Interim Report R&D Project 383

Experimental Management of Wetland Habitats at Pinkhill Meadow

Pond Action

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R&D 383/2/T

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EXECUTIVE SUMMARY

1. Introduction

This report is the second Interim Report of the National Rivers Authrority (NRA) National R&D Project F01(91) 2 383 "Wetland Creation/River Corridor Enhancement". The project has been undertaken for the NRA by Pond Action.

The project has two main parts:

(i) A post-project appraisal of the nature conservation value of an off-river enhancement scheme.
(ii) An experimental investigation of the management of vegetation in newly created wetland habitats.

The work is being undertaken at Pinkhill Meadow Nature Reserve, Farmoor Reservoir, Oxfordshire, where a new 2ha wetland was created between 1990 and 1992. The reserve is on Thames Water Utilities Ltd land and its establishment has been jointly funded by Thames Water Utilities Limited and NRA Thames Region. Construction took place in two phases: in Phase 1 four ponds of varying size, depth and water regime were created; these were extended in Phase 2 to establish a mosaic of wetland habitats with permanent and temporary water, mud flats and areas of new wet meadow.

2. Post-project appraisal

Post-project appraisal has focused on assessing the nature conservation value of the new wetland habitats, with monitoring of water chemistry, wetland plants, macroinvertebrates and wetland birds.

2.1 Water chemistry

There have been some changes in the chemistry of the ponds since 1992, although all ponds seem to have responded in a broadly similar way. Total oxidised nitrogen (TON) concentrations were high in all ponds in winter 1992/93 (in previous winters, concentrations were noticeably higher in only the Groundwater Pond) and remained detectable in the summer for the first time. This may be the result of flooding of the site in the winter by the Thames. Chloride concentrations continued to decline in all ponds, although the reasons for this are not known.

2.2 Wetland plants

Numbers of wetland plants colonising the site have continued to increase, with a total of 59 wetland species recorded in 1993 (49 in 1992, 36 in 1991). This represents about 20% of the British wetland flora. Communities dominated by tall emergents (*Typha latifolia*, *Juncus inflexus*, *Phalaris arundinacea* and *Carex riparia*) have begun to develop. The *Phragmites* beds have generally taken well and in many areas plants have sent out runners up to 15m long which could lead to *Phragmites* establishment well beyond the originally intended areas. Other significant changes in vegetation cover since 1992 include: (i) the development of a fringe of wetland herbs and grasses at the waters edge around much of the Northern Reed Pool, Main Pond and Scrape; and (ii) development of a mixed meadow and marginal wetland community in the southern wet meadow area.

The plant community of the Main Pond was of 'high' conservation value (on a four point national scale: low, moderate, high, very high). Communities in the three other individually monitored ponds were all of moderate conservation value. The aquatic plant community has remained rich in species with five Nationally Local species.

2.3 Aquatic macroinvertebrates

Numbers of invertebrate species recorded in the four Phase 1 ponds increased from 84 in July 1992 to 103 in July 1993. This represents about 14% of the British species within the groups recorded. Twenty Nationally Notable or Local species have now been recorded (compared with 15 in 1992). The conservation value of the communities in the four Phase 1 ponds remained "high" on a four point scale.

The slower-colonising groups (so-called "non-mobile" water snails, leeches, flatworms and crustaceans) are now becoming more widespread and abundant on the site and there is evidence that water snails have been brought in with flood water at the southern end of the site. Nine species of dragonfly have now been recorded breeding on the site but the water beetles are the most diverse group with 44 species recorded to date.

2.4 Birds

Three species of wading bird bred, or attempted to breed, on Pinkhill Meadow in 1993. Two pairs of Little Ringed Plovers bred (one pair in 1992) and three pairs of Lapwing (one pair in 1992). A pair of Redshank laid a clutch of three eggs but the nest was flooded out by high water levels in May. Mallard, Tufted Duck and Moorhen all bred on or near the site. Pinkhill was also regularly visited by Hobby during Summer 1993. Water Rail, Jack Snipe and Teal were recorded for the first time during the year.

In general, waders and waterfowl were most abundant during the breeding season, with few birds using the ponds in late autumn or winter. The only waders which seem to be regularly drawn down from the concrete basin of Farmoor reservoir to Pinkhill are Common Sandpiper and Greenshank. Other species which are common on the reservoir, such as Dunlin, Little Stint and Ruff, rarely (or never) visit Pinkhill.

Analysis of Farmoor Reservoir log-book data indicates that the construction of the Pinkhill wetlands has, as would be expected, led to a marked increase in the number of Little Ringed Plovers and Snipe using the Farmoor site. There is a slight indication that numbers of Greenshank have also increased.

In general, the site is proving very successful as a breeding habitat, but attracts few birds outside the breeding season. This suggests that for some scarce wetland species, quite small sites, which require relatively little land to be set aside, can provide valuable breeding habitats. In contrast, sites for migrant and overwintering wetland species may need to be much larger and therefore more difficult to establish.

3. Experimental ponds

Two experiments are in progress in a series of seven experimental ponds: Experiment 1 (Ponds 1-3) is concerned with the establishment of species-rich plant communities; Experiment 2 (Ponds 4-7) is an investigation of the relationship between vegetation species-richness and invertebrate species-richness.

3.1 Experiment 1

The main aim of the vegetation experiment management experiment is to investigate practical measures for establishing and maintaining species-rich plant communities. It is anticipated that this will revolve around the control of robust emergent species such as *Typha latifolia*.

Variable establishment of the nine plant species introduced into the ponds has meant that densities of plants are still very low and no control measures have so far been needed to prevent the spread of potentially dominating species.

3.2 Experiment 2

Two pond types have been established in this experiment: ponds with one emergent species (*Glyceria maxima*); and ponds with four emergent species (*Glyceria maxima*, *Schoenoplectus lacustris*, *Carex riparia* and *Phragmites australis*). It was initially hoped that ponds could also be maintained with rich/poor aquatic plant communities; however, the establishment of aquatic species was highly variable and all ponds have therefore been managed to minimise the differences in their aquatic plant communities. Emergent plants have generally established well, although there are some differences in density between ponds.

Surveys of invertebrate communities were undertaken in March and November. Analysis of the first two seasons' data suggest that so far there is little difference in the numbers of invertebrate species recorded in the two pond types.

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1. INTRODUCTION

This second Interim Report describes the results of the 1992/3 survey, monitoring and experimental work undertaken by Pond Action at Pinkhill Meadow Nature Reserve, Farmoor Reservoir, Oxfordshire. The work is being undertaken for NRA National R&D Project F01(91) 2 383 "Wetland Creation/River Corridor Enhancement".

The project as a whole has two main parts:

(i) A post-project assessment of the nature conservation value of a river corridor enhancement scheme (the Pinkhill Meadow Nature Reserve at Farmoor Reservoir, Oxford).

(ii) An experimental investigation of the management of wetland vegetation to promote plant and invertebrate community diversity, using seven experimental ponds on Pinkhill Meadow.

1.1 Background

1.1.1 Background to the study

Wetland creation and enhancement schemes are widely perceived as being an important tool for maintaining or re-establishing the nature conservation value of river corridors. However, despite their popularity, there is little information about the real conservation benefits of wetland enhancement and creation schemes.

Post-project assessment of the habitat creation work at Pinkhill aims to:

(i) Provide data on the conservation value of the plant, invertebrate and bird communities of new off-river wetland enhancements.

(ii) Provide data that will allow designs for similar schemes to be refined in the future.

More background information about the construction and monitoring of Pinkhill is given in Chapter 1 of the 1992 Interim Report.

1.2 Objectives of the Pinkhill project

1.2.1 Post-project monitoring

Post-project monitoring of the Pinkhill site has aimed to:

(i) Describe water quality in the ponds, providing basic data which will help interpretation of the developing wildlife communities.

(ii) Describe the development and conservation value of the wetland plant communities of the site.

(iii) Describe the development and conservation value of the aquatic invertebrate communities of the site.

(iv) Describe the use of the site as a feeding and breeding habitat for birds, particularly waders and waterfowl.

1.2.2 Experimental site management

The objectives of experimental site management are to set up experimental areas in which to investigate:

(i) Practical management methods used to establish species-rich plant communities in wetland habitats created during enhancement schemes: for example, management after planting by selective cutting, weeding or herbicide treatment.

(ii) The influence of plant species-richness on the species-richness of aquatic macroinvertebrate communities in ponds created as part of wetland enhancement schemes.

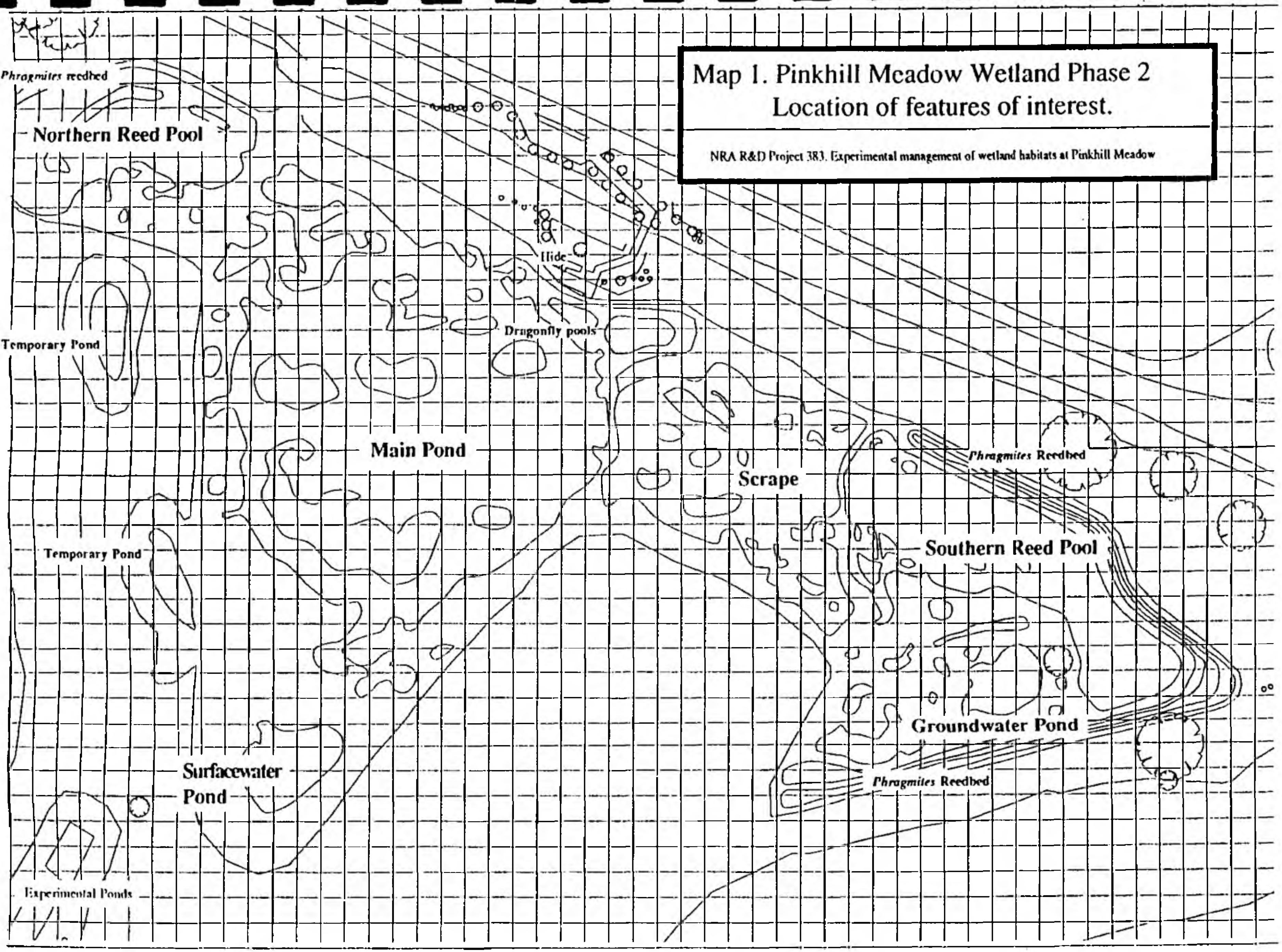
1.3 Aims of the report

This progress report describes the results of monitoring of the Pinkhill ponds since the initiation of Phase I of the Pinkhill Meadow Wetland Enhancement Project in 1990.

This includes information on:

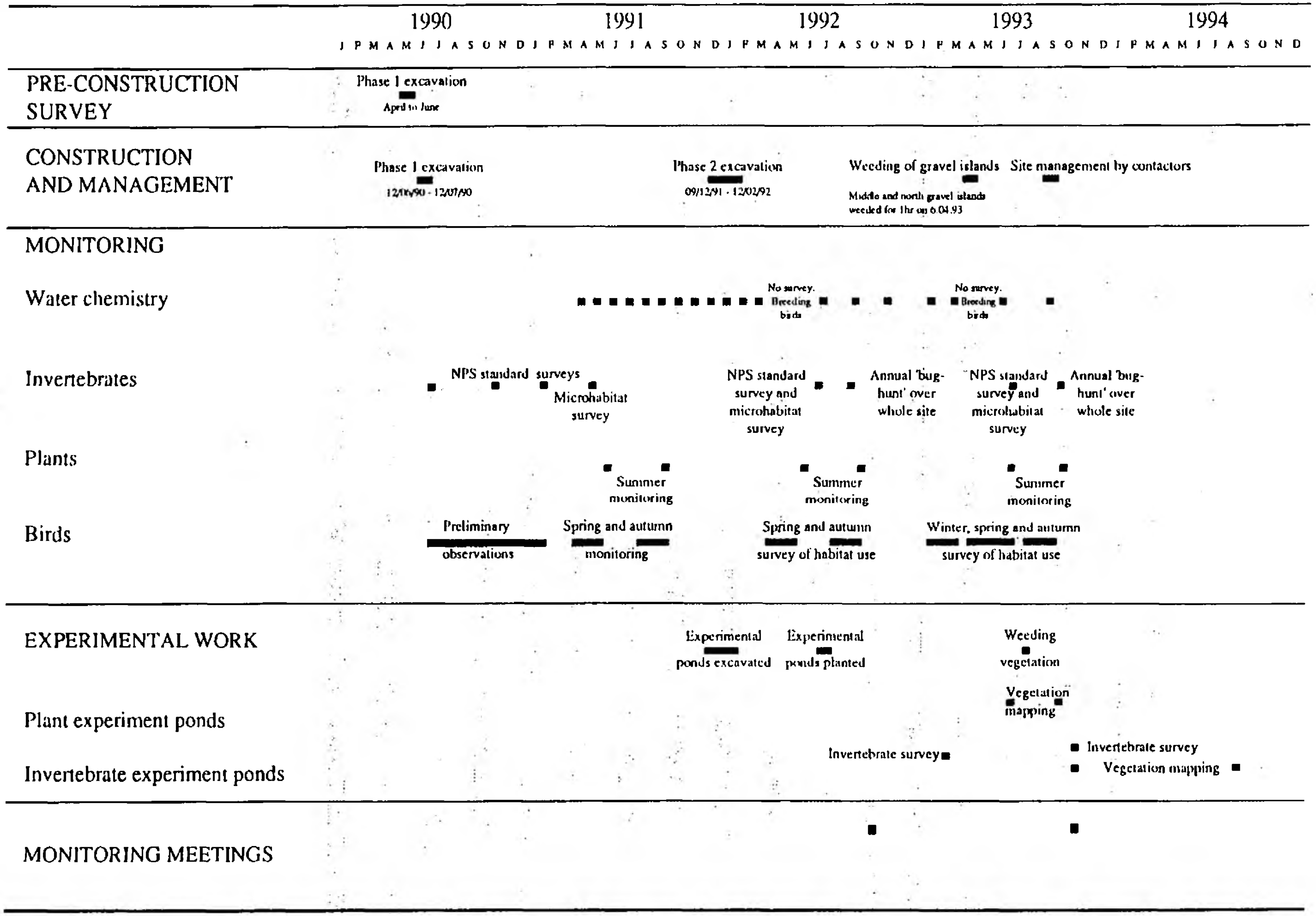
- Water chemistry (Section 2)
- Plant communities (Section 3)
- Invertebrate communities (Section 4).
- Birds (Section 5)
- Experimental ponds (Section 6)

A timetable of the work undertaken so far is shown in Figure 1.1.


Map 1. Pinkhill Meadow Wetland Phase 2
Location of features of interest.
NRA R&D Project 383. Experimental management of wetland habitats at Pinkhill Meadow
Phragmites reedbed
Northern Reed Pool
Hide
Dragonfly pools
Temporary Pond
Main Pond
Scrape
Phragmites Reedbed
Southern Reed Pool
Temporary Pond
Groundwater Pond
Surfacewater Pond
Phragmites Reedbed
Experimental Ponds

3

Figure 1.1 Pinkhill Meadow: work undertaken between April 1990 and October 1992



2. WATER CHEMISTRY

2.1 Introduction

The aims of water chemistry monitoring on site have been:

(i) To provide baseline environmental data for the site.
(ii) To compare the quality of surfacewater and groundwater ponds on the site.
(iii) To monitor changes in pond water chemistry through time.

Samples were taken monthly from April 1991 to March 1992 and then bi-monthly from July 1992, with the exception of the bird breeding season (see Figure 1.1).

Monitoring was carried out on the four waterbodies created during Phase 1 of the project (i.e., the Main Pond, Scrape, Groundwater Pond and Surfacewater pond).

The following determinands were measured:

(i) pH
(ii) Conductivity
(iii) Total oxidised nitrogen
(iv) Ionised ammoniacal nitrogen ($NH_4^+.N$)
(v) Un-ionised ammoniacal nitrogen (NH_3N)
(vi) Soluble reactive phosphate phosphorus (SRP.P)
(vii) Biochemical oxygen demand (BOD)

Temperature was also recorded. Methods used to collect water samples were described in Appendix 2 of the 1992 Interim Report.

2.2 Results

During the sampling programme five determinands were often below their detection limits. The three determinands $NH_3.N$, $NH_4^+.N$ and SRP.P were only at, or above, their detection limits on two, four and eleven occasions respectively in the 152 samples taken during the course of the study. Results for all determinands except $NH_3.N$ and $NH_4^+.N$ are shown graphically in Graphs 1 to 6.

The graphs show the average values from duplicate samples. Where only one sample was above the detection limit for a particular determinand, this value was averaged with the detection limit itself. In all graphs, where determinands occasionally fell below their detection limits (TON, SRP.P and BOD), the horizontal axis of the graph crosses the vertical axis at the detection limit, and the graph will be seen to fall below this line.

2.2.1 Total Oxidised Nitrogen (TON) (Graph 1)

Graph 1 shows TON plotted on a log10 scale. In 1991 and 1992 TON was normally high in winter and undetectable in summer. In the winter of 1991/92 the levels in the four ponds varied quite markedly, reaching between 0.3 and 0.45 mg/l in the Surface-water Pond, Main Pond and Scrape but 6.05 mg/l in the Groundwater Pond (note that these values are converted to log10 values on the graph). The difference in TON levels between the ponds may have been due to the greater hydrological continuity of the Groundwater Pond with the River Thames.

In 1993, winter concentrations were again high and, in two ponds, were detectable in summer. In the winter of 1992/93 the TON concentrations in all ponds rose to high levels, from 4.7 mg/l in the Scrape to 5.8mg/l in the Main Pond (beginning in November 1992 and peaking in early February 1993). The increase over the whole site was probably due to flooding of the site from the Thames at this time. By the end of March 1993 the high levels of TON had dropped in most ponds, but remained relatively high (0.7mg/l) in the Main Pond. By June 1993 the level of TON was still above the detection limit in the Main Pond (0.2mg/l) and detectable also in the Surfacewater Pond (0.15mg/l). Both results may be due to flooding of the site in May or, possibly, in the case of the Main Pond, a residual effect of the winter floods.

2.2.2 Soluble Reactive Phosphate. Phosphorus (SRP.P) (Graph 2)

The graph for SRP.P presented in the 1992 Interim Report shows a detection limit of 0.01 mg/l. Subsequent to this, the NRA analysts increased their quoted detection limit to 0.06 mg/l. This should be considered to be a retrospective change. This means that all but one of the data points on the previous graph are now below the new detection limit.

SRP.P, therefore has been detected at Pinkhill on four occasions: at its detection limit in July 1992 in the Main Pond; at its detection limit in September 1992 in the Scrape; at or above its detection limit in all four ponds in November 1993; and again above its detection limit in all four ponds in March 1993. It was not detected between November 1992 and March 1993.

It is possible that there is a general increase in the amount of this nutrient on the site, possibly promoted by flooding from the Thames. Why SRP.P would be detected in mid-November and late March but not in early February, however, is not clear.

2.2.2 Ammoniacal nitrogen (NH_4^+.N and NH_3.N)

Values for these two determinands were rarely above the detection limit. NH_4^+.N was measured at 0.13 mg/l in the Main Pond in May 1991, when the un-ionised form was estimated to be at a level of 0.0015 mg/l. NH_4^+.N was measured in two sites (Surface-water and Main Pond) in January 1992 (0.055 and 0.085mg/l respectively), and again measured at 0.065 mg/l in the Scrape in June 1993. On this latter occasion the un-ionised form was estimated to be present at a concentration of 0.001mg/l. None of these levels is known to be harmful to aquatic life.

2.2.4 Biochemical Oxygen Demand (Graph 3)

The BOD of ponds on the site continues to be rather varied. BOD appears to be recorded with greater consistency with time, though this is not statistically valid (Spearman's rank correlation). No particular season of the year, or any particular pond, appears to have higher BOD levels. It would seem reasonable that, as the sites mature, so BOD might be expected to increase with a general increase in biomass. BOD, by its very nature, is a rather variable determinand; it is, therefore, possible that further surveys will be able to demonstrate a statistically significant increase.

2.2.5 Chloride (Graph 4)

All ponds have shown a decrease in chloride levels over the course of the sampling period. This is statistically significant for all but the Surfacewater Pond (Spearman's rank correlation $p=<0.05$). The reason for the change in chloride levels is not known. Over the period of study the chloride levels were rather variable between ponds at the beginning but, towards the end of the sampling period, these differences seem to be lessening. This reduction in between-pond variability must be, in some part, due to the winter flooding of the site. It may be that variability will increase during years when no flooding occurs.

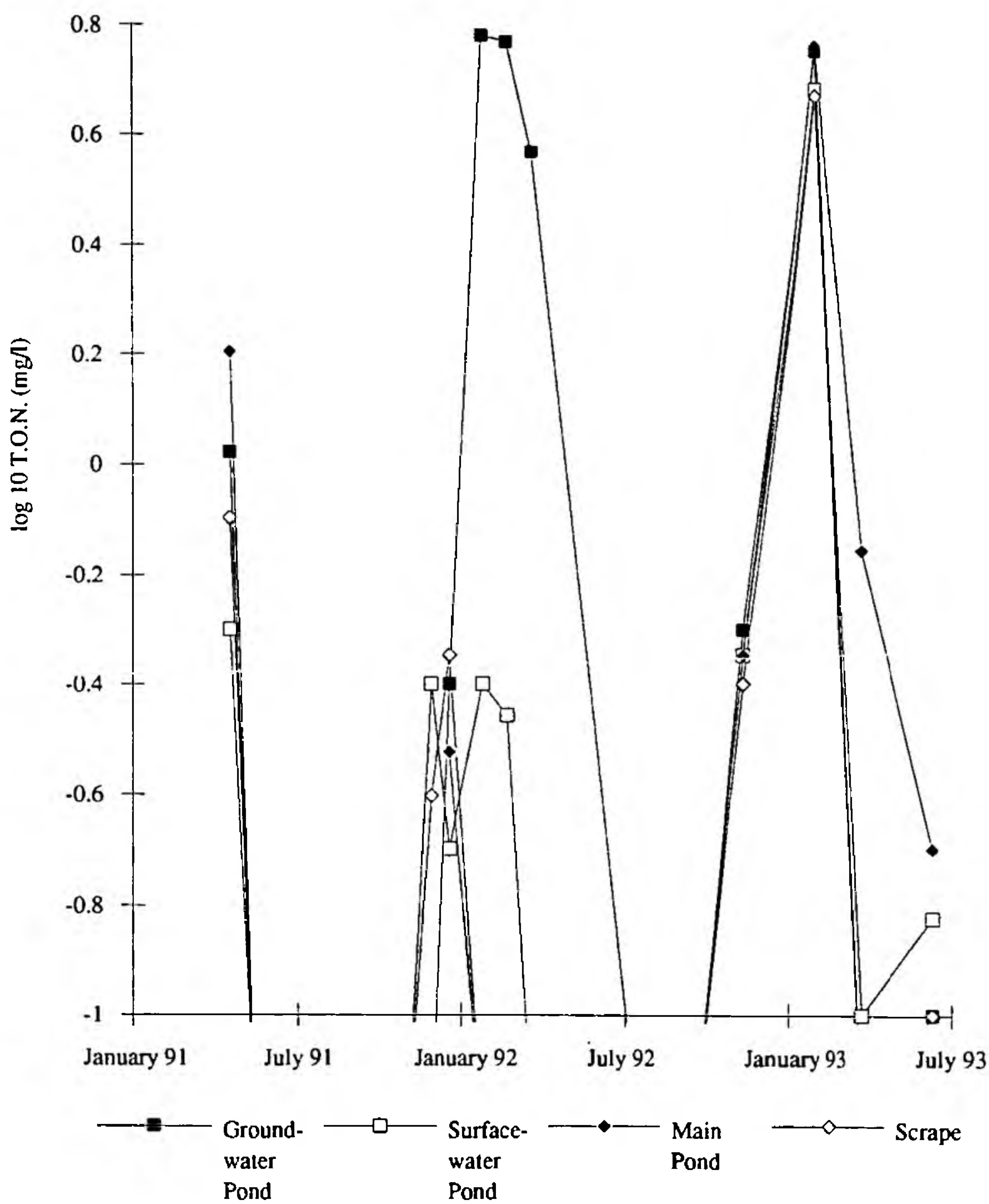
2.2.6 pH (Graph 5)

With the exception of rather high values in July 1991 and a single very low value in January 1992, the pH of the ponds has been relatively constant over the period of sampling. Over all ponds there has, in fact, been a slight increase in pH (Spearman's rank correlation $p=<0.01$). In many ponds there is a tendency for pH to be higher in summer and lower in spring and autumn (Pond Action, unpublished data). With the exception of the two extreme results mentioned, this does not seem to be the case at Pinkhill.

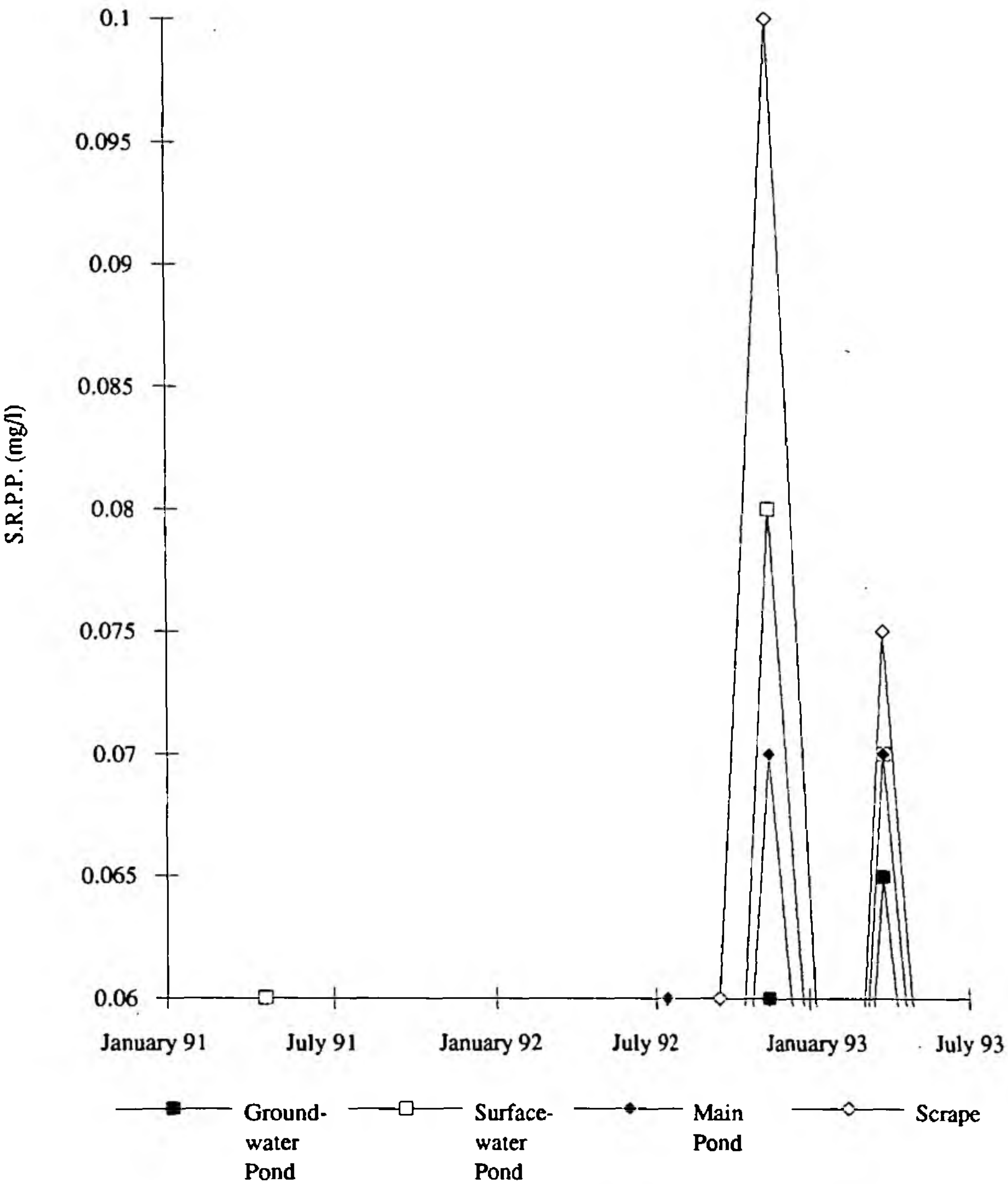
2.2.7 Temperature (Graph 6)

Since July 1991, when there was a large difference between the Main Pond and the other ponds, the temperature difference between the ponds has been small, with no pond particularly cool or warm.

