Report to English Nature

THE STATUS AND MANAGEMENT OF *DOLOMEDES PLANTARIUS* ON LOPHAM AND REDGRAVE FEN NATIONAL NATURE RESERVE IN 1993

CONTRACT No.: F-72-21-35
CONTRACTOR: Dr. Helen Smith

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SUMMARY

1. In 1993 English Nature funded four areas of work on *Dolomedes plantarius*, the fen raft spider, on Lopham and Redgrave Fen National Nature Reserve. These were: (1) the establishment of a new census scheme covering a wider area of the fen than in previous years; (2) an investigation of the effects of different vegetation types in the pools on the detectability of spiders; (3) management work on a random sample of the pools managed for spiders in 1992, and (4) monitoring of the effects of management on spider numbers.

2. The aims of the new census scheme were (1) to check the assumption made in the previous two years that spiders were largely confined to artificially irrigated pools and (2) to provide a baseline for monitoring recovery of the population.

3. A sample of 32 pools was selected in compartment 5 of Little Fen, including some of the machine-dug, irrigated pools monitored in previous years, unirrigated machine-dug pools and much older pool formed by peat-digging. On Middle Fen the census comprised 28 pools, all of which were machine-dug, in compartments 2, 3 and 4. Three census rounds, each comprising two counts, were made, in spring, summer and autumn. The location, size, sex and banding pattern of all spiders was recorded. Water levels in all pools were measured relative to a datum established in April 1992.

4. Spiders were found on pools throughout compartment 5 of Little Fen but on Middle Fen they were largely confined to pools in which they had been found in 1991 and 1992. Numbers on the irrigated pools on Little fen declined during the early summer and no breeding females or nursery webs were found on these pools. It is suggested that low water temperature in the irrigated pools may have made them sub-optimal for breeding. Similar total numbers of spiders were recorded on Little Fen and Middle Fen but densities per pool were higher on Middle Fen. This may have resulted from the relatively low water levels restricting the amount of suitable habitat available. There was some evidence that numbers of breeding attempts in 1993 were lower than in 1992. Because of the reduced sampling frequency and changed census area, no direct comparisons of numbers between 1993 and the previous two years was possible.

5. Water levels were higher in spring 1993 than in 1992, following a wetter winter. On Little Fen they remained above the April 1992 datum in the irrigated pools but fell progressively until early September in the remainder of the compartment. Water loss on Middle Fen was, on average, 20cm greater than on Little Fen. Irrigation was less effective in sustaining water levels, although water losses from the irrigated pools were less severe than in 1992.

6. Management work designed to reduce shading and infilling of the pools was carried out on 18 out of the 32 irrigated pools on Little Fen and on 13 of the 24 irrigated pools on Middle Fen, all of which were managed in 1992. In addition, management was carried out on six of the 12 unirrigated pools censused, but not managed, on Middle Fen in 1992. Management work comprised cutting the vegetation at the margins of the pools in March and cutting emergent vegetation from the centres of the pools from late July onwards.

7. The effects of the spring management work were assessed by comparing the numbers of spiders on managed and unmanaged pools. Spiders were counted on two dates in late June/early July and these data were supplemented by additional censuses carried out by a volunteer between mid-May and early August. Analyses of the differences between managed and unmanaged pools and the differences in numbers between 1992 and 1993 revealed no significant effects of spring management on spider numbers. It is suggested that any differences

are more likely to be apparent in 1994, when the effects of the summer management work can also be assessed. The value of continuing spring management work for a third year is questioned because it is likely to weaken seriously the growth of *Cladium mariscus*, which is important in providing cover and the vegetation structure needed for nursery web construction.

8. Replicated comparisons of counts of spiders on pools with dense vegetation overhanging the water's edge, or emerging from the water, revealed no significant differences in detectability from those on pools with edges relative unobscured by vegetation. The time of day at which counts were made also had no significant effects on the numbers of spiders seen. Although the sample sizes and for this exercise were relatively small, it is concluded that these factors are unlikely to be a major source of bias in the estimates of spider numbers obtained in the main census or in the management experiment (above).

9. Six recommendations are made for future work. (1) In view of the continuing precarious status of *D. plantarius* on the reserve, the new census scheme should be maintained, at least until water levels on the fen are restored and recovery is under-way. The population estimates should be based on the maximum count of three sample rounds at any point in time, and the number of census rounds needed in each year should be reviewed. (2) The present distribution of spiders on the reserve should be properly assessed. (3) Since maintenance of the population is likely to remain dependent on irrigation water supplies for at least another three years, the effects of water temperature on the spiders should be evaluated. (4) The frequency and extent of movements of spiders between pools should be measured by a mark-release-recapture programme, to assess both the effects of movements on population estimates, and the likely rates of spread of the population in the event of recovery. (5) The management experiment should be continued for a further year but consideration should be given to managing only in summer and monitoring should entail using triplicate counts, preferably in both early and late summer. (6) An autecological study of *D. plantarius* on the Fen is urgently needed if future management is to be soundly-based and the ability of the species to recovery from its present very low numbers is to be evaluated.

1 INTRODUCTION

In this report I describe the monitoring of *Dolomedes plantarius*, the fen raft spider, funded by English Nature's Rare Species Recovery Programme on Lopham and Redgrave Fen National Nature Reserve in 1993. Habitat management work funded by the Rare Species Recovery Programme and undertaken by the Suffolk Wildlife Trust (the owners/managers of the reserve) on some of the pools occupied by the spiders is also described.

1.1 Background

The background to this work is fully documented by Duffey (1991) and Smith (1992), and is summarised only briefly here. Lopham and Redgrave Fen NNR is one of only two sites for *Dolomedes plantarius* in Great Britain. Water abstraction from the Fen since 1960, exacerbated by four years of drought between 1989 and 1992, resulted in the decline of the spider population to very low levels. Detailed monitoring of its status was instigated by English Nature's Species Recovery Programme in 1991 and continued in 1992.

In both of those years it was assumed that the spider population was largely confined by the extreme drought to artificially dug pools on both Little and Middle Fen. From August 1991 these pools were irrigated during the summer months with dechlorinated water piped from the Suffolk Water Company Borehole adjacent to the Reserve. The aim of the monitoring exercise in both 1991 and 1992 was to estimate the numbers of spiders in different age and sex classes in the majority of the irrigated pools on both Little and Middle Fen. In 1992 additional data collected by volunteers also enabled more detailed information on the spiders' breeding success and biology to be gathered (Smith 1992).

1.2 Aims

In 1993 the aims of the monitoring programme were modified, and two additional objectives were incorporated into the work funded by English Nature. The aims and rationale behind these three areas of the work are described below.

1.2.1 MONITORING

Whilst the monitoring undertaken in 1991 and 1992 allowed the estimation of population density on what were thought to be the last strong-holds of the spider population on the fen, they neither allowed this assumption to be verified nor provided a baseline for monitoring recovery of the population. Plans to restore the water levels on the Fen, by ending water abstraction within the next few years, made the ability to detect recovery imperative. New census areas were therefore defined on both Little and Middle Fens, covering both the areas monitored in 1991 and 1992 and a much more extensive contiguous area of fen (see Section 2.1.1 below). These areas were monitored only three times during the year, with each monitoring round comprising two counts. As in previous years, relative water levels in the census pools were measured on the same dates.

This frequency of monitoring was thought likely to be adequate to provide a measure of the distribution of the population within the census area, and a baseline for an index of population size. It was accepted that it would be inadequate to provide estimates of breeding success equivalent to those derived for 1992. This change in the pools included in the census inevitably

makes comparisons of population size in 1991 and 1992 with 1993 difficult, although comparisons between 1993 and subsequent years can be standardised. The problem of assessing the status of the population in 1993 relative to that in 1992/1992 was largely overcome by the collection of data precisely equivalent to the 1992 survey, by a volunteer, Philip Lazaretti, between May and early August 1993. Analyses of these data will be reported elsewhere.

1.2.2 ASSESSING THE EFFECTS OF MANAGEMENT

Management operations designed to prevent pools occupied by spiders from becoming overshadowed, or choked by emergent vegetation, were undertaken on all of the irrigated pools in 1992 (see Smith 1992). The effectiveness of the operations on the spiders could not therefore be assessed. In 1993 management work was undertaken only on a randomised selection of pools, enabling rigorous comparison of spider numbers on managed and unmanaged pools. Although funding was given for this assessment to be made on the basis of a duplicated count at the peak of the season, analyses of the much more substantial data set collected for all of these pools by Philip Lazaretti (above) are also presented.

1.2.3 VALIDATION OF COUNTING METHODS

During 1991 and 1992 the assumption was made in our estimates that it was possible to count spiders with equivalent accuracy on all pools. It was suspected, however, that spiders were more difficult to detect on pools with dense emergent vegetation, or with dense *Cladium mariscus* overhanging their edges, than on pools which were less vegetated. The need to check for the existence of severe biases of this kind became more important in 1993 because they could seriously bias the results of the management experiment (above). Estimates from unmanaged pools might be expected to be lower simply because the spiders were harder to find, rather than because lack of management reduced the suitability of the pools.

Two comparisons of the effects of contrasting vegetation types were made on four, consecutive days. The numbers of spider numbers seen on pools with dense *C. mariscus* overhanging their edges were compared with those on pools with no overhanging marginal vegetation, and numbers on pools with areas of dense, emergent, marginal vegetation were compared with those on pools clear of emergent marginals. The effects of the time of day at which counts were made were also assessed.

1.3 Structure of the report

I describe these three areas of work in Sections 2, 3 and 4 of this report. The implications of the results, both for the conservation of the spider populations and for future monitoring and management requirements, are considered in Section 5. The management operations undertaken by the Suffolk Wildlife Trust are described in Section 3.1.2. All figures and tables are presented at the end of the report.

