also associated with urban areas or roads in the near vicinity, almost certainly because of the need for access in the vicinity of fishing lakes. Correlations of fish with environmental variables are shown in Table 3.10.

3.7 Ducks

Ducks were correlated with few significant or interpretable variables, but, not surprisingly, they were correlated with the presence of parks and gardens and negatively associated with the presence of floating-leaved species. Correlations of ducks with environmental variables are given in Table 3.10.

Table 3.9 Uncommon Macroinvertebrate Species (133 Ponds)

SPECIES	No. of sites recorded
Endangered (RDB1) species	
GASTROPODA (snails)	
Myxas glutinosa	1
Rare (RDB3) species	
COLEOPTERA (beetles)	
Enochrus isotae	7
Gyrinus suffriani	1
Schedule 5 (protected) species	
DECAPODA (crayfish)	
Austropotamobius pallipes	2
Nationally Notable A species	
COLEOPTERA (beetles)	
Gyrinus bicolor	1
Helophorus dorsalis	2
Nationally Notable B species	
GASTROPODA (snails)	
Gyraulus laevis	1
ODONATA (dragonflies)	
Sympetrum sanguineum	2
COLEOPTERA (beetles)	
Agabus chalconatus	12
Agabus labiatus	1
Agabus uliginosus	1
Anacaena bipustulata	8
Berosus signaticollis	1
Cercyon convexiusculus	5
Cercyon sternalis	3
Cercyon tristis	1
Cercyon ustulatus	1
Chaetarthria seminulum	1
Enochrus coarctatus	3
Enochrus melanocephalus	3
Enochrus ochropterus	1
Haliplus heydeni	4
Haliplus laminatus	7
Helochares lividus	15
Helophorus griseus	9
Helophorus nanus	3
Hydraena testacea	4
Hydroglyphus pusillus	5
Hydroporus marginatus	1
lybius fenestratus	10
Ilybius subaeneus	3
Laccobius sinuatus	2
Limnebius nitidus	3
Limnebius papposus	10
Ochthebius bicolon	1
Peltodytes caesus	2
Riolus cupreus	1
Riolus subviolaceus	1
Scarodytes halensis	1

SPECIES	No. of sites recorded
Local species	
TRICLADIDA (flatworms)	
Dugesia lugubris	5
GASTROPODA (snails)	
Aplexa hypnorum	1
Viviparus contectus	1
HIRUDINEA (leeches)	
Erpobdella testacea	42
Glossiphonia heteroclita	28
Hemiclepsis marginata	10
AMPHIPODA (freshwater shrimps)	
Niphargus aquilex	1
EPHEMEROPTERA (mayflies)	
Caenis robusta	13
Cloeon simile	3
LECOPTERA (stoneflies)	
Nemoura erratica	1
ODONATA (dragonflies)	
Erythromma najas	7
HEMIPTERA (bugs)	
Corixa dentipes	1
Corixa panzeri	13
Cymatia bonsdorffi	3
Cymatia coleoptrata	10
Gerris argentatus	4
Mesovelia furcata	2
Micronecta scholtzi	4
Ranatra linearis	3
Sigara concinna	7
COLEOPTERA (beetles)	
Cercyon marinus	3
Copelatus haemorrhoidalis	9
Cymbiodyta marginella	8
Enochrus testaceus	13
Haliplus obliquus	33
Helophorus granularis	6
Hydraena britteni	1
Hydroporus memnonius	6
Hygrotus versicolor	4
Laccobius biguttatus	4
Porhydrus lineatus	2
TRICHOPTERA (caddisflies)	
Beraeodes minutus	2
Ecnomus tenellus	1
Limnephilus decipiens	4

Table 3.10 Fish and Ducks

	Fish present	Fish stocked	Ducks
Pond size			
Pond area	+	+	ns
Pond circumference	+	+	ns
Pond depth			
Maximum dimension	+	+++	ns
Maximum total depth	+	+	ns
Maximum total depth	+	+	ns
Mean total depth	+	ns	ns
Maximum water depth	+	ns	ns
Mean water depth	+	+	ns
Permanence	+++	ns	ns
Shade			
Pond area overhung	ns	++++	ns
Pond margin overhung	ns	++++	ns
Water source			
Inflow volume	ns	+	ns
Water source: stream	ns	++	ns
Geology			
Surrounding geology: sandstone	ns	ns	-
Surrounding geology: gravel	ns	ns	+
Geology of water source: gravel	ns	ns	+
Chemistry			
Sodium	ns	----	ns
Potassium	ns	ns	-
Sulphate	ns	ns	++
Other			
Altitude	ns	+++	ns
Age	ns	+	ns
Disturbance	ns	-	ns
Landuse			
Improved grassland-5m	ns	+	ns
Improved grassland-100m	ns	+++	+
Improved grassland-total	ns	++	+
Ponds and lakes-5m	ns	ns	+
Fen, marsh and bog-total	ns	-	ns
Unimproved grassland-100m	ns	-	ns
Semi-natural-5m	ns	---	ns
Semi-natural-total	ns	ns	-
Urban and roads-5m	ns	++++++	ns
Urban and roads-total	ns	+	ns
Urban-total	ns	+++	ns
Parks and grassland-5m	ns	ns	+++
Parks and grassland-25m	ns	ns	+
Disturbed-25m	ns	ns	+
Disturbed-5m	ns	+++	ns
Disturbed-total	ns	ns	+
Plant cover			
% pond emergent cover	ns	-	ns
% pond floating	ns	ns	-
Number of floating species	+	ns	ns
Number of emergent species	ns	-	ns
Total number of plant species	+	ns	ns
Pond total cover	ns	--	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

CHAPTER 4

FACTORS AFFECTING THE WILDLIFE VALUE OF PONDS

4.1 Introduction

Previous chapters described the physical and biological character of ponds in the OPS data set. This chapter describes the interrelationships between the two in order to identify the factors which may have been important in shaping the plant or animal communities.

4.2 Methods of assessment

The main ecological variables used for correlation with the physical environment were species-richness or species numbers, and species rarity. In particular:

(i) The number of species per pond, considered as:

- Number of species of (a) aquatic; and (b) marginal wetland plants
- Number of species of aquatic macroinvertebrates (species-richness)

(ii) Species rarity:

This was assessed by giving each pond a numerical rarity score - the Species Rarity Index (SRI). The SRI was calculated by giving each plant or animal species recorded a rarity score (from 1 = common species to 64 = RDB1 species). Scores were totalled for each pond and then divided by the number of species present in the pond to give an average rarity value (see Appendix 6 and Appendix 6, Table A6.3).

Species Rarity Indices were calculated for the following:

- SRI of (a) aquatic; and (b) marginal plant communities
- SRI of the aquatic macroinvertebrate community

It is important to note that, since plants and invertebrates were not collected in the same way, plant and animal conservation parameters are not strictly analogous. All wetland plant species present at each pond were recorded. Species lists are, therefore, referred to as plant species number or number of species of plants. Invertebrate samples were time-limited, with the same amount of time given to each pond, irrespective of area, depth or complexity. Species lists from these samples are, therefore, a measure of species-richness and will be referred to as such. In contrast, SRIs are more likely to be analogous. Note also that invertebrate sampling includes all records from ponds from 1989 and 1990, including all the 1989 replicates.

4.3 Environmental factors which correlate with the plant and invertebrate communities

Correlations were made between the environmental variables and the main ecological variables to indicate the main factors which were associated with different aspects of pond conservation value. These are described below.

4.3.1 Pond area

The number of *plant* species was positively correlated with pond area, pond circumference and maximum dimension, strongly suggesting that, within this data set, larger ponds supported more aquatic and more emergent plant species than smaller ponds.

In contrast, there was no clear relationship between pond size and *invertebrate* species-richness. This does not necessarily mean that small ponds supported as many species as larger ponds, since (as indicated above) invertebrate

Table 4.1 Pond Area

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts	Plants		Inverts
	Aquatic	Emergent		Aquatic	Emergent	
Pond area	+	++	ns	ns	ns	ns
Pond circumference	+	++	ns	ns	ns	ns
Maximum dimension	+	++	ns	ns	ns	ns
Index of shore complexity	ns	-	ns	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

sampling methods were time-limited rather than proportional to area. Further information relating to this point is discussed in Appendix 3, Section A3.2.

Interestingly, there was no evidence of a relationship between Species Rarity Indices and pond size, suggesting that small ponds support just as high a proportion of rare and uncommon species as larger ponds.

4.3.2 Water depth and sediment depth

Total pond depth and water depth both correlated positively with the number of *aquatic* plants and macroinvertebrate species-richness, suggesting the presence of richer communites in deeper ponds. Although the number of marginal plant species recorded was related to area (see above), it did not correlate with depth. This is probably because many large, deep ponds are also very steep-sided, with limited edge area available for emergent growth.

It is interesting to note that, although invertebrate richness did not correlate with area, it *was* relatively strongly correlated with depth (especially mean pond and water depth). This might suggest that the presence of a small amount of deepwater habitat can add significantly to the numbers of species of macroinvertebrates recorded from a pond.

Species rarity was not related in any way to water depth, again suggesting that uncommon species are as likely to be recorded from shallow ponds as deep ponds.

Table 4.2 Depth

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts	Plants		Inverts
	Aquatic	Emergent		Aquatic	Emergent	
Maximum total pond depth	+	ns	+	ns	ns	ns
Mean total pond depth	++	ns	+++	ns	ns	ns
Maximum water depth	+	ns	+	ns	ns	ns
Mean water depth	+++	ns	+++	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.3 Tree and shrub cover

As would be expected, the *percentage* of a pond which was overhung was more important in affecting plant conservation value than the actual *area* of tree and shrub cover (i.e., a small pond with an area of $50m^2$ overhung would be more affected by shade than a large one).

There was a negative relationship between the percentage of pond shade and the numbers of *aquatic* plant species. There was also some evidence that greater shading of pond margins had a detrimental effect on the invertebrate species-richness.

The only relationship between shade and species rarity was a weak correlation between aquatic plant SRI and the percentage of the pond margin which was overhung by trees and shrubs, suggesting that the extent of shade had little effect on the quality of the invertebrate and emergent plant communities.

Overall, the results more or less concur with our current understanding of pond wildlife in suggesting that a high percentage of shade around a pond may result in slightly lower quality plant and macroinvertebrate communities. It would, however, be a mistake to infer from this that shaded ponds are of low value to wildlife; for example, leaf-litter and shade are important for certain plant and invertebrate species. In addition, many of the species which are characteristic of shaded ponds (such as Diptera) were not covered by the OPS.

Table 4.3 Tree and Shrub Cover

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts	Plants		Inverts
	Aquatic	Emergent		Aquatic	Emergent	
% pond area overhung	--	ns	ns	ns	ns	ns
% pond margin overhung	-	ns	-	-	ns	ns
Pond area overhung	ns	ns	ns	ns	ns	ns
Area of pond margin overhung	ns	ns	ns	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.4 Pond age

Pond age was weakly positively correlated with the number of aquatic plants, and negatively correlated with the number of invertebrate species. The positive correlation with aquatic plants is likely to be related to a cross-correlation with larger ponds. The negative correlation between invertebrates and age is unexpected since it would be expected that older ponds would also support more invertebrate species. This result may be related to the familiar phenomenon of new or disturbed sites initially having a high proportion of colonising species which become out-competed as the pond ages. No correlation was found between species rarity and pond age.

4.3.5 Altitude

Altitude was correlated (weakly) with emergent plants alone, suggesting a higher abundance of emergent plants at lower altitude. This may be a general trend since there are no direct correlates with other altitude-linked factors such groundwater, flooding, etc.

Table 4.4 Pond Age and Altitude

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		**Inverts**	**Plants**		**Inverts**
	Aquatic	Emergent		Aquatic	Emergent	
Pond age	+	ns	-	ns	ns	ns
Altitude	ns	-	ns	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.6 Water source

The most consistent and significant correlations with water source are negative correlations between the presence of an inflow and the quality of the invertebrate fauna. This, apparently deleterious, effect of a high surface inflow volume might be due to inflows bringing nutrients, biocides or other pollutants into ponds from a larger catchment, without the buffering effect that drainage through surrounding land might bring. This was further supported by the negative association with drainage ditches, many of which drain arable land (see Section 2.2.6). Neither plant number nor rarity are correlated with inflow *per se*, so it would seem likely that, *if* the effect on the invertebrate community is due to a contaminant in the water, then this is not a herbicide.

Since the *number* of species of invertebrate is *not* correlated with inflows it also seems possible that many of the more common invertebrates may be able to tolerate the pollutants or can recolonise rapidly after a pollution event.

The positive correlation between invertebrate rarity and both groundwater and floodwater sources may be in part a simple corollary of the relationship between surfacewater and invertebrate rarity. However, the relationship between floodwater and both aquatic plant species numbers and invertebrate species-richness and rarity is likely to reflect, at least partly, the richness of many of the floodplain ponds in the data set (see Section 2.2.6). This may in turn reflect the paucity of undrained (or incompletely drained) floodplain in Britain, i.e., rare habitats are likely to support rare species.

Table 4.5 Water Source

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		**Inverts**	**Plants**		**Inverts**
	Aquatic	Emergent		Aquatic	Emergent	
Inflow (presence /absence)	ns	ns	ns	ns	ns	-
Inflow volume	ns	ns	ns	ns	ns	---
Inflow volume/water volume (turnover)	ns	ns	ns	ns	ns	--
Water source - ditch	ns	-	ns	ns	ns	-
Water source - flood	+	ns	++	++	ns	+++
Water source - groundwater	ns	ns	ns	ns	ns	+

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.7 Water chemistry

A number of water chemistry parameters had significant relationships with invertebrate rarity. In particular, ponds with high conductivity, alkalinity and sulphate levels tended to have a relatively low proportion of uncommon species. There is a weak negative correlation between nitrate and invertebrate rarity, though this is not quite significant. There were few other significant correlations except for a relatively weak, negative relationship between alkalinity and aquatic plant numbers.

Table 4.6 Water Chemistry - 1989/1990 Correlations (34 Ponds)

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts (89/90)	Plants		Inverts (89/90)
	Aquatic	Emergent		Aquatic	Emergent	
Sulphate	ns	ns	ns	ns	ns	-
Alkalinity	-	ns	ns	ns	ns	--
Conductivity	ns	ns	ns	ns	ns	--

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

The correlations between water chemistry determinands and invertebrate rarity may be due to an effect of the ions *per se*, or to correlations with other pollutants such as biocides or intensive agricultural practices (see Section 4.2.6). It should be noted that the database is drawn from an area with broadly similar geology and with no marine influence. If the area of study had been geographically wider, and included ponds on harder rocks than those found in Oxfordshire, then only nitrate could be reliably thought of as indicating high agricultural activity.

The data from the 1988 study allows a comparison of invertebrate species-richness and SRI within a much larger database (127 ponds), including a larger percentage of sites in disturbed landuse than were present in the 34-pond data set. The correlations show the same basic trend as those for the 1989/90 data set with increasing dissolved solutes being negatively correlated with SRI. The main difference is that correlations are stronger for conductivity and nitrate is also significant. Interestingly, nitrate also correlates with the *number* of invertebrate species as well as their rarity. The correlation with sulphate, seen in the 1989/90 data set, is no longer statistically significant.

There is a positive correlation between chloride and species-richness which was not seen in the 1989/90 data set. High chloride levels are often associated with road runoff (not likely in this case) and also with a decreasing proportion of groundwater. Neither of these would appear to explain the correlation here.

Table 4.7 Water Chemistry - 1988 Correlations (127 Ponds)

	NUMBER OF SPECIES	SPECIES RARITY INDEX
	Invertebrates (88)	Invertebrates (88).
Alkalinity	ns	--
Conductivity	ns	-----
Nitrate	-	---
Chloride	+++	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.8 Landuse

Plant conservation parameters showed some fairly consistent correlations with landuse. In particular, there were positive relationships between the SRI, the amount of unimproved grassland and, to some extent, fen, marsh and bog in the surrounds. The total amount of semi-natural landuse was also correlated with species numbers.