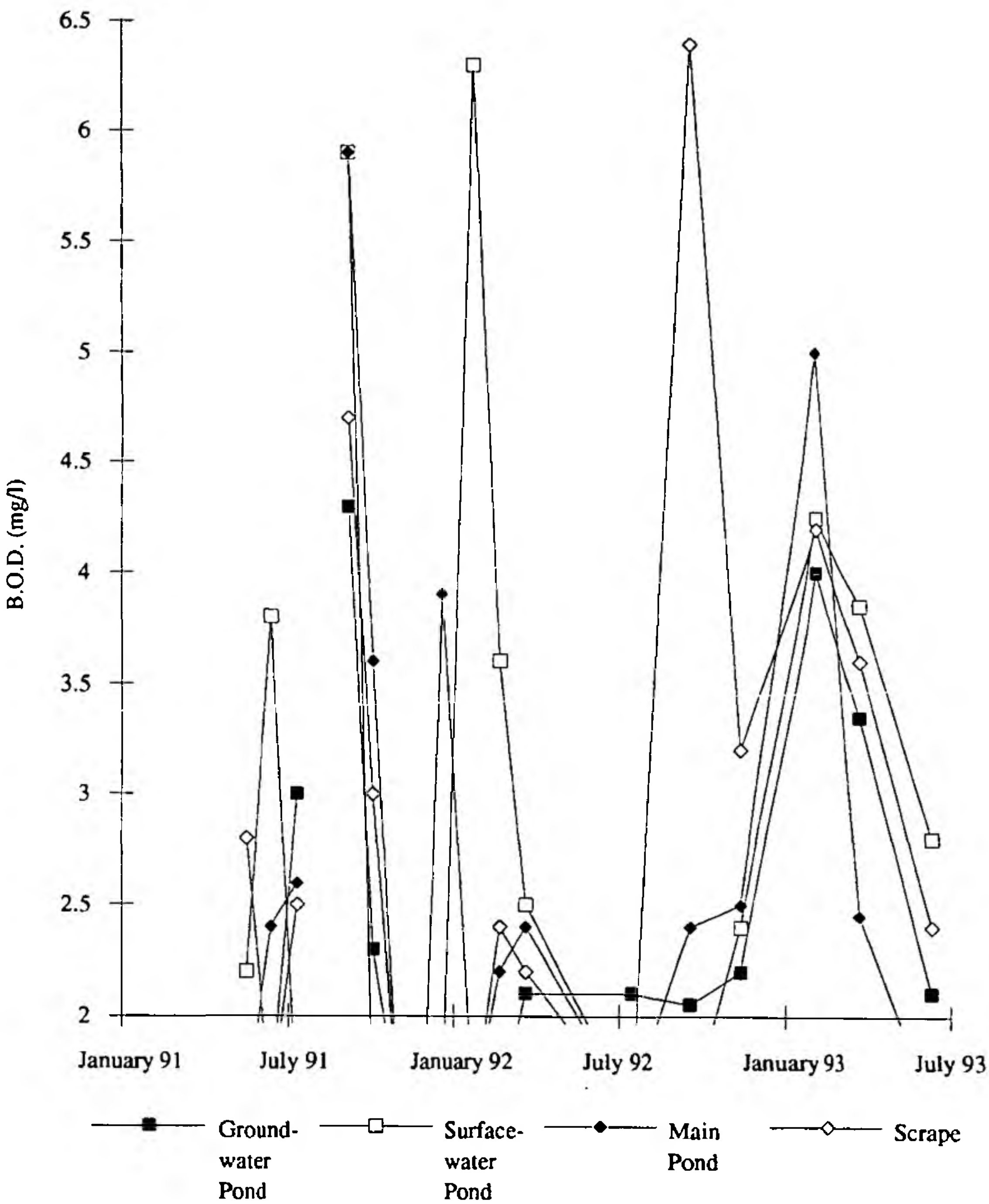
GRAPH 1: **Change in concentration of total oxidised nitrogen (T.O.N) with time in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93 (log scale)**



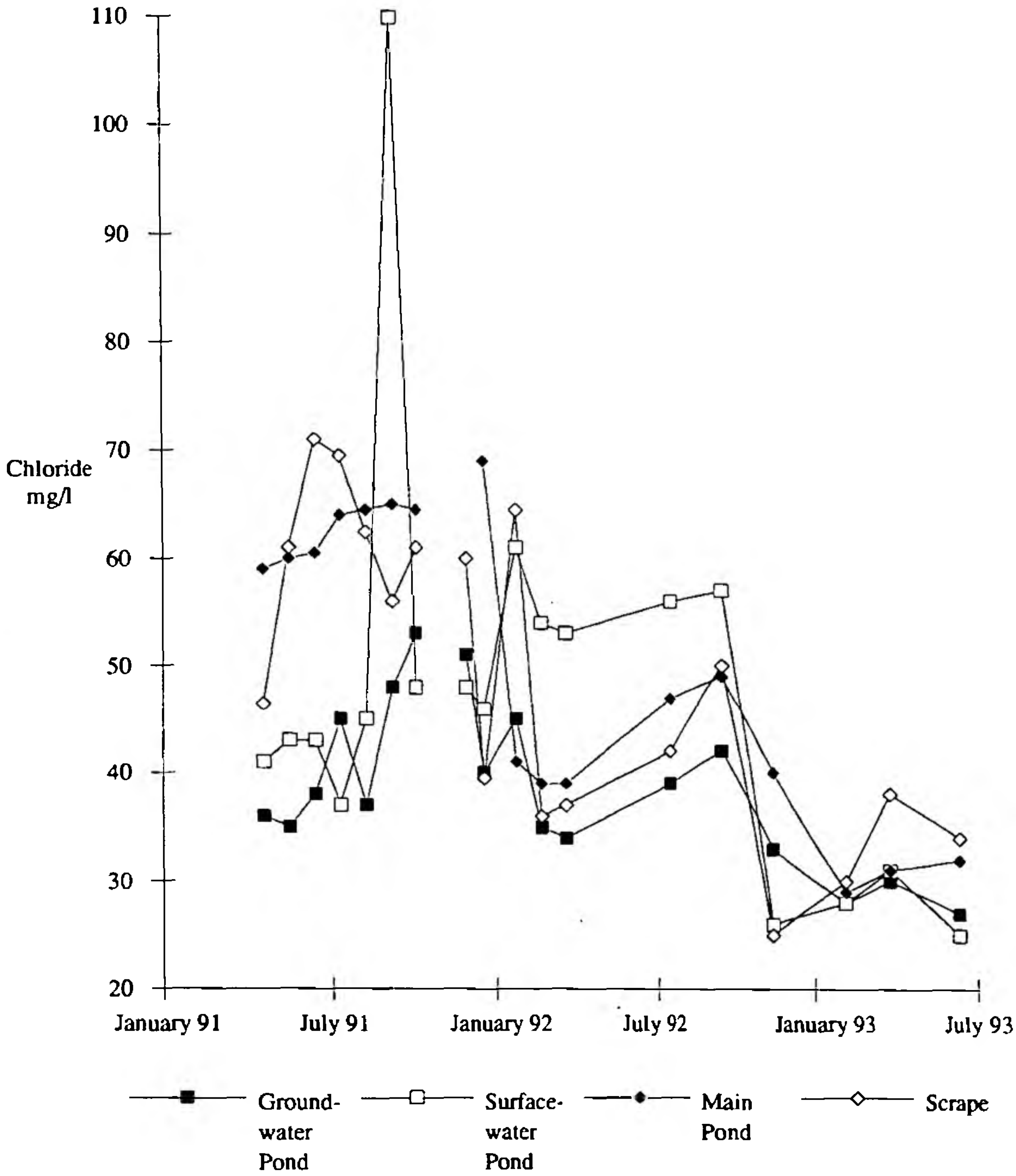
GRAPH 2: **Change in concentration of soluble reactive phosphate phosphorus (S.R.P.P.) with time in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93**



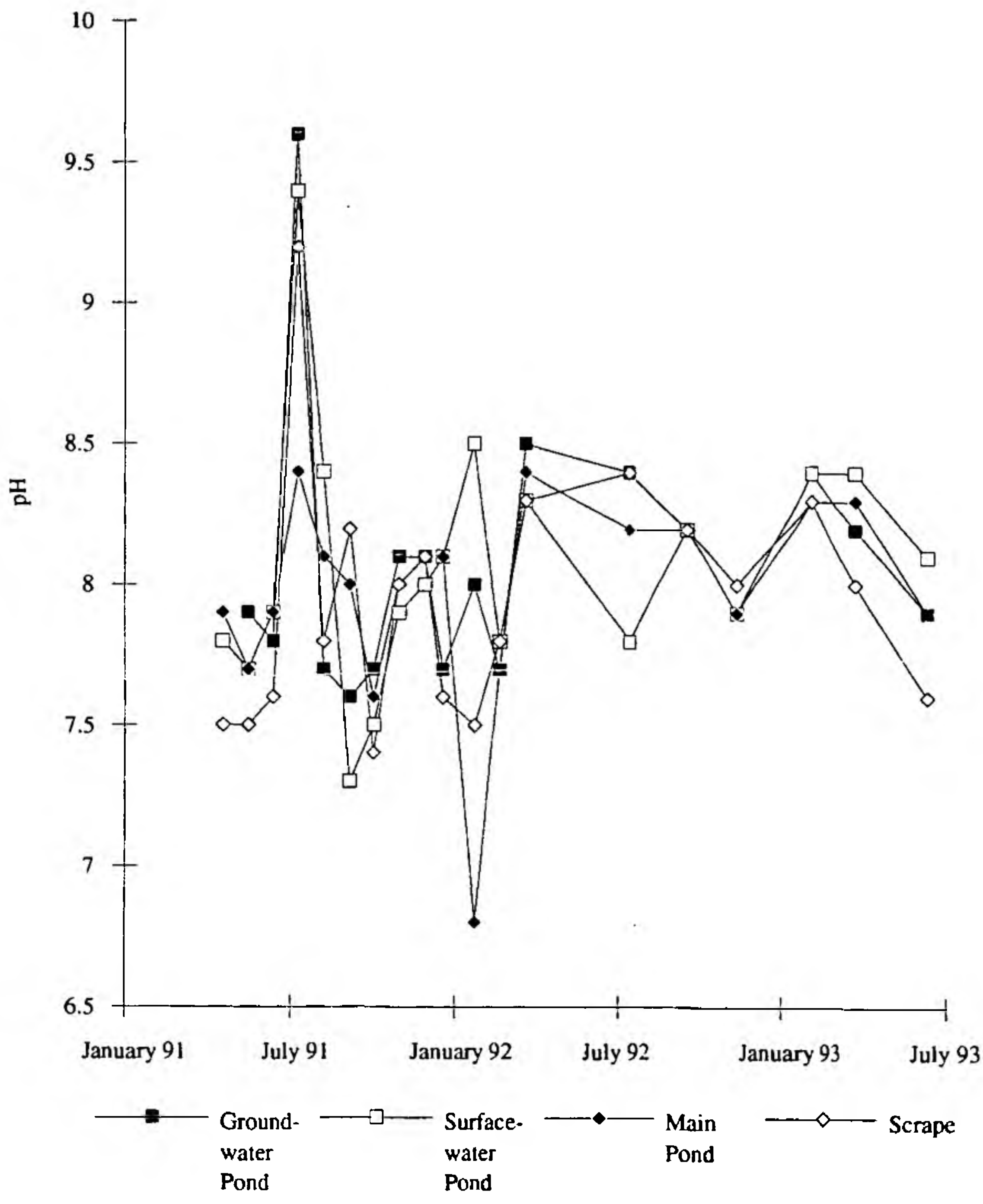
GRAPH 3: **Change in Biochemical Oxygen Demand (B.O.D.) with time in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93**



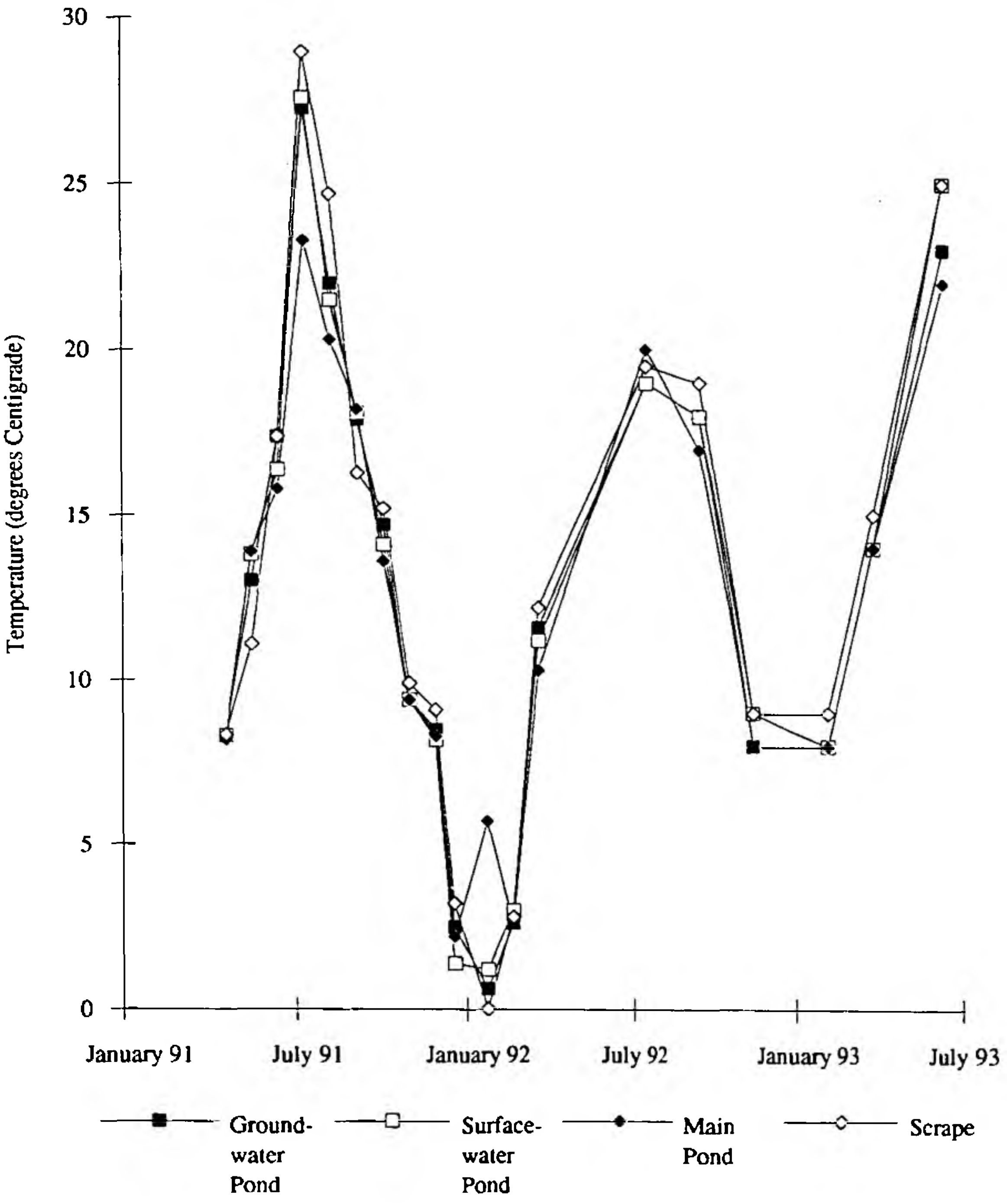
GRAPH 4: **Change in concentration of chloride in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93**



GRAPH 5: Change in pH with time in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93



GRAPH 6: Change in temperature with time in four ponds on Pinkhill Meadow between 18/4/91 and 10/6/93



3. WETLAND PLANTS

3.1 Introduction

The main aims of plant survey work on the site are:

(i) List the wetland plants which have colonised the new site.
(ii) Describe the development of the wetland plant community.
(iii) Provide estimates of the abundance of vegetation colonising the site.
(iv) Assess the conservation value of the new plant community.
(v) Monitor the success of *Ophioglossum* relocation on Pinkhill Meadow.

Surveys were undertaken in Summer 1991, 1992 and 1993. Methods used to survey wetland plants are described in Chapter 3 and Appendix 3 of the 1992 Interim Report.

3.2 Wetland plants colonising the site (1991 to 1993)

The new Pinkhill wetland has seen a progressive increase in the number of plant species recorded since its creation in 1990 (1991 = 36 species; 1992 = 49 species; 1993 = 59 species). As shown in Table 3.1 below, all the four original Phase 1 ponds also increased in species-richness. A full species list for the site is given in Appendix 1.1. English names of wetland plants are given in Appendix 1.2.

Between 1992 and 1993 eleven new species colonised the site. Nine of these were marginal species. The two new aquatic species were both non-native (*Elodea nuttallii* and *Crassula helmsii*). Interestingly, both aquatic species seem to have initially colonised the site in the south-eastern corner of the Southern Reed Pool. Amongst the new marginal wetland species to colonise the site was a relatively uncommon species of water-plantain, *Alisma lanceolatum* (Narrow-leaved Water-plantain).

Two species recorded in 1992 were not re-recorded from the site in 1993 (*Zannichellia palustris* and *Polygonum lapathifolium*).

Table 3.1 The number of wetland plant species recorded from the Pinkhill wetland (1991-1993)

MP - Main Pond **SW** - Surfacewater Pond **GW** - Groundwater Pond **SC** - Scrape **TS** - Total Site
(Year of survey: 91- Summer 1991 92 - Summer 1992 93 - Summer 1993)

	MP			GW			SW			SC			TS		
	91	92	93	91	92	93	91	92	93	91	92	93	91	92	93
No. of marginal species	15	29	35	12	14	20	10	10	17	15	21	23	32	40	49
No. of aquatic species	4	8	8	1	2	2	0	2	3	1	2	2	4	9	10
Total number of species	19	37	43	13	16	22	10	12	20	16	23	25	36	49	59

Note: The colonisation of *Crassula helmsii* is of particular importance since it is a pest species which is known to be causing considerable damage to pond wildlife communities across Britain. On the Pinkhill site it currently seems to be restricted to approximately 20-30 small stands distributed along the eastern arm of the reed bed in the Southern Reed Pool.

3.3 Plant communities

The plant communities identified on the site in 1993 were broadly similar to those identified in 1992, i.e., meadow; mixed meadow and marginal wetland ruderals; wetland herbs and grasses; stands of *Phragmites australis*; and the aquatic plant community (See Map 2). More detailed descriptions of these communities are given in Section 3.4 of the 1992 Interim Report. As in 1992, the broad distribution of these communities largely reflected the influence of underlying physical factors, particularly topography, water levels and substrate type.

The most notable changes in the distribution of plant communities in 1993 compared to previous years were:

(i) Development of a narrow but semi-continuous fringe of wetland herbs and grasses around the water's edge in the northern reed pool and much of the Main Pond and Scrape.

(ii) Development of a sparse but distinct mixed meadow and marginal wetland community around the southern wet meadow area (which had previously been very poorly colonised).

(iii) The beginning of the development of communities of monodominant stands of tall emergents, particularly *Typha latifolia*, *Juncus inflexus*, *Phalaris arundinacea* and *Carex riparia*. *Phalaris* was the most common of these species: it not only extended outwards from the large existing stand on the northern edge of the meadow, but colonised new sites, particularly around some of the marginal pools. Individual plants of *Typha* also colonised the site widely, but have now been weeded out of many areas. Stands of *Juncus inflexus* locally colonised the muddy margins of some ponds and are becoming extensive on the more muddy islands.

(iv) *Phragmites australis*: the *Phragmites* beds which were planted up (using pot-grown stock) in 1991 developed well over most parts of their planting area. In many areas they sent out extensive aerial runners up to 15m in length, with new shoots rooting at node points. Locally, however, reed-bed development was patchy, particularly at the northern end of the northern reed pool where it is likely that the very high water levels which occurred during planting caused an initial die-back from which the plants have not recovered.

3.4 Vegetation cover

Not surprisingly, changes in vegetation cover were generally most pronounced in areas where cover was sparse in previous years. In particular, the wet meadow and pool area (which lies approximately 200mm above baseline water levels) developed a relatively open but continuous mixed meadow and marginal wetland community for the first time.

Submerged plants were more extensive over the site than they have been in previous years, and submerged plant communities were generally more diverse. In particular, large stands of *Chara vulgaris* developed over most of the northern and southern reed pools, whilst *Potamogeton pusillus* colonised much more widely, extending into the Scrape and the two northern temporary ponds for the first time since their creation.

3.4.1 Bare areas

One of the main aims for the design and creation of the Pinkhill site was to retain some shallow-water areas (for wading birds) which remained bare and muddy and needed little management.

It was noticeable around the site as a whole that the areas which retained most bare ground were the areas of clayey alluvial substrate around the water's edge. In particular this included:

(i) Areas at or a few centimetres below water level for most of the year, which presumably remained bare because of the stress of constant water level fluctuations.

(ii) Areas with relatively uniform and even slopes. It was noticeable that in areas where undulations reached more than a few centimetres above water level, this gave a "toehold" for the colonisation of wetland ruderals, which then spread out into deeper water.

(iii) Areas relatively distant from the existing meadow, presumably because this reduced the potential for transport of seeds and runners from adjacent plants.

The most extensive area to consistently retain bare ground on the site is the area of mud flats at the western side of the Main Pond. This area has all the attributes listed above, but in addition it is the area of the site most consistently used by feeding and roosting wading birds and waterfowl, and this may in itself help to keep the ground open.

3.5 The conservation value of the wetland plant community

The conservation value of the plant community of individual ponds has been assessed on the basis of:

(i) The number of wetland plant species present (see Table 3.1).
(ii) The occurrence of nationally uncommon plant species (see Table 3.2).

This information has been used to place each pond in one of four National Conservation Categories: low, moderate, high, or very high (see Table 3.3). Definitions of these categories are given in Table 3.4. More detailed descriptions of methods used to assess the conservation value of plant communities are given in the 1992 Interim Report.

3.5.1 Current conservation value of the site

Plant diversity at the Pinkhill site continued to increase in 1992/3. However, the overall conservation value of both the individual monitoring ponds and the site as a whole remained broadly similar to the previous year (see Table 3.3 below and 1992 Interim Report).

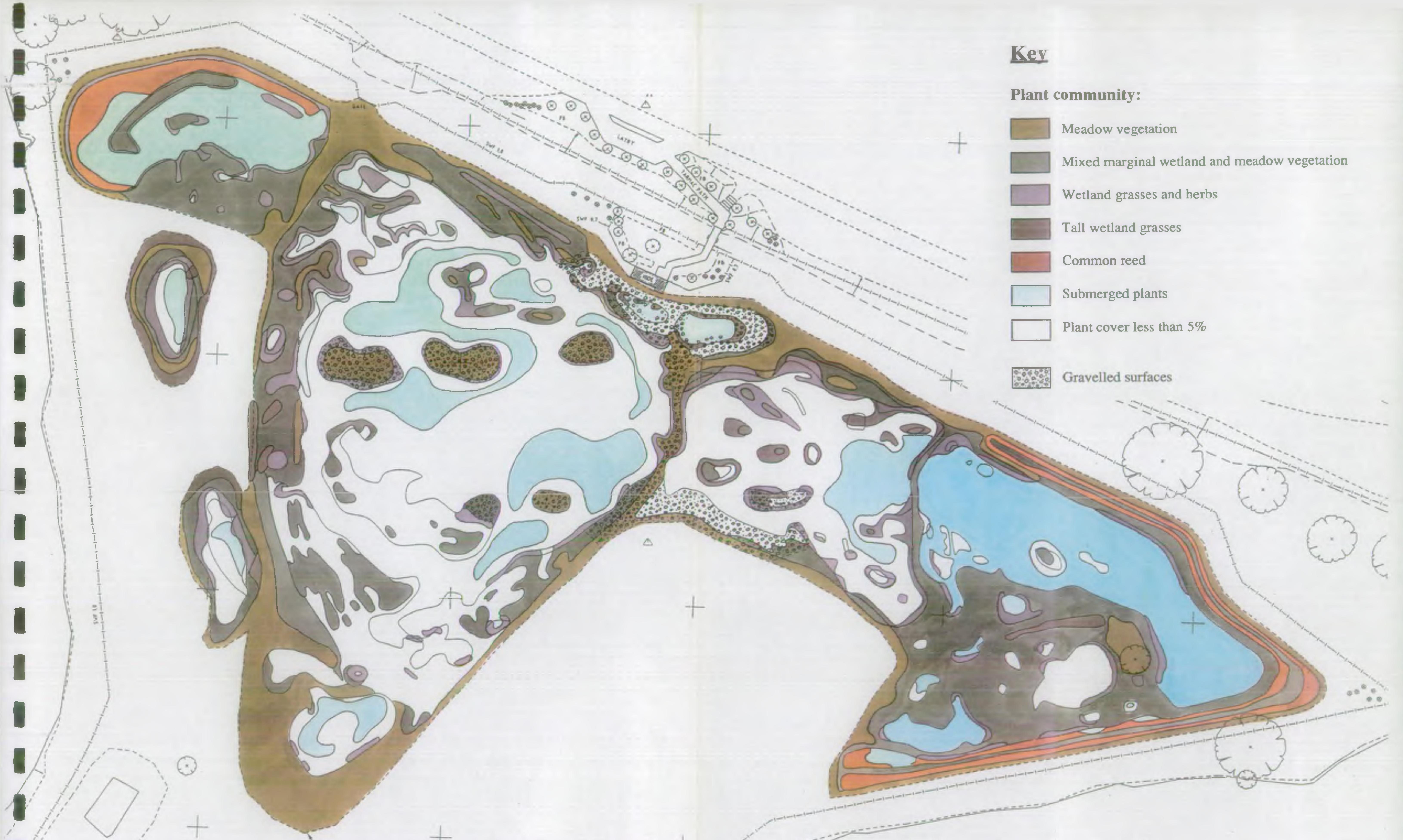
The most notable feature of the site was again the rich aquatic plant community, which includes eleven submerged species, of which five can be considered to have a nationally "local" distribution. The Main Pond retained the richest aquatic flora, although *Potamogeton pusillus* began to spread to other ponds during 1992/3 and others (e.g., *Myriophyllum spicatum*) may also do so in future years. On the other hand, one noticeable feature of many gravel-based river valley ponds in southern England is that they seem to support their richest communities in the early years, with later domination by single species stands of *Elodea* species. The first occurrence of *Elodea nuttallii* in the northern reed pool during 1993 may herald the beginning of this process.

One aquatic species, *Zannichellia palustris*, which colonised three areas of the northern reed pool during late summer 1992, was lost from the site. It has not reappeared in 1993.

