Fen Raft Spider Recovery Project:
2006 Summary Report for Redgrave and Lopham Fen

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Summary

1 This report describes the results from the sixteenth year of systematic monitoring of the nationally endangered fen raft spider (*Dolomedes plantarius*) at Redgrave and Lopham Fen National Nature Reserve, Norfolk. This work was undertaken as part of English Nature's (now Natural England) Species Recovery and BAP programmes in 2006. Habitat management work and measurements of surface water levels are also documented and discussed in relation to spider population trends.

2 Throughout the 16-year census the population was very small and its range restricted to two small and spatially separated areas, on Little Fen and Middle Fen.

3 Desiccation of the fen by artesian abstraction, thought to be responsible for the decline in this essentially aquatic species, ended in 1999 with relocation a borehole that had drained the fen. This, in combination with higher than average rainfall in the following two years, resulted in rapid hydrological recovery.

4 The census data for the seven years since borehole closure, including those for 2006, showed that hydrological recovery did not result in any recovery in either the abundance or range of *D. plantarius*. The population remained concentrated in the two areas of ponds that were irrigated during the droughts of the 1990s.

5 An annual index of population size that allowed statistical comparison between years, and between sub-populations, showed that 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.

6 Modelling of the data sets for both the Little and Middle Fen sub-populations showed that there was a highly significant difference between them in the pattern of annual variation.

7 Rotational mowing of *Cladium mariscus,* which dominated the core areas for *D. plantarius*, was abandoned in favour of extensive grazing in summer 2002. Failure of the stock to graze much of the *D. plantarius* range on Little Fen grazing necessitated supplementary by mowing of stands of tall fen vegetation outside the former mown areas from 2004 onwards. On Middle Fen mowing of dense, mature stands of *C. mariscus* that were left ungrazed by stock, was resumed in 2006.

8 2006 saw a severe drought in late July that left the majority of ponds in the core *D. plantarius* area on Middle Fen completely dry. Its effects were slightly less severe on Little Fen, which may have been buffered by better retention of water from the previous winter's recharge. Ponds dug on Great Fen in 1998 for a potential re-introduction of *D. plantarius*, dried out completely for the second time since closure of the bore-hole, and the for the first time since a new sluice to facilitate water retention on this part of the fen became operational.

9 Continued failure to make any progress towards a sustained and significant recovery of *D. plantarius* at Redgrave and Lopham Fen makes it imperative that effective population monitoring is maintained. The results of more detailed modelling of the long-term census data together with those from two research projects, supported by English Nature at the University of East Anglia, should help both to explain the failure of Redgrave and Lopham Fen population to recover and to inform conservation management decisions during 2007.

Contents

1 Introduction

This report summarises 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) in 2006, the sixteenth year of monitoring and targeted management for *D. plantarius* at this site. Redgrave and Lopham Fen remains one of only three UK sites for this Schedule 5 species. The recovery project was initiated in 1991, under the auspices of English Nature's Species Recovery Programme, to prevent extinction of this population, which had been reduced to very low levels by desiccation of the site by artesian abstraction, compounded by droughts in the 1980s (Smith 2000). The remnant population had become restricted to turf ponds on two separate parts of the NNR. Throughout the 1990s, despite targeted habitat management, monitoring showed not only that there was no significant increase in population size, but also that its range continued to contract. 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 a public water supply borehole adjacent to the fen 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 targets for this site (U.K. Biodiversity Steering Group 1999), 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, seven years after the fen became wet again, the spider population remained both very restricted in its distribution on the fen and precariously small. The 2006 results from a highly standardised annual census are presented and discussed in the context of the previous 15 years' data. This report also describes the results of monthly monitoring of water levels in the census ponds and documents management tasks carried out by the Suffolk Wildlife Trust (SWT), the NNR managers, on the fen vegetation in the areas occupied by *D. plantarius.* The census results are discussed in the context vegetation and water level management and recommendations are made for these in 2007. However, discussion in this report of the reasons for failure of the population to recover, and of means of addressing this, is limited because substantial new analysis and research information will become available in 2007. New models of the long-term census data in relation to water levels and vegetation management, the completion of autecological research being undertaken by Phil Pearson at the University of East Anglia (UEA) and the integration of both of these with genetic research recently completed by Marija Vugdelic (unpublished PhD thesis, UEA Norwich) should provide much greater insight into the *D. plantarius* recovery problem than is currently possible.

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).

2 Methods

2.1 Annual census

The annual census of *D. plantarius* followed the methodology adopted in 1993 and described by Smith (1993, 2000, 2006). 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 2000 and 2001 very high water levels made it impossible to census Little Fen during the summer. 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 and 2006 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 and 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 is derived from casual records and from sedge-cutting management 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, 2005 and 2006.

2.4 Water levels

Routine water level measurements against 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 the measurements are expressed relative to Ordnance Datum.

Ground water levels on the fen have been monitored by the 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) each year. Although this is a coarse measure, it gives a good picture of differences between years over the 30-year recording period.

3 Results

3.1 Distribution

On **Little Fen**, since closure of the artesian borehole in 1999, *D. plantarius* was found predominantly in the southern part of the census area (Fig. 3). This area also held the core of the population during the 1990s when it was irrigated with a piped water supply to maintain summer water levels in the ponds. 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. 2006 saw a limited recolonisation of ponds that were more remote from the core, southern margin of the census area.

The number of ponds on which spiders were recorded varied from year to year but the range of variation since borehole closure was similar to that in the 1990s (Table 2). In 2006 the numbers of core area ponds on which spiders were recorded in July was slightly lower than in recent years but the number of more distant ponds was correspondingly higher.

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). Throughout the 16-year census, spiders were recorded on ponds to the west of this area only in some years. They were not recorded on any of these ponds in 2004 or 2005 but in 2006 they re-appeared right at the western end of their range recorded since 1993.

3.2 Abundance

Since census work began in 1991, the size of the *D. plantarius* sub-populations on both Little and Middle Fens has varied substantially, and in some cases significantly between the years but at no time has there been any evidence of sustained or significant recovery (Table 3, Fig. 5). Numbers in 2006 were very similar to those in the previous two years on both Middle and Little Fen.

Separate analysis of the 16 year data set 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 –166.5 (Wald test for significance of deviation from linear trend: 102.7, $p<0.001$, df=12). Linear-trend and no-time-effects models had AIC values of 5.12 and 23.9 respectively. For Middle Fen this model had an AIC value of –22.0 (Wald test for significance of deviation from linear trend: 156.51, $p<0.001$, df=14). Linear-trend and no-time-effects models had AIC values of 296.2 and 295.0 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-'06: Wald test for difference between fens: 83.4, $p<0.001$, df=13).