2 THE NEW CENSUS

2.1 Methods

2.1.1 THE CENSUS AREAS

Little Fen

The 1993 census covered the whole of compartment five of Little Fen (Figure 2.1). The pools on the southern side of this compartment form part of the machine-dug, irrigated series, monitored in 1991 and 1992. Along the paths on the northern side of the compartment are a further 26 pools that were also machine dug, at the same time, in 1989. Away from the paths bounding the compartment, old peat diggings form pools of varying sizes and depths which are unevenly distributed throughout the compartment. This compartment has been the focus of earlier census work (e.g. Kennett 1985, Thornhill 1980, Orr (unpublished) 1987) and so additional historical information exists on spider numbers in some of these pools.

All pools in the interior of the compartment which were mapped by Thornhill (1980) were relocated in March 1993 (*ca* 100 pools), but only some of these were considered suitable for the new census scheme. Pools were selected from amongst those with at least some deep water and a reasonable area of open water surface, since these pools were most likely both to retain water in dry summers and to remain suitable for spiders throughout a census lasting several years. At the time that pools were selected, the irrigated pools had between 50 and 75 cm of water at their depth gauges. 50 cm was chosen as the minimum depth for pools included in the new survey and $2m^2$ as the minimum area of open water surface. The only exceptions allowed to the later criterion were deep pools with sparse emergent *Phragmites australis* Common Reed over much of the water surface. These pools were similar to unirrigated pools censused on Middle Fen in 1992, on which good numbers of spiders were found (see Smith 1992).

Selection of pools was randomised in three strata so that the three different types of pools in the compartment were represented. They were as follows:

1. Irrigated pools: all of the irrigated pools in compartment 5 were included in the management experiment (Section 3.1). Seven of the 16 pools were left unmanaged as part of this experiment and these were chosen for the new census because they were more comparable with those in the remainder of the compartment, all of which were unmanaged.

2. Former peat diggings: to ensure that pools distributed throughout the area of the compartment were included in the survey, 15 pools were selected from amongst 32 that fulfilled the survey criteria by choosing the nearest pools to a rectangular grid laid over a map of the area.

3. Machine-dug pools on N side of compartment: a random selection was made of six of the 26 of these pools.

In addition to the randomly selected pools, four additional old pools from the interior of the compartment were included in the census because they were substantially larger and deeper than other pools in the vicinity. These pools are most likely to retain water throughout dry summers and may therefore act as local foci for the spider population.

A total of 32 pools was thus included in the Little Fen census area.

Middle Fen

The survey on Middle Fen was confined to pools that were machine-dug in 1986 (Figure 2.2). No old peat-digging pools that fulfilled the depth/area criteria were found during thorough searching of compartments 2,3 and 4. A few pools which just failed to meet the criteria were marked for examination in the summer.

The sample was divided into three strata, representing three distinct areas of pools:

1. Irrigated pools censused in 1991/1992 in compartment 4: pools from both sides of the path were included and a random selection of seven pools was made from amongst 11 left unmanaged as part of the management experiment.

2. Pools on either side of the east-west path in compartment 3: most of easterly pools along this path were included in the 1992 survey. These 12 pools were included in the management experiment and six were left unmanaged. Eleven pools were selected at random from amongst these six pools plus 11 more easterly pools that were not monitored in 1991.

3. Board-walk pools: twelve pools were selected at random from amongst 27 machine-dug pools on either side of the board walk (Figure 2.2).

A total of 28 pools was thus included in the Middle Fen census area.

2.1.2 MONITORING METHODS

Spiders

Spiders were counted on the pools during the early, mid and late parts of their season, with each of the three censuses comprising two counts made on separate days. The original intention was to do the first round of the survey in late April, immediately after the spiders were thought to emerge from hibernation, so that their distribution was likely to reflect that at the end of the previous season. However, in 1993 spiders were observed on the pools as early as 8 March, although densities remained low for some time, probably because the fen was very wet and the area of suitable habitat was extensive. The first census round was therefore delayed until the first period of fine, settled weather, in mid-May, when numbers on the pools had built up.

It had also been intended that, whenever possible, the two counts comprising each census round should be completed on successive days, so that the probability of immigration and emigration occurring between counts was minimised. Again, this proved not to be feasible. The weather conditions were unreliable throughout the summer and consecutive days of suitable weather were rare. For the mid-summer round, numbers on the pools were so low at the first count that the second count was delayed for approximately three weeks, in case the low numbers were very temporary. The dates of the counts on Little and Middle Fens were as follows:

Census round	Little Fen	Middle Fen
Spring round:	17 May	18 May
	22 May	23 May
Summer round:	28 June	5 July
	22 July	2 August
Autumn round:	6 September	16 September
	21 September	29 September

The counting method was the same as that used for most of the 1992 census (Smith 1992). The use of chest waders made it possible to search all pools from the water. The marginal emergent vegetation and water surfaces were searched thoroughly and the rate at which each unit length of bank was searched was standardised as far as possible. As in 1992, the following criteria were recorded where possible or appropriate, for each individual:

1. Sex
2. Body length in mm
3. Size/life cycle stage category. The following categories were recorded for adults and other stages where more precise body length measurement could not be made: L, large (adult or immature); M, half-grown; S, small immature).
4. Banding pattern (banded or unbanded).
5. Band and body colour
6. Whether pregnant, carrying egg sac or attending web with young or empty web.
7. Whether the individual 'dived' (diving behaviour usually involved spiders walking a short distance under the water surface on stems or under leaves).
8. Location. A sketch map was drawn of the locations of each individual on the pool. These locations were later summarised as falling in one of four quadrants of the pools and as at either the edge, on the open water, or on a vegetation island (e.g. emergent clumps of *Cladium mariscus*).

Separate records were made of all skins (including variables 1,3,4, and 8) and nursery webs. The presence of young, height in the vegetation, species composition of the vegetation and location of each web was recorded.

Water levels

At each sample round the water level in each pool was recorded. Oak marker posts were already installed in all of the pools monitored in 1992. Similar posts were installed in all of the new census pools in late April 1993. At that stage in the season the water table was consistent throughout the census areas and the posts were levelled to the same height above the water surface as the existing posts in the irrigated pools. Water levels were recorded to the nearest 0.5 cm, as the distance from the tops of the posts to the water surface. To facilitate comparison between 1992 and 1993, and it was later computed as the difference between the April 1992 datum and the level recorded on each date in 1993.

2.2 Results

2.2.1 THE DISTRIBUTION AND ABUNDANCE OF SPIDERS

Little Fen

Distribution Spiders were found throughout most of the new census area on Little Fen although they were absent from pools on the extreme north western edge of the compartment. The higher of the two counts at each of the three census rounds is shown for each pool in Figure 2.3. Records of skins were included only where the total number of skins exceeded that of spiders. Spiders were found on very few pools at all census rounds, although the small number of counts makes it impossible to distinguish whether this resulted from movements between pools during the season, or simply from low sampling efficiency.

Abundance The total maximum counts of small, medium and large spiders in the census area at each monitoring round are given in Table 2.1. These counts are very conservative estimates because they are based only on the maxima of two counts, which were likely to have included a proportion of different individuals.

The data in Figure 2.3 suggest that the numbers of spiders on the irrigated pools dropped substantially in mid-summer. This is also reflected in the substantial drop in the mean numbers recorded on these pools whilst numbers on the unirrigated pools increased (Table 2.2). The greater sampling intensity of the volunteer survey of the irrigated pools confirmed that the low numbers of spiders recorded on irrigated pools at the summer census round formed part of a consistent pattern amongst these pools. In contrast to 1992, numbers on these pools dropped to very low levels in June. Although they increased slightly later in the summer, virtually all of the increase was in immature animals. Adults were encountered only on the unirrigated pools in the remainder of the compartment.

Middle Fen

Distribution In contrast to Little Fen, spiders were restricted to the pools on which they were found in 1992. These included both the irrigated pools and the unirrigated pool at the eastern end of compartment 3 (Figure 2.4). None was found on the new pools to the west of the 1992 census area. The only exception to this pattern was the discovery during the May census round of a single pregnant female spider on a pool in an old peat digging approximately 250m to the south of pool 26. This pool was originally excluded from the census because it did not fulfil the size and depth criteria (Section 2.1.1 above). By July this pool was completely overgrown with only a small area of open water remaining in deep shade. No spiders were found.

Abundance The total maximum counts for the Middle fen pools were similar in magnitude to those on Little Fen (Table 2.1). However, the spiders were restricted to a much smaller numbers of pools (36% of total in spring, 36% in summer and 20% in autumn). This is reflected in the much higher mean numbers of spiders per pool on the irrigated pools on Middle than on Little Fen (Table 2.2). In contrast to Little Fen, spider numbers on the irrigated pools tended to increase, rather than fall, at the summer census.

Breeding success

Breeding records from the pools within the census areas were few. Only eight pregnant females were recorded in total during the season. Seven females were recorded carrying egg sacs and four nursery webs were found. These small numbers of breeding records in comparison with 1992 (see Smith 1992) are likely to be attributable largely to the much lower recording frequency, although the change in survey area makes it impossible to assess the extent to which there were real differences in numbers of breeding attempts between the two years. However, preliminary analysis of the 1993 volunteer census data, which allows comprehensive comparison between the 1992 and 1993, suggests that breeding success on the irrigated pools was much poorer in 1993 than 1992. Full analysis of these data will allow better comparison of breeding success in the two years.

Indirect evidence of the success of breeding during the current and previous seasons can potentially be obtained from examination of the changes in relative numbers of spiders in different size/age categories during the season. However, although this was possible in 1992, the change in census area, together with the reduced sampling frequency (which failed to provide an adequate measure of seasonal variation), in 1993, largely invalidates such comparisons.

2.2.2 WATER LEVELS

As a result of a much wetter winter, water levels in spring 1993 were much higher than those in 1992. When the census started in mid-May, large areas of both Little and Middle Fen were waterlogged. Water levels were between 10 and 15 cm higher than in 1992 on Little Fen and about 5cm higher on Middle Fen (1993 data from pools monitored as part of the volunteer survey).

On Little Fen the mean water levels in the irrigated pools included in the new census were sustained at levels well above the 1992 datum (Figure 2.5). The levels in the pools in the remainder of compartment 5 dropped progressively until early September when sustained heavy rains resulted in a rapid recovery. There was a strong gradient in water loss across the compartment, with pools on the north-western edge of the compartment having the greatest water loss. Figure 2.6 shows the levels in early September, which were the lowest recorded during the season on most unirrigated pools.