The most notable marginal colonist to the site was Narrow-leaved Water-plantain (*Alisma lanceolatum*). Approximately 10 individual plants were recorded growing together with Common Water-plantain (*Alisma plantago-aquatica*) in very shallow water in the north-eastern corner of the Main Pond.

3.6 Monitoring of *Ophioglossum vulgatum* (Adderstongue Fern) relocation

During the Phase 1 excavation of the Pinkhill site in 1990 a one-metre square area of meadow turf supporting seven plants of *Ophioglossum vulgatum* was transported approximately 10m and replanted in an adjacent area of meadow. This turf was monitored between 1991 and 1993 to assess the outcome of the *Ophioglossum* relocation.



Map 2. Plant communities recorded from Pinkhill Meadow wetland (1993)

In 1991 and 1992 no specimens of *Ophioglossum* were recorded, either in the monitoring plot or in the meadow as a whole. It is likely that in 1993 this was, again, due to spring/early summer competition from surrounding tall rank vegetation in the meadow. The establishment of a more consistent cutting or grazing regime to the meadow may, however, encourage the reappearance of this species in future years.

3.7 Establishment of *Phragmites* reedbeds

Two *Phragmites* reedbeds were planted at Pinkhill in 1992 using pot-grown stock. The subsequent establishment of these beds proved very successful, and the following account provides a description of the method used.

(i) Pot-grown *Phragmites* were supplied by a commercial grower and planted at Pinkhill during June/July.

(ii) The *Phragmites* plants were introduced into trenches, with water levels 0-400m deep (but see point (iv) below).

(iii) The pot-grown stock was individually hand planted at a density of aproximatly five per square metre. The plants were planted directly into the inorganic alluvial substrates at the base of the trench. There was no pre-preparation of the bed by adding topsoil or a dressing of fertiliser. This was because in a trial planting the previous year it was found that adding topsoil led to rapid colonisation of the bed by wetland herbs and grasses such as *Alisma plantago-aquatica*, *Glyceria fluitans* and *Juncus inflexus*.

(iv) The planting success rate was one hundred per cent across most areas of the bed. The single exception was an area of deeper water in the northern reedbed where many of the plants rotted *in situ*. Observations made on site suggest that this occurred to plants which had all their leaves completely submerged at planting.

It is suggested, therefore, that pot-grown *Phragmites* should only be introduced into water which is shallow enough to leave at least one leaf-tip above water.

(v) The main disadvantages of using pot-grown *Phragmites* stock at the site were: (a) approximately 50 of the plants were not *Phragmites* but *Phalaris arundinacea* and these had to be removed; and (b) it is likely that a number of alien species were introduced to the site with the pot-grown stock. These include *Mimulus guttatus* (Monkey Flower) and possibly the invasive and potentially damaging species *Crassula helmsii*. Measures are now being taken to eradicate *Crassula* from the site.

Table 3.2 Uncommon wetland plants recorded from the Pinkhill Meadow wetland

Abbreviations:
MP - Main Pond **SW** - Surfacewater Pond **GW** - Ground-water Pond **SC** - Scrape **TS** - Total Site
Survey : **91** - Summer 1991 **9 2** - Summer 1992 **93** - Summer 1993

Local* species	**MP**			**GW**			**SW**			**SC**			**TS**		
	91	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**
Aquatic species															
Myriophyllum spicatum	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Potamogeton obtusifolius	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Potamogeton perfoliatus	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Potamogeton pusillus	-	+	+	-	-	+	-	-	+	-	-	+	-	+	+
Ranunculus trichophyllus	+	+	+	-	+	+	-	+	+	-	+	+	+	+	+
Zannichellia palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Marginal species															
Alisma lanceolatum	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
Bidens tripartita	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+
Carex riparia	-	+	+	-	+	+	+	+	+	-	-	+	+	+	+
Myosoton aquaticum	-	+	+	-	-	-	-	-	-	-	+	-	+	+	+
Veronica catenata	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+

*Local = Recorded from between 100 and 700 10 x 10 km grid squares in Britain. Note that the list of local species has been modified since 1992.

Table 3.3 Conservation value of the plant community

	MP			**GW**			**SW**			**SC**			**TS**		
	91	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**	**91**	**92**	**93**
Aquatic plants															
Score aquatic spp.	5	13	13	1	3	3	0	3	5	1	3	3	5	15	15
Index aquatic species	1.25	1.63	1.63	1.00	1.50	1.50	0	1.50	1.67	1.00	1.50	1.50	1.25	1.67	1.50
Conservation Category*	high	v.high	v.high	low	high	high	low	high	high	low	high	high	high	v.high	high
Marginal plants															
Score marginal spp.	16	32	40	12	15	21	11	11	18	16	23	27	16	23	27
Index marginal spp.	1.07	1.10	1.14	1.00	1.07	1.05	1.10	1.10	1.06	1.07	1.10	1.08	1.09	1.10	1.12
Conservation Category*	mod	mod	mod	low	mod	mod	mod	mod	mod	mod	mod	mod	mod	mod	mod
Total plants															
Score total spp.	21	45	53	13	18	24	11	14	23	17	26	30	40	59	70
Index total species	1.11	1.22	1.23	1.00	1.13	1.09	1.10	1.17	1.15	1.06	1.13	1.11	1.11	1.20	1.19
Conservation Category*	mod	high	high	low	mod	mod	mod	mod	mod	mod	mod	mod	mod	mod	mod

*See Table 3.6 and Appendix 3 for explanation

Table 3.4 Provisional system for assessing the conservation value of plant and aquatic macroinvertebrate communities

CONSERVATION CATEGORY	DESCRIPTION OF TYPE OF COMMUNITY
VERY HIGH	Typically supporting a very rich community of plant and/or macroinvertebrate species, including local and rare (RDB) species (though note that some sites with rare species can be relatively species-poor). Sites in this category would normally have National Conservation Indices in excess of 1.5.
HIGH	Supporting a rich community of common plants and/or macroinvertebrate species. Generally an above-average number of local species recorded. No RDB species. Sites in this category would normally have National Conservation Indices between 1.2 and 1.5.
MODERATE	Supporting a moderately rich or rich community of common plant and/or macroinvertebrate species, with at least one local species. Sites in this category would normally have National Conservation Indices between 1.01 and 1.19.
LOW	Supporting a species-poor community of common plants and macroinvertebrates. No rare or local species. Sites in this category will have National Conservation Indices of 1.00.

4. AQUATIC MACROINVERTEBRATES

4.1 Introduction

This section presents the results of studies of the macroinvertebrates in the four main survey ponds on Pinkhill Meadow: the Main Pond, Groundwater Pond, Surfacewater Pond and Scrape (See Map 1). This updates Section 4 of the 1992 Interim Report.

During the year following construction, five surveys of each pond were made. These surveys were carried out in July 1990, November 1990, February 1991 and May 1991. Further surveys were made 14 and 26 months later, in July 1992 and July 1993. The May 1991, July 1992 and July 1993 surveys were more detailed than those preceding them. Details of survey dates are given in Figure 1.1.

In addition to the surveys of these four individual ponds, surveys of the aquatic macroinvertebrates of the entire Pinkhill Meadow wetland were carried out in September 1992 and October 1993. The methodology for this survey (the "bug-hunt") was described in Appendix 4.1.3 of the 1992 Interim Report.

The surveys of the aquatic macroinvertebrates had three main aims:

(i) To describe the colonisation by macroinvertebrates of the four ponds.
(ii) To assess the nature conservation value of the macroinvertebrate communities of the four ponds.
(iii) To assess the relative importance for macroinvertebrates of different microhabitats within the ponds.

Colonisation of the ponds was described in terms of the numbers of species recorded in each pond and the abundance of individual species recorded in each pond. Macroinvertebrate community structure of the ponds was analysed using the ordination technique Detrended Correspondence Analysis (DECORANA).

The current nature conservation value of the communities was assessed using Pond Action's provisional technique for assessing the conservation value of invertebrate communities (see Table 3.4).

The value of the different microhabitats within each pond was assessed by comparing the number of species found in each microhabitat.

4.2 Results of the surveys of the Phase 1 ponds

4.2.1 The numbers of species recorded in the four ponds during the standard surveys

The numbers of invertebrate species recorded from the four ponds increased from between five and seven in the first (July 1990) sample, to between 46 and 57 in the final (July 93) sample. The cumulative total of species for all four ponds increased from 12 in July 1990 to 103 in July 1993.

As described in the 1992 Interim Report there has been a steady increase in the number of species recorded from the individual ponds since survey work began. In the first report it was noted that there were two main exceptions to the general trend. The numbers of species recorded declined over the first winter in the Main Pond and the Groundwater Pond and fewer species were recorded in the July 1992 survey of the Surfacewater Pond than in the preceding survey (May 1991). The further increase in species numbers in the ponds between July 1992 and July 1993 suggests that these decreases in species numbers were only temporary phenomena.

Numbers of species in the major groups of macroinvertebrates are summarised in Appendix 2.1. Full species lists for surveys of all four ponds in the six seasons are given in Appendix 2.2.

Table 4.1 Macroinvertebrate taxa collected at Pinkhill Meadow and the taxonomic levels to which they were identified

Groups identified to species level (where present)

Tricladida	(Flatworms)
Hirudinea	(Leeches)
Gastropoda	(Snails and limpets)
Bivalvia (excluding *Pisidium* sp.)	(Bivalves)
Malacostraca	(Shrimps and slaters)
Ephemeroptera	(Mayflies)
Odonata	(Dragonflies and damselflies)
Plecoptera	(Stoneflies)
Heteroptera	(Water bugs)
Megaloptera	(Alderflies)
Trichoptera	(Caddis flies)
Coleoptera*	(Water beetles)

*Adults from the following families of Coleoptera were identified: Dryopidae, Elminthidae, Gyrinidae, Hygrobiidae, Haliplidae, Noteridae, Dytiscidae, Heteroceridae, Hydraenidae, Hydrophilidae.

Table 4.2 Correlation of DECORANA axes with macroinvertebrate composition of microhabitat samples (1991, 1992 and 1993 surveys)

	Axis 1	Axis 2
Total species	------	+
% composition		
Gastropoda	------	++++++
Hirudinea	------	ns
Malacostraca	------	++
Ephemeroptera	++++++	--
Odonata	------	------
Heteroptera	ns	------
Coleoptera	ns	++++++
Megaloptera	------	---
Trichoptera	++++++	ns

Spearman's rank correlation. All correlations adjusted for ties. - =negative correlation. + = positive correlation. Levels of significance. p=<0.05 (+); p=<0.01 (++); p=<0.005 (+++); p=<0.001 (++++); p=<0.0005 (+++++); p=<0.0001 (++++++). ns = not significant.

4.2.2 Abundance of macroinvertebrates in the standard surveys

During the first twelve months of colonisation, the abundance of macroinvertebrates increased throughout the year (though with a slight decrease after the winter months). Some species (for example, the mayflies *Cloeon dipterum* and *Caenis luctuosa* and the diving beetle *Hydroglyphus pusillus*) were particularly abundant during the first year.

In the July 1992 survey, after the second year of colonisation, the total abundance of specimens and the abundance of several species was much less than in the previous survey (May 1991). In terms of total numbers of specimens recorded from all four ponds, the decrease was from 8,785 in May 1991 to 2,576 in July 1992. The July 1993 survey showed an increase in number of specimens recorded to 9,727, with all ponds showing larger numbers of specimens collected than during the 1992 survey. This was particularly marked in the scrape, where specimen numbers increased from 418 to 4,885 between the two surveys. The decrease in numbers of mayflies, which had been largely responsible for the overall decrease seen in the July 1992 survey, has been compensated for in the July 1993 survey by an increase in specimens from other groups (most notably the snails).

Of the three species which were noted to have declined between the May 1991 and July 1992 surveys (a mayfly, *Caenis luctuosa*, a lesser water boatman, *Sigara lateralis*, and a diving beetle, *Hydroglyphus pusillus*), only *Caenis luctuosa* has continued to decline. In May 1991, 5,749 specimens of this species were recorded, compared with 41 in July 1992 and 32 in July 1993. The possibility that this is an effect of season rather than year cannot be ruled out since all species of mayfly, with the exception of *Caenis horaria*, were present in greater numbers in the May 1991 survey than in either of the two subsequent surveys.

Sigara lateralis, which had declined from 303 to 57 specimens between May 1991 and July 1992, had increased in number again to 1,400 specimens in July 1993. One other lesser water boatman, the locally uncommon species *Arctocorisa germari*, did show a consistent decrease during the three surveys (28 specimens in May 1991, 14 in July 1992 and four in July 1993). This was parallelled by a decrease in the frequency of its occurrence in the microhabitat samples (from 14 samples in May 1991 to just two samples in July 1993). *Hydroglyphus pusillus*, which had declined in the July 1992 survey, had increased by the July 1993 survey to numbers comparable with the May 1991 survey.

Species from the slower-colonising groups continue to increase in abundance. The Wandering Snail (*Lymnaea peregra*) increased from nil specimens in May 1991 to 89 specimens (from 21 microhabitat samples) in July 1992, to 2,491 specimens (from 61 microhabitat samples) in July 1993. These trends reflect the general increase in abundance of species of snail, leech and Crustacea on the site. All species in these groups (now totalling 18), with two minor exceptions, show an increase in abundance over the three surveys.

Increases in abundance are not confined to the slower-colonising groups. Species such as the lesser water boatmen *Corixa punctata* and *Corixa panzeri*, and beetles such as *Laccophilus minutus* and the Nationally Notable B species *Laccobius sinuatus*, have also shown consistent increases. The Nationally Notable A species *Coelambus nigrolineatus* (previously classified as RDB3*), which had decreased between the May 1991 survey (19 specimens) and the July 1991 survey (one specimen), was again present in good numbers (24 specimens) in the July 1992 survey.

4.2.3 Composition of the macroinvertebrate communities of the ponds shown by the standard surveys

The 1992 Interim Report noted that early colonisation of the site had been primarily by beetles and bugs and these groups still constituted a major component of the fauna of the ponds in July 1992 (between 33% and 54% in the case of the beetles). Although the numbers of beetle species have generally increased between the July 1992 survey (with ten to 18 species in the ponds) and the July 1993 survey (17 to 19 species in the ponds), the percentage of beetle species has decreased slightly, with between 30% and 39% of species being beetles in the July 1993 survey compared to between 33% and 54% in the July 1992 survey.

The water bugs, which also contributed significantly to species-richness (between 18% and 27%), continue to constitute a major part of the species richness (between 17% and 27% in the July 1993 survey).

With the maturation of the communities, the number of species of the more slowly colonising groups is increasing. Taking the flatworms, snails, leeches and Crustacea as a whole, over the whole site, the number of species has increased from three in the May 1991 survey to seven in the 1992 survey, and to 19 in the July 1993 survey. This increase in the numbers of these groups is almost certainly not complete. The Main Pond alone may be expected to support at least 18 species of snails when it has matured fully.

The rich still-water mayfly community mentioned in the previous report is still present, though some species seem to be scarcer on site than previously. *Caenis luctuosa*, recorded present in 63 of the 64 microhabitat samples in May 1991, declined to only 15 (July 1992) and 16 (July 1993) of the later microhabitat samples. Similarly, *Ephemera vulgata* decreased in frequency of recording from 14 microhabitat samples in May 1991 to four and one microhabitat samples in July 1992 and July 1993 respectively. Again, as with numbers of specimens (see earlier comments), these may be seasonal effects.

Dragonflies continue to increase in numbers on the site with the July 1992 survey seeing the first larval records of the Azure Damselfy (*Coenagrion puella*) and the Four-Spotted Chaser (*Libellula quadrimaculata*).

There were more records of caddisflies in the July 1993 survey than in previous surveys (5 species). However, the number of still-water caddisflies which can be recorded as larvae in summer is limited and the full importance of the site for this order is difficult to assess without a spring survey.

4.3 DECORANA analysis of the microhabitat surveys

4.3.1 Differences in the communities of the four ponds as demonstrated by DECORANA

Data set, analysis and presentation

Macroinvertebrate species abundance data, obtained from the May 1991, July 1992 and July 1993 microhabitat sampling, was analysed using the ordination technique Detrended Correspondence Analysis, running as the Fortran programme DECORANA. The data-set consisted of 192 samples from four sites in the three seasons.

Each polygon on the DECORANA diagram (see Figure 4.1) encloses the ordination coordinates of the microhabitat samples (not shown individually) from one pond in one season.[1] In this way, the polygons represent, graphically, the total range of variation in the macroinvertebrate communities of each pond in each season.

The analysis of the 1991, 1992 and 1993 data

The addition of the data from the 1993 survey allows a re-interpretation of the data from all three seasons of sampling. In the previous report it was noted that both the DECORANA analyses of the 1991 data and the 1991/1992 data showed significant correlations with the bugs and the beetles. After the addition of the 1993 data, and with more species of other groups present in the four ponds, a fuller examination of the relationship of the DECORANA axes and the different groups of invertebrates is desirable. The total number of species, and the proportion of species in each of the major groups (with the exception of flatworms) in each of the microhabitat samples has been correlated (Spearman's rank correlation) with the first and second axes of DECORANA. Results of these analyses are given in Table 4.2.

As with the 1991/92 analysis, the present analysis separates the three years of sampling on the first axis of DECORANA. Though there is some overlap, in a one way analysis of variance the separation of the three seasons is seen to be significant ($p=<0.0001$, F test) and each year is separated from each other year ($p<0.05$, Scheffé test). Similarly, in any given year, the ponds are also separated ($p<.0001$, F test).

[1] Note: Two samples from the 1992 and two from the 1993 survey differed significantly from the other samples taken from these ponds. In order to simplify visual interpretation, these are plotted separately on the diagram.

With the continued importance of bugs and beetles as a component of species-richness in 1993, the earlier (1991/92) correlation of proportions of beetles and bugs with the first axis is no longer evident. All other groups, however, are significantly correlated (positively or negatively) with axis 1. The proportions of two groups, the mayflies and the caddisflies, are positively correlated with axis 1 and the proportions of all other groups, and total number of species, are positively correlated with this axis.

In terms of individual species, several are indicative of the left-hand side of the axis and a few are indicative of the right-hand side. In practice, as with the 1991/1992 analysis, these are species which have either increased or declined (respectively) over the period of sampling. Thus, the species most indicative of the right-hand side of the axis is a mayfly, *Caenis luctuosa*, which was present in 63 of the 64 microhabitat samples from 1991 and only 31 of the total 128 microhabitat samples from 1992 and 1993. In terms of numbers of specimens, this species was recorded in numbers greater than five in 62 of the 64 1991 samples, but only two of the 1992/1993 samples. Several species are indicative of the left-hand side of the axis, including the Wandering Snail (*Lymnaea peregra*), the Dwarf Pond Snail (*Lymnaea truncatula*), the Common Darter (*Sympetrum striolatum*), and the Black-tailed Skimmer (*Orthetrum cancellatum*).

The correlation between water beetles and the top of axis 2, and water bugs and the bottom of axis 2, which was seen in the 1991/1992 analysis, is maintained with the addition of the extra data from the 1993 survey. In addition, the snails and crustaceans are significantly correlated with the top of the axis, and the dragonflies, mayflies and alderflies with the bottom of the axis.

Individual species are also characteristic of the top and bottom of the axis. Several species of beetles and snails are associated with the top of axis 2, though only beetle species were recorded frequently enough to be considered to be characteristic. Of those species most characteristic were the hydrophilid beetles *Laccobius sinuatus* and its congener *Laccobius striatulus*. These two species have increased and decreased respectively with the colonisation of the site and, thus, show dissimilar associations with the first axis. They nevertheless characterise the second axis well. A diving beetle, *Hydroglyphus pusillus*, is also characteristic of the top of the second axis, despite a decline in numbers of specimens recorded in the second year.

The bottom of the second axis is characterised principally by species of bug and, to a lesser extent, dragonflies. The lesser water boatmen *Sigara falleni* and *Sigara distincta* are both characteristic with the former, showing a decline over the period of survey and the latter an increase. The Common Darter is also characteristic of the bottom of the axis though this species was recorded only once in the May 1991 survey.

4.3.2 Environmental factors causing differences in the composition of the macroinvertebrate communities

In the 1992 Interim Report it was concluded that the variation along the first axis of DECORANA was either due to the maturation of the site or to a seasonal difference. With the continued movement of the microhabitats along the axis in the third season it seems most probable that the differences are due, principally, to the continued process of colonisation rather than a seasonal difference.

In Figure 4.1 the second axis of DECORANA does not appear to separate the ponds particularly well. In order to investigate those factors which are important on this axis the scores from the axis were analysed in a two-way analysis of variance (ANOV), with year and pond as possible sources of variation. The analysis shows that averaged over all ponds the years are in fact separated on the axes ($p=<0.002$), with the first and third years being slightly higher on the axis. Averaged over all years the ponds are also separated on the second axis ($p=<0.0001$), with the Scrape being the highest, followed by the Main Pond, the Surfacewater Pond and the Groundwater Pond. Furthermore, there is an interaction between year and pond ($p=<0.0001$), suggesting that within any given year ponds differ on axis 2, but not necessarily in the same order each year. This interaction makes the analysis difficult to interpret.

The possibility that habitat is a major factor in macroinvertebrate composition was investigated by assessing each habitat as either emergent and floating vegetation, inorganic, or aquatic vegetation. These categories were used in a one-way ANOV of axis 2. The results show that habitat is important on the second axis ($p=<0.0001$), with emergent/floating vegetation habitats at the top of the axis, inorganic habitats in the middle of the axis, and aquatic habitats at the bottom of the axis. All habitat groups test as being separate from each other using a Scheffé test ($p=<0.05$).

Ideally, habitats as a possible source of variation would be assessed as part of a three-way ANOV, with year and pond as the other two sources of possible variation. However, the data set is heavily imbalanced by the lack of some vegetation types in some years and in some ponds in some years making the analysis difficult. In order, therefore, to test the possibility, in any given year, in any given pond, that habitat type is an important factor in determining the position on the second axis, 12 separate one-way ANOVs were run on the effect of habitat in each pond in each year. Of course, where only two habitats existed, the one-way ANOV reduces to a Student t test and in one case (Groundwater 1991) no analysis was possible as only one habitat type was present. The analyses show that in seven of the 11 cases tested the order emergent/floating, inorganic, and aquatic, on the second axis, was maintained. In all four cases where a difference between habitat type was significant ($p=<0.005$), this order was also seen. Notably, three of the four cases where significant differences were found were in 1993, and these were all sites where aquatic vegetation was well developed.

The number of species in each microhabitat was also tested to determine differences between the three habitat types. The number of species in each type was significantly different ($p=<0.0001$), and each tested separately from the other (Scheffé test, $p=<0.05$). Average species numbers in emergent/floating, inorganic and aquatic habitat types were 7.9, 12.3 and 17.0 respectively. Of course, this analysis will be affected by the fact that no emergent habitats were present at an early stage of colonisation, when species numbers were generally lower. In order to remove this possibility 11 separate analyses were carried out on species numbers in any given year in any given site. In nine of the 11 analyses, and in all four where habitat type was significantly different in a one-way ANOV, the inorganic habitat had less species than the emergent habitat. In three of the five cases where aquatic habitats were present, these had higher species numbers. It seems likely, therefore, that any vegetation is better than no vegetation, but that it is not possible at this stage to comment on the relative merits of emergent/floating and submerged aquatic habitats.

The results from these analyses of species richness suggest the possibility that the second axis of DECORANA is, in fact, principally a split between good emergent/floating habitats at the top of the axis and submerged aquatic habitats at the bottom. The presence of the species-poor inorganic habitats in the middle of the axis might be due to the fauna here being composed, principally, of animals which normally prefer either of the other two habitats, but which use this habitat in an adventitious manner.

The ponds at Pinkhill are becoming more densely vegetated, and both emergent and aquatic habitats are developing well. The results from the 1994 survey should allow a more definitive analysis of some of the questions raised here.

4.4 The relative importance of different microhabitats for macroinvertebrates of the four Phase 1 ponds

The species-richness of each microhabitat is listed in Table 4.3. The range of microhabitats within the ponds during the 1991 and 1992 surveys was rather small, mainly because of the sparseness of aquatic and marginal plants. In the 1993 survey the range of microhabitats had increased, particularly in the Main Pond and the Scrape. In general, as well as increasing in diversity, the microhabitats were also better established. For example, the grasses microhabitat in the Scrape in 1991 and 1992 consisted of somewhat sparse stands of grasses, whereas by the 1993 surveys more luxuriant stands had developed.

Over all three years, the species-richness of the microhabitats has increased. In the May 1991 survey, species-richness varied from five species (open water microhabitat of the Scrape) to 16 species (marginal grass/*Chara* sp. microhabitat of the Main Pond). In the July 1992 survey, species-richness varied from three species (deep ruts in the Surfacewater Pond) to 28 species (*Chara* sp. in the Main Pond). In the July 1993 survey, species-richness varied from 13 species (*Juncus inflexus* in the Groundwater Pond) to 33 species (*Chara* sp. in the Main Pond).

The increase in species-richness over the three years is not solely a result of the increase in number of microhabitats. In most recognisably similar habitats between the three years, the number of species has increased. For example, gravel habitats in 1993 appear to be more species-rich than gravel habitats in 1991. This pattern is not always consistent, as the 1992 survey found less species in some microhabitats (particularly those in the Groundwater and Surfacewater Ponds) than the 1991 survey. Nevertheless, there is an overall trend of increasing species-richness.

Because of the number of different microhabitat types, it is not feasible to statistically test the importance of each microhabitat type. Nevertheless, some microhabitats do appear to be consistently richer than others in the survey. In particular, both aquatic plant microhabitats, *Chara* sp. and *Potamogeton* species (mainly *P. pusillus*), usually show high species richness. The emergent/floating species seem more variable as microhabitats, with only the grasses microhabitats being consistently species-rich. This is probably a reflection of the sparser nature of some of the other microhabitats.

4.5 The nature conservation value of the macroinvertebrate communities in the four Phase 1 ponds

The cumulative total of 107 species recorded during the standard surveys included one Nationally Notable A, four Nationally Notable B and 12 local species. In addition to this, one other Nationally Notable B species was recorded during the "bug hunt" in the Main Pond. The occurrence of uncommon species on the Pinkhill site is detailed in Appendix 2.3. Definitions of terms used to describe the rarity of species are given in Table 3.5 in the 1992 Interim Report.

National Conservation Indices were calculated for all the ponds (see Appendix 2.1). This index is explained in Appendix 4.1.4 of the 1992 Interim Report. Values of the index associated with the different categories of conservation value are given, together with criteria for assessing the conservation value of macroinvertebrate communities, in Appendix 2.1.

All four of the Phase 1 ponds supported communities which were of "high" conservation value. The last three seasons' National Conservation Indices (NCIs) for the four sites vary between 1.18 (Surfacewater Pond in 1992) and 1.42 (Scrape in 1991). Only on one occasion (Surfacewater Pond 1992) has a NCI dropped below 1.2 and, therefore, to the lower "moderate" conservation value banding. All the ponds have relatively rich macroinvertebrate communities, with good numbers of local and notable species, and the richness of the ponds is still increasing.

The 1992 Interim Report noted that the water beetle *Coelambus nigrolineatus* was only provisionally categorised as "rare" (it was a Red Data Book 3* species). The "rare" classification has now been dropped (Hyman and Parsons, 1992) to Nationally Notable A. However, we have categorised this species as Nationally Notable B for the purpose of calculating NCIs, owing to the uncertainty surrounding its distribution and current range expansion.

With species-rich communities, good numbers of local and Nationally Notable species, and NCIs which rarely drop below 1.2, the four main ponds should be regarded as being of high value for nature conservation.

When the results for the "bug-hunts" are put together with those of the main surveys, the total number of aquatic macroinvertebrate species recorded from Pinkhill Meadows is 120. This is approximately equivalent to 16% of the British list in those groups identified to species level.

4.6 Results of the 1993 "bug-hunt" survey across the entire Pinkhill wetland site

4.6.1 Introduction

The "bug-hunt" survey involves the on-site collection and sorting of aquatic macroinvertebrates from waterbodies across the whole site. Its aim is to cover areas of the site not included in the three-minute samples from the four Phase 1 ponds, and pick up species which might otherwise have been missed. The results can be used to:

(i) Assess the progress of macroinvertebrate colonisation over the entire wetland site.

(ii) Further update the assessment of the nature conservation value of the macroinvertebrate community of the whole wetland.

In 1993 the "bug-hunt" was undertaken on 15 and 21 October 1993. The methodology used is described in Appendix 4.1.3 of the 1992 Interim Report.