There were also negative relationships between the presence of disturbed land, particularly improved grassland, and various conservation parameters.

Interestingly, there was usually a greater correlation between land 25m and 100m from the ponds than in theimmediate surrounds (5m). This may suggest that buffer zones around ponds need to be wider than the 5-10m generally suggested.

Table 4.8 Landuse

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts	Plants		Inverts
	Aquatic	Emergent		Aquatic	Emergent	
Pond area	+	++	ns	ns	ns	ns
Fen, marsh and bog - 25m	ns	ns	+	+++	+	+
Fen, marsh and bog - total	ns	ns	ns	+	ns	ns
Unimproved grassland - 5m	ns	ns	+	ns	ns	ns
Unimproved grassland - 25m	ns	ns	ns	++	ns	ns
Unimproved grassland - 100m	ns	ns	++	+	ns	+++
Unimproved grassland - total	ns	ns	+	++	+	+
Semi-natural - 5m	ns	ns	+	+	ns	ns
Semi-natural - 25m	ns	ns	+	ns	ns	ns
Semi-natural - 100m	ns	ns	+	ns	ns	+
Semi-natural - total	ns	ns	+	ns	ns	+
Improved grassland -5m	ns	ns	-	ns	ns	ns
Improved grassland - 25m	ns	ns	ns	-	ns	ns
Improved grassland - 100m	ns	-	ns	-	-	ns
Improved grassland - total	ns	-	ns	ns	ns	ns
Urban and roads - 25m	ns	ns	-	ns	ns	ns
Urban and roads - 100m	ns	ns	-	ns	ns	ns
Urban and roads - total	ns	ns	-	ns	ns	ns
Disturbed land - 5m	ns	ns	-	ns	ns	ns
Disturbed land - 25m	ns	ns	-	ns	ns	-
Disturbed land - 100m	ns	-	-	ns	ns	-
Disturbed land Total	ns	ns	-	ns	ns	-

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

As with the results from the plant data, the invertebrate species-richness and SRI of a site are positively correlated with aspects of semi-natural landuse in the vicinity, the corollary being true for disturbed landuse The presence of unimproved grassland in the vicinity (to 100m) of the pond appears to be particularly important. There are insufficient ponds on other semi-natural landuse types in the data set to satisfactorily estimate the importance of these landuse types around ponds. Species-richness shows the same pattern as SRI, though species-richness is correlated more often with various aspects of landuse.

The correlation between landuse type and conservation value is probably due to two interacting factors. Firstly, semi-natural landuse around ponds, and waterbodies in general, can 'buffer' them against harmful impacts such as fertiliser and pesticide runoff. These results are broadly in keeping with the results from the chemical data (see previous section). Secondly, many aquatic invertebrates have a terrestrial stage during their life-cycle, either as adults (e.g., dragonflies), larvae (e.g., some of the hydrophilid water beetles) or pupae (e.g., most of the diving beetles). It is notable that the species-richness of the beetle fauna is highly correlated with the presence of unimproved grassland around ponds.

4.3.9 Legal designation and statutory protection of sites

There was a poor correlation between plant species numbers and rarity and their protection as a SSSI or LNR. This implies that many of the best sites for plants do not enjoy statutory protection and that many sites in nature reserves have low quality plant communities.

The 1989/90 data show that ponds on SSSIs or LNRs have higher invertebrate SRIs than those which do not enjoy this level of protection. It is noticeable that, if only SSSI designation is considered, this correlation is much weaker. The results illustrate the valuable contribution made by LNRs to the protection of pond faunas. Despite the high correlation seen here, there are still many ponds of high conservation value which enjoy no form of protection. This is discussed more fully with respect to the 1988 data. The 1988 data set allows an analysis of conservation value and land designation for a much greater number of sites.

Table 4.9 Legal Designation and Statutory Protection of Sites - 1989/1990 Correlates

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts (89/90)	Plants		Inverts (89/90)
	Aquatic	Emergent		Aquatic	Emergent	
SSSI	ns	ns	ns	ns	ns	+
SSSI+LNR	ns	ns	ns	ns	ns	++++

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

It might not seem unreasonable to expect that the best ponds in the county would be found on SSSIs and LNRs. However, SSSIs and LNRs are rarely designated for the ponds that are present. When ponds are present on SSSIs it is often a coincidence, in that they are associated with some other feature of ecological interest. At best, the pond may be mentioned in a SSSI citation as a feature contributing to the mosaic of the site.

The correlations between protected landuse and invertebrate species-richness and species rarity are highly significant. We can, therefore, rule out the possibility that ponds on protected land are no better than other sites in the county. It seems that they are significantly better. It is interesting to note that the correlation with species-richness is much higher than with species rarity. It might appear, therefore, that whilst many good ponds are being protected by the system, there is a bias against protecting sites with high conservation value but low species-richness. In Oxfordshire this might indicate a bias against protecting *naturally* species-poor temporary sites.

Table 4.10 Land Designation and Statutory Protection of Sites - 1988 Correlates

	NUMBER OF SPECIES Inverts	SPECIES RARITY INDEX Inverts
SSSI	++++++	+++
SSSI/LNR	++++++	+++

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

Figure 4.1 is a histogram of the percentage of sites which are on protected land in, first, the best (in terms of SRI) 10% of ponds; then in the next best 10%; and so on. As can be seen from the graph, whilst there is a distinct tendency for the better ponds to be on SSSIs, there are a considerable number of ponds of high conservation value which enjoy no form of protection at all.

Using a provisional system for assessing conservation value of ponds (see Appendix 6) and applying this to the 1988 data (Table 4.11), it can be seen that a high percentage of ponds with macroinvertebrate communities in the high and very high conservation categories are not on SSSIs or LNRs.

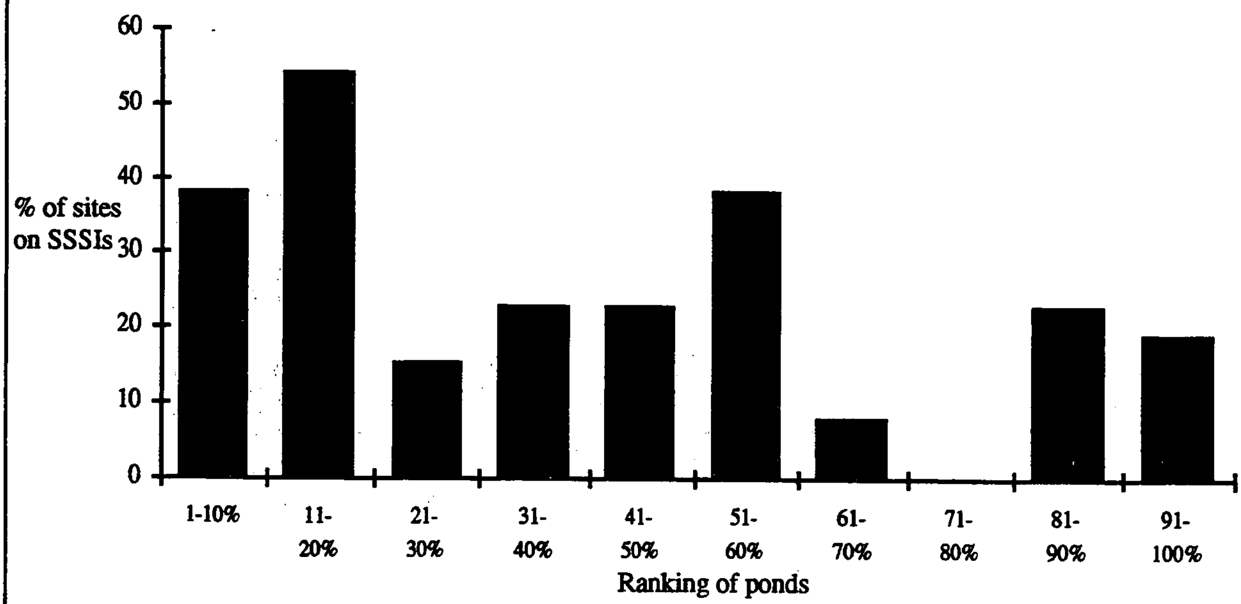


Figure 4.1 Ranking of Ponds on SSSIs in Oxfordshire

Table 4.11 Relationship between Conservation Category and the Statutory Protection of Sites

Conservation category of invertebrate community	Number of ponds	% of ponds on SSSIs/LNRs
Very high	8	63
High	21	38
Moderate	66	20
Low	38	16

4.3.10 Wetland plant cover

There was a general tendency for ponds with a larger area of vegetation to support more plant species. This was particularly notable for aquatic plants.

It was notable that it was only the physical *area* of plant cover that was important for plant conservation. *Percentage* cover showed no ranked correlations with either species-richness or rarity.

There was a weak correlation between area of submerged cover and number of species of invertebrate. This was perhaps a reflection of the increased number of plant species associated with a high area of submerged plant cover.

Table 4.12 Percentage of Pond Covered by Wetland Plants

	NUMBER OF SPECIES			SPECIES RARITY INDEX		
	Plants		Inverts	Plants		Inverts
	Aquatic	Emergent		Aquatic	Emergent	
Area of submerged cover	+	++	+	ns	+++	ns
Area of floating cover	+	ns	ns	ns	ns	ns
Area of total emergent cover	++++	ns	ns	ns	ns	ns
Area of pond total cover	+++	+++	ns	ns	+	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

4.3.11 Invertebrates and plants

Plant number and rarity

There was a positive relationship between the number of plant species and their average rarity, indicating that the highest quality sites were often both species-rich and supported uncommon species, whereas poor sites were often dominated by relatively few common species. This is probably not an area effect because large sites did not have more rare species.

Table 4.13 Invertebrate and Plant Correlations

	NUMBER OF SPECIES				SPECIES RARITY INDEX			
	Plants			Inverts	Plants			Inverts
	Total	Aquatic	Emergent		Total	Aquatic	Emergent	
Total wetland plant spp.	X	++++++	++++++	+++++	+++	+++	++++	++
No. of aquatic plant spp.	++++++	X	+	+++++	++	+	+	ns
No. of emergent plant spp.	++++++	+	X	+++	+	++	++	+++
No. of invertebrate spp.	+++++	+++++	+++	X	+	ns	ns	+
SRI - total wetland plants	+++	++	+	+	X	+++++	++++++	+
SRI - aquatic plants	+++	+	++	ns	+++++	X	++++	+
SRI - emergent plants	++++	+	++	ns	++++++	++++	X	ns
SRI - invertebrates	++	ns	+++	+	+	+	ns	X

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

Macroinvertebrate number and rarity

There was a positive, though weak, correlation between invertebrate richness and rarity, suggesting that species-poor communities tend to be low in terms of conservation value. It should be noted, however, that not all the ponds in the survey were in pristine condition, and that many of the species-poor communities were degraded rather than being naturally species-poor.

There was a strong positive relationship between the richness of invertebrate species at each pond and the number of plant species. There was also a positive correlation between invertebrate species-richness and plant SRI, though this was not as strong.

Invertebrate SRI correlated well with both the number of total plant species and the number of emergent species. The principal predictor of invertebrate SRI would appear to be the number of emergent plant species. There were also correlations, though not as strong, with the SRI of the whole plant community and the aquatic plant community. It would appear, therefore, that the best sites for invertebrates would be those with a diverse emergent plant community and a high quality aquatic plant community.

4.3.12 Invertebrate indices

The invertebrate indices BMWP (Biological Monitoring Working Party) score and ASPT (Average Score Per Taxon) are widely used in river water quality analysis, and there are a considerable number of workers who have the taxonomic knowledge to derive such indices relatively quickly. ASPT is believed to reflect the amount of dissolved oxygen in the water, making it ideal as a test of river water which is naturally relatively well saturated, but not for pond water which may be naturally quite low in oxygen.

The results of the correlations show the same relationship between plants and invertebrates as were seen previously (numbers of species, families, orders and BMWP are well correlated). The results suggest that there is a weak relationship between ASPT and macroinvertebrate species-richness, *but not with SRI*. This is a good indication that the low levels of oxygen found in ponds are not an anathema to conservation as is sometimes suggested, and that river water quality indices should not be used in assessing pond conservation value.

Table 4.14 Invertebrate Indices

	NUMBER OF SPECIES				SPECIES RARITY INDEX			
	Plants			Inverts	Plants			Inverts
	Total	Aquatic	Emergent		Total	Aquatic	Emergent	
No. of orders	ns	+++	ns	++	ns	ns	ns	ns
No. of families	+	++	ns	++++++	ns	ns	ns	ns
No. of species	+++++	+++++	+++	X	+	ns	ns	+
BMWP score	+	+	ns	+++++	ns	ns	ns	ns
ASPT	ns	ns	ns	+	ns	ns	ns	ns

+ = positive correlation, - = negative correlation, ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Correlations have been adjusted for ties.

CHAPTER 5

CLASSIFICATION OF POND WILDLIFE COMMUNITIES

5.1 Introduction

This chapter describes the results of ordination analyses of the plant and invertebrate communities of the main 34 ponds.

The methods for classification were TWINSPAN (Two Way INdicator SPecies ANalysis) and DECORANA (DEtrended CORrespondence ANAlysis). DECORANA axes were correlated with environmental variables using Spearman's Rank Correlation, and TWINSPAN end groups were correlated with environmental variables using a Mann-Whitney U test or Kruskal-Wallis analysis of variance by ranks. These correlations were used to elucidate the environmental factors which were important in helping to shape the wildlife communities (Sections 5.2 to 5.5). Appendix 5 gives a more detailed account of the ordination and statistical techniques used and their application to the OPS.

Three separate TWINSPAN and DECORANA analyses were performed:

Section 5.2: Aquatic plant communities
Section 5.3: Marginal plant communities
Section 5.4: Macroinvertebrate communities

5.2 Aquatic plant communities

5.2.1 DECORANA of aquatic plant communities

Figure 5.1 shows the results of the DECORANA analyses and Table 5.1 shows those environmental factors which correlated with the DECORANA analyses.

Both axes were primarily related to landuse and associated correlations with water quality and enrichment.
The right hand side of axis 1 was dominated by alkaline fen aquatic communities, predominantly with a limestone water source. These communites had relatively low DOME scores, suggesting low enrichment and nutrient status.

The ponds on the left-hand side of axis 1 were more likely to be located in areas of disturbed landuse. They were generally more turbid, and were more likely to be located in clay catchments. This was linked with a higher proportion of the aquatic plants being floating-leaved species and also with higher DOME scores. It is possible that the DOME scores may be related to turbidity rather than to nutrient status.

Axis 2 was less strongly correlated with environmental variables than Axis 1, but the axes show the same general trends. The top of axis 2 was strongly associated with grazing and unimproved grassland in the near vicinity. This was also linked with high numbers of aquatic and marginal plant species

Sites at the top of the axis show a positive association with lower DOME scores (i.e., less enriched water), a greater number of wetland plant species, and fewer floating-leaved species. Ponds at the bottom of axis 2 often had a ditch water source, perhaps explaining the high DOME scores and more enriched water.

5.2.2 TWINSPAN of aquatic plant communities

Figure 5.2 shows the classification derived from this analysis and Figure 5.3 shows the TWINSPAN groups plotted on the DECORANA axes. Table 5.1 shows those environmental parameters which were significantly associated with each of the TWINSPAN end groups.

