English Nature Research Reports

Fen Raft Spider Recovery Project: Report for Redgrave and Lopham Fen 2001-2005

Dr Helen Smith
helen.smith@wavcott.org.uk

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Summary

1 This report describes work undertaken as part of English Nature's Species Recovery and BAP programmes for the nationally endangered Fen Raft Spider *Dolomedes plantarius* at Redgrave and Lopham Fen National Nature Reserve between 2001 and 2005.

2 2005 was the fifteenth year of systematic monitoring of *D. plantarius* at this site, based on a standardised annual census in July. This comprised replicate counts made in a random sub-sample of turf ponds with maximum counts for each pond expressed as an annual index of population size. This allowed statistical comparison between years and between sub-populations.

3 Throughout this 15-year period the population was very small and its range restricted to two small and spatially separated areas, on Little Fen and Middle Fen.

4 Desiccation of the fen by artesian abstraction, thought to be responsible for the decline in this essentially aquatic species, ended in 1999 with relocation of a public water supply bore-hole. In combination with higher than average rainfall in the following two years, this resulted in rapid hydrological recovery.

5 The 2001-2005 census data showed that hydrological recovery did not result in any recovery in either the abundance or range of *D. plantarius*. The populations remained concentrated in areas of ponds that were irrigated during the droughts of the 1990s.

6 Numbers during this period were lower than the peak years of the 1990s. 2003 saw the lowest numbers ever recorded on Little Fen although there was a recovery by 2004.

7 The census data were best described by a model in which population size varied substantially and sometimes significantly between years, but with no evidence of a sustained upward or downward trend. The data for the Little and Middle Fen sub-populations showed a highly significant difference in the pattern of annual variation.

8 Rotational mowing of *Cladium mariscus,* which dominated the core areas for *D. plantarius*, was abandoned in favour of extensive grazing in summer 2002. On Little Fen the grazing was supplemented by mowing of tall stands outside the former mown areas but on Middle Fen no further mowing management was carried out.

9 Between 2004 and 2006, grazing stock conspicuously reduced shading by *Phragmites australis* around ponds at and beyond the current range of *D. plantarius* on Middle Fen. At the core of the range, grazing was concentrated on *C. mariscus* mown in 2003. On Little Fen the stock failed to make any impact on the vegetation in the core spider areas.

10 Water levels on the fen during this period were much higher, and less variable, than at any time since records were first kept, in the 1970s. Control of water levels in wet as well as dry years became an issue for the first time. Deep and protracted inundation of Little Fen with stagnant water between 1999 and 2001 was alleviated primarily by lower rainfall in subsequent years.

11 Two new sluices were installed to improve water level control: on Little Fen this had little impact on inundation of the core spider areas. The impact of a new fully variable sluice immediately downstream of the Redgrave and Lopham Fen complex remains to be assessed although preliminary studies suggest it will not retain sufficient water in the river channel to protect the surface hydrology of Great Fen in dry summers. Research is in progress to identify the best operational remit for this sluice.

12 Failure to progress towards a sustained and significant recovery of *D. plantarius* at Redgrave and Lopham Fen makes it imperative that effective population monitoring is maintained. While the population remains small, this is delivered most effectively by the standard census method. Pilots of alternative methods, potentially suitable for volunteers, failed to yield adequate sample sizes.

13 The results of two research projects, supported by English Nature at the University of East Anglia, should help to explain the failure of Redgrave and Lopham Fen population to recover, and to inform future conservation management decisions.

14 The risk of stochastic extinction of this population is so great that plans should be advanced for establishing additional populations, within the Redgrave and Lopham Fen complex and elsewhere, using captive-bred animals.

1 Introduction

This report describes monitoring and management work undertaken as part of the Fen Raft Spider *Dolomedes plantarius* Recovery Project at Redgrave and Lopham Fen National Nature Reserve (NNR) over a five-year period, between 2001 and 2005. 2005 marked the fifteenth year of monitoring and targeted management for *D. plantarius* at this site. Redgrave and Lopham Fen is one of only three known UK sites for this Schedule 5 species but the population there was reduced to very low levels by desiccation of the site by artesian abstraction, compounded by droughts in the 1980s and 1990s (Smith 2000). Initiated in 1991 under the Species Recovery Programme, this project aimed to prevent the extinction of the remnants of the population. These were by then restricted to turf ponds on two separate parts of the NNR. Throughout the 1990s, monitoring showed not only that there was no significant increase in population size, but also that the range of the population had contracted. Irrigation of the ponds inhabited by the spiders throughout this period appeared to be the key factor in their persistence (Smith 2000).

Rapid hydrological recovery of the fen following closure of the artesian bore-hole in 1999 was expected to result in a rapid increase in the spider population. This expectation was encapsulated in the *Dolomedes plantarius* Species Action Plan (U.K. Biodiversity Steering Group 1999) targets for this site, of a sustained increase in density per pond to the maximum recorded during the 1990s, and a ten-fold increase in range. However, this report shows that, six years after the fen became wet again, the spider population remained both very restricted in its distribution and precariously small. The results for this period from a highly standardised annual census are discussed in the context both of the reasons for the failure of the population to recover and of potential methods for promoting recovery. The problems of small population size are also being addressed through current autecological and genetic research, being undertaken by Phil Pearson and Marija Vugdelic respectively, at the University of East Anglia (UEA). The potential contributions of these projects to the Recovery Programme are considered.

This report also describes trials of an alternative census method. The annual census method used for monitoring *Dolomedes plantarius* at Redgrave and Lopham Fen since 1993 is unsuitable for adoption by volunteers (Smith 2001). In 1999 and 2000 a more suitable alternative census method for volunteers, using counts of nursery webs, was evaluated. It was concluded that numbers of webs produced by this population were far too low to provide an adequate index of the population size. Another alternative method, based on point counts, was piloted in 2000 (Smith 2001) and 2001. The relative merits of these monitoring methods are evaluated and recommendations are made for future monitoring.

A variety of management tasks are carried out every year by Suffolk Wildlife Trust (SWT), the NNR managers, on both the fen vegetation and the ponds occupied by *D. plantarius.* Management work undertaken between 2001 and 2005 is documented in this report, and its likely impact on the spider population is discussed in the context of the past and future habitat management policy.

The results of monthly monitoring of water levels in the census ponds are described in relation both to trends in groundwater, and to measures taken to control water levels within the fen complex. The need for further analysis of annual variation in spider numbers in relation to these factors is discussed.

Further background to the project, and details of previous years' work, are given by Duffey (1991) and Smith (1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001).

2 Methods

2.1 Annual census

The annual census of *D. plantarius* followed the methodology adopted in 1993 and described by Smith (1993, 2000). The three replicate counts were made at 29 turf ponds on Little Fen (Fig. 1) and 30 on Middle Fen (Fig. 2) in the second half of July (Table 1). The counts for each fen were made on three consecutive days, whenever consistent and favourable weather conditions allowed. In 2001, water levels on Little Fen were too high to allow any census work at any time during the summer.

Table 1 Census dates for 2001-2005

	Year				
	2001	2002	2003	2004	2005
Little Fen	-	14-18/07	18-22/07	21-27/07	21/07-05/08
Middle fen	17-20/07	19-21/07	23-27/07	12-24/07	18-21/07

From 2002 onwards, two Little Fen ponds included in the original scheme had to be excluded from the census because they had been substantially infilled with spoil during the fen restoration operations (Harding 2000). Counts at two other Little Fen ponds were made from the bank because the depth of sediment made work in the water unsafe. By 2004 two of the three replicate counts at a further pond were also made from the bank because of the depth of soft sediment: in 2005 all counts at this pond had to be made from the bank.

2.2 Analyses of annual census data

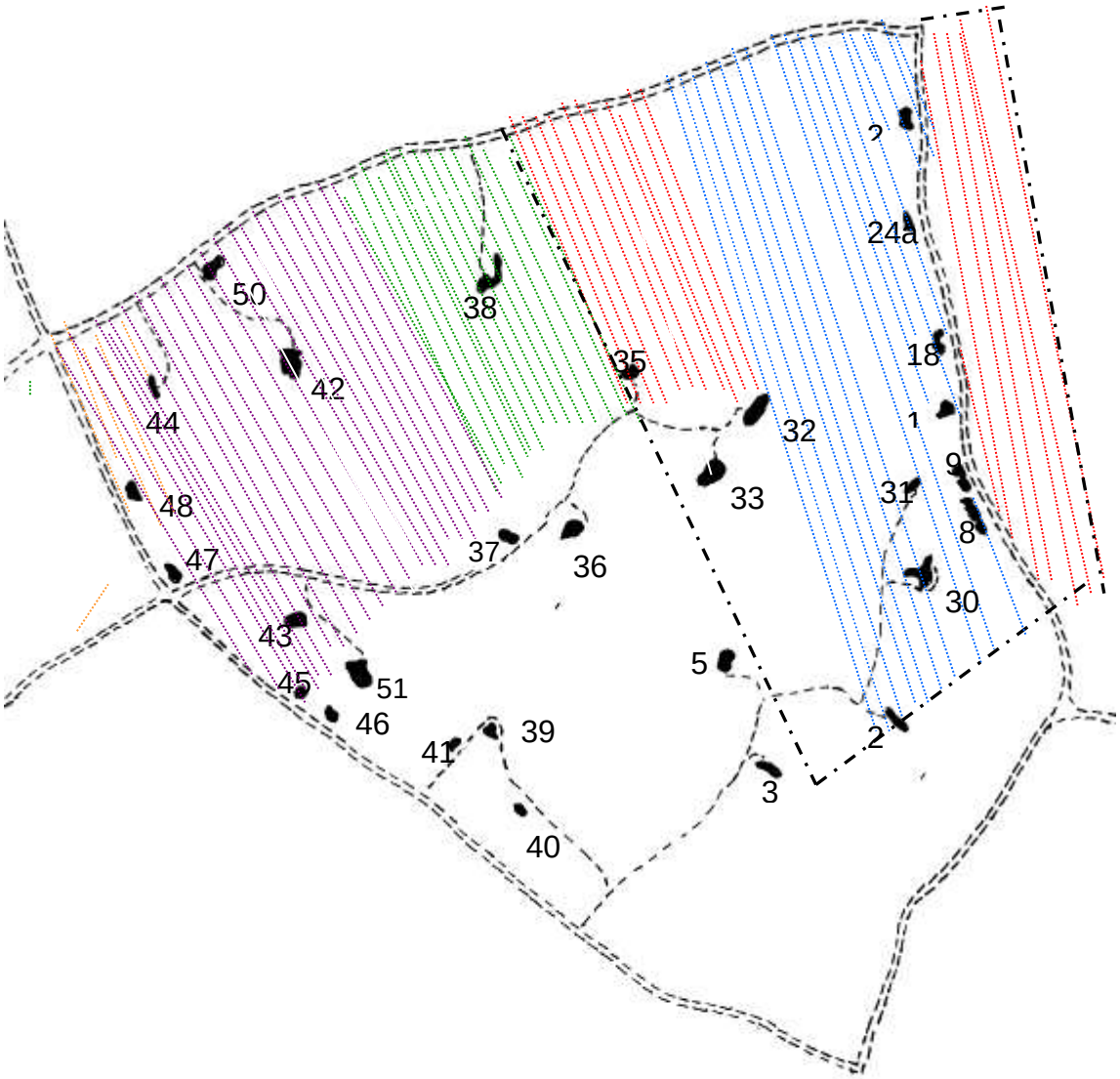
The annual census data are expressed as an index derived from analyses of population trends carried out using generalised linear models, with the maximum count for each pond in July as the response variable (Smith 1995, 2000). Log-linear Poisson regression models were fitted to the systematic data collected since 1991 (excluding Little Fen in 2000 and 2001, when it was deeply flooded)**,** as implemented in program TRIM (Pannekoek & van Strien, 1998). TRIM allows the data to be split into different strata: in this context Little and Middle Fens form separate co-variate strata. The model also allows sites to be censused in some years and not others and so both the data from the set of ponds censused at the outset of the project (1991-1995), and those from the set of ponds censused from 1993 onwards, could be utilised (see Smith 1995).