4.6.2 The number of species recorded in the 14 different areas surveyed

The total number of macroinvertebrate species recorded in the "bug-hunt" in 1993 was 101. Of these, 13 species have not been recorded in other surveys from the site. Two of these new species are Nationally Notable B: the water beetles *Enochrus melanocephalus* and *Berosus signaticollis*. In addition, species from two groups not previously found at all on the site (two orb mussels and one stonefly) were recorded.

New species were recorded from most of the 14 sections of the site surveyed. The four main exceptions were the Groundwater Pond, the Scrape, the northern section of the southern reed pond and the southern *Phragmites* bed. Interestingly, consistently fewer species were also recorded from each of these sections than in the 1992 "bug-hunt". Most other sections surveyed produced greater numbers of species, with the largest increase being 18. Overall, however, a Wilcoxon signed rank test of numbers of species in the various areas in 1992 and 1993 showed no significant difference between the two years.

The new species records tended to be distributed singly around the site: hence, the bivalves *Sphaerium corneum* and *Sphaerium lacustre* were found only in the old *Phragmites* bed, and the Keeled Ramshorn *Planorbis carinatus* was recorded only in the southern section of the southern reed pond. The caddis fly larvae *Athripsodes aterrimus* and *Molanna angustata* were recorded only from the Dragonfly Ponds in front of the hide and the west of the Main Pond respectively. The beetles *Agabus sturmii* (in the northern Temporary Ponds), *Berosus signaticollis* (in the undulating margins around the north of the Main Pond), and *Hydroporus angustatus* (in the old *Phragmites* bed) were each recorded from one site only. An adult female stonefly, *Leuctra geniculata* (again, a new order for the site), was recorded amongst the pools in the wet meadow area.

Other new species were recorded from a small number of sites (for example, the Saucer Bug *Ilyocoris cimicoides*, the beetle *Enochrus melanocephalus*, the Water Scorpion *Nepa cinerea* and the beetle *Helophorus aequalis).* However, none was recorded from more than three areas.

The areas which showed the greatest increases in species numbers since the 1992 "bug-hunt" were the northern *Phragmites* bed (from 30 species to 45); the Dragonfly Ponds (from 31 species to 48); and the northern temporary ponds (from 28 species to 46). Most of the species accounting for these increases were snails, crustaceans, bugs and beetles.

Most invertebrate species which were widely distributed across the site in 1992 appear to have remained so in 1993: for example, the snails *Lymnaea peregra* and *Lymnaea truncatula* and the water slater *Asellus aquaticus* were again recorded from almost every section surveyed. So too were the mayfly *Cloeon dipterum*, the Blue-tailed Damselfly *Ischnura elegans*, the Black-tailed Skimmer *Orthetrum cancellatum*, a number of water bugs (*Corixa panzeri*, *Notonecta glauca*, *Notonecta marmorea viridis*, *Sigara distincta* and *S. lateralis*), and beetles

(*Hydroglyphus pusillus*, *Hygrotus inaequalis* and *Laccophilus minutus*).

Species which seem to be increasing on the site include the snail *Anisus vortex* and the freshwater shrimp *Crangonyx pseudogracilis*, both of which were very much more numerous than before. Species which currently appear to be declining in their range include the water beetles *Coelambus impressopunctatus* and *Laccobius striatulus*, the bugs *Sigara nigrolineata* and *Gerris thoracicus*, and the mayfly *Cloeon simile*.

A complete summary of macroinvertebrate species recorded from all 14 sections of the Pinkhill site during the 1992 and 1993 "bug-hunts" is given in tabular form in Appendix 2.5.

4.6.3 Differences in the macroinvertebrate communities on the site

As noted above, there were no significant differences in total number of species recorded from the different areas of the site in the two years. However, three groups, the snails, the crustaceans and the alderflies, showed significant increases in species numbers over the two years (Wilcoxon signed rank test; $p=<0.005$, $p=<0.05$ and $p=<0.05$ respectively). Similarly, increases in percentage composition of these groups was also noted. Only two crustaceans and one alderfly are present on the site.

Two groups of invertebrates were significantly correlated (Spearman's rank correlation) with their proximity to the south-east corner of the site. Snails were positively correlated in both 1992 and 1993 (i.e., there were more species in the south-eastern corner) ($p=<0.05$), whilst beetles were negatively correlated in 1993 only (i.e., there were relatively few species in this area) ($p=<0.005$).

The correlation of snails may reflect inputs of floodwater from the River Thames, whilst the correlation between water beetles may be due to the snails displacing some of the beetles' more usual prey, such as mayflies.

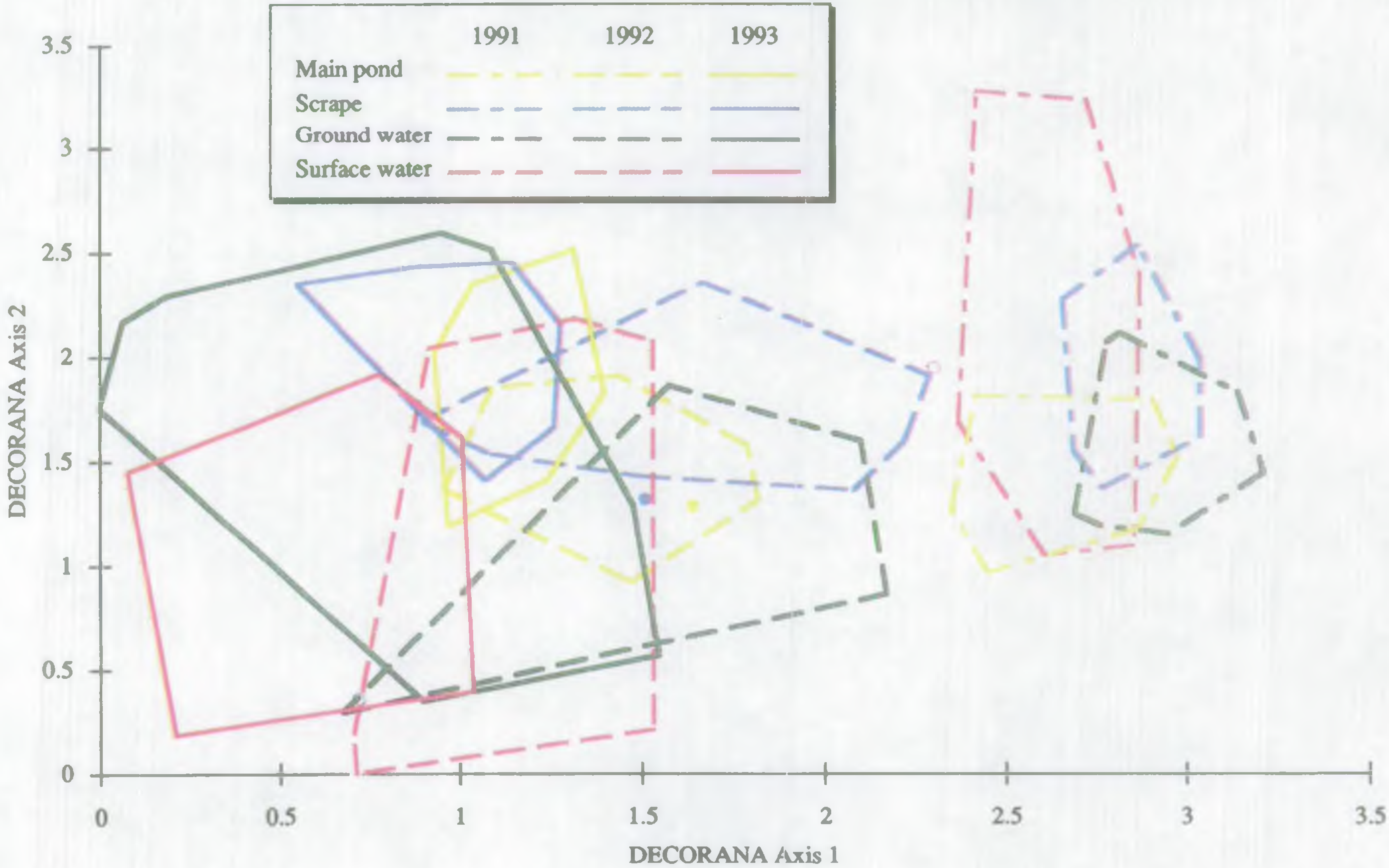
Two groups, the snails and the mayflies were significantly correlated with depth, with mayflies preferring deeper sites and snails shallower sites. The correlation with depth and mayflies was seen before with the 1992 "bug-hunt", and is possibly due to the preference of some species for more inorganic habitats. That snails prefer shallow sites is, perhaps, not surprising. Only one species of prosobranch snail (*Potamopyrgus jenkinsi*) was recorded during the "bug-hunt", so the snail fauna is composed largely of the pulmonate snails which are much better adapted to shallow water.

Age of the ponds was a significant (Mann-Whitney U test) predictor for two groups of animals: the leeches were positively correlated with age ($p=<0.05$) and the bugs were negatively correlated with age ($p=<0.05$). The result for the leeches is the same as demonstrated for the 1992 results. The result for bugs is possibly due to the aquatic vegetation being better developed in many of the younger ponds than in the older ones and not an age effect at all.

Table 4.3 Numbers of species recorded in each microhabitat in the spring and summer surveys

1991 Site & habitat	No. of spp.	1992 Site & habitat	No. of spp.	1993 Site & habitat	No. of spp.
Main Pond		**Main Pond**		**Main Pond**	
Grasses & *Chara* sp.(B)	16	*Chara* sp.	28	*Chara* sp.	33
Sandy/muddy bank (A)	16	Grasses (shallow)	27	*Juncus articulatus*	31
Shingle (B)	15	Grasses (deep)	25	*Potamogeton* sp.	30
Open water (B)	14	*Potamogeton* sp.	22	Grasses	25
Grasses & *Chara* sp.(A)	13	*Juncus* sp.	21	*Juncus effusus/inflexus*	24
Open water (A)	12	Mud (deep)	19	Gravels	23
Sandy/muddy bank (B)	11	Gravels	15	Other emergent vegetation	20
Shingle (A)	11	Mud (shallow)	8	Muddy bank	19
Groundwater Pond		**Groundwater Pond**		**Groundwater Pond**	
Gravels (deep) (D)	14	Gravels & mud (shallow) (A)	11	*Chara* sp. (A)	23
Gravels (deep) (C)	13	Grasses (A)	10	*Potamogeton* sp.(B)	19
Gravels (deep) (B)	12	Grasses (B)	8	*Potamogeton* sp.(A)	18
Gravels & mud (shallow) (B)	10	*Juncus* sp. (A)	8	Grasses & *Juncus articulatus* (A)	15
Gravels & mud (shallow) (D)	10	*Juncus* sp. (B)	8	*Chara* sp. (B)	15
Gravels & mud (shallow) (C)	9	Gravels & mud (shallow) (B)	8	*Juncus inflexus* (A)	14
Gravels & mud (shallow) (A)	8	Gravels (deep) (A)	6	Grasses & *Juncus articulatus* (B)	13
Gravels (deep) (A)	6	Gravels (deep) (B)	4	*Juncus inflexus* (A)	13
Surfacewater Pond		**Surfacewater Pond**		**Surfacewater Pond**	
Grasses (B)	14	Grasses (B)	18	*Carex* sp. & *Juncus* sp. (B)	28
Grasses (B)	13	Grasses (B)	14	*Carex* sp. & *Juncus* sp. (A)	25
Deep ruts (A)	13	Shallow ruts (A)	14	*Potamogeton* sp. & *Chara* sp. (B)	23
Shallow ruts (A)	12	Shallow ruts (B)	8	Muddy bank (shallow) (B)	18
Smooth shallows (B)	11	Smooth shallow (A)	7	Muddy bank (deep) (A)	17
Shallow ruts (B)	11	Smooth shallow (B)	7	*Potamogeton* sp. & *Chara* sp. (A)	17
Smooth shallows (A)	9	Deep ruts (B)	7	Muddy bank (deep) (B)	14
Deep ruts (B)	8	Deep ruts (A)	3	Muddy bank (shallow) (A)	14
Scrape		**Scrape**		**Scrape**	
Open water (B)	11	Muddy bank (A)	16	*Potamogeton* sp.	32
Shingle (B)	11	Grasses (B)	15	Grasses	30
Muddy bank (A)	10	*Juncus* sp. & grasses (A)	13	Gravels	25
Shingle (B)	9	*Juncus* sp. & grasses (B)	13	*Chara* sp.	24
Grasses (A)	9	Grasses (B)	10	*Juncus articulatus*	22
Grasses (B)	8	Muddy bank (A)	10	*Alisma plantago-aquatica*	21
Muddy bank (B)	7	Gravels (A)	10	*Veronica beccabunga*	20
Open water (A)	5	Gravels (B)	8	*Juncus inflexus*	14

Figure 4.1 DECORANA ordination showing the development of macroinvertebrate communities of four ponds on Pinkhill Meadows between 1991 and 1993.



5. BIRDS

5.1 Objectives of bird monitoring work

Bird monitoring at the Pinkhill site has three main objectives:

1. Record the species of waders and waterfowl using the Pinkhill Meadow wetlands.

2. Determine which areas of the Pinkhill wetlands are most attractive to different wetland birds.

3. Determine whether numbers of waders using the Farmoor site as a whole have increased following the creation of the new wetlands (i.e., are more birds attracted to Farmoor because of the Pinkhill wetlands, or do the same number of birds simply redistribute themselves on the site).

   Interim results of these three aspects of the monitoring programme are described below. Survey and analytical methods are described in Appendix 5.1. The programme of work undertaken to date is summarised in Figure 1.1 (page 4).

5.2 Interim results of objective 1: waders and waterfowl recorded on the Pinkhill Meadow wetlands

5.2.1 Sources of data

Four sources of data have been used in compiling the species list for the Pinkhill wetlands:

(i) The 1991 Spring and Autumn monitoring programme results (surveys undertaken by Pond Action).
(ii) Observations recorded by birdwatchers in the Farmoor Reservoir log-book.
(iii) Habitat-preferences monitoring data from Spring 1992 onwards (surveys undertaken by Pond Action).
(iv) Observations recorded by birdwatchers in the newly established Pinkhill Meadow log-book (from June 1992 onwards).

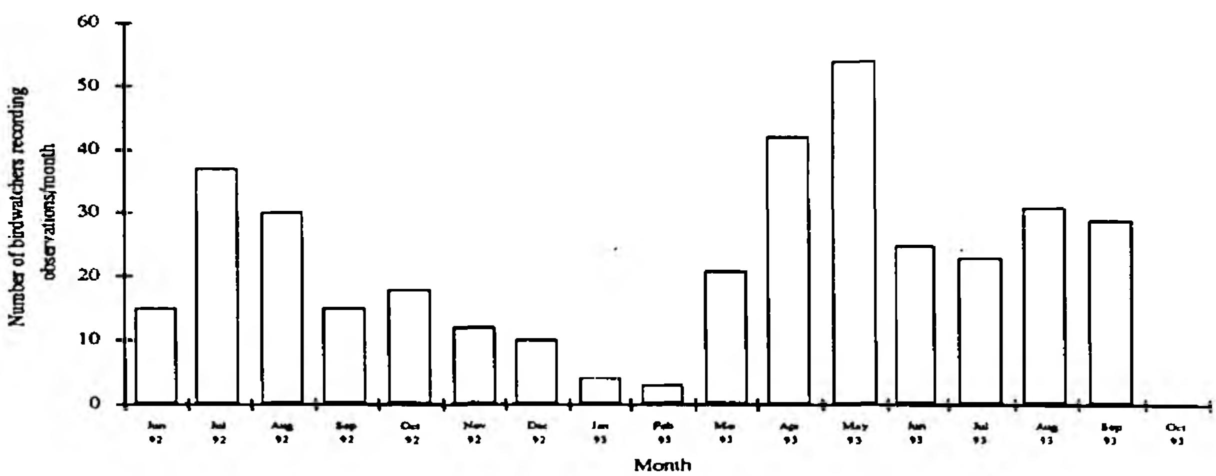


Figure 5.1 Number of birdwatchers recording observations in the Pinkhill Meadow log-book between June 1992 and September 1993

Table 5.1 Wetland birds (excluding passerines) recorded on the Pinkhill Meadow wetlands, May 1990 to September 1993

	1990-1991	1992	1993
Great crested grebe		+	
Little grebe		+	+
Cormorant		+	
Heron		+	+
Mute swan	+	+	+
Canada goose	+	+	+
Shelduck	+		+
Mallard	+	+	+
Gadwall		+	+
Pintail		+	
Teal			+
Garganey		+	
Shoveler			+
Tufted duck	+	B	?B
Water rail			+
Moorhen		+	+
Coot		+	+
Oystercatcher	+	+	+
Little-ringed plover	+	B	B
Ringed plover	+	+	+
Lapwing	+	B	B
Grey plover			+
Turnstone			+
Dunlin	+	+	+
Temminck's stint	+		
Sanderling		+	
Redshank		+	+
Greenshank	+	+	+
Common sandpiper	+	+	+
Green sandpiper	+	+	
Curlew		+	+
Whimbrel	+	+	
Bar-tailed godwit	+		+
Black-tailed godwit		+	
Snipe	+	+	+
Jack snipe			+
Common gull			+
Black-headed gull	+	+	+
Lesser black-backed gull		+	
Black tern			+
Common tern	+	+	+
Little tern	+		
Kingfisher		+	+
Number of wetland species recorded (cumulative total in parentheses)	**21 (21)**	**29 (34)**	**32 (43)**
Number of wader species recorded (cumulative total in parentheses)	**12 (12)**	**14 (16)**	**14 (18)**

Sources of data:

(i) The 1991 Spring and Autumn monitoring programme results (surveys undertaken by Pond Action).
(ii) Observations recorde by birdwatchers in the Farmoor Reservoir log-book.
(iii) Habitat-preferences monitoring data from Spring 1992 onwards (surveys undertaken by Pond Action).
(iv) Observations recorded by birdwatchers in the newly established Pinkhill Meadow log-book (from June 1992 onwards).

5.2.2 Wetland birds recorded on Pinkhill Meadow, June 1990 to September 1993

This section summarises the main changes in the bird community in 1993. Breeding species are described in more detail in the next section. Table 5.1 lists the wetland birds (excluding wetland passerines like Pied Wagtails and Reed Buntings) recorded on Pinkhill Meadow since May 1990.

Since the construction of the Pinkhill wetlands, 43 wetland bird species have been recorded on the site (see Table 5.1), including 18 wader species. The number of species recorded so far in 1993 (to September) is slightly greater than the total for 1992. During 1993 the first reported observations of Jack Snipe, Water Rail, Turnstone and Black Tern were made, although all were noted only once. Teal were also recorded for the first time, using the Scrape as it dried down in late August and early September. Moorhens were also more frequently seen on the site in 1993, presumably because of the increase in cover, and Kingfishers began to fish regularly on the Main Pond.

As in 1992, Mallard and Tufted Duck dominated the waterfowl. A courtship flock of Tufted Duck was present throughout the spring and early summer with up to 44 birds recorded. The highest number of Mallard recorded in the log-book was 27. Apart from these two common species, other wildfowl are also beginning to use the site. A pair of Gadwall remained on site for nearly a month, from mid-March to early April 1993 and a pair of Shovelers was present for about 10 days at the end of April. In the autumn up to three Little Grebes took up residence, presumably capitalising on the colonisation of the site by fish.

In general, the greatest numbers of species and individuals were present in the spring and early summer, when the site had an excellent feeling of activity (especially in 1993). There was a very pronounced contrast between this time of the year and the late autumn and winter (from October to February) when there were very few birds on the site (both 1992 and 1993).

As Figure 5.2 shows, there was also a considerable increase in the numbers of wetland birds using the site in the breeding season in 1993. In the two months with directly comparable data (June and July), numbers of birds recorded per observer roughly doubled in 1993, compared to 1992. This mainly reflected the increase in the numbers of pairs of breeding birds on the site (see Section 5.2.5).

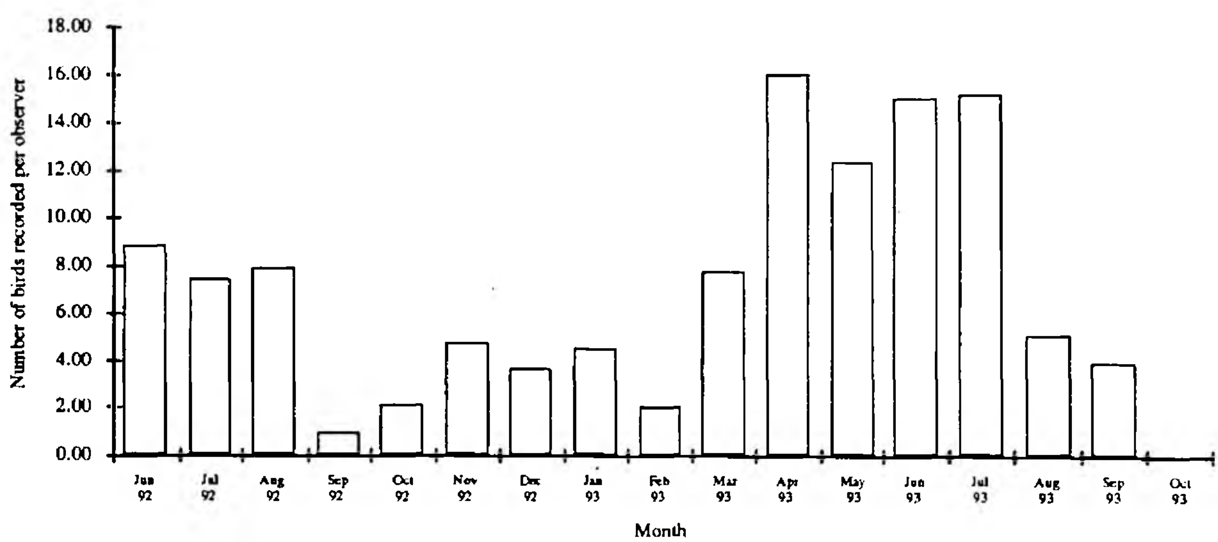


Figure 5.2 Seasonal variation in numbers of wetland birds recorded on Pinkhill Meadow

Note that the figure excludes Black-headed Gulls and data on Lapwings from six days in July and August 1992 when large flocks of juvenile birds visited the site. There were no juvenile Lapwing flocks recorded in 1993.

5.2.3 Waders using Pinkhill Meadow

The same number of wader species was recorded on the site in 1993 as in 1992 (14 species). However, the numbers of individual birds roughly doubled, due to increases in numbers of Little Ringed Plover, Lapwing and Redshank. All three species were seen almost exclusively in the breeding season. For example no Redshank were seen between 9 September 1992 and 12 March 1993, after which they were present more or less daily in the 1993 breeding season. Similarly, Little Ringed Plovers vacated Pinkhill at the end of July in 1993 and did not visit the site on the autumn migration. In 1992 only two individuals were recorded after 23 July. Figure 5.3 shows how the number of waders on the site has varied with the season (measured in terms of birds recorded per observer) since June 1992.

Over the two years numbers of waders were highest during the breeding season (March to July) with non-breeding migrants making up a relatively small proportion of the waders observed. The three species which bred (or attempted to breed) in 1992 and 1993 make up a large proportion of all wader records. During the winter the only wader species recorded using the site has been Snipe, although it is possible that Jack Snipe have been present and unrecorded.

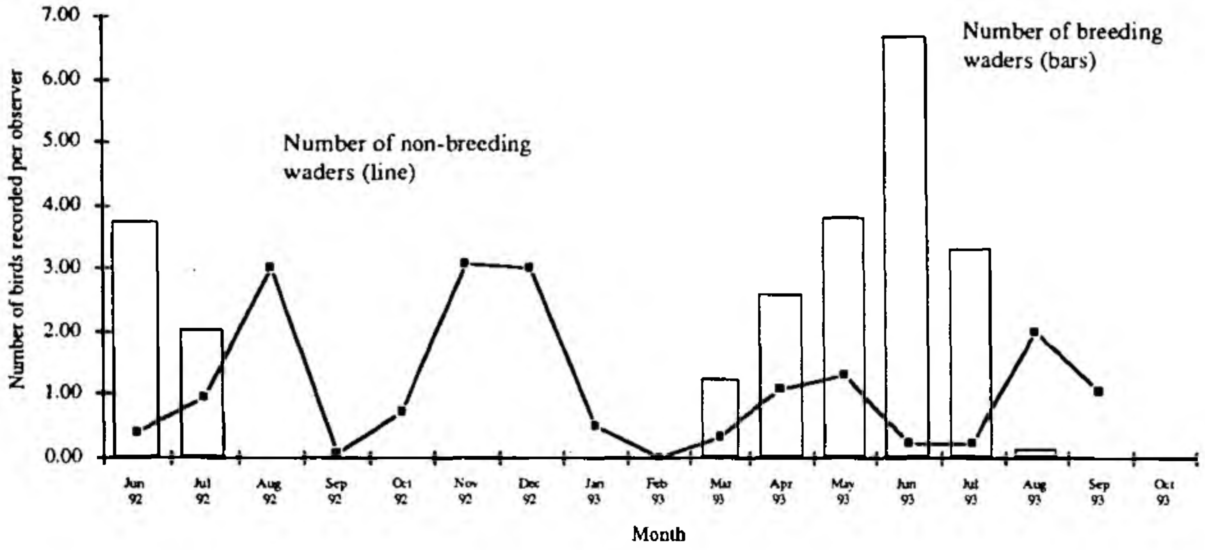


Figure 5.3 Seasonal variation in numbers of breeding and non-breeding waders on Pinkhill Meadow (1992 and 1993). Data is derived from the Pinkhill Meadow log-book

5.2.4 Wetland birds breeding on Pinkhill Meadow in 1993

In 1993 Little Ringed Plover, Lapwing, Tufted Duck, Moorhen, and probably Mallard, bred on the Pinkhill site. Redshank attempted to breed but the nest (with 3 eggs) was flooded.

Little Ringed Plover

First clutches

Two pairs of Little Ringed Plovers bred on the Pinkhill Meadow islands in 1993, fledging two and three young birds. The first pair bred close to the original nest site on the middle gravel island (site reference EJ50) and the second pair bred on the island in front of the hide (nest site EF50). During the breeding season a maximum of five individual adult Little Ringed Plovers were seen on the site.

The first pair arrived on site at the end of March and scrape making was first seen on 29 March. Mating was first seen on 4 April and incubation was under way by 2 May. The two chicks were first seen on 21 May. In contrast to the 1992 breeding season, the chicks remained on the island for at least the first nine days. This may have been because the middle island was more densely vegetated than in 1992, providing more invertebrate food for the chicks. Both young birds were reared to independence and were presumed to have left the site successfully.

A second pair of Little Ringed Plovers was seen from the first week in April onwards, although they were not regularly present until 23 April. This pair was first noted using the nest scrape on the island in front of the hide on 6 May. The four eggs hatched on 1 June, although one of the four chicks had disappeared by 10 June. The chicks from this brood had moved off the breeding island by 6 June. The three remaining chicks probably fledged successfully.

Second clutch

One pair of Little Ringed Plovers started a second brood with scrape making seen on the middle gravel island on 22 June. Eventually a scrape was made on bare clay (lined with small dried clay fragments) in the north-east corner of the Main Pond (grid reference FC55). The nest was first seen on 12 July by which time it contained a clutch of four eggs. Unfortunately, the nest was flooded four days later and the birds deserted. However, second clutches are not all that common in Little Ringed Plovers (Cramp and Simmons, 1983) which suggests that the Pinkhill site is proving attractive to the birds. The fact that the nest was built on the bare mud of this area may have been the result of the dense growth of vegetation on the middle gravel island making this area unsuitable as a nest site for the Plovers late in the summer.

Juvenile and adult Little Ringed Plovers were last seen on the site on 12 July (two adults and all five juveniles). All the birds had departed within two days (14 July).

Ringing information on adult and young Little Ringed Plovers

Two of the adult Little Ringed Plovers were carrying rings (the females of each pair). The ring number of one bird was taken and is currently being checked in the BTO ringing system. The chicks were ringed by Dr Andy Gosler of the Edward Grey Institute (Oxford University).

Lapwing

Three pairs of Lapwings bred on the Pinkhill site in 1993, up from one pair in 1992. Pairs nested on the middle gravel island (at EJ50 close to the nest site of 1992), on the northern gravel island nest site, and on the bare ground at the back of the Main Pond.

At least seven, and possibly eight, chicks hatched (broods of four, three and one) and four to fiveyoung were reared to fledging.