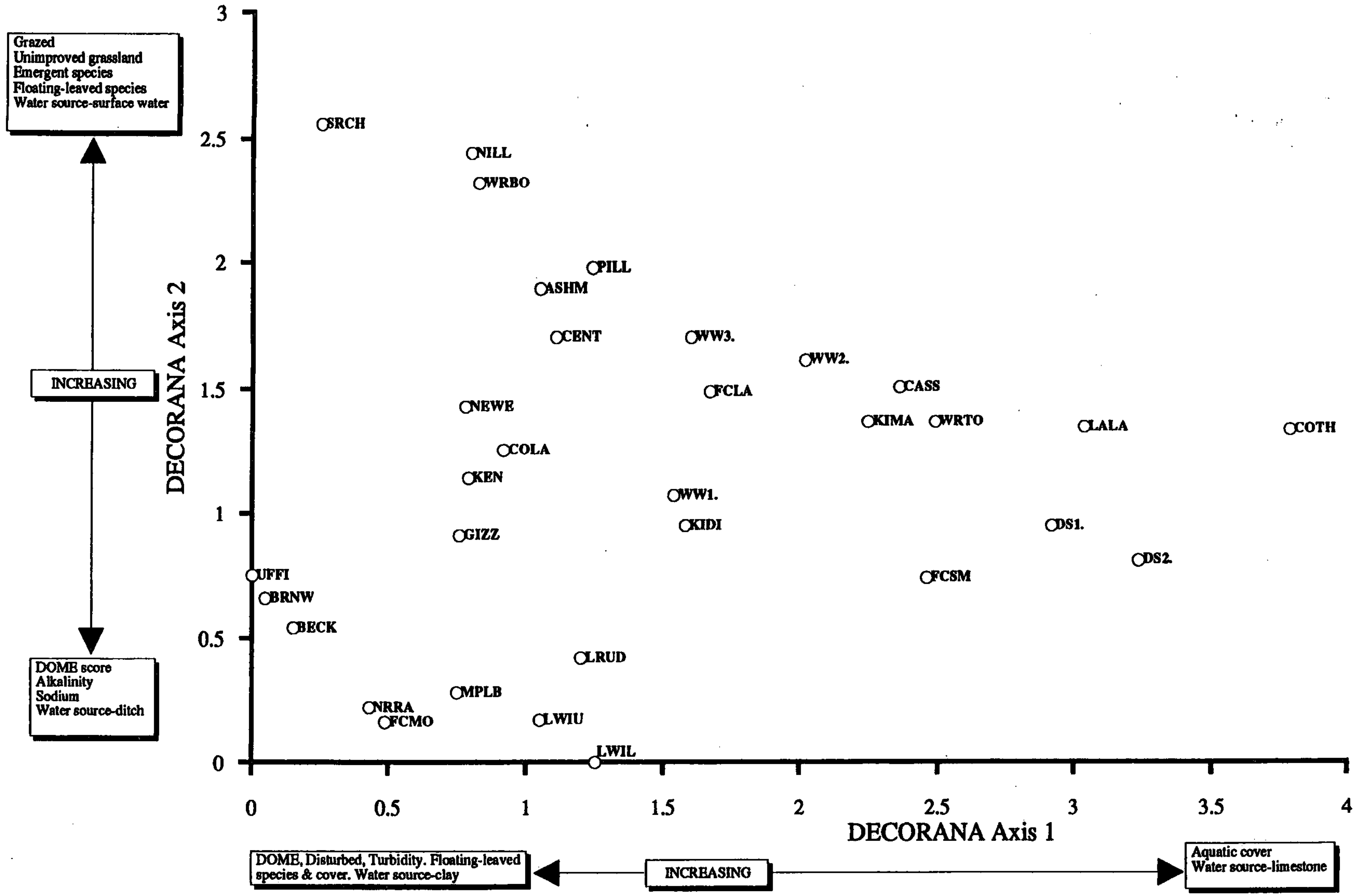


Figure 5.1 DECORANA Ordination of Aquatic Plant Communities

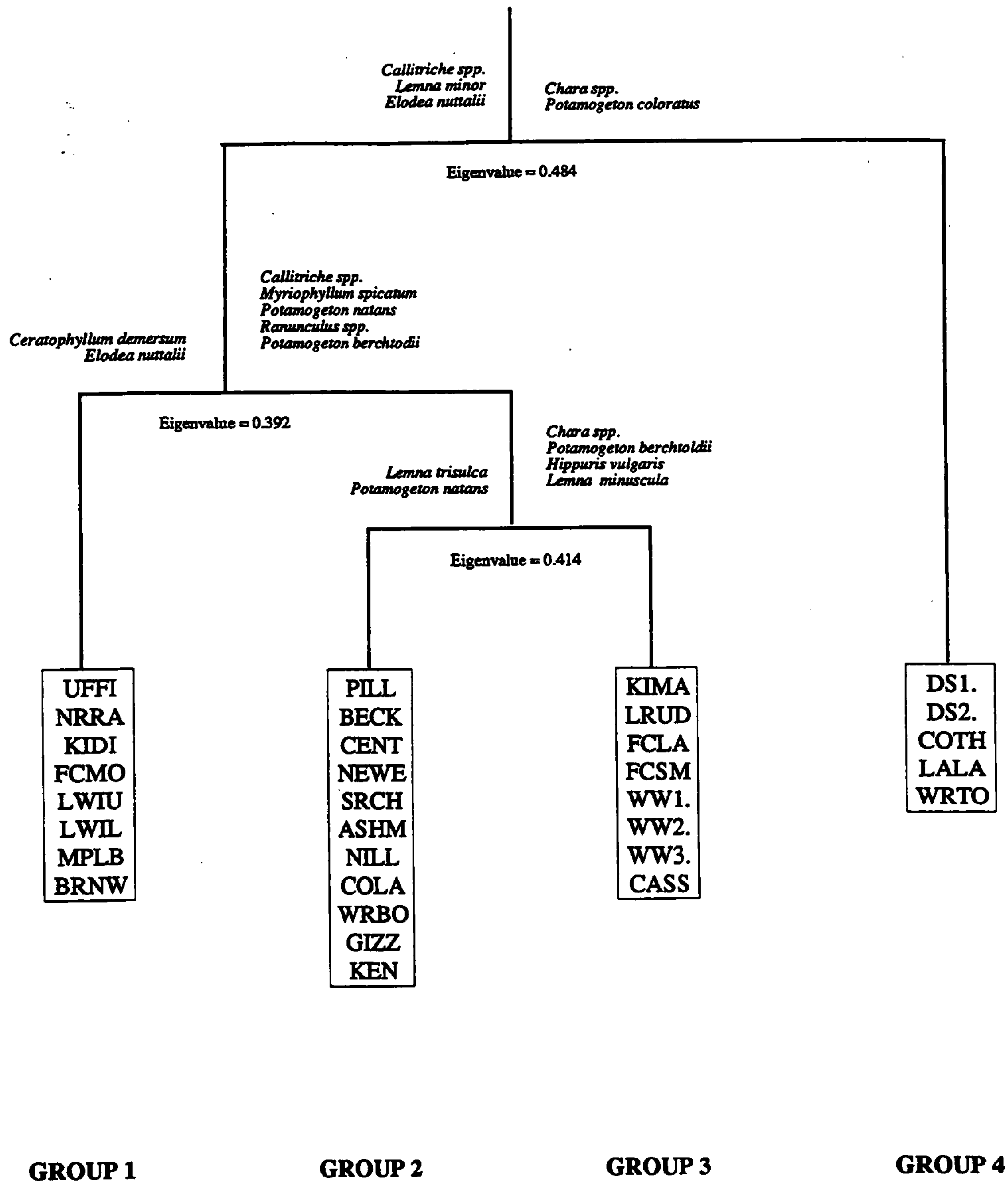


Figure 5.2 TWINSPAN Dendrogram of Aquatic Plant Communities (32 Sites)

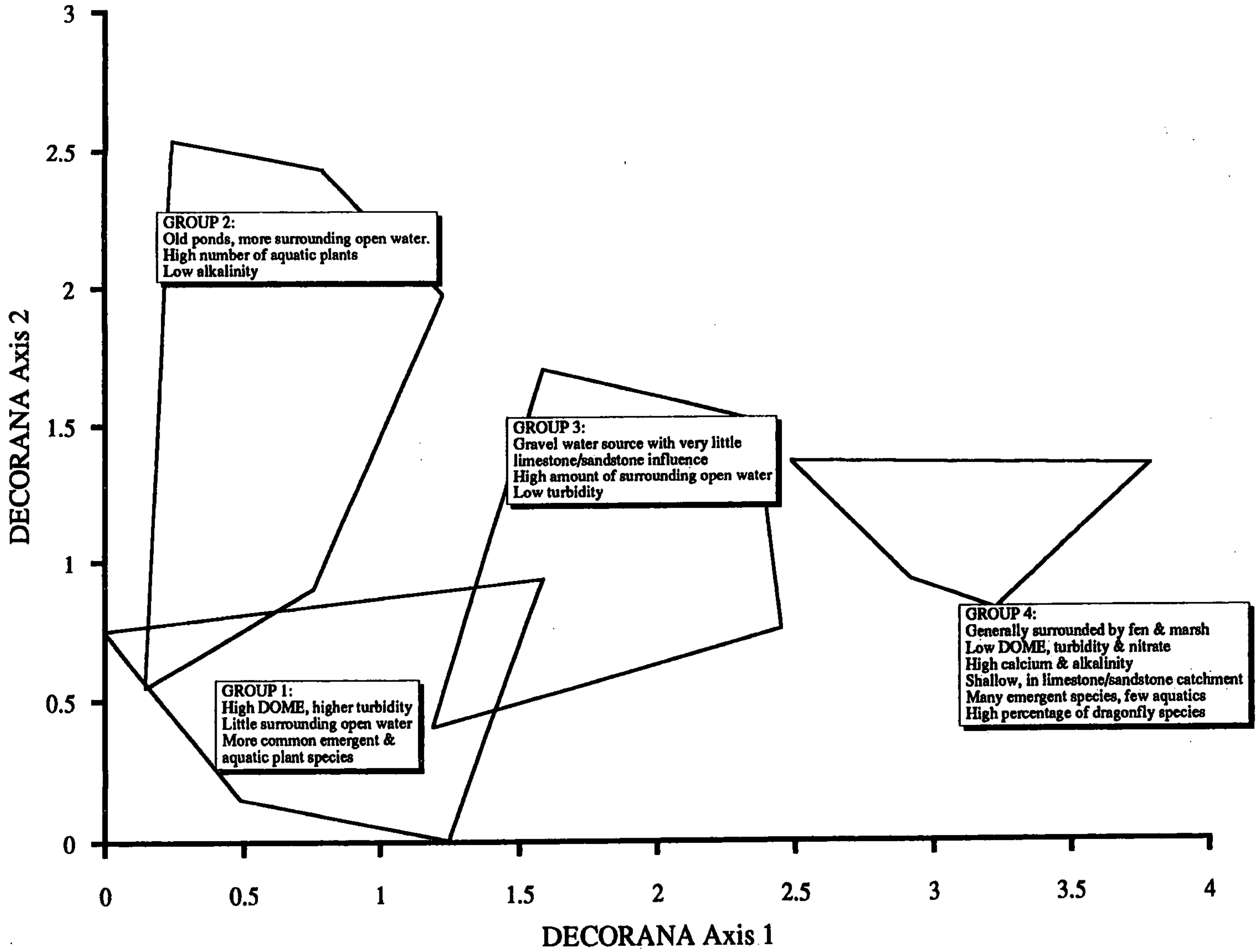


Figure 5.3 DECORANA Ordination of Aquatic Plant Communities Showing TWINSPAN End-groups

Table 5.1 Aquatic Plant DECORANA and TWINSPAN Correlates

	Axis 1 SR	Axis 2 SR	All gps K-W	Gp 1 MW-U	Gp 2 MW-U	Gp 3 MW-U	Gp 4 MW-U
Pond depth							
Maximum water depth	ns	ns	ns	ns	ns	ns	-
Mean water depth	ns	ns	ns	ns	ns	ns	-
Water source							
Water source: ditch	ns	-	ns	ns	ns	ns	ns
Water source: surface	ns	+	ns	ns	ns	ns	ns
Geology							
Surrounding geology-sandstone	ns	ns	•	ns	ns	--	+
Surrounding geology-limestone	ns	ns	•••	ns	ns	--	+++
Surrounding geology-clay	ns	ns	•	ns	ns	ns	--
Surrounding geology-gravel			ns	ns	ns	+	ns
Geol. main water source-limestone	+	ns	ns	ns	ns	ns	+
Geol. main water source-clay	-	ns	ns	ns	ns	ns	ns
Geol. main water source-gravel	ns	ns	ns	ns	ns	+	ns
Geol. all water sources-limestone	+	ns	ns	ns	ns	ns	+
Geol. all water sources-clay	-	ns	ns	ns	ns	ns	ns
Geol. all water sources-gravel	ns	ns	ns	ns	ns	+	ns
Chemistry							
Calcium	ns	ns	ns	ns	ns	ns	+
Sodium	ns	-	ns	ns	ns	ns	ns
Nitrate	ns	ns	ns	ns	ns	ns	-
Alkalinity	ns	-	ns	ns	-	ns	+
Miscellaneous							
DOME	——	——	••••••	++++++	ns	ns	---
Age	ns	ns	•	ns	+++	ns	ns
Grazed	ns	+++	ns	ns	ns	ns	ns
Turbidity-dw	————	ns	•••	+	ns	-	-
Biological turbidity	-	ns	ns	ns	ns	ns	ns
Land use							
SSSI	ns	ns	ns	ns	ns	ns	+
Coniferous woodland-25m	ns	ns	ns	ns	ns	ns	+
Coniferous woodland-100m	ns	ns	ns	ns	ns	ns	+
Scrub-100m	+	ns	•	ns	ns	ns	+++
Scrub-total	ns	ns	ns	ns	ns	ns	ns
Fen, marsh and bog-100m	+++	ns	•••	ns	ns	ns	++++
Fen, marsh and bog-total	+	ns	•	ns	ns	ns	+++
Unimproved grassland - 5m	ns	+	ns	ns	ns	ns	ns
Total ponds and lakes	ns	ns	ns	ns	-	+	ns

(cont.)

Table 5.1 (contd)

	Axis 1 SR	Axis 2 SR	All gps K-W	Gp 1 MW-U	Gp 2 MW-U	Gp 3 MW-U	Gp 4 MW-U
Landuse (contd)							
Parks and gardens-5m	-	ns	ns	ns	+	ns	ns
Parks and gardens-25m	--	ns	ns	ns	ns	ns	ns
Parks and gardens-100m	-	ns	ns	ns	ns	ns	ns
Parks and gardens-total	--	ns	ns	ns	ns	ns	ns
Urban and roads 25m	---	ns	ns	ns	ns	ns	ns
Urban and roads-total	-	ns	ns	ns	ns	ns	-
Disturbed land - 25m	ns	ns	ns	ns	ns	ns	-
Disturbed land - 100m	-	ns	ns	ns	ns	ns	ns
Area of surrounding wetlands							
Ponds and lakes-250m	ns	ns	•	ns	ns	++	ns
Ponds and lakes-500m	ns	+	••	-	+	ns	ns
Ponds and lakes-total	ns	ns	•	ns	ns	+	-
Rivers-500m	ns	ns	ns	ns	ns	+	ns
Rivers-total	ns	ns	ns	ns	ns	+	ns
Fen marsh and bog-10m	++	ns	••••	ns	ns	ns	++++++
Fen marsh and bog-250m	+++	ns	••••	ns	ns	ns	++++++
Fen marsh and bog-total	+++	ns	••••	ns	ns	ns	++++++
Plant cover							
% pond floating cover	-	ns	ns	ns	ns	ns	-
Species richness							
No. of floating plants	-	+	ns	ns	ns	ns	ns
No. of aquatic plants	ns	ns	•••	ns	++	ns	ns
No. of emergent plants	ns	+	ns	ns	ns	ns	ns
No. of all plants	ns	++	ns	ns	ns	ns	ns
% aquatic plant species	ns	ns	•	ns	ns	ns	--
% emergent plant species	ns	ns	•	ns	ns	ns	++
No. aquatic spp./pond area	ns	ns	ns	ns	ns	ns	-
No. of isopod species	ns	ns	ns	ns	ns	+	ns
No. of stonefly species	ns	ns	ns	ns	-	ns	ns
No of dragonfly species	+	ns	ns	ns	ns	ns	ns
No of caddisfly species	+	ns	ns	ns	ns	ns	ns
Presence of alderflies	ns	ns	•	---	ns	ns	ns
% of stonefly species	ns	ns	ns	ns	-	ns	ns
% of dragonfly species	+	ns	ns	ns	ns	ns	+
Species rarity							
Regional index of emergent plants	ns	ns	ns	-	ns	ns	ns
Regional index of aquatic plants	ns	ns	ns	-	ns	ns	ns

+ = positive correlation, - = negative correlation, • overall significance (Kruskal-Wallis), ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Probabilities from: SR - Spearman's rank correlation, MW-U - Mann-Whitney-U test, KW - Kruskal-Wallis test. Correlations have been adjusted for ties.

