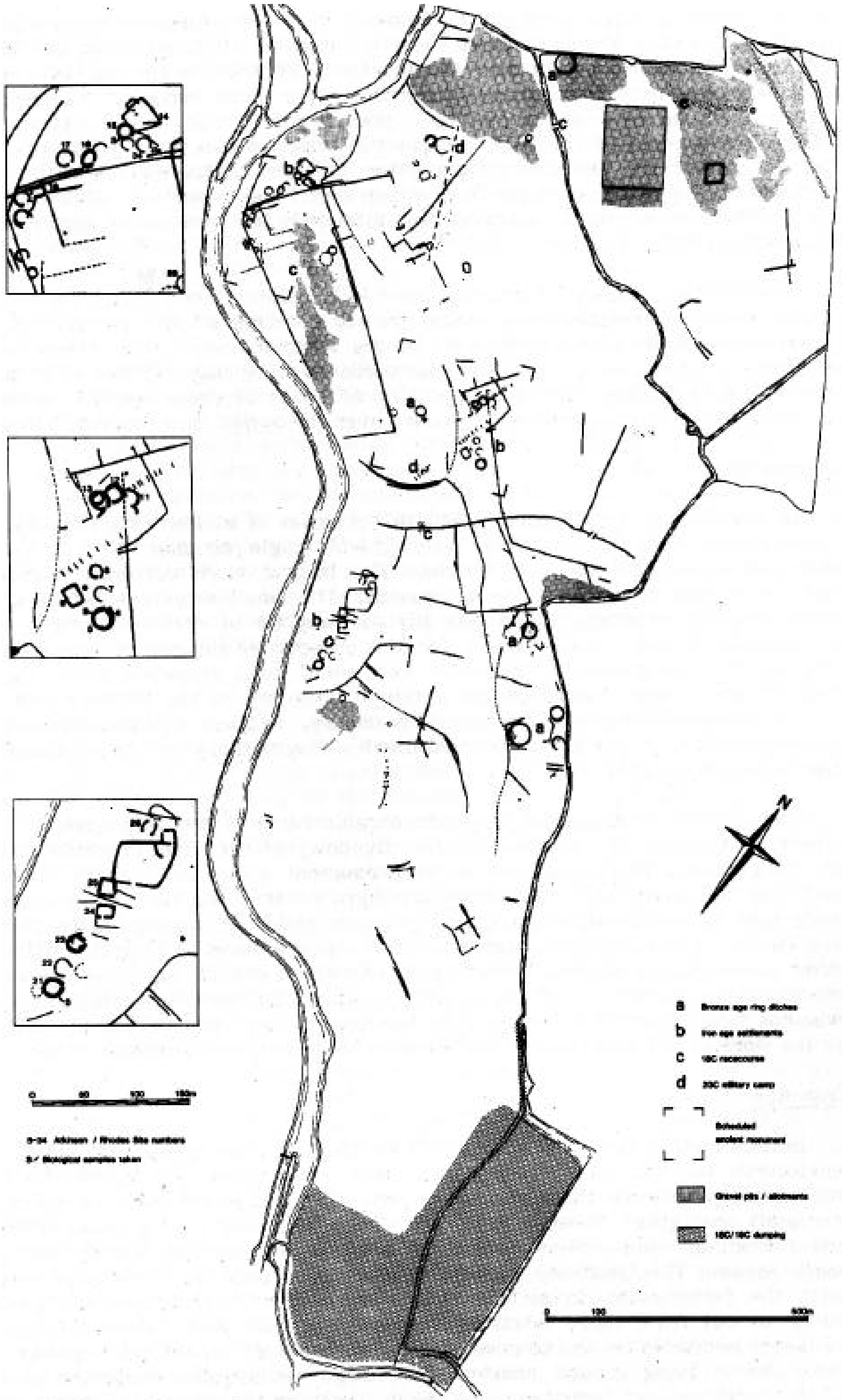
4 Vegetation dynamics on Port Meadow

4.1 History of Port Meadow

Port Meadow (132 ha) and Wolvercote Common (39 ha) (the Meadow) are adjacent commons lying on the River Thames flood-plain within Oxford City boundary **(Map 2.5)**. They have been grazed since at least the Bronze Age and have never been ploughed. Shiplake Ditch forms the boundary between Port Meadow and Wolvercote Common. The common land and Hook Meadow form part of a larger Site of Special Scientific Interest first notified in 1952 and re-notified under the Wildlife and Countryside Act 1981. The Nature Conservancy Council's citation (1983) states that the history of ecological interest in the Meadow was taken into account so the SSSI should be extended to the whole of Port Meadow with Wolvercote Common, with the exception of the Wolvercote allotment gardens. The Meadow is also important as a gene bank of species, particularly well adapted to heavy grazing, which have already been fundamental in the development of agricultural leys (McDonald forthcoming). In 2004, Port Meadow was confirmed as a Special Area of Conservation under European Union legislation because of the presence of *Apium repens*. The whole was registered as a Scheduled Ancient Monument in 1993 because there are the remains of six Bronze Age burials and three Iron Age settlement sites and field systems on the commons **(Map 4.1)**.

Both commons are owned or held in Trust by Oxford City Council and Oxfordshire County Council under Section 9 of the Commons Registration Act 1965. Under the same Act, the Freemen of Oxford and the Wolvercote Commoners registered grazing rights for 1,365 horses, 1,890 cattle, 6 donkeys, 48 ducks and 1,192 geese. Clearly these will have to be regulated to prevent over-grazing. In the 20th century, such stinting on Port Meadow could only be ordered with the Freemen's unanimous agreement at a meeting of Common Hall. The Freemen have no authority over Wolvercote Common and neither Oxfordshire County Council nor Oxford City Council has the power to impose a stint on Wolvercote Common under the 1965 Act because this Act does not cover the management of commons. The 1965 Act also allows the Wolvercote Commoners to graze their horses on the common all year round. The effect of this has been that the number of horses grazing the Meadow has risen from c.50 in 1945 to 120 in the summer of 1986 and 61 in 2004 (Anthony Roberts pers. com.) **(Figure 4.1)**.

Although cattle numbers have fluctuated considerably over the years, there has been a reduction overall from 425 in 1943 to *c.*248 in 1991 and 179 in 2004. In 2001 DEFRA banned the movement of animals for fear of the spread of foot and mouth disease. Some horse owners who found alternative grazing have not returned. Increased numbers from 2003 are thought to be due to letting rights to dealers.



Map 4.1. Port Meadow and Wolvercote Common showing the archaeology so far recorded. From Lambrick 1984. In McDonald forthcoming.

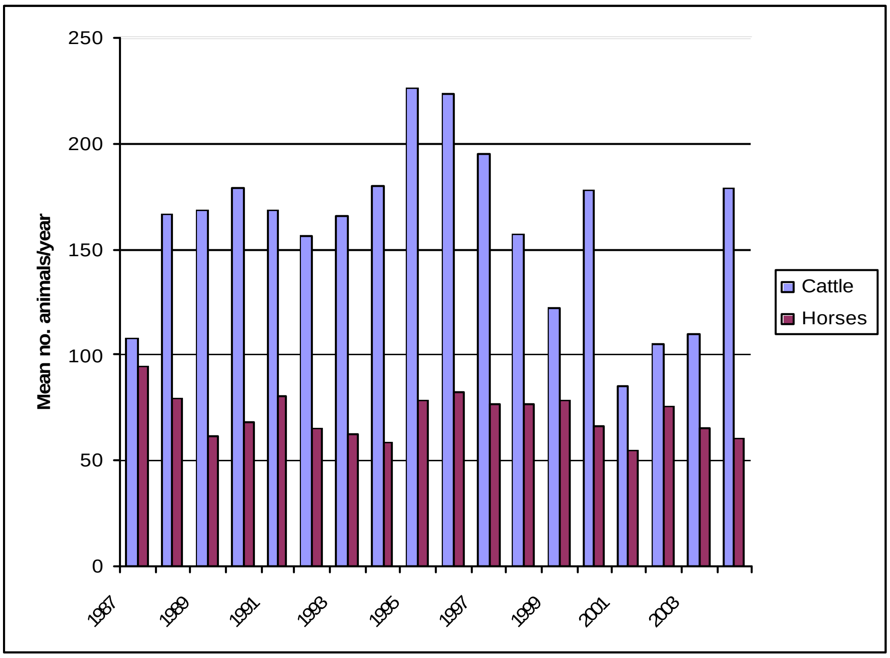


Figure 4.1. The mean number of grazing animals on Port Meadow and Wolvercote Common between 1987 and 2005. Note the reduction in numbers in 2001 due to a ban on moving animals between fields because of foot and mouth disease. One cow over-wintered in 1995/6 and was given a companion from February to April 1996.

Ministry of Agriculture, Fisheries and Food guidelines for good grazing suggest a rate of 1 horse = 2 cows = 10 geese. An acceptable stint would be in the order of 2.5 grazing units/ha. amounting to 405 over the 162 ha. available in summer and none in winter. These numbers indicate that normally the pasture is not over-grazed in summer but is often over-grazed in winter. In winter, the horses eat the grass so short that farmers wishing to exercise their rights to graze cattle often cannot do so until late May or early in June when the grass has grown sufficiently long. Horse owners fear that if winter grazing was reduced or banned the rich spring grassland, which suits cattle, will make their horses lame with laminitis. The Wolvercote Commoners graze their horses all year round because the Commons Register allows them to do so. Individual rights which are underused in summer at present are supplemented by those let to dealers (contrary to traditional practice).

4.2 Ecological history of the meadow

The ecological history of the Meadow has been recorded for some 80 years. The vegetation on Port Meadow was described by Baker of the Oxford Botany School, (1937) from observations made in 1923. He drew attention to the Thames which passes through the oolitic limestone of the Cotswolds and the limestone gravel river terraces beside the Thames absorbing calcium carbonate into the water. This gives the water a pH of 8.0. By the time rainwater (pH 5.6) has been leached through the meadow soils the grassland tends to have a pH of 6 or 7 and so comes into Tansley's category for neutral grassland. In the area of the North and South populations Baker noted a short *Festuca pratensis, Trifolium repens* sward with *Myosotis laxa, Poa trivialis, Agrostis stolonifera, Ranunculus repens* and *Veronica beccabunga.* These species were unusual for their miniature form, each about one inch high or prostrate. This habit allowed them to flower despite the closeness of the grazing. If the grazing pressure were to be removed Baker predicted that a marsh community would develop in seral succession to the *Glyceria maxima* community growing near the river at Medley. A.H. Church (1922/3) (also of the University of Oxford Botany School) photographed habitats in and around Oxford including the mud bank north of Medley Boat Station which became eight acres of pasture after the river was dredged and confined to a deeper channel in 1931.

The Nature Conservancy produced a Conservation Management Plan for Port Meadow in 1952 which summarised the published ecological history of the area and later included vegetation maps based on botanical surveys carried out in 1971 and earlier years which are no longer available for study. The surveys distinguished three types of grassland, namely, Lower, (where *Apium repens* grows) Mid and Higher Level grassland, together with the first record of an area of dense creeping thistle. Various ditches and part of the river bank were described separately, as being of special botanical interest but no species lists survive.

J.L. Harper and G.R. Sagar of the University of Oxford Department of Agriculture studied the ecology of meadow buttercup, bulbous buttercup and creeping buttercup on Port Meadow in the early 1950s (Harper & Sagar 1953). These species are closely related, yet they co-exist successfully in the same community. Harper and Sagar found that their distribution was non-random not only as a result of the clumping of seedlings round the parent plants, but also because each species had different moisture tolerances. Their Ellenberg's values are F6, F4 and F7 respectively (Hill and others 1999).

A.D. Bradshaw, also of the University of Oxford Department of Agriculture, studied the natural hybridisation of common bent-grass with creeping bent-grass on Port Meadow (Bradshaw 1958). He found that, as often happens, hybrids were vigorous but generally sterile. They were abundant in the boundary zone between the Dry and Moist Pasture, almost to the exclusion of the parent species. The dominance of the hybrid in that area reflects not only the vegetative spread of one hybrid plant, but also the repeated formation of different hybrids which were F1, F2 or even back-cross generations. Bradshaw, in keeping with other ecologists of the day, thought that ancient grassland was a closed community, which kept its own balance without space for new species. He was therefore surprised by the high frequency of these hybrids on Port Meadow. Bradshaw also studied *Festulolium*. This hybrid grass is adapted to moderately grazed pastures in contrast to its parents, *Festuca pratensis,* which grows where grazing is very light and *Lolium perenne,* which can tolerate very heavy grazing. A.D. Bradshaw found the hybrid in quantity on Port Meadow in the mid-1950s but it was scarce in 1981.

Port Meadow and Wolvercote Common together form the largest area of unimproved flood-plain pasture in lowland England (Allen 1978). Its plant communities lie within the European phytosociological hierarchy (later described by Rodwell (1992)) but of course it differs in detail because of its geographical location and Atlantic climate The Marsh, as its name implies, is the wettest part of Port Meadow. The top-soil is mostly well structured and freely draining but in the lowest area it lies over a layer of alluvium *c*.1 m. thick. Even here the ground-water usually flows in a south-south-westerly direction keeping the soil moist except in summer (McDonald 1988; forthcoming).

4.3 Physical features

Port Meadow gives the appearance of being flat but in reality there is a fall in ground-level from 58.1 m OD in the north to 56.9 m in the south near Aristotle Lane. The ground surface comprises variable thicknesses of riverine alluvium and gravel of pH 5.2 to 7.6. The gravel aquifer is largely unconfined and allows a significant movement of base-rich groundwater up through the alluvial layer which counteracts any acidification effect from excess rainfall. Annual flooding for at least 2,000 years has been a natural feature in the lower areas because of their physiographic position, although at different times the details of the flooding regime have been greatly altered by human intervention. Currently, there are few areas on the Meadow not reached by flood-water except in the south where the land rises abruptly onto an area raised approximately 1m by the dumping of Oxford City rubbish between 1888 and the early 1920s. Although Gowing and Youngs (2005) consider that the nutrients brought in by annual flooding are more important to the vegetation than nutrients from the adjacent landfill sites, the high conductivity values in the groundwater of 190 µs at Stand 37 and of 290 µs at Stand 40 measured in 1981 (McDonald forthcoming) should be taken into account.

4.4 Hydrology and rainfall

There is an important relationship between the soil-water regime and the behaviour of vegetation types, especially those including *Apium repens*, growing in the lowest part of Port Meadow. In 1999, the Environment Agency produced a Water Table Management Plan as part of a drive to protect and enhance all wetland SSSIs in the UK and to review the effects of extraction consents on Habitat Directives sites. The Agency then employed David Gowing of the Open University and Cranfield University to investigate the hydroecology of Port Meadow.

A series of five pairs of dip-wells and peizometers were placed into Port Meadow and a stilling well in the Thames beside Rainbow Bridge. A vegetation survey in six blocks associated with the dip-wells to define the plant communities was undertaken by the ANHSO Rare Plants Group on August 23-24, 2003, in collaboration with the Botanical Society of the British Isles. The analysis is given in Gowing and Youngs 2005.

4.4.1 Effects of rainfall, sunshine and flooding

The flooding situation in 1981, the previous occasion when there is comparable botanical data, is shown in **Figure 4.2.** Water lay over the north and south population areas for 28 days. **Figure 4.2** shows that most of the rain fell in March before the growing season for most species in the area, but December 1980, and May and September 1981 were also wet but not apparently sufficient to cause summer fouling (see below).

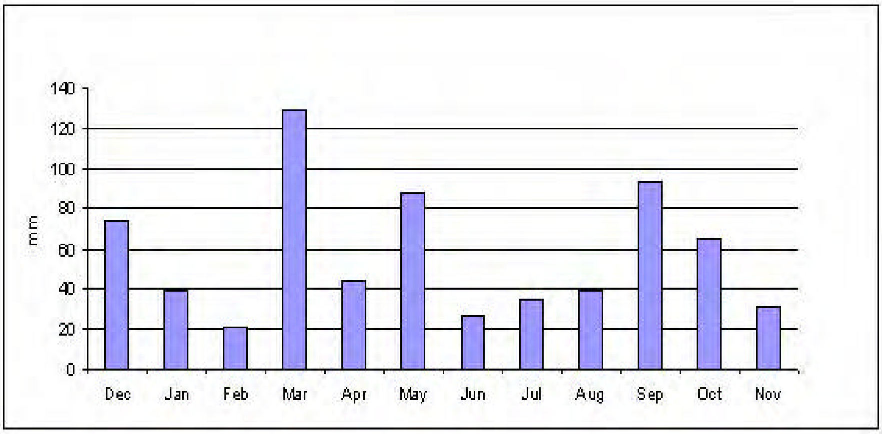


Figure 4.2. Total monthly rainfall in 1981 at the Radcliffe Meteorological Station, Oxford. Note a wet March and May giving good growing conditions and a dry summer – June to August.

Monthly rainfall figures over the period of the current study, 1994 –2004, shown in **Figure 4.3,** help in interpreting flood-levels as expressed by measurements taken daily at Godstow Lock tail-water and the appearance of a raised water-table in the region of the North and South populations. Following a wet December in 1994, in 1995 flooding took place in January, February and December. The summers of 1994 – 1996 were dry and hot **(Figures 4.3, 4.4)** so the rain in September and November 1995 was needed to fill the aquifers**.** In 1997 May and July were the warmest months, thereafter the summer weather was cooler. In 1997 there may have been low-floods in February, June and August whilst 1998 had low floods in April, and the high rainfall in June caused water to lie on the Meadow and subsequent plant mortality.

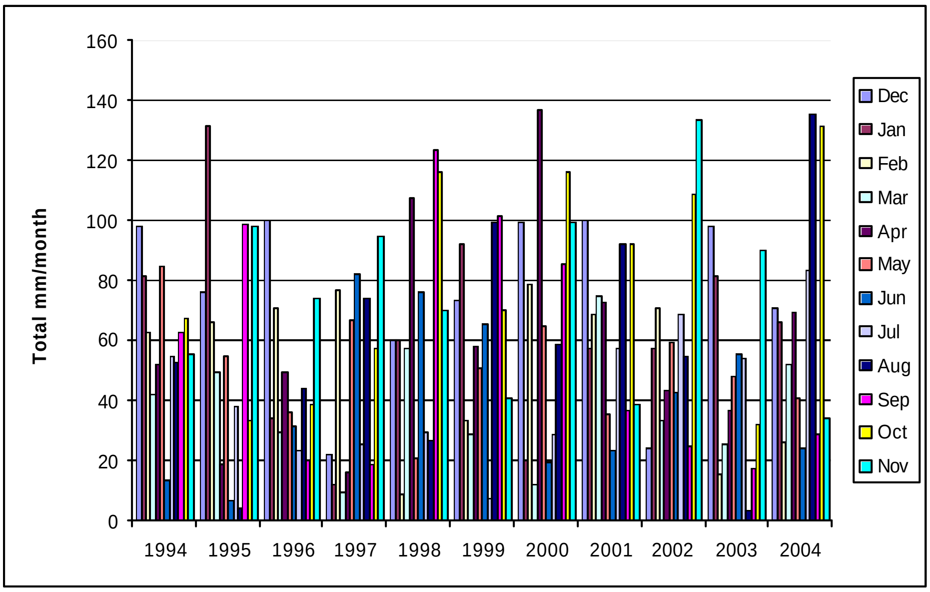


Figure 4.3. The monthly rainfall at the Radcliffe Meteorological Station, Oxford, 1994 to 2004. Note that December values are from the previous year.

The rain was again significant in April 2000, it filled the aquifers so that rain in May and early June unusually produced flooding. Although 2002 was wet in October, November and December the rains had followed a dry period in which the aquifers were depleted. A dry spring in 2003, followed by almost no rain in August provided unusually dry conditions at the south end of Port Meadow during the extended survey that year. Figure 4.4 shows the number of hours of bright sunshine over a ten year period in which the summers in the early 1990s were sunnier than latterly.

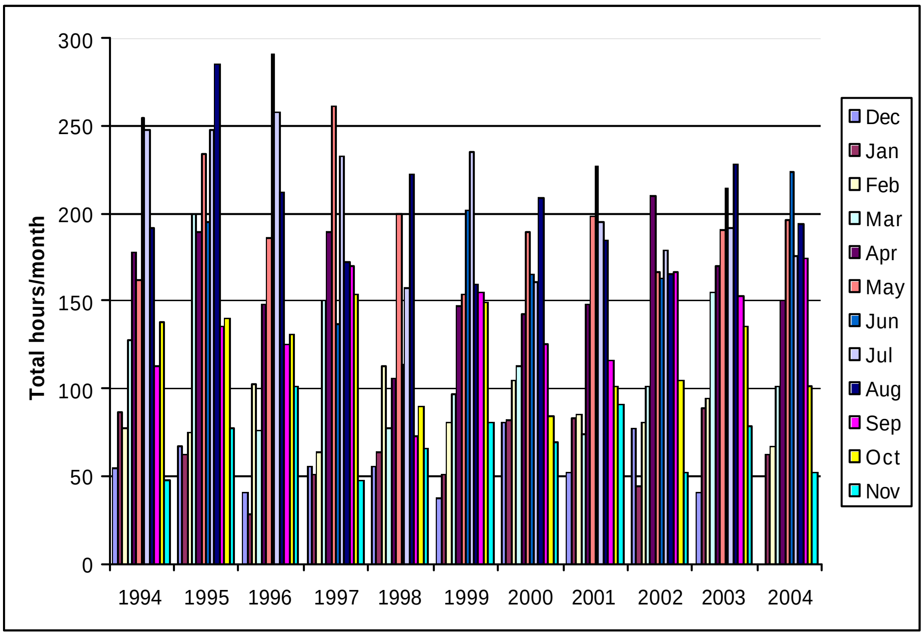


Figure 4.4. The number of hours of bright sunshine at the Radcliffe Meteorological Station, Oxford, from 1995 to 2004. Note that December values are from the previous year.

Flooding increased between1896 and 1910 by up to ten days p.a. **(Figure 4.5).** From 1911 to 1930 high-flood levels were even more frequent. In 1931 Medley Weir was removed and the river dredged to form a single navigable channel and flooding was immediately reduced. During the early 1940s there were fewer than ten days of low-floods. This puts the increasing wetness of Port Meadow at the beginning of the 21st century into perspective.