Pair 1: middle gravel island

Birds took up residence on 18 April, the first mating was seen on 21 April, and the birds were first seen sitting on the nest on 8 May. The four chicks were first seen on 24 May, suggesting that the clutch was started around 27-28 April. By 22 June the two remaining chicks were fully grown and presumably fledged successfully.

Pair 2: northern gravel island

Although four Lapwings were seen on the site on 25 April, a second pair only started to use the site regularly from the third week in May. Scrape-making was first seen on 21 May and birds were sitting from at least 23 May. Three chicks were probably hatched from this site between 17 and 20 June. By 22 June the brood was probably reduced to two, which were still present on 18 July.

Pair 3: bare ground on the west edge of the Main Pond

A bird sitting on a nest at this site was first noted on 5 June, and birds were still incubating on 20 June. No further comments were recorded on this nest in the log-book (and there were no habitat use monitoring visits at this time).

so further progress of the nest is uncertain. However, one immature Lapwing was present until at least 7 August which suggests that one bird was reared from this nest. No Lapwings were recorded after this date.

Redshank

Redshank were present on the Pinkhill site regularly from 20 March, with the first attempted mating on 18 April. Up to four birds were regularly seen on the site until the end of June. The nest hollow, in a patch of Gypsywort on the middle island (EJ50), was being shaped from at least 4 May onwards, and eggs were probably being incubated from 13 June onwards. At least two clumps of vegetation on the middle gravel island had been investigated before the nest site, on the east side of the island, was chosen. Unfortunately, heavy rain in the week of last week of May led to the site being flooded, water just reaching the level of the Redshank nest on 28 May. Although the birds continued to sit on the nest until 22 June, no young hatched. When the nest site was inspected in mid-July, no eggs or shells were found.

Mallard

The first Mallard duckling was recorded on 17 April, when a female was seen with one duckling that was probably two to three days old. Although Mallard were seen with ducklings on various dates, no searches for nests were undertaken so it is not known whether Mallard actually bred on the site.

Tufted Duck

Up to 44 Tufted Ducks used Pinkhill Meadow regularly during Spring and Summer 1993, with groups engaging in communal courtship (males and females chasing around in groups of 10 to 15 birds). No evidence of nest sites was obtained this year, but three females were seen with broods of seven, four and one chicks, of varying ages, on 31 July.

Up to five juvenile Tufted Duck remained on site until 20 August. It was not possible to tell what proportion of these birds was successfully fledged.

Moorhen

One pair of Moorhens nested at the south end of the southern reed pool amongst branches placed in the water (nest site BH38). At least two broods of young birds used the site during the summer (for example, broods of four and two juveniles were seen on 31 July).

5.3 Interim results of objective 2: habitat-preferences of wetland birds using Pinkhill Meadow

5.3.1 Introduction

Habitat-preference surveys were started in Spring 1992, following the completion of the Phase 2 excavation. This section provides a brief update on the work undertaken so far. An introduction to the aims of the habitat use work was given in the 1992 Interim Report.

5.3.2 Survey work

The survey work has two practical components:

(i) Descriptions of the distribution of birds on the site.
(ii) Descriptions of the physical and botanical features of the site.

Bird distribution patterns are being recorded on a 5m x 5m grid (see Figures 5.4 to 5.7) over two hours on selected days. Although most survey work is being undertaken during migration periods (see Table 5.2), some observations have also been made during the breeding season, principally to record habitat-preferences of breeding waders.

Timing of bird survey work

It was originally intended that surveys would be undertaken on 10 days in each of four months (April, May, August and September) to coincide with the peaks of migration. During 1992, however, two of the 20 days of survey work for the "spring" were reallocated to June to ensure that more of the wader breeding season was included. In 1993 four days, rather than two, were allocated to recording in mid-summer (July). During each month days for survey work were chosen at random. The time of day when surveys were undertaken was also chosen at random. Days are divided into four: early morning (0400-0830), mid-morning (0831-1300), afternoon (1301-1730) and evening (1731-2200). In each season, the aim is to start five visits in each of these periods, the time of the survey on any particular day being chosen at random (see Table 5.2). In Autumn 1992 time was available for only 17 visits.

Very few birds were present in the latter half of September 1992, giving very limited results. To make more effective use of the survey time, some days were reallocated to the winter. However, even then, very few birds were present until the beginning of the breeding season. For example, on 20 February the only birds seen in two hours were two Snipe. Since no benefits were derived from extending the autumn survey period over winter, this modification to the method was not repeated in 1993.

Environmental data relating to wader habitat use

Surveys of vegetation density were undertaken in late September 1992 and early October 1993. Vegetation density was scored on a scale of: 0-5 (0 = 0-1% cover; 1 = 2-20% cover; 2 = 21-40% cover; 3 = 41-60% cover; 4 = 61-80% cover; 5 = 81-100% cover).

Other environmental data is being derived from the survey map of the site, for example, disturbance (distance from the footpaths around the site), water level (as contour height) and importance of edges.

5.3.3 Analysis of data

It is intended to do most of the analysis of habitat use data on an ArchInfo GIS database, which is currently under development. All analyses shown here are preliminary and have been undertaken using small portions of the whole data set.

The NRA survey base map of Pinkhill Meadow has been transferred to the ArchInfo GIS, and Pond Action is currently working on developing software programmes to rapidly analyse and display data from the study (bird use of squares and grid square attributes) on the 5m x 5m grid.

5.3.4 Interim results of habitat-preference study

Little Ringed Plover

Figures 5.4 and 5.5 show habitat use by Little Ringed Plover in April and May during 1992 and 1993. The results suggest that in 1993 birds spent more time in the north-east corner of the Main Pond and the Scrape and less time on the main mud bank in the Main Pond. The south-west corner of the Main Pond was also used less for foraging in 1993.

As in 1992 activity was concentrated around the nest sites (the southern and central islands of the Main Pond). The birds also spent 10-15% of their time during daylight standing motionless, presumably roosting, in various parts of the site in both years.

Monitoring also indicates that Little Ringed Plovers characteristically feed at Pinkhill just on the landward edge of the water line, straying into shallow water from time to time. This means that, in practice, the amount of habitat available to them is probably a very small proportion of the site.

Lapwing

Preliminary analysis of Lapwing habitat use data showed that in 1992 this species ranged more widely over the site than Little Ringed Plovers (Figure 5.6). Lapwings also made slightly more use of the Scrape than Little Ringed Plovers in 1992. Lapwings appear to spend more time feeding in areas of denser vegetation than Little Ringed Plovers (detailed analysis is required to confirm this impression), although like the Plovers they spend relatively little time wading.

Redshank

In 1993, when first breeding on the site, Redshank ranged less widely than Lapwing, being restricted to the more open areas similar to those used by Little Ringed Plovers (see Figure 5.7). Most activity was concentrated in three areas: the central islands (including the nest site), the western mud bank of the Main Pond and the north-east corner of the Main Pond. A small proportion of time was spent on the Scrape.

In contrast to the two plover species, Redshank seemed to spend most time foraging in shallow water just below the water line. Redshanks appeared to spend about 15-20% of their time roosting during daylight.

Table 5.2 Dates of habitat use surveys

Date	Period of day
Spring and Summer 1992	
4/4/93	3
8/4/92	3
9/4/92	1
11/4/92	1
12/4/92	3
14/4/92	4
17/4/92	4
24/4/92	3
25/4/92	3
27/4/92	2
10/5/92	4
13/5/92	1
21/5/92	4
22/5/93	No data
23/5/92	2
24/5/92	1
25/5/92	1
26/5/92	1
7/6/92	2
12/6/93	2
Autumn and Winter 1992/93	
9/8/92	2
15/8/93	4
18/8/92	4
22/8/92	3
28/8/92	3
28/8/92	4
29/8/92	1
5/9/92	3
10/9/92	3
11/9/92	1
13/9/92	2
21/9/92	3
30/9/92	4
20/2/93	3
13/3/93	2
20/3/93	3
26/3/93	4

Date	Period of day
Spring and Summer 1993	
2/4/93	4
3/4/93	2
9/4/93	1
16/4/93	3
18/4/93	1
19/4/93	4
30/4/93	No data*
1/5/93	No data*
2/5/93	3
3/5/93	No data*
5/5/93	No data*
6/5/93	4
7/5/93	3
8/5/93	2
11/5/93	No data*
13/5/93	2
12/7/93	4
25/7/93	3
28/7/93	2
31/7/93	1
Autumn 1993	
6/8/93	4
7/8/93	2
11/8/93	4
12/8/93	4
13/8/93	4
21/8/93	2
22/8/93	2
23/8/93	1
25/8/93	3
30/8/93	3
3/9/93	1
5/9/93	1
6/9/93	1
7/9/93	4
10/9/93	4
14/9/93	4
18/9/93	3
24/9/93	3
27/9/93	2
28/9/93	2

*Recording tapes unreadable, probably due to tape recorder having damaged recording head.

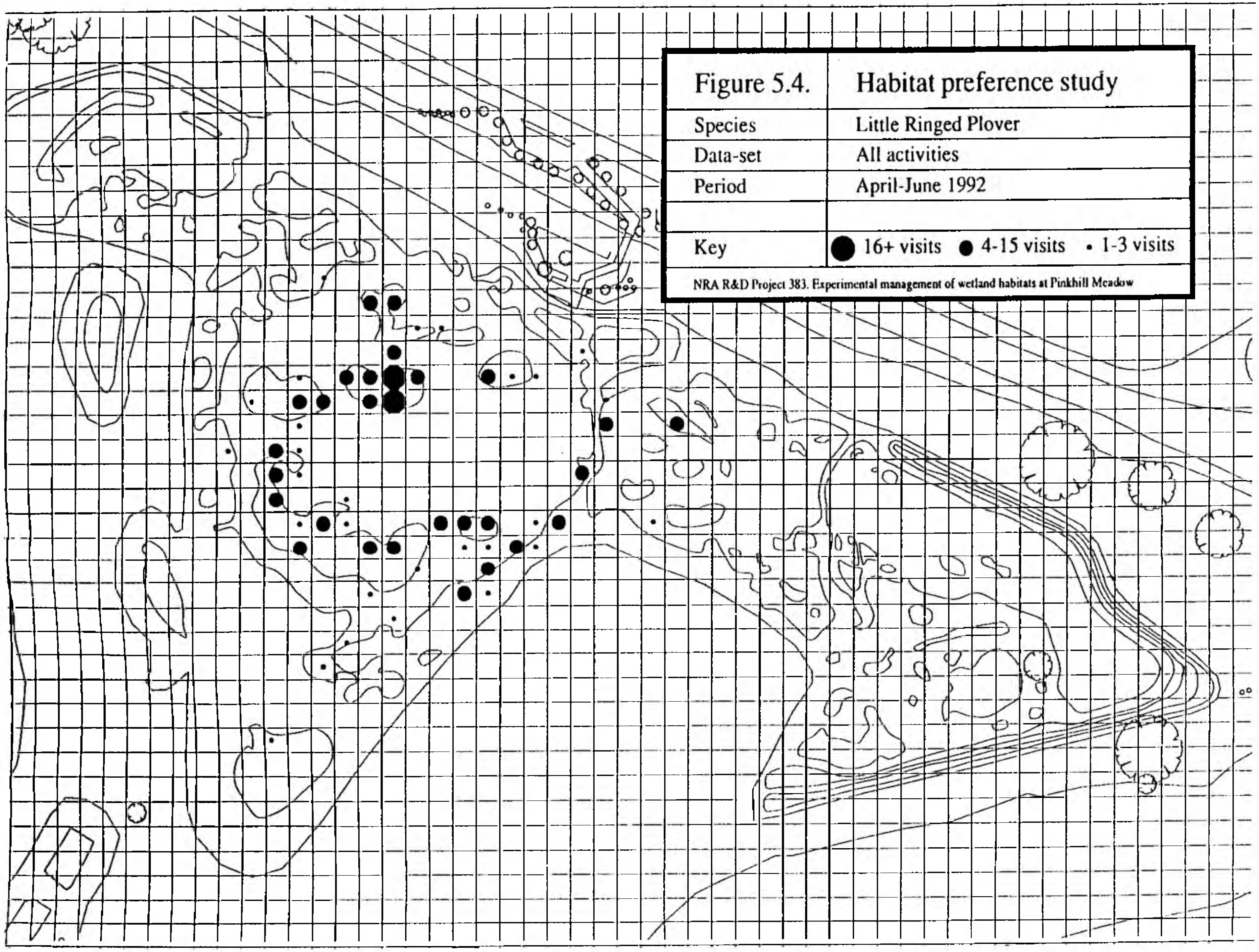


Figure 5.4.
Habitat preference study
Species
Little Ringed Plover
Data-set
All activities
Period
April-June 1992
Key
16+ visits
4-15 visits
1-3 visits
NRA R&D Project 383. Experimental management of wetland habitats at Pinkhill Meadow

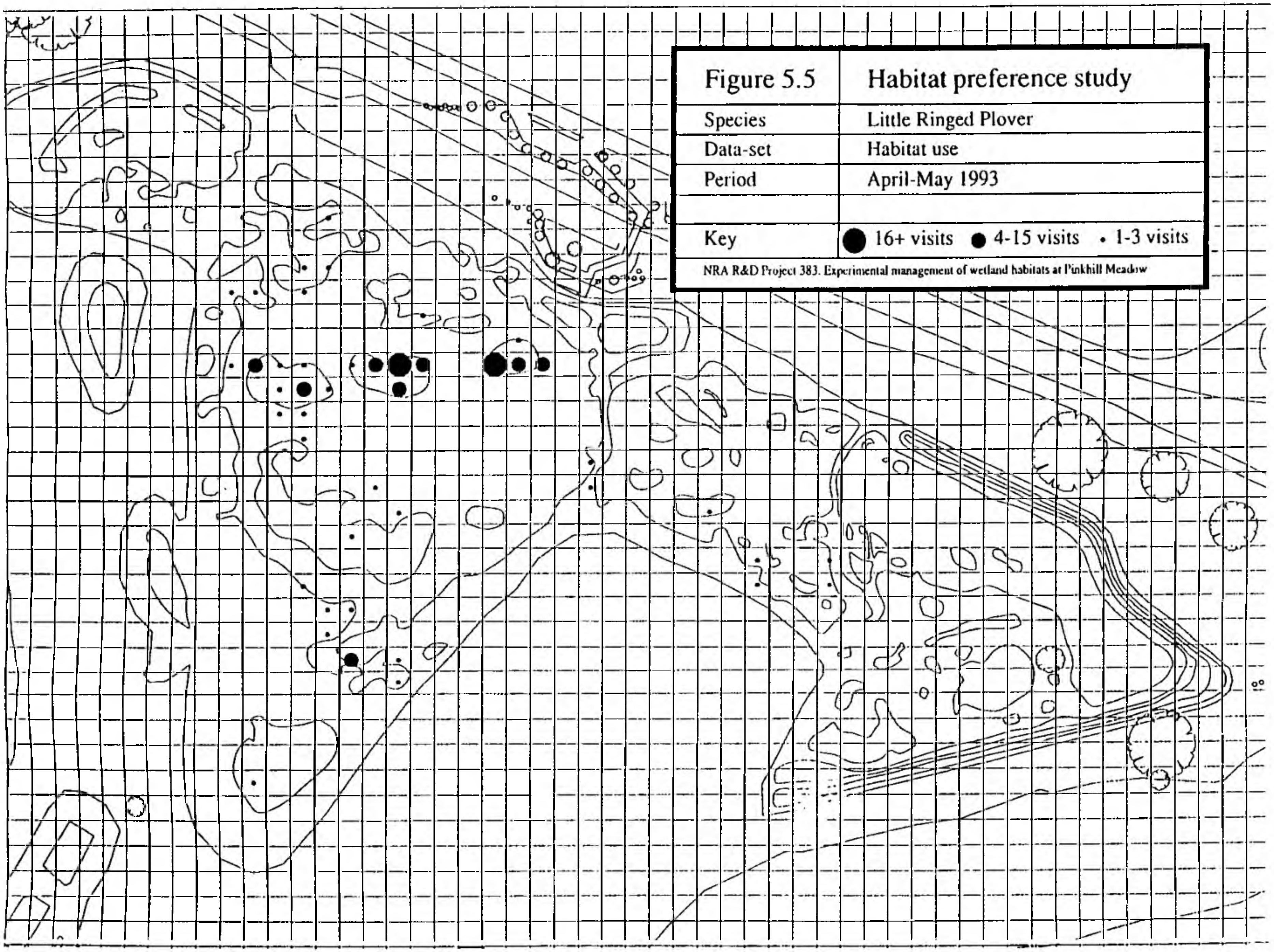


Figure 5.5	Habitat preference study
Species	Little Ringed Plover
Data-set	Habitat use
Period	April-May 1993
Key	16+ visits · 4-15 visits · 1-3 visits

NRA R&D Project 383. Experimental management of wetland habitats at Pinkhill Meadow

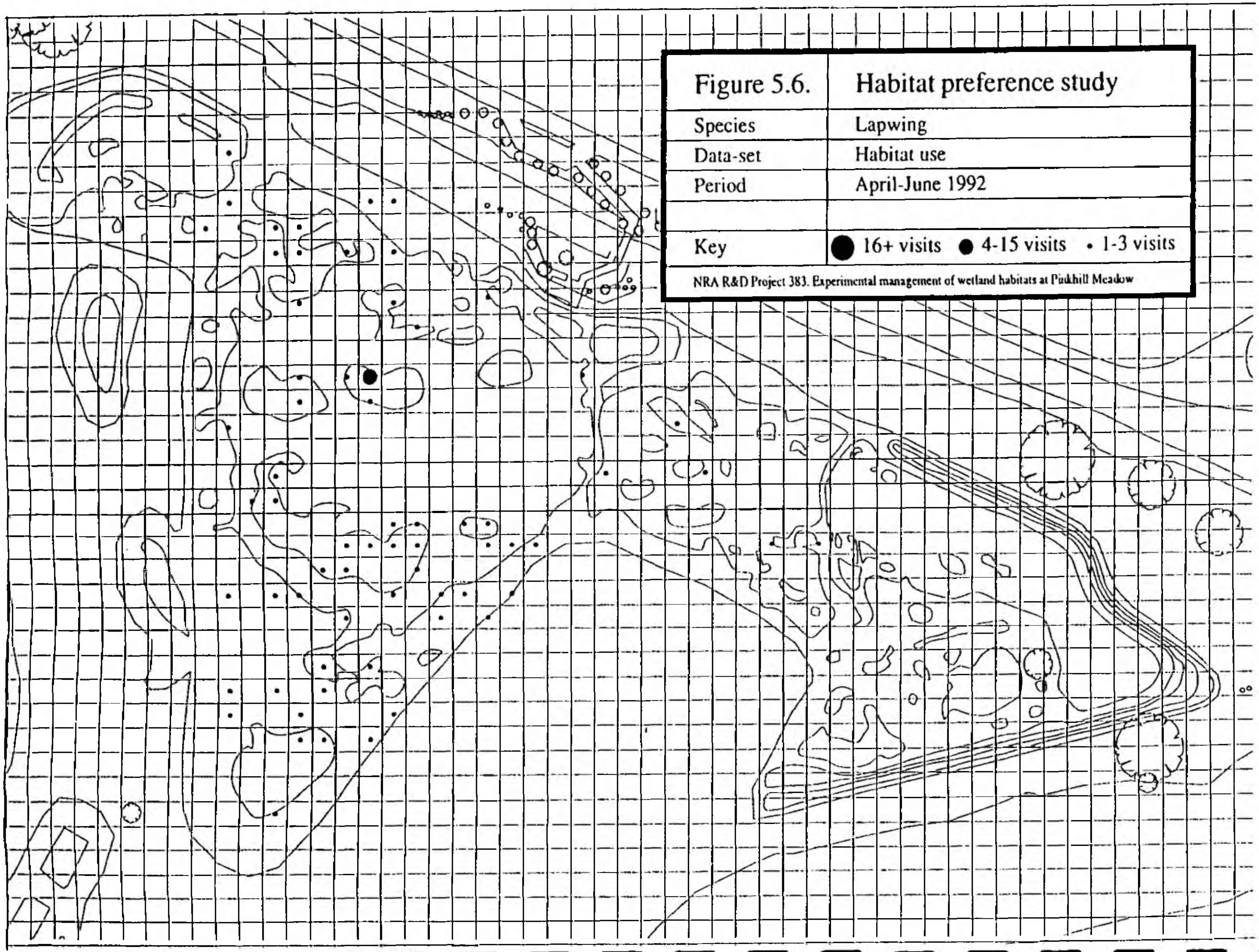


Figure 5.6.
Habitat preference study
Species
Lapwing
Data-set
Habitat use
Period
April-June 1992
Key
16+ visits
4-15 visits
1-3 visits
NRA R&D Project 383. Experimental management of wetland habitats at Pulkhill Meadow

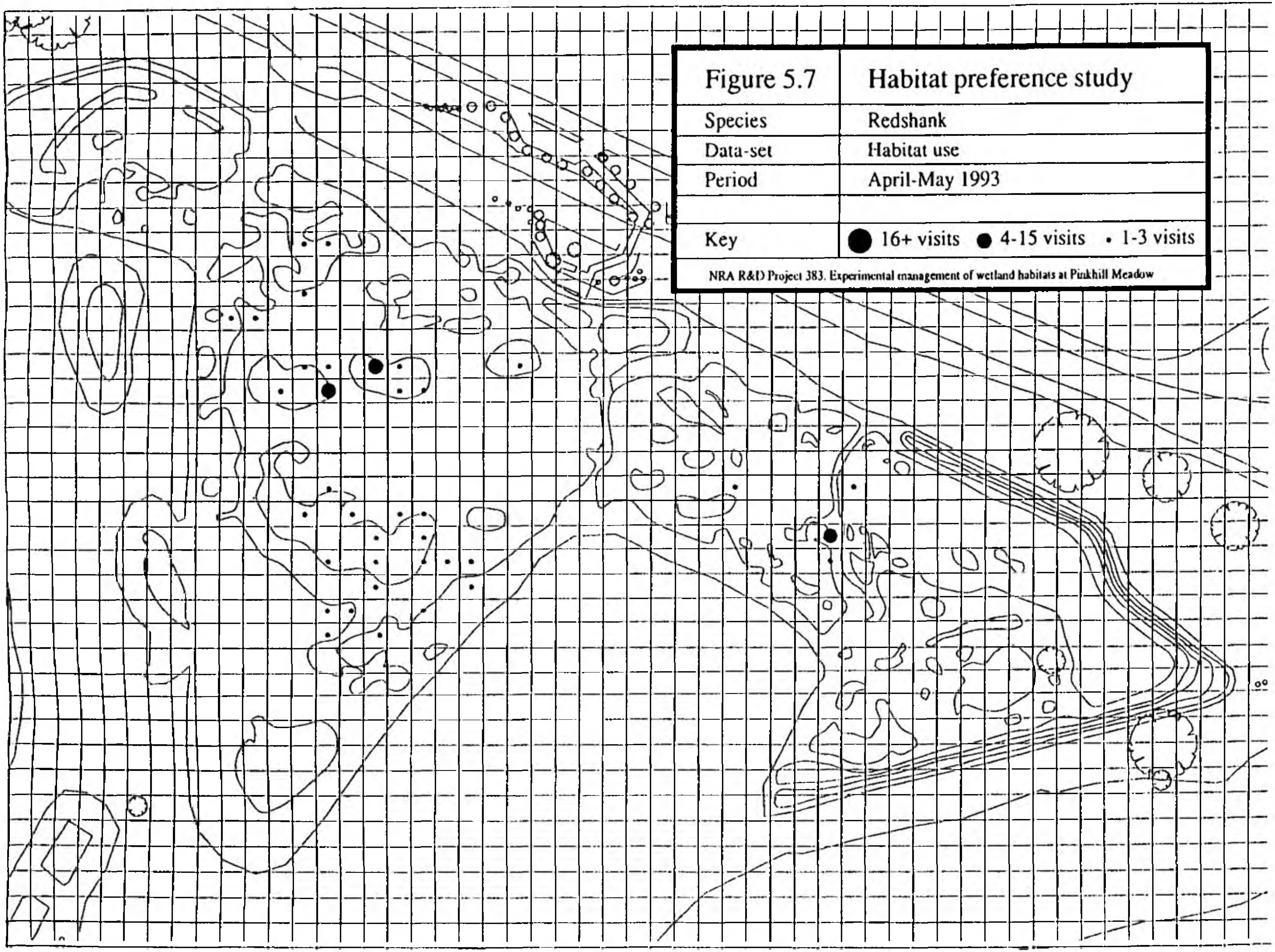


Figure 5.7
Habitat preference study
Species
Redshank
Data-set
Habitat use
Period
April-May 1993
Key
16+ visits
4-15 visits
1-3 visits
NRA R&D Project 383. Experimental management of wetland habitats at Pinkhill Meadow

5.4 Results of objective 3: to determine whether numbers of waders using the Farmoor site have increased following the creation of the Pinkhill wetlands

5.4.1 Approach to the work

The approach used in assessing whether wader numbers had changed at Farmoor following the construction of the Pinkhill wetlands was described in detail in the 1992 Interim Report. In outline, the numbers of waders expected at Farmoor in the autumn in the absence of a wader scrape was predicted using multiple regression equations based on 1982-91 climate and bird data.

In this section the results of that analysis are updated to include the Farmoor log-book wader counts for October 1992 and August and September 1993. Note that predictions are only possible for the autumn. In the spring no environmental variables predicted wader numbers well enough to make useful predictions.

In addition to this predictive approach, which is applicable only to total wader numbers in autumn, changes in the numbers of four individual species (Little Ringed Plover, Greenshank, Snipe and Common Sandpiper) are also described.

5.4.2 Prediction of numbers of waders at Farmoor reservoir

The methods used to predict numbers of waders at Farmoor reservoir (using the data for the period 1982-91 as the basis of predictions) was described in the 1992 Interim Report.

To update the predictions for 1992 and 1993, the relevant climate data was substituted into Equation Total 2 (see 5.6 in the 1992 Interim Report) to give estimates of total wader numbers for the three months.

Predictions were then compared with the actual numbers of waders recorded in the Farmoor log-book. All wader numbers are described in terms of numbers of birds seen per birdwatcher visit to remove bias due to variations in the numbers of observers. Note that there was also a correction to the calculation for August 1992 which led to the observed number of birds being lower than that predicted.

5.4.3 Numbers of waders using Farmoor reservoir in the autumn: predictions and actual numbers

In 1992 numbers of waders in all three months were below the predicted level (note that an error was made in the calculation of the August 1992 value in Figure 5.4 of the 1992 Interim Report).

In 1993 numbers in August were a little above the predicted level and numbers in September were considerably above the predicted level. Climate data is not yet available for October 1993, so predictions cannot be made for this month.

Following construction of the Pinkhill wetlands wader numbers have now been above predicted levels on eight out of 11 months. Although at first sight this suggests that numbers of waders have increased since the construction of the Pinkhill wetlands, a longer run of data is still needed for greater certainty. Time series analysis is also in progress to assess the statistical significance of the difference between the predictions and the observed numbers of birds.

5.4.4 Changes in numbers of individual species

Numbers of individuals of three species show evidence of increasing since the construction of the Pinkhill wetlands. The clearest (and least surprising) overall increase is in numbers of Little Ringed Plovers. As a result of the birds breeding on the site in 1991 and 1992, the annual number of birds recorded in the Farmoor log-book has increased three to four times (see inset in Figure 5.9).

There is a very clear indication that numbers of Snipe have also increased, and in 1992 as many birds were noted in the Farmoor log-book as over the previous 10 years (see Figure 5.10). Note that not many Snipe have been recorded in 1993 because the main period of recording the birds comes in the late autumn and winter. Again, this result is not surprising since Farmoor reservoir does not provide any suitable habitat for Snipe. In fact the figures probably greatly underestimate the numbers of Snipe at Pinkhill, since most of the birds on the site go unrecorded.

There is a slight suggestion that numbers of Greenshank are also increasing at Farmoor (see Figure 5.11). Greenshank are one of the few non-breeding waders which occur as often at Pinkhill as on the reservoir. The numbers of birds recorded in 1993 (corrected for variations in the numbers of birdwatchers) was the largest reported in the last 12 years. Numbers have also been fairly consistently high since 1990.

Finally, Figure 5.12 shows the corrected numbers of Common Sandpiper recorded over the last 12 years. Apart from Greenshank, Common Sandpipers are the only non-breeding waders which occur in large numbers at both Pinkhill and on the main reservoir, birds regularly moving between the two areas. There has been a general increase in numbers of Common Sandpipers since 1989, although only in 1993 has the number of birds reached the level of counts in the mid-1980s. At present it is impossible to say whether Pinkhill has had any effect on the numbers of Common Sandpipers using Farmoor.