There are four groups, based mainly on a combination of water source and DOME scores.

Group 4 are clean fen ponds associated with limestone and peat geologies. These ponds had high alkalinity with low levels of nitrate, low turbidity and low DOME scores. They were often relatively shallow, often on SSSIs and with little floating plant cover. Ponds in group 4 tended to have large numbers of emergent species and fewer aquatic plant species. This group was separated from the other three groups which tended to be in clay or gravel catchments and which were often more disturbed, with more eutrophic aquatic plant assemblages.

Group 3 ponds, like those of group 4, tended to have low turbidity, but had a predominantly gravel water source rather than a limestone/sandstone water source. Sites in group 3 tended to be in areas with much open water (other ponds and lakes) nearby.

Group 2 ponds were more heterogenous with respect to water sources and geology. The group was characterised by older ponds with high numbers of aquatic plant species. Like ponds in group 3, they tended to be in areas with relatively high numbers of other ponds and lakes.

Ponds in group 1 were most dissimilar to those in group 4, with high DOME scores and relatively high turbidity. Unlike groups 2 and 3 these sites tended to be rather isolated from other ponds and lakes. These sites also appeared to be rather poor in terms of species rarity with communities of both aquatic and emergent species comprised mainly of common species.

5.3 Emergent plant communities

5.3.1 DECORANA of emergent plant communities

Figure 5.4 shows the results of the DECORANA analyses and Table 5.2 shows those environmental factors which correlated with the DECORANA analyses.

Axis 1 relates primarily to landuse and shade, with open habitats such as grassland and fen at the right-hand side of the axis and more shaded woodland ponds at the left-hand end. Ponds on the right of the axis were generally groundwater-fed and the wooded ponds on the left-hand side were more usually stream-fed. This latter water source category was, in turn, linked with higher nitrate levels (see Section 2.2.6). Ponds on the right-hand side of the axis tended to be younger than those on the left-hand side.

The groundwater ponds on grassland or fen were generally of higher quality, with more wetland species and a higher proportion of local or notable species. They also supported dragonfly and mayfly species.

Axis 2 again mainly relates to woodland and shade, with ponds at the top of the axis more wooded and overhung and often in areas of limestone. The less wooded and shaded ponds at the bottom of the axis were more likely to be in gravel or clay areas. These ponds typically had a much more extensive cover of emergent plants, and more species of plant for a given area of pond. They were also likely to support more mayfly species.

5.3.2 TWINSPAN of emergent plant communities

Figure 5.5 shows the classification derived from this analysis and Figure 5.6 shows the TWINSPAN groups plotted on the DECORANA axes. Table 5.2 shows those environmental parameters which were significantly associated with each of the TWINSPAN end groups.

Three distinct groups of ponds were apparent from this analysis. Group 1 ponds were heavily wooded and shaded. They were mainly stream-fed and in limestone catchments, though with a clay base. Many of these sites were stocked fish ponds, situated above the floodplain. They tended to have a smaller cover of emergent plants, often restricted to a fringe around the edge.

Group 2 ponds were small and shallow, with little sediment and low shading. Many of these were in areas with a geology of clay. Many of the sites had been recently disturbed by man, that is, they were either new or had been recently managed. These ponds were particularly associated with arable, and, to a lesser extent, unimproved grassland, often with a large number of ditches in the vicinity. Many had a high percentage of emergent plant cover, and they tended to be relatively rich in aquatic and emergent plants for their area. Group 3 is a rather a poorly-defined group. These ponds are more associated with fen than the other two groups, generally groundwater-fed and often in gravel bedrock. These ponds were often of high quality for their aquatic plant flora with higher numbers of macroinvertebrates than the other groups, particularly dragonflies and water bugs.

Table 5.2 Emergent Plant DECORANA and TWINSPAN Correlates

	Axis 1 SR	Axis 2 SR	All K-W	Gp1 MW-U	Gp2 MW-U	Gp3 MW-U
Pond size						
Pond circumference	ns	ns	ns	ns	-	ns
Index of shore complexity	ns	ns	•	ns	++	ns
Sediment volume	ns	ns	•	ns	—	ns
Pond volume	ns	ns	•	ns	-	ns
Pond depth						
Mean total depth	ns	ns	•	ns	-	ns
Maximum sediment depth	ns	ns	ns	ns	-	ns
Mean sediment depth	ns	ns	ns	ns	-	ns
Shade						
Pond area overhung	ns	+++	ns	ns	ns	ns
% of pond area overhung	—	ns	••	+	ns	ns
% of pond margin overhung	—	ns	ns	+	ns	ns
Water source						
Water source: inflow present	—	ns	ns	ns	ns	ns
Water source: inflow volume	—	ns	ns	ns	ns	-
Inflow vol./water volume (turnover)	ns	ns	ns	ns	ns	-
Water source: stream	-	ns	•	+	ns	ns
Water source: surfacewater	ns	+	ns	ns	ns	ns
Water source: groundwater	+++	ns	ns	-	ns	ns
Geology						
Pond base geology-gravel	ns	ns	•	-	ns	+
Pond base geology-clay	ns	ns	••	++	ns	—
Surrounding geology-sandstone	ns	+	ns	ns	ns	ns
Surrounding geology-gravel	ns	-	ns	-	ns	ns
Surrounding geology-limestone	ns	+++	•	+	-	ns
Surrounding geology-clay	ns	—	•	-	++	ns
Geol. main water source-gravel	+	ns	•	-	ns	+
Geol. main water source-limestone	ns	ns	ns	+	ns	ns
Geol. main water source-clay	-	ns	ns	ns	ns	ns
Geol. all water sources-sandstone	ns	ns	ns	+	ns	ns
Geol. all water sources-gravel	++	ns	•	-	ns	+
Geol. all water sources-limestone	ns	ns	ns	+	-	ns
Geol. all water sources-clay	-	ns	ns	ns	ns	-
Chemistry						
Magnesium	-	-	ns	-	+	ns
Sodium	ns	-	•	—	+	ns
Nitrate	-	ns	ns	ns	ns	ns
pH	ns	ns	ns	ns	+	ns

(cont.)

Table 5.2 (cont.)

	Axis 1 SR	Axis 2 SR	All K-W	Gp1 MW-U	Gp2 MW-U	Gp3 MW-U
Management						
Disturbance	ns	ns	ns	ns	+	ns
Fish stocked	ns	ns	•	++	—	ns
Miscellaneous						
Altitude	ns	+	•	+++	-	ns
Pond age	-	ns	ns	ns	ns	ns
Land use						
LNR	ns	+	ns	ns	ns	ns
Deciduous woodland-5m	-	+++	•	++	ns	ns
Deciduous woodland-25m	ns	++++	••••••	++++++	—	-
Deciduous woodland-100m	-	++++	••••••	++++++	—	ns
Deciduous woodland-total	-	+++	••••	++++++	-	ns
Coniferous woodland-25m	ns	ns	ns	ns	ns	+
Wood and scrub-5m	ns	ns	•	+++	-	ns
Wood and scrub-25m	ns	ns	••••	++++++	—	ns
Wood and scrub-100m	ns	+	•••	++++	—	ns
Wood and scrub-total	ns	ns	•••	+++	-	ns
Fen, marsh and bog-5m	ns	ns	ns	-	ns	ns
Fen, marsh and bog-25m	++	ns	•	-	ns	+
Fen, marsh and bog-100m	+	ns	ns	ns	ns	ns
Fen, marsh and bog-total	+	ns	•	-	ns	ns
Unimproved grassland - 5m	ns	-	ns	ns	+	ns
Unimproved grassland - 100m	+++	ns	ns	ns	ns	ns
Unimproved grassland - total	+	ns	ns	ns	ns	ns
Arable-100m	ns	ns	•	ns	+	ns
Arable-total	ns	ns	•	ns	+	ns
Parks and gardens-25m	ns	ns	ns	+	ns	ns
Urban-25m	ns	+	ns	ns	ns	ns
Urban-100m	ns	ns	ns	ns	ns	+
Disturbed land - 100m	-	ns	ns	ns	ns	ns
Area of surrounding wetlands						
Ponds and lakes-10m	ns	+	ns	ns	ns	ns
Rivers-10m	-	ns	ns	ns	ns	ns
Ditches-250m	ns	ns	•	-	+	ns
Ditches-500m	ns	-	•••	—	++++	ns
Ditches-total	ns	-	•••	——	++++	ns

(cont.)

Table 5.2 (cont.)

	Axis 1 SR	Axis 2 SR	All K-W	Gp1 MW-U	Gp2 MW-U	Gp3 MW-U
Area of surrounding wetlands (contd)						
Fen, marsh and bog-10m	+	ns	ns	ns	ns	+
Fen, marsh and bog-250m	+	ns	ns	ns	ns	ns
Fen, marsh and bog-total	+	ns	ns	ns	ns	+
Plant cover						
% pond emergent cover	ns	—	•••	—	+++	ns
% pond total cover	ns	-	••	-	+++	ns
Species richness						
No. of emergent plant species	+	ns	ns	ns	ns	ns
No. of all wetland plant species	+	ns	ns	ns	ns	ns
No. of aquatic plants/pond area	ns	-	•	ns	+	ns
No. of emergent plants/pond area	ns	-	ns	ns	+	ns
No. all wetland plants/pond area	ns	ns	•	ns	+	ns
Number of isopod species	ns	-	•	-	+	ns
Number of crustacean species	ns	ns	•	-	+	ns
Presence of water spiders			ns	ns	ns	+
Number of beetle species	ns	-	ns	ns	ns	ns
Number of flatworm species	-	ns	ns	ns	ns	ns
Number of dragonfly species	+++	ns	•	ns	ns	++
Number of mayfly species	++	ns	ns	ns	ns	ns
Number of waterbug species	++	ns	ns	ns	ns	+
Number of caddisfly species	ns	ns	ns	ns	-	ns
No. of macroinvertebrate species	+	ns	ns	ns	ns	+
% amphipod species	-	ns	•	ns	+	ns
% isopod species	-	ns	•	ns	+	ns
% mayfly species	-	ns	•	ns	+	ns
% dragonfly species	+	ns	•	ns	ns	++
% caddisfly species	ns	ns	ns	ns	-	ns
Species rarity						
Rarity index of aquatic plants	+	ns	•	ns	ns	+++
Rarity index of all wetland plants	+	ns	ns	ns	ns	ns
Rarity index of macroinvertebrates	+	ns	ns	ns	ns	ns
TWINSPAN and DECORANA						
Axis 1 aquatic plants	+	ns	ns	ns	ns	ns
Axis 1 macroinvertebrates	ns	ns	ns	ns	+	ns
Axis 2 macroinvertebrates	ns	ns	•	ns	+	-

+ = positive correlation, - = negative correlation, • overall significance (Kruskal-Wallis), ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Probabilities from: SR - Spearman's rank correlation, MW-U - Mann-Whitney-U test, KW - Kruskal-Wallis test.
Correlations have been adjusted for ties.