3.3 Breeding indicators

On **Little Fen** evidence of breeding in July 2006 suggested that, at this stage in the year, this was the best breeding season for at least five years, both in terms of the numbers of adult females sighted and the numbers of nurseries recorded (Table 3). Sedge cutting operations revealed a further two nurseries, within the core area but immediately south of the track defining the boundary of the census area (Pool 13 from the 1991-1995 census: see Smith 1995). No evidence of breeding was encountered during cutting of fen vegetation outside the core area for *D. plantarius* (Fig. 1).

On **Middle Fen** the July census data suggested that 2006 was a fairly average breeding season. No evidence of breeding was encountered during cutting of the mature sedge in the north-west of the core area (Fig. 2). However, in the area of youngest sedge, last cut in 2003, and studied intensively by Phil Pearson since 2004, breeding numbers were high. Thirty-two adult females (18 nursery webs) were encountered in 2006 compared with 19 (11 webs) in 2005 and eight (and 8 webs) in 2004.

3.4 Water Levels

2006 saw the lowest surface water levels on Middle Fen since closure of the borehole in 1999. Figure 8 suggests that levels were also lower than during the droughts of the 1990s but the latter data underestimate the troughs because dry ponds were excluded from the data set. Figure 9 shows that more ponds dried out in extreme years in the 1990s than in 2006. During the 1990s, however, the ponds in core of the Middle Fen *D. plantarius* population were protected by irrigation and rarely dried out. By contrast, in 2006, in the absence of irrigation, the core pools dried out more rapidly that the formerly unirrigated pools to the west. For the first time since the census began in 1991, most were completely dry in early August. The only ponds in which any water remained in this area were those excavated in 1996 (Fig. 2). The extreme drought was relatively short-lived, with all ponds regaining some water by the third week of August.

The 2006 drought had less impact on the ponds on Little Fen than on Middle Fen. It had less extreme effects than the drought of 2003 both in terms of the depth and duration of the trough in water levels (Fig. 7) and the numbers of pools that dried out completely (Fig. 9), although many ponds were empty or at very low levels. Surface water levels during the preceding winter recovered better on Little than on Middle Fen (Figs. 7 and 8) and may have buffered it against the extremes of the summer drought.

In 2006, and in the dry summers of 2003 and 2005, water quality in many Little Fen ponds appeared to be poor, showing symptoms of strongly reducing conditions. By July, many of the ponds were characterised by spectacular blooms of purple sulphur bacteria over dense mats of rotting *Chara* spp. exposed by the falling water level, together with water with a milky appearance and very strong smell of hydrogen sulphide.

On Great Fen, the ponds dug in 1988 (Smith 1988) dried out completely at the beginning of August although they remained dry for less than a month, in contrast to the 2003 summer when they remained dry for nearly three months (Fig. 10). Water levels in these ponds during the 2005-2006 winter were conspicuously lower than in any of the preceding winters since recording began in 2000.

4 Habitat management

4.1 Rotational mowing of *Cladium mariscus*

The *C. mariscus* cutting rotation initiated in 1998 (Smith 1998) in stands surrounding the ponds that supported the highest density of *D. plantarius* on both Little and Middle Fen (Figs. 1 and 2) was abandoned after 2003. In 2004 the fences around these areas were removed to allow stock to enter (Smith 2005). However, because of failure of the stock to graze much of the wetter fen, the SWT initiated limited cutting of stands deemed to be in most need of management, from 2004 onwards.

In 2006 an area of mixed, tall fen vegatation was cut within the *D. plantarius* range on Little Fen (Fig. 1). All cutting was done in the last two weeks of July or the first week of August and cut material was raked-up and removed from the site using a winch to minimise compaction and damage to *C. mariscus* which, in this area, was confined to the margins of the turf ponds.

On Middle Fen failure of stock to graze dense mature *C. mariscus* (4.2 below) led to the cutting of a block of sedge within the core of the *D. plantarius* range (Fig.2) for the first time since the rotation was abandoned.

4.2 Grazing

In 2006 the grazing management of areas occupied by *D. plantarius* continued to be much more successful on **Middle Fen** than on Little Fen. Grazing on Middle fen was by cattle and on Little Fen by cattle in the summer and Konik ponies in the autumn and winter (full records of stock types, rates and movements are maintained by the SWT).

In the late 1990's, tall *P. australis* became very dominant in the western part of the range of *D. plantarius* on Middle Fen, away from the fenced *C. mariscus* beds (4.1 above). Most of the turf ponds in this area were densely shaded. Cattle grazing from late summer 2001 onwards had a substantial impact on the reed, and shading of the ponds was much reduced. *C. mariscus* stem densities appear to have improved in some areas of Middle Fen, away from the dense stands in the core spider areas, probably as a result both of grazing and elevated ground-water levels (Stone *et al*. 2004).

Within the formerly fenced and cut *C. mariscus* beds in the core *D. plantarius* area on Middle Fen, the stock primarily entered drier areas where species such as Calamogrostis epigeos and *Juncus subnodulosus* were important elements within the *C. mariscus* beds. They only entered the *C. mariscus*-dominated stands that had had been cut most recently (2003: Fig. 2) and were still relatively short and open. Mature, dense stands were left ungrazed.

On **Little Fen,** as in previous years (Smith 2005), stock once again made very few incursions into the areas occupied by *D. plantarius* and had a negligible effect on the vegetation. They appeared to be deterred by the much wetter conditions than on Middle Fen. During the winter they made some incursions along former barrow-ways into the predominantly grassy area that was cut in summer 2006 although they did not venture into the adjacent wet fen.

5 Discussion and Recommendations

In 2006 both of the *D. plantarius* sub-populations on Redgrave and Lopham Fen followed the pattern of recent years, with a very restricted range and low numbers. At no time during the 16 year census had there been any evidence of no evidence of a sustained or significant increase (Smith 2000, Smith 2006). Modelling showed that fluctuations in numbers between years continued to differ significantly between the two sub-populations, suggesting that the factors controlling them are complex. As in many other years, positive signs, including a good start to the breeding season on parts of Middle Fen, and a some evidence that both sub-populations had of re-occupied ponds from which they have been absent in recent years, were matched by negative indicators. The drought of 2006 showed clearly that, despite the substantial improvement in average hydrological conditions on the Fen since closure of the borehole in 1999, the turf ponds on which the spiders rely remain very vulnerable to desiccation. The impact of the summer drought on *D. plantarius* will be described in Phil Pearson's thesis, to be published in 2007.

Although the persistence of *D. plantarius* at Redgrave and Lopham Fen shows that it is robust to intermittent dry summers, the current trend towards a rapidly increasing frequency of hotter and drier summers is of great concern. Two successive summers with complete breeding failure would result in extinction of this species, which has a two-year life cycle. The 2006 drought also illustrated for the first time that the ponds occupied by the core of the population on Middle Fen, and which were irrigated during the 1990s, are now more vulnerable to water loss than the sub-optimal ponds further west. The bulk of the Middle Fen sub-population is therefore at extreme risk from drought.