5.4.5 Conclusions

Pinkhill Meadow seems to be most attractive to wading birds, and other wetland species, during the breeding season. At the moment the majority of non-breeding migrant waders which drop in at Farmoor do not make use of Pinkhill. This was well illustrated during the Autumn of 1993 which was one of the best on record at Farmoor. Counts of four species (Little Stint, Dunlin, Common Sandpiper and Ruff) exceeded 100 on the site as a whole. Of these, no Ruff or Little Stint were seen at Pinkhill and only a handful of Dunlin, even though Dunlin were on the reservoir on most days during August and September. Only Common Sandpiper (as mentioned above) were visiting Pinkhill.

Overall, the results suggest that even small sites like Pinkhill can, if carefully positioned and designed, provide valuable habitat for breeding birds. However, even though obviously good for breeding birds, there are so few birds on site during autumn and winter that birdwatchers are often disapointed. Because of the high profile of the site, this is important. There may be several reasons why the site attracts few birds outside the breeding season:

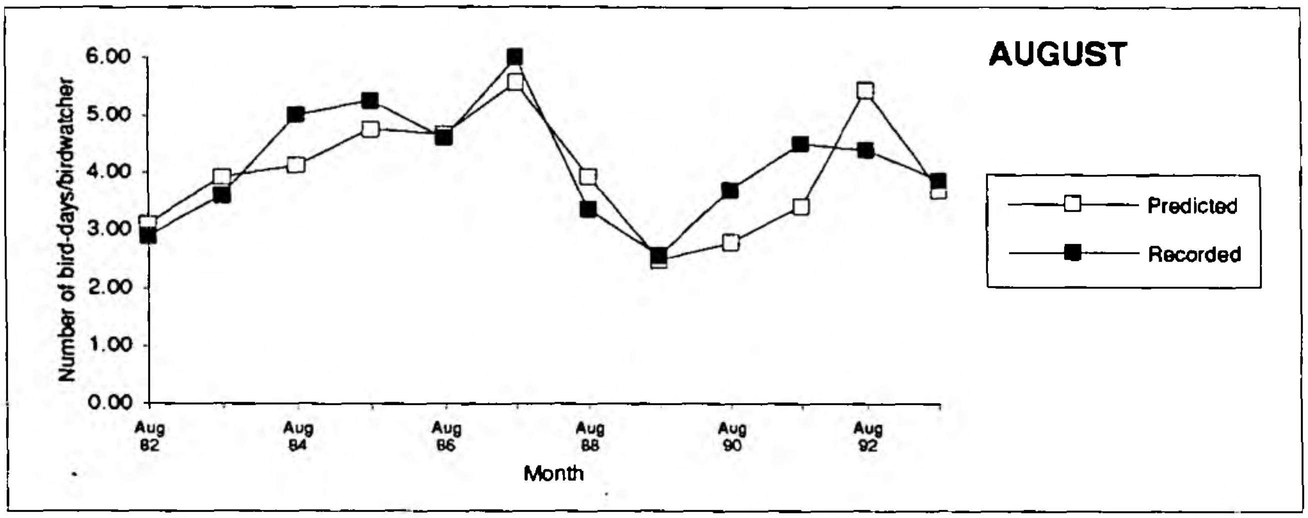
(i) It is too small. Certainly larger areas always support more species and give greater opportunities to create secure, undisturbed habitats.

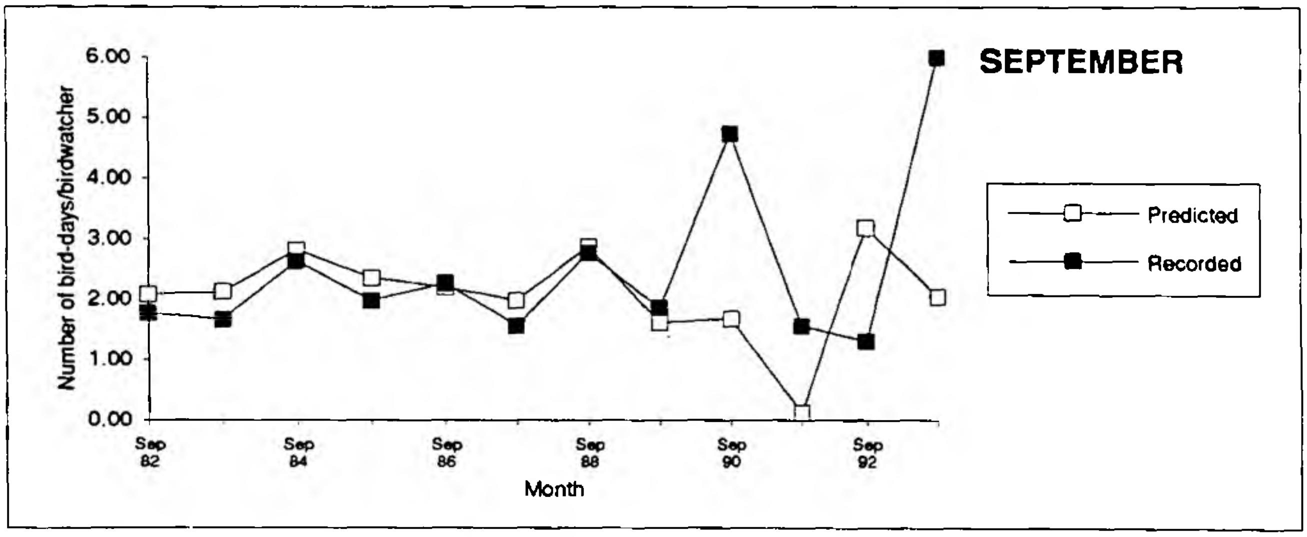
(ii) It may not provide enough food. The Scrape probably has too little silt at the moment and does not yet provide the kind of muddy habitat which was intended. However, it is not clear why some common species (Coot, Tufted Duck) do not use the site outside the breeding season. Submerged plants and invertebrates are abundant, and the Main Pond at least is obviously suitable for Tufted Duck during the spring and summer.

(iii) It may be too disturbed. Although birds are disturbed from time to time, disturbance is probably not a very important problem at Pinkhill: for example, during September up to six Teal used the Scrape regularly. Although they were disturbed by people on the footpath from time to time, they usually only flew to the far side of the Scrape. If flushed from the site they returned fairly quickly. In addition, many (if not the majority) of the waders on the reservoir use the Causeway. This is (i) the most disturbed part of the reservoir; and (ii) effectively the most isolated, being at the centre of the large expanse of water. Although many of the waders using the reservoir are regularly disturbed by people, it is possible that the sense of security provided by being out in the centre of the reservoir is enough to overcome the regular disturbance. Only the larger waders (for example, Whimbrel, Bar-tailed Godwit) regularly leave the site when disturbed from the causeway.

(iv) It may not be open enough. The reservoir is extremely open whereas Pinkhill is relatively enclosed. The site may simply not have enough space for many species.

Figure 5.8 **Predicted and recorded wader numbers at Farmoor Reservoir before pre-June 1990) and after construction of the Pinkhill wetlands.**





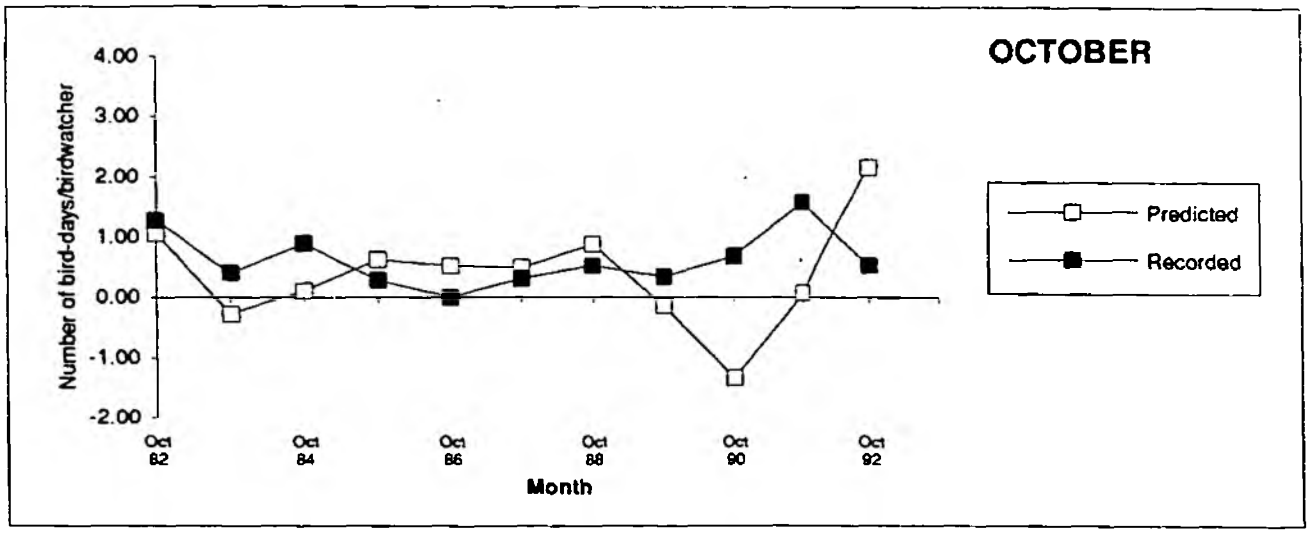


Figure 5.9. Corrected numbers of Little Ringed Plover recorded at Farmoor Reservoir. January 1982 to September 1993.

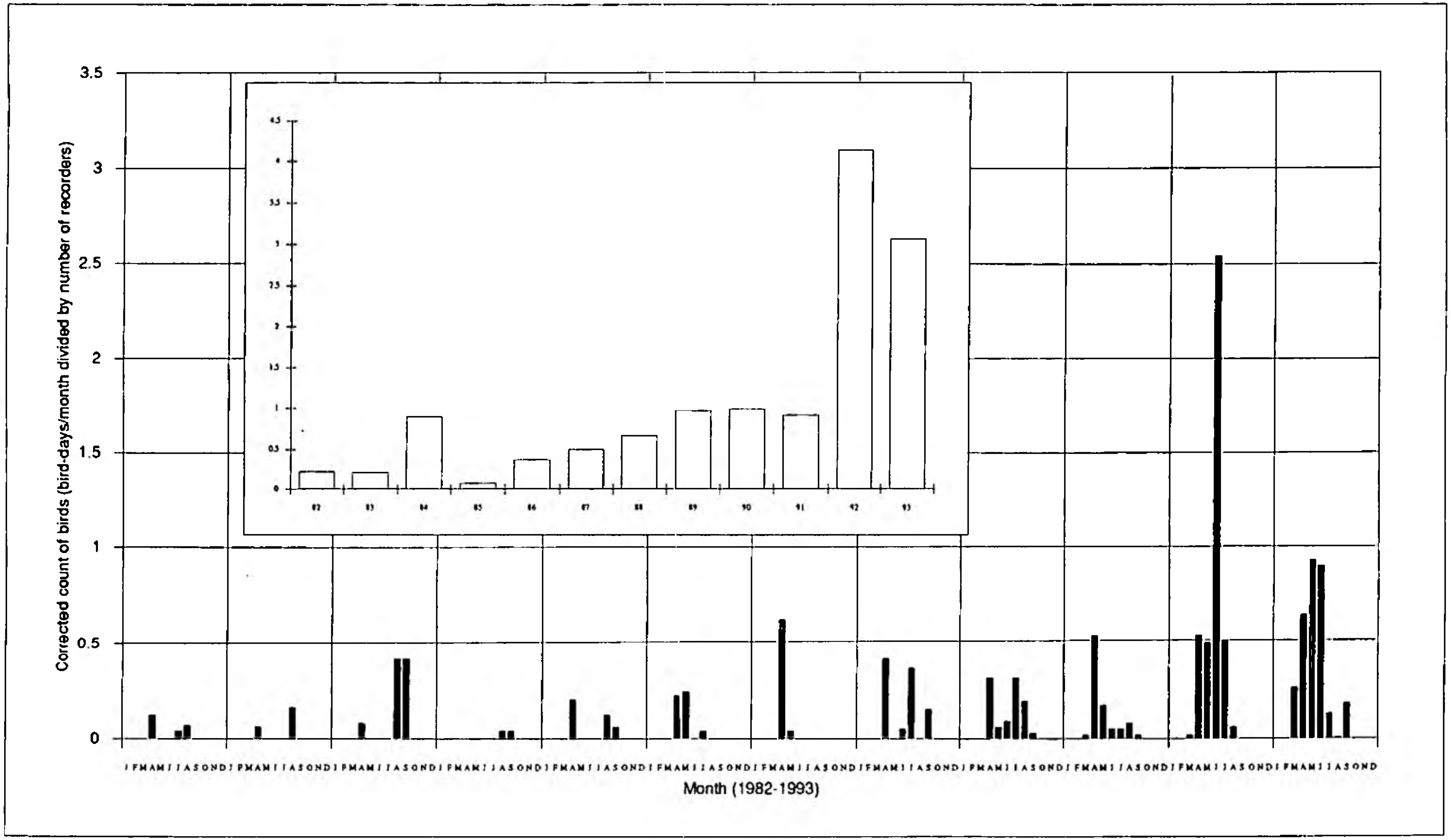


Figure 5.10. Corrected numbers of Snipe recorded at Farmoor Reservoir. January 1982 to September 1993.

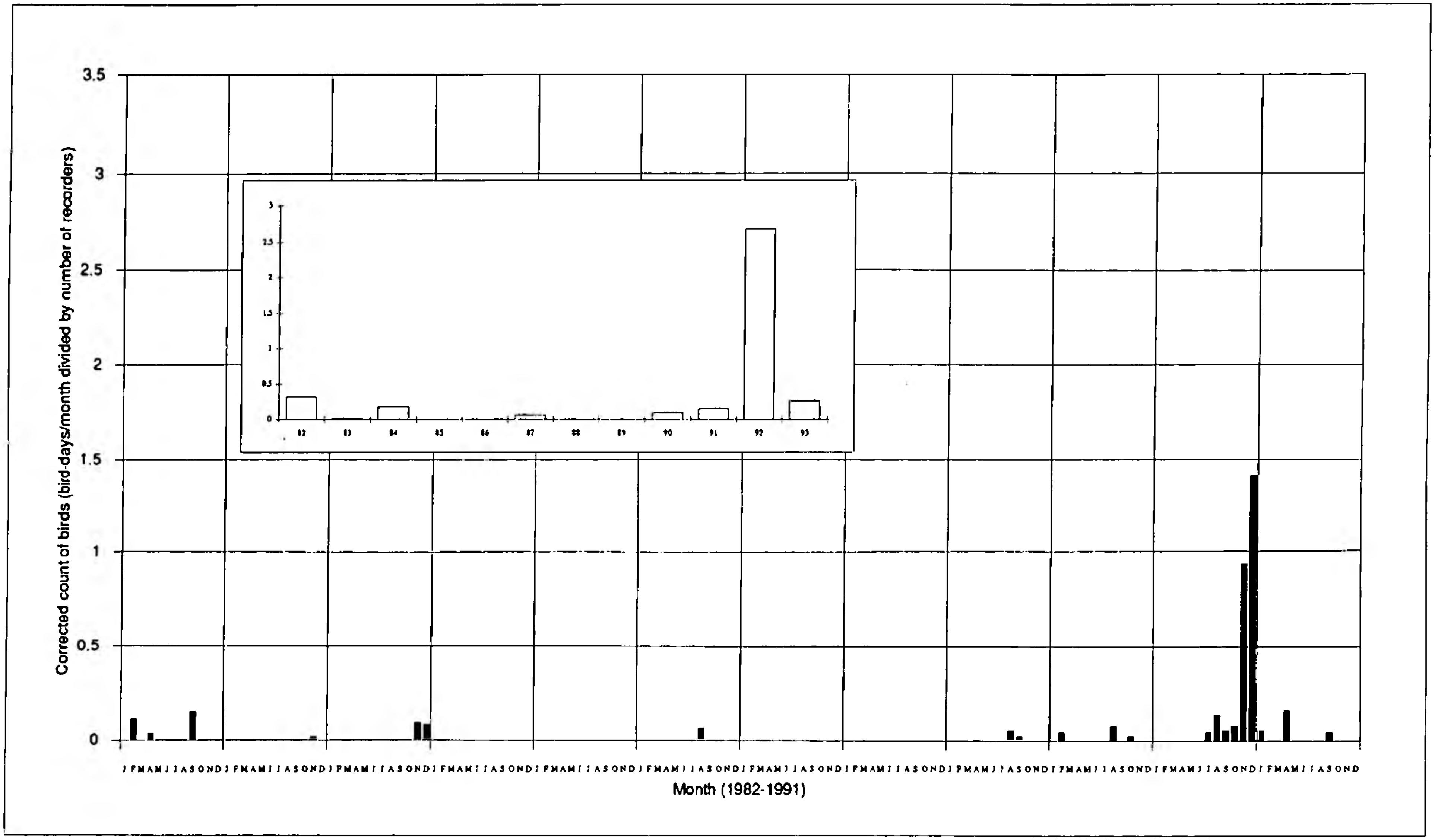


Figure 5.11. Corrected numbers of Greenshank recorded at Farmoor Reservoir. January 1982 to September 1993.

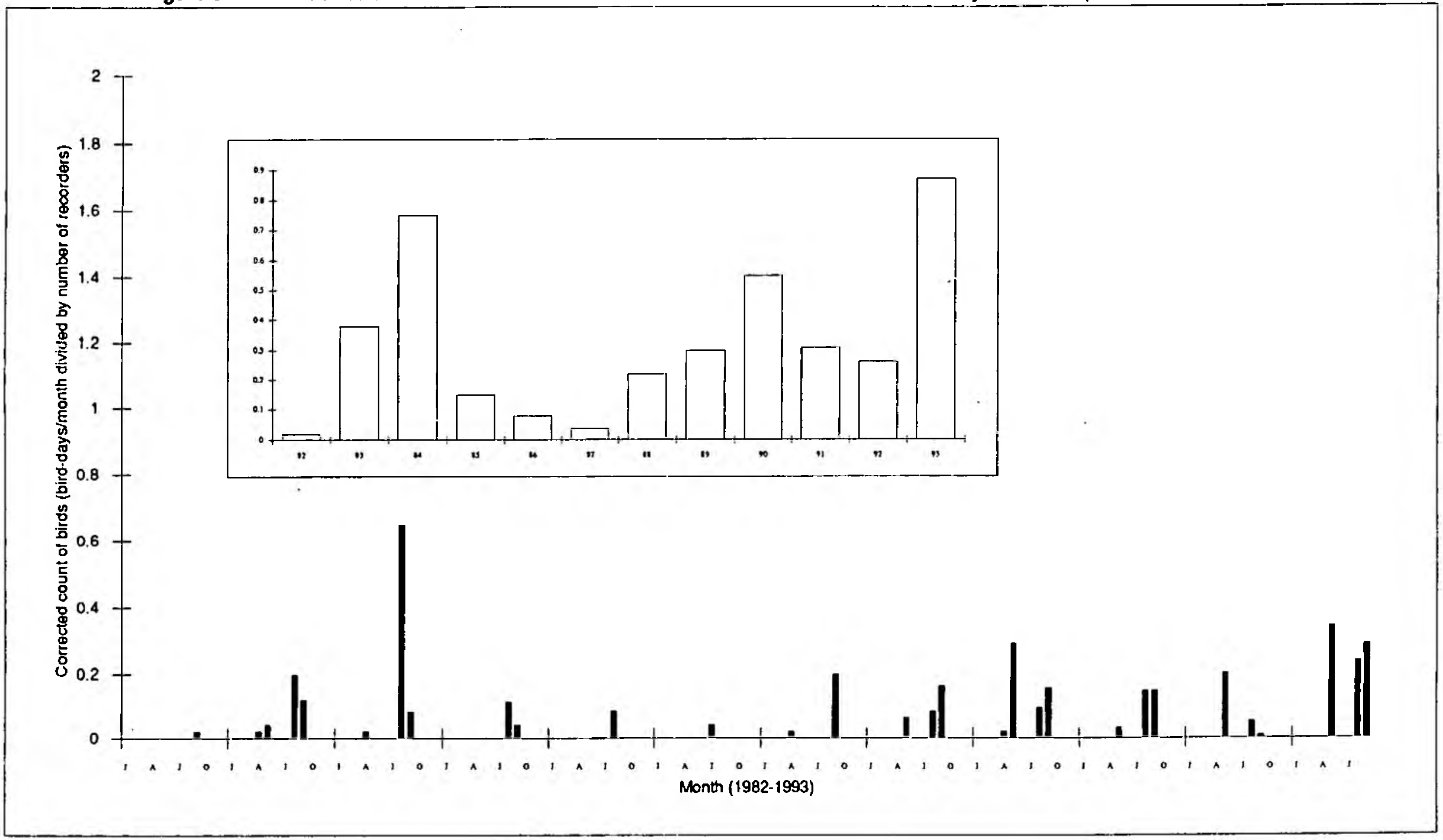
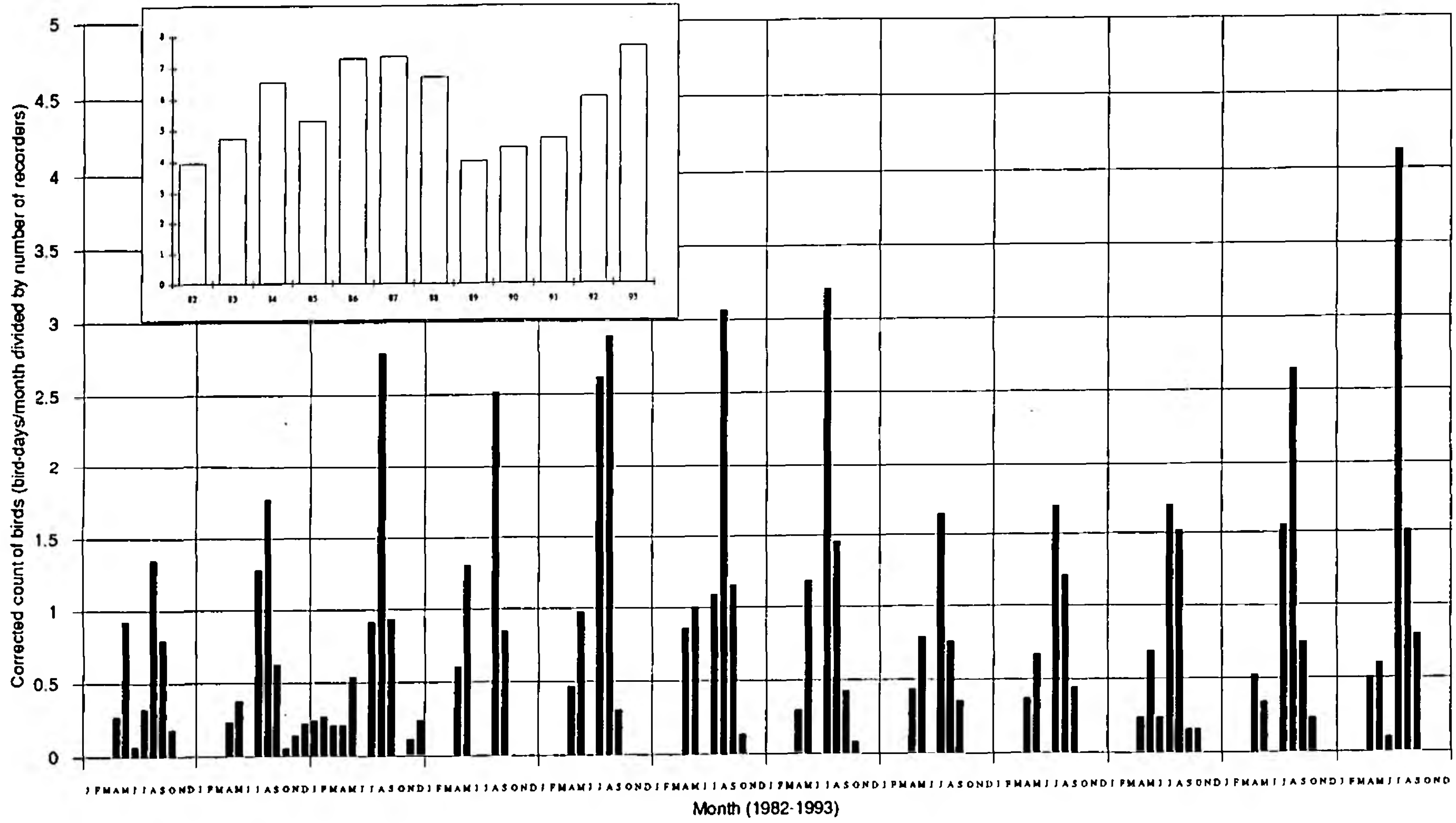


Figure 5.12. Corrected numbers of Common Sandpiper recorded at Farmoor Reservoir. January 1982 to September 1993.



6. EXPERIMENTAL PONDS

6.1 Background

Seven experimental ponds were created during Phase 2 of Pinkhill construction. The ponds are being used to undertake two experiments:

(i) Experiment 1 (ponds 1-3): an investigation of management techniques for establishing species-rich plant communities in new wetlands

(ii) Experiment 2 (ponds 4-7): an investigation of the relationship between the species-richness of aquatic macroinvertebrate communities and wetland plant species-richness.

6.2 Experiment 1. Establishing species-rich plant communities

This experiment aims to investigate the best means of managing newly planted waterbody margins to establish rich plant communities with a diverse range of emergent, marginal and floating-leaved species.

The experiment uses three duplicate ponds (each $150m^2$). Each pond is divided into eight randomised blocks which have been planted up with a variety of wetland plant species, using local stock taken from Pinkhill Meadow itself. Each block is the subject of one of four management treatments (see below). To ensure that differences between ponds are take into account there is a replicate of each treatment in each pond.

The four management techniques have been chosen to represent "practical" techniques which are most frequently and easily available in the conservation sector.

The management techniques are:

(i) Planted. No management.
(ii) Planted. Cut.
(iii) Planted. Selective hand-weeding of undesirable species.
(iv) Planted. Selective spot-treatment of undesirable species with contact herbicides.

The effectiveness of the management treatments will be assessed in terms of:

(i) Composition and structure of the vegetation.
(ii) The time required for the management work.
(iii) Estimated cost of mangement work.

6.2.1 Success of planting and establishment

Nine plant species were planted up using a stratified random design: *Alisma plantago-aquatica*, *Glyceria fluitans*, *Phalaris arundinacea*, *Polygonum amphibium*, *Ranunculus sceleratus*, *Typha latifolia*, *Veronica beccabunga*, *Agrostis stolonifera* and *Juncus articulatus*. Planting density was five plants per square metre.

Water levels were exceptionally high during the summer months of 1992, so species were planted into water that was deeper than ideal.

Monitoring during 1993 has focussed on: (i) assessing the extent to which planting has been successful; and (ii) monitoring 120 fixed-point $0.5m^2$ quadrats (five in each experimental plot) (see Appendix 3.1). The location of each monitoring point was chosen randomly, and their position marked by permanent numbered poles.

The results of monitoring indicate that cover in all ponds was exceptionally low until late Summer 1993 (<2%)

and that the success of establishment is still highly variable. In particular:

(i) Four of the species did not colonise successfully after planting in any ponds (*Ranunculus sceleratus*, *Veronica beccabunga*, *Agrostis stolonifera* and *Juncus articulatus*).

(ii) With other species the success of planting up varied considerably: on average *Polygonum amphibium* only colonised successfully in approximately 2% of cases, *Glyceria fluitans* and *Alisma plantago-aquatica* in approximately 5% of cases and *Typha latifolia* in approximately 50% of cases.

(iii) There was also considerable variation in the extent of colonisation both between and within ponds. Successful colonisation within individual ponds was: 13% (South Pond), 7% (Middle Pond), 17% (North Pond). However, the success of planting within individual experimental plots varied from <2% to approximately 25%.

In view of the very poor colonisation of the ponds no experimental treatments were undertaken.

6.2.2 Implications and options for the future of the experimental ponds

The very poor plant colonisation rate in the three ponds means that an experiment to maintain species-rich plant swards is not viable in its present form. This leaves two main options for work at the ponds: (i) the ponds are replanted; or (ii) the original experiment is modified or replaced by another. These options are discussed in more detail below.