The program fits five standard models: (i) no time (year) effects; (ii) linear trend (in log numbers); (iii) linear trends within covariate strata (linear trends differ between Little and Middle Fen); (iv) time effects (separate effects for each year); (v) time-effects within covariate strata (year effects differ between Little and Middle Fen.

2.3 Breeding indicators

Very limited but comparable quantitative information on breeding success each year is derived from the counts of adult females and of nursery webs during the annual census (above). Additional information was derived from casual records, including during sedge-cutting as part of the rotational management cycle, but this cannot be used for quantitative comparison between years. An intensive study by Phil Pearson, of an area of ponds in the core of the spiders range on Middle Fen, provided a much larger data set that allowed comparison between 2004 and 2005.

Figure 1 The Little fen census area showing ponds included in the census. Hatching shows areas where vegetation was cut and removed in July/August each year: 2001, 2002, 2003, 2004 and 2005. Broken black line shows boundary of area from which stock were excluded.



2.4 2001 Pilot point count census

In 2001, for a second consecutive year, a point count census was piloted by a team of volunteers at the standard census ponds. The same methodology was used as in 2000 (Smith 2001). In 2000 the census was carried out on 6 August but unsuitable weather on two consecutive Sundays in 2001 meant that the count was delayed until 26 August. Fifteen volunteers took part, most of whom either had experience of using point count methods in the field or were familiar with *D. plantarius*. In the morning the weather was mild and bright but with high cloud. Cloud cover increased during the afternoon and the count was curtailed by rain from mid-afternoon onwards.

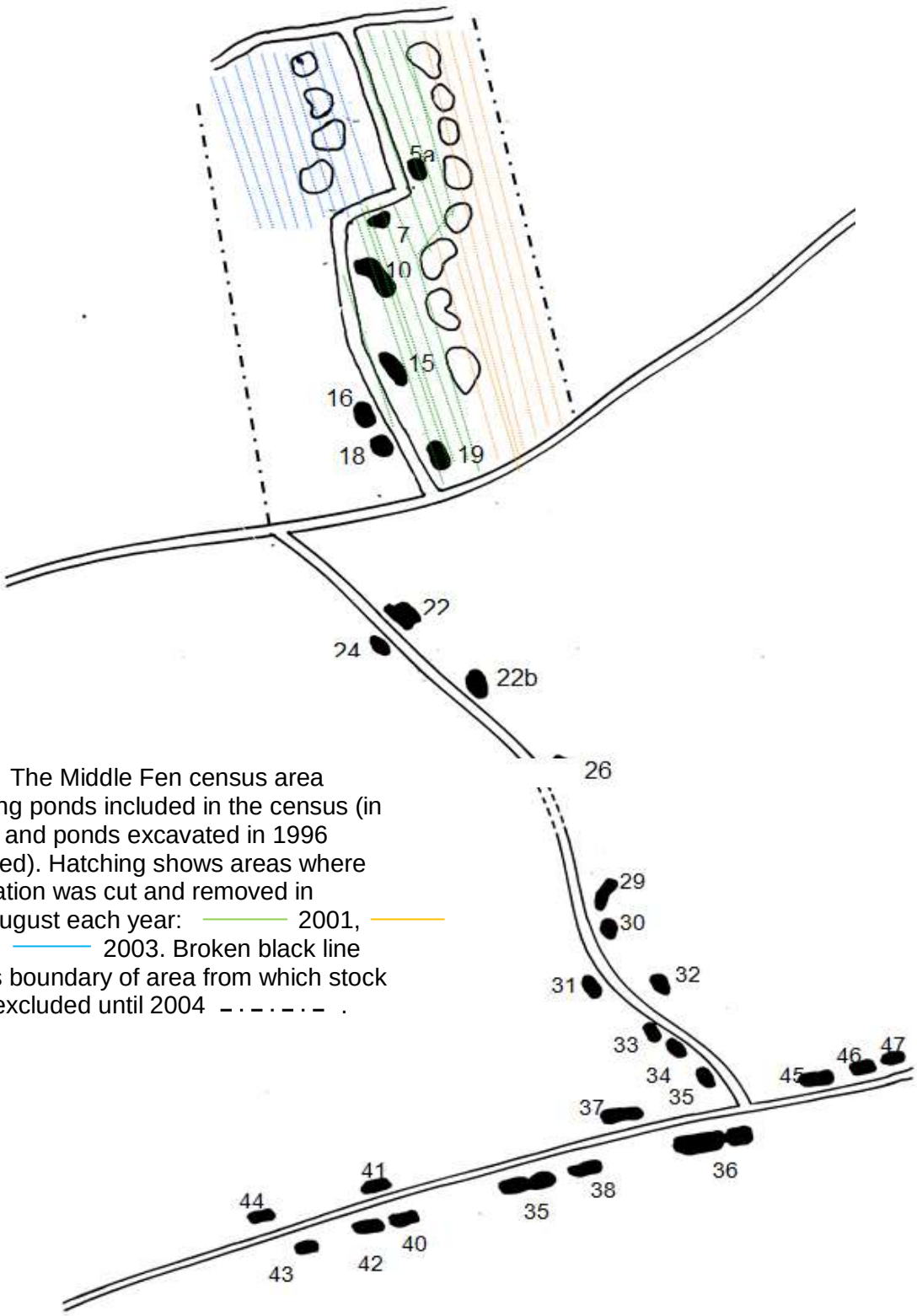


Fig. 2 The Middle Fen census area showing ponds included in the census (in black) and ponds excavated in 1996 (outlined). Hatching shows areas where vegetation was cut and removed in July/August each year: ——— 2001, ——— 2002, ——— 2003. Broken black line shows boundary of area from which stock were excluded until 2004 – · – · – · – .

On Little Fen 15-minute point counts were made at 20 of the 31 ponds normally used in the standard annual census. Most of the eleven ponds that were not covered by point counts were outside range occupied by *D. plantarius* in recent years. Counts were made by two independent observers on all but three ponds, where single counts were made.

On Middle Fen counts were made at those annually censused ponds that were within the recent range of *D. plantarius* (11 ponds). Fifteen-minute counts were made at each pond by between three and six observers.

The counts were made from pre-defined points marked by canes on the banks of each pond. Observers were asked to count from these points only and not to try to increase their field of view by moving. Most observers used binoculars and recorded whether each spider was first seen with binoculars or with the naked eye. The start time for each count, and the time at which each subsequent sighting was made, was recorded. Estimates of the size of the spiders (as small, medium and large), and individual features (including whether or not they were banded, and for adult females the stage of the breeding cycle) were recorded. At the end of the 15 minute count, observers were asked to record how many of the spiders spotted were still visible. To avoid biasing individual results, observers were asked not to communicate their results to other members of the team.

2.5 Water levels

Routine water level measurements against permanent posts in the census ponds on Little and Middle Fens, and in the ponds dug on Great Fen in 1998 (Smith 2000, 1998), were carried out at approximately monthly intervals. The levels in the Little and Middle Fen ponds are expressed relative to an arbitrary datum established in April 1992. The heights of the measuring posts in the Great Fen ponds were levelled and so these measurements are expressed relative to Ordnance Datum.

Ground water levels on the fen have been monitored by Suffolk Wildlife Trust since 1976 using a network of 54 piezometer tubes (Smith 2000). Most of these monitor near-surface hydrology: eight are sunk into the underlying chalk. The data presented in this report are the highest monthly mean recorded from all of these tubes between November and April (winter maximum) and the lowest monthly mean recorded between May and September (summer minimum). Although this is a coarse measure, it gives a useful picture of differences between years over the 30 year recording period.

3 Results

3.1 Distribution

On **Little Fen** *D. plantarius* was found predominantly in the southern part of the census area throughout the reporting period (Fig. 3). This area also held the core of the population during the 1990s, when it received a piped water supply to maintain water levels in the ponds in summer. In most years spiders were recorded on some of the relatively isolated ponds further north but the number of these ponds occupied was lower than in the peak years in the 1990s. They remained absent from the ponds on the northern and western margin of the census area.

The number of ponds on which spiders were recorded varied from year to year but, in general, the range of variation was similar to that in the 1990s (Table 2). 2003 saw the lowest number of occupied ponds on Little Fen since the census started in 1993, although the density of spiders there was so low that the census data may have underestimated the distribution.