As in 1992 (see Smith 1992) irrigation was less effective in sustaining water levels in the irrigated pools on Middle Fen than on Little Fen although the fall was much less severe than in 1992. Water levels in the unirrigated pools fell throughout June and July, by an average of 20cm more than in the Little Fen pools (Figure 2.7). As on Little Fen, there was a marked gradient in the water table over the census area, with water levels falling from the east to the west (Figure 2.8).

2.3 Discussion

The discovery of spiders on pools throughout much of compartment 5 of Little Fen, suggests that the spider population on this fen may have been rather greater than was assumed in 1991 and 1992. Some of these pools were very deep and would almost certainly have retained some water in these very dry years. It is highly unlikely that the spiders found on these pools arrived by migration early in 1993. Many of the pools or groups of pools were isolated by substantial

distances from the irrigated pools and well grown spiders were recorded on them as early as March, when the census pools were first located.

The decline in numbers of spiders on the irrigated pools on Little Fen in summer 1993 is likely to have been attributable to the higher water levels which increased enormously the area of suitable habitat available to the spiders, particularly in the immediate hinterland of the irrigated area. Spiders were recorded on many pools in this area and included records of breeding females and of nursery webs, both of which were absent from the irrigated pools. Whilst it seems likely that the relatively low numbers recorded reflect a shift in distribution, rather than a decline in overall population size, they do suggest that conditions, particularly for breeding females, on the irrigated pools were sub-optimal. One possible cause of this which warrants more rigorous investigation was that water temperatures in pools receiving relatively direct supplies of irrigation water were lower than those in unirrigated pools. This may have affected the spiders' food supply.

In contrast to Little Fen, the distribution of spiders on Middle Fen was found to be restricted largely to the pools censused in previous years. There was some evidence that spiders used pools in relatively shallow peat diggings in their immediate hinterland in the early part of the season. No spiders were found in the many machine-dug pools to the west of the old census area although spiders were commonly seen in the most westerly of these pools, on the board-walk, as recently as 1987.

The fall in water levels in all of these pools was greater than in the pools in which spiders were found, although all retained some water throughout the summer. It seems likely that low water levels resulted, either directly or indirectly, in conditions inimical to the spiders. The distances separating these pools from those in which spiders were found were relatively short and it seemed likely that spiders could have colonised had conditions been suitable. It is also notable that the only area of pools from which spiders were completely absent in compartment 5 of Little Fen was that in which water loss was greatest.

The higher densities in the irrigated pools on Middle Fen than on Little Fen are difficult to interpret. They may suggest that the Middle Fen pools were intrinsically more favourable for spiders, but it is equally possible that the spiders were concentrated on these pools simply because of the relatively low water levels elsewhere on Middle Fen. However, if the latter is the case, and the spiders are enduring sub-optimal conditions, it might be expected that the Middle Fen population, even in the core pools, would decline over a period of time.

3 THE MANAGEMENT EXPERIMENT

3.1 Methods

3.1.1 POOL SELECTION

Pools on which management operations were to be carried out were selected at random from amongst those censused in 1992. Since management was regarded as a safer option for the spiders than leaving pools unmanaged, more pools were managed than left unmanaged. On Little Fen 18 of the 32 irrigated pools were managed (Figure 3.1: N.B. the two unirrigated, machine-dug pools included in the 1992 survey were excluded from the experiment). On Middle Fen the sample was stratified between the irrigated pools in compartment 4 and the unirrigated pools in compartment 3. Thirteen of the 24 pools in the irrigated series and 6 of the 12 pools in the unirrigated series were managed (Figure 3.2).

The numbers of the managed pools on Little Fen were: 3, 4, 6, 7a, 10, 11, 12, 13, 16, 17, 20, 20b, 21, 22, 23, 23A, 24A and 25. The numbers of the managed pools in the irrigated series on Middle Fen were: 1, 2, 3, 4, 5, 5B, 6, 7A, 11, 12, 13, 14, 20, and in the unirrigated series: 21, 22A, 22C, 23, 24A and 25.

3.1.2 MANAGEMENT WORK

Vegetation at the pool margins was cut with a brush cutter between 17 and 23 March on Little Fen and between 23 and 26 March on Middle Fen. As in 1992 cutting was done with a single sweep of the cutter, aligned at approximately 45° to the water. Emergent vegetation around the pool margin was thus cut at water level and the vegetation on the banks was left progressively taller, up to about a metre from the pool edge. Some emergent tussocks and islands of *C. mariscus*, which appeared to be favoured breeding habitat in 1992, were left uncut. Cut material was collected and removed immediately.

During mid to late summer a long-handled cutting blade was used to cut tall emergent vegetation (mostly *P. australis* and *C. mariscus*) from the centres of the pools. Cutting was done with great care to avoid disturbance to the water and particularly to the marginal vegetation. Cutting, and subsequent removal of cut material, was all done from one point on the bank of each pool. Cutting was completed on Middle Fen between 20 July and 29 September and on Little Fen between 14 July and 30 September.

3.1.3 MONITORING

It was originally planned only to monitor spider numbers on the pools comprising the management experiment using a single, duplicated count in the middle of the season. However, the data collected for these pools by Philip Lazaretti, at fortnightly intervals, from May to early August (see Section 1.2.1 above), provided an invaluable addition to these data. Analyses of spider numbers on these pools are therefore based on up to seven monitoring rounds. The dates of these rounds were as follows:

Little Fen	Middle Fen
25 May	18 May
7 June	1 June
22 June	17 June
28 June	29 June
5 July	5 July
21 July	13 July
3 August	27 July

Because the summer-cutting of emergent vegetation was done later than originally planned, all of these monitoring rounds were completed before this work began. Only effects of managing in early spring were therefore tested.

Monitoring methods were the same as those used in the main census (see Section 2.1.2 above).

3.2 Results

Comprehensive analyses of spider numbers on managed and unmanaged pools provided no evidence that the March management operations had any significant effect on spider numbers on the pools at any time between emergence and the end of July. The similarity in magnitude, and lack of consistency in direction, of the means for managed and unmanaged pools at each of the seven volunteer census rounds show immediately that there were no major effects (Table 3.1). The analyses performed on the data were as follows:

(i) Comparison of the maximum numbers of spiders recorded on the pools during the two monitoring rounds funded by English Nature in late June/early July: two-way analysis of variance (fen*management) of these data revealed no significant effect of management or of fen on spider numbers on the pools. However, since the data could not be normalised by transformation, non-parametric comparisons (Mann-Whitney U-tests) of managed and unmanaged pools were also carried out. Neither separate comparisons of the managed and unmanaged pools on Little and Middle Fens nor comparison of the data for the two fens combined revealed any significant results.

All of these analyses were repeated on a smaller data set from which pools on which no spiders were recorded in either 1993 or 1992 were removed (one pool on Little Fen and five on Middle Fen). Since it seems likely that these pools were intrinsically unsuitable for spiders their presence could bias the results. Exclusion of these pools had no effect on the significance of the differences between the management regimes.

(ii) Comparisons of the mean numbers of spiders seen on each pool over the seven volunteer survey rounds between mid-May and the end of July: two-way analysis of variance of these data failed to reveal any significant differences either between the managed and unmanaged pools or between Little and Middle Fen. Pooling the data for the two fens again failed to reveal any significant effects of management, as did removal of pools on which no spiders were recorded in either 1992 or 1993 (above).

(iii) Separate comparisons of the numbers of spiders on managed and unmanaged pools at each of the seven volunteer sample rounds: if the effects of management are subtle or short-lived, at least within any one season, it might be expected that significant effects of management would be manifest only at some points in the season. Analyses of variance revealed only one significant effect of management, which was detected only when pools on which no spiders were recorded in 1992 or 1993 were excluded from the data set. It occurred in mid-June, when unmanaged pools had significantly more spiders than managed pools ($F_{[1,62]}=5.75$, $P<0.05$). Little and Middle Fen differed significantly only on 5 July, when Middle Fen had significantly more spiders than Little Fen ($P<0.05$ for the complete data set and $P<0.01$ when pools with zero spiders in 1992 and 1993 were removed). Because none of these data sets could be normalised by transformation, all analyses were repeated using non-parametric tests (Mann-Whitney U-tests) both for Middle and Little Fens separately and for the two data sets combined. Significant effects of management were detected in early July, when unmanaged pools had more spiders than managed pools on Little Fen but not on Middle Fen ($P<0.05$). This effect was also significant for the combined data set when pools with no spiders in either 1992 and 1993 were excluded. Exclusion of pools with zero spiders also revealed a significant effect of management on Middle Fen in mid-July, again, with unmanaged pools having more spiders than managed pools ($P<0.05$).

(iv) Comparisons of the differences in spider numbers between 1992, when all pools were

managed, and 1993: analyses of variance of the mean differences between managed and unmanaged pools over the period during which the 1992 and 1993 census coincided (mid-May to end July) revealed no significant effects of management.

3.3 Discussion

The failure to detect significant effects of management on spider numbers must be interpreted cautiously. The relatively low numbers of spiders recorded on the irrigated pools during the season (Section 2.2.1) reduced the likelihood of detecting significant effects, as did the virtual absence of nursery webs which are the main indicators of suitability of the pools for breeding. It is nevertheless clear from these results that the spring management operations in 1993 had no very substantial, short-term effects on the suitability of the pools for spiders. Little weight should be placed on the two analyses which revealed significantly more spiders on unmanaged pools since both were significant only at the 0.05% level and were isolated results amongst a large number of tests.

It is unlikely that the results were influenced strongly by bias in the detectability of spiders between managed and unmanaged pools. If such a bias existed, it would be expected that a smaller proportion of spiders present on unmanaged pools would be detected and would thus decrease the probability of detecting deleterious effects of management on spider numbers. However, the results in Section 4.2 suggest that such bias is unlikely to be important.