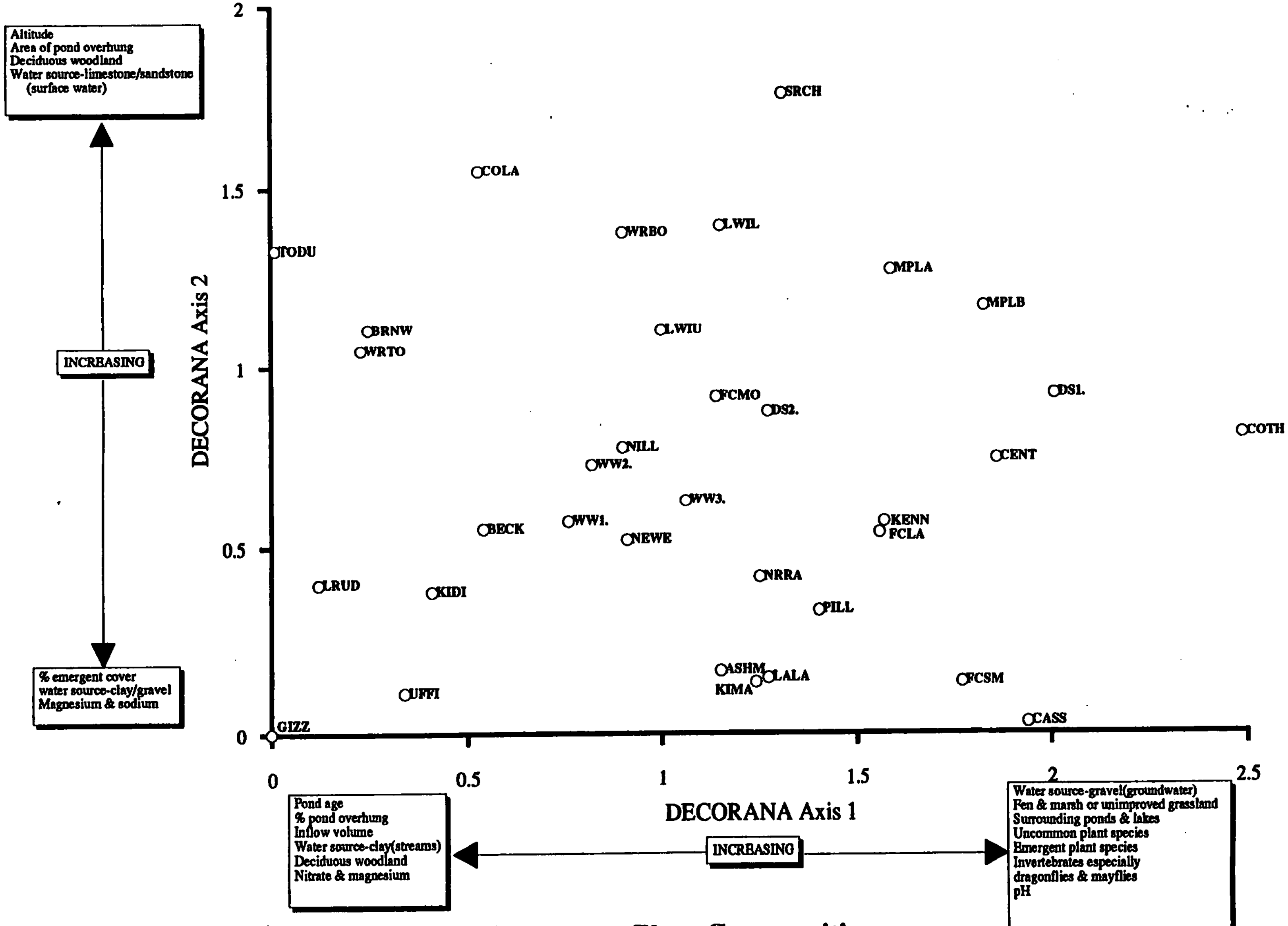


Figure 5.4 DECORANA Ordination of Emergent Plant Communities

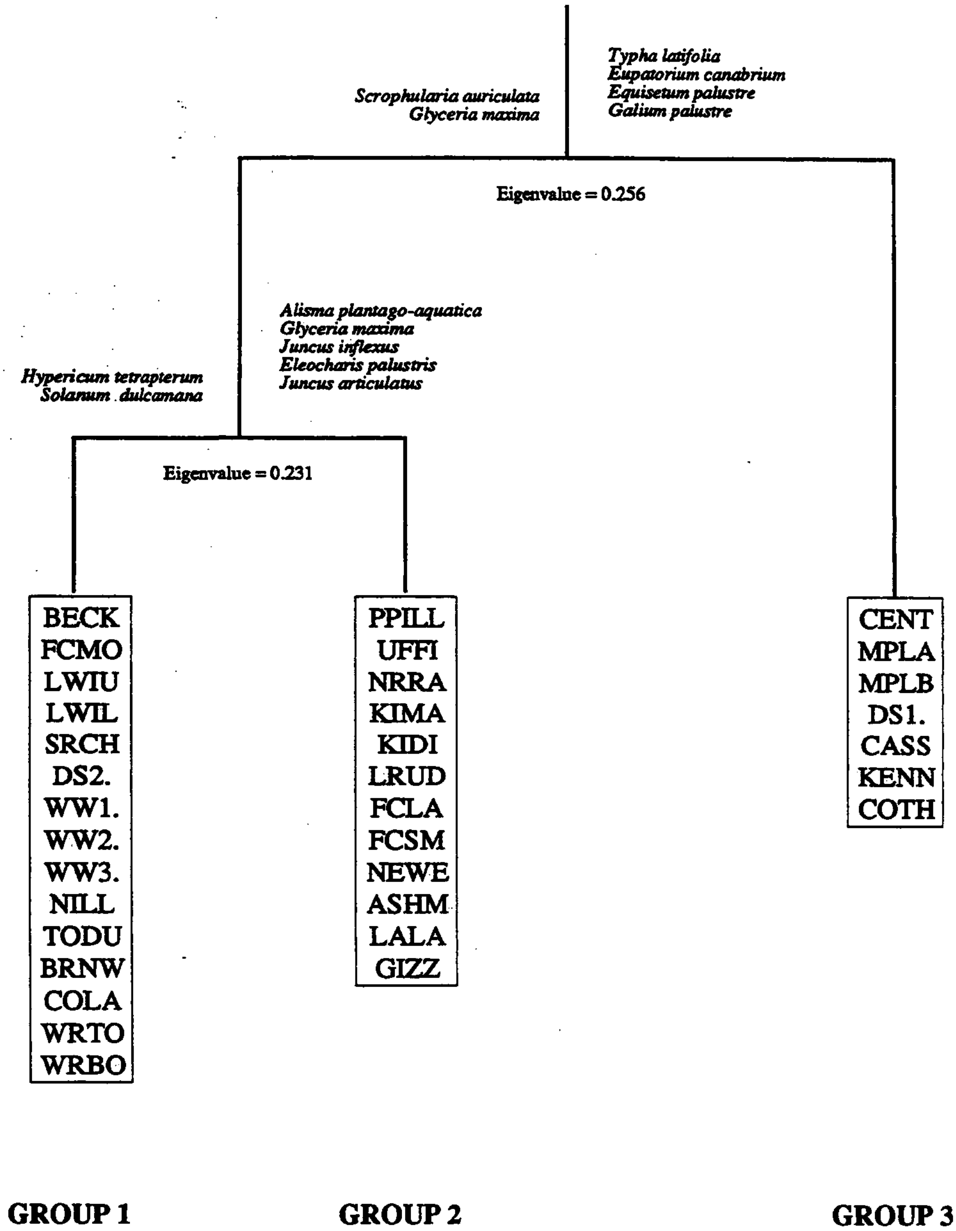


Figure 5.5 TWINSPAN Dendrogram of Emergent Plant Communities (34 Sites)

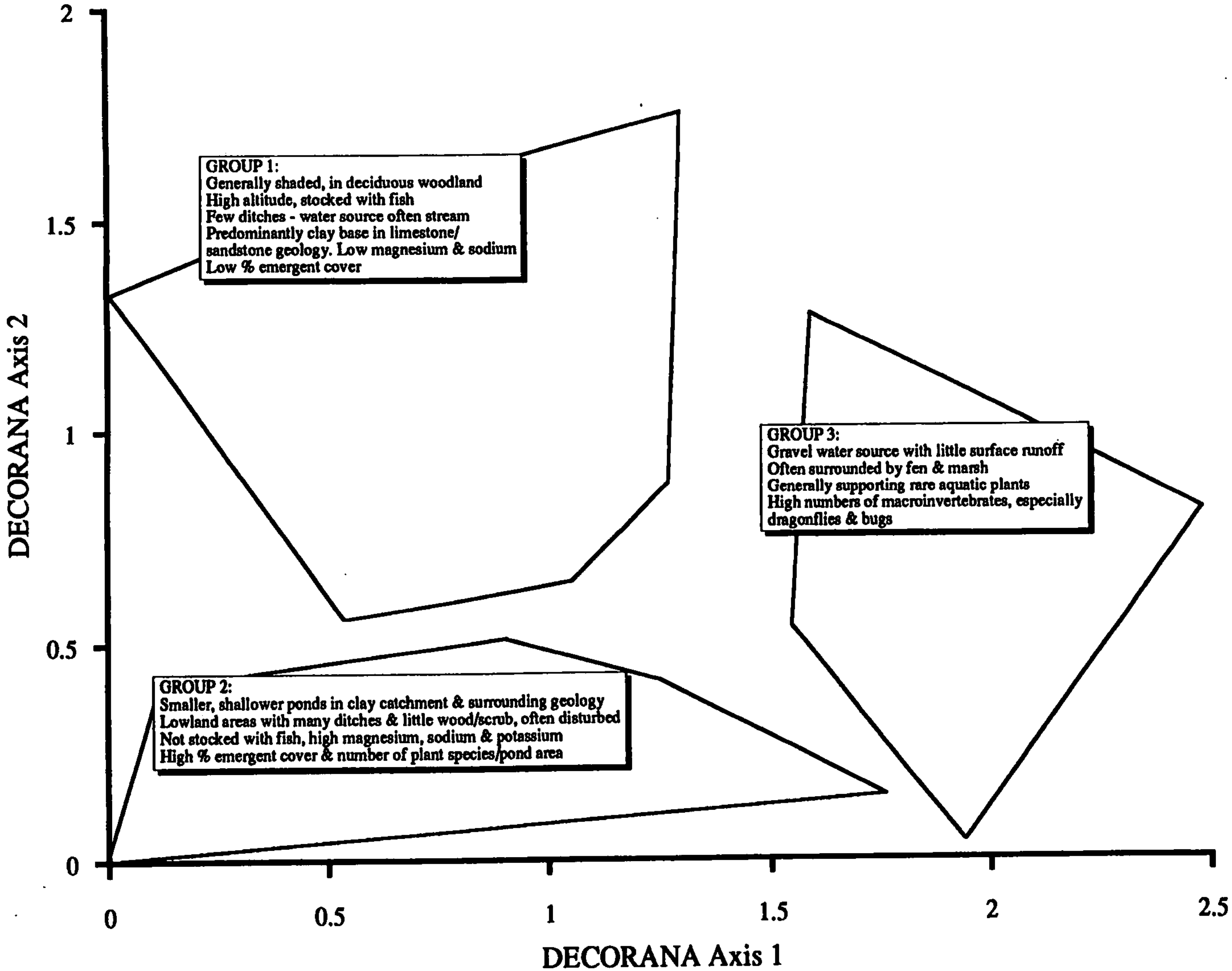


Figure 5.6 DECORANA Ordination of Emergent Plant Communities Showing TWINSPAN End-groups

5.4 Macroinvertebrate communities

Species lists and abundances from replicate sample number 1 from the 1989 season and the sample from the 1990 season were combined and analysed using TWINSPAN and DECORANA. The rationale behind using the classification shown here is given in Appendix 3, Section A3.3.

DECORANA is the most suitable technique for elucidating the principal environmental parameters which shape communities. The DECORANA axes represent the variation in community structure within a database and, as such, need no further analysis. It is often informative, however, to correlate the axes with community factors such as the proportions of beetle species in the samples in order to gain a better understanding of the way in which communities differ. The axes of DECORANA will first be considered in terms of the environmental factors which correlate with them and the types of community change which they represent (e.g., proportion of snail species in samples). The TWINSPAN end groups will then be discussed in relation to the results from DECORANA, the type of invertebrate communities which the groups represent, types of site which the groups represent and the species of invertebrate which are indicative of the groups.

5.4.1 DECORANA of macroinvertebrate communities

Figure 5.7 shows the results of the DECORANA analyses and Table 5.3 shows those environmental factors which correlated with the DECORANA analyses. Figure 5.7 also shows the relationship of the axes to community composition and environmental variables.

Axis 1

Axis 1 explains approximately 47% of the variation in macroinvertebrate community structure which is explained by the first four axes of DECORANA combined.

The environmental parameter which correlates (negatively) most strongly with axis 1 is the permanence of the water. This parameter alone explains 45% of the variation on axis 1. Water permanence was, however, judged subjectively and so the results should be considered in relation to the other environmental parameters correlating with the axis.

The next most strongly negatively correlated parameters are the depth of the site and whether or not it is stocked with fish, both features which correlate strongly with permanence. Size, as judged by area, is weakly correlated with axis 1, presumably because of the strong correlation between depth and size. Large, shallow ponds are uncommon in Oxfordshire; the one large shallow pond in the survey, in fact, comes out on the right-hand side of axis 1, further suggesting that depth or permanence is the principal environmental factor.

Also correlating strongly and negatively with the first axis are the presence of stream inflows, altitude, area of ponds and lakes nearby, and a limestone geology. All these environmental parameters are typical of many large, deep valley fishponds in the county which are above the main Thames flood plain and often in series (hence the correlation with pond and lake area). Area of deciduous woodland and the presence of roads near the ponds also correlate negatively with the first axis. Deciduous woodland is more prevalent in areas above the flood plain in Oxfordshire, and the presence of roads near the ponds is likely to be connected with the fact that many of the larger ponds are stocked and have access roads running around them.

A clay geology, grazing and turbidity all correlate positively with axis 1. These are features associated with many ponds on flood plain (not all of which still floods) in the county. Many of these ponds are field ponds which are prone to drying out.

Magnesium and sodium ion concentrations are positively correlated with axis 1. This may relate to the clay geology or, possibly, to a concentration effect of the processes of drying out. pH is negatively correlated with axis 1. All the 34 ponds surveyed are alkaline or circumneutral. Several of the ponds on the right-hand side of the axis are fed by water draining from unimproved grassland. This water is likely to be more ombrogenous in character than that draining from ploughed land or that present in streams, and hence more likely to have a low pH. Drying out of the

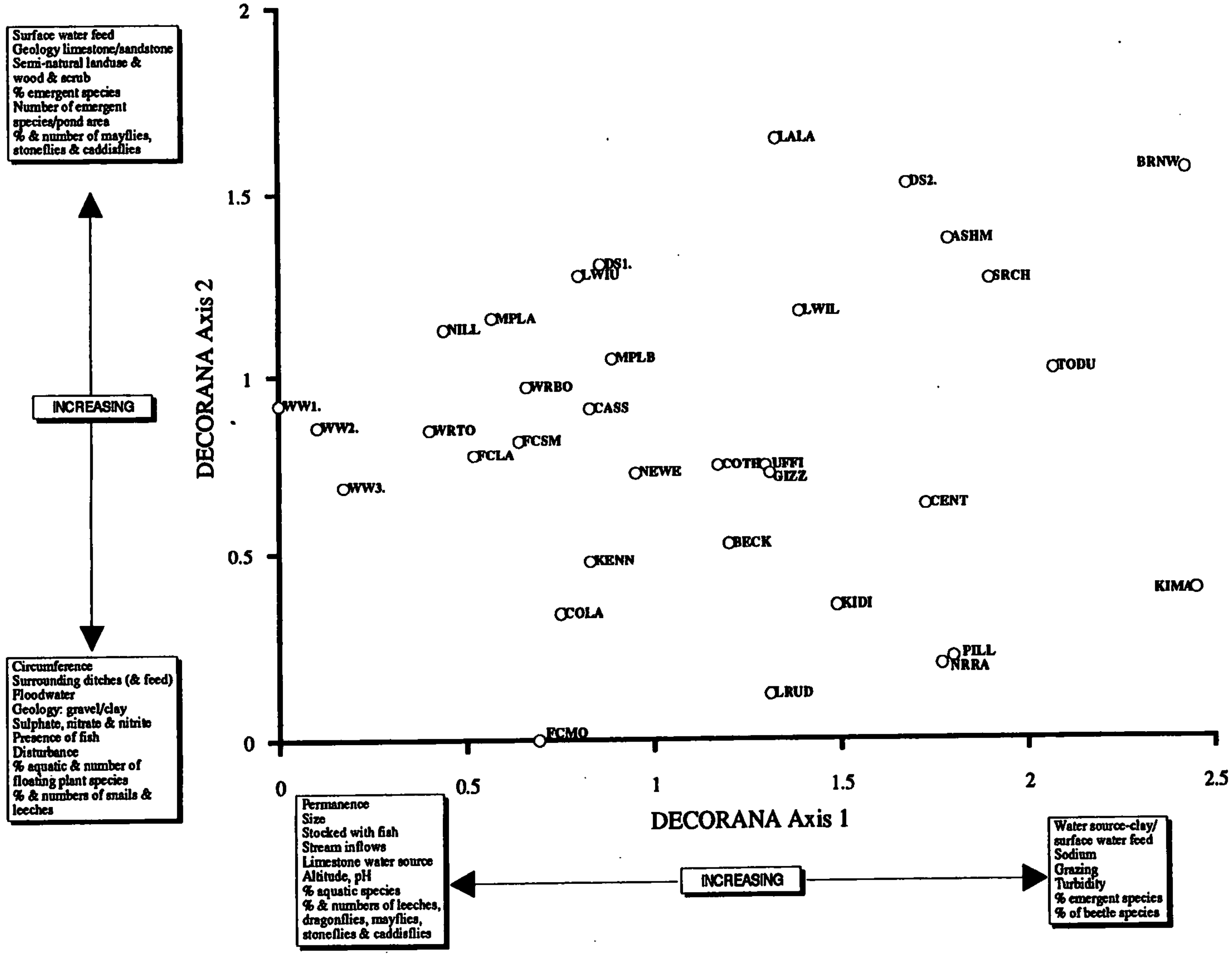


Figure 5.7 DECORANA Ordination of Macroinvertebrate Communities (89.1 & 90.1 Combined)

ponds on the right-hand side of the axis is also likely to affect the pH of their water, as drying out leads to oxidation of sediments and the production of acidity.

Not surprisingly, given the relative depths of the ponds, there is also a correlation of the axis with various floristic features. The axis is negatively correlated with the percentage of aquatic species present and positively correlated with the percent of emergent species present: i.e., as the ponds become shallower, the aquatic species make less of a contribution to species-richness and the emergent species a greater contribution. The number of emergent plant species and the total number of species is also positively correlated wth the axis. This is due to the greater range of conditions created in sites which either dry out or which are shallow and have gently sloping margins.

If we wished to choose two ponds in Oxfordshire which had very different invertebrate communities, therefore, we should pick one large, permanent, valley fishpond with steeply shelving banks and one small, shallow temporary pond with a shallow bank profile and hence a good number of wetland plant species for its size.

The numbers and percentages of all the major groups in the samples (e.g., percentage of leech species) were correlated against the DECORANA axes. Those groups which were significantly correlated are shown in Tables 5.3 and Figure 5.7.

The total number of species is correlated with axis 1. Ponds on the left-hand side of the axis have greater species-richness than those on the right-hand side of the axis. Presumably, the deeper, more permanent sites have a greater variety of habitats than the the smaller, less permanent sites. It should be recognised that many of the larger sites will have areas of less temporary water which may provide suitable habitat for animals more normally associated with more temporary sites.

The most strongly positively-correlated group is the beetles. The proportion of beetle species is much higher in the smaller, more temporary sites on the right-hand side of the DECORANA axis than on the left. Water beetles are noted for their preference for shallow margins and drydown zones and many are adapted to a life cycle in temporary water. In addition, in temporary waters a large percentage of the species found will simply be strong fliers which are using the site as a food resource and not necessarily breeding there. Many species of water beetle are known to fly quite widely. The actual number of beetle species (rather than the proportion of beetle species), however, is not correlated with axis 1, suggesting that the beetles dominate the fauna of the more temporary sites on the right-hand side of the axis, as many other species are excluded from this type of habitat.