On **Middle Fen**, *D. plantarius* was similarly largely restricted to the area of ponds that had benefited from irrigation between 1991 and 1999 (Fig. 4, Table 2). As in the 1990s, spiders were recorded on

ponds to the west of this area only in some years. Although 2002 saw the most westerly record since the census started, no *D. plantarius* were recorded on any of these ponds in either 2004 or 2005. The total numbers of ponds on which spiders were recorded in 2001 to 2005 was in the same range as that in the 1990s.

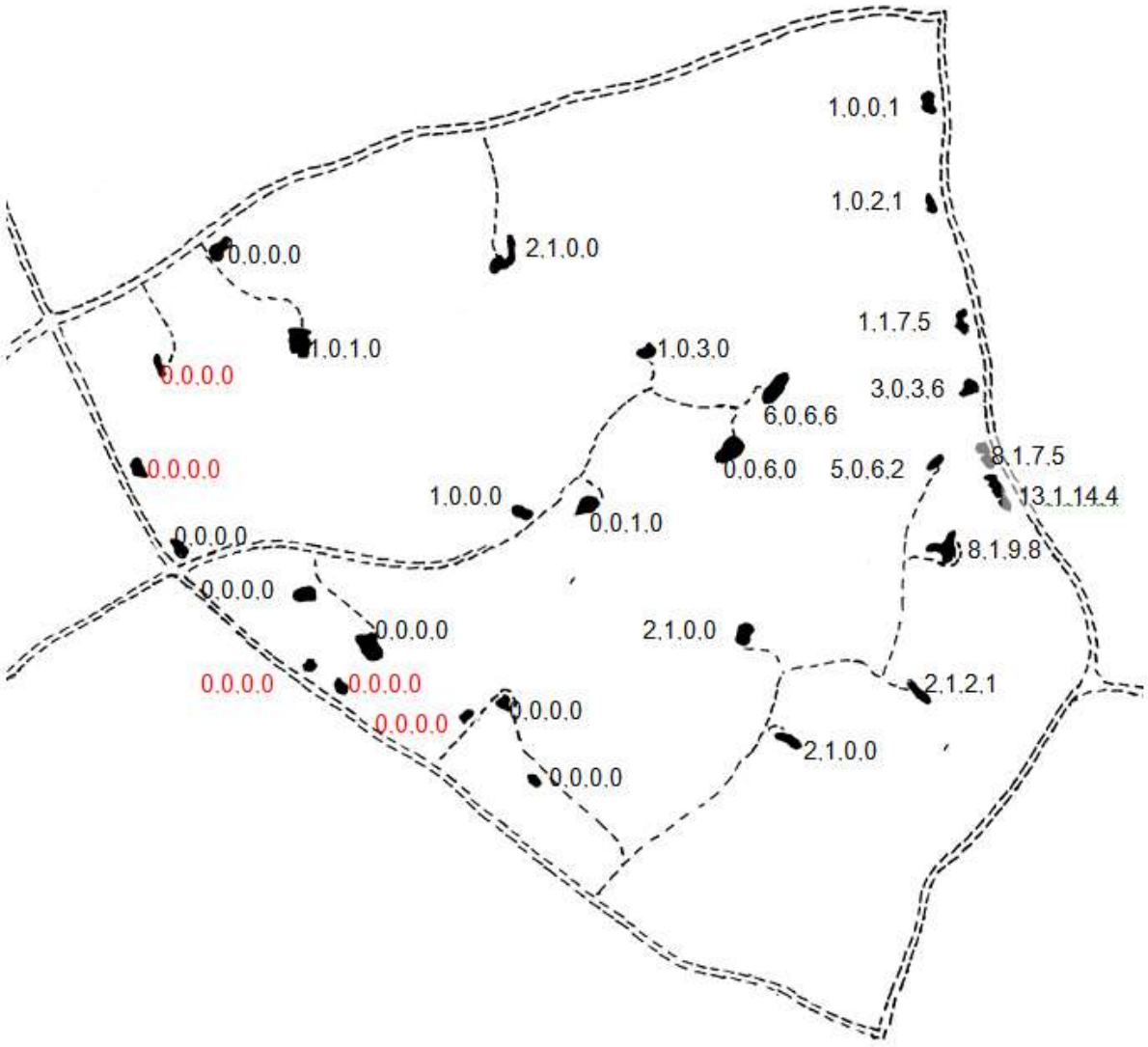


Fig. 3 Numbers of spiders recorded at each of the Little Fen census ponds between 2002 and 2005 (no data were collected in 2000: see text). Numbers represent maximum count for consecutive years. Red numbers denote ponds on which *D. plantarius* has not been recorded at any time in the last 15 years.

3.2 Abundance

The size of the *D. plantarius* sub-populations on both Little and Middle Fens varied substantially, and in some cases significantly, between the years covered by this report but showed no evidence of any sustained or significant recovery (Table 3, Fig. 5). In general, the annual population indices for this period were lower those for peak years in the 1990s.

Separate analysis of the 15 year run of data for the Little and the Middle Fen sub-populations shows that, in both cases, the annual time effects models gave a better description of the data (lowest AIC values) than either the linear-trend or the no-time-effects model. For Little Fen this model had an AIC value of –170.59 (Wald test for significance of deviation from linear trend: 99.10, $p<0.001$, $df=11$). Linear-trend and no-time-effects models had AIC values of 21.82 and –1.79 respectively.

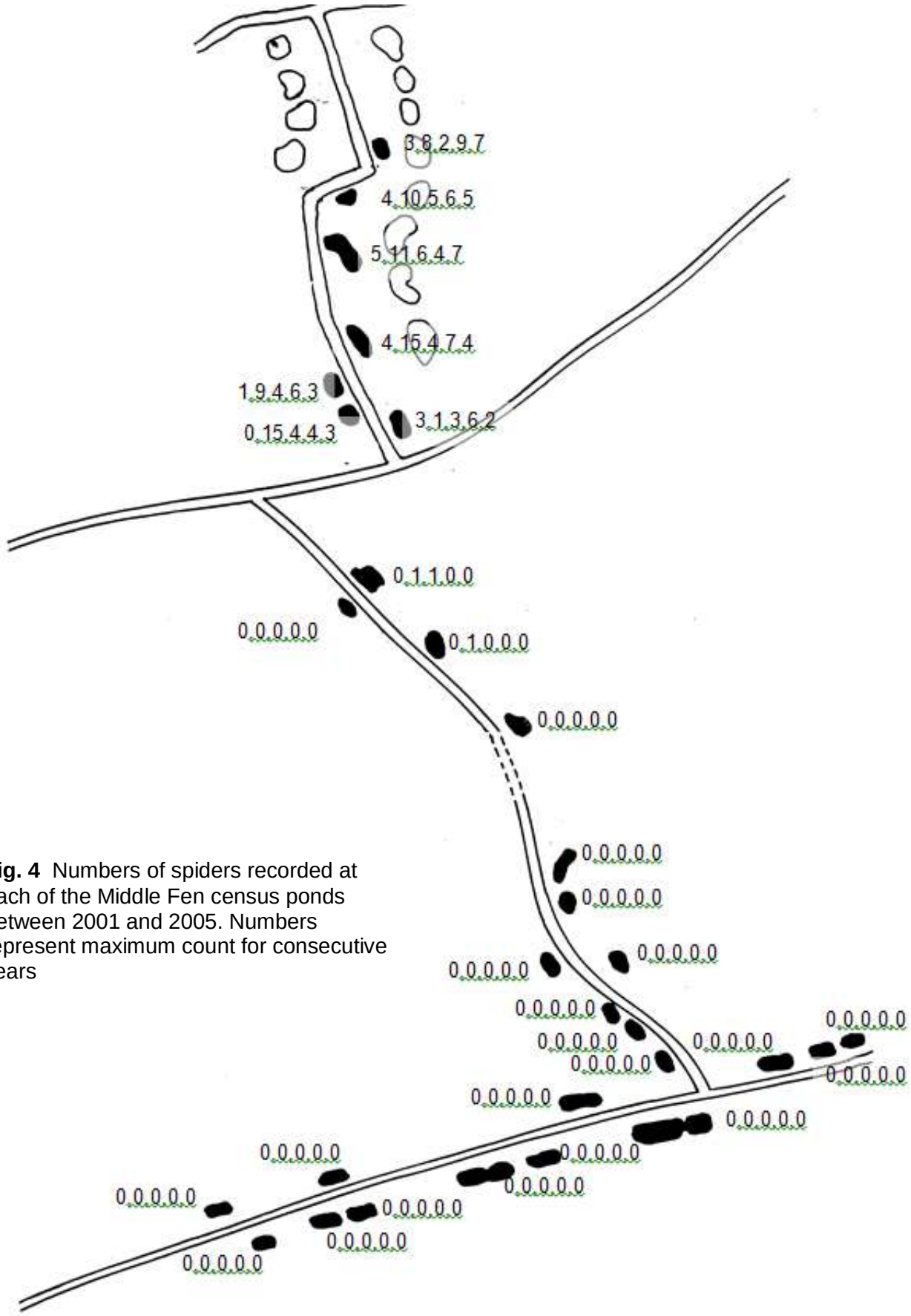


Fig. 4 Numbers of spiders recorded at each of the Middle Fen census ponds between 2001 and 2005. Numbers represent maximum count for consecutive years

For Middle Fen this model had an AIC value of –30.03 (Wald test for significance of deviation from linear trend:=161.48, $p<0.001$, $df=13$). Linear-trend and no-time-effects models had AIC values of 281.28 and 278.42 respectively.

Inclusion of the data for both fens in the population models showed that, as in previous years when such comparison was possible, there was a highly significant difference in the annual pattern of variation between Little and Middle Fen (analysis of data for 1991-'99 and 2002-'05: Wald test for difference between fens=83.04, $P_{12}<0.001$).

3.3 Breeding indicators

On **Little Fen** there was no evidence that any of the breeding seasons between 2001 and 2005 was as successful as the peak seasons in the previous decade (Table 3). The lack of any systematic summer census in 2001 (2.1 above) makes any qualitative assessment of breeding success that year impossible, although the discovery of eight nursery webs during sedge cutting operations shows that there was some successful breeding.