The principal effect of the spring management operations was to reduce shading, particularly at the pool edges, usually by reducing the height and density of fringing *Cladium mariscus*. However, dense *C. mariscus* growth *per se* is not necessarily detrimental to the spiders. As well as providing the main support used for nursery web-construction on the fen (Smith 1992), it appears to provide shelter and probably a rich feeding area for the spiders. Most of the pools on which spiders were found in the interior of compartment 5 of Little Fen were fringed with very dense *C. mariscus* and the majority of spiders recorded were found on the water under the dead *C. mariscus* leaves. Spiders found basking on the open water always retreated under the dense cover when threatened.

The summer management operations are likely to have more substantial effects on spiders but could not be monitored in 1993 because of their timing (above). Removal of emergent vegetation in the centres of the pools is likely to have more radical effects on shading of the main water surfaces of the pools, particularly where, as is often the case, *P. australis* is the main emergent species.

The effects of both management operations are more likely to be manifested in the second year of the experiment when the differences between the pools will become more pronounced. However, whilst beneficial effects of the summer management operations remain likely, the possibility of deleterious effects resulting from a third successive year of spring management should be considered. It is generally accepted that *C. mariscus* growth is weakened by repeated cutting and the loss of structure suitable for breeding and of cover at the pool edges may become deleterious to the spiders.

4 VALIDATION OF COUNTING METHODS

4.1 Methods

4.1.1 COMPARISONS

Three comparisons were made of factors that were thought most likely to affect the numbers of spiders detected. These were:

(1) The effects of dense, old *C. mariscus* overhanging the pool edges: especially on pools formed in old peat diggings in the interior of compartment 5 of Little Fen, most of which had been left unmanaged for many years, up to a metre width of the water at the pool margin was often completely obscured by a dense curtain of, mostly dead, *C. mariscus* leaves. Thorough searching of this material was impossible but even limited searching often revealed spiders hiding amongst it. The numbers of spiders found on four pools with margins of this type were compared with those on four pools with margins clear of overhanging vegetation.

(2) The effects of dense, emergent vegetation around the pool margins: many of the machine-dug pools are bordered by areas of shallow water which is colonised by dense growth of *C. mariscus*. These areas, like those with the dense, overhanging *C. mariscus*, are very difficult to search thoroughly. The extent of this problem is considerably greater when the water table is high than in very dry summers. The numbers of spiders found on four pools with margins of this type were compared with those on four pools with margins relatively clear of emergent vegetation.

(3) Time of day: since spiders are poikilothermic, their activity and detectability may be influenced by the time of day. Counts of spiders from eight pools were compared at approximately 09.00 hrs, 13.00 hrs and 17.00 hrs. During the summer months all survey work was normally carried between these hours.

Comparisons (1) and (2) were repeated on four successive days in consistently fine weather. Two of the eight replicate pools used for comparison (3) were counted on each of the same four days. The comparisons were made on pools on Little Fen on 16 to 19 August. In all cases the spiders were recorded in the same way as during the standard census. The search rate was standardised as far as possible, with no attempt being made to search more thoroughly the pools 'perceived' as being more difficult. The search time for each pool was recorded to check this potential bias. For comparisons (1) and (2) the location, body length, sex (where possible), and details of banding and colour patterns were recorded for each spider. These details were then used to estimate the numbers of new individuals seen on each pool on successive days (the cumulative totals).

Individuals were only identified as being 'new' if they could be distinguished very reliably from those seen on previous days. At the time of recording the majority of spiders on the pools was juvenile, amongst which it was relatively difficult to distinguish individuals. Many were too small to sex reliably. Differences in length estimates of two millimetres or less were not to distinguish individuals because length could not be estimated with sufficient precision. Differences in band colour and dot patterns were also treated cautiously because details may have been missed on occasions when sightings were brief. The estimates of cumulative total numbers derived from these data are therefore likely to be very conservative.

4.1.2 ANALYSES

The data were analyzed in two, complementary ways. Both made the assumption that the final cumulative total, after four days, approximated to the true total. First, I tested whether the final cumulative total was approached more rapidly on some pools than on others, as might be expected if it was easier to detect the spiders on some pools than on others. The daily cumulative totals were expressed as proportions of the final cumulative total and these proportions were compared for the different pool types by t-tests for each day. Second, I examined the differences between the pool types in the daily probability of detecting spiders. Daily detection probabilities on the different pool types were estimated by expressing number seen each day as a proportion of the final cumulative total. The means of this variable over the four days were compared by t-tests between the contrasting pool types. Both types of analyses were done for comparisons (1) and (2) above (Section 4.1.1). These data sets were then combined by lumping all of the pools with clear edges and those with edges that were obscured by vegetation and the analyses were repeated.

The data for the time-of-day comparison were analyzed as a two-way analysis of variance, comparing the numbers on different pools at different times of day.

4.2 Results

4.2.1 THE EFFECTS OF DENSE, OVERHANGING *C. MARISCUS*

No differences were found between the detectability of spiders in pools in which dense old *C. mariscus* overhung the water's edge and those in which the edges were clear of overhanging vegetation. There were no significant differences either between the proportion of the final total detected on each day (Table 4.1) or between the mean daily detectability of spiders (Table 4.2).

4.2.2 THE EFFECTS OF DENSE EMERGENT VEGETATION

No differences were found in the detectability of spiders between pools with dense emergent vegetation and those clear of such vegetation. Neither the proportions of the final cumulative totals reached on successive days nor the mean daily detectability differed significantly between the two pools types (Tables 4.1 and 4.2).

4.2.3 THE EFFECTS OF VEGETATION OBSCURING THE WATER'S EDGE

Pooling the above two data sets to double the sample size again failed to reveal any significant effects on the detectability of spiders of the vegetation type in and around the pool (Tables 4.1 and 4.2).

4.2.4 THE EFFECTS OF TIME OF DAY

The time of day at which counts were made (between 09.00 and 17.00 hrs) had no significant effect the numbers of spiders seen on the pools ($F_{[2,10]}=0.69$, $P<0.05$).

4.3 Discussion

These results suggest that the density of vegetation obscuring the margins of the pools had no major effects on the detectability of spiders. However, both the number of pools that it was possible to sample and the conservative estimates of spider totals which resulted from the majority of spiders at the time of sampling being small juveniles, reduced the probability of detecting more subtle effects. The extent to which relatively subtle biases in the counts obtained from pools with different vegetation types are important depends on the objectives of the monitoring exercise. For most purposes slight variations in detectability are unlikely to influence significantly the results.

The data also suggest that, within the hours normally used for the survey work on the Fen, the time of day at which the records were made had no important influence on detectability. It might be expected, however, that both very early and very late in the season, low air temperatures at the beginning and end of the day would reduce the mobility and detectability of spiders. In the absence of data to verify this, it should continue to be assumed that survey work should be started later in the day and completed earlier at these times of year.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 The 1993 census

The new 1993 census showed that on Middle Fen spiders were largely confined to the pools on which they had been recorded in the previous two years, most of which were irrigated. On Little Fen, however, spiders were found to be distributed throughout compartment 5 of the fen. There was some indication that the old peat diggings on which they were found provided better breeding habitat than the irrigated pools.

On both fens the new scheme fulfils its objective of providing a baseline from monitoring recovery of the population should such occur. On Middle Fen the census covers an extensive network of pools from which spiders are absent, but which are contiguous with the source population, and which have been suitable for spiders in the past. Within the Little Fen census area, spiders were absent from at least 40 percent of pools. Although a proportion of these may remain intrinsically unsuitable for reasons not associated with water levels, it may be expected that the proportion with spiders would increase in the event of a radical recovery in the population. It is also likely that the densities of spiders in the pools, which were very low on Little Fen, would increase in the event of a general recovery.

Although on Middle Fen the new census area appears likely to encompass much of the present population, this is less likely to be the case on Little Fen. The presence of similar, deep pools in contiguous compartments of the fen make it likely that this population covers a wider area than that covered by the new census. It would be of considerable value to assess the full extent of the population prior to the restoration of water levels so that any expansion in distribution can be properly assessed.

Although the new census provided invaluable data on the distribution of the spiders, the 1993 data on spider abundance are difficult to interpret. Several reasons for this have been suggested in previous Sections of this report. First, the higher water levels in 1993 than in previous years increased the area of suitable habitat. Although this is likely to have contributed to the relatively low numbers recorded on irrigated pools on Little Fen there is no way of demonstrating this conclusively. Second, the change in the pools censused makes direct comparison of population estimates from 1993 with those from previous years impossible. However, analysis of the 1993 volunteer data will allow comparison between these years and, if the new census is maintained in future years, comparability will be restored. Third, the relatively low sampling frequency in 1993 reduces the precision of the estimates, and the ability to detect changes in breeding success.

Preliminary analysis of the volunteer data for the pools monitored in 1991 and 1992 suggests that numbers of breeding attempts were lower in 1993 than in 1992. Less pregnant females, females with eggs and nursery webs were found during the peak of the season and more egg sacs were found abandoned. The success of second breeding attempts was also likely to have been low. Pregnant females and those with eggs found in September were very unlikely to have reared young successfully because of the extremely wet and frosty weather in the first half of October. These results, together with the estimates of numbers, suggest that the status of *D. plantarius* at Lopham and Redgrave Fens NNR remains precarious. Its survival is likely to remain dependent on weather conditions and on artificial water supply, at least until water levels on the Fen are restored.

5.2 Counting methods

5.2.1 THE VALIDATION EXPERIMENT

The validation experiment suggested that the differences in the detectability of spiders between pools with different vegetation types or between different times of day, were unlikely to introduce serious bias to counts made using the standard methodology described in Section 2.1.2. The high proportion of small juveniles present at the time of the exercise reduced the sensitivity of the analyses but for most purposes it can be assumed that differences in detectability do not present serious problems. However, if the monitoring methods are changed, the same assumption cannot be made. In particular, if monitoring from the pool edges replaced monitoring from the water, dense vegetation may lead to more serious bias. If such monitoring is intended only to detect the distribution of spiders and if counts are replicated, bias is unlikely to be a serious problem. However, if such methods are used to detect differences in spider numbers, for example, between managed and unmanaged pools, re-assessment of bias would be required.