Urgent attention is clearly needed to the maintenance of summer water supply on the fen. While re-instatement of irrigation is unlikely to be feasible, increasing the depth of turf ponds, a rolling programme of creation of new ponds**,** and continual exploration of the potential of sluices to maximise winter recharge and retard summer losses, are all options that demand serious consideration.

The role of vegetation management in the conservation of *D. plantarius* at Redgrave and Lopham Fen remains difficult to quantify because it has always been undertaken on a 'best-guess' rather than an experimental basis. During 2007, however, analysis of both the long-term census data in relation to the sedge cutting rotation, and of vegetation structure in relation to *D. plantarius* numbers (being undertaken by Phil Pearson), should provide much more robust basis for advise on this aspect of habitat management.

Also largely unexplored to-date, better information on the role of water quality in the conservation of *D. plantarius* should also become available during 2007, as a result of Phil Pearson's autecological study.

The bringing together of new analyses of the long-term data and the results of the PhD studies of the genetics and autecology of this species, 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 led to the inclusion in the 2005 revision of the Species Action Plan targets of the possibility of establishing new foci of population, both within the fen complex and further afield. Ensuring that these plans can fulfil the JNCC and IUCN is an urgent priority for 2007.

While the *D. plantarius* population at Redgrave and Lopham Fen remains so precarious, there is a clear need to continue consistent monitoring of its size and range, and of the water levels in the parts of the fen that it occupies. The regular measurement of water levels in the ponds included in the *D. plantarius* census continues to provide 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 remains essential for evaluating the effectiveness of the new sluice in maintaining sufficiently reliable summer levels to support the proposed future introduction of *D. plantarius*. 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. During 2007 surface water level monitoring will be expanded to include areas between the turf ponds: this will allow quantification of the highly non-linear relationship between water depth in the ponds and the aerial extent of flooding over the fen surface. The latter is likely to influence the dispersal of the spiders and also, in combination with research on their use of inter-pond habitat, provide a better indication of the area of habitat that is potentially available to them.

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Table 1 Census dates for 1994-2006.

Year	July (& Aug.) Census dates	
	Little Fen	Middle Fen
1994	26-29	9-18 (08)
1995	20-25	27-1 (08)
1996	18-21	22-26
1997	24-21	22-26
1998	18-21	21-24
1999	17-19	21-26
2000	-	17-20
2001	-	17-20
2002	14-18	19-21
2003	18-22	23-27
2004	21-27	12-24
2005	21-05 /(08)	18-21
2006	13-17	17-20

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 Smith 2005)

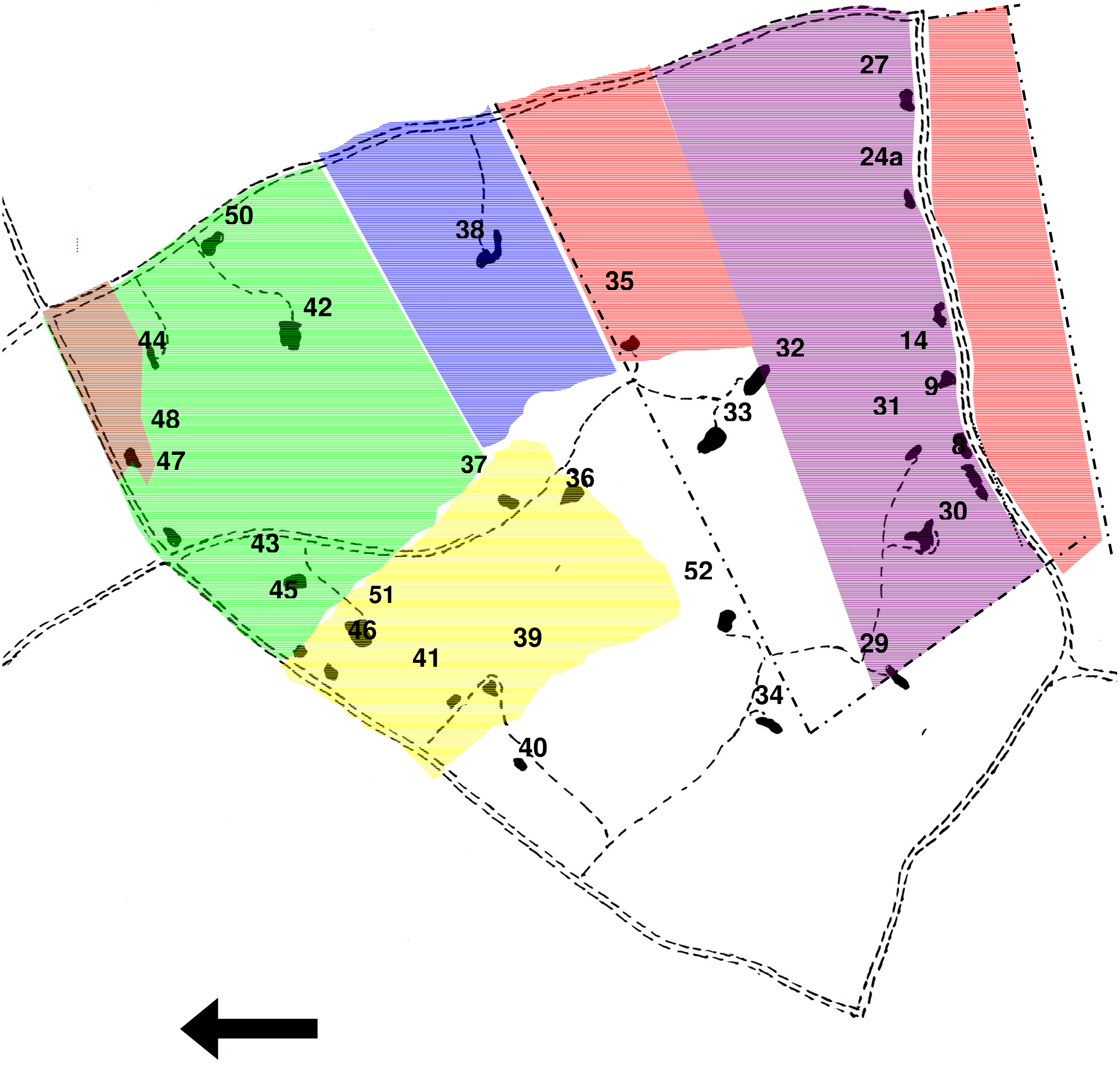
Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Little Fen														
'Irrigated' n=15[1] ponds	8	8	12	9	12	14	11	-	-	12	6	12	11	9
'Unirrigated' n=14[1] Ponds	2	2	4	0	1	6	4	-	-	2	1	2	0	4
Total	**10**	**10**	**12**	**9**	**13**	**20**	**15**	**(11)`**	**-**	**14**	**7**	**15**	**11**	**13**
Middle Fen														
'Irrigated' n=7 ponds	6	7	7	5	6	7	6	7	6	7	7	7	7	7
'Unirrigated' n=23 pond	2	3	0	0	0	0	1	2	0	2	1	0	0	1
Total	**8**	**10**	**7**	**5**	**6**	**7**	**7**	**9**	**6**	**9**	**8**	**7**	**7**	**8**

[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 2006.