The next most strongly correlated group were the caddisflies (negatively with axis 1). The large permanent ponds would appear to be the sites with the largest numbers and proportion of caddis species. This result should be treated with a certain amount of caution since the caddisflies of more seasonal sites may well have emerged before surveying took place at the smaller sites. It would certainly be true to say that very few caddisfly species are found late in the season in the smaller, more temporary sites.

The mayflies and dragonflies are also strongly negatively correlated with axis 1 (both in terms of numbers of species and percentage of the fauna) These groups appear to favour the deeper, more permanent sites. Many dragonflies take more than one year to complete their lifecycle and so the preference for permanent water is not surprising. Also of significance may be the fact that deeper sites, especially those with steep banks, tend to maintain some areas of relatively inorganic substrate which is favoured by some species of dragonflies and mayflies. For example, the two mayflies of the genus *Ephemera* which were recorded during the survey are only found, in still water, in gravels.

Less well negatively correlated with axis 1 are the leeches. Their preference for the more permanent sites is probably a consequence of their inability to colonise new and disturbed sites as rapidly as other groups.

Thus, axis 1 would appear to represent a change from the caddisfly, mayfly, dragonfly and leech-rich communities of larger permanent ponds, to the communities of smaller, shallower, less permanent ponds with a high proportion of beetle species.

Axis 2

Axis 2 represents the second major variation in community structure in the OPS dataset. The eigenvalues of axes 1 and 2 suggest that this secondary variation in community structure is 51% as important as that illustrated by the first axis, and that axis 2 explains 24% of the variation in community stucture which is interpreted by the first four axes combined. Correlations of environmental parameters with axis 2 are listed in Table 5.3 and these correlations are summarised in Figure 5.7.

The bottom of the axis correlates with the ponds' close proximity to ditches, with many having ditch inflows. A surrounding geology of clays and gravels is also correlated with the bottom of the axis, as well as (less strongly) floodwater contributing to the hydrology. Ponds near the bottom of the axis, therefore, are likely to be on floodplain. Most of these ponds will be in areas of more intensive landuse (near to and fed by ditches), though a few will be in areas of less intensive landuse (fed by floodwater). The predominance of sites in areas of high intensity landuse is reflected in the correlation between the bottom of the axis and disturbed landuse around the ponds, and also with various chemical parameters including nitrate, nitrite and sulphate, which are themselves indicative of intensive agriculture.

Ponds at the bottom of the axis tend to have fish and a larger percentage of both aquatic and floating plant species than those at the top of the axis. This may reflect the floodwater and ditch influence on the sites, as even the less permanent ponds will be able to recolonise rapidly due to their direct connection to other waterbodies.

Ponds at the top of the axis are characterised by limestone and sandstone geologies and the associated dominance of semi-natural scrub and deciduous woodland.

The axis, therefore, appeared to separate ponds on the basis of their being *either* on the floodplain in areas with ditches or which flood periodically (the bottom of the axis), *or* above the floodpain and more isolated.

In terms of the faunistic character of the ponds, the axis is most strongly correlated (negatively) with the numbers and proportion of snail species present. The ponds at the bottom of the axis which tend to have permanent or temporary connections with other water bodies have far greater numbers of snail species than those at the top of the axis. The presence of connections, therefore, seems to outweigh the effects of permanence, as sites on the left of axis 1 do not have, on average, greater numbers of snail species than the more temporary sites on the right-hand side of the axis. The strong association of leech species with the bottom of the axis is presumably caused by similar considerations.

Percentage (and, to a lesser extent, numbers) of caddisfly species are positively correlated with axis 2. Caddisfly faunas of ditches are never particularly rich (M Drake, pers. comm.) though the reason for this is not clear. Many caddisflies do have a life history which is adapted to temporary water, though this is not indicated by the first axis of this analysis. Possibly, caddisflies are particularly susceptible to fish predation and are not suited to temporary sites which refill with either floodwater or water from ditches, both of which are potential sources of fish colonisation.

Axis 3

Axis 3 represents the third major variation in community structure in the OPS dataset. The eigenvalues of axes 1, 2 and 3 suggest that this tertiary variation in community structure is 34% as important as that illustrated by the first axis, and explains 16% of the variation which is described by the first four axes. Correlations of environmental parameters with axis 3 are listed in Table 5.3.

It will be noted that there are few environmental parameters which correlate strongly with axis 3. This is to be expected as it represents less of the variation within the data set.

The environmental parameter correlating most strongly (negatively) with the axis is the presence of ducks. Also negatively correlated with the axis is a surrounding landuse with a high percentage of improved grassland. Water sources for ponds at the negative end of the axis appear to be groundwater, usually from a geology of gravels. The negative end of the axis, therefore, appears to represent rather disturbed still water sites.

The positive end of the axis is most strongly correlated with a sandstone geology and semi-natural landuse. Associated with these characteristics is a tendency to be on SSSIs or LNRs. Sites at this end of the axis also tend to have large amounts of silt present. The axis would, therefore, appear to represent a change from anthropogenically disturbed conditions (ducks, improved grassland) to semi-natural conditions. That neither invertebrate nor plant rarity indices correlate with this axis is perhaps due to the larger amounts of silt, which are also associated with the semi-natural end of the axis.

Four animal groups are correlated with axis 3. The most strongly (and negatively) correlated is the percentage of bugs found. Many aquatic bugs fly widely and, like the beetles, can rapidly colonise sites which have recently been disturbed. Though prone to predation by ducks, they may, nevertheless, benefit from the large amounts of algae which tend to flourish where ducks are present. Less strongly, and positively, correlated with the axis are the numbers of snail and leech species and the percentage of amphipod species. These may reflect the less disturbed nature of these sites since they are slowly colonising species which would take a considerable time to gain a foothold following disturbance.

5.4.2 TWINSPAN of macroinvertebrate communities

Figure 5.8 shows the classification derived from this analysis and Figure 5.9 shows the TWINSPAN groups plotted on the DECORANA axes. Table 5.3 shows those environmental parameters which were significantly associated with each of the TWINSPAN end groups.

The divisions of TWINSPAN

The following discussion considers how the initial set of 34 sites is broken down by TWINSPAN into the final four groups and the invertebrate species which are chosen to classify the groups.

The first division

The first division of TWINSPAN follows axis 1 of DECORANA, groups 3 and 4 are on the right hand of the axis, and groups 1 and 2 on the left. The indicator for the left division (groups 1 and 2) is the Blue-tipped Damselfly, *Ischnura elegans*. Indicator species are those which are most likely to be found in one group of ponds but not another. In this case the indicator is, in fact, not *Ischnura elegans* but *Ischnura elegans* in numbers; i.e., it is possible to find the species in groups 3 and 4 (in fact, seven sites in groups 3 and 4 supported this species), but in none of these sites was more than five individuals recorded in the two combined samples. The indicator species for the right-hand side of the division is a hydrophilid water beetle, *Helophorus grandis*, a species of shallow and often temporary water bodies.

Other species which are highly indicative of this division include the Common Blue Damselfly, *Enallagma cyathigerum*, present in 14 sites in groups 1 and 2, and only two sites in groups 3 and 4; and a small caddisfly, *Athripsodes aterrimus*, which was present in 13 sites in groups 1 and 2, and two sites in groups 3 and 4. Both these two species are characteristic of more permanent waters. Several beetles are indicative of groups 3 and 4, including a diving beetle, *Colymbetes fuscus*, which was recorded from 10 sites in groups 3 and 4 and no sites in groups 1 and 2.

That beetles are indicative of the right and dragonflies and caddisflies of the left side of the dendrogram is in accordance with the findings from the DECORANA analyses with respect to both animal communities and environmental variables, i.e., groups 1 and 2 represent more permanent and deeper water bodies than those of groups 3 and 4.

The second division (groups 1 and 2)

The left-hand arm of the dendrogram divides into two groups (1 and 2) of ponds. There is only one indicator species for this division, a haliplid water beetle, *Haliplus wehnckei*. As with *Ischnura elegans* in the first division, *Haliplus wehnckei* is only indicative when found in numbers. This lack of more indicators for the division might suggest that there is not a large amount of difference in invertebrate communities between these two groups. Nevertheless, the

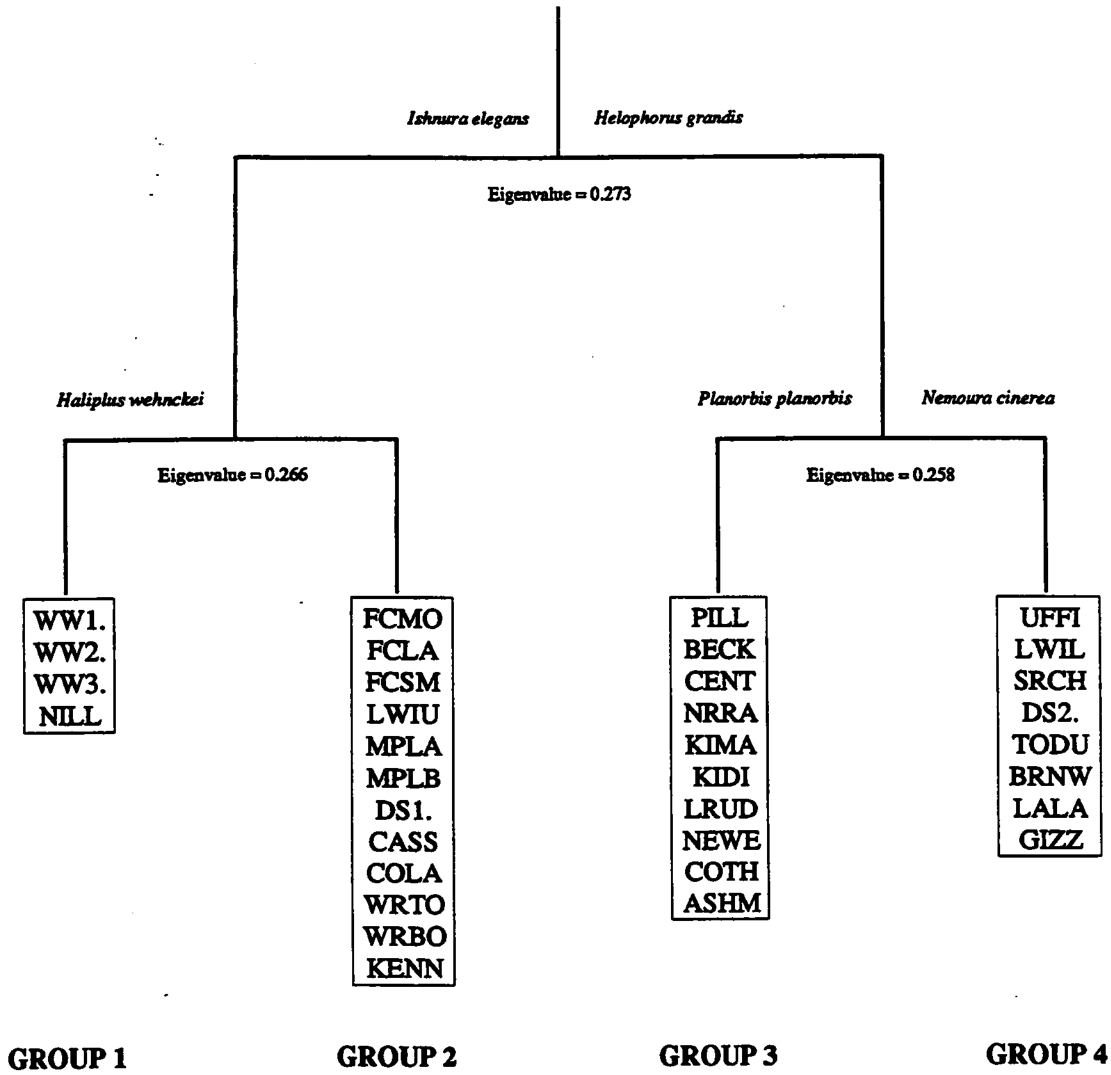


Figure 5.8 TWINSPAN Dendrogram of Macroinvertebrate Communities (34 Sites: Samples from 89.1 & 90.1 Combined)

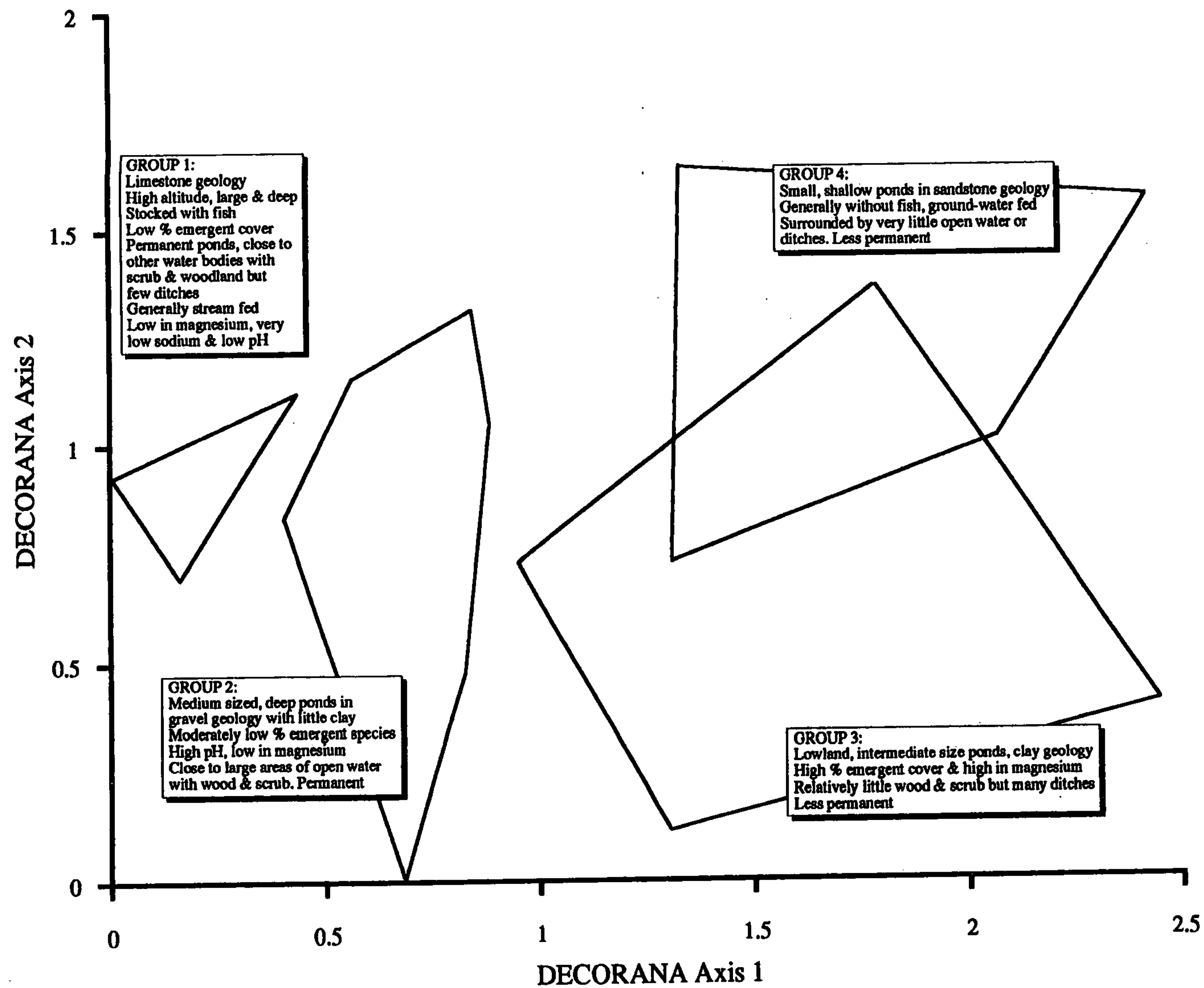


Figure 5.9 DECORANA Ordination of Macroinvertebrate Communities Showing TWINSPAN End-groups (89.1 & 90.1 Combined)

groups are well separated on the DECORANA axes and the eigenvalue for the division (a measure of its significance) is quite high (0.266).