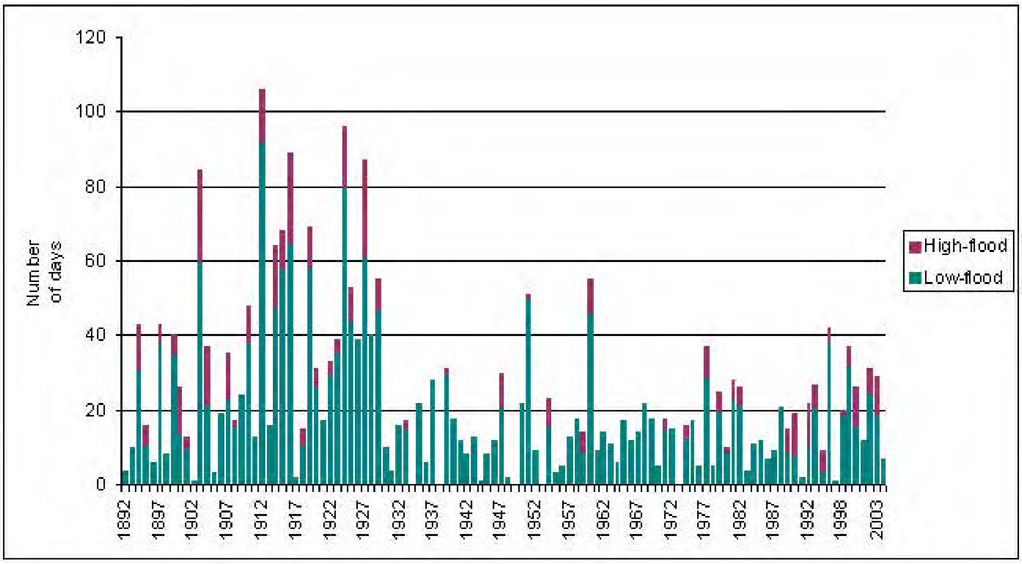


Figure 4.5. The number of days the river Thames reached low- (above 57.43 m) and high-flood (above 57.73 m) levels at Godstow Lock tail-water from 1892 to 2003. (Environment Agency unpublished data.)

There is a correlation between the height of the water at Godstow Lock tail-water and the level of the water at Rainbow Bridge but the level of the water-table below the *Apium repens* populations is more a function of the groundwater flowing into the site from the North East (Gowing and Youngs, 2005). These populations can be under water before the Thames reaches low-flood level. One method of analysing the vegetation in the study area is to compare the number of flood-days on Port Meadow per annum year on year **(Figure 4.6.)**.

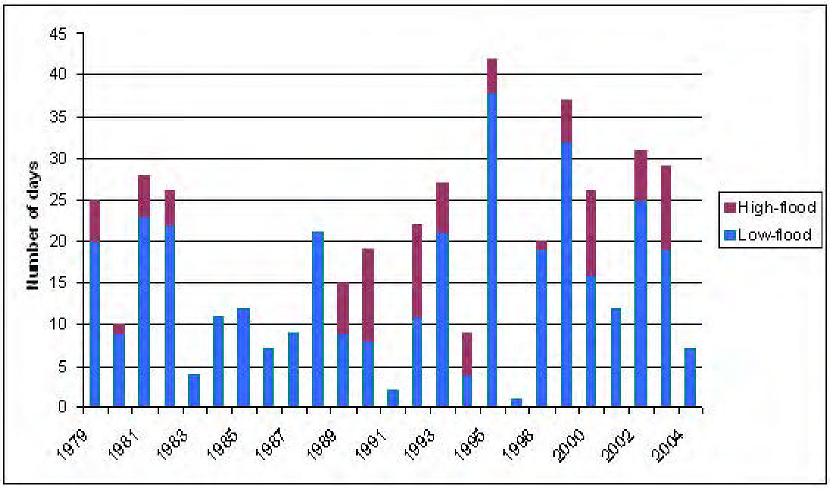


Figure 4.6. The number of days the River Thames reached low (above 57.43 m) and high-flood (above 57.73m) levels at Godstow Lock tail-water during the study period, 1979 – 2003. Note: there is no data for 1997. (Environment Agency unpublished data.)

4.4.2 Summer fouling

Generally extended flooding in May or June, when the ambient temperature is warm and the soil microbes are active, causes depletion of oxygen and the conversion of sulphates to toxic sulphides. This condition, known as 'summer fouling', is caused by soil anoxia and leads to plant mortality. Such events in the Dutch Rhine valley enable recolonisation of vegetation on lower flood-plain habitats (van Eck and others 2004). **Photo 4.1** shows the lower end of Port Meadow on 14 May 2000 when it is likely that the aquifer had been filled by >35 mm rain which fell in April 2000 thus there was nowhere for the May rainfall to go **(Figure 4.3)**. The Environment Agency has addressed this problem (Gowing & Youngs 2005). They gave a dominant role to ground-water in relation to the North and South population areas. When rain falls in the River Thames catchment some enters the aquifer under Port Meadow where it flows through the gravels from a north-easterly direction. Gowing and Youngs (2005) found no close link between the level of the River Thames adjacent to Port Meadow and the water-table depth below the *Apium repens* sites. The water-table at the south end of Port Meadow is raised and lowered by the amount of water flowing through the aquifer. Andy Dixon of Groundwater Monitoring and Drilling Ltd, who has been working for the Environment Agency on this Project, also agrees (pers. com.) that it is rainfall which re-charges the river gravels and determines the extent of flooding.

Photo 4.1. Looking across the flooded South end of Port Meadow towards Medley Boat Station on 14 May 2000. Photo. A.W. McDonald.

4.5 Vegetation analysis on Port Meadow

4.5.1 The 1981 study

In 1981, McDonald collected frequency data from 25 contiguous quadrats in 5m x 5m stands, with the stands 200 m apart, on a grid over the whole of Port Meadow and Wolvercote Common (McDonald forthcoming). The results of a two-way detrended-correspondence analysis (TWINSPAN) and Principal Components Analysis enabled a description of the vegetation including Stands 37 and 40 which lie in the area associated with *Apium repens.* The results are shown in Table 4.1. This community in the wettest part of Port Meadow (Port Meadow Marsh) was named as a new *Mentha aquatica* variant within the Association *Rumici-Alopecuretum geniculati.* The constant species of the *Mentha aquatica* variant are: *Glyceria fluitans, Mentha aquatica, Oenanthe fistulosa, Myosotis scorpioides* and *Eleocharis palustris* with *Galium palustre, Stellaria palustris, Ranunculus flammula* and *Veronica scutellata* frequent. This *Rumici-Alopecuretum geniculati* association is named Mesotrophic Grassland 13 Agrostis stolonifera-Alopecurus geniculatus flood-plain grassland in Rodwell 1992 p. 103. It has two constant species: *Agrostis stolonifera* and *Alopecurus geniculatus* and no frequent ones. Listed occasional species are: *Ranunculus repens, Holcus lanatus, Poa trivialis, Juncus effusus* and *Glyceria fluitans.*

More recent analysis of the 1981 data suggests that along the edge of Castle Mill Stream there was Open Vegetation 30 *Bidens tripartita-Polygonum amphibium* river's edge community; in trampled areas was Open Vegetation 21 *Poa annua-Plantago major* trampled gate-way community and in the North and South population areas (designated the Marsh by McDonald forthcoming) was Mesotrophic Grassland 13 *Agrostis stolonifera-Alopecurus geniculatus* (Rodwell 1992; 2000).

Using Ellenberg's F values for moisture, analysis of McDonald's 1981 data showed that water-mint (Ellenberg's moisture value F8) and fifteen other species in this community scored F9 or F10 for moisture and suggested that the Port Meadow Marsh community in 1981 was on the wetter side of MG13 with its characteristic species *Agrostis stolonifera* (value F6) and *Alopecurus geniculatus* (value F8). MG13 is often a linear community on trampled soils round ponds and along stream edges. Seven species in the Marsh, scoring F5 -

F7, are annuals which grow on soils which are usually damp but not wet. They do not become established in wetter years.

4.5.2 Methods of the 1996 – 2004 study

In 1995 two areas were selected as the main localities of *Apium repens*; they are known as the North population (30 m x 12 m) and South population (30 m x 20 m) areas (see section 5.2). Transponders had been buried at three corners in both rectangular areas so that they could be re-found using a retriever. English Nature recommended that species be recorded in randomly located nested 1 m^2 quadrats in the North population and along a transect at 2 m intervals in the South population area **(Map 4.1)** (see section 4.6). All vascular plant species were scored in each nested quadrat from 1996 – 2004, except for 1997. The nested quadrats were 1 m^2 frames with strings to define squares at 10 x 10 cm (scored as 1), 20 x 20 cm (scored as 2) and 50 x 50 cm (scoring 5). In each quadrat species were recorded first in the 10 x 10 cm cell and only new species added in each cell thereafter. Species found only in the remainder of the quadrat scored 9. Vegetation height and % bare soil were recorded for the whole quadrat. Species recorded in 1981 and in the North population area in 1996 – 2004 are presented in Appendix 4**.**

The statistical packages TWINSPAN, DECORANA and MATCH were designed to take data collected in 2m x 2m quadrats from homogeneous areas. The first two were used to carry out principal components analysis and two-way detrended-correspondence analysis, but these did not clarify the situation and the results are not presented.

4.5.3 Analysis using MATCH

The MATCH program was designed to aid the assignment of vegetation data to the communities and subcommunities of the National Vegetation Classification (Malloch 1996). It first matches the data with data on all the vegetation types in the National Vegetation Classification, then lists the 'best fit' together with its co-efficient. **Table 4.1** shows the results for data from the southern part of Port Meadow.

Table 4.1. The MATCH results suggesting that the vegetation did not fit any NVC class, but changed between resembling mesotrophic grassland, sand dune vegetation and open vegetation in a dynamic way over the study period (Courtesy of David Gowing)

Year	**Community giving 'best fit'**	**Co-efficient**
1981 Stand 37	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	34.6
1981 Stand 40	SD 17 *Potentilla anserina- Carex nigra*	33.2
North 1996	SD 17 *Potentilla anserina- Carex nigra*	28.6
North 1997	SD 17 *Potentilla anserina- Carex nigra*	28.3
North 1998	SD 17 *Potentilla anserina- Carex nigra*	26.5
North 1999	OV 21 *Poa annua-Plantago major*	29
North 2000	OV 21 *Poa annua-Plantago major*	29
North 2001	OV 21 *Poa annua-Plantago major*	29.3
North 2002	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	31.1
North 2003	OV 21 *Poa annua-Plantago major*	35.3
North 2004	OV 28 *Agrostis stolonifera-Ranunculus repens*	30.1
South 1996	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	31.1
South 1998	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	35.2

Year	Community giving 'best fit'	Co-efficient
South 1999	OV 28 *Agrostis stolonifera-Ranunculus repens*	29.4
South 2000	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	38.5
South 2001	OV 32 *Myosotis scorpioides-Ranunculus sceleratus*	31.3
South 2002	OV 29 *Alopecurus geniculatus-Rorippa palustris*	27.3
South 2003	OV 29 *Alopecurus geniculatus-Rorippa palustris*	33.5
South 2004	MG 13 *Agrostis stolonifera-Alopecurus geniculatus*	28.1

Typically, a 'good fit' would have a co-efficient of c.70 with the most closely matching subcommunity a co-efficient of *c*.85 (Malloch 1996). The results for1981 and 1996 – 2004 gave very low co-efficients, even lower than those for 2003 shown by Gowing and Youngs (2005)**.** These co-efficient scores are, therefore, almost meaningless, except to point out a dynamic situation. The following description of the Port Meadow vegetation is made in accordance with Rodwell (1992; 2000). The MG13 *Agrostis stolonifera – Alopecurus geniculatus* community at Stand 37 was predicted in 2004 and was also identified by MATCH in the North population in 2002 and in the South population in 1996, 1998, 2000 and 2004. The Sand dune SD17 *Potentilla anserina - Carex nigra* result is very surprising for an alluvial flood-plain community, and may have come about due to the large amounts of *Eleocharis palustris* present which is not found in Rodwell's tables for MG13. The Open Vegetation OV21 *Poa annua-Plantago major* community, indicated for the North population in 1999, 2000, 2001 and 2003, is characteristic of heavily trampled tracks and gateways and thus is much more likely on this common pasture but *Poa annua* was recorded at a very low frequency in 1999 to 2001 inclusive and 2003 (Appendix 4). This supports the low co-efficient values given by the MATCH program. However, the presence of *Polygonum aviculare*, *Ranunculus repens*, *Agrostis stolonifera* and *Potentilla anserina* point to a similarity with the OV21 *Polygonum aviculare-Ranunculus repens* sub-community**.**

In 1999, the South population and in 2004 the North population apparently resembled the OV28 *Agrostis stolonifera-Ranunculus repens* community which occurs widely on damp silts and clays near rivers and other water-logged places. It has either an open or closed sward with a mat of stolons of these two species, but *Ranunculus repens* was only occasional in the South population in 1999 and rare in the North population in 2004. The OV28 *Poa-Plantago* sub-community is typical of pastures which are wet in winter and dry out in summer, conditions which describe those in the North population area in most years. The OV 29 *Alopecurus geniculatus-Rorippa palustris* community was chosen by the MATCH program as the closest to the community in the South population in 2002 and 2003. It is usually found on expanses of riverine sediment laid bare by flooding. In these years the OV28 companion species *Alopecurus geniculatus, Persicaria lapathifolia, Polygonum aviculare* and *Potentilla anserina,* were abundant in the South population but the other companions down to and including class II *Rorippa palustris, Rumex crispus, Elymus repens, Poa trivialis, Phalaris arundinacea* and *Polygonum hydropiper* were rare or absent. Finally, in 2001 the South population was identified with the OV 32 *Myosotis scorpioides – Ranunculus sceleratus* community which is usually found in mosaics of other inundation vegetation round ponds and ditch edges trampled in spring. Unfortunately, *Mysosotis scorpioides* was rare in the South population that year and *Ranunculus sceleratus* was not recorded nor were *Glyceria maxima, Rorippa islandica, Veronica catenata* and *Rorippa nasturtium aquaticum*.

The drought years of 1995, 1996 and 1997, with little or no flooding and high summer temperatures, may have put the MG13 community under stress but it was probably 'summer fouling' in June1998, April and June 1999 and in April and May 2000 (See Section 4.3.4) which caused plant mortality, especially grass species, and increased the amount of bare ground in the North population area sufficiently for it to be recorded **(Figure 5.2).** This enabled the colonisation of the North and South population areas by ruderals which is reflected in the Open Vegetation designation in 1999, 2001, and 2002 in both population areas. Similarly, the extraordinarily dry conditions in August 2003 had an effect by favouring species such as *Plantago major* (which can behave like an annual), *Juncus bufonius*, *Chenopodium rubrum* and *Polygonum aviculare*.

4.5.4 Water-table, vegetation height and bare ground relationships

In 1996, the study areas were well vegetated with little bare ground **(Figure 4.7)**. From 1997 there was increasing bare ground in the North population area each year it was recorded, except for 2000 and 2003. In both areas the percentage of bare ground rose substantially in 1998 and 1999 and remained high rising above 60% in 2002. Vegetation height **(Figure 4.7)** was greatest in 1981 when there was c.6% bare soil and *Apium repens* was rare and so removed from the analytical program. During the study period the vegetation grew tallest in 2004 in both the North and South population areas and least well in 1999 in the North area and in 1998 and 2001 in the South population area.

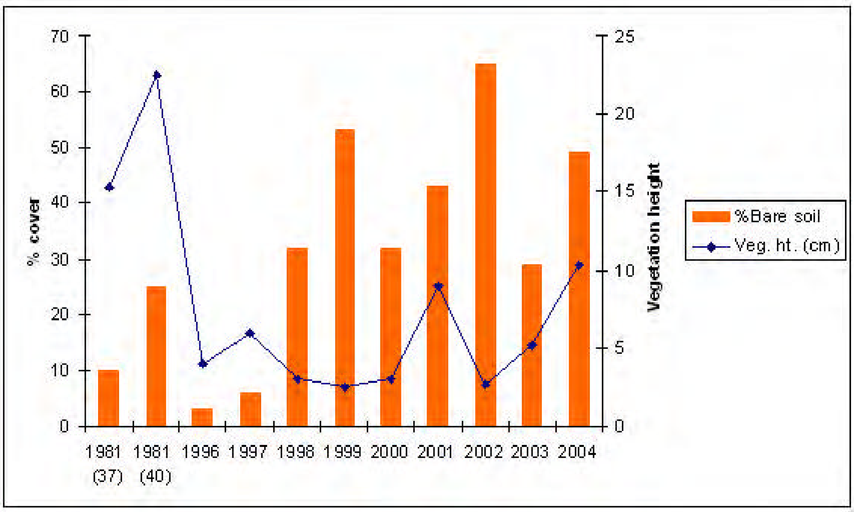


Figure 4.7. Vegetation height (line) (mean value for quadrats per annum) (tall indicates better growth in damper conditions; short indicates little growth in dry conditions) and percentage of bare ground (columns) (mean value for quadrats per annum) (low score = good vegetation growth; high score = poor vegetation growth) in 1981 and in the North and South populations 1996 – 2004.

The North population area (elevation 57.0 m) is slightly higher than the South population (elevation 56.9 m) yet it is the South population area which tends to dry out first in summer. Gowing and Youngs (2005) suggest that the South population might have preferable conditions for *Apium repens*. Appendix 4 shows the % frequency of the 55 species studied and suggests that the contrary is true. Taking into account that more quadrats were recorded in the North population, the population of *A. repens* there was greater than in the South most years. Taller vegetation would exclude light-demanding species which could take advantage of germination sites in short vegetation and, more readily in bare ground, but the data in **Figure 4.7.** does not support this hypothesis. It is true however, that most species remain dormant in the winter months and so can survive the considerable flooding but can succumb to flooding in summer. The increase in the amount of bare ground in summer is important to *A. repens* and the population of annual and ruderal species**.**

4.5.5 Changes in species abundance in the North population area

Changes in vegetation can be expressed by Raunkier's life-form for individual species (Clapham and others 1962). Plotting the scores of species per life-form group in the North population area **(Figure 4.8.)** shows that, unsurprisingly in a pasture, the species with buds at soil level form the largest the largest and most abundant group (n = 24), marsh plants (n = 16) is the next largest group closely followed by annuals (therophytes) (n = 14). Within each life form group, species abundance differed between species year from year. However, both annuals and perennials of wet or dry conditions have been recorded in the MG13 community and the subsequent ruderal communities each year so this analysis has not taken us forward.

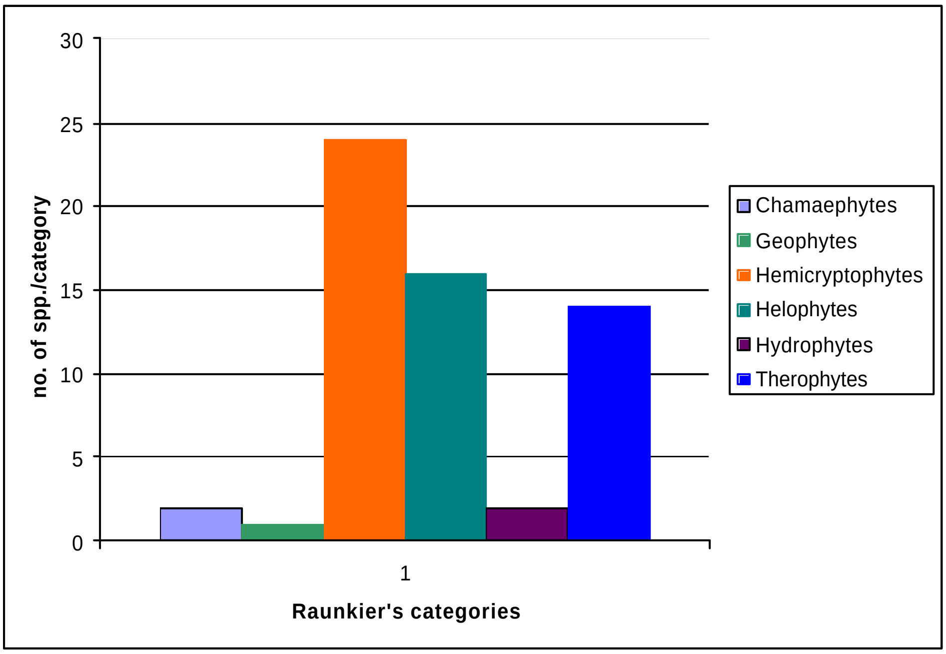


Figure 4.8. The number of species in each of the relevant groups of Raunkier's life forms: col. 1. Chamaephytes, herbs with buds above soil level but below 25cm (n = 2); col. 2. Geophytes with buds on roots and with rhizomes have been combined (n = 1); col. 3. Hemicryptophytes, herbs with buds at soil level (n = 24); col. 4. Helophytes, marsh plants (n = 16); col. 5. Hydrophytes, water plants (n = 2); col. 6. Therophytes, plants which pass the unfavourable season as seeds (n =14).

The ten most abundant species in 1981 represent the Port Meadow *Mentha aquatica* variant of **MG13** *Alopecurus geniculatus – Agrostis stolonifera* wet grassland **(Table 4.1)**. *Apium repens* is a rare species which was only recorded once in 1981 although it was growing elsewhere at the south end of Port Meadow at the time. The % frequency of many of these species including *A. repens* fluctuates greatly in both North and South populations**.** Its low-frequency or absence in some years in the South population between 1996 and 2004 may be due to the smaller sample and not reflect its true abundance in the area. This report therefore concentrates on the North population.

A number of species declined dramatically in 1998, **(Figure 4.9)**, these tend to be the species which are associated with MG13 *Agrostis stolonifera-Alopecurus geniculatus* grassland, *Mentha aquatica* variant. **Figure 4.9** shows that in contrast to *Apium repens* in 1996 and 1997 the % frequency of *Agrostis stolonifera, Mentha aquatica, Alopecurus geniculatus, Myosotis scorpioides* and *Oenanthe fistulosa*, was high in 1996 and 1997 but their populations were significantly reduced in 1998. This appears to be the result of a 'summer fouling' or a soil anoxia event (see section 4.3.4). *Agrostis stolonifera* soon recovered and was up to 100% frequency in 2004. *Mentha aquatica* and *Myosotis scorpioides* had also recovered by 2004 but not to their earlier abundance. The frequency of *Oenanthe fistulosa* continued to drop after 1998 and this species was not recorded in 2003 and only once in 2004. *Ranunculus flammula* became rarer in 1997 and never regained its former abundance, and *Galium palustre* disappeared in 2001 but reappeared in 2004. Although *Veronica scutellata* increased in abundance in 1997, after 1998 it seemed to behave differently from the other species except *Apium repens*. However, *Apium repens* plants were also destroyed in 1998 and, to a lesser extent, in 1999, 2000 and 2001. The % frequencies in **Figures 4.9–4.11** for *A. repens* were high in these years due to seedling swarms counted in the August survey each year (See Section 5, **Figure 5.12).** Other species which increased in 1998 tend to behave as ruderals **(Figure 4.10)**. *Veronica catenata* was the most volatile having maximum % frequency in 1998 and 1999 and low frequency thereafter. The population of *Chenopodium rubrum* increased in 1999, stayed at 90% in 2000 but dropped to 45% in 2001 and was not recorded in 2002 or 2004.