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
<u>Little Fen</u>														
% Large	36	21	20	65	30	5	8	-	-	9	28.5	4.4	10	6
% Medium	57	37	66	15	41	50	53	-	-	57	43	67.6	87.5	19
% Small	7	42	15	20	29	45	39	-	-	34	28.5	28.0	2.5	17
Max. spider count	**14**	**19**	**41**	**20**	**66**	**94**	**62**	**-**	**-**	**53**	**7**	**68**	**40**	**42**
Adult females*	0	1	6	6	16	4	4	-	-	4	2	3	4	7
Nursery web count	0	2	0	0	9	0	4	-	-	0	0	1	2	4
<u>Middle Fen</u>														
% Large	29	30	3	17	47	5	15	6	20	6	10	4.8	12.9	3
% Medium	33	48	62	34	53	32	46	49	30	55	48	50	45.2	19
% Small	38	22	35	49	0	63	39	45	50	39	42	45.2	41.9	8
Max.spider count	**21**	**44**	**102**	**41**	**15**	**99**	**52**	**112**	**20**	**72**	**29**	**42**	**31**	**30**
Adult females*	0	8	1	5	6	5	7	7	0	2	2	1	4	3
Nursery web count	1	3	i	0	0	0	7	0	0	0	0	0	3	1

Figure 1 The Little fen census area showing ponds included in the census. Shading shows areas where vegetation was cut and removed in July/August each year: [red] - 2001, [brown] - 2002, [purple] - 2003, [blue] - 2004, [green] - 2005 and 2006 - [yellow]. Broken black line: _._._ shows boundary of area from which stock were excluded until 2004.



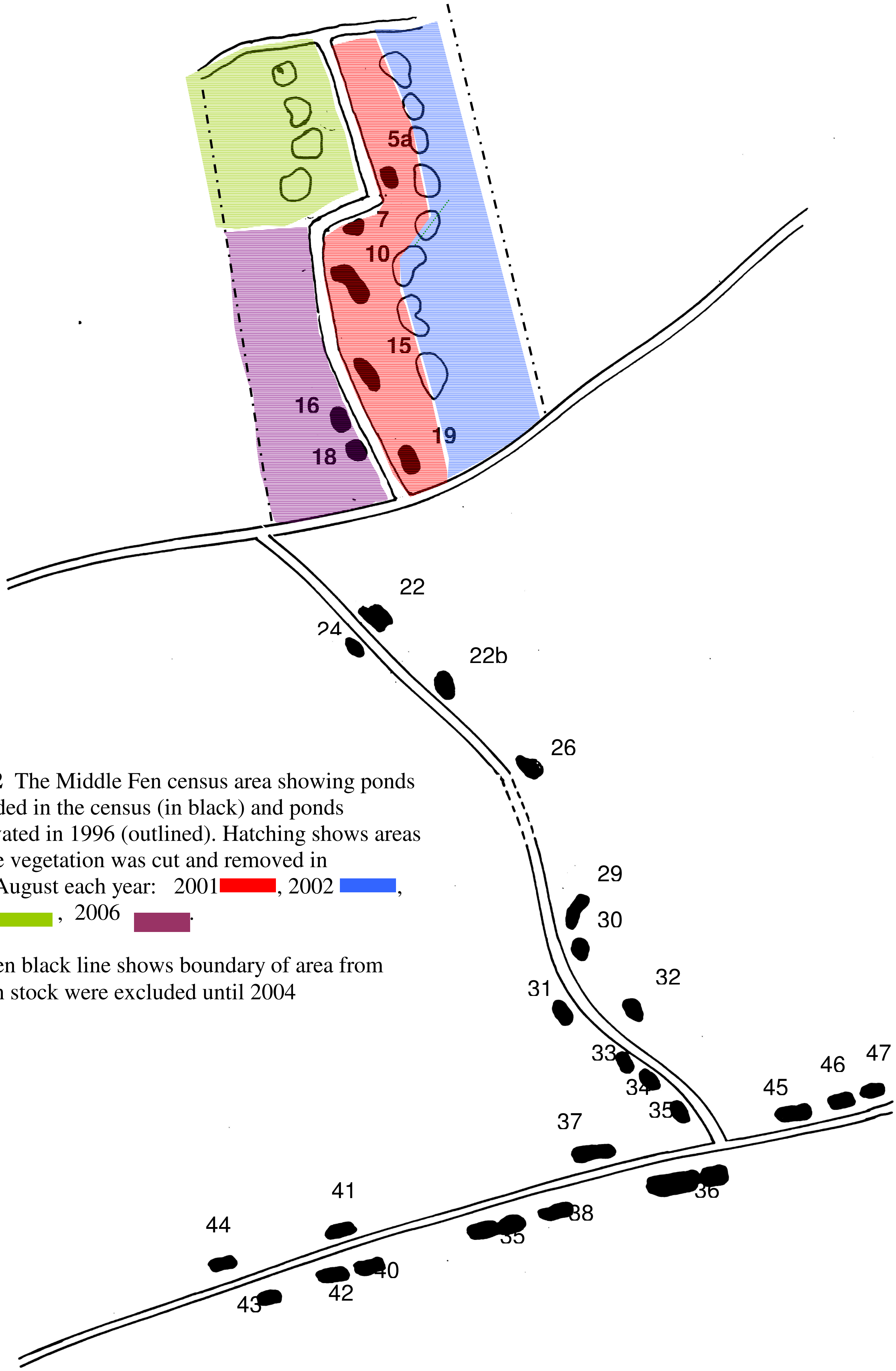
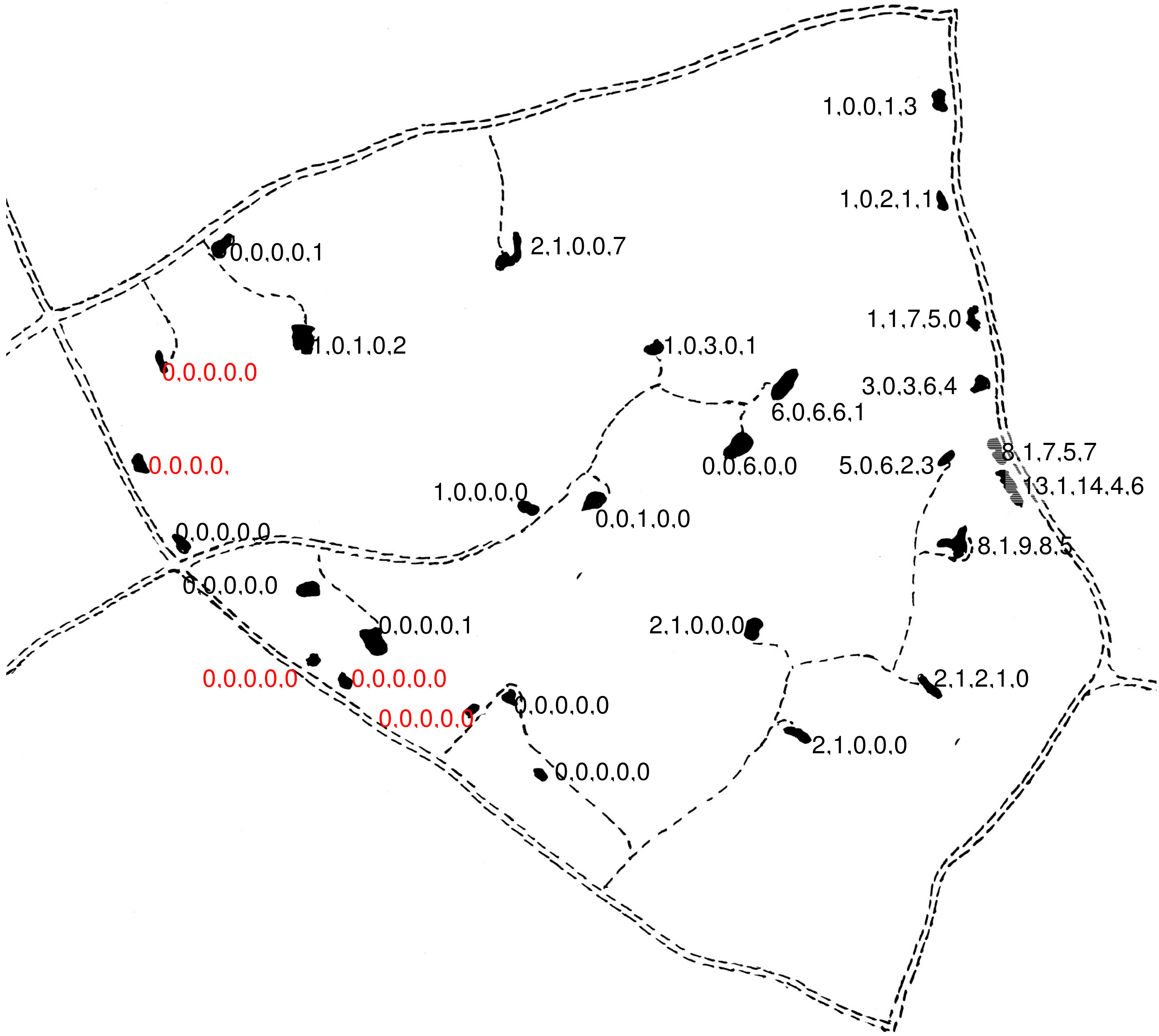