5.2.2 METHODS OF POPULATION ESTIMATION

Other aspects of the methods of population estimation also require review. The reduced sample frequency in the new census scheme results in loss of sensitivity to population changes. Population estimates to-date have been made on the basis of maximum counts in given time-periods (Duffey 1991, Smith 1992). The more counts that are made within a time-period, the higher the probability of detecting the maximum. In 1993 two counts were used for each of these estimates. There are two ways in which the estimates at any time-period could be improved.

First the number of counts contributing to the estimates can be increased. Examination of the repeated counts from the validation experiment (Section 4) suggest that increasing the number of counts contributing to each time-period estimate from one to two can increase the estimate by 31% (combined data for all pools). Increasing from two to three counts increased the estimate by a further 23% while increasing from three to four counts increased it by only 4%. These figures suggest that increasing the number of counts contributing to each population estimate from two to three is likely to lead to substantial improvements in the estimates but that any further increase is not justified.

An alternative method of estimating numbers is to attempt to identify new individuals seen at successive counts and to increment each previous count by this number. This method was used to derive the cumulative totals for analysis of the validation experiment in Section 4.1.2. It resulted in an increase of 34% in the estimate between one and two counts, a further increase of 28% between two and three counts and an increase of 7% between three and four counts. Although the rate of improvement in the estimate was similar to that obtained by the method of maximum counts (above), the final total estimate was 16% higher. However, the more accurate counts obtainable by this method require substantial additional analytical time because of the detailed comparison required of the characteristics of individuals seen on each day. Thus, if the objective is to obtain repeatable, rather than accurate population estimates, the best method appears to be to retain the use of maximum counts but to base each time-period estimate on three rather than two counts.

The extent to which spiders move between pools may be an important factor influencing the accuracy of counts although all of the estimates made in this and previous years (Smith 1992, Duffey 1991) are based on the assumption that such movements are relatively rare. This assumption was supported by Kennett's (1985) finding from mark-release-recapture study that only 13% of recaptured spiders had moved from their pool of capture. However, 61% of marked spiders were not recaptured, leaving the possibility that some of these may have moved outside the search area. Observations in both 1992 and 1993 suggested that movements of spiders in all ages classes may be common. In particular, the loss of all adult spiders from the irrigated pools prior to the main breeding season in 1993 suggested that mobility may be the norm, particularly when habitat conditions become sub-optimal.

The mobility of the spiders has implications for their conservation beyond its effects on population estimation. It is likely to determine the rate of expansion in the distribution of the population should water levels on the fen be restored. The distance that individuals can travel, and the extent to which different vegetation or physiographic features present barriers to their movements, is further likely to influence their ability to recolonise areas of the fen from which they are now absent. In 1993, although the distribution of spiders throughout compartment 5 of Little Fen was thought unlikely to have resulted from dispersal at the outset of the season (Section 2.2.1), lack of information on their potential for movement means that this possibility cannot be ruled out.

The current complete ignorance of either the frequency or extent of spider movements should be rectified in view of its importance to their conservation on the fen. An intensive programme of individual marking and detailed follow-up survey is required to obtain basic data on this subject.

5.3 The management experiment

The results of the management experiment showed that the early spring management had no significant effect on the numbers of spiders on the pools in July the same year. Although the

numbers on all irrigated pools were low at this time and this reduced the probability of detecting significant effects, it seems likely that any effects of management at this stage were unimportant. The second planned year of the experiment requires careful review. Any effects of the late-summer management work and any delayed effects of the spring management work will not be detectable until 1994. However, repetition of the spring management work in a third year might be expected to have deleterious effects on spiders by weakening the *C. mariscus* growth at the water margins (Section 3.3). Maintenance only of the summer management work, with monitoring in early summer to detect any delayed effects of the 1993 management, and monitoring in late summer to detect proximate effects of summer management, may be a preferred option.

5.4 Summary of Recommendations

1. **Census scheme**: the status of *D. plantarius* on Lopham and Redgrave Fen NNR remains precarious. Its low numbers, poor breeding success and restricted distribution of makes it imperative that a proper monitoring programme, that is sensitive to changes in numbers as well as in distribution, is continued, at least until substantial recovery has been achieved. I recommend that the census scheme initiated in 1993 is retained and that the accuracy of the estimates of population size is improved by using three rather than two counts in each time-period. The utility of using three census rounds during the season should be reviewed. No accurate assessment of breeding success can be made with this census frequency. Any reduction in the frequency is likely to lead to a less accurate picture of the spider's distribution, particularly since the 1993 data suggested that spiders left some pools during the season.

Personnel requirement: six day's field work per census round (*ie* three replicate counts (see Section 5.2.2) on each of Little and Middle Fens) plus allowance for data entry and analysis.

2. **Broad-scale survey of distribution**: an additional survey should be carried out in 1994 to ascertain the current distribution of *D. plantarius* on the fens. Because of the scale of the exercise, it is expected that survey work will be carried out by volunteers although funding should be sought for setting-up the survey and writing-up the results. Only a single search of each pool is likely to be feasible for this exercise but this should be adequate to give a much better indication of distribution than is currently available.

Personnel requirement: 3 days.

3. **Measurement of water temperate**: I suggested in Section 2.3 that the loss of spiders from the irrigated pools on Little Fen by mid-summer 1993, and the failure of adults to recolonise later in the year, may have resulted from low water temperatures in pools receiving direct supplies of irrigation water. Whilst the availability of alternative suitable habitat in the immediate hinterland of the pools may have limited any deleterious consequences of this in the relatively wet summer of 1993, the potential consequences in dry summers, when the spiders are restricted to the irrigated pools, are more serious. Since it seems likely that the water will not be restored until 1996 at the earliest, and that irrigation will therefore continue be important, this possibility should be investigated. Monitoring of water temperature should be done in conjunction with census work since understanding is required of the relationship between water temperatures and spider numbers.

This monitoring would nevertheless require a separate exercise from the census work since it is likely to be too time-consuming to complete on the same days. Replicate measurements should be taken from each pool and allowance must be made for pools where areas of shallow water

result in local temperature differences. Consideration should also be given to the advantages of taking measurement before as well as after the irrigation water is turned on.

Personnel requirement: two day's field work plus one day for data entry and analysis.

4. **Measurement of spider movements**: most of the marking required for this exercise can probably be completed in a single day. It is expected that subsequent monitoring will have to be done on a voluntary basis.

Personnel requirement: one day's field work.

5. **Management experiment**: I suggested in Section 5.2 above, that the management experiment should be continued for a second year, as originally proposed, but that consideration should be given to abandoning the early spring management work. Monitoring should ideally be done both early in the summer and in late summer, after the summer management work is completed. Both census rounds should comprise three rather than two replicate counts.

Personnel requirement: 6 days field work per census (may be reduced to five days if the count can be done at the same time as the main census) plus allowance for data entry and analysis (two days per census).

6. **Study of ecological requirements**: The 1993 study on *D. plantarius* highlights the lack of understanding of its ecological requirements. At an applied level, lack of understanding of its breeding biology, dispersal and ecological preferences makes it impossible either to generate soundly-based management proposals or to predict the potential of this endangered species to recover from its current very low numbers.

ACKNOWLEDGEMENTS

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Table 2.1 Maximum numbers of spiders counted in Little and Middle Fen census areas in 1993

	Spring	Summer	Autumn
Little Fen			
Large	13	5	8
Medium	5	8	19
Small	1	1	5
Middle Fen			
Large	11	6	3
Medium	5	7	14
Small	2	8	10

Table 2.2 Mean[1] numbers of spiders on irrigated and unirrigated pools within the 1993 census areas

	Little Fen		Middle Fen	
Census period	Unirrigated	Irrigated	Unirrigated	Irrigated
Spring	0.32±0.32[2]	1.57±1.14	0.09±0.12	1.781±0.94
Summer	0.48±0.31	0.29±0.36	0.13±0.19	2.00±1.06
Autumn	0.60±0.44	1.71±1.42	0.00	2.86±2.11

[1] Data are means of the maximum of the two counts carried out during each census period. There were 25 unirrigated and 7 irrigated pools and Little Fen and 23 unirrigated and 7 irrigated pools on Middle Fen

[2] 2 S.E.s

Table 3.1 Mean numbers of spiders on managed and unmanaged pools

	Unmanaged pools			Managed pools		
Monitoring round	Mean[1]	±	2 S.E.s[2]	Mean[3]	±	2 S.E.s
late May	0.760	±	0.370	0.676	±	0.258
early June	0.742	±	0.425	0.500	±	0.219
mid June	0.607	±	0.416	0.189	±	0.152
late June	0.323	±	0.194	0.351	±	0.193
early July	0.419	±	0.275	0.324	±	0.258
mid July	0.452	±	0.305	0.351	±	0.222
late July	0.516	±	0.276	0.730	±	0.326

[1] n=31

[2] 2 S.E.s
[3] n=37

Table 4.1 Mean daily cumulative total spider counts as proportion of final cumulative total on different pool types

Pool	Total[4]	Day 1	Day 2	Day 3[5]
1) Overhanging *C. mariscus*	4	0.38	0.61	0.94
vs clear edge	2.5	0.80	0.9	1.00
$t_{(5)}$[1], significance[2]		-1.84 ns	1.28 ns	-1.20 ns
2) Dense emergent vegetation	4.5	0.43	0.69	1.0
vs clear edge	4.25	0.38	0.69	0.83
$t_{(6)}$[1], significance[2]		0.02 ns	0.34 ns	2.94 ns
3) Edge obscured by vegetation	4.3	0.41	0.66	0.97
vs clear edge[3]	3.4	0.59	0.79	0.91
$t_{(13)}$[1], significance[2]		-1.39 ns	-0.91 ns	1.13 ns

[1] t-tests performed on angular-transformed data. One pool in comparison a) had no spiders, resulting in only 5 degrees of freedom
[2] Significance level: ns, not significant
[3] Pooled data from a) and b)
[4] Mean cumulative totals after 4 days
[5] Note that the proportion for day four is by definition 1.0 (see Section 4.1.2)