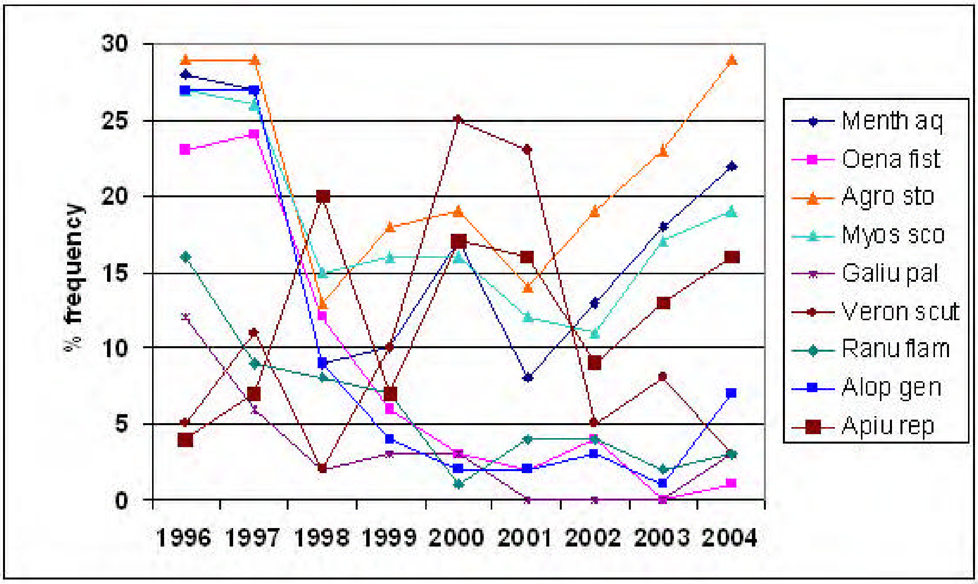


Figure 4.9. Species in the North population area of Port Meadow which decreased in abundance in 1998 as compared with *Apium repens*.

Persicaria amphibium increased to 90% by 2000, remained at that level in 2001 then, like *Chenopodium rubrum*, dropped to 30% in 2002 and was not recorded in 2003 or 2004. Small plants of *Urtica dioica* were at their greatest frequency in 1998 but then declined and this species was not recorded in 2001 or later. *Rorippa nasturtium-aquatica* showed a similar decline, was absent in 2003 and at very low frequency in 2004.

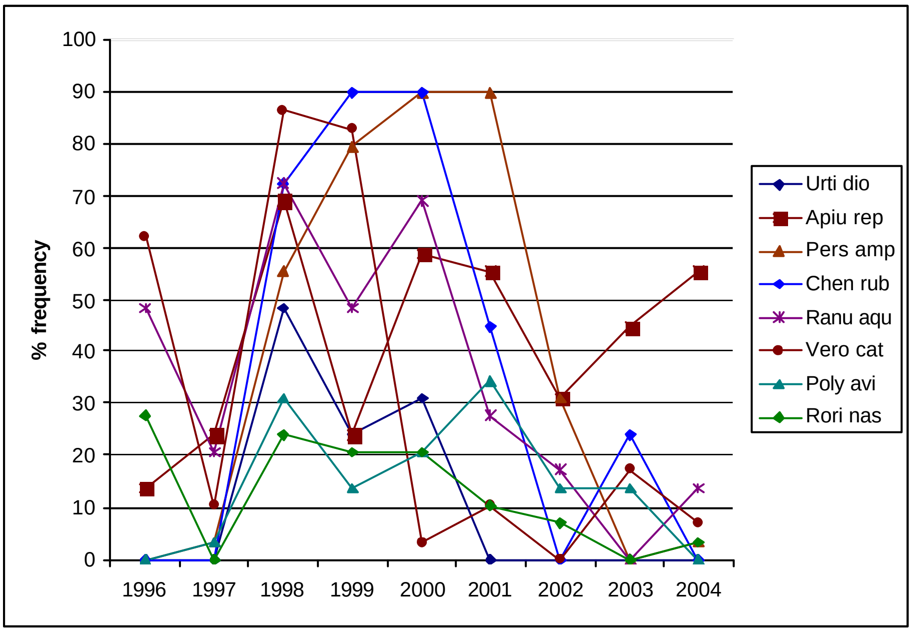


Figure 4.10. Species in the North Population which increased in abundance in 1998 as compared with *Apium repens.*

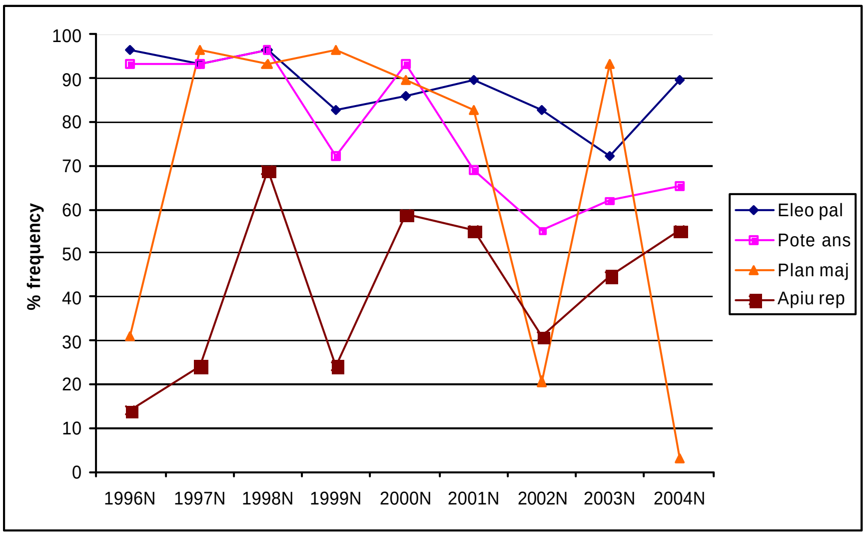


Figure 4.11. Species in the North population area on Port Meadow which were not apparently affected by the 'summer fouling' in 1998 as compared with *Apium repens.*

Polygonum aviculare certainly increased in abundance in 1998 but its population was at its greatest in 2001 and declined thereafter, although it increased in % frequency in 1998, was also at its highest frequency in 2001, having decreased in 2002, like *Veronica catenata* and *Chenopodium rubrum*, increased in 2003 and declined once more in 2004. *Ranunculus aquatilis* was at its highest frequency in 1998 and nearly at the same level in 2000 then, like the others in this group, its population declined. It was not recorded in 2003 but was at low abundance in 2004. *Ranunculus aquatilis* shows a similar frequency to *Apium repens.*

Only three species, *Eleocharis palustris, Potentilla anserina* and *Plantago major*, were apparently unaffected by 'summer fouling' in 1998 (**Figure 4.11).** They remained at or above 69% frequency until 2001 when all three species declined in abundance with recovery in

2003. In 2004 *E. palustris* and *Potentilla anserina* populations increased somewhat but the *Plantago major* population plummeted in 2004. From 1998 the population of *Apium repens* followed that of *Potentilla anserina* though at lower numbers.

4.5.6 Ellenberg indicator values

To try and get some insight into the reasons for the dynamic behaviour of so many species over time we decided to apply Ellenberg indicator values for British plants (Hill and others.1999) to species which declined due to 'summer fouling' in1998 **(Figure 4.12)**, species which increased as a result of the flood-event (**Figure 4.13)** and species not apparently affected **(Figure 4.14).** The species are arranged according to their Ellenberg moisture (F) values.

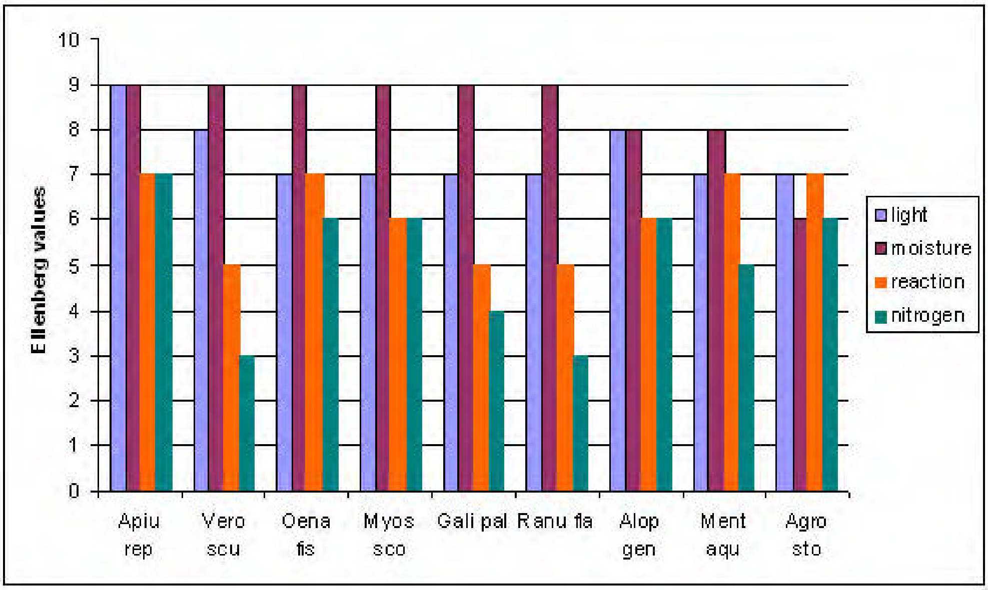


Figure 4.12. These species which declined in % frequency in 1998, arranged according to their Ellenberg moisture values (F).

Declining species have high light values between L7 and L9. *Apium repens* is the least tolerant of shade and *Veronica scutellata* and *Alopecurus geniculatus* are the closest (L8) to *A. repens* in their requirements for light. These species are found in neutral to slightly acid conditions (R 5 – R7) with medium to low nitrogen (N3 – N7). The range of Ellenberg values relating to these species does not suggest that any of them could be considered to be *Apium repens* companion species. They do show, however, that *A. repens* prefers very wet, but neutral and fairly rich soils with short vegetation giving plenty of light, conditions which are not all preferred to the same extent by the other species in **Figure 4.12**.

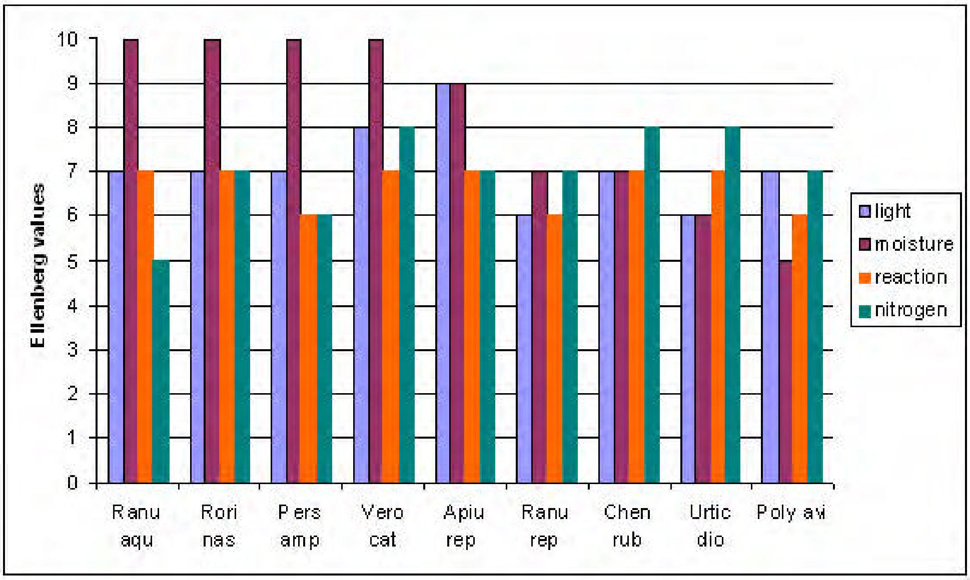


Figure 4.13. These species increased in % frequency in 1998 and are arranged according to their Ellenberg moisture (F) values.

Increasing species prefer slightly wetter conditions and cope with less light than *Apium repens*. All the species in **Figure 4.13** grow very well with less than maximum light (L10). *Persicaria amphibia*, *Ranunculus repens* and *Polygonum aviculare* prefer slightly acid soils while *Veronica catenata*, *Chenopodium rubrum* and *Urtica dioica* prefer more enriched habitats. This lack of similarity suggests that the common denominator is simply an ability to take advantage of the bare ground conditions by germinating in summer. *A. repens* seems to germinate in July and August but the plants are not easily seen until late August.

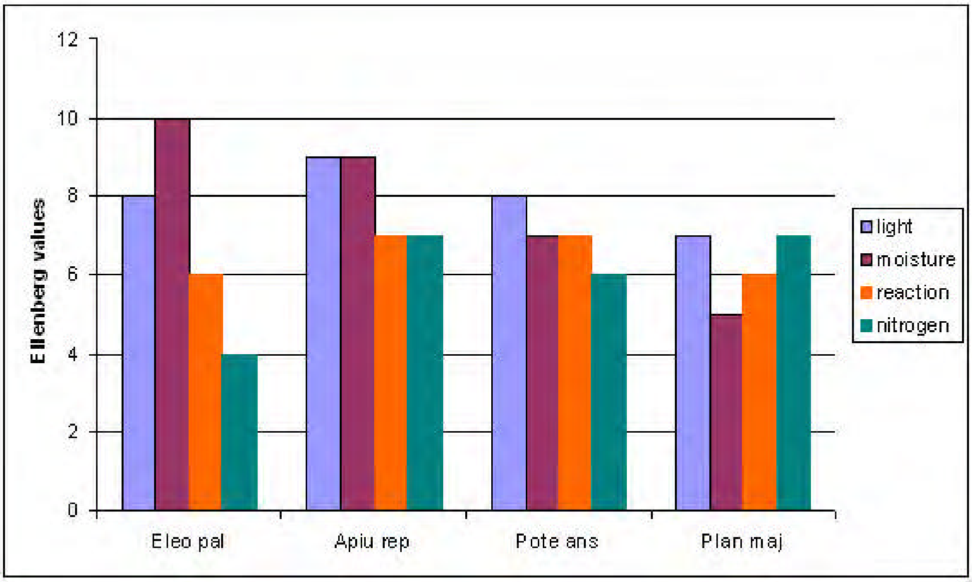


Figure 4.14. These species were not apparently affected by 'summer fouling' in 1998 and are arranged according to their Ellenberg moisture indicator values (F).

Those species apparently unaffected by 'summer fouling' in 1998 show little resemblance in their Ellenberg values to those of *Apium repens*, except that *Potentilla anserina* shares the preference for neutral soils (R7) whilst *Plantago major* shares a preference for moderately enriched soils (N7) (**Figure 4.14)**.

4.5.7 Companion species for *Apium repens*

Extracting those species which share one or more Ellenberg scores for light, moisture, reaction and nitrogen, shown in Figures 4.12–4.14, high-lights those two species which resemble *Apium repens.* Only *Oenanthe fistulosa* which has not recovered its former frequency shares scores for moisture and reaction and *Rorippa palustris* which is currently about midway between its maximum and minimum frequency, shares scores for reaction and nitrogen. However, *Ranunculus aquatilis*, as is shown in **Figure 4.10**, has a similar behaviour in terms of frequency to *A. repens.* Ellenberg values, like other methods, have not produced any companion species for *A. repens.*

Looking at a larger data set of the vegetation in 2003, Gowing and Youngs (2005) used mean Ellenberg F values, for each of the six blocks, together with the surface topography, as variables in a Canonical Correspondence Analysis of the vegetation. They noted that the software brought together *Oenanthe fistulosa, Myosotis scorpioides* and *Veronica scutellata* as associates of *A. repens.* It is true that these four species share the same F9 and O*enanthe fistulosa* also has the same R7 preference **(Figure 4.12)** but the patterns of their frequency in the North population vary**.** In years when these species are abundant *Apium repens* is relatively rare in the North population. When *Oenanthe fistulosa, Myosotis scorpioides* and *Veronica scutellata* are rare or absent the general behaviour of *Veronica scutellata, Ranunculus aquatilis, Rorippa palustris* and *Potentilla anserina* reflect that of *A. repens* but at different frequency.

4.5.8 Conclusions from vegetation analysis of the North population area

Of the three statistical packages used in this study only MATCH results have proved useful but these are inconclusive. They suggest that the vegetation associated with *Apium repens* on Port Meadow is very dynamic. The community does not match any NVC class closely but resembles MG13, SD17 and various OV types. The proportion of closed sward species fell dramatically after 'summer fouling' in 1998 and to a lesser extent in 2001. This agrees with discussions which took place at the Workshop 16/17 September, 2005, in which it was suggested that *A. repens* does not belong to any one community. It seems to grow on the edge of several communities provided that the associated species are low-growing, such as *Plantago major*, or are kept short by cutting or by grazing. Also important for *A. repens* are the abiotic conditions notably open areas and wet soils in winter, dry and preferably warm soils in summer and even occasional 'summer fouling' events, with its anoxic soils, after which *A. repens* germinates from the seed bank.

Gowing & Youngs (2005) suggested that the South population area soil dries out in summer to a greater extent than that in the North population area and that the degree of water-logging in the North and South populations is higher than that of any grassland community previously studied. It is only the grazing which prevents the South end of Port Meadow from developing into a swamp type of vegetation.

4.6 Transect across the South population area

4.6.1 Method

In order to study the different plant associates of *Apium repens* compared with those of *A. nodiflorum* a transect was set up in the south population area **(Map 4.1)** running from an area prone to flooding (*A. repens*) towards the area raised by dumping (*A. nodiflorum*). The transect was recorded in 1996 and then annually from 1998 to 2004. One metre quadrats were positioned every 2 m along a 28 m line. Nested quadrats **(Photos 4.2 and 2.8)**, were recorded as described in Section 4.5.2.

Photo. 4.2. Recording the transect in the South population area in 1998. Alison McDonald (with Tibbie Shields sheltering from the sun) and Susan Erskine on the deeply poached ground recording a nested quadrat. Photo. C.R. Lambrick.

4.6.2 Results

In 1996 *Apium repens* was found along the transect at 12 m and 14 m whereas *A. nodiflorum* was recorded at 26 m and 28 m **(Figure 4.15)**. The larger amount of *Ranunculus repens* at 20 m, 26 m and 28 m suggests that *A. nodiflorum* prefers drier conditions on Port Meadow than does *A. repens*. *Rumex conglomeratus* forms a distinct zone around the edge of the dumped land, possibly responding to nutrients and/or salts seeping from the dump (Grassly and others 1996).

In 1996 the sward was almost entirely closed, and many of the characteristic species of the closed sward areas of Port Meadow were relatively evenly distributed at high levels along the transect, notably *Agrostis stolonifera*, *Alopecurus geniculatus*, *Eleocharis palustris*, *Mentha aquatica*, *Myosotis scorpioides*, *Oenanthe fistulosa* and *Potentilla anserine.* In most years at the *A. repens* end (0 m) of the transect the sward tended to be short (2-8 cm) and longer (3-15 cm) at the *A. nodiflorum* end (28 m).

Subsequently, however, dramatic changes occurred. In 1998 **(Figure 4.16)** and in 2000 **(Figure 5.1, Photo. 4.2** and **Figure 4.17)** the percentage of bare ground in the quadrats had risen from 0 or 1 to 30-80%, the soil was deeply poached and neither species of *Apium* was recorded in that or the following year. Indeed *A. nodiflorum* was not recorded again.

In 2001 some annuals appeared including *Juncus bufonius*, *Polygonum* spp. and *Chenopodium* spp., *Eleocharis palustris* and *Rorippa palustris* were abundant. In 2002 *Oenanthe fistulosa*, *Agrostis stolonifera* and *Alopecurus geniculatus* were relatively abundant but *Apium repens* was found only at 12 m and *Plantago major* was somewhat reduced in frequency while *Eleocharis palustris* and *Potentilla anserina* were almost unaffected. The year 2003 had a very dry summer **(Figure 4.18)**; *Agrostis stolonifera* and *Alopecurus geniculatus* were infrequent and *Apium repens* was found only at 18 m and 24 m. where there was a great mixture of species typical of MG13 and of Open Vegetation types.

In 2004 **(Figure 4.19)** the general picture was more similar to that in 1996 except that *Oenanthe fistulosa* had become very rare (as had less frequent perennial components of drier vegetation types, such as *Ranunculus repens* and *Trifolium repens*). *Apium repens* returned at the wetter end of the transect. Whereas *Rorippa palustris* was rare at the beginning of the study it had become pervasive by the end, rather irrespective of conditions.

4.6.3 Conclusions from the transect across the South population area

The result of sampling along a transect in the South population area did not show a clear difference in the vegetation between the wetter area where *Apium repens* grew in 1995 and the drier area where *A. nodiflorum* grew that year. This was in part because of the way the data were collected which meant that we had not sufficient quantitative data for each species.

The transect did show dramatic changes associated with soil anoxia in 1998 and 2000. The amount of bare ground, especially at the wetter, *A. repens* end, greatly increased and then declined. MG13 species declined and then recovered somewhat. Ruderals, after a slow start, appeared in great numbers. Some species showed trends which were independent of year, for instance the annual *Rorippa palustris,* which steadily increased, presumably as seed built up.