Fig. 2 The Middle Fen census area showing ponds included in the census (in black) and ponds excavated in 1996 (outlined). Hatching shows areas where vegetation was cut and removed in July/August each year: 2001, 2002, 2003, 2006.

Broken black line shows boundary of area from which stock were excluded until 2004

Fig. 3 Numbers of spiders recorded at each of the Little Fen census ponds between 2002 and 2006 (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 16 years.



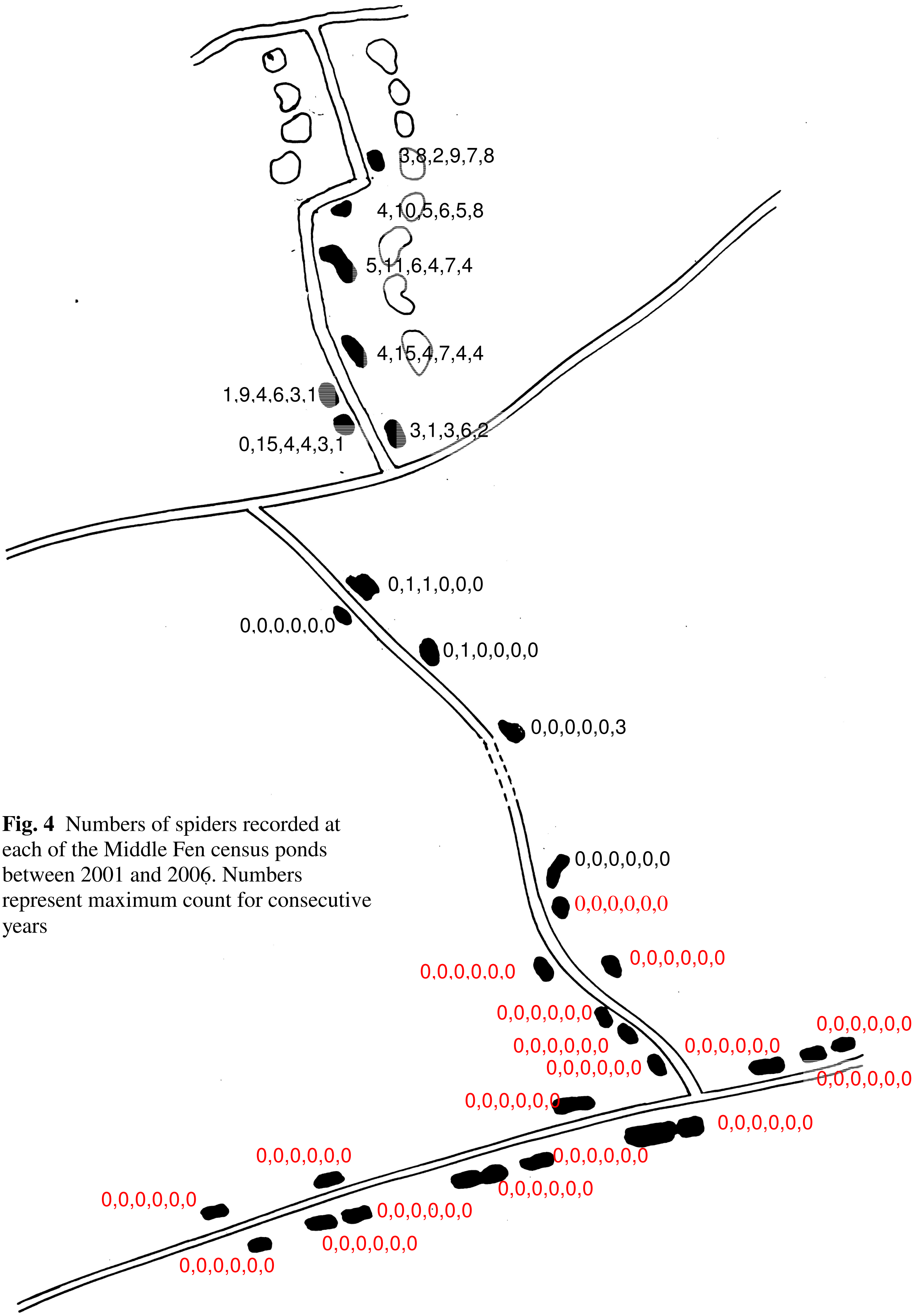


Fig. 4 Numbers of spiders recorded at each of the Middle Fen census ponds between 2001 and 2006. Numbers represent maximum count for consecutive years

Fig. 5 Annual population indices for *D. plantarius* on Middle and Little Fens in July 1991-2006, generated by a log-linear Poisson regression model and plotted on a linear scale. See text for missing data on Little Fen. 2SEs shown by positive vertical bars for Middle Fen and negative bars for Little Fen.