3
Table 4.2 Comparison of mean daily probabilities of detection of spiders on different pools types

Pool contrast:	Mean detectability	t=	Significance[2]
a) Overhanging *C. mariscus*	0.67	$t_{(5)}$[1]=0.026	ns
vs clear edge	0.67		
b) Dense emergent vegetation	0.61	$t_{(6)}$=0.489	ns
vs clear edge	0.57		
c) Edge obscured by vegetation	0.64	$t_{(13)}$=0.217	ns
vs clear edge[3]	0.62		

[1] One pool in comparison a) had no spiders, resulting in only 5 degrees of freedom
[2] Significance level: ns, not significant
[3] Pooled data from a) and b)

Figure 2.1 The location of pools included in the 1993 *D. plantarius* census on Little Fen

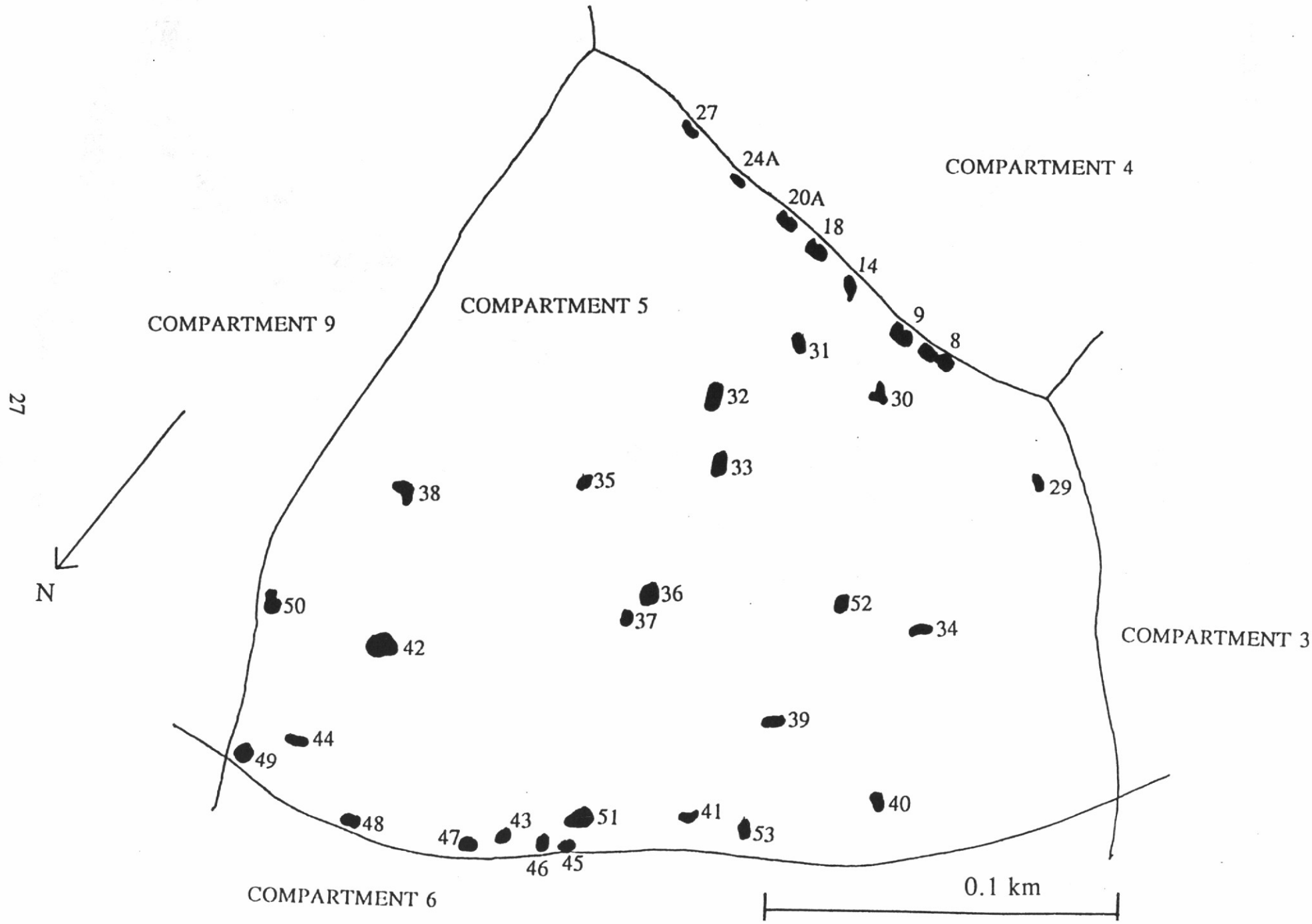


Figure 2.2 The location of pools included in the 1993 *D. plantarius* census on Middle Fen

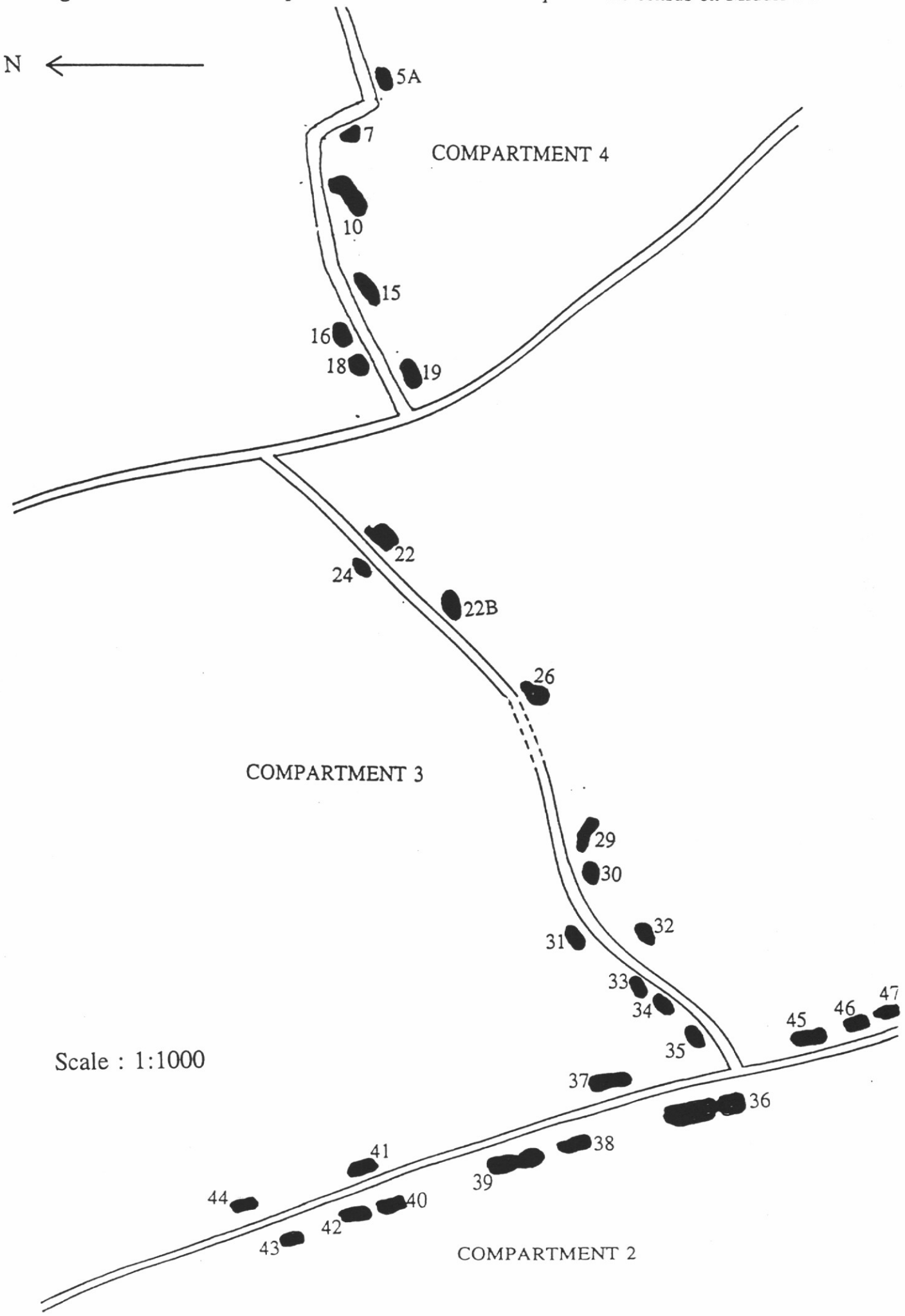


Figure 2.3 Maximum numbers of *D. plantarius* seen on each pool during the spring, summer and autumn censuses on Little Fen