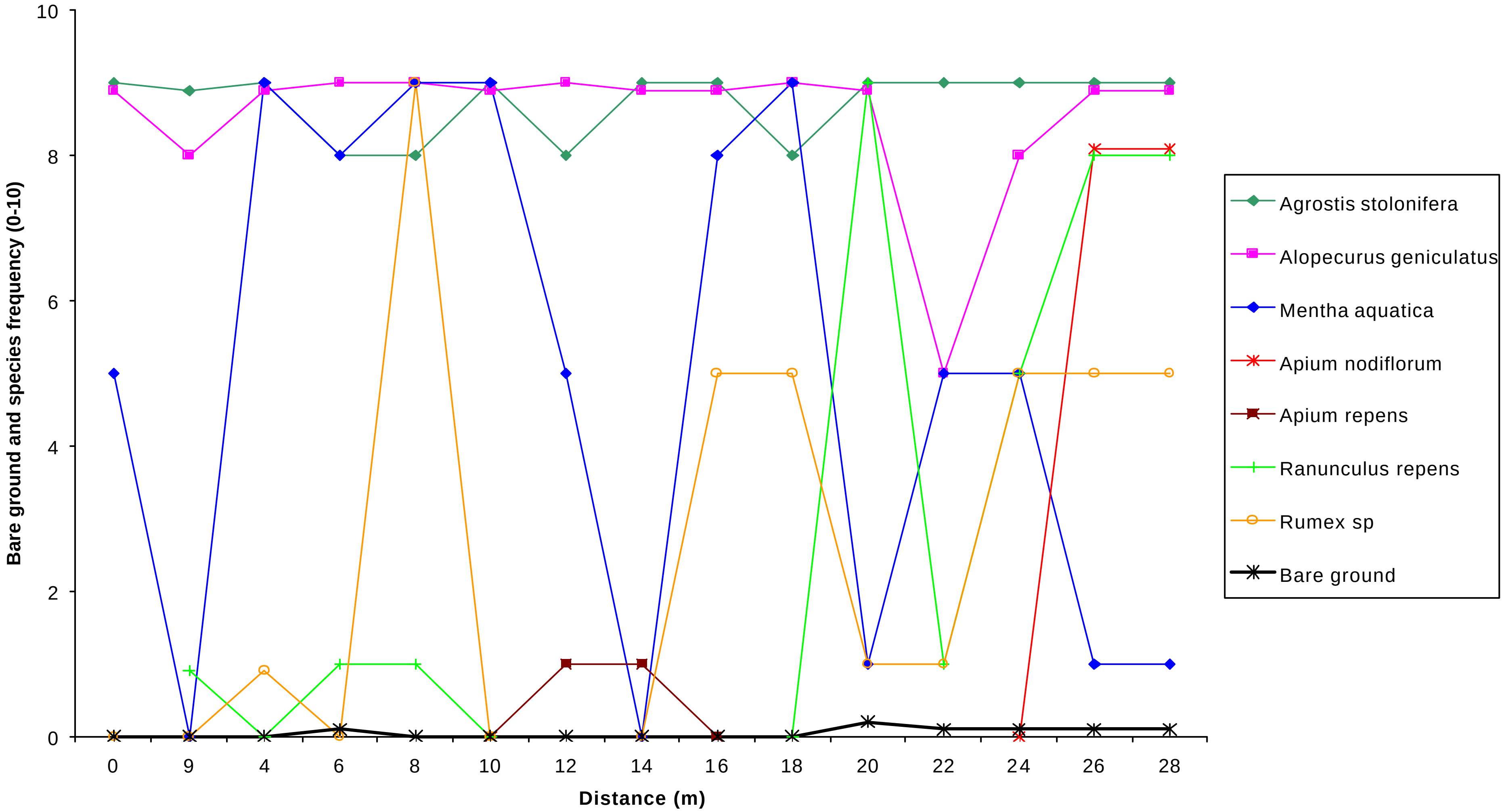


Figure 4.15. Transect in 1996. There was little bare ground. *Mentha aquatica* and *Alopecurus geniculatus* were frequent. There were no ruderals.

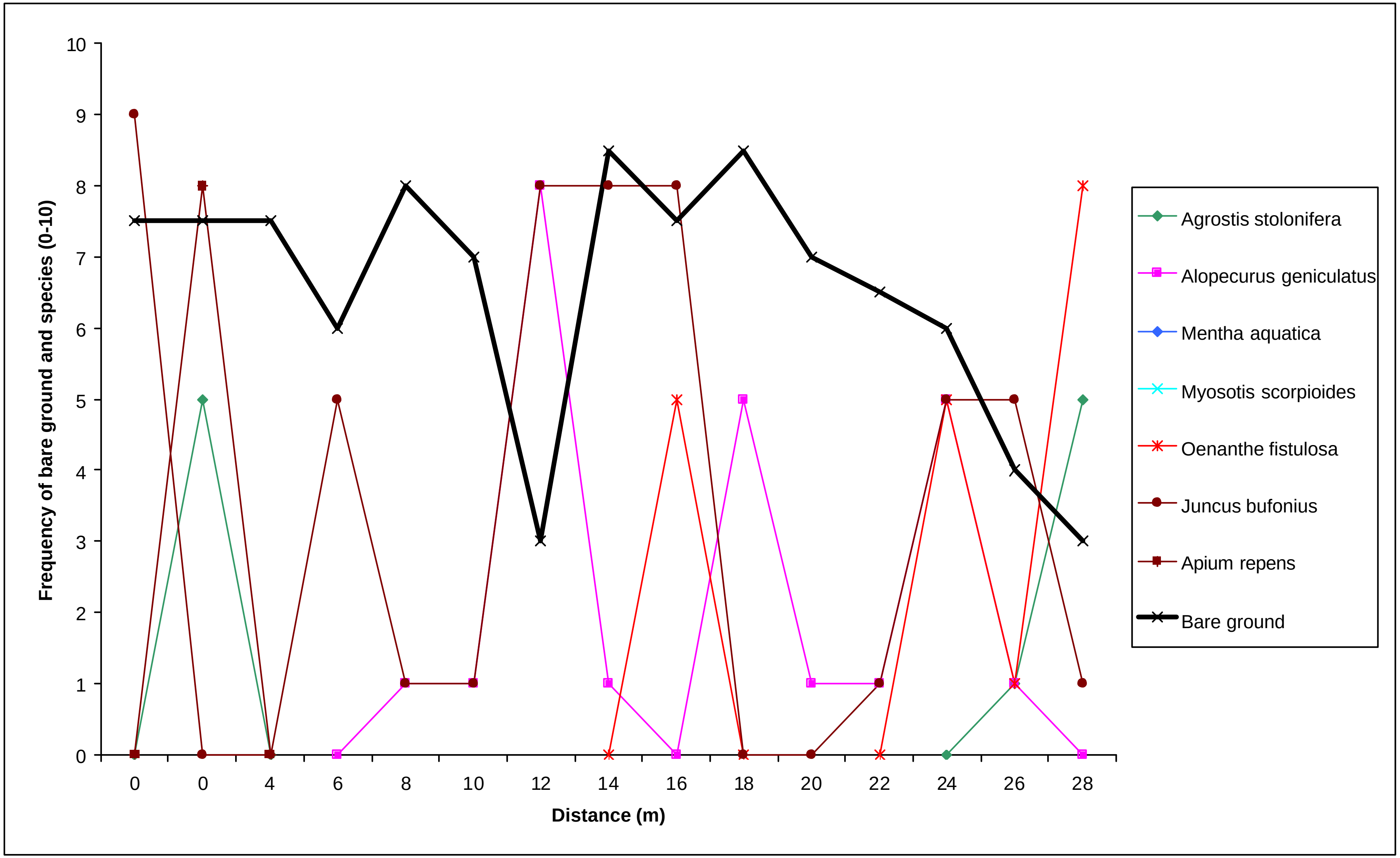


Figure 4.16. Transect in 1998. Bare ground suddenly rose to a high frequency. *Apium repens, Apium nodiflorum* and most other species were greatly reduced. *Mentha aquatica* and *Ranunculus repens* were not recorded. Ruderals did not appear.

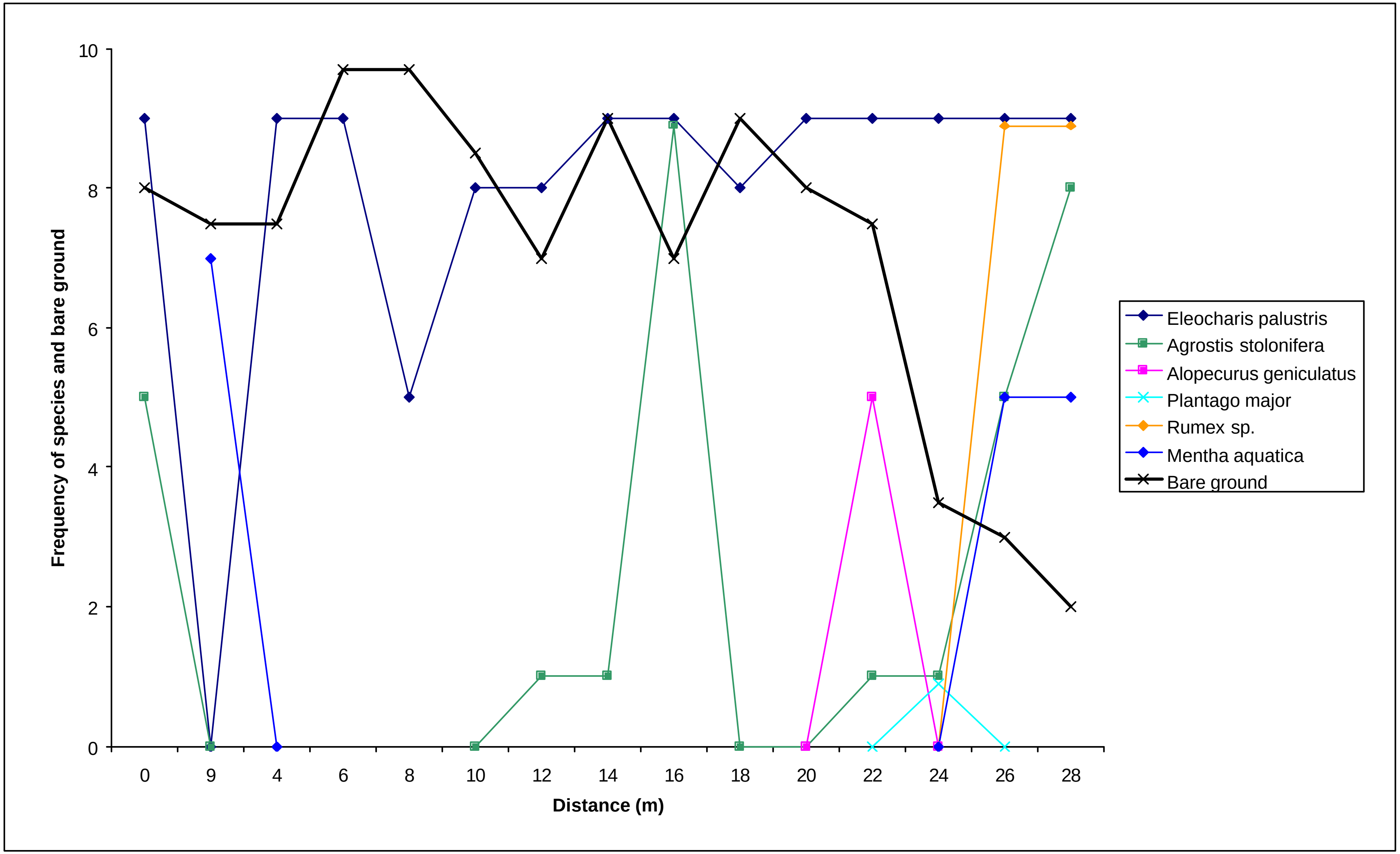


Figure 4.17. Transect in 2000. Bare ground for the first 19 m in which few species (not including *Apium repens*) survived. *Alopecurus geniculatus*, *Plantago major*, *Rumex sp.* and *Mentha aquatica* were present at low levels in the last eight meters. Ruderals were present at low levels.

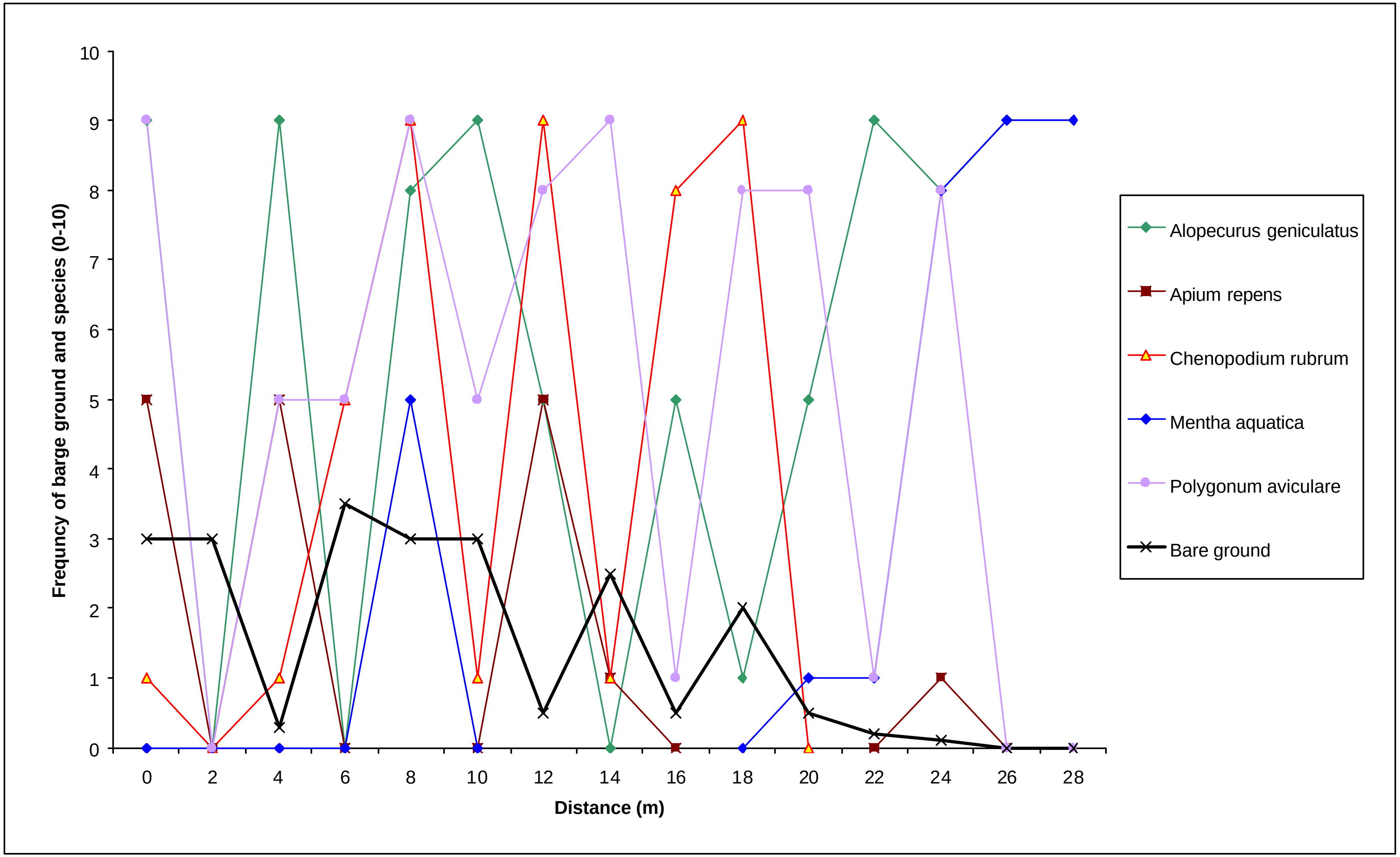


Figure 4.18. Transect in 2003. Bare ground was less and *Apium repens, Alopecurus geniculatus, Mentha aquatica* had returned sporadically. Ruderals had become frequent throughout the transect.

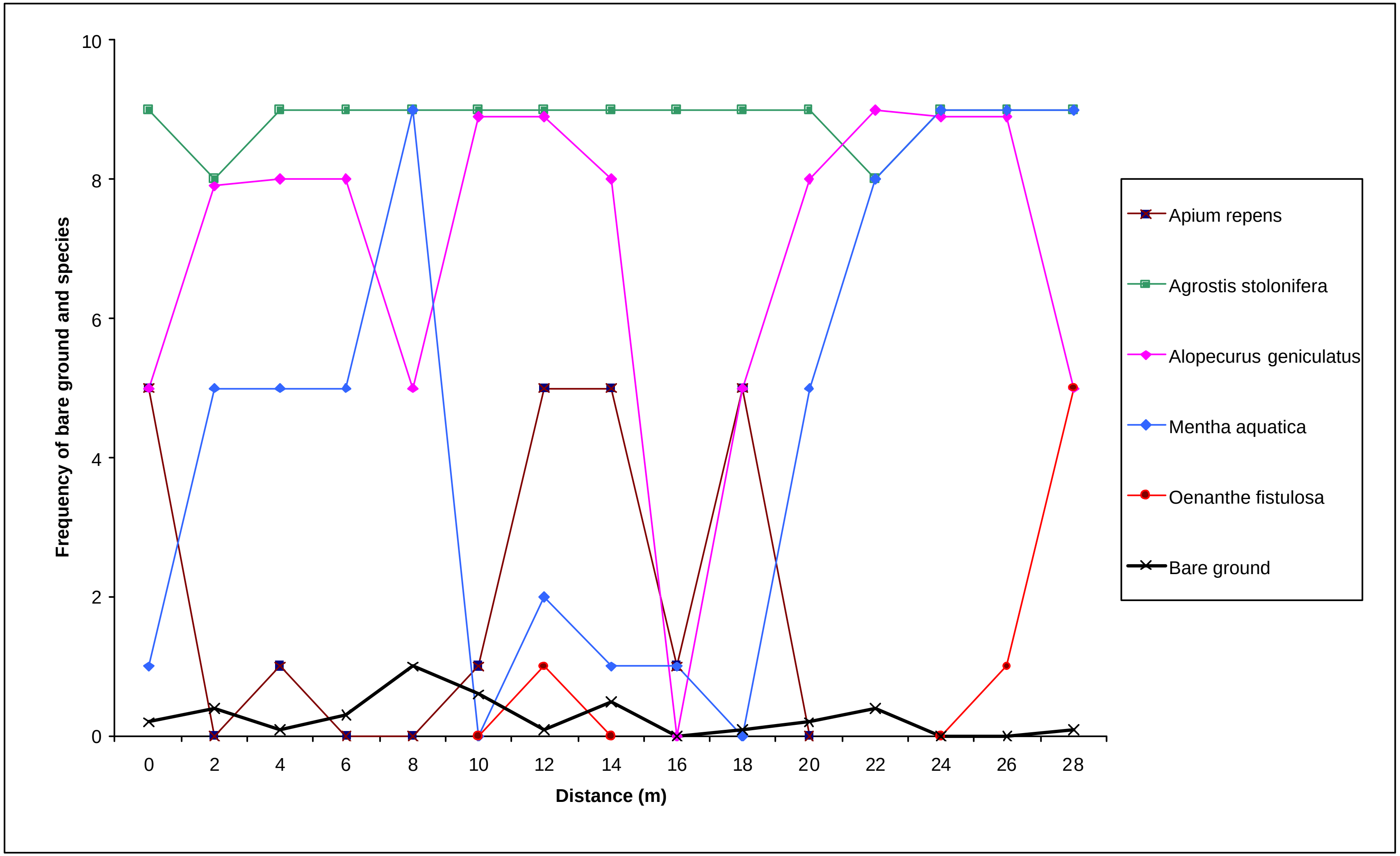


Figure 4.19. Transect in 2004. Bare ground was reduced and *Apium repens* reappeared close to its original position in 1996. *Alopecurus geniculatus* and *Mentha aquatica* also had low scores. Ruderals were fewer.

5 *Apium repens* population studies

5.1 Introduction

Among the most important questions for the conservation of a species are those about its demography. For *Apium repens* we needed to know whether the plants are perennial or annual and whether they spread vegetatively or by seed. A study of the population dynamics in the field was undertaken.

5.2 Methods

In order to follow the populations on Port Meadow two permanent areas were laid out in the south end of Port Meadow in 1995 (see Section 4.5.2.) to include the two major areas of *Apium repens* then observable **(Map 4.1).** The *Apium repens* plants and their associated vegetation were mapped annually in late August. Measure tapes and string are laid out dividing each area into 1 m wide strips. Volunteers then work along the strips (see cover picture), marking each plant with a small green horticulture stake with a sticky paper flag on it **(Photo 5.1).** A pair of volunteers then follow to record the co-ordinates of each plant to the nearest 5 cm. The proforma is shown in Appendix 5.

Photo 5.1. Flags on horticultural canes marking *Apium repens* plants on the North population area of Port Meadow in August 2001, note the wet condition of the low-lying north-western part of the study area (the north west corner of the area is marked by a tall cane). Photo C.R. Lambrick.

The length of the peduncle and number of bracts on flowering plants are recorded to confirm their status as *A. repens* or *A. nodiflorum*. A plant was recorded as a seedling if it has fewer than three lateral leaflets. On mature plants the degree of lobing of the leaflets was recorded (the largest, or third leaflet up from the base being used for this assessment). This had been selected as the best available way to distinguish *Apium repens* from *A. nodiflorum* when in a vegetative state.

The grey marking at the base of the leaflets in some plants was also recorded in the early years as this is variable. However no pattern was discernable and this measurement was discontinued. The proforma used for recording *Apium repens* is shown in Appendix 5.

5.3 Problems with the methods

Consistency of recording was a major problem both across years and by different volunteers. When one plant was spreading by runners, it was recorded as a single point. When recording seedlings it is easy to distinguish the separate plants and tempting to record them all individually. However when there is a large interwoven patch it is not possible to distinguish single clones, and such patches were sometimes recorded as areas covered by *Apium repens*. Recording of seedling or mature plants was often inconsistent between volunteers giving rise to such patterns as seen in 1997 and 2001 where rectangular blocks are apparently either predominantly seedling or mature plants. In this case it is likely that these were young plants which had arisen that year and were just becoming large enough to count as mature plants. Thus the designation 'mature' will include some plants newly germinated that year and plants from the previous year. The numbers of plants have generally risen during the recording period with very high numbers present in some years; volunteer time was not always available for the whole area and only part of the area was then recorded. In July and August 2004 large areas of the North and South populations were under water and recorded with considerable difficulty.

In order to consider that a plant is likely to be the same as one recorded the year before it is necessary to have a method that returns to within about 10 cm, though even so identity is not certain. The transponders can only be located to within about 20 cm, so ascertaining the identity of plants from year to year was not possible.