Option 1. Replanting the ponds

The poor establishment of wetland herbs in the experimental ponds was principally caused by pond water levels which were much higher than expected (approximately 40 cm instead of 10-20 cm as predicted). This meant that water levels were too deep for the wetland herb species which were planted. By careful selection of species it should be possible to replant with more suitable wetland emergents which will tolerate relatively high water levels if they persist in future years. Observation of species successfully colonising deeper water at Pinkhill suggests that suitable species would include: *Typha latifolia*, *Glyceria fluitans*, *Alimsa plantago-aquatica*, *Schenoplectus lacustris*, *Glyceria maxima*, *Carex riparia* and *Sparganium erectum*. There are two main implications arising from this option:

(i) The focus of the experiment will change from one which looks at the maintenance of herb-rich swords to one which looks at maintaining communities of tall emergents.

(ii) The period of establishment/monitoring for the experiment would need to be extended.

Option 2. Modifying/replacing the original experiment

A second option for the three experimental ponds is to modify or change the original concept, making use of the ponds as they are or leaving them to develop naturally before undertaking further work.

For example, without management it is probable that the three ponds will develop more or less monospecific stands of *Typha* over two to three years. It would then be possible to undertake management experiments on *Typha* control. One of the most relevant studies would be to examine the effect of *Typha* removal on the plant and invertebrate populations of the ponds. The cost-benefits of vegetation removal on the conservation value of ponds is one of the most pressing problems of pond management, and an area in which there is currently nothing but very limited anecdotal information. The main implications of this approach are:

(i) The ponds would need to be left to recolonise for a period of two to three years with some provision made for a low-level of maintenance management

(ii) Plant and invertebrate surveys would need to be undertaken for a period of at least two years in order to establish a pre-management baseline.

(iii) Post-manangement surveys of plants and invertebrates would need to be undertaken over a period of three years.

6.3 Experiment 2. The influence of plant species-richness on the richness of the invertebrate community

The aim of this experiment is to investigate whether a greater number of invertebrate species are present in ponds if the pond contains more species of emergent and aquatic plants. The results should also give a preliminary indication of how much effort should be directed towards the maintenance of vegetation for the benefit of aquatic invertebrates.

The experiment involves two pairs of replicate ponds, one pair maintained as species-poor sites, the other as species-rich. Species poor sites were planted up with one emergent species (*Glyceria maxima*) and one aquatic species (*Elodea nuttallii*).

Species-rich sites were planted up with five emergent species (*Carex riparia*, *Schenoplectus lacustris*, *Phragmites australis*, *Glyceria maxima* and *Sparganium erectum*) and five submerged species (*Potamogeton pusillus*, *Myriophyllum spicatum*, *Elodea nuttallii*, *Ranunculus trichophyllus* and *Ceratophyllum demersum*).

6.3.1 Plant establishment in the experimental ponds

Plant colonisation in the invertebrate ponds was rather mixed. Most emergent species took well with the exception of *Phragmites australis*, where less than 10% of plants established successfully. This presents a difficulty since it means that the initial planting density of emergent species in the ponds was not even. It is very difficult to modify this situation because new introduction of *Phragmites* plants risks further selective introduction of invertebrates into the species-rich ponds.

The establishment of submerged plants in the ponds was not ideal: three of the submerged species showed very poor (or no) growth (*Myriophyllum spicatum*, *Ranunculus trichophyllus* and *Ceratophyllum demersum*). *Elodea nuttallii* established moderately well in all ponds, but the cover was patchy and not very consistent between ponds. Paradoxically, *Potamogeton pusillus* did not colonise well in the five-species ponds, but large stands developed in one of the "single species" ponds.

The effect of this very poor submerged plant community colonisation is that this part of the experiment which looks at the effect of submerged plant diversity on invertebrate diversity is not really viable, so management work at the site has focused on maintaining the submerged plant communities to be as similar to each other as possible in all ponds.

6.3.2 Experimental design

Removal of invertebrates introduced on plant material

Any invertebrates introduced during the initial planting would, hopefully, be removed by the selective use of a pesticide. Consultation with NRA and MAFF, however, suggested that such an approach would not be practicable. Removal of invertebrates, though desirable, does not preclude an ability to analyse the results from the invertebrate surveys of the ponds.

Survey and analytical methods

Surveys of the macroinvertebrates of each pond were carried out 11 November 1992 and 30 March 1993. Each pond was divided into four quadrats and the corners of these quadrats, an area five metres by three metres, were sampled. Each quadrat was sampled in duplicate for 22.5 seconds with a standard pond net. Samples (32 on each occasion) were placed in polythene bags and returned to the laboratory where they were sorted exhaustively. Specimens in those groups listed in Table 4.1 of this report were identified to species level.

Initial analysis has concentrated on the number of species and specimens recorded from the ponds using analysis of variance (ANOV).

6.3.3 Results from the first two seasons of sampling

Numbers of specimens, numbers of species and a simple index of species richness are given in Table 6.1. The index of species richness ("richness index") was calculated simply by dividing the number of species in each sample with the log10 number of specimens found. Ponds are numbered from north to south with the species-rich ponds being Pond 1 and Pond 3 and the single-species ponds Pond 2 and Pond 4.

For the purposes of an initial assessment of the differences in the macroinvertebrate communities of the ponds, two-way ANOVs were run using season and pond type (i.e., plant species rich or poor) as possible sources of variance for species numbers, specimen numbers and richness index. Two other possible sources of variation exist, pond (as opposed to pond type) and area position. The effect of area position has been tested in several variations of the analyses described here, but has never proved significant. The eight samples from the ponds are best treated, therefore, as replicates. As will be mentioned later, pond, rather than pond type, does have an effect on the analysis and this will be described, qualitatively, later. The three ANOV tables are presented below as Table 6.2.

As can be seen from the ANOV table of species, the number of species does not vary significantly with pond type considered over both seasons, or with season considered over both pond types (though this latter is nearly significant). There is, however an interaction between the two factors (pond type and season). Looking at the summary at the bottom of Table 6.1 it can be seen that in the first season, though the ponds varied, one plant species-poor pond had a relatively high, and one a relatively low, number of invertebrate species, the same being true for the plant species-rich ponds (on average the plant species-rich ponds had slightly more species). However, in the second season, both plant species-poor ponds had higher numbers of invertebrate species than the respective plant species rich ponds. Thus, there were differences between the ponds, but these differences were dependent on year. This is the basis of the interaction factor AB.

Results for specimen numbers are similar, though the effects here are more marked, and the difference between seasons is significant. In addition, though there is no significant difference between ponds types, the species-poor ponds have, on average, more invertebrate specimens in any given year than the species-rich ponds. For this reason the difference between pond types is nearly significant and there is no significant interaction between pond type and season.

Richness index shows no significant relationship to season or to pond type and there is no interaction between the two factors. In fact, richness index closely parallels species numbers, but the differences between pond types and seasons are small in comparison to random variation.

6.3.4 Conclusions from the first two seasons of sampling

If the first season of sampling is considered to be a baseline, then it is clear that numbers of specimens and numbers of species have fallen in the species-rich plant ponds. This might be explained by the poor establishment of the plants in these ponds. However, there is a considerable amount of random variation, particularly between individual ponds of the same type, and so a final conclusion should await the gathering of more data.

Given the possible effects of difference in vegetation cover between individual ponds it would seem prudent to include this in any final analysis. Vegetation cover will be measured in the Autumn 1993 survey and all future surveys.

The fact that the richness index varies less between pond types and seasons might suggest that the difference in species numbers may be due to netting efficiency in the different habitats, rather than any real difference in numbers of species. However, it was noted that those habitats with fewest specimens appeared to be those with sparser vegetation, where netting efficiency might, if anything, be expected to be higher. Given the relative consistency of the richness index, this may prove a useful measure when analysing future data.

Table 6.1 Numbers of species, specimens, and richness index of macroinvertebrate taxa collected from experimental ponds at Pinkhill Meadow

			Season 1			Season 2		
Pond	Area	Replicate	Species numbers	Specimen numbers	Richness index	Species numbers	Specimen numbers	Richness index
1	A	1	16	92	8.15	14	48	8.33
1	A	2	15	61	8.40	14	63	7.78
1	B	1	15	96	7.57	14	70	7.59
1	B	2	13	85	6.74	8	43	4.90
1	C	1	12	73	6.44	9	21	6.81
1	C	2	15	92	7.64	15	48	8.92
1	D	1	13	59	7.34	11	30	7.45
1	D	2	18	97	9.06	15	46	9.02
2	A	1	21	67	11.50	15	51	8.78
2	A	2	13	49	7.69	14	39	8.80
2	B	1	18	53	10.44	12	39	7.54
2	B	2	9	66	4.95	16	74	8.56
2	C	1	14	36	9.00	17	88	8.74
2	C	2	11	44	6.69	17	102	8.46
2	D	1	11	30	7.45	23	123	11.01
2	D	2	10	45	6.05	18	126	8.57
3	A	1	18	65	9.93	14	75	7.47
3	A	2	16	89	8.21	15	39	9.43
3	B	1	18	75	9.60	9	28	6.22
3	B	2	16	72	8.61	14	25	10.01
3	C	1	22	236	9.27	15	69	8.16
3	C	2	20	144	9.27	16	61	8.96
3	D	1	20	70	10.84	10	30	6.77
3	D	2	18	58	10.21	9	30	6.09
4	A	1	23	94	11.66	13	48	7.73
4	A	2	11	86	5.69	11	70	5.96
4	B	1	19	167	8.55	11	95	5.56
4	B	2	18	152	8.25	13	65	7.17
4	C	1	18	143	8.35	24	170	10.76
4	C	2	15	282	6.12	20	71	10.80
4	D	1	22	147	10.15	16	81	8.38
4	D	2	19	131	8.97	18	68	9.82
Summary								
1 (species-rich)		Averages	14.6	82	7.67	12.5	46	7.60
2 (species-poor)		Averages	13.4	49	7.97	16.5	80	8.81
3 (species-rich)		Averages	18.5	101	9.49	12.8	45	7.89
4 (species-poor)		Averages	18.1	150	8.47	15.8	84	8.28
All ponds		Averages	16.2	96	8.40	14.4	64	8.15

Table 6.2 Analysis of variance tables for numbers of species, specimens, and richness index of macroinvertebrate taxa collected from experimental ponds at Pinkhill Meadow

Anov table for a 2-way analysis of variance on number of species

Source	Degrees of freedom	Sum of Squares	Mean Square	F-test	Probability
Season (A)	1	50.766	50.766	3.954	.0513
Pond Type (B)	1	28.891	28.891	2.25	.1389
AB	1	74.391	74.391	5.793	.0192
Error	60	770.438	12.841		

Anov table for a 2-way analysis of variance on number of specimens

Source	Degrees of freedom	Sum of Squares	Mean Square	F-test	Probability
Season (A)	1	16256.25	16256.25	8.125	.006
Pond Type (B)	1	7921	7921	3.959	.0512
AB	1	3249	3249	1.624	.2075
Error	60	120053.5	2000.892		

Anov table for a 2-way analysis of variance on number of specimens

Source	Degrees of freedom	Sum of Squares	Mean Square	F-test	Probability
Season (A)	1	1.052	1.052	.419	.52
Pond Type (B)	1	.705	.705	.804	.5882
AB	1	5.8	5.8	2.186	.1491
Error	60	150.74	2.512		

Appendix 1.1 Wetland plants recorded in the Pinkhill Meadow wetland

Abbreviations:

MP - Main Pond SW - Surfacewater Pond GW - Groundwater Pond S - Scrape TS - Total Site

Survey : 91- Summer 1991 92 - Summer 1992 93 - Summer 1993

Bold text: Aquatic species

SPECIES NAME	MP			GW			SW			SC			TS		
	91	92	93	91	92	93	91	92	93	91	92	93	91	92	93
Agrostis stolonifera	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alisma lanceolatum	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
Alisma plantago-aquatica	-	+	+	-	+	+	-	-	+	+	+	+	+	+	+
Alopecurus geniculatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Angelica sylvestris	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+
Apium nodiflorum	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Barbarea vulgaris	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+
Bidens tripartita	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+
Butomus umbellatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Callitriche sp*	+	+	+	-	-	-	-	-	-	-	-	-	+	+	+
Carex flacca	-	+	+	-	-	+	-	+	+	-	+	+	+	+	+
Carex otrubae	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+
Carex riparia	-	+	+	-	+	+	+	+	+	-	-	+	+	+	+
Cardamine pratensis	+	+	+	-	-	-	-	-	-	+	-	+	+	+	+
Chara vulgaris	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
Crassula helmsii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Deschampsia caespitosa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eleocharis palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Elodea nuttallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Epilobium hirsutum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eupatorium cannaibinum	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+
Filipendula ulmaria	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+
Glyceria plicata	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+
Glyceria fluitans	-	+	+	-	-	-	-	-	-	-	+	-	+	+	+
Glyceria maxima*1	-	-	-	-	-	+	-	-	-	+	-	-	+	+	+
Hypericum tetrapterum	-	-	-	+	-	+	-	-	+	-	-	-	+	+	+
Iris pseudacorus*1	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Juncus bufonis	-	+	+	-	+	+	-	-	-	-	+	+	-	+	+
Juncus articulatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Juncus effusus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Juncus inflexus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lotus uliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Lychnis flos-cuculi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Lycopus europaeus	-	+	+	-	+	+	-	-	+	-	+	+	-	+	+
Lythrum salicaria	-	-	+	-	-	-	-	+	-	-	-	+	-	+	+
Mentha aquatica	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+
Mimulus guttatus*1	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Myriophyllum spicatum	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Myosoton aquaticum	-	+	+	-	-	-	-	-	-	-	+	-	+	+	+
Nasturtium officinale	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Phalaris arundinacea	-	+	+	-	-	-	-	-	-	-	+	+	+	+	+

SPECIES NAME	MP			GW			SW			SC			TS		
	91	92	93	91	92	93	91	92	93	91	92	93	91	92	93
Phragmites australis*1	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+
Polygonum amphibium	+	+	+	-	-	-	-	-	-	-	-	-	+	+	+
Polygonum lapathifolium	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-
Polygonum persicaria	-	+	+	-	-	-	-	-	-	-	+	+	+	+	+
Potamogeton obtusifolius	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Potamogeton perfoliatus	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Potamogeton pusillus	-	+	+	-	-	+	-	-	+	-	-	+	-	+	+
Ranunculus sceleratus	-	+	+	-	+	+	-	-	-	-	+	+	+	+	+
Ranunculus trichophyllus	+	+	+	-	+	-	-	+	+	-	+	-	+	+	+
Rorippa palustris	+	+	+	-	+	+	-	+	+	+	+	+	-	+	+
Salix cinerea	-	-	+	-	-	-	-	-	+	-	-	-	-	-	+
Schoenoplectus lacustris*1	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Scrophularia auriculata	+	+	+	+	-	+	-	-	-	+	-	-	+	+	+
Sparganium erectum*1	-	-	+	-	-	-	-	-	-	-	-	-	+	+	+
Stachys palustris	+	+	+	-	+	+	-	-	+	-	-	-	+	+	+
Typha latifolia	+	+	+	-	-	-	-	-	-	-	+	+	+	+	+
Veronica anagallis-aquatica	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+
Veronica beccabunga	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+
Veronica catenata	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+
Zannichellia palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
TOTAL MARGINAL SPECIES	15	29	35	12	14	20	10	10	17	15	21	25	31	40	50
TOTAL AQUATIC SPECIES	4	8	8	1	2	2	0	2	3	1	2	2	4	9	9
TOTAL SPECIES	19	37	43	13	16	22	10	12	20	16	23	27	35	49	59
CUMULATIVE TOTAL FOR THE SITE													35	49	61

NOTES:

* Fruiting material not available for most stands of *Callitriche* during the surveys, so it was not possible to consistently identify plants to species level. However, fruiting plants in one of the pools adjacent to the hide, was identified as *C. stagnalis*.

*1 Species introduced when the site was planted up with *Phragmites*.

Appendix 1.2 Common names of wetland plants recorded from Pinkhill Meadow

SPECIES NAME	COMMON NAME
Aquatic species	
Callitriche sp.	Starwort
Chara vulgaris	Common Stonewort
Crassular helmsii	New Zealand Stonecrop
Elodea nuttallii	Nuttall's Waterweed
Myriophyllum spicatum	Spiked Water-milfoil
Polygonum amphibium	Amphibious Bistort
Potamogeton obtusifolius	Blunt-leaved Pondweed
Potamogeton perfoliatus	Perfoliate Pondweed
Potamogeton pusillus	Long-stalked Pondweed
Ranunculus trichophyllus	Thread-leaved Water-crowfoot
Zannichellia palustris	
Emergent species	
Agrostis stolonifera	Creeping Bent
Alisma lanceolatum	Narrow-leaved Water-plantain
Alisma plantago-aquatica	Water-plantain
Alopecurus geniculatus	Marsh Foxtail
Angelica sylvestris	Wild Angelica
Apium nodiflorum	Fool's Water-cress
Barbarea vulgaris	Winter-cress
Bidens tripartita	Trifid Bur-marigold
Butomus umbellatus	Flowering Rush
Carex flacca	Glaucous Sedge
Carex otrubae	False-fox Sedge
Carex riparia	Cuckoo flower
Deschampsia caespitosa	Tufted Hair-grass
Eleocharis palustris	Common Spike-rush
Epilobium hirsutum	Great Willowherb
Eupatorium cannaibinum	Hemp-agrimony
Filipendula ulmaria	Meadowsweet
Glyceria fluitans	Floating Sweet-grass
Glyceria plicata	Plicata Sweet-grass
Glyceria maxima	Reed Sweet-grass
Hypericum tetrapterum	Square-stalked St John's-wort
Iris pseudacorus	Yellow Flag
Juncus articulatus	Jointed Rush
Juncus bufonis agg	Toad Rush
Juncus effusus	Soft Rush
Juncus inflexus	Hard Rush
Lotus uliginosus	Greater Bird's-foot Trefoil
Lychnis flos-cuculi	Ragged-robin
Lycopus europaeus	Gipsywort
Lythrum salicaria	Purple-loosetrife
Mentha aquatica	Water Mint
Mimulus guttatus	Monkeyflower
Myosoton aquaticum	Water Chickweed
Nasturtium officinale	Water-cress
Phalaris arundinacea	Reed Canary-grass
Phragmites australis	Common Reed
Polygonum amphibium	Amphibious Bistort

Polygonum lapathifolium	Pale Persicaria
Polygonum persicaria	Redshank
Ranunculus sceleratus	Celery-leaved Buttercup
Rorippa palustris	Marsh Yellow-cress
Salix cinerea	Grey Willow
Schoenoplectus lacustris	Common Club-rush
Scrophularia auriculata	Water Figwort
Sparganium erectum	Branched Bur-reed
Stachys palustris	Marsh Woundwort
Typha latifolia	Bulrush
Veronica anagallis-aquatica	Blue Water-speedwell
Veronica beccabunga	Brooklime
Veronica catenata	Pink Water-speedwell
Zannichellia palustris	

English equivalents from Dony *et al.* (1986) (2nd ed).

Appendix 2.1 Macroinvertebrates recorded from the main survey ponds on Pinkhill Meadow

Sites
MP = Main Pond GW = Groundwater Pond SW = Surface water Pond SC = Scrape
Dates
a = July 1990 b = November 1990 c = Februaury 1991 d = May 1991 e = July 1992 f = July 1993

	MP						GW						SW						SC					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
TRICLADIDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Five-season total						0						0						0						1
GASTROPODA	0	0	0	0	4	8	0	0	0	0	1	6	0	0	0	0	1	4	0	0	0	0	2	7
Five-season total						8						6						4						7
HIRUDINEA	0	1	0	1	2	3	0	0	0	0	2	1	0	0	0	0	0	2	0	0	0	0	2	3
Five-season total						3						2						2						3
MALACOSTRACA	0	0	0	2	1	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2
Five-season total						2						2						2						2
EPHEMEROPTERA	0	2	2	3	6	4	1	4	2	4	3	4	1	3	3	4	4	4	2	3	3	4	4	5
Five-season total						6						5						6						5
ODONATA	0	0	0	1	3	4	0	0	0	1	3	3	0	1	0	1	3	6	0	0	0	0	3	3
Five-season total						5						3						6						3
HEMIPTERA	1	4	2	9	11	14	3	8	5	9	7	14	0	7	8	7	5	8	3	5	6	3	8	10
Five-season total						16						16						17						13

Macroinvertebrates recorded from the main survey ponds on Pinkhill Meadow

	MP						GW						SW						SC					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
COLEOPTERA	3	6	3	16	18	17	3	4	4	11	10	19	5	8	11	16	15	18	3	2	3	7	10	17
Five-season total						30						26						31						23
MEGALOPTERA	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1
Five-season total						1						1						1						1
TRICHOPTERA	0	1	3	2	3	4	0	1	2	1	0	2	0	2	1	2	0	1	0	1	0	4	1	2
Five-season total						6						4						4						4
TOTAL	4	14	10	34	48	57	7	17	13	26	27	52	6	21	23	30	28	46	8	11	12	18	30	50
Five-season total						77						65						73						62
NATIONAL CONSERVATION INDEX	1	1.36	1.09	1.35	1.31	1.33	1.14	1.35	1.08	1.27	1.25	1.29	1	1.19	1.43	1.4	1.18	1.34	1.13	1.27	1.17	1.42	1.27	1.29

Appendix 2.2 Macroinvertebrates recorded from the main survey ponds on Pinkhill Meadow

Sites

MP = Main Pond GW = Groundwater Pond SW = Surface water Pond SC = Scrape

Dates

a = July 1990 b = November 1990 c = Febrauary 1991 d = May 1991 e = July 1992 f = July 1993

Abundance categories

1 = 1-5; 2 = 6-25; 3 = 26 - 125; 4 = 126 - 625; 5 = 626 - 4,000

	MP						GW						SW						SC					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
TRICLADIDA																								
Dugesia polychroa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
GASTROPODA																								
Potamopyrgus jenkinsi	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bithynia tentaculata	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Lymnaea auricularia	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Lymnaea palustris	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Lymnaea peregra	-	-	-	-	3	5	-	-	-	-	-	4	-	-	-	-	-	3	-	-	-	-	2	5
Lymnaea stagnalis	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Lymnaea truncatula	-	-	-	-	4	4	-	-	-	-	1	3	-	-	-	-	3	3	-	-	-	-	3	4
Anisus leucostoma	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisus vortex	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	4
Bathyomphalus contortus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Gyraulus albus	-	-	-	-	1	3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
Hippeutis complanatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
HIRUDINEA																								
Theromyzon tessulatum	-	-	-	1	2	2	-	-	-	-	1	2	-	-	-	-	-	2	-	-	-	-	1	3
Glossiphonia complanata	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glossiphonia heteroclita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Helobdella stagnalis	-	1	-	-	3	3	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	1	2
MALACOSTRACA																								
Asellus aquaticus	-	-	-	1	4	4	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	5
Crangonyx pseudogracilis	-	-	-	1	-	2	-	-	-	-	-	3	-	-	-	-	-	3	-	-	-	-	-	4
EPHEMEROPTERA																								
Cloeon dipterum	-	3	3	3	4	3	1	5	3	5	3	3	1	5	5	4	3	3	3	3	2	3	3	4
Cloeon simile	-	-	-	3	2	2	-	3	-	1	-	2	-	-	-	-	-	1	-	3	-	2	2	3
Ephemera vulgata	-	-	-	-	2	-	-	1	-	3	-	-	-	1	-	1	-	-	-	-	-	-	-	1
Caenis horaria	-	-	-	-	3	3	-	-	-	-	2	2	-	-	3	3	1	3	2	-	2	2	2	4
Caenis luctuosa	-	3	1	5	3	1	-	5	4	5	1	1	-	4	2	4	1	2	-	4	2	5	2	2
Caenis robusta	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-

Appendix 2.2
(Continued)

	MP						GW						SW						SC					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
ODONATA																								
Ischnura elegans	-	-	-	-	2	1	-	-	-	-	1	1	-	-	-	-	1	2	-	-	-	-	2	1
Enallagma cyathigerum	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Coenagrion puella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Orthetrum cancellatum	-	-	-	1	-	2	-	-	-	2	2	3	-	-	-	-	3	3	-	-	-	-	2	3
Libellula quadrimaculata	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Sympetrum striolatum	-	-	-	-	2	1	-	-	-	-	3	1	-	1	-	1	3	3	-	-	-	-	3	2
HEMIPTERA																								
Microvelia reticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Gerris lacustris	-	-	-	-	-	1	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	-	-
Gerris odontogaster	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gerris thoracicus	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1
Ranatra linearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Notonecta glauca	-	-	-	-	2	2	-	-	-	1	1	1	-	-	-	-	1	1	-	-	-	-	2	1
Notonecta maculata	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Notonecta marmorea	-	-	-	-	2	1	-	-	-	-	1	1	-	-	-	-	2	1	-	-	-	-	2	-
Cymatia coleoptrata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Cymatia bonsdorffi	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Callicorixa praeusta	-	1	1	1	-	1	1	1	1	-	-	-	-	-	1	-	-	-	1	1	1	-	1	1
Corixa panzeri	-	-	-	-	2	2	-	1	-	1	-	2	-	1	1	1	-	-	-	-	1	-	-	2
Corixa punctata	-	-	-	-	2	2	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-
Arctocorisa germari	-	-	-	2	2	1	-	1	-	2	-	1	-	1	1	1	-	-	-	1	1	1	-	-
Sigara dorsalis	-	-	-	1	-	-	-	1	-	1	-	1	-	-	-	-	-	1	-	-	-	-	1	1
Sigara distincta	-	-	-	1	2	2	-	1	1	-	-	3	-	-	1	1	-	2	-	-	-	-	-	1
Sigara falleni	-	-	-	3	1	1	-	2	1	1	-	1	-	-	1	-	1	-	-	-	1	-	1	1
Sigara fossarum	-	-	-	1	-	1	-	-	-	1	-	2	-	-	-	1	-	1	-	-	-	-	-	-
Sigara lateralis	1	3	2	4	2	5	1	3	2	2	2	3	-	2	3	1	2	2	1	3	3	3	2	4
Sigara nigrolineata	-	1	-	1	1	-	1	3	1	2	1	1	-	1	1	-	-	-	1	1	1	1	1	1
Sigara concinna	-	1	-	2	1	1	-	-	-	1	-	-	-	1	1	1	-	-	-	1	-	-	-	-
COLEOPTERA																								
Haliplus confinis	-	-	-	1	1	-	-	-	-	-	-	1	-	-	-	-	1	1	-	-	-	1	1	1
Haliplus flavicollis	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-
Haliplus fluviatilis	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Haliplus immaculatus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Haliplus lineatocollis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Haliplus obliquus	-	-	-	-	1	2	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1
Haliplus ruficollis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Noterus clavicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Laccophilus hyalinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Laccophilus minutus	-	1	-	1	2	3	-	-	1	-	1	2	-	1	3	2	1	2	-	-	-	-	2	4
Hyphydrus ovatus	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 2.2
(Continued)

	MP						GW						SW						SC					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
COLEOPTERA (continued)																								
Hydroglyphus pusillus	-	2	2	4	3	4	1	2	2	4	2	3	-	3	3	3	2	2	1	1	1	3	3	4
Hygrotus inaequalis	-	-	-	-	1	2	-	-	-	-	1	1	-	1	-	-	1	2	-	-	-	-	1	2
Hygrotus versicolor	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Coelambus confluens	-	1	-	1	-	2	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-
Coelambus impressopunctatus	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	2
Coelambus nigrolineatus	-	1	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Hydroporus palustris	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-
Hydroporus planus	-	-	-	-	-	-	-	-	1	-	-	-	1	1	1	-	1	-	-	-	1	-	-	1
Hydroporus pubescens	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydroporus tessellatus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamonectes depressus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Agabus bipustulatus	-	-	-	-	1	-	-	1	-	1	1	-	-	-	-	-	1	1	-	-	-	-	-	-
Agabus nebulosus	-	-	-	1	2	1	-	-	-	-	1	1	-	1	-	1	2	1	-	-	-	-	1	-
Rhantus suturalis	-	-	-	1	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Colymbetes fuscus	1	-	-	1	1	-	-	-	-	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-
Gyrinus substriatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Helophorus grandis	-	-	-	-	-	-	-	-	-	1	-	-	-	1	2	2	-	-	-	1	-	1	-	-
Helophorus brevipalpis	-	-	-	1	1	4	1	-	-	1	-	3	1	1	1	2	2	1	-	-	1	2	2	4
Helophorus granularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	2	-	-
Helophorus minutus	-	-	-	-	1	1	-	-	-	1	-	1	-	-	-	2	1	1	-	-	-	-	-	1
Helophorus obscurus	-	-	1	1	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-
Hydrobius fuscipes	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	1	1	-	-	-	-	-	-	1
Anacaena limbata	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Laccobius minutus	-	-	-	-	-	1	-	-	-	1	1	1	-	-	-	-	-	1	-	-	-	-	1	1
Laccobius bipunctatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Laccobius sinuatus	-	-	-	-	1	2	-	-	-	-	1	2	-	-	-	-	-	1	-	-	-	-	1	3
Laccobius striatulus	1	1	1	2	2	2	1	1	1	2	1	1	-	-	1	3	1	1	1	-	-	2	1	-
Helochares lividus	-	-	-	-	-	1	-	-	-	-	-	1	-	-	1	1	-	1	-	-	-	-	-	2
Ochthebius dilatatus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Ochthebius minimus	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Elmis aenea	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oulimnius tuberculatus	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Dryops. sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
MEGALOPTERA																								
Sialis lutaria	-	-	-	-	-	1	-	-	-	-	1	2	-	-	-	-	-	3	-	-	-	-	-	1

Appendix 2.2
(Continued)

	MP						G W						S W						S C					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
TRICHOPTERA																								
Agraylea multipunctata	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agraylea sexmaculata	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Anabolia nervosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Limnephilus affinis/incisus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Athripsodes cinereus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Leptocerus tineiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mystacides longicornis	-	-	1	2	3	2	-	1	-	-	-	1	-	1	-	1	-	-	-	-	-	1	-	2
Oecetis lacustris	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-
Oecetis ochracea	-	1	1	3	1	1	-	-	1	2	-	-	-	-	-	2	-	-	-	1	-	1	1	2
Agrypnia varia	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 2.3 Notes on rare, Nationally Notable and local species recorded from Pinkhill Meadow wetland site

Nationally Notable A = Scarce: recorded from only 15 - 30 10-km grid squares.