In 2002 four adult females, all with egg sacs, were encountered during the census. There was no rotational sedge cutting that year (only a small area of reed was cut: Fig. 1). In 2003 two adult females, one gravid and one post-partum, were found during the census. Although no nursery webs were encountered, five were found during cutting of a large stand of sedge. In 2004 three adult females were encountered during the census, one guarding a nursery web, one carrying an egg sac and the third gravid. Another female was seen with a nursery web on an uncensused pond. Four adult females were encountered during 2005 census, two with nurseries and two with egg sacs. No nursery webs were found during sedge cutting in either of these years but the areas cut were not in the core area for the spider population (Fig. 1).

On **Middle Fen** no nursery webs were encountered during the censuses between 2001 and 2004. In 2001 there were no sightings of adult females. Only one was encountered during casual recording, including during sedge-cutting operations, and there was evidence that her breeding attempt failed.

In 2002 two adult females were encountered during the census. One of these was the most westerly record of the 15-year census period (Fig. 4) but she was neither obviously gravid nor post-partum and it seemed possible that she had not been mated. No nurseries were found during sedge cutting operations. Again, in 2003, only two adult females were encountered during the census, one gravid and one with an egg sac, and no nurseries were found during sedge cutting operations.

In 2004 only one adult female was encountered during the census. The abandonment of the sedge-cutting rotation on Middle Fen (Fig. 3) meant the loss of this source of casual records, but eight females carrying egg sacs and eight nurseries were found during the season in the ponds studied intensively by Phil Pearson (pers. comm.). In 2005, the numbers of nursery webs encountered during the late July census were the highest in this five-year reporting period. Adult female numbers were higher than at any time since the population peak in 2000, despite relatively poor numbers overall (Table 3). This finding was consistent with results from the intensive study area where 19 females were found with egg sacs and 11 with nursery webs.

Table 2 Numbers of census ponds on which *D. plantarius* was recorded in July each year. Numbers are given separately for ponds that were and were not influenced by the irrigation supplied between 1993 and 1999. The 2000 data for Little Fen are based on two, rather than three replicate counts, made in September rather than July: no data were collected on Little Fen in 2001 (see text).

Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Little Fen													
'Irrigated' n=15[1] ponds	8	8	12	9	12	14	11	-	-	12	6	12	11
'Unirrigated' n=14[1] Ponds	2	2	4	0	1	6	4	-	-	2	1	2	0
Total	**10**	**10**	**12**	**9**	**13**	**20**	**15**	**(11)`**	**-**	**14**	**7**	**15**	**11**
Middle Fen													
'Irrigated' n=7 ponds	6	7	7	5	6	7	6	7	6	7	7	7	7
'Unirrigated' n=23 pond	2	3	0	0	0	0	1	2	0	2	1	0	0
Total	**8**	**10**	**7**	**5**	**6**	**7**	**7**	**9**	**6**	**9**	**8**	**7**	**7**

[1] Prior to 2003, n=16 irrigated and 15 unirrigated ponds respectively

Table 3 Proportions of *D. plantarius* in different size classes, and maximum counts of all individuals, adult females and nursery webs, in the standard annual census ponds on Little and Middle Fen at the July census from 1993 to 2005.

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Little Fen													
% Large	36	21	20	65	30	5	8	-	-	9	28.5	4.4	10
% Medium	57	37	66	15	41	50	53	-	-	57	43	67.6	87.5
% Small	7	42	15	20	29	45	39	-	-	34	28.5	28.0	2.5
Max. spider count	**14**	**19**	**41**	**20**	**66**	**94**	**62**	**-**	**-**	**53**	**7**	**68**	**40**
Adult females*	0	1	6	6	16	4	4	-	-	4	2	3	4
Nursery web count	0	2	0	0	9	0	4	-	-	0	0	1	2
Middle Fen													
% Large	29	30	3	17	47	5	15	6	20	6	10	4.8	12.9
% Medium	33	48	62	34	53	32	46	49	30	55	48	50	45.2
% Small	38	22	35	49	0	63	39	45	50	39	42	45.2	41.9
Max.spider count	**21**	**44**	**102**	**41**	**15**	**99**	**52**	**112**	**20**	**72**	**29**	**42**	**31**
Adult females*	0	8	1	5	6	5	7	7	0	2	2	1	4
Nursery web count	1	3	1	0	0	0	7	0	0	0	0	0	3

3.4 Pilot point count census

On Middle Fen only five spiders were recorded compared with 63 in 2000 (Table 4). My own point counts in 2000 were consistently and significantly higher than those of other observers (Smith 2001 and shown in parentheses in Table 4). I did not record point counts in 2001: exclusion of my records for 2000, to make a more valid comparison between the two years, gives a total of 47 sightings. This is still a significantly higher count than in 2001 (Wilcoxon matched pairs signed-rank test $p<0.001$).

On Little Fen, there were only three sightings of *D. plantarius* during the point count census in 2001. This result was very similar to that for 2000, when there was one confirmed and two possible sightings.

3.5 Water Levels

The salient feature of water levels from 2001 to 2005 is that they were consistently and substantially higher than during the preceding decade, before closure of the bore-hole in 1999 (Fig. 6). This is particularly striking in the case of summer levels. Even in the dry summer of 2003, the summer mean minimum recorded in the piezometers was similar to that in the four wettest summers between 1977 and 1998. Winter levels were also markedly higher than in the years before bore-hole closure. Levels in the piezometers in the drier winters during the reporting period were exceeded by only one winter (1987) in the whole data set from between 1977 and 1998.

This pattern is equally apparent from the levels measured in the census ponds (Figs. 7 & 8). Winter water levels on Little Fen were consistently much higher that before bore-hole closure. The pre-bore-hole pattern of dramatic summer water loss, ameliorated in some ponds by irrigation, ended in 1999. In 2001 and 2004, high water levels were sustained throughout the summer. Drier summers in 2002, 2003 and 2005 resulted in a marked draw-down but only in 2003 was the drought sustained and many ponds left with exposed muddy shores. Some were left dry at the depth gauge, with only a small residual pool of water in the bottom, and others dried out completely for the first time since 1998 (Fig. 9). Partial or complete drying-out of the ponds was a consistent feature in summers prior to 1988.

Water quality in many Little Fen ponds in the dry summers of 2003 and 2005 appeared to be poor, showing symptoms of strongly reducing conditions. Spectacular blooms of purple sulphur bacteria over dense mats of rotting *Chara* spp. exposed by the falling water level, together with a milky appearance and very strong smell of hydrogen sulphide in the water, characterised many of the ponds by July.

Water levels in the Middle Fen ponds showed the same pattern as on Little Fen although, as in the previous decade, the winter peaks were neither as high nor as sustained as on Little Fen and the summer troughs were more marked. The 2003 drought had comparable effects on water levels in the spider ponds to the wetter summers of the 1990s, with some ponds partially drying out (Fig. 9).

In the ponds dug on Great Fen in 1988 (Smith 1988) water levels also drew down substantially in the summers of 2002, 2003 and 2005 (Fig. 10). In 2002, two of the five ponds on which measurements were made were almost dry and one was completely dry by September. In the more severe drought of 2003 they were all dry between July and October. Although the dry summer of 2005 had more effect on Middle Fen water levels than that of 2002 (Fig. 8), it had less effect on on Great Fen: none of the ponds dried out at any stage in 2005. With the exception of the very wet spring of 2001, winter water levels on Great Fen were very consistent between years. The hydrology of Great Fen appears to be more isolated from the river channel than that of Middle Fen, probably as a result both of significant deposits of aquitard marl overlying the chalk and stronger associations with discharging groundwater. This discharge is concentrated in the area dominated by *Cladium mariscus* and in which the ponds dug in 1998 with a view to eventual re-introduction of *D. plantarius* are located (A.Excell, pers. comm).

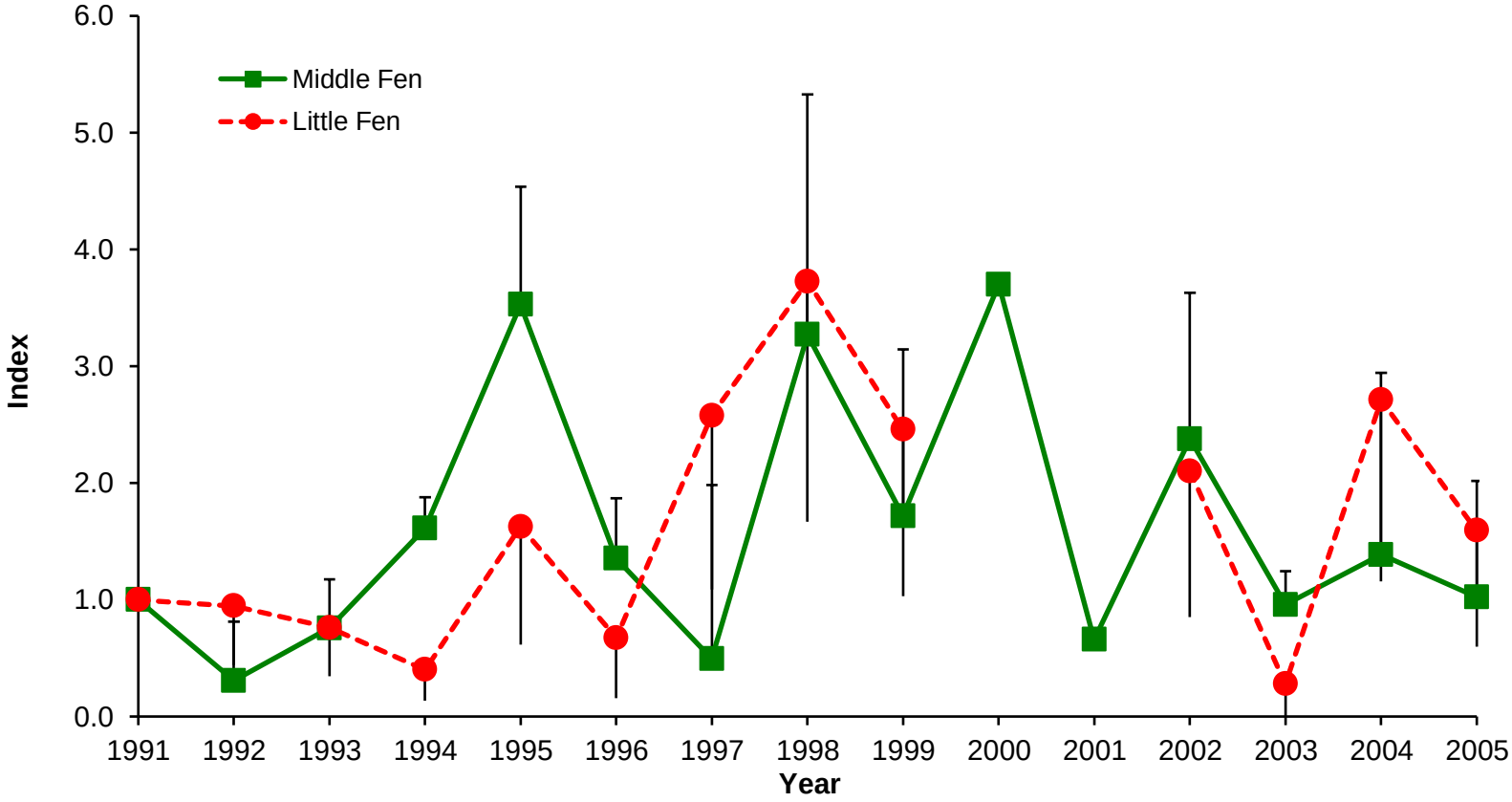


Fig. 5 Annual population indices for *D. plantarius* on Middle and Little Fens in July 1991-2005, generated by a log-linear Poisson regression model and plotted on a linear scale. See text for missing data on Little Fen. Vertical bars denote 2SEs.