5.4 Results

5.4.1 Physical conditions

The vegetation in the marked areas altered markedly during the ten years of observation (Section 4). The sward was almost entirely closed in 1995, by 1999 a substantial part of the North population area was bare soil, and by 2004 a large part of the area was bare soil **(Figure 5.1)**. In summer this bare area is usually a dust bowl, but at any season can be a deep and glutinous mud **(Photo 5.1)**. The population of *Apium repens* in the North population area has been plotted so that the distribution can be assessed against the areas of bare ground and against each other **(Figure 5.2- 5.11).** The distribution of *A. repens* in the North population area is presented and discussed here. The pattern in the South population was generally similar, but differed somewhat in the pattern of flowering and seedlings in the different years.

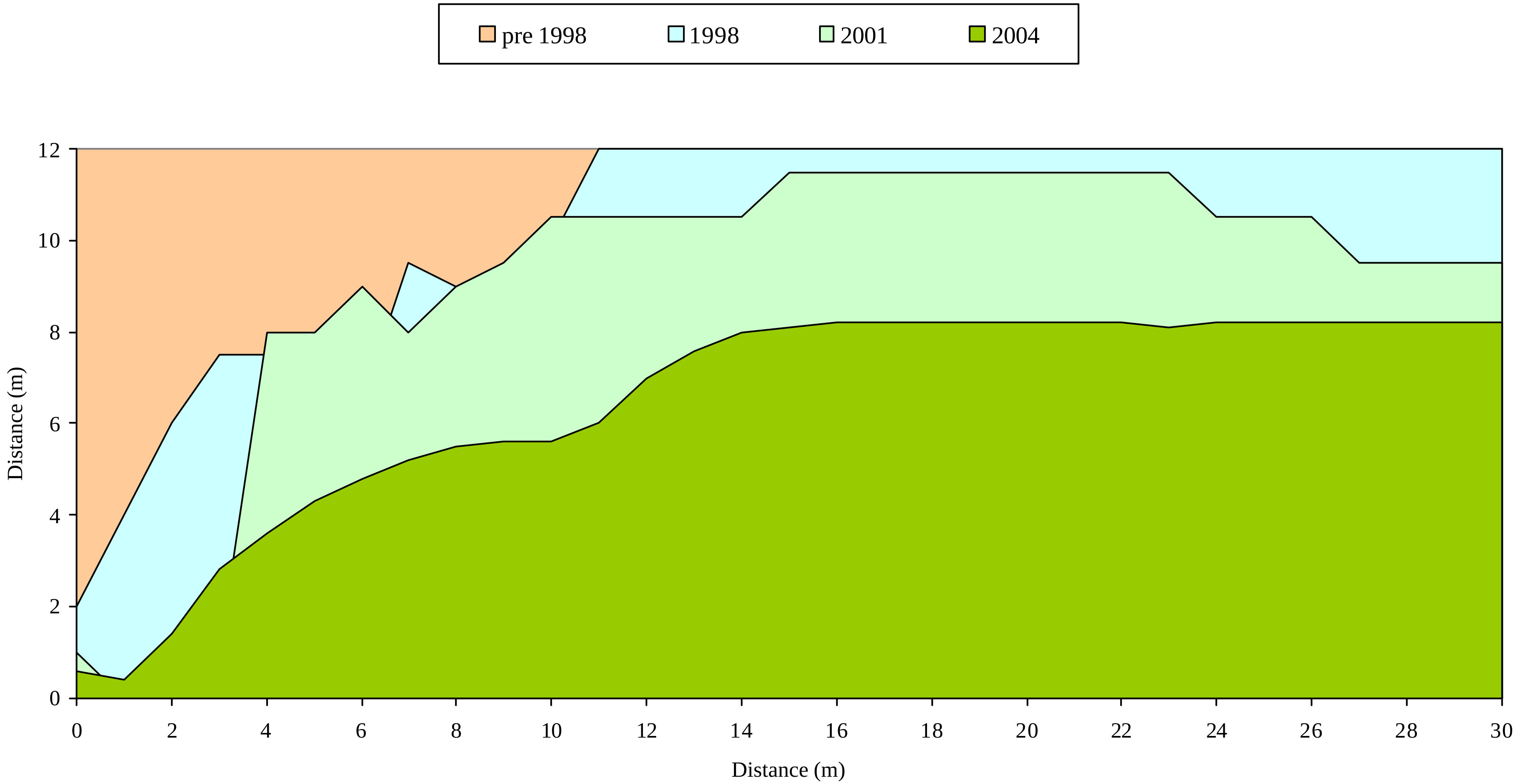


Figure 5.1. Extent of bare ground and closed sward on the North population area of Port Meadow.

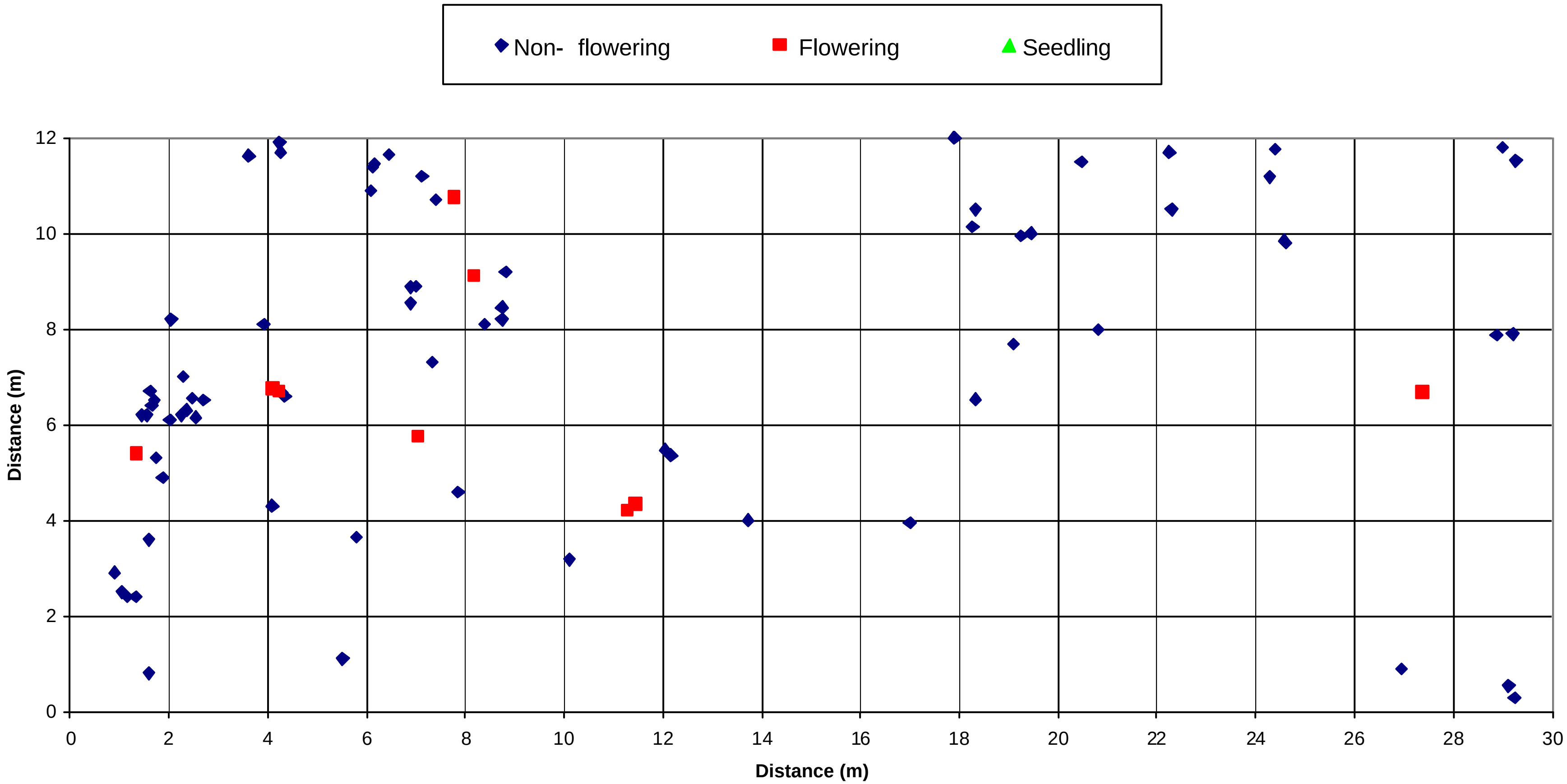


Figure 5.2. *Apium repens* in the north population area of Port Meadows in 1995.

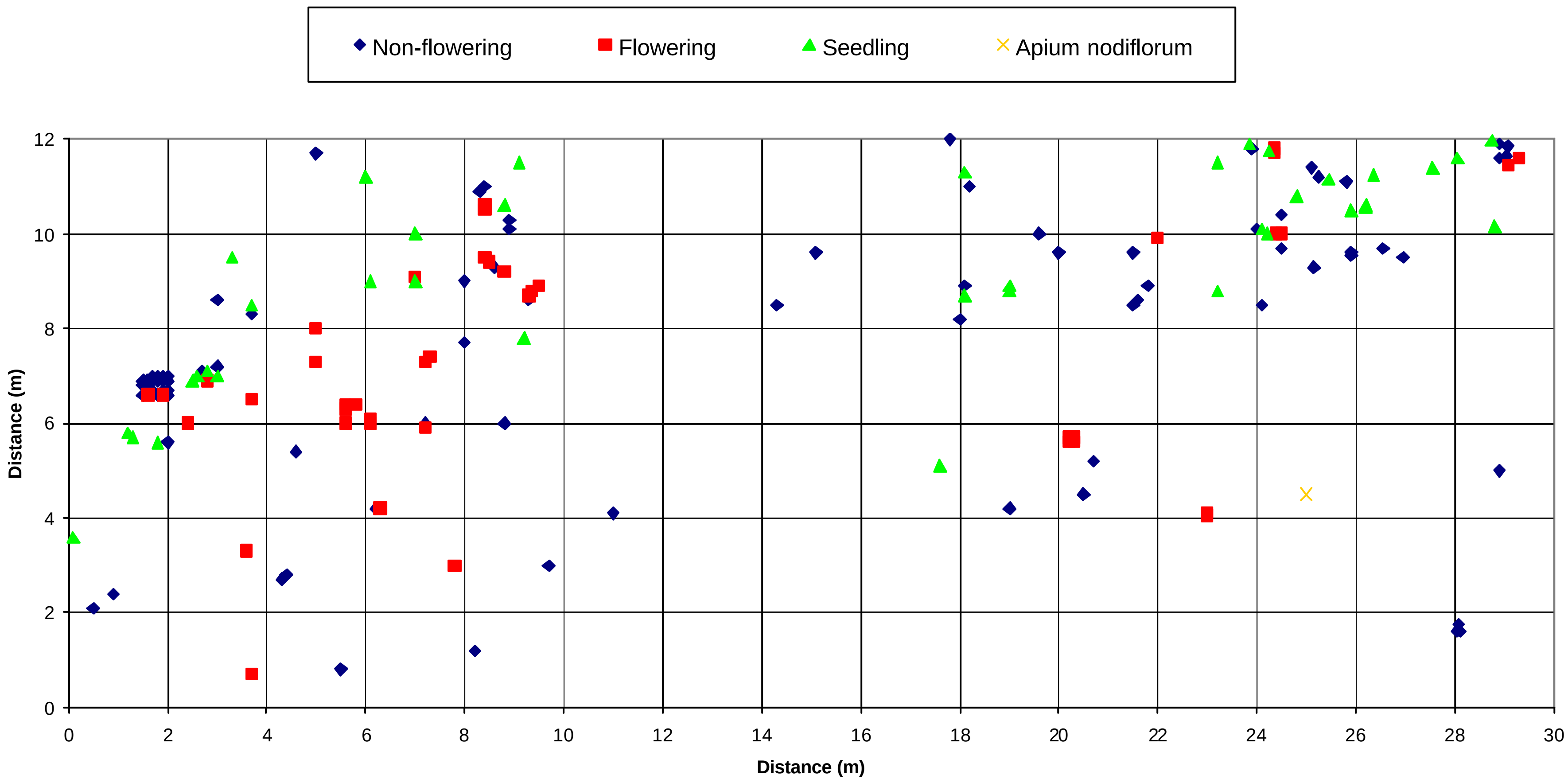


Figure 5.3. *Apium repens* in the north area of Port Meadows in 1996.

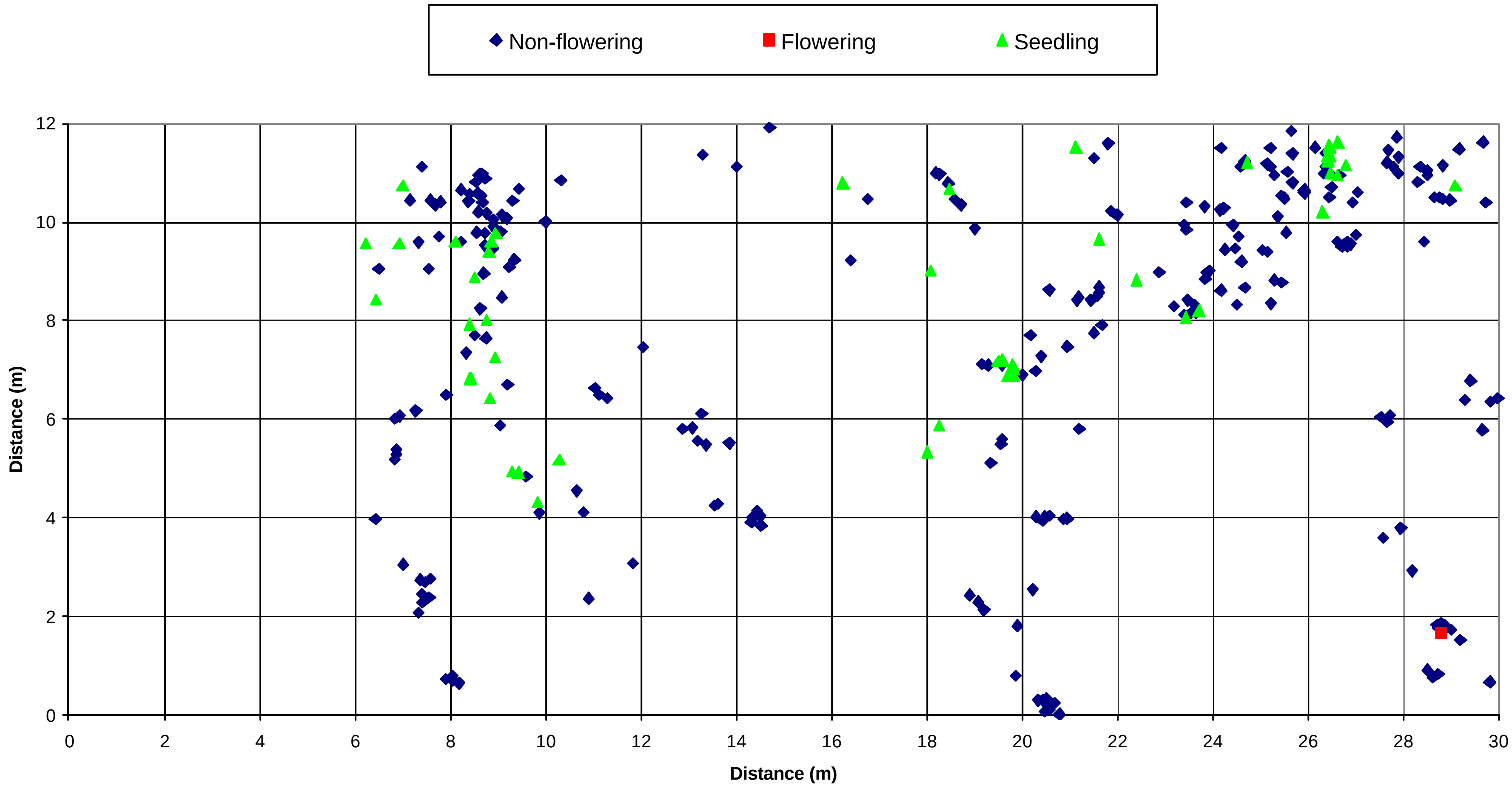


Figure 5.4. *Apium repens* in the north population area of Port Meadow in 1997. The area to the left of 7 m was not recorded.

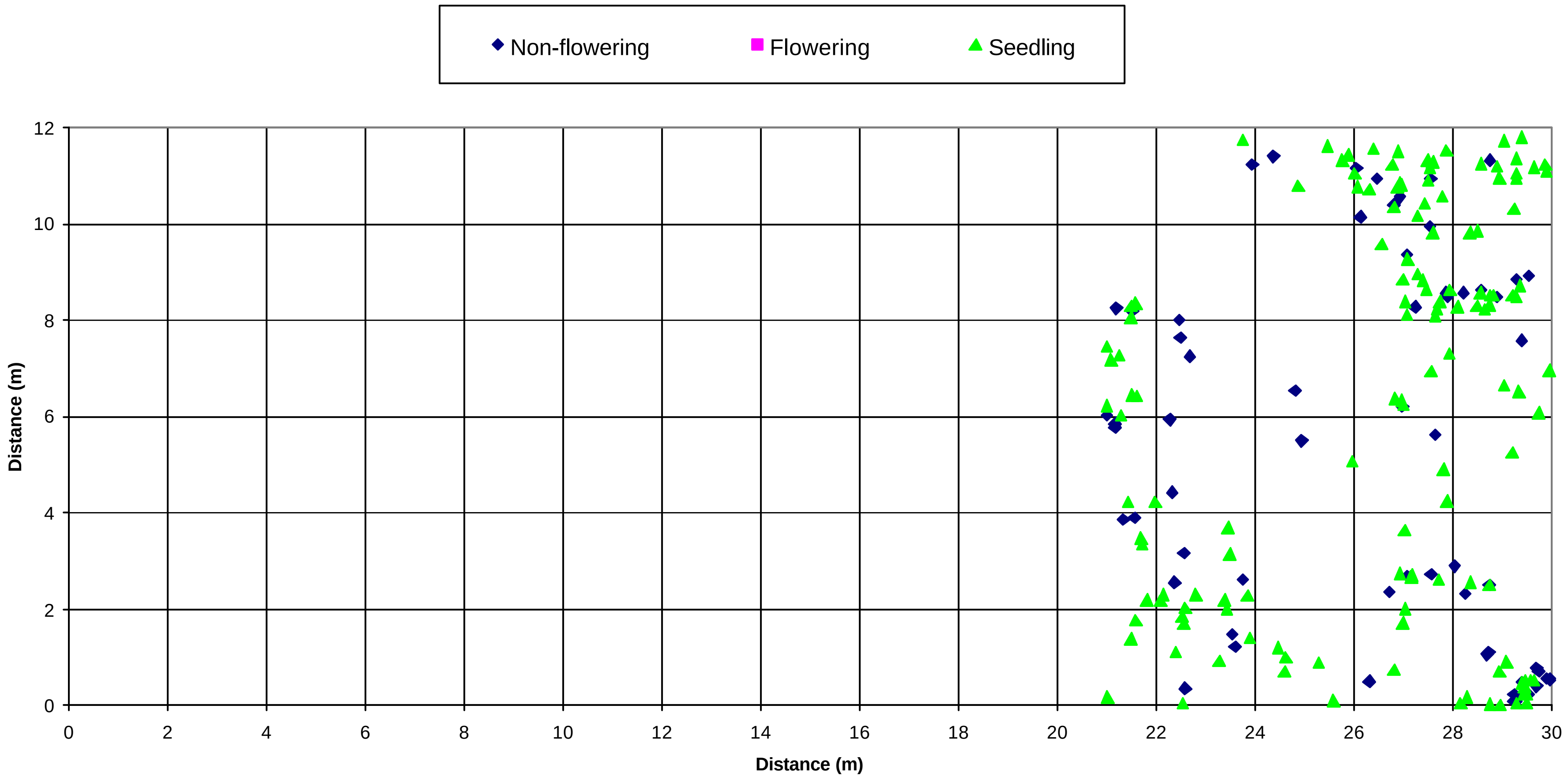


Figure 5.5 Apium repens in the north area of Port Meadow in 1998. The area to the left of 21 m was not recorded.

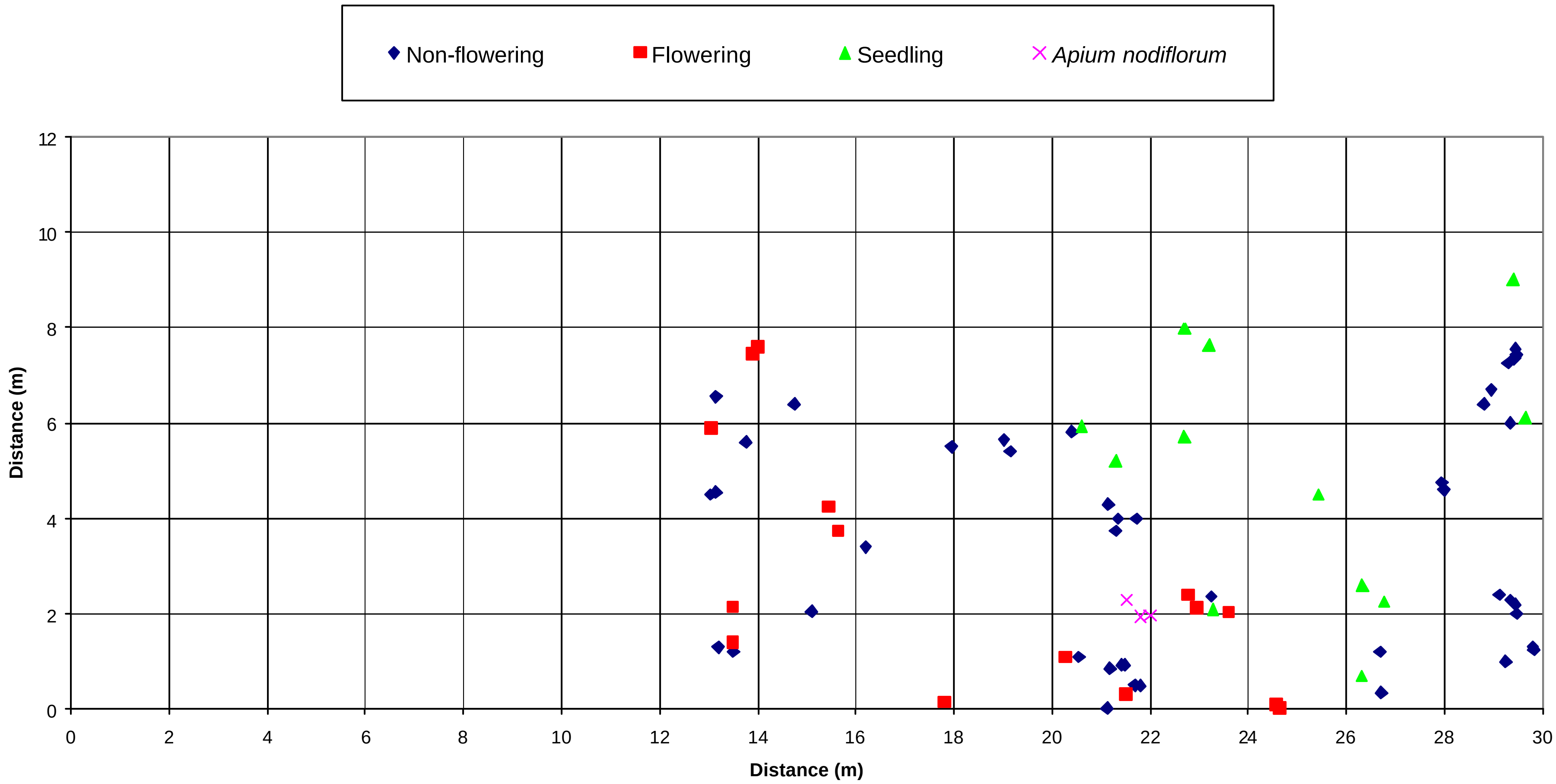


Figure 5.6. *Apium repens* in the north population area of Port Meadow in 1999. The area to the left of 13 m was not recorded.