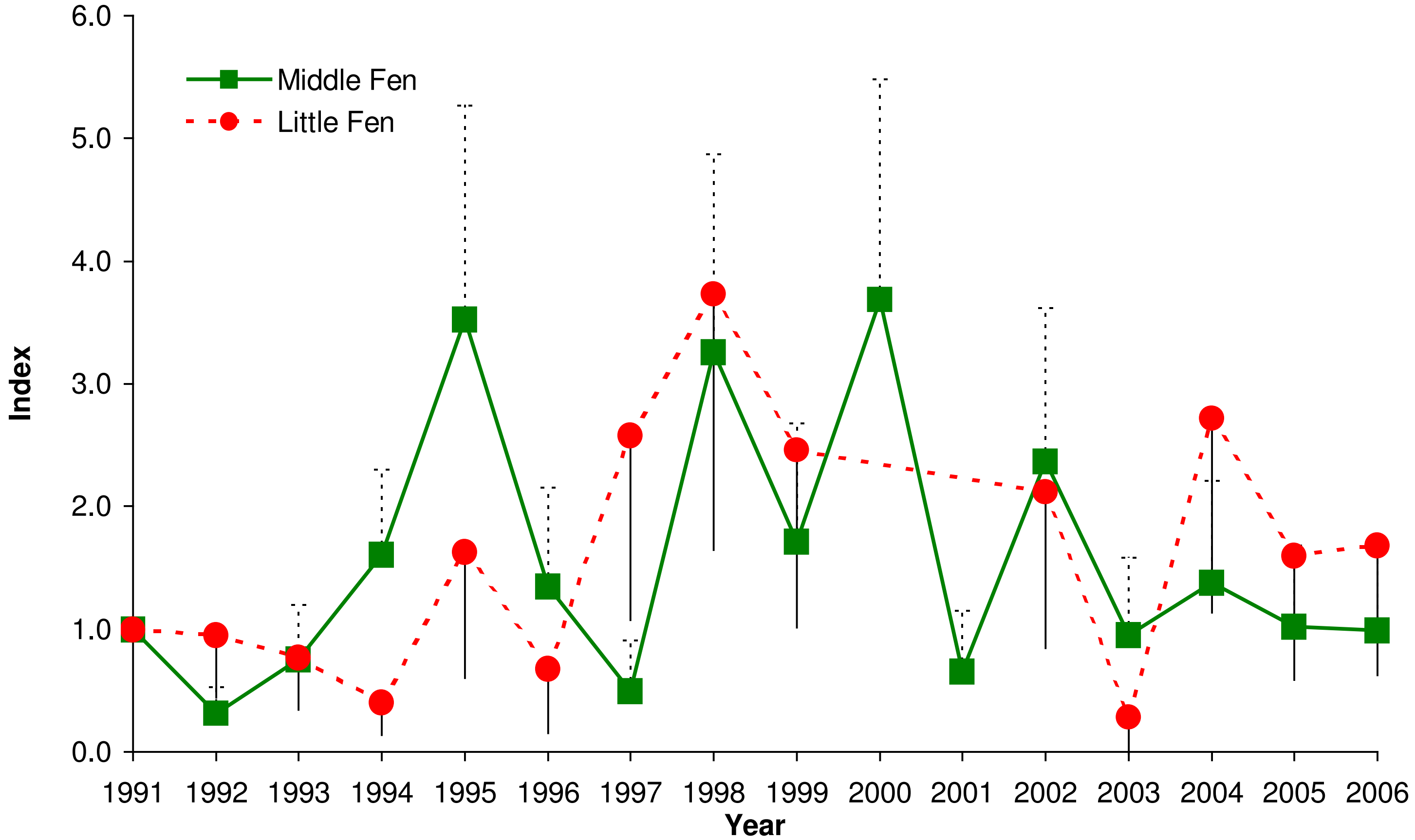


Fig. 6 Mean winter maximum and summer minimum water levels in piezometers on Redgrave and Lopham Fen NNR