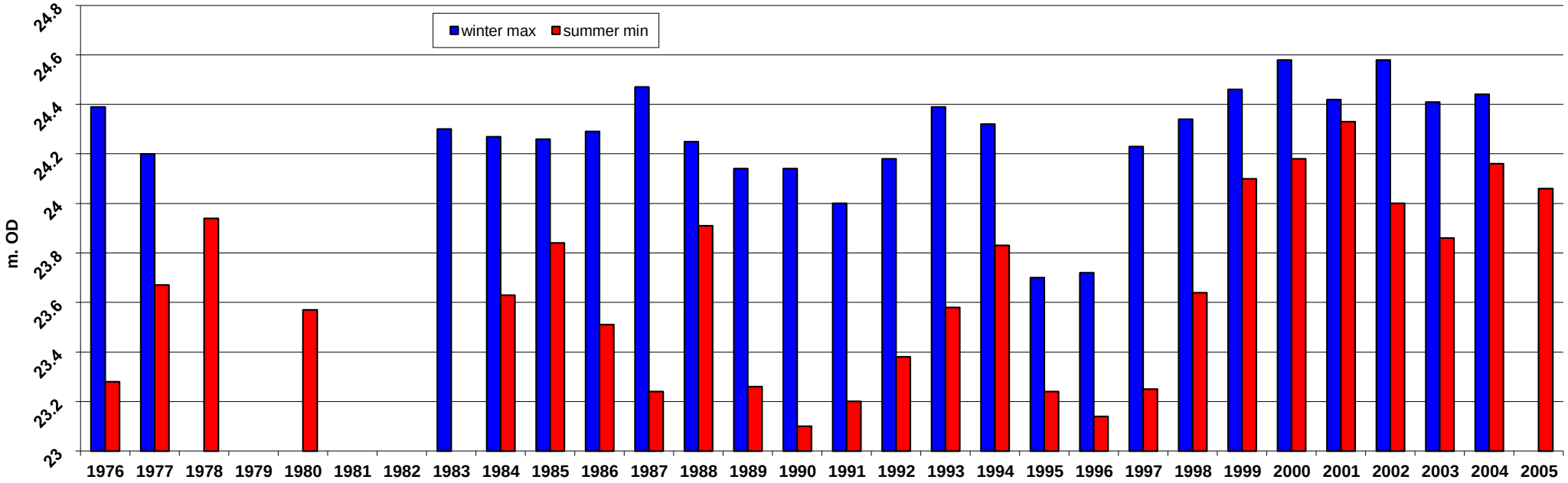
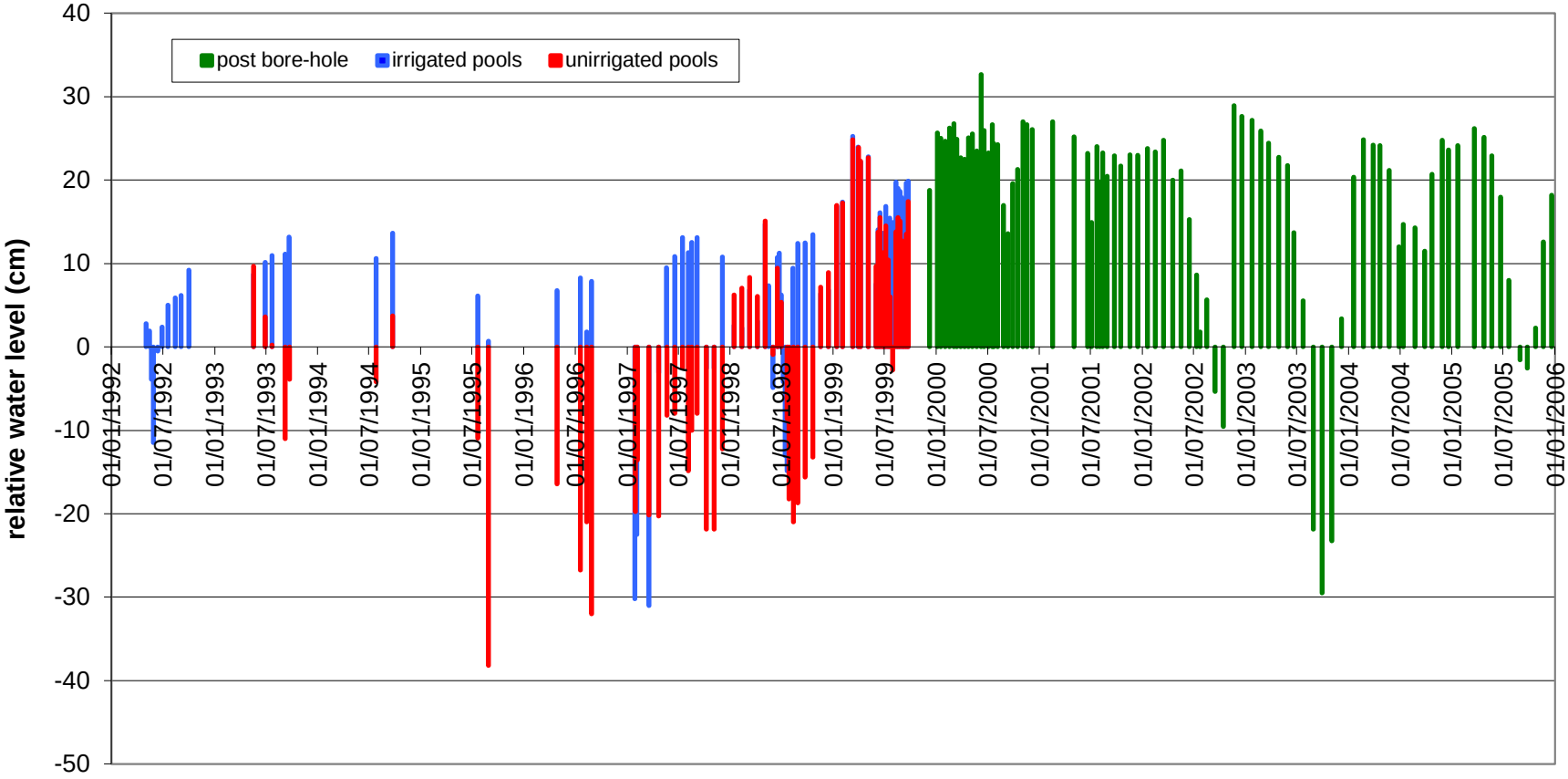


Fig. 6 Mean winter maximum and summer minimum water levels in piezometers on Redgrave and Lopham Fen NNR


post bore-hole
irrigated pools
unirrigated pools
relative water level (cm)
40
30
20
10
0
-10
-20
-30
-40
-50
01/01/1992
01/07/1992
01/01/1993
01/07/1993
01/01/1994
01/07/1994
01/01/1995
01/07/1995
01/01/1996
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01/07/2003
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Fig. 7 Water levels in Little Fen ponds 1992-2005. Horizontal line represents the April 1992 datum. Blue and red lines represent mean levels in irrigated and unirrigated ponds respectively : summer irrigation stopped in 1999 (see text).