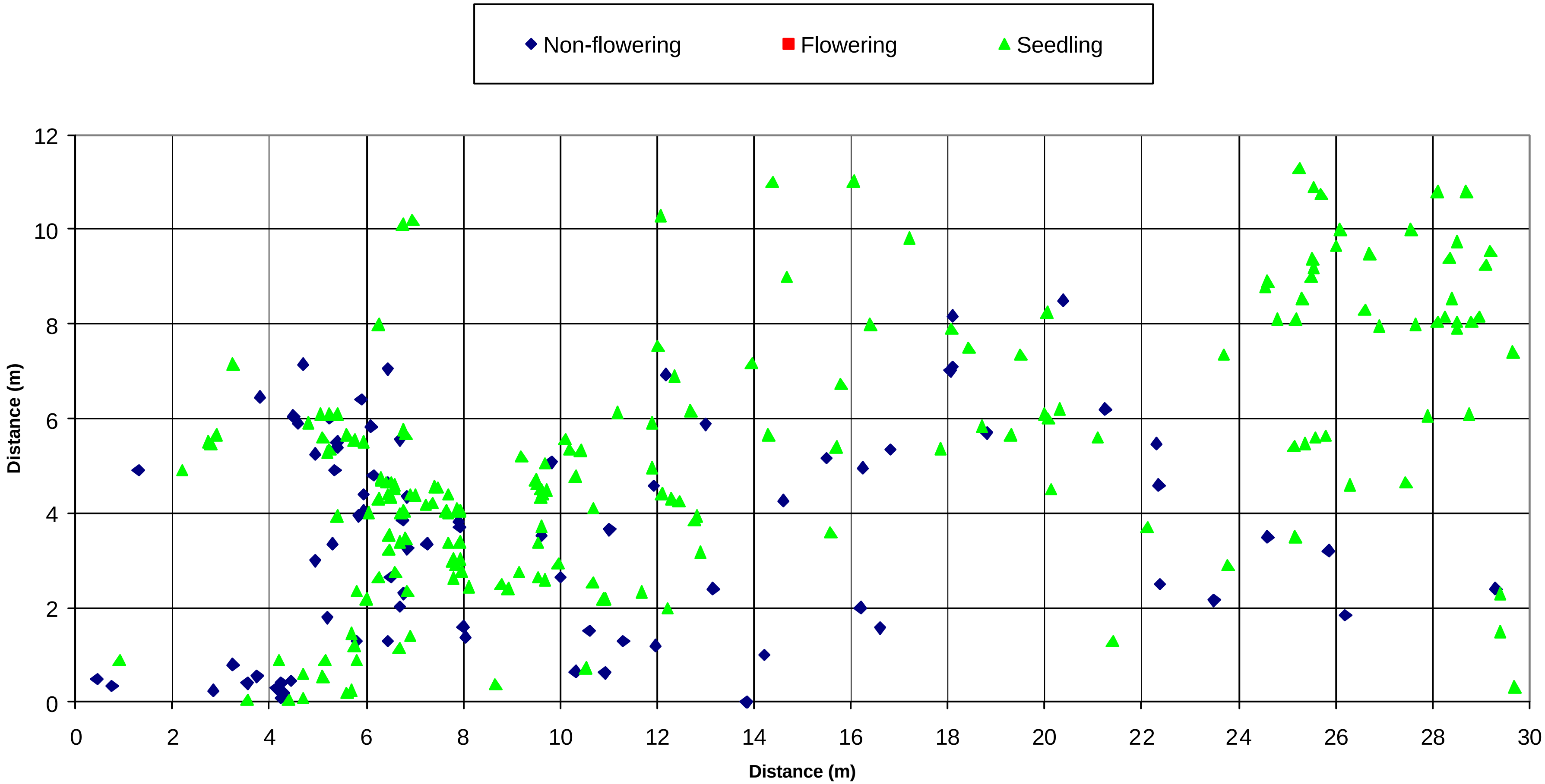


Figure 5.7. *Apium repens* in the north area of Port Meadow in 2000.

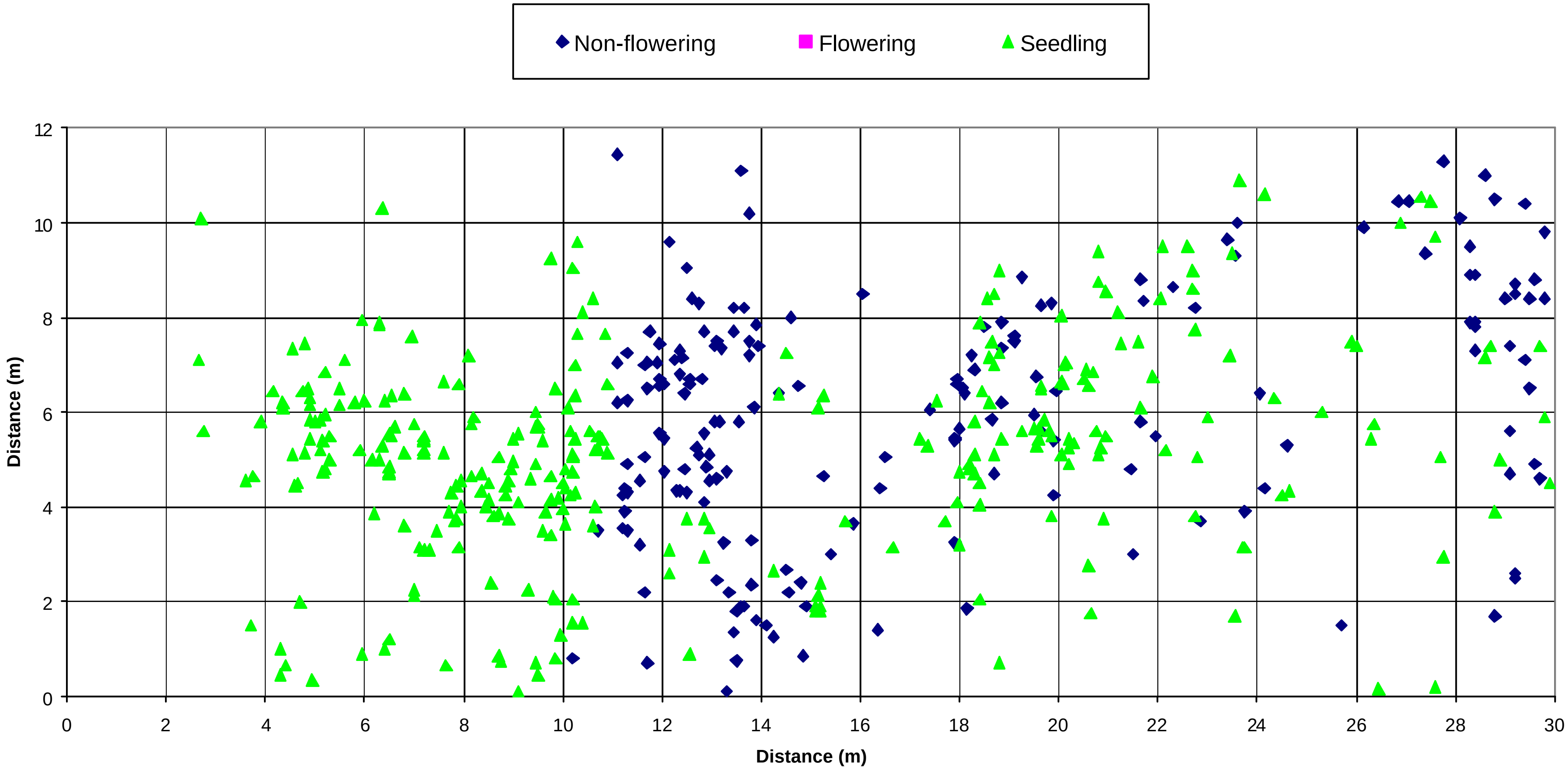


Figure 5.8. *Apium repens* in the north area of Port Meadow in 2001.

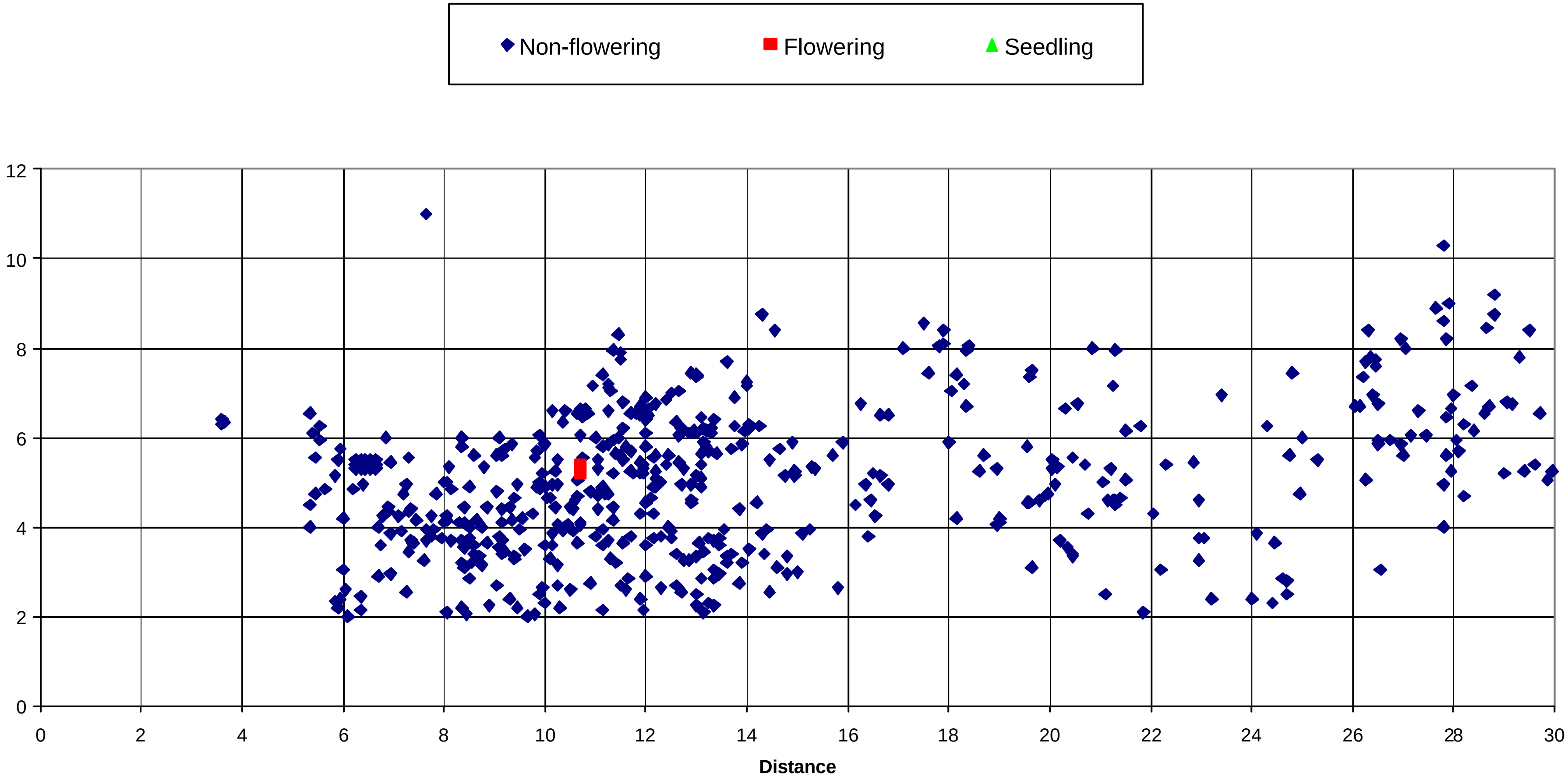


Figure 5.9. *Apium repens* in the north area of Port Meadow in 2002.

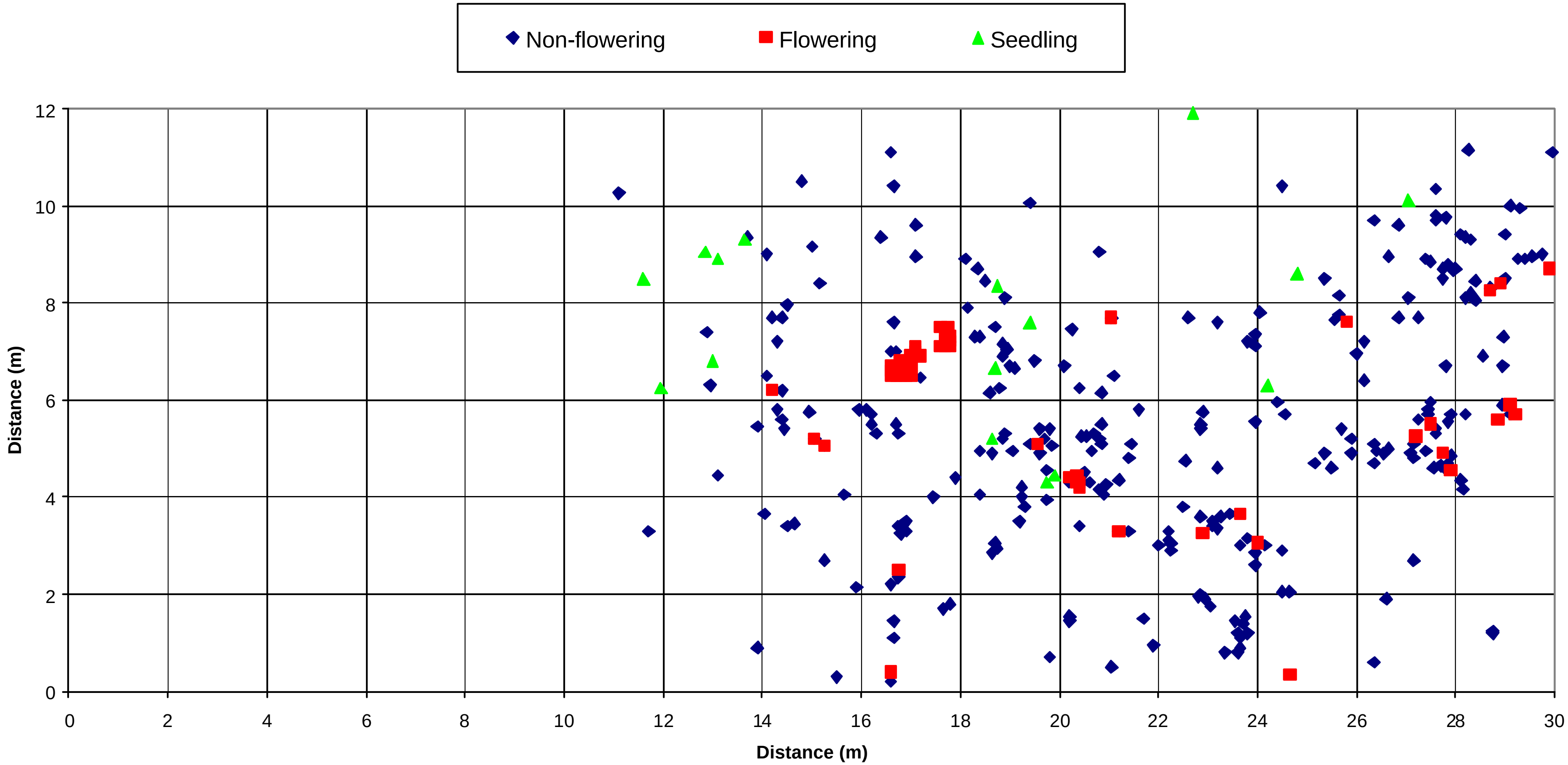


Figure 5.10. *Apium repens* in the north area of Port Meadow in 2003. The area to the left of 11 m was not recorded.

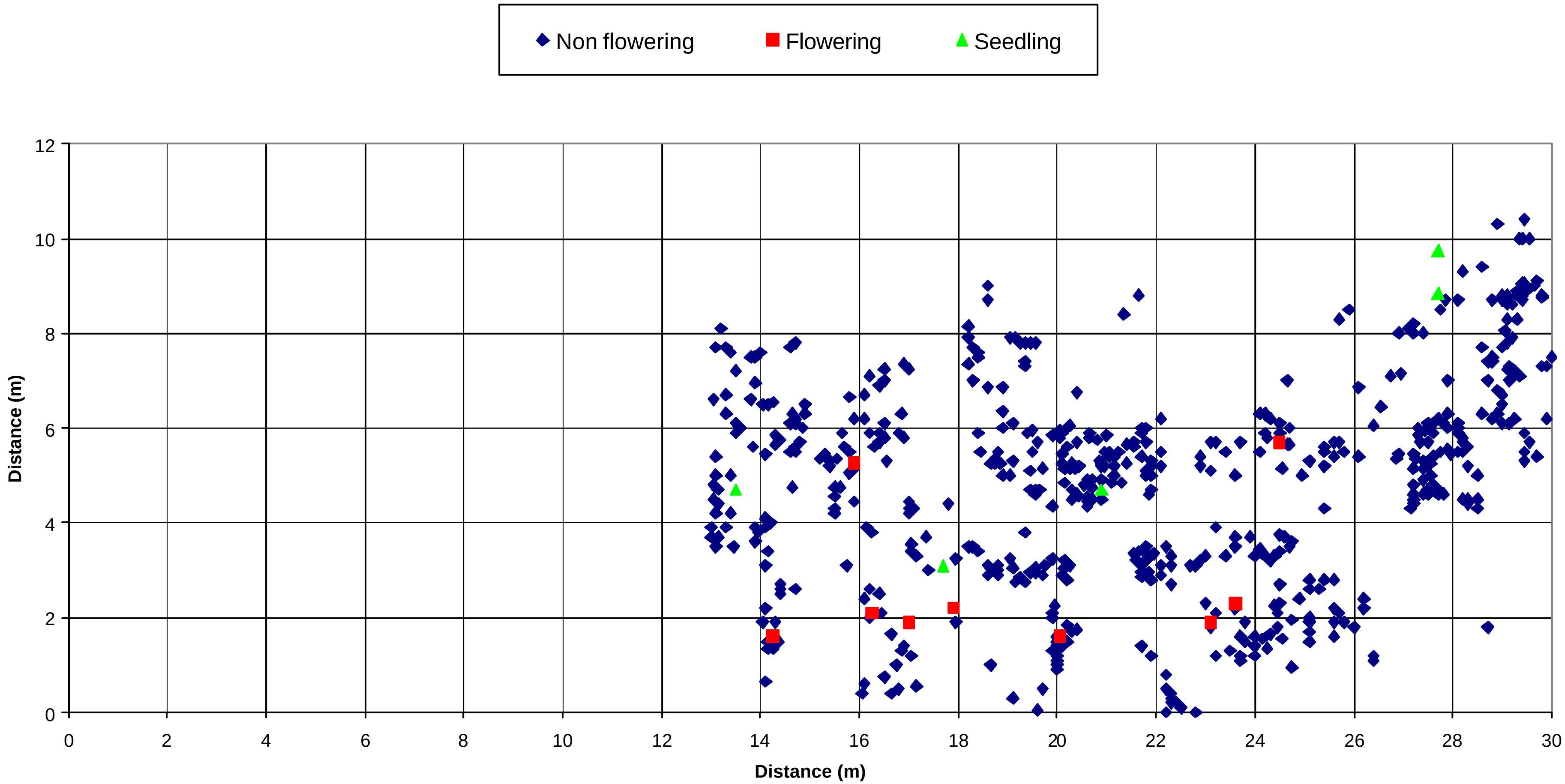


Figure 5.11. *Apium repens* in the north area of Port Meadow in 2004. The area to the left of 13 m was not recorded.

5.4.2 Mobility of *Apium repens*

Apium repens plants frequently appeared in areas where none had been the year before, eg in 1996 and 1997 **(Figures 5.2, 5.3 & 5.4)**. This mobility suggests that plants were arising from seed as well as spreading by stolons. Over the ten years *A. repens* has ceased to occupy the northwest part of the North population area. This is the most low-lying part, which retains water longest in the spring and, over the last ten years has lost its continuous sward cover of perennial species and consists of bare areas colonized by widely spaced ruderals and annual species of wet conditions **(Photo 5.1)** see Section 4.

The high mobility of *Apium repens* on Port Meadow contrasts with that at its other Oxfordshire sites (Burgess Field corner on Port Meadow, North Hinksey and Binsey Green). At these sites the patches of the plant are usually in the same position from year to year and increase gradually by vegetative growth; new patches are relatively infrequent despite abundant flowering in some years.

There was a substantial loss of mature *Apium repens* plants in the North population area in several years, most notably during the months preceding August 1998 and 1999, and to a lesser extent in 2001and 2003 **(Figure 5.5, 5.6, 5.8 and 5.10).** The loss of plants in 1998 and 1999 in particular was paralleled by widespread loss of mature plants of different species in the wet areas of Port Meadow **(Figure 4.9.)**. This was probably due to 'summer fouling' which occurs when flood water lies into May or June (See Section 4.4). However, in 2000 *A. repens* both survived and germinated well **(Figure 5.12);** whereas some MG13 species again declined, others, such as *Veronica scutellata* and *Mentha aquatica*, preferring wetter conditions, recovered. From 2001 to 2004 numbers of *A. repens* plants gradually built up.