The second division (Groups 3 and 4)

The right-hand arm of the dendrogram divides into two groups (3 and 4) of ponds. The indicator for the left-hand side of the division is the Ramshorn, *Planorbis planorbis*, a species assocated with more permanent stagnant water. The indicator for the right-hand side of the division is a stonefly, *Nemoura cinerea*. Another ramshorn snail, *Bathyomphalus contortus*, is also quite indicative of the left-hand side of the division (group 3), as are several other snail species. Group 4 appears to be a rather heterogenous group in terms of species composition, the indicator species (*Nemoura cinerea*) being present in only four of the six sites.

The final four groups

Classifications can be taken down until there is only one site in each group. This is obviously not a rational strategy as it does not permit comparison of sites within the groups. On the basis of the DECORANA and TWINSPAN analysis of the OPS database, it would seem that there are four fairly recognisable types of pond in the database. This compares with the 10 different types of lake recognised by Palmer in Britain as a whole on the basis of their plant communities (Palmer, 1989), and three or four groups of alkaline ponds recognised by Verdonschodt in the province of Overijssel, Netherlands (Verdonschodt, 1990).

Given the small amount of variation in the acidity of Oxfordshire ponds and the geographic restrictions of this small county, four pond types is a reasonable number on which to base strategic decisions for the conservation of ponds in the county. It allows a reasonable comparison between unknown sites and sites within the database, and allows for a range of different pond types to be selected for protection or monitoring.

Environmental parameters and invertebrate composition

The following sections discuss each group of sites in terms of the environmental parameters and invertebrate compositions associated with it. The environmental parameters and invertebrate compositions which correlate with each of the four groups (Mann-Whitney U test) are given in Table 5.3, and a summary is given in Figure 5.9. Also indicated in the table are those parameters which are of overall significance in the separation of all groups (Kruskal-Wallis test). Broadly speaking, those parameters which are of overall significance will also be correlated with one or more individual groups, whereas parameters which correlate with an individual group need not necessarily be of overall significance in the whole of the analysis.

Group 1

Group 1 is a small group with only four sites included. The two main environmental parameters which separate the group from the other groups are a water source with a limestone geology and the presence of stocked fish. Surrounding landuse tends to be scrub woodland in the immediate vicinity of the ponds with deciduous woodland behind that. The sites tend to be be above the floodplain with discrete stream inflows and with fewer ditches in the surrounding land than other sites in Oxfordshire. Group 1 sites, then, are wooded limestone-vale ponds. All four ponds are rather deep and, as a consequence, all are stocked with fish.

Perhaps because of the small size of the group, only one order, the caddisflies, is particularly associated with this group. Both numbers of caddisfly species and the proportion of the species-richness which they represent are positively associated with group 1.

Group 2

Group 2 sites are characterised by a gravel geology and a relatively high pH. The pond base is also gravel, not clay, unlike many other Oxfordshire ponds. Other features associated with these sites are permanence, a low amount of sediment in comparison to depth, and a surrounding landuse with a relatively high percentage of ponds and lakes. Group 2, then, is a group of permanent ponds with a gravel geology which is often part of a mosaic or chain of pond and lake habitats.

This group has the largest average numbers of invertebrate species of all the four groups, though this is not statistically significant. Particularly associated with this group are a high number and percentage of dragonfly species and a high number of mayfly species. The association of these orders with this group may be a reflection of their preference for inorganic substrates (the index of sediment accumulation for this group is low). The group has a significantly low proportion of beetles as part of the fauna.

The group has a high number of different invertebrate families and a high BMWP score and ASPT. BMWP and ASPT are used in river surveys as indices of organic pollution. Essentially, they (particularly ASPT) measure the oxygen stress of the water (low values indicate high stress). Oxygen stress in rivers is indicative of pollution, but in ponds is quite natural. This group of ponds, therefore, tends to have relatively well oxygenated water, presumably due to a combination of the high throughflow rates associated with gravels, and low sediment accumulation.

Group 3

Group 3 sites are characterised by a clay geology with little limestone or sandstone influence. These sites tend to be at low altititude, often floodplain and, as a consequence, there are many ditches in the surrounding landscape. Also strongly correlated with this group is an extensive cover of emergent plants with only a small amount of submerged plants. Less strongly correlated are magnesium ion concentration (presumably due to the influence of the clay geology), a low amount of deciduous woodland in the vicinity (typical for floodplain), and a low area of ponds and lakes.

Only two invertebrate groups show any correlation with this group of ponds. The stoneflies are negatively correlated (though with only three species in the whole survey, this result should be treated with caution). The number of snail species, as a percentage of the fauna, are correlated with this group. The position of the sites on the floodplain, and the resulting potential for the colonisation of these sites by snails, is the probable explanation for this correlation.

Sites in this group have a significantly lower ASPT than those of other groups, indicating that these groups have high oxygen stress. Most of these sites are on the floodplain and will have little overland throughflow due to the gentle gradient associated with floodplain, and little groundwater throughflow due to the insulating effects of the clay geology.

Group 4

These sites are characterised, principally, by their small size and depth, a lack of fish, and a surrounding geology of sandstone. There is a tendency for these sites to be located in areas of improved grassland with few ditches in the vicinity. There is little emergent cover and there are few plant species, particularly aquatic plant species. However, presumably due to their small size, there is a relatively high number of plant species per unit area of the ponds.

The ponds in this group are significantly species-poor in terms of macroinvertebrates. This is not a reflection of conservation value, which is not correlated with any of the groups. Several groups have very poor representation in this group of sites. These include the snails, leeches, mayflies, dragonflies and bugs. Of these groups, however, only the snails have a low representation in terms of the percentage of the fauna which they represent. The beetles represent a major component of the fauna in this group of sites. These community attributes probably reflect the rather temporary nature of many of these ponds (not significant on its own) allied to a dearth of potential sources for colonisation. Total families and BMWP are low for this group, which simply reflects the species-poor nature of the community rather than oxygen stress (the ASPT value is not similarly low).

Summary

In summary, the main environmental features which separate these groups are geology (limestone, sandstone, gravels or clay), position (on or off the floodplain), and size. Most other environmental variables would appear to be correlated with these three basic features.

Table 5.3 Macroinvertebrate DECORANA and TWINSPAN Correlates

	Axis 1 SR	Axis 2 SR	Axis 3 SR	All K-W	Gp 1 MW-U	Gp 2 MW-U	Gp 3 MW-U	Gp 4 MW-U
Pond size								
Pond area	-	ns	ns	•	ns	ns	ns	—
Pond circumference	-	-	ns	•	ns	ns	ns	—
Maximum dimension	-	-	ns	•	ns	ns	ns	—
Index of shoreline complexity	+	ns	ns	ns	ns	ns	ns	+
Pond volume	ns	ns	ns	•	ns	ns	ns	—
Pond depth								
Maximum total depth	—	ns	ns	•	ns	ns	ns	-
Mean total depth	—	ns	ns	•	ns	ns	ns	-
Maximum water depth	—	ns	ns	••	ns	ns	ns	-
Mean water depth	-	ns	ns	•	ns	ns	ns	-
Maximum sediment depth	ns	ns	+	ns	ns	ns	ns	ns
Mean sediment depth	ns	ns	+	ns	ns	ns	ns	ns
Permanance	———	ns	ns	•	ns	+	ns	ns
Shade								
Pond area overhung	-	ns	ns	ns	ns	ns	ns	ns
Water source								
Water source: inflow present	-	ns	ns	ns	ns	ns	ns	ns
Water source: inflow vol.	-	-	ns	ns	ns	ns	ns	ns
Water source: stream	—	ns	ns	ns	+	ns	ns	ns
Water source: ditch	ns	—	ns	ns	ns	ns	ns	ns
Water source: flood	ns	-	ns	ns	ns	ns	ns	ns
Water source: surface water	+	+	ns	ns	ns	ns	ns	ns
Water source: groundwater	ns	ns	-	ns	-	ns	ns	ns
Geology								
Pond base geology-gravel	ns	ns	ns	•	ns	+++	ns	ns
Pond base geology-clay	ns	ns	ns	•	ns	—	ns	ns
Surrounding geology-sandstone	ns	+++	++	•	ns	ns	-	+++
Surrounding geology-gravel	ns	-	ns	ns	ns	+	ns	ns
Surrounding geology-limestone	ns	+	ns	ns	ns	ns	ns	ns
Surrounding geology-clay	ns	-	ns	ns	ns	ns	+	ns
Geology of main water source-gravel	ns	ns	ns	•	ns	+++	ns	ns
Geology of main water source-limestone	ns	ns	ns	•	++	ns	-	ns
Geology of main water source-clay	ns	ns	ns	•	ns	ns	+++	ns
Geology of all water sources-sandstone	ns	ns	+	•	ns	ns	ns	+
Geology of all water sources-gravel	ns	ns	-	••	ns	++++	ns	ns
Geology of all water sources-limestone	—	ns	ns	•••	+++	ns	—	ns
Geology of all water sources-clay	+	ns	ns	•	ns	-	+++	ns
Chemistry								
Magnesium	+	ns	ns	•	ns	ns	+	ns
Sodium	+++	ns	ns	•	—	ns	ns	ns
Sulphate	ns	—	ns	ns	ns	ns	ns	ns
Nitrate	ns	-	ns	ns	ns	ns	ns	ns
Nitrite	ns	—	ns	ns	ns	ns	ns	ns
pH	-	ns	ns	•	ns	+++	ns	ns

(cont.)

Table 5.3 (cont.)

	Axis 1 SR	Axis 2 SR	Axis 3 SR	All K-W	Gp 1 MW-U	Gp 2 MW-U	Gp 3 MW-U	Gp 4 MW-U
Management								
Grazing	+	ns	ns	ns	ns	ns	ns	ns
Fish present	ns	-	ns	•	ns	ns	ns	—
Fish stocked	——	ns	ns	•••	+++	ns	ns	-
Ducks present	ns	ns	——	ns	ns	ns	ns	ns
Miscellaneous								
Altitude	-	ns	ns	••	+	ns	——	ns
Turbidity	+	ns	ns	ns	ns	ns	ns	ns
Land use								
SSSI	ns	ns	+	ns	ns	ns	ns	ns
SSSI + LNR	ns	ns	+	ns	ns	ns	ns	ns
Deciduous woodland-25m	-	ns	ns	ns	+	ns	ns	ns
Deciduous woodland-100m	ns	ns	ns	ns	+	ns	ns	ns
Deciduous woodland-total	ns	ns	ns	ns	ns	ns	-	ns
Scrub-5m	ns	+	ns	ns	+	ns	ns	ns
Wood and scrub-5m	ns	+	ns	ns	ns	ns	ns	ns
Wood and scrub-25m	ns	+	ns	ns	ns	-	ns	ns
Wood and scrub-100m	ns	+++	ns	ns	ns	ns	ns	ns
Wood and scrub-total	ns	++	ns	•	ns	-	ns	ns
Ponds and lakes-25m	—	ns	ns	ns	ns	ns	ns	ns
Ponds and lakes-100m	-	ns	ns	•	ns	+++	ns	ns
Ponds and lakes-total	-	ns	ns	ns	ns	+	ns	ns
Improved grassland - 5m	ns	ns	—	ns	ns	ns	ns	ns
Improved grassland - 25m	ns	ns	-	ns	ns	ns	ns	-
Improved grassland - 100m	ns	ns	-	ns	ns	ns	ns	-
Improved grassland - total	ns	ns	-	ns	ns	ns	ns	-
Parks and gardens-100m	ns	ns	ns	•	ns	ns	-	ns
Urban-5m	-	ns	ns	•	++	ns	ns	ns
Semi-natural-100m	ns	++	ns	ns	ns	ns	ns	ns
Semi-natural-total	ns	+	+	ns	ns	ns	ns	ns
Area of surrounding wetlands								
Ponds and lakes-10m	ns	ns	ns	ns	ns	++	ns	ns
Ponds and lakes-250m	—	ns	ns	••	ns	++	—	ns
Ponds and lakes-500m	ns	ns	-	•	+	-	ns	ns
Ponds and lakes-total	-	ns	-	ns	ns	ns	ns	ns
Rivers-10m	-	ns	ns	ns	ns	ns	ns	ns
Rivers-250m	ns	ns	ns	ns	-	ns	ns	ns
Ditches-10m	ns	—	ns	ns	ns	ns	ns	ns
Ditches-250m	ns	-	ns	ns	ns	ns	ns	ns
Ditches-500m	ns	——	ns	••	ns	ns	+++	-
Ditches-total	ns	—	ns	••	-	ns	+++	ns

(cont.)

Table 5.3 (cont.)

	Axis 1 SR	Axis 2 SR	Axis 3 SR	All K-W	Gp 1 MW-U	Gp 2 MW-U	Gp 3 MW-U	Gp 4 MW-U
Plant cover								
Total cover	ns	—	ns	ns	ns	ns	ns	-
% pond total emergent cover	ns	ns	ns	•	ns	ns	+++	ns
% pond total submerged cover	ns	ns	ns	ns	ns	ns	-	ns
Plant species richness								
Total plant species	ns	ns	ns	ns	ns	ns	ns	-
% emergent plant species	+	+	ns	ns	ns	ns	ns	ns
% aquatic plant species	-	-	ns	ns	ns	ns	ns	ns
Total plant species/pond area	+	ns	ns	ns	ns	ns	ns	+
No. of emergent species/pond area	++	+	ns	ns	ns	ns	ns	+
No. of all floating plant species	ns	-	ns	ns	ns	ns	ns	ns
No. of all aquatic plant species	ns	ns	ns	ns	ns	ns	ns	-
TWINSPAN and DECORANA								
Axis 1 emergent plants	ns	ns	ns	ns	ns	+	ns	ns
Axis 2 emergent plants	ns	+	ns	ns	ns	ns	ns	ns
Invertebrate groups								
Total invertebrate species	ns	ns	ns	ns	ns	ns	ns	—
Number of species of snail	ns	——	+	••	ns	ns	ns	—
Number of species of leech	—	—	ns	ns	ns	ns	ns	-
Number of species of amphipod	ns	ns	+	ns	ns	ns	ns	ns
Number of species of mayfly	—	+++	ns	•••	ns	+	ns	—
Number of species of stonefly	ns	ns	ns	ns	ns	ns	-	+
Number of species of dragonfly	——	ns	ns	•••	ns	++++	ns	-
Number of species of bug	ns	ns	ns	•	ns	+	ns	—
Number of species of beetle	-	ns	ns	ns	ns	ns	ns	ns
Number of species of caddisfly	——	+	ns	•	+	ns	ns	ns
% species of snail	ns	———	ns	•	ns	ns	+	-
% species of leech	-	—	ns	ns	ns	ns	ns	ns
% species of amphipod	ns	ns	+	ns	ns	ns	ns	ns
% species of mayfly	—	ns	ns	ns	ns	ns	ns	ns
% species of stonefly	ns	+++	ns	ns	ns	ns	-	+
% species of dragonfly	—	ns	ns	•	ns	+++	ns	ns
% species of bug	ns	ns	—	ns	ns	ns	ns	ns
% species of beetle	+++++	ns	ns	•••	ns	—	ns	++
% species of caddisfly	—	+++	ns	•	+	ns	ns	ns
Invertebrate attributes								
Total families	——	ns	ns	•	ns	+	ns	-
BMWP score	———	ns	ns	••	ns	+	ns	-
ASPT	—	+++	ns	••	ns	+	-	ns

+ = positive correlation, - = negative correlation, • overall significance (Kruskal-Wallis), ns = not significant
Level of significance: +<0.05, ++<0.01, +++<0.005, ++++<0.001, +++++<0.0005, ++++++<0.0001
Probabilities from: SR - Spearman's rank correlation, MW-U - Mann-Whitney-U test, KW - Kruskal-Wallis test.
Correlations have been adjusted for ties.