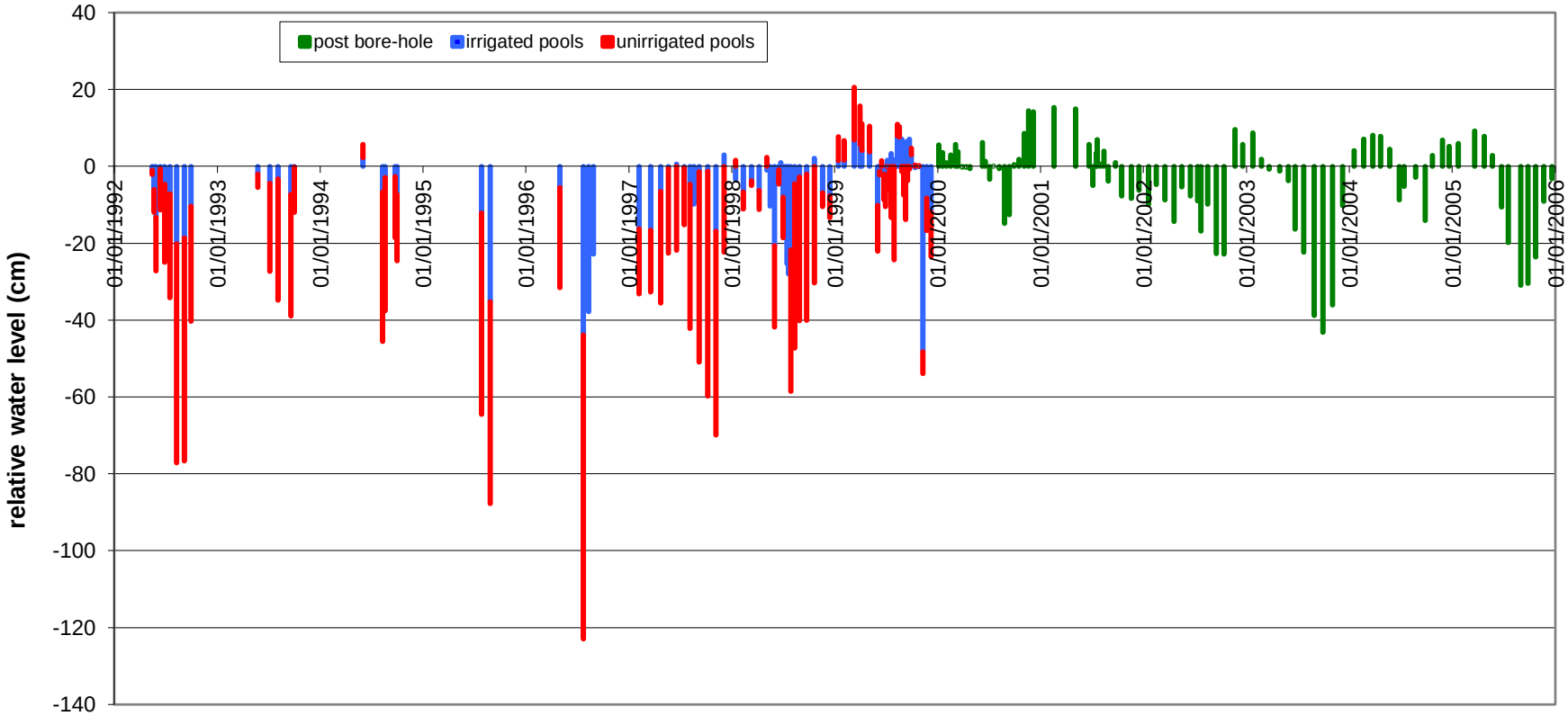


Fig. 8 Water levels in Middle Fen ponds 1992-2005. Horizontal line represents the April 1992 datum. Blue and red lines represent mean levels in irrigated and unirrigated ponds respectively : summer irrigation stopped in 1999 (see text).

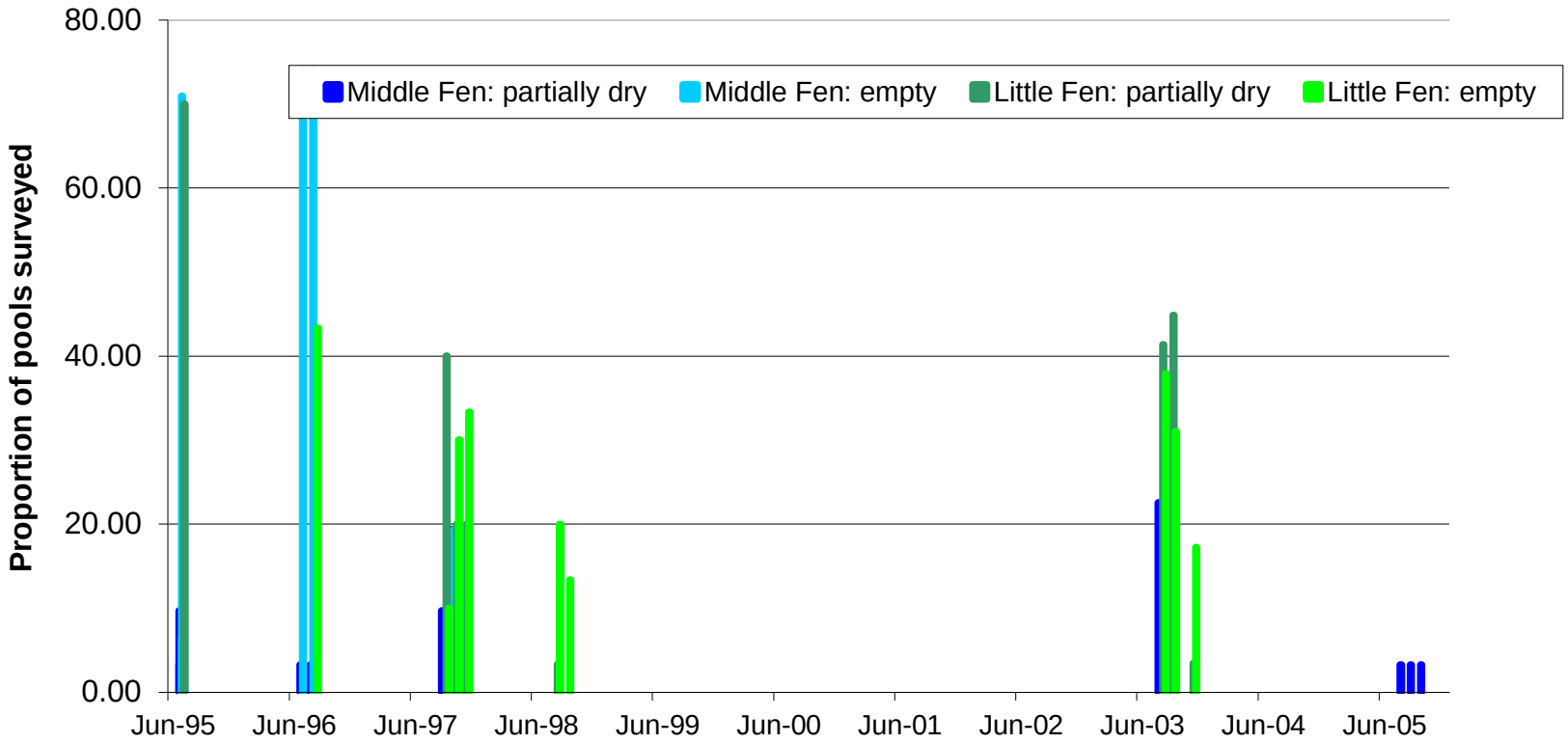


Fig. 9 Percentage of ponds that were either partially* or completely dry (*see text)

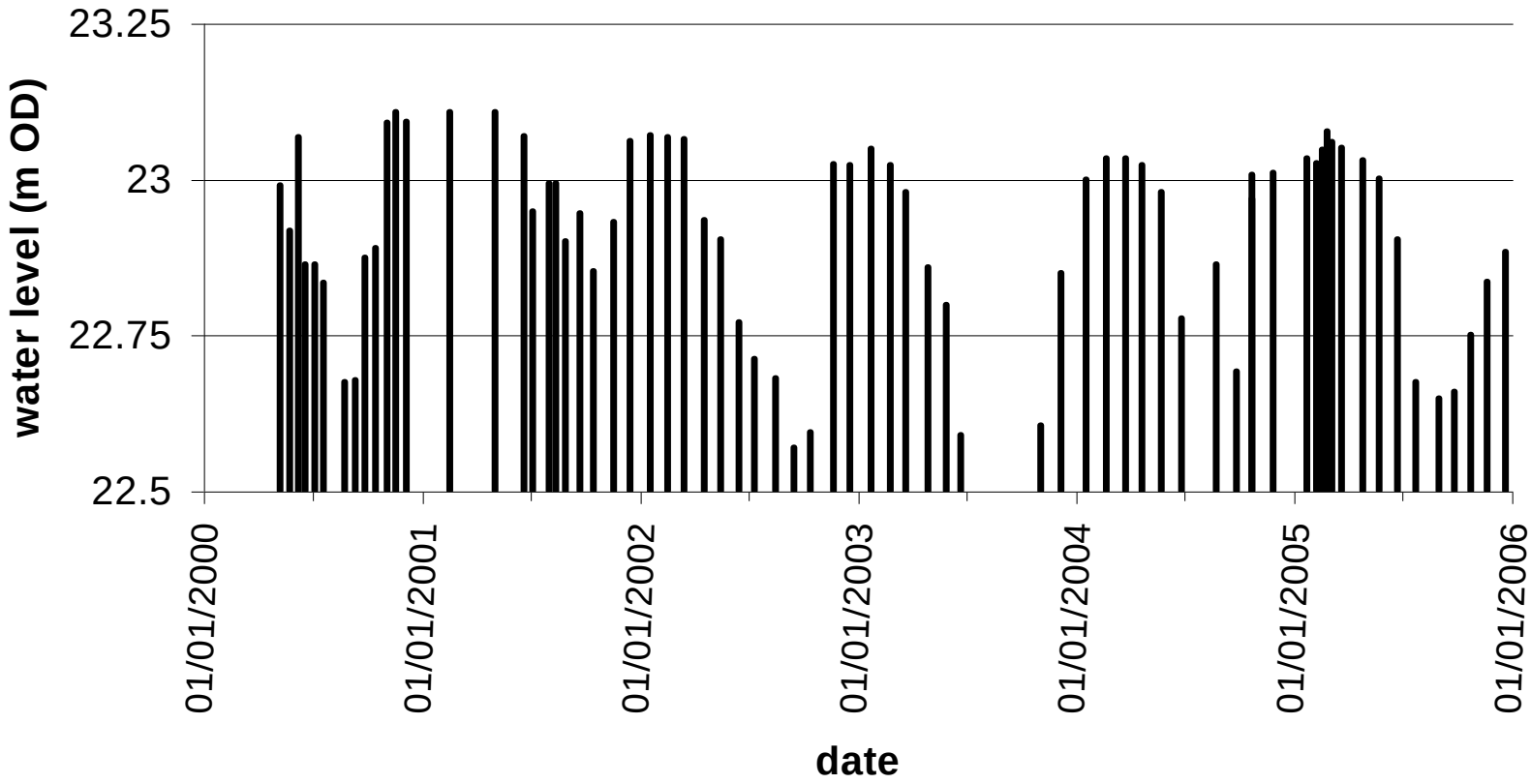


Fig. 10 Water levels in ponds excavated on Great Fen in 1998. Broken line denotes level below which most ponds are dry.

4 Habitat management

4.1 Rotational mowing of *Cladium mariscus*

The *C. mariscus* cutting rotation initiated in 1998 (Smith 1998), in dense stands that surround the ponds that support the highest density of *D. plantarius* on both Little and Middle Fen (Figs. 1 and 2), was abandoned after 2003 (Steering Group meeting notes 11/01/05). In 2004 the fences around these areas were removed to allow stock to enter. No further cutting of fen vegetation was carried out on Middle Fen. On Little Fen, a mature *C. mariscus*-dominated block outside the former exclosure was cut in 2004. In 2005 a further area that had been left unmanaged, and dominated by *Pragmites australis* and *Calamagrostis epigeos,* was cut (Fig. 1). All cutting was done in the last two weeks of July or the first week of August. Cut material was raked-up and removed from the site using a winch to minimise compaction and damage to *C. mariscus*.