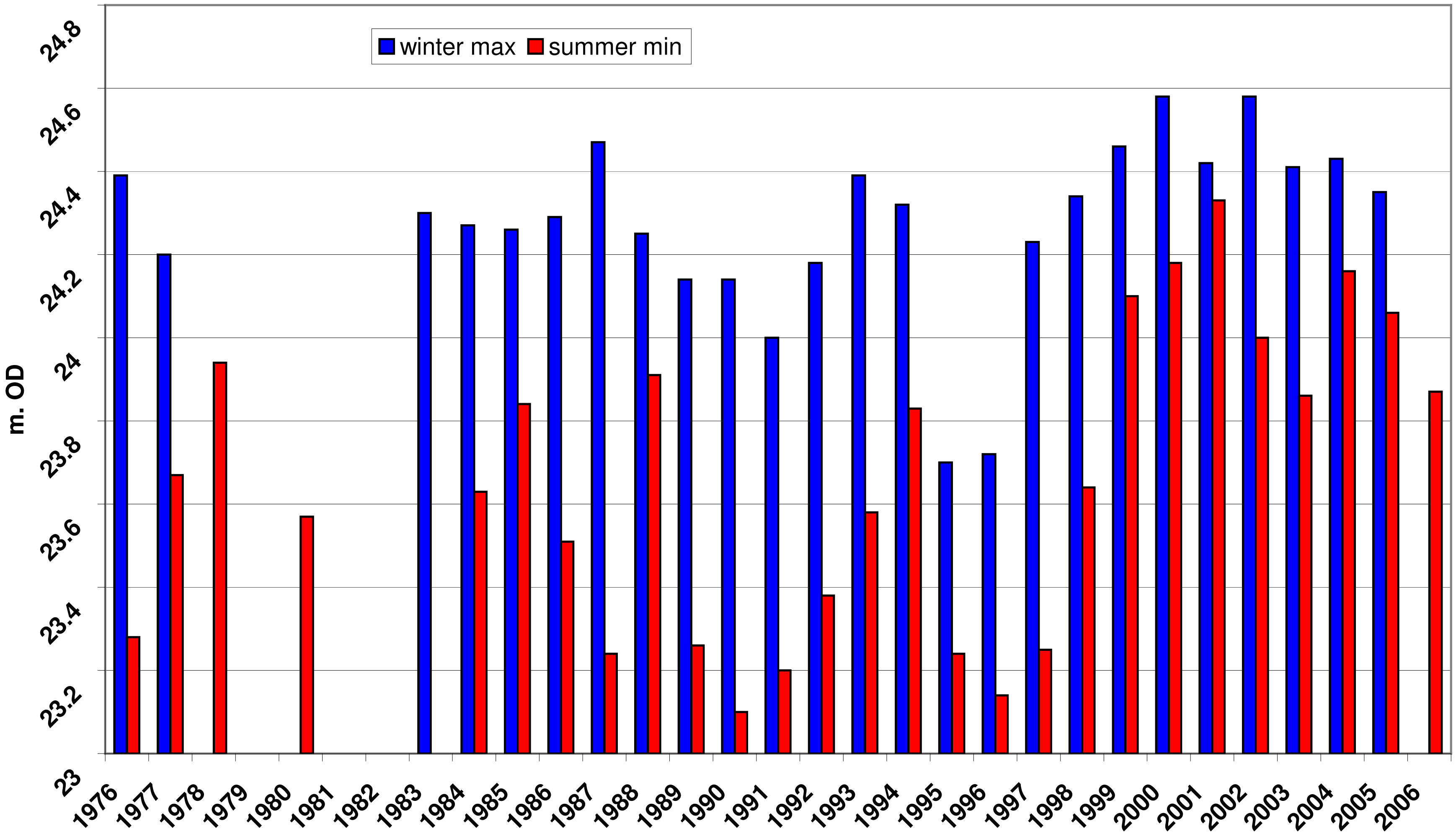


Fig. 7 Water levels in Little Fen ponds 1992-2006. Horizontal line represents the April 1992 datum. Blue and red lines represent mean levels in irrigated and unirrigated ponds respectively : summer irrigation stopped in 1999 (see text).

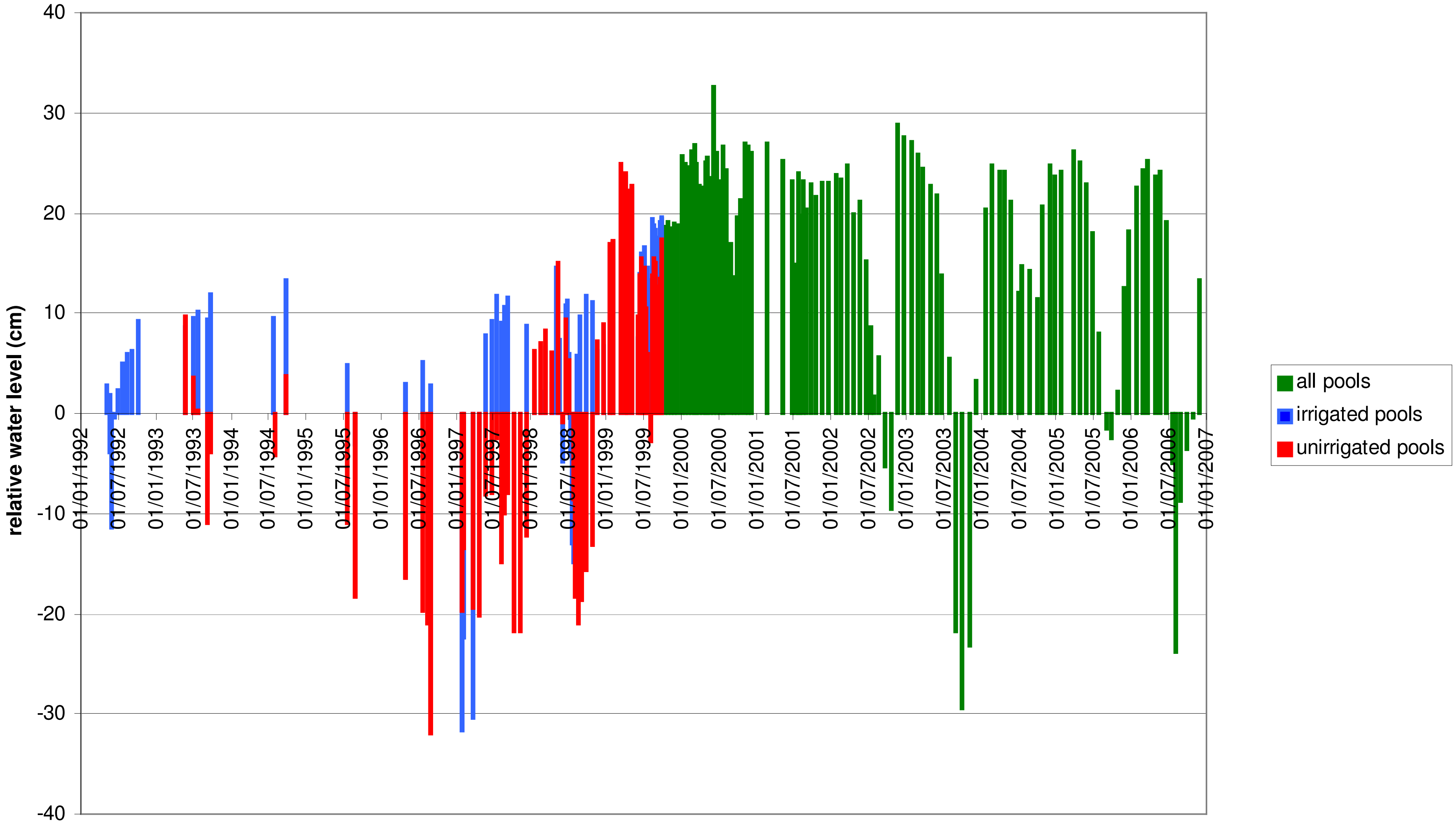


Fig. 8 Water levels in Middle Fen ponds 1992-2006. Horizontal line represents the April 1992 datum. Blue and red lines represent mean levels in irrigated and unirrigated ponds respectively : summer irrigation stopped in 1999 but differences between the two sets of pools are shown again for 2006 (see text).