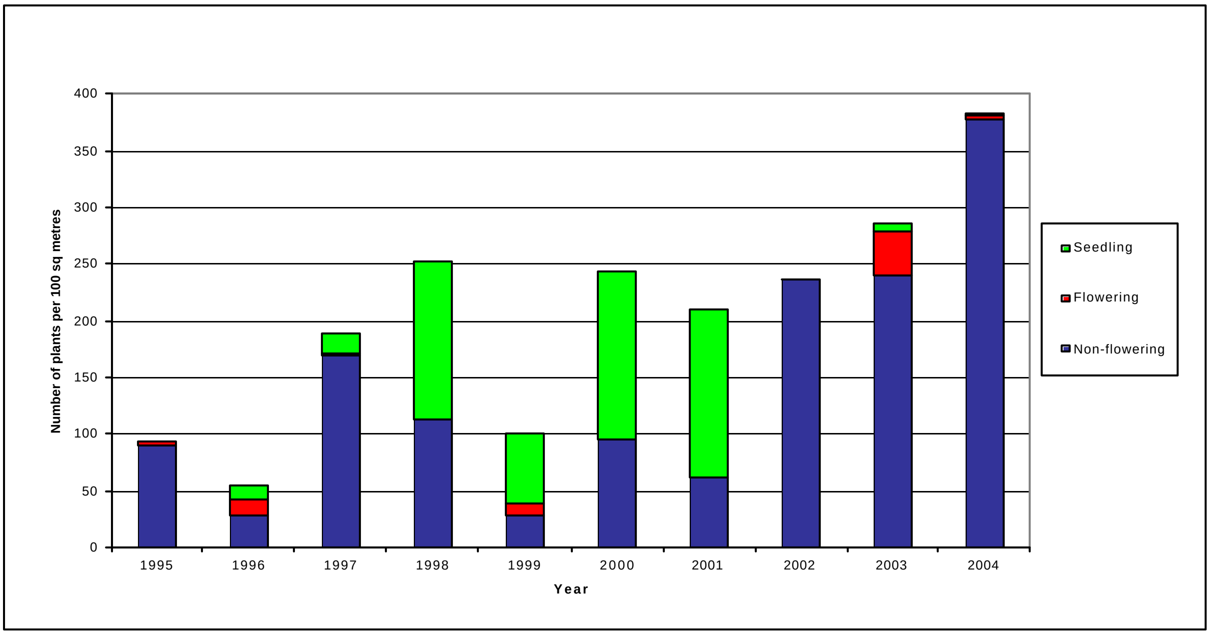


Figure 5.12. Number of *Apium repens* plants flowering, non-flowering and seedlings in the North and South population areas of Port Meadow combined, 1995 – 2004.

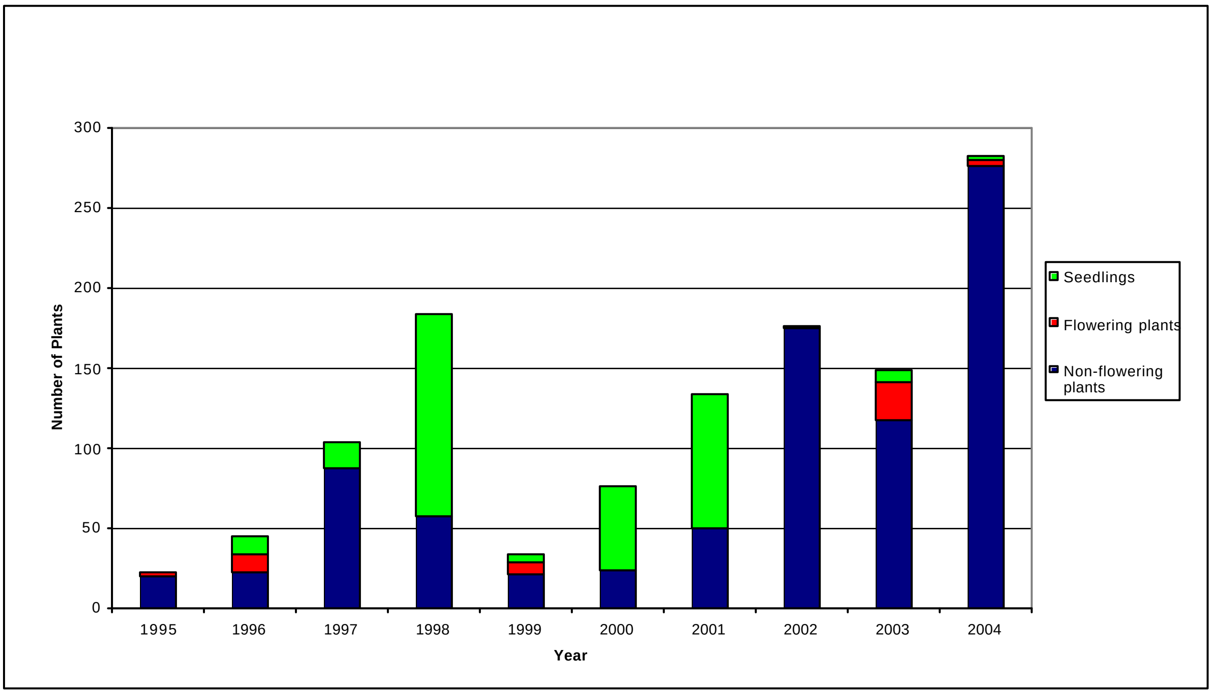


Figure 5.13. Numbers of non-flowering, flowering and seedling plants of *Apium repens* per 100 m² in the North population area of Port Meadow, 1995 – 2004.

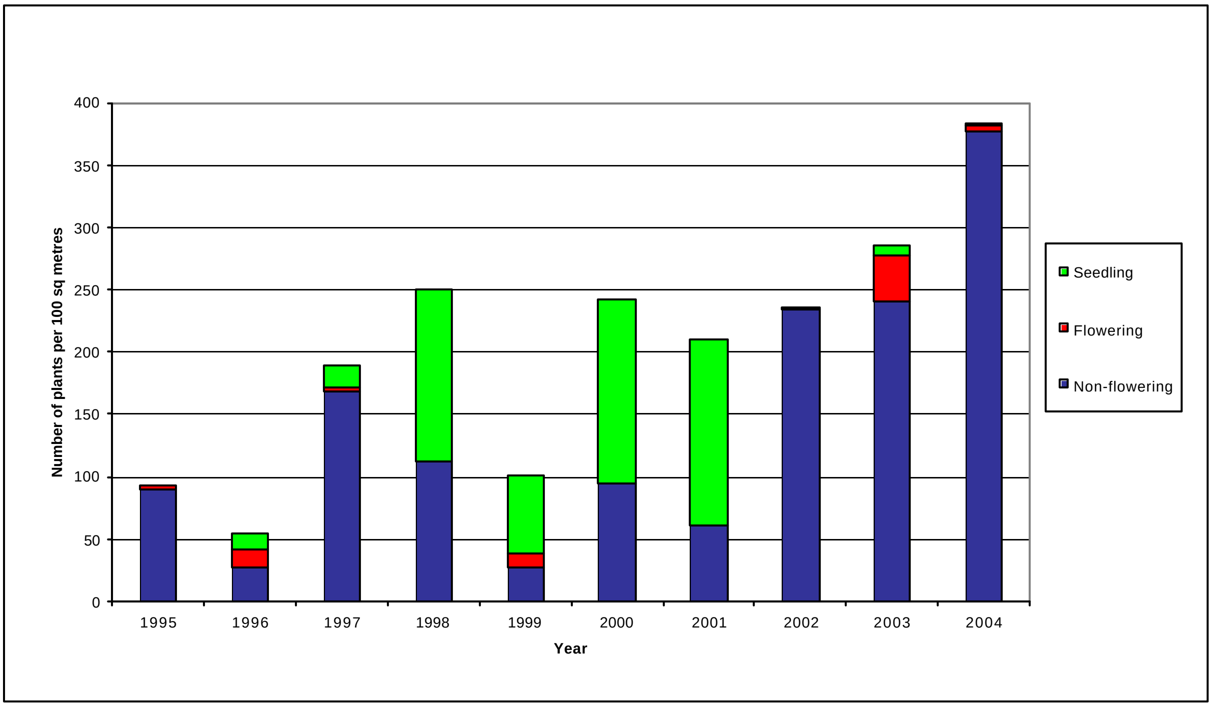


Figure 5.14. *Apium repens* mature non-flowering, flowering and seedling numbers per 100 m² in the South population area of Port Meadow, 1995 – 2004.

5.4.3 Germination of *Apium repens*

Germination during the summer was a feature of several years, notably 1998, 2000, 2001 and to a lesser extent 1999 **(Figure 5.12).** This pattern was partly correlated with high rainfall from March to June but there was some variation between North and South population areas. Large numbers of seedlings were present in 1998, 2000 and 2001 in the North population area and in 1999, 2000 and 2001 in the South population area. This presumably reflects very local variations in the conditions suitable for germination. As discussed in Problems with the Methods (section 5.3) the timing of the recording relative to the seedling development in any year affected whether plants were recorded as mature or seedling.

This pattern is also reflected in the behaviour of other species **(Figure 4.10.),** notably annuals and others which are able to behave as annuals such as *Plantago major*. The frequent germination on Port Meadow contrasts with behaviour at Binsey Green and North Hinksey **(Map 2.1)** where new patches of *Apium repens* are relatively few. It is thought that the germination is usually from seed in the seed-bank on Port Meadow and that the open conditions on the edge of the bare areas are suitable for establishment of seedlings. The more closed sward at Binsey Green, North Hinksey and Burgess Field corner would make establishment more difficult (and would also make any seedlings very hard to see).

5.4.4 Flowering of *Apium repens*

The frequency of flowering of *Apium repens* was quite consistent between the North and South population areas on Port Meadow but varied greatly from year to year **(Figure 5.13 and 5.14)**. There was no flowering recorded in either area in 1998, 2000, 2001 or 2002**,** and relatively high flowering in 2003 in contrast to other sites **(Figure 5.15)**.

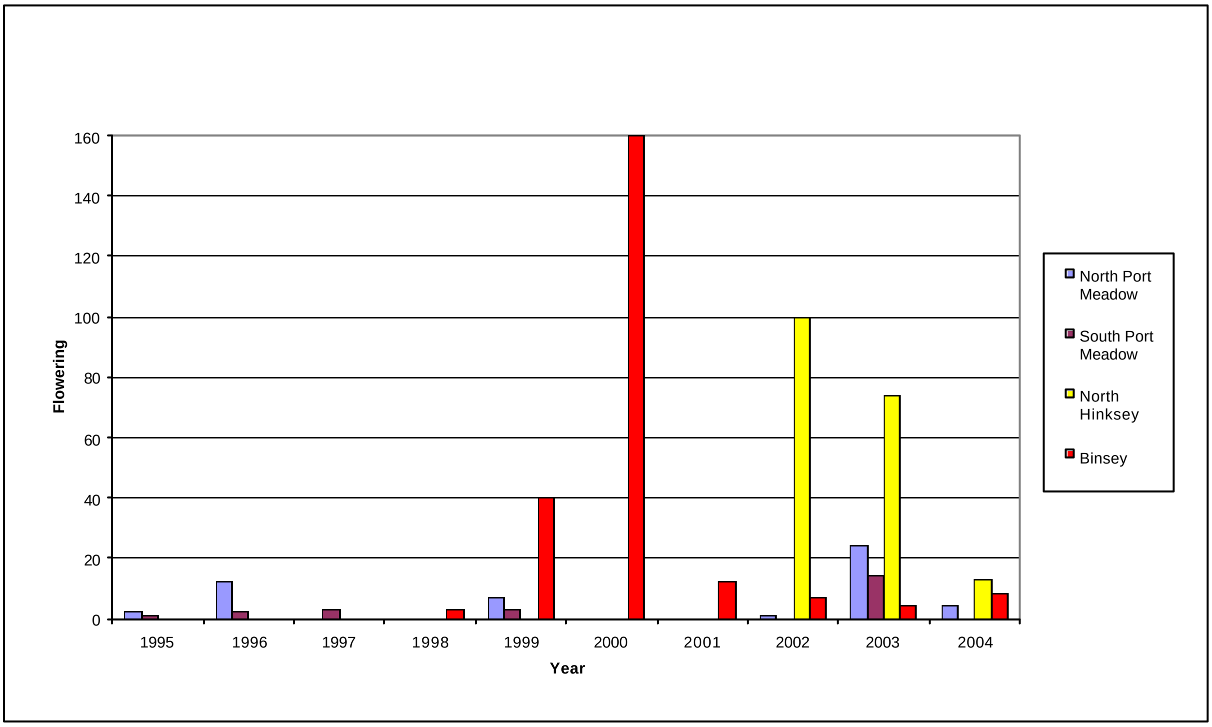


Figure 5.15. Number of flowering plants of *Apium repens* at the four populations in Oxfordshire, 1995–2004. Total number of inflorescences seen at Binsey Green and North Hinksey (both less than 100 m²), and number of flowering plants per 100 m² in the North and South population areas of Port Meadow.

At Binsey Green the flowering in 2000 was much higher than in any of the other years **(Figure 5.15).** Moreover flowering decreased in 2003 which was the best year on Port Meadow. This site is higher and drier than Port Meadow, and in dry years may be too dry for *Apium repens* to flower well. Flowering at North Hinksey was different again with high flowering in 2002 and 2003. Soil water conditions have not been studied on Binsey Green, North Hinksey or Burgess Field corner, but peizometers have now been located at these sites and more data will become available (Andy Dixon pers. comm.).

5.5 Conclusions from the *Apium repens* population studies

Apium repens varied greatly in numbers from year to year. Mature plants were lost, especially in years of summer floods which cause soil anoxia. The populations were very mobile, both spreading vegetatively and appearing from seed. The pattern of these movements probably depended on soil conditions due to the pattern of rainfall influencing the height of the water-table in the underlying gravel. *Apium repens* plants were most abundant in the areas of the sward adjacent to those which had lost continuous vegetation cover. These areas have a broken sward allowing germination of seeds and rapid spread by stolons. Germination was also very variable, with large numbers of seedlings in some years especially after 'summer fouling'. This presumably depends on soil moisture, but we were unable to prove this.

Apium repens is dependent upon hot, dry summers for flowering and replenishing the seed bank, as well as occasional disturbance by May/June floods for plant mortality and thus the provision of germination sites. Flowering was also variable with differences between the different sites suggesting that it is favoured by sunny warm conditions, but some sites become too dry in hotter years.

6 Experimental studies

6.1 Seed-set under self- and cross-pollination

6.1.1 Introduction

One of the major questions at the beginning of the project was whether *Apium repens* was setting seed on Port Meadow, and not hybridizing with *A. nodiflorum*. Nothing was known about pollination of *A. repens* or its seed-set, but it is likely that the flowers are pollinated by hoverflies as in other members of the genus. In *A. graveolens* seed set was between two and 20 times higher when hoverflies had access than when insects were excluded from the plants (Knuth 1906-1909). In order to address the questions of seed-set a simple experiment was conducted in 1996.

6.1.2 Methods

Fourteen volunteers each took one or two potted *Apium* plants and kept them in their gardens in and around Oxford for the summer. This enabled the different treatments to be well separated and the likelihood of cross-pollination between treatments to be minimized. The plants were placed in 3 inch pots and kept in trays with shallow water in full sunlight. Artificial pollination was carried out daily when the plants were in flower by dabbing a small paintbrush four times on appropriate inflorescences.

The following four treatments were set up:

1. Selfing within six clones of *Apium repens* from Port Meadow.
2. Crossing between seven different pairs of *A. repens* clones.
3. Selfing one typical and two meadow plastodeme clones of *A. nodiflorum.*
4. Hybridizing between *A. repens* and both typical and meadow plastodeme *A. nodiflorum.*

6.1.3 Results

Self-pollinated plants produced on average only one seed which germinated, while out-crossed plants produced 15-28 seeds which germinated. No success was obtained in crossing *Apium repens* with *A. nodiflorum* - the flowering season of the two species scarcely overlapped; *A. nodiflorum* flowers in July and August whereas *A. repens* came into flower in August and has been seen still flowering in November.

6.1.4 Conclusions

Apium repens sets more seed when cross-pollinated and is therefore likely to benefit from an abundance of possible pollinators, possibly small hoverflies. It is unlikely to hybridize with *A. nodiflorum.*

6.2 Preliminary submergence experiment

6.2.1 Introduction

The behaviour of *Apium repens* when subjected to summer flooding was not known but it was thought to be intolerant. It was decided to test by comparing the survival of *A. repens* and *A. nodiflorum* under conditions of deep and shallow submergence compared with no submergence.

6.2.2 Methods

In 1996 a simple experiment was set up by Kathy Warden at the University of Oxford Botanic Garden. She planted young *Apium repens* and *A. nodiflorum* plants into 3 inch pots. These were selected at random and placed on bricks in plastic tanks **(Photo 6.1)**.

Three treatments were arranged:

1. Pot placed at base of tank - water covered the soil surface to a depth of 15 cm.
2. Pot on one brick – water covered the soil surface to a depth of 6 cm.
3. Pot on two bricks - the water covered the bottom 2 cm of the pot with the soil surface 5 cm above the water level.

There were seven replicates of each treatment for each of the two species.

6.2.3 Results

After six weeks most of the deeply submerged *Apium repens* plants and some of the shallowly submerged plants had come loose from the soil, floated to the surface of the tanks and did not flower **(Photo 6.1).** Plants which remained anchored were pale and did not grow. On the other hand all the *A. nodiflorum* in all the different depths grew well, extended above the water and flowered.

6.2.4 Conclusions

This preliminary experiment showed that *Apium repens,* unlike *A. nodiflorum,* would not be likely to tolerate summer flooding. It was unexpected that *A. repens* lost its root attachment. In nature this might enable flooded plants to be washed away and reach other localities, possibly more suitable for growth.

Photo 6.1. A tank of the submergence experiment at the University of Oxford Botanic Garden. The two plants at the far end of the tank are *Apium repens* which are in the process of coming loose from the soil and floating to the surface, the *A. repens* towards the front left is more attached. The three *A. nodiflorum* plants, centre and front, are growing tall. Photo by C.R. Lambrick.

7 Habitat requirements and strategies

7.1 Physical requirements of *Apium repens*

In northern Europe *Apium repens* is mostly found at low altitude, while in Bavaria it occurs in hill conditions, and in the Atlas Mountains of Morocco is found at 2,300 m.

The soils in which *Apium repens* grows are neutral to somewhat alkaline (Ellenberg value R7). Soils may be organic, peaty, silty or sandy. *Apium repens* tolerates quite high levels of nitrogen (Ellenberg N7) and slightly saline conditions, and requires wet (F9) soils. These requirements are confirmed by British and Continental findings.

7.2 Vegetation composition

The vegetation on Port Meadow where *Apium repens* grows did not closely match any of the National Vegetation Classification types. Over the period of ten years there were striking changes from vegetation resembling Mesotrophic grassland (MG13) and Sand Dune (SD17) vegetation types to various forms of Open Vegetation. Significantly *Apium repens* prefers to grow in the intermediate zone between the closed and open vegetation types.

At the other Oxfordshire localities *Apium repens* grows in closed semi-improved mesotrophic grasslands. In Essex it appeared on a newly exposed soil and spread rapidly. These vegetation types in which *A. repens* grows in the UK are similar to those in which it is found in the Netherlands and Belgium. However, further south *A. repens* is found in a range of habitats including recent river shingle in Slovenia, and in Bavarian hill pastures.

7.3 Plant associates of *Apium repens*

The closed sward in the North and South population areas is normally dominated by *Agrostis stolonifera, Eleocharis palustris, Alopecurus geniculatus, Potentilla anserina* and *Mentha aquatica*. In wetter areas these species are accompanied by *Oenanthe fistulosa, Myosotis scorpioides, Veronica scutellata, Ranunculus flammula* and *Glyceria spp.*; while drier areas have *Ranunculus repens* and *Trifolium repens*. However areas which have become open through soil anoxia have a range of ruderals, including *Juncus bufonius, Veronica catenata, Plantago major, Persicaria maculata, P. lapathifolium, Polygonum aviculare, Chenopodium spp.* and *Rorippa palustris*. *Ranunculus aquatilis* is also frequent as a seedling on wet mud, but does not usually survive the summer.

7.4 Companion species

No close companion species of Apium repens was identified. However, in its requirements for moisture *A. repens* is similar to *Veronica scutellata, Oenanthe fistulosa, Myosotis scorpioides, Galium palustre, Ranunculus flammula* and *Veronica scutellata*. These MG13 species can all cope with annual fluctuations in soil moisture, including winter flooding. However *A. repens*, and to some extent *Veronica scutellata*, recover particularly fast after ‘summer fouling’.

7.5 Grazing, vegetation height, light and openness

Ellenberg's values indicate that *Apium repens* requires the high light (L9) conditions of a short sward. Evidence from various sites, especially Grootvogel north, suggests that *Apium repens* cannot tolerate tall swards (section 2.2). Under natural conditions it therefore depends on grazing, water-table fluctuations or soil anoxia to maintain a suitably low vegetation height. Grazing on Port Meadow is by horses in the winter and horses and cattle in the summer. Two of the Dutch sites were cattle grazed. Donkeys are used at one site in Belgium (A. Ronse pers. comm.). Grazing by geese also occurs on one site, but Canada geese were thought to damage *A. repens* at one of the Oxford introduction sites (New Marston). In Belgium mowing appears to maintain a suitable sward in Vreijbroek Park (Section 2), as it does on mown graves in a cemetery in Vienna (A. Ronse pers. comm.).

Apium repens is found in both open and closed swards. On Port Meadow it does best at the transition between closed sward and the bare soil areas that hold water longest. These may be areas where germination and establishment are easiest. *Apium repens* does not grow in the central parts of these bare areas which become very unstable with wet mud usually turning to dry dust in August. *Apium repens* survives and spreads at Burgess Field corner, which becomes muddy in winter, and in closed swards in Binsey Green, North Hinksey and grazed sites in the Netherlands. *Apium repens* also grows in slightly open conditions in Belgium on open gravel paths in the Vreijbroek Park and the sandy edges of ponds with fluctuating water levels. At Walthamstow Marshes it grows on a ditch-ledge (berm) which was re-profiled in 2003 and has not yet become densely vegetated. In Slovenia it grows on fresh river shingle.