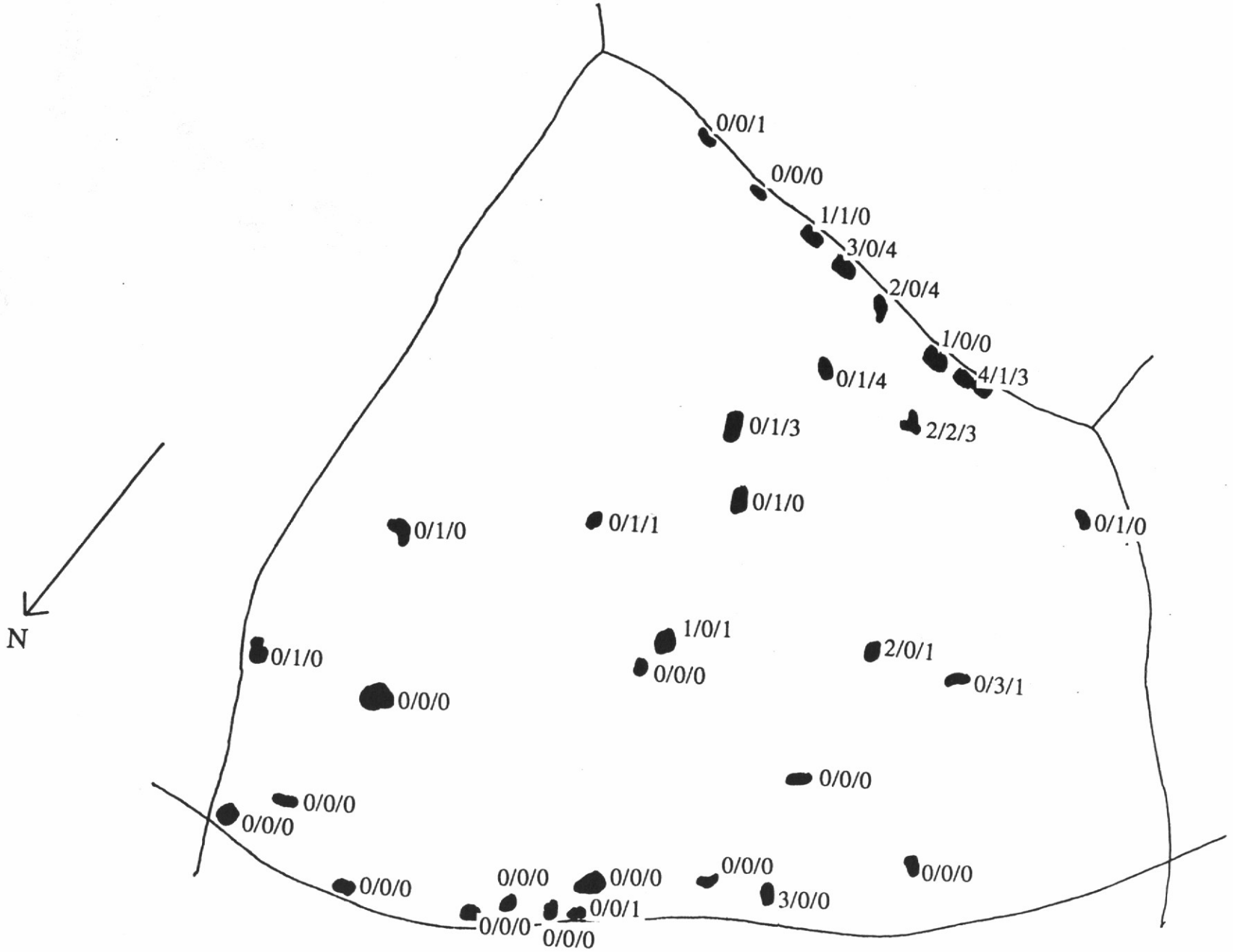


Figure 2.4 Maximum numbers of *D. plantarius* seen on each pool during the spring, summer and autumn censuses on Middle Fen

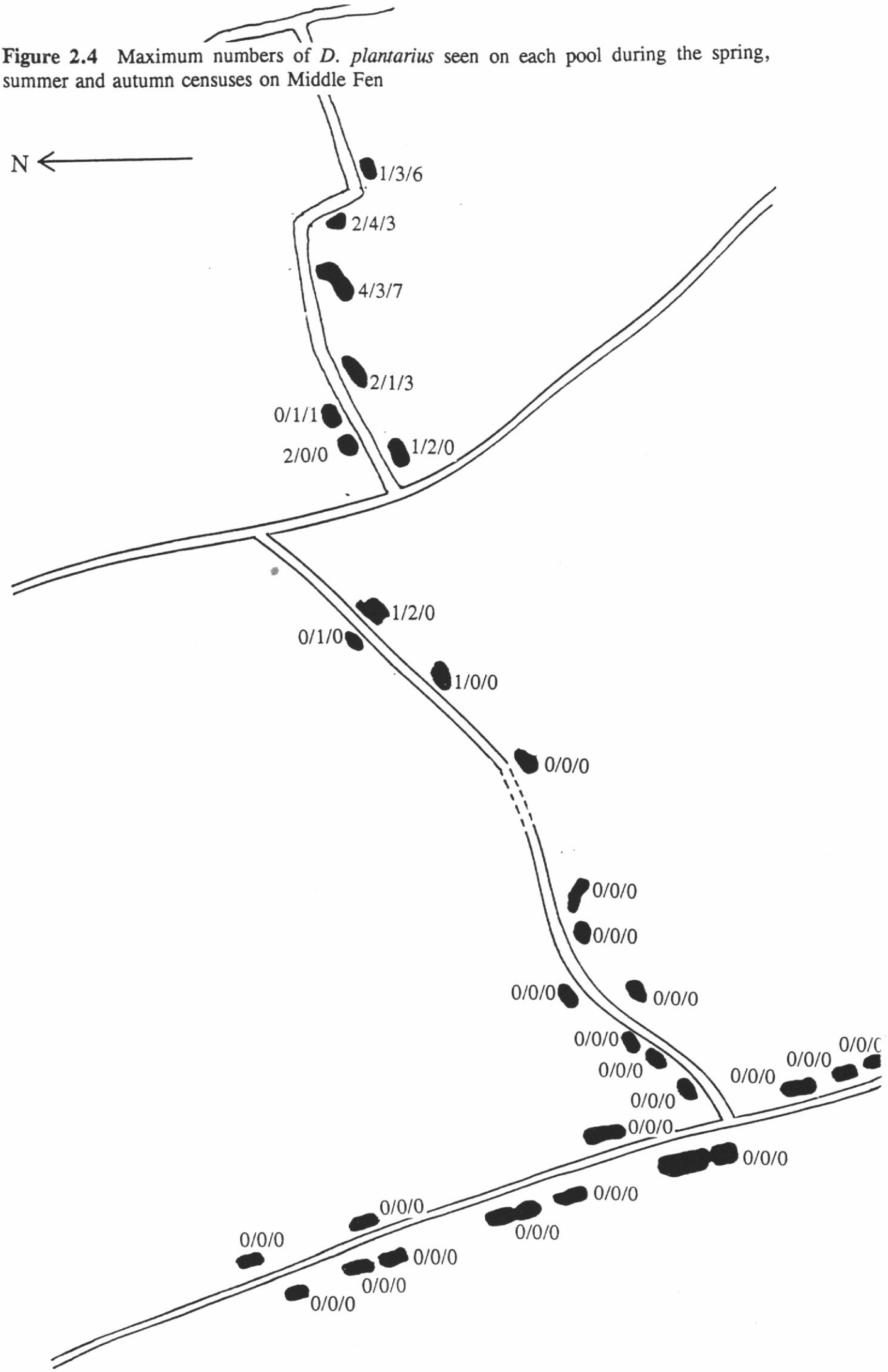
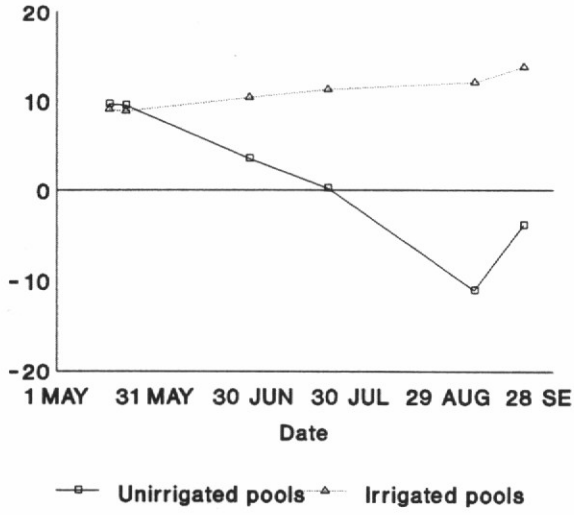
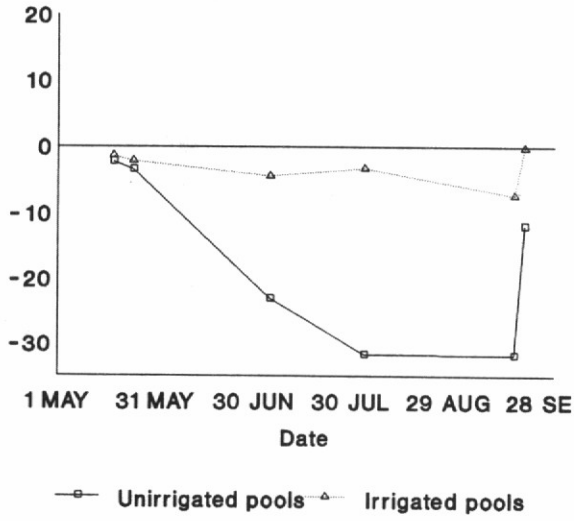


FIGURE 2.5 Mean water levels in the irrigated and unirrigated pools in the Little Fen census area in 1993