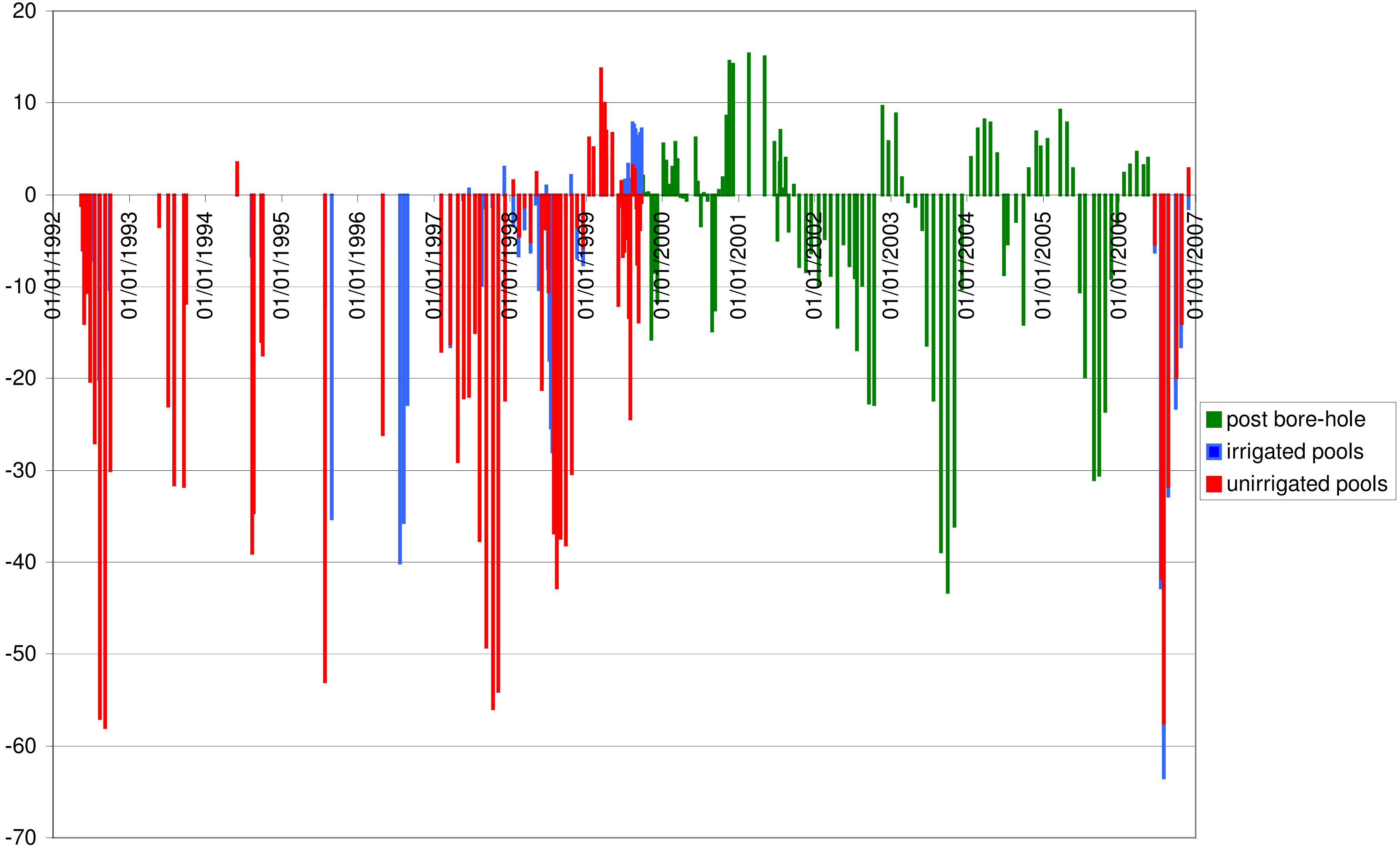


Fig. 9 Percentage of ponds that were either partially* or completely dry (*see text)

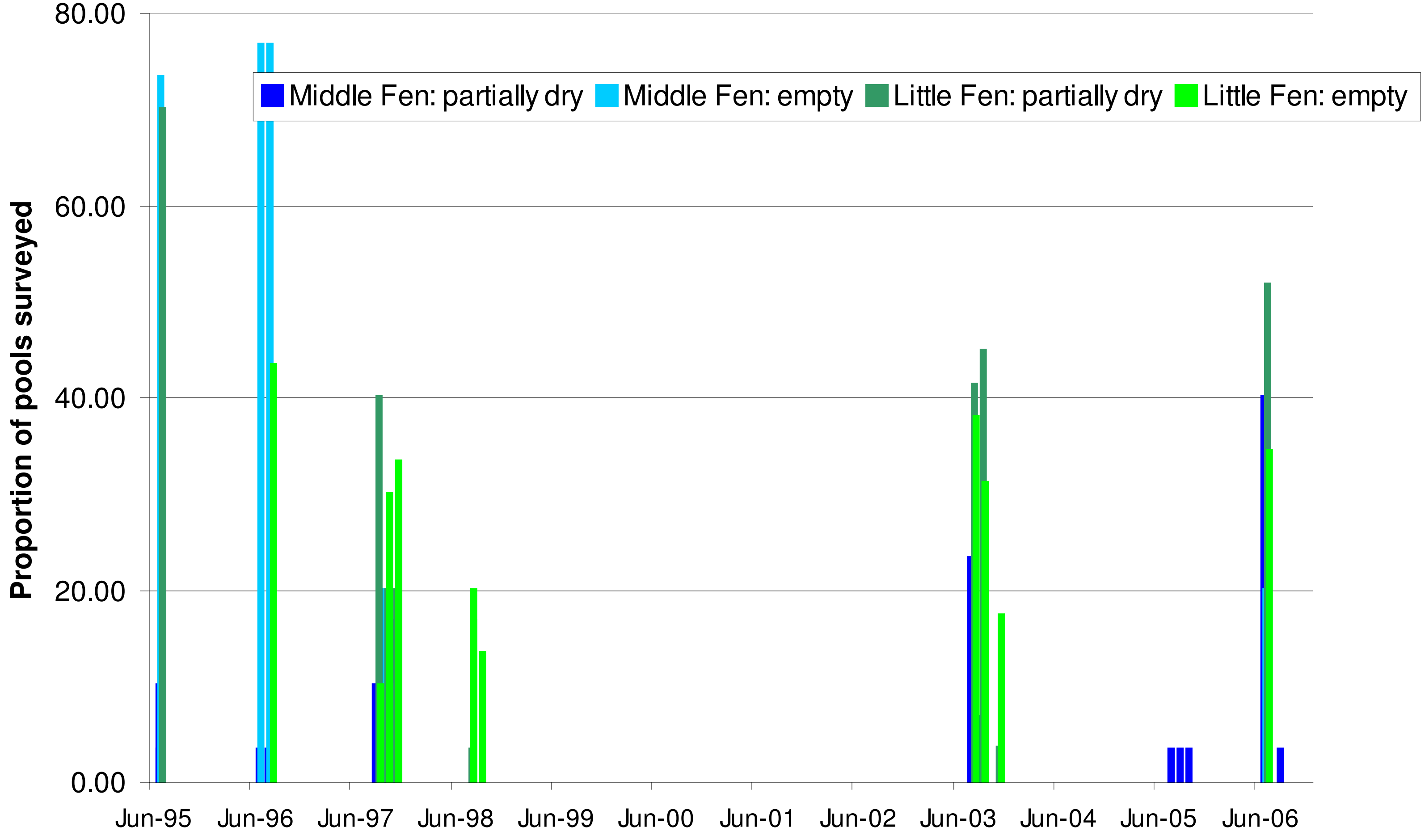


Fig. 10 Water levels in ponds excavated on Great Fen in 1998. Broken line denotes level below which most ponds are dry. Red indicated dates on which all ponds were completely dry.