Nationally Notable B = Scarce: recorded from only 31 - 100 10-km grid squares.

Local = Species not falling into 'RDB' or 'Notable' categories, but usually either (a) confined to certain limited geographical areas where they may, however, be present in large numbers; (b) of widespread distribution, but present only in small numbers where they occur; or (c) restricted to a very specialised habitat of which, however, they may be a common component.

Note: References to 'Britain' are to mainland Britain, and do not include Ireland. Species not recorded at Pinkhill before 1993 are marked with a † .

NATIONALLY NOTABLE A SPECIES

Coelambus nigrolineatus (COLEOPTERA: Dytiscidae). A diving beetle.

Previously placed in the category **RDB3*** (species whose Category 3 status is uncertain, i.e., those only recently discovered or recognised in Britain), but since allocated a Nationally Notable A status. Appears to be an immigrant from the Continent: until very recently it was thought to be present in Britain in only one Kent gravel pit, but it is presumably at present still increasing its range in Britain. Its exact distribution, and its preferred habitat in this country, are as yet unclear. (Shirt, 1987; Hyman and Parsons, 1992; Friday, 1988.)

NATIONALLY NOTABLE B SPECIES

Berosus signaticollis† (COLEOPTERA: Hydrophilidae). A water scavenger beetle.

A scarce species, apparently limited in range to the south and west of England. Typically found in shallow, muddy and silty ponds, where it appears to be tolerant of intense fouling by livestock (and birds?): perhaps influenced by occasional brackish conditions. 'An important part of the southern heathland community...Even in the deep south, any *Berosus* species makes the day a little more cheerful' (Foster). (Foster, 1987; Foster and Eyre, 1992.)

Enochrus melanocephalus† (COLEOPTERA: Hydrophilidae). A water scavenger beetle.

Usually a coastal species frequenting brackish water in southern England (though it may occasionally be found in the north of England), but in south-east England it may occur, locally, inland. (D. Bilton, pers. comm.; Friday, 1988.)

Helochares lividus (COLEOPTERA: Hydrophilidae). A water scavenger beetle.

Typically found in ponds with some aquatic plant cover. More likely to occur in the south-east than in other parts of Britain, and apparently absent altogether from Scotland. (The species may well, however, have been under-recorded in the past, since it is by no means always easy to distinguish from *H. punctatus*.) (Friday, 1988; Pond Action, unpublished data.)

(Continued)

Appendix 2.3 Notes on rare, Nationally Notable and local species recorded from Pinkhill Meadow wetland site

Hydroglyphus pusillus **(COLEOPTERA: Dytiscidae). A diving beetle.**

Found in heath pools, mossy ditches, and (most characteristically, and sometimes in abundance) in new, man-made ponds, where it is often one of the earliest colonisers (as at Pinkhill Meadow). Locally distributed in the south of England, where it is fairly common, and the Midlands. (Foster, 1981; Friday, 1988; Pond Action, unpublished data.)

Laccobius sinuatus **(COLEOPTERA: Hydrophilidae) A water scavenger beetle.**

A species of slow-flowing drains and, often, of new ponds, where it may be an early coloniser, being particularly associated with muddy habitats. Locally scarce in England but absent from Scotland, and nowhere common (although it is sometimes present in large numbers where it does occur). (Friday, 1988; Foster and Eyre, 1992; Pond Action, unpublished data.)

Rhantus suturalis **(COEOPTERA: Dytiscidae). A diving beetle.**

Locally distributed over most of England, but more especially in the south. Prefers silt and detritus pools. (Foster, 1985; Friday, 1988.)

LOCAL SPECIES

Caenis robusta **(EPHEMEROPTERA: Caenidae). A mayfly ("white midge" or "angler's curse").**

The larvae are locally common and widespread, both in running and still waters. Found in the pools and margins of rivers and in ponds and canals, chiefly in mud or silt that is rich in organic matter. (Elliott, Humpesch and Macan, 1988.)

Cloeon simile **(EPHEMEROPTERA: Baetidae). The Lake Olive.**

Widespread, but rather less common than *C. dipterum* (the Pond Olive), although the two species are similar in appearance, and may occur together in some localities (as at Pinkhill). The nymphs are found in the margins and pools of slow-flowing sections of streams and rivers, and in the deeper water of large ponds and lakes. (Elliott, Humpesch and Macan, 1988.)

Orthetrum cancellatum **(ODONATA:Libellulidae). The Black-tailed Skimmer.**

Locally common in south-east and southern Britain, where it appears to be on the increase. Shows a marked liking for clay and gravel pits, and readily wanders in search of new habitats which it quickly colonises. Known to be an early coloniser of gravel-pit lakes in the Thames Valley. (Hammond and Gardner, 1985; J. Campbell, pers. comm.)

(Continued)

Appendix 2.3 Notes on rare, Nationally Notable and local species recorded from Pinkhill Meadow wetland site

Corixa panzeri **(HETEROPTERA: Corixidae). A lesser waterboatman.**

A local species with a widespread distribution throughout mainland Britain, but scarce where it occurs; found only at low altitudes, in ponds or pools with a moderate amount of aquatic and/or emergent plant cover. (Savage, 1989.)

Cymatia bonsdorffi **(HETEROPTERA: Corixidae). A lesser waterboatman.**

A small, carnivorous water bug which occurs in still-water, often acidic and/or base-poor, habitats where there is plenty of aquatic and emergent plant cover. Distribution is scattered throughout Britain, but the species is somewhat more frequent in low-altitude areas of Wales and the north of England than in other regions. (Savage, 1989.)

Cymatia coleoptrata **(HETEROPTERA: Corixidae). A lesser waterboatman.**

A small water bug, related to *C. bonsdorffi*, but much less widespread: found in the south of England and the Midlands, but the north-west Midlands are believed to be the northern limit of its range. (Past records of the species from further north than this are now thought to have been misidentifications.) Found in lakes and ponds with moderate to large amounts of aquatic and emergent plant cover, at low altitude. (Savage, 1989.)

***Ranatra linearis*†** **(HETEROPTERA: Nepidae). The Water Stick Insect.**

Very local: a frequent species in more southern counties (particularly the south-east), but scarce in Wales and the Midlands, and absent from the rest of Britain. Prefers ponds and lakes, but is also occasionally found in slow-flowing sections at the margins of rivers and streams. Requires plenty of emergent plant cover, since floating dead stems of, for example, bur-reed (*Sparganium*) or bulrush (*Typha*) are utilised as egg-laying sites. (Savage, 1989; Kirby, 1992; Pond Action, unpublished data.)

Sigara concinna **(HETEROPTERA: Corixidae). A lesser waterboatman.**

Found throughout mainland Britain, particularly in the Midlands, but scarce where it occurs. Restricted to still waters, usually with some vegetation; often associated with new or disturbed sites. (Savage, 1989; Pond Action, unpublished data.)

***Oecetis lacustris*†** **(TRICHOPTERA: Leptoceridae). A cased caddis fly.**

Common throughout England, but uncommon in Scotland, where it only occurs south of the Great Glen. Inhabits ponds, lakes, canals, and slow-flowing rivers; requires a muddy sand substratum. (Often, as here, found in association with the similar, but much commoner and more widespread, *O. ochracea*.) (Wallace, 1991.)

***Haliplus confinis*†** **(COLEOPTERA: Haliplidae). A haliplid water beetle.**

Widespread but local. Found in fen ditches and dykes, pools and streams. (D. Bilton, pers. comm.; Friday, 1988.)

(Continued)

Appendix 2.3 Notes on rare, Nationally Notable and local species recorded from Pinkhill Meadow wetland site

Haliplus obliquus **(COLEOPTERA: Haliplidae). A haliplid water beetle.**

Widespread but local, occurring throughout Britain except in the Scottish Highlands. Usually a species of permanent base-rich waters, it is often found in ponds or ditches where the aquatic vegetation includes *Chara* sp (stonewort), with which it appears to be associated (although this is as yet incompletely studied). (Certainly, however, *Chara* is abundant in much of the water at Pinkhill.) (Foster, 1981; Foster and Eyre, 1992; Pond Action, unpublished data.)

Helophorus granularis **(COLEOPTERA: Hydrophilidae). A water scavenger beetle.**

A tiny *Helophorus* species, typically preferring shallow, grassy ponds. Widespread, but very local in distribution. Although not frequently found, when it does occur it may do so in considerable abundance, often sharing its habitat with large numbers of *Helophorus* of one or more different species. (Friday, 1988; Pond Action, unpublished data.)

Appendix 2.4 Macroinvertebrates recorded from Pinkhill Meadow in September 1992 and October 1993

KEY

a =Main Pond, east section
b = Main Pond, west section
c = Groundwater Pond
d = Surfacewater Pond
e = Scrape
f = Phragmites bed, north
g = Northern isolated ponds
h = Undulating margins, north
i = Dragonfly ponds
j= South Pond, northern section
k = South Pond, southern section
l = Old Phragmites bed
m = Phragmites bed, south
n = Undulating margins, south
(1 = 1992; 2 = 1993)

	a a	b b	c c	d d	e e	f f	g g	h h	i i	j j	k k	l l	m m	n n
	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2
TRICLADIDA														
Dendrocoelum lacteum	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -
Dugesia lugubris	+ -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	+ -	- +	- -
Dugesia polychroa	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- +	- -	- -
GASTROPODA														
Anisus leucostoma	- -	- -	- +	- -	- -	- +	- -	- +	- -	- -	- -	- -	- -	- -
Anisus vortex	- -	- -	+ +	- +	- +	- +	- +	- -	- +	- +	+ +	+ +	+ +	+ +
Bathyomphalus contortus	- -	- -	- -	- -	- -	- -	- +	- -	- +	- -	- +	+ -	- -	- -
Gyraulus albus	- +	- -	- +	- -	- -	- -	- -	- -	- +	- +	- +	- -	- +	- +
Hippeutis complanatus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -
Lymnaea palustris	- -	- -	- -	- -	- +	- +	- -	- +	- -	- -	- +	- -	- -	- +
Lymnaea peregra	+ +	+ +	- +	+ +	+ +	- +	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Lymnaea stagnalis	- -	- -	- +	- -	- +	- +	- -	- -	- +	+ +	- +	+ +	- +	- +
Lymnaea truncatula	+ +	+ +	+ -	+ +	+ +	+ -	+ +	+ +	+ +	+ +	+ +	- +	+ -	+ +
Physa acuta	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	+ -	+ -
Planorbis carinatus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -
Potamopyrgus jenkinsi	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -
BIVALVIA														
Sphaerium corneum	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -
Sphaerium lacustre	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -
HIRUDINEA														
Erpobdella octoculata	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -	- -	- -
Helobdella stagnalis	+ -	+ -	+ -	+ -	- -	- -	- +	+ +	- +	- -	- -	+ +	- -	- -
Theromyzon tessulatum	+ +	+ +	- -	+ +	+ +	+ +	- -	+ -	- +	- +	- -	+ -	+ -	+ +

Appendix 2.4 (Continued)

	aa	bb	cc	dd	ee	ff	gg	hh	ii	jj	kk	ll	mm	nn
	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2
CRUSTACEA														
Asellus aquaticus	+ +	+ +	+ -	+ -	+ +	- +	- +	+ +	+ +	+ +	+ +	+ +	- -	+ +
Crangonyx pseudogracilis	- +	- +	- +	- +	- +	- +	- +	- +	- +	+ +	+ -	+ +	- +	- +
EPHEMEROPTERA														
Caenis horaria	- -	- +	- +	- -	- +	- +	- +	- -	- +	- +	- +	- -	- -	- +
Caenis luctuosa	+ -	+ -	+ -	- -	- -	+ +	- +	- -	- +	+ -	- -	- -	+ +	- -
Cloeon dipterum	+ +	+ +	- +	+ +	+ +	+ +	+ +	+ -	+ +	- +	+ +	- +	- +	- +
Cloeon simile	+ -	+ +	+ -	+ -	+ -	+ +	- -	+ -	- +	+ -	+ -	- -	+ -	+ -
Ephemera vulgata	+ +	+ -	- -	- -	- +	+ -	- -	- -	- -	+ +	+ -	- -	- +	- -
ODONATA														
Aeshna cyanea	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -
Anax imperator	- -	- -	- -	- -	- -	+ +	- -	- -	- -	- -	- -	- -	- -	- +
Coenagrion puella/pulchellum	+ +	- -	- -	- -	- -	+ +	- -	- -	- +	- -	- -	- -	- -	- -
Enallagma cyathigerum	+ +	+ +	- +	- +	+ +	- +	- +	- -	+ +	+ +	+ -	- -	+ -	+ -
Ischnura elegans	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ +	+ +	+ +	+ -	+ +	+ +
Libellula depressa	+ +	- -	+ +	- -	+ +	+ +	+ +	- -	- +	- +	+ +	- -	+ -	+ +
Orthetrum cancellatum	+ +	+ -	+ +	+ -	+ +	+ +	+ +	+ -	- -	+ +	+ -	- -	+ -	+ +
Sympetrum striolatum	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	+ -	+ -	- -
PLECOPTERA														
Leuctra geniculata (adult)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +
MEGALOPTERA														
Sialis lutaria	- -	- -	- +	- +	- -	- +	- -	- +	- +	+ -	+ +	- +	- +	- +
TRICHOPTERA														
Agraylea multipunctata	+ +	- -	- -	- +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Agrypnia varia	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	+ -	- -
Athripsodes aterrimus	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Molanna angustata	- -	- +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mystacides longicornis	- +	+ +	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Oecetis ochracea	+ -	+ -	- -	- -	- -	- -	- -	- -	- +	- -	+ -	- -	- -	- +
Phryganea bipunctata	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -

Appendix 2.4 (Continued)

	aa	bb	cc	dd	ee	ff	gg	hh	ii	jj	kk	ll	mm	nn
	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2
HEMIPTERA														
Arctocorisa germari	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Callicorixa praeusta	- -	- -	- -	- -	+ -	- -	+ +	- -	- -	- -	+ -	- -	- +	- -
Corixa panzeri	+ +	+ -	+ +	+ +	+ -	+ +	- +	+ -	+ +	+ +	+ -	- -	+ +	+ -
Corixa punctata	+ -	- -	- -	- +	+ -	+ +	+ +	- -	+ +	- +	+ -	- -	+ -	+ +
Cymatia bonsdorffi	- -	- -	- -	- -	- -	- +	- -	- -	- +	- -	- -	- -	- -	- -
Gerris lacustris	- +	- +	- -	+ -	- -	- -	- +	+ +	- +	- +	+ -	- -	+ +	- -
Gerris thoracicus	- +	- +	+ -	+ -	+ -	- -	+ -	+ -	+ +	+ -	+ +	- -	+ -	+ -
Hesperocorixa sahlbergi	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -
Ilyocoris cimicoides	- +	- -	- -	- -	- -	- +	- -	- +	- -	- -	- -	- -	- -	- -
Microvelia reticulata	- -	- -	- -	- -	- -	- -	- +	- -	- -	+ -	- -	- -	- -	- -
Nepa cinerea	- -	- -	- -	- +	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -
Notonecta glauca	+ +	- -	+ -	+ +	+ -	+ +	+ +	+ -	+ +	+ +	+ +	+ +	+ +	+ +
Notonecta maculata	- -	- -	- -	- +	- -	+ -	- -	- -	- -	- -	- -	- -	+ -	- -
Notonecta marmorea viridis	+ +	- +	+ +	+ +	+ -	+ +	+ +	+ -	+ +	+ +	+ -	+ -	+ +	+ +
Sigara concinna	- -	+ +	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Sigara distincta	+ +	- +	+ +	+ +	+ -	+ +	- +	+ -	+ +	+ +	+ -	- -	+ +	+ +
Sigara dorsalis	+ -	- -	- -	- -	+ -	+ -	- -	- -	+ +	+ -	+ -	- -	+ -	+ -
Sigara falleni	+ -	- -	+ +	- -	+ -	+ +	- -	- -	- -	+ +	- +	- -	- -	+ +
Sigara fossarum	- +	- -	- +	- -	- +	- +	- +	- -	- -	+ +	+ +	- +	- -	- +
Sigara lateralis	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	- +	+ +	+ +
Sigara nigrolineata	- -	+ -	+ -	+ -	+ +	- +	+ -	+ -	- -	+ -	+ -	- +	+ -	+ +
COLEOPTERA														
Agabus bipustulatus	- +	- +	- -	+ +	- -	- +	+ +	+ +	- +	- -	- -	- -	- -	+ +
Agabus nebulosus	- -	+ -	+ -	+ +	+ -	+ -	+ +	+ +	+ +	+ -	- -	+ -	+ -	- -
Agabus sturmii	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -	- -
Anacaena limbata	- -	- -	+ -	- -	- -	- -	- +	- -	- -	- -	- -	+ -	- -	- -
Berosus signaticollis	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -
Coelambus confluens	- +	- +	- -	- +	+ -	+ -	- +	- -	+ -	+ -	- -	- -	- -	- -
Coelambus impressopunctatus	- +	+ +	+ -	+ +	+ -	- +	- +	+ +	+ +	+ -	+ -	+ -	+ -	+ -
Coelambus nigrolineatus	- +	+ +	- -	- -	- -	+ -	- -	- -	+ -	- -	- -	- -	- -	- -
Colymbetes fuscus	- -	+ -	- -	+ +	- -	- +	+ -	+ +	+ -	+ -	+ -	+ -	- -	- -
Enochrus melanocephalus	- +	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Gyrinus substriatus	- -	- -	- -	- -	- -	+ -	- -	- -	- -	- -	- -	- -	- -	- -
Haliplus confinis	- -	- -	- -	- -	- -	- +	+ -	- +	+ -	- -	- -	- -	- -	- -
Haliplus flavicollis	- -	- -	- -	+ -	- -	- -	+ -	+ -	- -	- -	- -	- -	- +	+ -
Haliplus fluviatilis	- +	- -	- -	- +	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Haliplus immaculatus	- -	- -	- -	- +	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -
Haliplus lineatocollis	- -	- -	- -	- -	- -	+ -	- +	- -	+ -	- -	- +	- -	- -	- -
Haliplus obliquus	- -	- -	- -	- +	- -	- -	- +	- +	- +	- -	- +	- -	+ -	- -
Haliplus ruficollis	- -	- -	- -	- -	- -	- -	+ -	- -	+ -	- -	- -	- -	- -	- -

Appendix 2.4 (Continued)

	a a	b b	c c	d d	e e	f f	g g	h h	i i	j j	k k	l l	m m	n n
	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2
COLEOPTERA (continued)														
Helochares lividus	+ +	- -	+ -	- +	+ -	- +	- +	- -	- +	+ -	- +	- -	+ -	+ +
Helophorus aequalis	- -	- +	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- +
Helophorus brevipalpis	- -	+ -	- -	- -	- -	- -	+ -	- +	+ -	- -	- +	- +	- -	- +
Helophorus grandis	- -	- -	- -	- +	- -	- -	+ -	- -	- +	- -	- -	- -	- -	- -
Helophorus granularis	- -	- -	- -	- -	- -	- -	+ -	- -	- -	- -	- -	- -	- -	- -
Helophorus minutus	- -	- -	- -	- +	- -	- -	- +	- +	- -	- -	- -	- -	- -	- -
Helophorus obscurus	- -	- -	- -	- -	- -	- -	+ -	- -	- -	- -	- -	- -	- -	- -
Hydrobius fuscipes	- -	- -	- -	- -	- +	- -	- -	- +	- -	- -	- -	- -	- -	+ -
Hydroglyphus pusillus	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ +	+ +
Hydroporus angustatus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -
Hydroporus palustris	- -	- +	+ -	+ -	- -	- -	- +	+ +	- -	- -	- -	+ -	- -	- -
Hydroporus planus	- -	- -	- -	+ -	- -	- -	- +	- +	+ -	- -	- +	- -	- -	- -
Hydroporus tesselatus	- -	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -
Hygrotus inaequalis	+ +	- +	+ -	+ +	+ +	+ +	- +	+ +	+ +	+ -	+ +	+ -	+ +	+ +
Hygrotus versicolor	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -	- -
Hyphydrus ovatus	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	+ -	- -	- -	- +
Ilybius fuliginosus	- -	- -	- -	- +	+ -	- +	+ +	- +	- -	+ -	- -	- -	+ -	+ -
Laccobius bipunctatus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	+ -	- -	- -
Laccobius minutus	+ +	- +	- -	+ -	+ +	- +	- +	+ +	+ -	+ -	+ +	+ -	+ +	+ -
Laccobius sinuatus	+ +	+ +	+ -	- +	+ -	- -	+ -	- +	+ -	- -	+ +	- -	+ +	+ +
Laccobius striatulus	+ +	- -	+ +	+ -	+ -	+ +	+ +	+ +	+ +	+ -	+ -	+ -	+ -	+ -
Laccophilus hyalinus	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -	- +	- -
Laccophilus minutus	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ +	+ +
Noterus clavicornis	+ +	- -	+ -	+ -	+ -	- -	- +	+ +	- +	+ -	+ +	- +	- +	+ -
Ochthebius minimus	- -	+ -	- -	- -	- -	- +	- +	- +	- -	- -	- -	- -	- -	- -
Potamonectes depressus elega	- -	+ -	- -	- -	- -	- -	- -	- -	+ -	- -	- -	- -	- -	- +
Rhantus suturalis	- -	- -	- -	- -	- -	- -	+ +	- -	+ -	- -	- -	- -	- -	- -
Scarodytes halensis	- -	- -	- -	- -	- -	+ -	- -	- -	- +	- -	+ -	- -	- -	- -

Appendix 3.1. Raw data from pond Experiment 1

POND 1

	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	Total
Pond 1 Section 1	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	Total
1	3	0	0	0	0	0	0	0	0	3
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
Pond 1. Section 2	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	2	0	0	0	2
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
Pond 1. Section 3	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
11	0	0	0	0	0	0	0	0	0	0
12	0	3	0	0	0	0	0	0	0	3
13	0	1	0	0	0	0	0	0	0	1
14	3	2	0	0	0	0	0	0	0	5
15	0	0	0	0	0	0	0	0	0	0
Pond 1. Section 4	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
16	3	0	0	0	0	0	0	0	0	3
17	19	0	0	0	0	0	0	0	0	19
18	6	0	0	0	0	0	0	0	0	6
19	17	0	0	0	0	0	0	0	0	17
20	0	2	0	0	0	0	0	0	0	2
Pond 1 Section 5	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
21	9	0	12	0	0	0	0	0	0	21
22	2	0	0	0	0	0	0	0	0	2
23	2	0	0	0	0	0	0	0	0	2
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
Pond 1 section 6	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
26	0	0	0	0	0	0	0	0	0	0
27	5	0	0	0	0	0	0	0	0	5
28	11	0	0	0	0	0	0	0	0	11
29	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0
Pond 1 section 7	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
31	0	0	0	0	0	0	0	0	0	0
32	7	0	0	0	0	4	0	0	0	11
33	0	1	0	0	0	0	0	0	0	1
34	13	0	0	0	0	0	0	0	0	13
35	7	0	30	0	0	0	0	0	0	37
Pond 1 section 8	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
36	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
38	11	0	0	0	0	0	0	0	0	11
39	18	0	0	0	0	0	0	0	0	18
40	23	0	0	0	0	0	0	0	0	23

POND 2										
	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
Pond 2 section 1										
41	0	0	0	0	0	0	0	0	0	0
42	3	0	0	0	0	0	0	0	0	3
43	6	0	0	0	0	0	0	0	0	6
44	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0
Pond 2 section 2	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
46	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0
50	0	0	40	0	0	0	0	0	0	40
Pond 2 section 3	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
51	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0
Pond 2 section 4	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
56	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0
58	0	4	0	0	0	0	0	0	0	4
59	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0
Pond 2 section 5	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
61	0	3	0	0	0	0	0	0	0	3
62	0	0	0	0	0	3	0	0	0	3
63	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0
Pond 2 section 6	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
66	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0
Pond 2 section 7	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
71	34	0	0	0	0	0	0	0	0	34
72	0	3	0	0	0	0	0	0	0	3
73	0	0	0	0	0	0	0	0	0	0
74	4	0	0	0	0	0	0	0	0	4
75	0	0	0	0	0	0	0	0	0	0
Pond 2 section 8	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
76	0	0	0	0	0	2	0	0	0	2
77	18	0	0	0	0	0	0	0	0	18
78	3	0	0	0	0	0	0	0	0	3
79	0	2	0	0	0	0	0	0	0	2
80	0	0	0	0	0	3	0	0	0	3

POND 3									
	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
Pond 3 section 1										
81	0	0	0	0	0	0	3	0	0	3
82	0	0	0	0	0	0	0	0	0	0
83	3	0	0	0	0	0	0	0	0	3
84	0	0	0	0	0	0	0	0	0	0
85	2	0	0	0	0	0	0	0		2
Pond 3 section 2	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
86	0	0	27	0	0	0	0	0	0	27
87	20	0	0	0	0	0	0	0	0	20
88	0	0	0	0	0	0	0	0	0	0
89	5	0	0	0	0	0	0	0	0	5
90	0	1	0	0	0	0	0	0	0	1
Pond 3 section 3	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
91	9	0	0	0	0	0	0	0	0	9
92	3	0	0	0	0	0	0	0	0	3
93	5	0	0	0	0	0	0	0	0	5
94	8	0	0	0	0	0	0	0	0	8
95	5	0	0	0	0	0	0	0	0	5
Pond 3 section 4	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
96	16	1	0	0	0	0	0	0	0	17
97	0	0	19	0	0	0	0	0	0	19
98	3	6	13	0	0	0	0	0	0	22
99	6	0	0	0	0	0	0	0	0	6
100	10	0	0	0	0	0	0	0	0	10
Pond 3 section 5	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
101	0	5	0	0	0	0	0	0	0	5
102	0	0	41	0	0	0	0	0	0	41
103	8	0	106	0	0	0	0	0	0	114
104	22	0	99	0	0	0	0	0	0	121
105	0	2	0	0	0	0	0	0	0	2
Pond 3 section 6	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
106	8	0	0	0	0	0	0	0	0	8
107	8	0	0	0	0	0	0	0	0	8
108	1	0	1	0	0	0	0	0	0	2
109	1	0	25	0	0	0	0	0	0	26
110	22	0	0	0	0	0	0	0	0	22
Pond 3 section 7	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
111	3	1	0	0	0	0	0	0	0	4
112	0	0	0	0	0	0	0	0	0	0
113	8	0	97	0	0	0	0	0	0	105
114	0	0	11	0	0	0	0	0	0	11
115	19	0	0	0	0	0	0	0	0	19
Pond 3 section 8	Typha	Alisma	Glyceria	Juncus	Agrotis	Phalaris	P. amph.	Ran. scel	Veronica	
116	22	0	5	0	0	0	0	0	0	27
117	0	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0
120	24	0	0	0	0	0	0	0	0	24