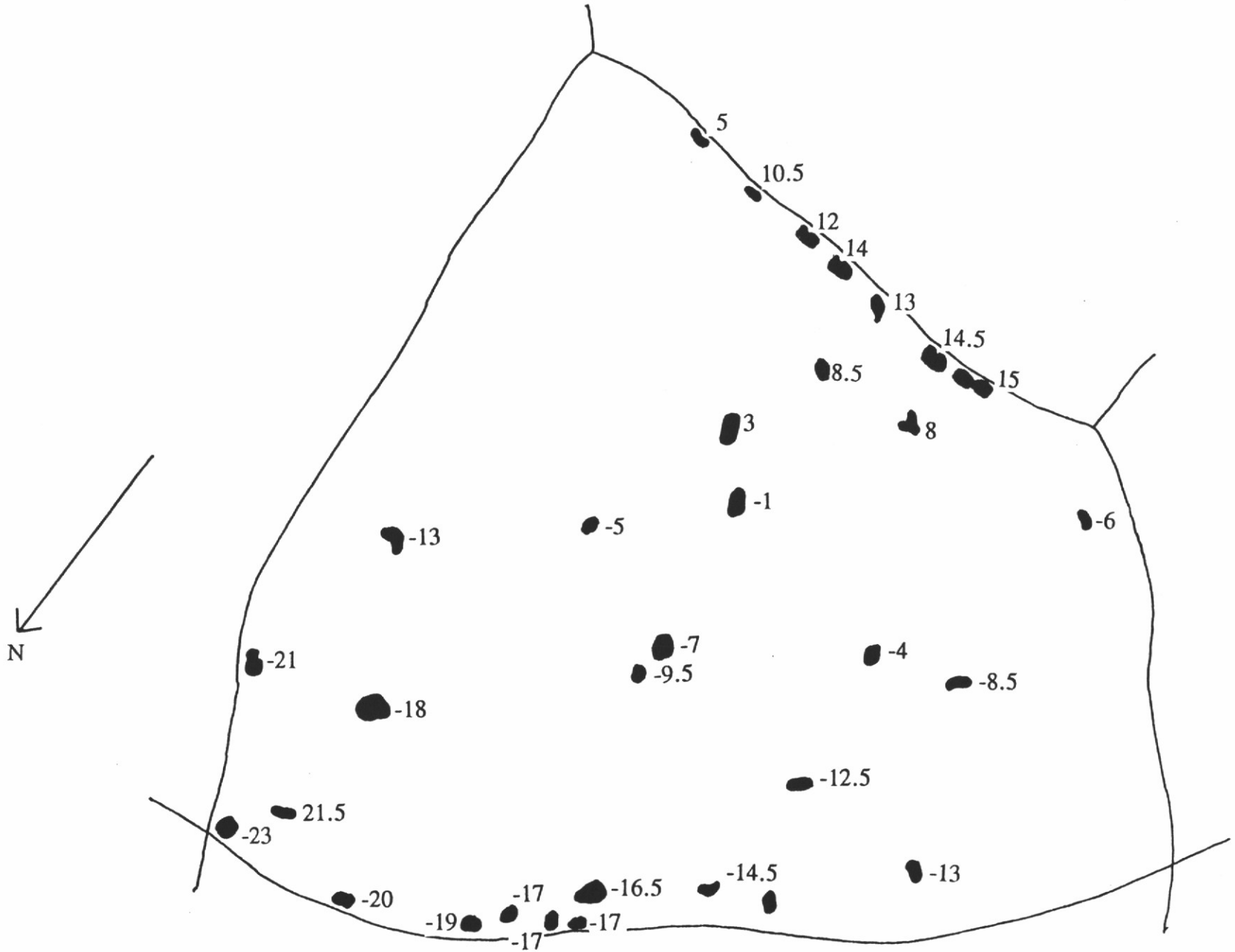
Horizontal line represents the April 1992 datum

FIGURE 2.7 Mean water levels in the irrigated and unirrigated pools in the Middle Fen census area in 1993



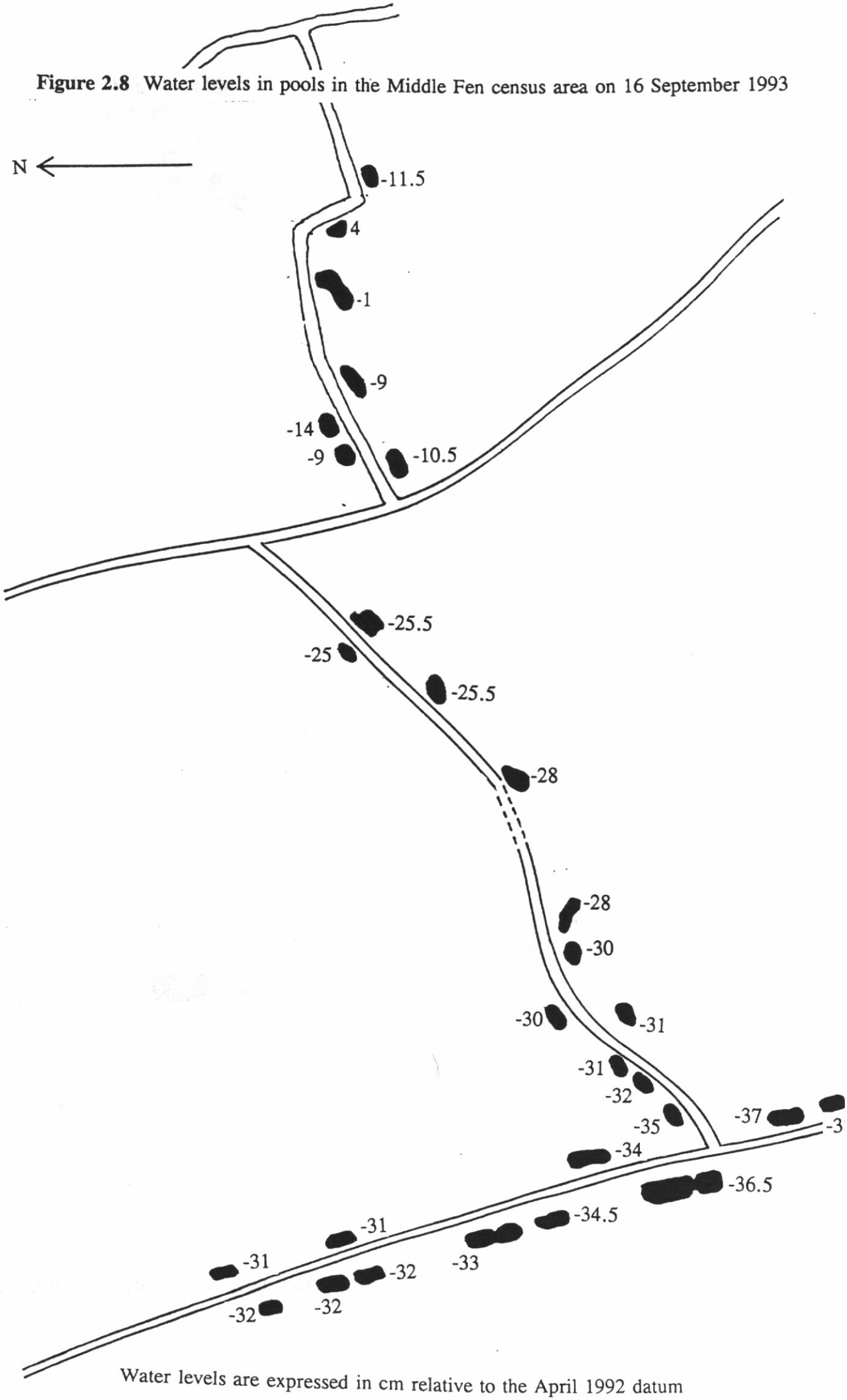
Horizontal line represents the April 1992 datum

Figure 2.6 Water levels in pools in the Little fen census area on 6 September 1993



Water levels are expressed in cm relative to the April 1992 datum

Figure 2.8 Water levels in pools in the Middle Fen census area on 16 September 1993



Water levels are expressed in cm relative to the April 1992 datum

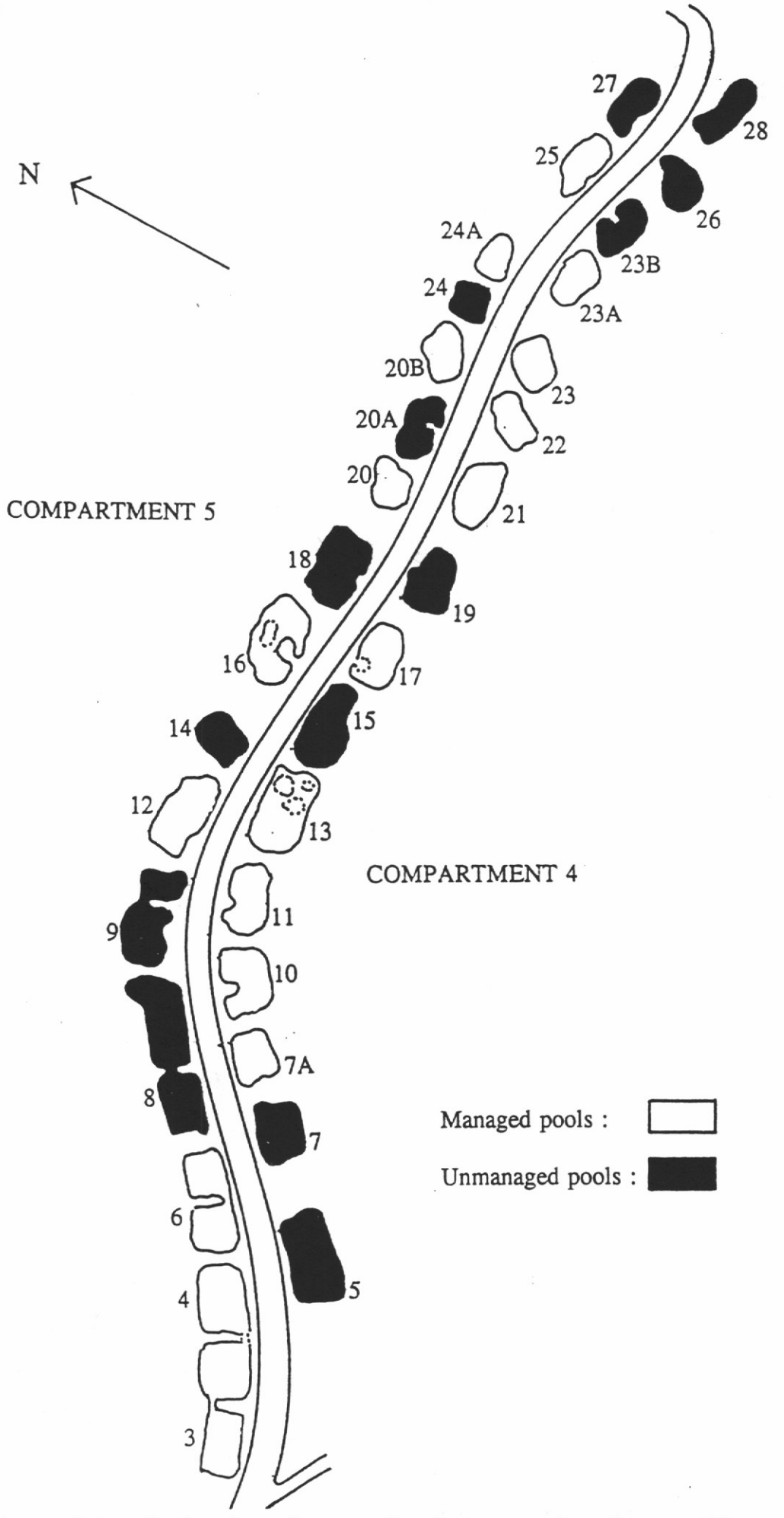


Figure 3.1 The location of managed and unmanaged pools comprising the Little Fen management experiment