4.2 Grazing

Between 2001 and 2005 the grazing management of areas occupied by *D. plantarius* was much more successful on Middle Fen than on Little Fen. Grazing was by both Konik ponies and Sussex cattle in varying combinations (records of stock types, rates and movements are documented by Excell, 2004).

On **Middle Fen** in the late 1990's, tall *P. australis* became very dominant in the western part of the range of *D. plantarius,* away from the fenced *C. mariscus* beds (4.1 above). As a result, most of the turf ponds in this area were densely shaded. In late summer 2001, grazing by Sussex cattle started to have a substantial impact on the reed, and shading of the ponds was reduced. Grazing over the next four years re-enforced this effect, leaving the ponds much more open. In 2004, the grazing pressure around the ponds was such that, had spiders been present, it would almost certainly have been detrimental to successful breeding. *Cladium mariscus* stem densities have improved in some areas of Middle Fen away from the dense stands in the core spider areas, probably as a result of both grazing and elevated ground-water levels.

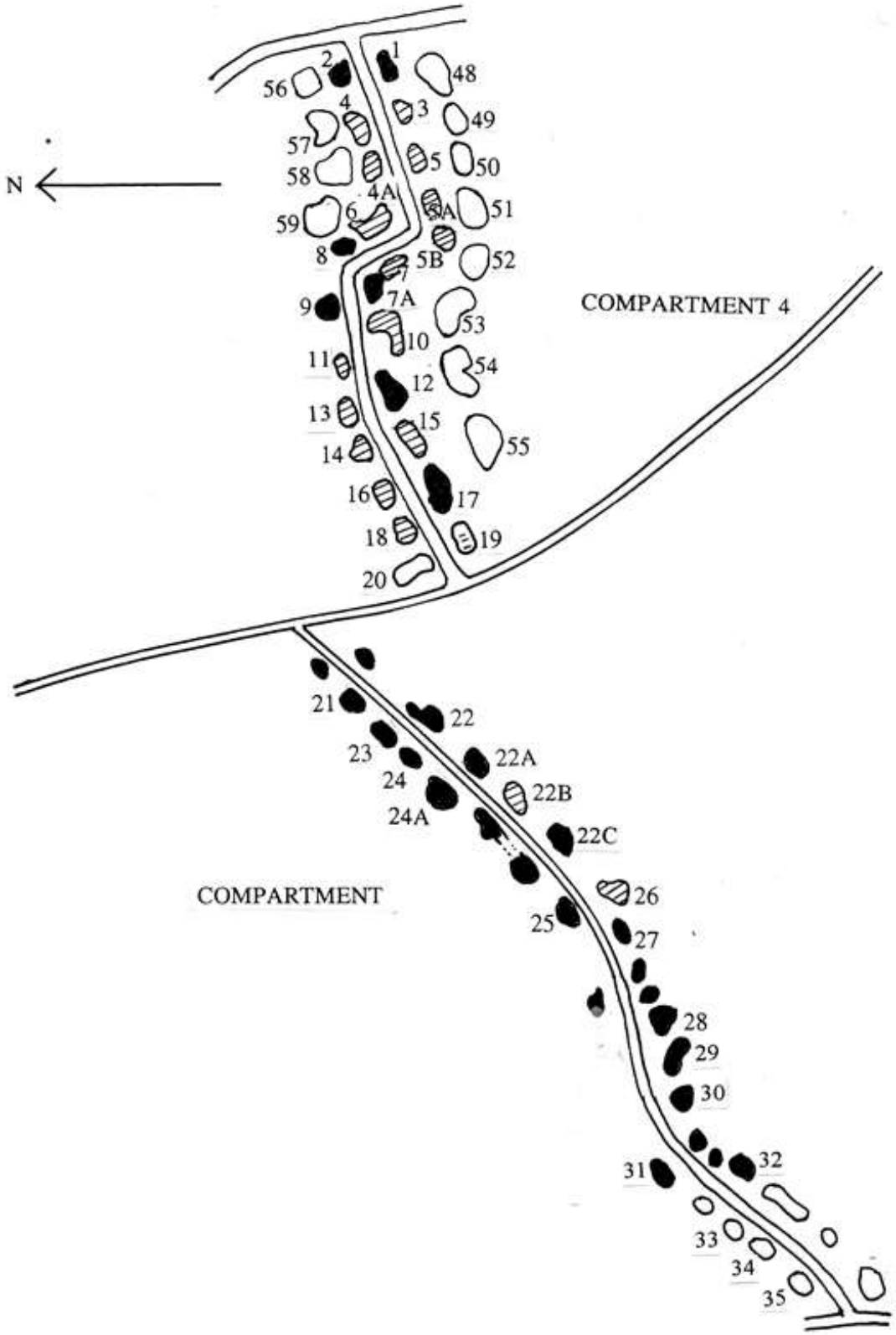
When cattle were allowed into the formerly fenced and cut *C. mariscus* beds in the core area for *D. plantarius* on Middle Fen in 2004 (above), they restricted their activity primarily to the relatively short sward where *C. mariscus* had been cut the previous year (Fig. 2), leaving taller, dense stands ungrazed. They grazed between the sedge clumps but used the area primarily as a thoroughfare between grassier areas. Although the trampling could potentially have resulted in the loss of some nursery webs, it was not thought to be a major threat.

On **Little Fen** the Konik ponies and Sussex cattle made very few incursions into the areas occupied by *D. plantarius* and had a negligible effect on the vegetation. They appear to have been deterred by the much wetter conditions than on Middle Fen. Although removal of the fences (4.1 above) allowed them access to the whole area in 2004 and 2005, they still failed to enter any of it, preferring to graze on the many drier, grassier areas available to them.

4.3 Clearance of *Phragmites australis* from Middle Fen ponds

Removal of mud and reed rhizomes from some of the machine-dug ponds within the *D. plantarius* range on Middle Fen was carried out between 8 and 10 September 2001 using a standard 5Tmini digger. Ponds within the spider's recent range, plus as many ponds as possible further west, were included (45 ponds in total: Fig. 11). Some material was taken from the majority of ponds but the amount removed varied according to the extent of invasion of open water by *P. australis*. This clearance augmented the effects of grazing (4.2

above) in reducing shading around the ponds. Many of ponds along the north-south path at the western end of the census area were cleared in the same way in the 2003/2004 winter.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4.4 Path restoration

Tracks bounding the north, west and east sides of the core area for *D. plantarius* on Little Fen (Compartment 5: Fig. 1) became almost permanently flooded and impassable in the years immediately after recovery of the water table. In spring 2002 they were built up and re-enforced with plastic mesh. Drainage pipes (150mm) were laid under these causeways at intervals to try to prevent any ponding of water. In subsequent wet winters a substantial flow through these pipes suggests that causeways may increase water retention time within the core spider area.

The condition of minor tracks and former ‘barrow-ways’ within the census areas deteriorated over the reporting period making access to many of the census ponds more difficult. This

resulted from a combination of waterlogged ground conditions and their use as causeways by grazing stock.

4.5 Control of Water Levels

Little Fen became permanently and deeply flooded following closure of the bore-hole in 1999. The existing sluice system was inadequate to control levels and maintain a flow of surface water across the fen for much of the year and there was concern that the resulting stagnant and anoxic conditions may have been unfavourable to *D. plantarius* as well as to the fen plant communities. This problem was addressed in March 2001 by the installation of a second 300mm pipe sluice in the earth bund across the Waveney, just above its junction with Worby's Drain at the eastern end of Little Fen.

Although this additional sluice reduced water retention in the southern part of Little Fen and adjacent Redgrave Fen, it did not appear to have any effect on surface water levels in the core *D. plantarius* areas to the north: there were no substantial differences in the surface water levels in the spider ponds between 2000 and 2001 which might be attributed to the new sluice (Fig. 7). This may imply that water from the north-west side of Little Fen moves predominantly east, towards Worby's drain, rather than south towards the Little Fen section of the Waveney. In this case, this water may be impounded on Little Fen by the bunds and causeways that transect its route, as well as by shrinkage of peat.

Although the problem of deep inundation of the core spider area could not be addressed with the existing sluice system, it was relieved after 2002 by lower rainfall which reduced the extent and duration of inundation. More favourable swamp conditions developed, with water at or just below the surface in most summers and some through-flow**.** However, since water levels on Little Fen cannot be lowered further using the existing sluice and channels, a different system could be required to control water levels in the event of another series of very wet years. A bypass through the main north-south bund could potentially alleviate additional discharge directly into the river.

The main potential for relieving flooding on Little Fen now appears to be by adjusting the level of the Middle Fen sluice (Excell, pers. comm.). If this is confirmed, there is a potential conflict of interest between the need to reduce water retention in Little Fen and the west end of Redgrave Fen, and the maintenance of sufficiently high levels on Middle Fen.

In mid-March 2002 the Little Fen section of the Upper Waveney was dredged and large quantities of *P. australis* and silt removed. Although there was a fall in surface water levels in the spider census area (Fig. 7) coincident with this work, both the lowering of the Middle Fen sluice during the operation (below), and the rapid and complete recovery of surface water levels in early winter, suggested that the dredging had little effect in relieving the impeded drainage in the core areas for *D. plantarius* on Little Fen.

Middle Fen water levels are controlled by a fully variable sluice on the river Waveney. They respond rapidly to variations in river levels despite the elevated groundwater levels since bore-hole closure. Normal policy is to raise the sluice fully to retain water during the summer and to adjust it more frequently during winter to prevent flooding. In 2002 levels were reduced, first in spring to allow contractors to work on the Little Fen stretch of the channel, and again in August to allow work on the upper end of Redgrave Fen.