CHAPTER 6

THE IMPLICATIONS FOR POND CONSERVATION

6.1 The wildlife resource of ponds

6.1.1 Introduction

It is clear from the Oxfordshire Pond Survey that ponds are a vital wildlife resource, and play a significant role in maintaining the biodiversity of Britain's wetland flora and fauna. In particular:

- Ponds support a very *large number* of freshwater species: just 34 ponds in this one county supported almost 60 per cent of all Britain's freshwater snail and flatworm species, over a third of the aquatic beetle species and almost 40 per cent of all Britain's aquatic and wetland plant species.

- Ponds also support many of our *rarest* freshwater plants and animals; the 34 ponds surveyed for the OPS contained over 100 species of uncommon plants and animals including two rare (RDB3) water beetles and the Glutinous Snail - one of Britain's most endangered animals.

- Amongst the more generalist wetland species, i.e., species which live in a number of different habitats (for example, both ponds *and* streams or marshes), ponds can *provide an important refuge* maintaining freshwater populations in an area when other habitats are lost or polluted.

- Some plant and animal species, are more or less completely restricted to pond habitats (the Natterjack Toad, for example); if ponds are not maintained we risk losing these species completely from the British countryside

These four points are outlined in more detail below.

6.1.2 The range of wildlife recorded during the Oxfordshire Pond Survey

The ponds surveyed for the Oxfordshire Pond Survey supported a surprisingly large number of freshwater species. Information presented in Chapter 3 showed that 39 per cent of the British wetland plants and 35 per cent of the British aquatic macroinvertebrate fauna (in those groups covered) were recorded from only 34 ponds in the county. Even individual ponds contained up to 15 per cent of the British wetland flora (Kennington Pit) and 11 per cent of the aquatic macroinvertebrate fauna (Central Pond, Otmoor). Oxfordshire ponds also supported five of our six native amphibians, including the protected Great Crested Newt.

These are very impressive results, and the clear implication is that ponds represent a considerable resource for our native wetland plants and animals.

6.1.3 The occurrence of uncommon species during the Oxfordshire Pond Survey

Oxfordshire's ponds are not only rich in wildlife, they also supported many uncommon species. These 34 ponds included 36 local wetland plant species and 2 species of Nationally Notable B status. A particularly large number of uncommon aquatic (submerged and floating) plant species were recorded; over 60 per cent were of at least local status - a fact which partly reflects the extensive pollution of so much freshwater in Britain (see Chapter 3).

An even greater number of uncommon invertebrate species were recorded, 30 per cent of all the macroinvertebrates found (75 species) were either local, notable or Red Data Book (RDB) status. Of particular note was the endangered (RDB1) Glutinous Snail (*Myxas glutinosa*), one of Britain's rarest species, and an animal which was previously thought to be extinct in Britain. In addition two rare (RDB3) water beetles were also recorded: the whirligig, *Gyrinus suffriani*, and the water scavenger beetle, *Enochrus isotae*.

The clear conclusion is that ponds not only support a wide range of common species, they are also vital in protecting some of our rarest and most vulnerable wetland species.

6.1.4 Ponds as refuges

There is strong evidence from the OPS to support the idea that ponds can be important as wildlife refuges, supporting species which are more typically found in other habitats (e.g., streams, marshes, fens, bogs). It is important to note that ponds do not by any means substitute for these habitats. However, in drained and damaged landscapes, ponds may sometimes help to retain wetland species when the original habitat has been destroyed.

An excellent example is Kennington Pond which is one of the only remaining British sites for the endangered Glutinous Snail (*Myxas glutinosa*). Kennington Pond was dug in the 1920s or 30s, probably to provide gravel ballast during construction of an adjacent railway line. The last detailed record of *Myxas glutinosa* in Oxfordshire was in 1857 at a site in the Hinksey Stream a few miles north of Kennington. This stream is indirectly connected to Kennington Pond via the local ditch system and it seems likely that the snail colonised the pond either from a population in the ditch system or from the Hinksey stream via these ditches. Recent searches of the stream and ditches have failed to find *Myxas*, except for a single specimen, taken from the connecting ditch immediately adjacent to Kennington Pond (Pond Action, 1994). The implication is that at some time after *Myxas* colonised Kennington Pond, the Hinksey Stream and most adjacent ditches were damaged, possibly by pollution, leading to the loss of their *Myxas* populations. As a result Kennington Pit and a small section of the adjacent ditch now provide its last British refuge.

Given the level of pollution in many rivers and streams, it is quite possible that other riverside ponds provide a similar refuge for riverine flora and fauna. They may also create a stock of species from which the rivers or streams may recolonise once the pollution problems have improved. Although ponds cannot provide the whole range of habitats found in rivers (the fast running riffles of an upland stream, for example), a surprising number of species are common to both habitats. For example, small gravel pits surveyed during the OPS supported species much more typically associated with streams or rivers (such as the riffle beetle, *Elmis aenea*; the riverine snail, *Viviparus viviparus*, and the mayfly, *Ephemera danica*). Presumably this is because, like rivers, gravel-based ponds have coarse bottom substrates and quite rapid through-flows of groundwater.

Many species typically associated with fens can also be found in ponds. For example, the Nationally Notable aquatic fen plant, *Potamogeton coloratus*, is largely restricted in Oxfordshire (and indeed most of central England) to Cothill Fen LNR. However, the species has also colonised a nearby pond in an old limestone quarry (Dry Sandford) approximately 1 km to the south east. This quarry pond therefore acts both as an extension of the original fen habitat and as a reservoir of the species should the Cothill fen population deteriorate or be lost.

6.1.5 Ponds as ancient habitats with unique species

Studies of geology and landscape suggests that small waterbodies have always been a natural feature of our landscape, and although individual ponds may be relatively short-lived, the environment provided by ponds is one which has been continuously available to freshwater plants and animals for many millennia. Given the very ancient origin of ponds it is not surprising that many animal species have adapted to specialise in the distinctive still water conditions that ponds provide. Good examples include our six native species of amphibian, all of which more-or-less totally depend on ponds as a site for egg-laying and for the early development of their young.

6.2 Pond management and design

Interpretation of the OPS data provides insights into the ways in which pond management techniques can be improved.

6.2.1 Buffer zones

One of the most important findings of the OPS was that land use factors were significantly correlated with the conservation value of ponds. Thus, ponds surrounded by areas of semi-natural habitat, especially fen or unimproved grassland, generally had a high conservation value (either in terms of the number of species they supported or the proportion of uncommon plants and animals). In contrast, ponds located in disturbed or intensively farmed landscapes had significantly lower values.

It is clear from this that buffer zones of semi-natural land around a pond are of considerable importance in either protecting or enhancing wildlife value. This may be for a number of reasons. First, many aquatic species need not only water but also terrestrial habitats during their life cycle. Thus flowering herbs are used as a source of nectar by adult hoverflies when they emerge from the pond margins, whilst woodlands and scrub are particularly attractive as feeding and overwintering sites for many adult amphibians. Second, freshwaters are sinks for liquids and solids draining from the surrounding land. Thus, if landuse around a pond becomes more intensive, the volume of pollutants such as silt, nutrients, organic wastes and biocide sprays draining into the water can rapidly increase significantly decreasing water quality. Finally, where there are areas of semi-natural wetlands (fens, bogs, streams and rivers) in the area around a pond, these may also act as a source of colonising animals for new ponds or sites which have been damaged in some way.

In terms of pond management and design there are clear implications here:

(i) the protection of any semi-natural areas around a pond is one of the most important pieces of management work that can be done to maintain pond conservation value;

(ii) adding or extending a natural buffer zone around a pond is likely to benefit both the pond community and create additional wildlife habitats for terrestrial species;

(iii) New ponds created in semi-natural areas have a high potential conservation value;

iv) where ponds are located in the wider countryside their design should incorporate a protective buffer zone whenever possible.

The OPS does not provide definitive information about the optimal width for buffer zones, but it is noticeable that plant and invertebrate communities were generally of higher value (i.e., had more species and/or more uncommon species) where the area of semi-natural land around the pond was at least 25m wide.

6.2.2 Size and depth

The OPS results suggests that pond depth and permanence are important factors affecting the type of aquatic invertebrate community present in a pond. Depth and permanence, were however, not important in terms of the rarity of species present. Similarly silt depth did not correlate with either high or low quality pond communities. The implication from this is that ponds of *all* depths can be of value for wildlife, and that shallow or temporary ponds can support distinctive communities including uncommon species. It is therefore very important that pond management which involves dredging of silt or deepening of a pond is done with considerable care: dredging shallow, and especially long established temporary ponds, may cause considerable damage to the specialised communities which currently use them.

In terms of pond creation it seems clear that, overall, larger ponds generally support more invertebrate than smaller ponds and there was some evidence from the OPS that deeper ponds were important in increasing the number of species of aquatic plants. In addition, as stated above, there is a clear indication that pond depth has a critical influence on the type of invertebrate community present on a site. The conclusion seems to be that pond creation project should generally be as large as possible, but should ideally include a number of different waterbodies forming a mosaic of different depths and degrees of permanence. A practical example of this has been carried out at Pinkhill Meadow, Farmoor, Oxfordshire, where Pond Action gave ecological advice on the design of a new small (3 ha) wetland nature reserve. Interim results from this project indicate that the site has been highly successful, and already supports about 20% of all British wetland plants, 14 per cent of the aquatic macroinvertebrates in groups surveyed together with uncommon breeding birds such as Little Ringed Plover and Redshank (Pond Action, 1993).

6.2.3 Shade

A typical piece of pond management advice is to cut back or coppice trees which overhang a pond. There is some evidence from the OPS data that ponds with heavy shading *do* have lower numbers of aquatic plant species than unshaded ponds, however, as with water depth and silt there is little evidence that these ponds support fewer uncommon species. In addition, it should be noted that the OPS did not include surveys of groups such as Diptera (two-winged flies) for which shaded/wooded ponds can be an important habitat. The implication here is that care should be taken when removing trees around ponds. There are a number of species such as the beetles *Helophorus dorsalis* and *Agabus melanarius* particularly associated with wooded ponds. In addition a wide variety of pond invertebrates need or exploit woody debris and other tree products. For example some fly and beetle larvae feed on decaying wood, some caddisflies (for example, *Glyphotaelius pellucidus* and *Trigostegia minor*) use leafy or woody detritus for case building, and the submerged roots of surrounding trees frequently provide a habitat for species of haliplid beetle and baetid mayflies.

6.2.4 Water source

It seems clear from the OPS data, that ponds with inflows have higher pollutant levels and lower wildlife values than ponds without inflows. Therefore, it seems highly advisable not to link ponds to ditches or streams which could be polluted. If existing ponds have an inflow which is thought to be bringing in pollutants there may be a case for diverting the inflow, particularly if it is only of minor importance as a water source to the pond. If chronic pollution is suspected then there is perhaps also a case for dredging out existing polluted sediment that the inflow has brought in.

The OPS results also indicated that ponds fed only by groundwater seemed to have some of the highest value communities of all the site surveyed - perhaps because groundwater sources are of better quality, without the high levels of phosphorous and other pollutants which can be associated with surface flows. The implication is that siting ponds in locations where they can be fed by groundwater may give them a better chance of attaining or maintaining high value plant and invertebrate communities.

6.3 A strategy for protecting Oxfordshire ponds

6.3.1 Selecting sites for conservation

One of the uses for the data collected for the Oxfordshire Pond Survey is that it can help in the formulation of a strategy to conserve ponds. For example there may be situations where it is necessary to (a) quickly assess areas of particular promise or risk; (b) identify sites where it would be particularly advantageous to create ponds; or (c) identify where to take particular care with management. Two criteria are of particular importance in selecting sites in this respect: pond quality and pond type .

6.3.2 Selecting ponds of high quality

It is clear that any conservation strategy will need to be able to quickly identify and prioritise ponds of highest quality, i.e., ponds which support very diverse communities or those with uncommon species. As noted above, the factor which correlates most consistently with the conservation value of all three different types of community (aquatic plants, marginal plants and inverts) is landuse. This is valuable because it suggests that desk studies using OS maps, aerial/satellite photographs or perhaps Phase 1 survey information could be used as the basis for a quick assessment of pond quality.

6.3.3 Selecting a range of pond types

One of the ways of conserving the greatest diversity of species and community types in any area by selecting at least one representative from a range of different pond types.

The TWINSPAN classification of Oxfordshire ponds can provide the basis for this, dividing all the pond surveyed into dissimilar group based on their aquatic, marginal plants and aquatic invertebrate communities. Picking the best pond from each end-group of the classification gives us a number of ponds, which represents the range of pond communities present in Oxfordshire.

The wide range of environmental factors which correlate with the different classifications for aquatic plants, marginal plants and aquatic invertebrates, suggests that one of the most important strategies for protecting ponds is to ensure that a wide range of ponds are maintained in a wide range of habitats. This should include ponds of different size and depth (including temporary ponds), ponds located on different types of geology and landuse, ponds with varied water sources, and ponds with a variety of plant cover.

6.4 Conclusions

Ponds are clearly important habitats both in their own right, supporting species which have no other habitat, and sometimes as the only remaining relict wetland habitat in highly urban or intensively-used rural environments.

Ponds are also very ancient features, so that when we create new ponds, whether deliberately or accidentally, we mimic this natural process. Both natural and man-made ponds are the modern representatives of an ancient habitat type, and they continue to provide habitats needed by pond plants and animals.

This makes the loss of ponds of great concern. Recent estimates indicate that, over the past century, in the order of 1,100,000 ponds have been lost or destroyed. Assuming the average pond to be a conservative 0.1 hectares, this represents a loss of 110,000 hectares (1,100 square kilometres) - an alarmingly large area.

In view of the value of ponds there is clearly a need for action which reduces the extent of pond loss and increases the protection of ponds which remain.

GLOSSARY

Amphibians
There are six native British species: the Common Frog (*Rana temporaria*); the Common Toad (*Bufo bufo*) and the Natterjack Toad (*Bufo calamita*); and the Smooth Newt (*Triturusvulgaris*), Palmate Newt (*T.riturushelveticus*) and Great Crested (or Warty) Newt (*Triturus cristatus*).

Aquatic macroinvertebrates
Invertebrates whose adult length is generally greater than 1mm. Not all aquatic macroinvertebrate species, however, were included in the Oxfordshire Pond Survey: a full recording list is given in Appendix 3, Table A3.6.

Aquatic plants
A group combining both submerged and floating-leaved species. A list of the aquatic plants recorded in the Oxfordshire Pond Survey is given in Appendix 2, Table A2.2.

DECORANA
DEtrended CORrespondence ANAlysis. Elucidates major community trends in environmental data sets. See Appendix 5.

Distribution
Distribution status (Common, local, etc.) is described in Appendix 6.

Emergent plants
Wetland plants generally having most of their leaves above water level, e.g., tall emergent species such as Bulrush (*Typha latifolia*) and Soft Rush (*Juncus effusus*); wetland herbs such as Water Forget-me-not (*Myosotis scorpioides*) and Purple Loosestrife (Lythrum *salicaria*); and low-growing grasses such as Creeping Bent (*Agrostis stolonifera*).

Floating-leaved plants
Aquatic plants with most of their leaves floating on the water surface, e.g., Common Duckweed (*Lemna minor*), water lilies.

Species Rarity Index (SRI)
A numerical assessment of the average species rarity of a particular community or sample. Calculation of SRIs is explained in Appendix 6.

Species-richness
The number of plant or animal species recorded by a constant sampling/recording effort. (In this report, species-richness is applied only to macroinvertebrate records.)

Submerged plants
Aquatic plants which are generally submerged for most of the year, e.g., hornworts (*Ceratophyllum* spp.), water milfoils (*Myriophyllum* spp.), Canadian Pondweed (*Elodea canadensis*).

TWINSPAN
Two-Way INdicator SPecies ANalysis. Highlights groups of sites/samples with similar communities. See Appendix 5.

Wetland plants
All wetland plant species, including those which are emergent, floating-leaved, and submerged. Plants included as wetland' are defined by the Pond Action Wetland Plant List, given in Appendix 2, Table A2.1.

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