Adequate protection against very low summer water levels on **Great Fen** is a critical pre-requisite for the proposed translocation of *D. plantarius* to the ponds excavated in 1998 (Section 5.1 below). A new sluice, which it was hoped would deliver this control, was constructed at the east end of Lang Fen between August 2001 and spring 2002. However, commissioning was delayed until spring 2005 and the commissioning 'step' tests were run

over too short a period to assess their effects on water levels in the Great Fen turf ponds. As a result of large volumes of weed in the channel throughout summer 2005, the water level in the channel held at its legally-allowed maximum (23.7m) from Feb onwards (A. Excell, pers. comm.). Adequate water levels were maintained in the ponds throughout the summer but the relative contributions to this, of different hydrological factors, remains to be assessed. It is expected that the sluice will be most effective in winter to late spring, when it will be used to slow water loss from the system. Although it unlikely to be effectively in countering water loss from the Great Fen ponds in severe droughts, its impact on summer water retention on Great Fen remains to be assessed.

5 Discussion and conclusions

5.1 The distribution and abundance of *D. plantarius* population

By 2005, despite the seven years that had elapsed since closure of the bore-hole and hydrological restoration of the fen (Smith 2001), there was no indication that the *D. plantarius* population had started to recover from the low numbers seen throughout the1990s. The population remained small, very restricted in its range, and highly vulnerable to stochastic extinction.

Despite elevated water levels leading to flooding between the ponds for much of the year, there was little change in the range of either sub-population. On both Little and Middle Fen the spiders remained confined primarily to areas that received summer irrigation between 1991 and 1999 (Smith 2001). The most likely explanation for this is that these areas were inherently most favourable – and it was because they still harboured a spider population at the beginning of the 1990s that they were selected to receive an artificial water supply.

An inability to disperse from these core areas is a possible, but less likely, explanation of their distribution. The protracted periods during which areas between the ponds were flooded in the years after closure of the bore-hole, must have given the potential for spiders to disperse easily within these areas of the fen. The discovery by Phil Pearson (pers. comm.), as part of his PhD study, that juvenile *D. plantarius* have some tendency to disperse by ballooning further suggests that failure to disperse, at least over limited distances, is unlikely.

Although water levels during the reporting period were unlikely to explain the restricted distribution of *D. plantarius*, the low water levels frequently encountered between the 1970s and 1990s are more likely to have influenced dispersal and distribution. Water levels, past and present, are also likely to be an important element in determining habitat suitability for this essentially aquatic species. Water is known to be required at several stages in its life history. Detecting prey by vibration at the meniscus is thought to be the commonest hunting strategy and the use of vibration of the meniscus also appears to be a vital element in the *D. plantarius* courtship ritual. Successful breeding also depends on water levels, requiring stiff-leaved vegetation emerging from water.

Smith (2000) showed that the relationship between water levels in the census ponds and the numbers of spider counted between 1991 and 1999 was weak (Smith 2000). The relationship was curvilinear, with the highest counts at intermediate water levels. The low counts at very low water levels may have been due either to spiders moving into damp vegetation, or to mortality. The lower counts at high water levels may have resulted from increased opportunities for spiders to move away from the study pools although further analysis showed that the annual population indices were robust to this variation.

Since these analyses were carried out, flooding of wide areas of the fen has become common and new analysis of the relationship between spider numbers and distribution over the fen is required. This needs to incorporate the highly non-linear relationship between water levels in the ponds and the area of water surface available when the fen is inundated. A pre-requisite for this is to quantify this relationship in the field, over the range of water levels normally encountered.

In addition to the availability of water, many factors are likely to influence the suitability of the fen habitat for *D. plantarius*. Phil Pearson's PhD study is attempting to address the difficult question of what constitutes favourable habitat and how variations in different environmental factors influence demography. Factors including the composition and structure of the vegetation, the availability of prey, and quality as well as quantity of water, are being investigated. The results need to explain the pattern of significant annual variation within the sub-populations and the causes of the significant differences in this pattern between them.

A further possible cause of the failure of the *D. plantarius* population to respond to hydrological restoration is a loss of genetic variability as a result of bottlenecking at very low population levels. The potential role of genetic bottlenecks in the failure of the *D. plantarius* population to respond to hydrological recovery of the fen was addressed by Marija Vugdelic's PhD project between 2002 and 2005. This is an essential element not only in understanding the causes of low population size but also in finding appropriate means to address it.

By 2006/2007, the results of the PhD projects at UEA will help to address the reasons why the spider population remains so precarious, and to inform both management of the fen vegetation and hydrology, and possible genetic manipulation of the population. In the meantime, the survival of the population remains dependent on pragmatic decisions about management and the hope of avoiding protracted droughts. The acute risk of stochastic extinction at this site makes it imperative that plans are in place for establishing new foci of population, both within the fen complex and further afield. Translocation to Great Fen has been under discussion since 1997 (Smith 1997) but still awaits further evaluation of the impact of the new Lang Fen sluice in dry summers. Successful captive breeding at UEA has demonstrated that stock can be reared for translocation without impacting significantly on the existing wild populations. Whilst the UEA research projects should inform much of the detail of the translocations, other aspects of planning for the project should be advanced as soon as possible.

5.2 Census Methods

The pilot point count census in 2001 highlighted the inadequacies of this method for monitoring such a small and variable population. When the method was first piloted, in 2000, and spider numbers were higher, the point count method recorded 38.5% of the number of spiders found at the July census, although this figure was increased to over 50% by inclusion of my own point count records (Smith 2001). In 2001 the point count volunteers recorded only five individuals, constituting 25% of the numbers found at the July census. Low counts were an even more acute problem on Little Fen.

The second pilot year identified other problems that were not encountered in 2000. Some concerned the constraints of using volunteers. Because the weather was unsuitable for census work on both the weekend for which the census was arranged and on the following, standby weekend, the administrative task of recruiting, setting up marked ponds in the field, cancelling and re-recruiting, was substantial. The team assembled at the third weekend was smaller than that available for the first weekend, for which adequate notice had been given.

Postponing the count to this extent also reduced the comparability of the data between years. Because spider numbers were very much lower on Middle Fen in 2001 than in 2000, volunteers found it much more difficult to sustain their interest and morale. This is likely to make it more difficult to recruit the same people in future years.

The point count method was thus substantially less sensitive and informative than the existing census method even when carried out by a very experienced observer. It was less sensitive still, and likely to lack consistency between years, when carried out by volunteers, even if they had some familiarity with *D. plantarius* and good field skills. A pilot census based on counts of nursery webs in 1999 and 2000 yielded even small sample sizes (Smith 2001).

Both of these alternative methods could be successfully employed by volunteers but clearly remain inappropriate until there is a substantial recovery in population size. Because of the continuing failure of the *D. plantarius* population to show any sign of significant or sustained recovery, despite full recovery of water levels, the standard census scheme, initiated in 1993, still remains the only adequately sensitive method of monitoring either the Little or Middle Fen populations.

In addition to the census, checks should be maintained for the establishment of new sub-populations on other areas of the Redgrave and Lopham Fen complex. This was last done as a wide-scale systematic exercise, with volunteers, in 1994 (Smith 1994) although regular checks have since been kept on existing and new water bodes. Although the present restricted distribution, even within the apparently suitable habitat in the census areas, suggests that new population foci are unlikely, the changing nature of wet areas on the fen since completion of the restoration project (Harding 2000) makes a repeat of this systematic, large-scale survey timely.

5.3 Vegetation management

There is currently no quantitative basis either for defining the vegetation structure that is optimal for *D. plantarius* or for evaluating the relative merits of mowing and grazing, or of leaving the sedge beds unmanaged. As well as the differing indirect effects of these regimes on *D. plantarius* through their effect on vegetation structure, both mowing and grazing are likely to have differing direct effects through the destruction of nursery webs**.** The autecological research being undertaken by Phil Pearson should provide a better basis for these management decisions by 2007. Until then, the Recovery Project Steering Group (meeting on 11/01/05) agreed to the pragmatic approach of relying primarily on grazing management whilst keeping the need for resuming rotational mowing of the sedge beds under annual review.

The change from a mowing to a grazing regime in 2004 was driven primarily by the labour-intensive nature of rotational mowing and maintenance of electric fencing on an otherwise extensively-grazed site. On Little Fen the SWT thought it preferable to transfer effort to occasional mowing of blocks of fen vegetation over a wider area, to encourage the grazing stock to enter the wettest areas of the fen. However, although this management may rejuvenate the remaining *C. mariscus* in these areas, it did not result in any more substantial incursion and grazing by stock in either in 2004 or 2005.

Although the area of habitat that appears to be suitable for spiders on both Little and Middle Fens is rather greater than their present range, and thus unlikely to be the current limiting factor, the area into which they could spread in the event of a sustained population increase is limited by both the availability of sufficiently deep ponds and of stands of *C. mariscus*. An apparent negative correlation between the extent of *P. australis* encroachment around the ponds and the abundance of *D. plantarius* is a cause for concern. The 2004 NVC survey of the NNR (Stone *et al.* 2004) suggested that the density of *C. mariscus* had declined since

the 1992 NVC survey, away from the core sedge beds, on both Middle Fen and Little Fen. It is therefore important that the relative extent of *P. australis* and *C. mariscus* stands on the fen is properly quantified. The Fen Vegetation Monitoring programme, based on a grid of permanent quadrats, gives inadequate coverage to evaluate these changes (Parmenter 2001). The NVC surveys, if maintained, give some information but more tailored monitoring may be required to assess adequately changes in the extent and location of *D.plantarius* habitat.

5.4 Water level monitoring and management

The regular measurement of water levels in the ponds included in the *D. plantarius* census on Little and Middle Fens provides data essential to the understanding of the relationship between water levels and the abundance and distribution of *D. plantarius*. This relationship is likely to be a key element in understanding the causes of decline and informing the changes in management that may be required to promote recovery. Regular monitoring of water levels in the ponds dug on Great Fen in 1998 is essential for evaluating the effectiveness of the new Lang Fen sluice in maintaining sufficiently reliable summer levels (Section 4.2) to support the future introduction of *D. plantarius* (5.1 above). The collection and analysis of these data is currently carried out by volunteers and remains a very important element in the *D. plantarius* recovery programme for this site.

Although water levels on Redgrave and Lopham Fen have been much higher and their variation less extreme since closure of the bore-hole in 1999, the drought of 2003 showed that the potential remains for damagingly low levels. The primary danger for *D. plantarius* is likely to be protracted draw-down in summer that leaves ponds with exposed muddy shores and no emergent vegetation suitable for nursery web construction. As long as the sub-populations remain at the low levels encountered throughout this reporting period, droughts resulting in breeding failure and food shortage, particularly for more than one successive year, remain a real threat to their survival.

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