7.6 Flooding, winter and summer

Winter flooding, sometimes for several months, is normal at the four UK sites and also at the sites seen the Low Countries. It was pointed out in the Netherlands that winter flooding has the effect of protecting plants from frost, and there was some evidence at Oostduinkerke that *Apium repens* had suffered from frost damage when exposed to the air by low water levels.

Summer submergence with soil anoxia is not tolerated by *Apium repens*, as suggested both by the submergence experiment and the loss of the plant on Port Meadow following early summer flooding. However, soil anoxia (fouling) and the death of many species increases the openness of low-lying vegetation and is beneficial for *A. repens* because it provides bare ground which allows swarms of seedlings to germinate.

The experiment suggested that *A. repens* becomes less firmly rooted when submerged during the summer and thus may become dislodged and float to new sites. Observations by Anne Ronse in northern Italy indicate that *A. repens* can survive in streams under fast flowing water – which would presumably be well oxygenated.

7.7 Flowering and seed-set

Flowering of *Apium repens* is late in the season, August to November, and varies dramatically between sites and years. In most years more flowering and seeding plants were found on Binsey Green and North Hinksey than on Port Meadow, these sites are currently drier, and perhaps therefore warmer, than Port Meadow. However the Burgess Field corner site on Port Meadow is drier than the North and South population areas, but this population has never been observed to flower.

Seed set is not high. *Apium repens* sets more seed when the plants are out-crossed but seed production does not happen every year on Port Meadow.

7.8 Survival strategies

Apium repens seems to have a range of strategies. It can behave as a perennial, spreading rapidly by prostrate stems rooting at each node. It sometimes goes without flowering for several years. The seed appears to be long-lived in the soil. After mature plants are killed by 'summer fouling' the species can regenerate in the bare ground that follows. If this happens in consecutive years *A. repens* appears to behave as a ruderal. It is possible that *A. repens* is more drought tolerant than the other species in MG13 and its habit of rooting at the nodes might give it a competitive advantage in this dynamic situation. This variation of behaviour may be crucial in enabling *A. repens* to exploit the unstable conditions on the flood-plains of large rivers.

7.9 Seed longevity – not done

It became apparent that the survival of seed in the soil was important for *Apium repens* particularly when, in 1998, all the observed mature plants on Port Meadow succumbed to prolonged flooding. Variables such as temperature, flooding and availability of oxygen and soil nutrients are known to have considerable effect on longevity of seed in the soil (Bekker and others 1998, Hötzel and Otte 2001). It was decided to set up an experiment burying seed in mesh bags in soil in flower pots. The pots would be buried at different depths in two areas subject to different amounts of winter flooding. It was estimated that 2000 seeds would be needed for testing viability and the experiment itself. Kathy Warden at the Oxford University Botanic Gardens multiplied up plants and for one season 400 seeds were collected. However, the plants succumbed to root aphid attack and could not be maintained. Wakehurst Place (Royal Botanic Gardens, Sussex) was unable to bulk up seed at that time and the experiment was abandoned.

7.10 Grazing experiment – not done

The palatability of *Apium repens* was questioned in view of its presence in grazed habitat. Evidence to date suggested that *A. repens* is more palatable than the famously poisonous fool's water-cress, *A. nodiflorum*, and that this might affect its susceptibility to grazing. Riddelsdell (1917) and personal experience of growing the plants indicated that *A. repens* is palatable to slugs and also to root aphids. Quentin Cronk reported (pers. comm.) that *A. repens* tastes like parsley without the bitter aftertaste of *A. nodiflorum*. Moreover, in the Atlas Mountains of Morocco *A. repens* is sought out and eaten by Barbary apes (G. Drucker, in Grassly and others 1996).

Accordingly it was felt that an experiment to contrast the effects of different levels of cattle grazing on *A. repens* and *A. nodiflorum* would be informative. It was hoped to show the different effects on the two species and the meadow plastodeme of *A. nodiflorum* as well as the optimal sward height for *A. repens* to grow and set seed.

An unimproved pasture in the flood-plain adjacent to the River Thames at Chimney Meadows NNR, Oxfordshire, **(Map 2.4, p 28)** was selected. The sward here was a mosaic of tall *Juncus inflexus* and short sward similar to that at Canisvliet Reserve, the Netherlands **(Photo 2.5.)**. English Nature which owned the land, agreed to fund the necessary fencing, but changes in land management by the new tenant, the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust, made an experiment impractical.

8 Threats and factors leading to loss or decline

8.1 Habitat destruction

Historically, *Apium repens* has suffered from loss of suitable habitat, for instance at Witney where the field become too dry and was improved. Cessation of grazing probably caused the vegetation to become too dense at the Line Ponds in Yorkshire, and also to have suppressed *A. repens* at Walthamstow Marsh. Habitat loss is no longer a threat as all *A. repens* four sites are managed sympathetically. Through Higher Level Stewardship there is now the potential for arable to be reverted to permanent pasture especially in the flood-plain (Department of the Environment, Food and Rural Affairs). The tolerance of *A. repens* to high nutrient levels may make it a suitable species for introduction to former arable land.

8.2 Environmental conditions – summer flooding

Our studies have shown that the vegetation on Port Meadow is prone to sharp changes following spring/early summer flooding. This causes widespread death of mature plants. In the years we observed it there was substantial germination from the seed bank. However if the seed production is not sufficient this could lead to depletion of the seed-bank and so possible failure of the population to recover in future. It might be useful to set up a warning system so that when such a flooding event extends into May, the possibility of letting water off the meadow could be considered, see section 9.1. However, a balance must be struck here because soil anoxia causes grass-kill events which are recruitment opportunities for *Apium repens*. Winter flooding occurs at the other *A. repens* sites and it is hoped this would continue in the future.

8.3 Management - grazing

The level of grazing on Port Meadow appears currently to be favourable for *Apium repens*, however if this level were to rise or fall substantially, then the situation might not be favorable. Presently there is permission for many more animals to be grazed than are counted each year (figures are recorded by Oxford City Council) and some rights are being let to dealers. Changes to the agri-environment payments might result in an incentive for more of these grazing rights to be taken up. Conversely, if it became uneconomic to graze animals on Port Meadow then the sward would be likely to become too dense for *Apium repens*. At the other sites the level of grazing can be controlled.

8.4 *Crassula helmsii*

The highly invasive alien *Crassula helmsii* was found at the north end of Port Meadow in September 1998 by Keith Payne of English Nature. It already extended over several square metres around the edge of Long Pond by the Jubilee gate and in 2004 had spread west into Wrens Pond. Studies in the New Forest have shown it to be tolerant of prolonged summer drought and there is a possibility that it could invade the *Apium repens* areas.

The Oxford City Council entered discussions with the Wolvercote Commoners Committee over ways to combat *Crassula helmsii*. Treatment with glyphosate was agreed as this is not harmful to grazing animals. The area of *Crassula* expanded during 1999 and 2000, but thereafter has reduced though it has not been eliminated. Eradication of the species was not achieved because the plants remained covered by water for long periods during 1999, 2000, 2001, 2002 and 2004 making it difficult to spray repeatedly.

8.5 Residential development at Binsey

In 2004 the owners of the farm at Binsey applied for permission to develop the site for residential use. This would mean there would be a threat to the new dwellings from winter flooding. Actions to protect new buildings from floods might result in Binsey Green becoming too dry for *Apium repens*. Increased recreational pressure from dog walkers might prohibit grazing animals and thus allow the area to become too densely vegetated for *A. repens.*

8.6 Flood relief proposals

Options for flood relief for Oxford are under discussion, they include new and two-stage channels to take water more rapidly round the West and South of the city. The Environment Agency does not expect them to change the seasonal patterns of water-levels on Port Meadow. One possible element is to build a new two-stage channel leaving the Thames adjacent to Port Meadow, crossing Binsey Green and the North Hinksey *Apium repens* sites. Alternatively a new channel may leave the Thames at the Seacourt Stream. The Environment Agency is aware of *A. repens* on all three sites, Port Meadow, Binsey Green and North Hinksey. Two-stage channels can be beneficial for wildlife in the UK (Morris *et al* 2004) and for *A. repens* in the Netherlands (W. van Wijngaarden in Lambrick and McDonald in prep).

9 Conservation action for *Apium repens*

9.1 *In situ* – sites and their management

9.1.1 Port Meadow

Conditions on Port Meadow appear to be generally favourable for *Apium repens*. In years when there has been soil anoxia other species die back creating opportunities for *A. repens* to germinate from the seed-bank. This process is probably beneficial for the maintenance of the population and genetic variation of *A. repens*, but it should not occur too often so that the seed-bank is depleted. The vegetation in low-lying areas has become more open and has changed from resembling MG13 or Sand Dune types to more like Open Vegetation. This has not adversely affected the population or flowering of *A. repens*, and indeed reflects vegetation types where it is found in continental Europe, for instance dune slacks and mobile river gravels.

It might be useful to set up a warning system, so that when a flooding event extends into May, the possibility of letting water off Port Meadow could be considered. This would also require dredging channels which can be controlled leading from the low-lying areas to the river. Note: Port Meadow is a Scheduled Ancient Monument and permission might be needed from English Heritage.

9.1.2 Water-level Management Plan

A Water-level Management Plan for Port Meadow, Wolvercote Common and Wolvercote Green SSSI was drawn up by the Environment Agency, in 1997. Unresolved issues include the requirements of *Apium repens* and the potential to increase winter flooding. These are being addressed by the Environment Agency which has funded David Gowing's hydroecological study, as well as further hydrological work by Andy Dixon arising from the flood relief studies.

9.1.3 Binsey Green County Wildlife Site

The habitat here generally appears favourable for mature plants, but in 2005 it seemed to be undergrazed and some patches of *Apium repens* were not re-found. The current regime of grazing by cattle in summer, with topping to control thistles and nettles as necessary, should be continued. There is, however, little open ground and it is likely that more intense grazing with some poaching would give the open conditions conducive to germination.

9.1.4 North Hinksey

Again the habitat here appears favourable for vegetative spread and flowering. At least some germination appears to have taken place as Anne Ronse pointed out a few isolated rosettes. Continuation or intensification of grazing by horses (or by cows) in summer is recommended.

9.1.5 Walthamstow Marshes SSSI

It will be useful to continue to monitor the effects of low-density cattle grazing on the *Apium repens* population and surrounding vegetation. If the grazing is not sufficient to control growth of tall vegetation in the *A. repens* area, then grazing should be increased, or supplemented with cutting, to provide the light and some disturbance which are the conditions preferred by *A. repens* to germinate and flourish.

9.2 *Ex situ* – seed-bank conservation

It is important to contribute to the Millennium Seed Bank at Wakehurst Place, Royal Botanic Gardens, Sussex, by adding material from Binsey Green CWS and Walthamstow Marshes SSSI. Living material has been difficult to maintain due to root aphids and is no longer held at the Oxford University Botanic Gardens.

9.3 Annual monitoring

The current recording of *Apium repens'* populations and vegetation is essential and should be continued.

9.3.1 Port Meadow SAC

The current monitoring of *Apium repens* and other species in the North population area gives a valuable data series and should be continued. The existing ten-year run shows substantial changes in species frequency and variation in weather conditions but the data set is not long enough to predict responses of *A. repens* and other species to these variations, particularly flooding. The populations in the South area and Burgess Field corner should be monitored annually in less detail. Guidance for assessment of *A. repens* (Appendix 6). (www.jncc.gov.uk)

9.3.2 Binsey Green County Wildlife Site

An annual check should be carried out in late August to relocate the patches, measure them and count inflorescences. The condition of the sward in the different patches should be noted, ie height, openness, associated species (species within one metre, measured on a DAFOR scale) and negative indicator species should be agreed. A species list for the field should be made periodically (perhaps every four years).

9.3.3 North Hinksey, Oxford

An annual check should be made in late August, recording the length and breadth of the patch and a count of inflorescences. The condition of the sward should be noted including height and prevalence of negative indicators such as thistles and nettles.

9.3.4 Langel Common, Witney

The scrape at this site was probably not rotavated in 2004 and needs to be rotavated and monitored annually in August. The whole field should be monitored periodically and if a new scrape is made this should also be monitored.

9.3.5 Walthamstow Marshes SSSI, Essex

This population should be monitored annually, and the suitability of the associated vegetation assessed and action taken as necessary.

9.4 Further introduction site

The original Species Action Plan proposed five sites for *Apium repens*. Future reintroduction at Langel Common, Witney, might be considered if the plant does not return spontaneously but a suitable grazing regime should be established first. A second site on the River Lea in Essex would be appropriate to extend the Essex genotype given the recent appearance of the plant at the Walthamstow Marshes.

10 Future research

10.1 International collaboration

There is extensive experience and interest in *Apium repens* in other countries, especially Belgium, France, Slovenia and Spain. All would benefit from a continuing exchange of information and ideas.

10.2 Vegetation studies

Floristically the studies on Port Meadow show dramatic variations in composition of the sward. The hydroecological study by Gowing and Youngs (2005) recommended further recording because 2003 was an unusually dry summer. Continuing the vegetation recording would help develop an understanding of the conditions under which the closed sward becomes open. It is suggested that recording under the same protocol be continued in the North population area of Port Meadow, and a repeat of the 2003 methodology be undertaken when appropriate.

10.3 *Apium repens*: biology and ecology

10.3.1 Grazing

At the beginning of the study a grazing experiment was planned. *Apium repens* grows in the wild under a wide range of vegetation conditions from closed to very open swards. However, a short sward, either grazed or cut, is a feature of all the sites where it is flourishing, while on sites where the sward had become tall. *A. repens* was either etiolated and declining (Grootvogel North) or lost (de Plate, Holland). This provides sufficient evidence of a requirement for a short sward for grazing experiments not to be needed at this stage. Grazing is an important variable on Port Meadow which cannot be easily controlled as the area is common land.

10.3.2 Frost sensitivity

Seasonal flooding occurs at all the natural *Apium repens* sites that have been studied and it has been suggested that the plant may be frost sensitive since if it is not covered by water it can be killed back in hard winters. This has still to be tested experimentally and it would be informative to do so.

10.3.3 Soil nutrient levels

Evidence from the hydroecological study, the Dutch sites and the Ellenberg indicator values suggest that *Apium repens* is tolerant of nitrogen and salt levels which are somewhat higher than usual in inland unimproved soils. Thus the potential dangers considered at the beginning of the study from nutrient seepage and diffuse pollution do not appear likely to threaten *A. repens* at present and therefore do not require investigation at this stage.

10.3.4 Demography

The study of population dynamics of *Apium repens* on Port Meadow showed that in different years there was a wide variation in the numbers of seedlings and the extent of flowering. The very varied weather in different years over the duration of the study showed that *A. repens* was able to survive by germination from the seed bank and vegetative spread. Provided that enough seed is set in some years to replenish the seed bank, it is likely to be able to continue to do so. However, details of the time of germination, flowering, pollinators and seed set were not studied, and this would be a useful addition to the current information about the species. A demographic study should be made of individual plants through the season to determine the time of germination, flowering and seeding and their responses to the conditions in the five UK sites (including Burgess Field corner on Port Meadow). Anne Ronse in Belgium has developed techniques which it would be useful to follow so that results are comparable (Ronse and Vanhecke 2004).

10.3.5 Seed longevity

Apium repens, at least when subject to soil anoxia events on Port Meadow, depends on having a large seed bank. The longevity of seeds in the soil may be critical to its long term survival and therefore should be investigated although information from the Netherlands (Wim van Wijngaarden pers. com.) suggests that it has the capacity to survive in the soil over many years and the small ness of the seeds indicates that they might survive in the seed bank for a long time (Thompson and others 1998).

10.3.6 Chromosome numbers

Professor Clive Stace has indicated his willingness to evaluate *Apium repens*' chromosome number.

10.3.7 Physiological and morphological adaptations to flooding

These may include such features as aerenchyma formation, under-water photosynthesis and/or switching from aerobic to anaerobic metabolism. Such adaptations have not been studied and might provide insight into how *Apium repens* is able to survive in a range of physical conditions.

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Appendix 1 Species Action Plan

1. 1 Legal status of *Apium repens*

Creeping marshwort *Apium repens* (Jacq.), Lag. is listed in Annexes II and IV of the *European Union Directive on the Conservation of Habitats and Wild fauna and Flora* (the 'Habitats Directive') and also in Appendix I of the Council of Europe's *Bern Convention*. It is also listed on Schedule 8 of the Wildlife and the Countryside Act, 1981.

1. 2 Action Plan objectives and targets

1. Maintain the population at the Oxfordshire Site. Revised.

2. Restore to two Thames Valley sites by 2005. Revised from five sites.

Proposed actions

1 Policy and legislation

Encourage landowners of former sites where this species could be re-established in Oxfordshire to enter in to the Upper Thames Tributaries ESA scheme, and encourage appropriate management of these sites. (ACTION: ADAS, EN).

2. Site safeguard and management

Ensure management plans for the current SSSI take account of the ecological requirements of this species. (ACTION: EN)

3. Species management and protection

Encourage management of all former sites to enable any buried seed which is still viable to germinate. (ACTION: EN).

If natural regeneration is unsuccessful, re-introduce cultivated plants to suitable sites in the Thames Valley (ACTION: EN).

Keep plants in cultivation and collect seed, where possible, for the national seed bank at Wakehurst Place. Plants (of both genotypes) have already been collected in the absence of viable seeds and are in cultivation at Oxford University Botanic Garden (this was true when the Action Plan was written, but not currently).

4. Advisory

Ensure that Oxford City Council is aware of the presence, legal status and appropriate management procedures needed to protect and maintain the current population.

5. Future research and monitoring

Carry out a thorough survey and regular monitoring of former sites to establish whether any suitable habitat remains for re-introduction or translocation. (Action EN, JNCC)

Promote research in the ecological and habitat requirements of this species relative to *A. nodiflorum*, to enable correct management procedures and re-introduction. This should include its reproductive biology and possible pollinators, tolerance of grazing and the effects of periodic submergence. (ACTION EN, JNCC).

Promote further genetic research to clarify the taxonomy of this species. (ACTION EN, JNCC).

Encourage research on this species on the ecology and conservation at an international level and use the information and expertise gained towards its conservation in the UK. (ACTION EN, JNCC).

Pass information gathered during the survey and monitoring of this species to JNCC or BRC so that it can be incorporated in the national database (ACTION EN, JNCC).

Provide information annually to the World Conservation Monitoring Centre on the UK status of the species to contribute to maintenance of an up-to-date global Red Data List. (ACTION EN, JNCC).

Communications and Publicity – none proposed.

Appendix 2 Vascular plants associated with *Apium repens* at two British and seven current and recent Dutch and Belgian sites

PM = Port Meadow (% occurrence in quadrats in the north and south populations); BF = Burgess Field corner, on Port Meadow (percent cover); Cv = Canisvliet (DOMIN scale for single quadrat); O1, O2 and O3 Oostvoorduinen pond A (DOMIN scales for three quadrats); OB Oostvoorduinen pond B (presence of associated species); GN = Grootvogel north (estimated DOMIN scale for associated species); GS = Grootvogel south (presence of associated species); DP = De Plate (species found in area where *A. repens* was recently recorded); Vp = Vrijbroekpark (DOMIN scale for single quadrat); Vg = Vroongronden (presence of species in zone around pond where *A. repens* was recently present). + = records made by Leo Spoormakers of species associated with *A. repens* in 1991.

Species arranged according to frequency of occurrence with *A. repens;* sites arranged according to similarity.

	PM	**BF**	**Cv**	**O1**	**O2**	**GN**	**GS**	**DP**	**Vp**	**O3**	**OB**	**Vg**
Plantago major	95	15	1	5	1	1	1	+	1		1	1
Agrostis stolonifera	98	10-15	7	7	7		1	1	8	8	1	
Juncus articulatus	47	<1	6	2	1	5	1	1			1	1
Apium repens	30	50-55	5	2	5	2	1		4	1	1	
Trifolium repens	92	1	6	7	1	2		+	9		1	1
Ranunculus repens	40	1	5	1	1	4	1		1		1	
Eleocharis palustris	90	<1	3	6	5	7		+		9		
Mentha aquatica	95		2	2	6	7	1				1	1
Potentilla anserina	96	3		6	3		1	1		4		
Trifolium fragiferum	7	1	7				1		1			1
Holcus lanatus				3	1	4			5		1	1
Juncus bufonius	28		2					1			1	1
Cardamine pratensis	23		2			4	1		8			
Galium palustre	10		3			2			1			1
Taraxacum officinale agg.	7	<1	1					+	2			
Carex hirta		2	1		1				1		1	
Bellis perennis	2	<1	1					+	2			
Poa trivialis		1	1			7			7		1	
Poa annua		<1							1		1	1
Alopecurus geniculatus	93	2-5	1									
Myosotis sp.	83		1									1
Lolium perenne	3	5							8			
Juncus inflexus			3			1					1	
Festuca arundinacea			1			2	1					
Carex disticha			1			2		1				
Achillea millefolium				1	1				1			
Ranunculus acris				1	1			+				
Leontodon autumnalis				2	1			+				
Rumex conglomeratus	12		1									
Urtica dioica	2					1						
Cynosurus cristatus	2							+				
Stellaria graminea	2								1			
Veronica catenata	25										1	
Equisetum palustre	3										1	
Chenopodium rubrum	2										1	
Oenanthe fistulosa	72											1
Ranunculus flammula	38											1
Glyceria declinata			3				1					
Triglochin palustre			2				1					
Sagina procumbens			1						1			
Lysimachia nummularia			2									1
Trifolium pratense				5	7							
Senecio jacobea				2	1							
Euphrasia tetraquetra				2	1							
Prunella vulgaris				2	1							
Dactylis glomerata				1	1							

	PM	BF	Cv	O1	O2	GN	GS	DP	Vp	O3	OB	Vg
Rumex crispus				1							1	
Eleocharis uniglumis				1				+				
Carex panicea						1		1				
Schoenoplectus tabernaemontani						1		1				
Cerastium fontanum									2			1
Ranunculus baudotii											1	1
Veronica scutellata	37											
Glyceria fluitans	15											
Ranunculus aquatilis	13											
Rorippa islandica	13											
Polygonum aviculare	12											
Poa pratensis	8											
Alopecurus pratensis	2											
Geranium molle	2											
Persicaria lapathifolia	2											
Festuca pratensis			1									
Carex ericetorum					1							
Phragmites australis						7						
Samolus valerandi						7						
Oenanthe lachenalii						6						
Carex otrubae						2						
Cirsium palustre						1						
Eupatorium cannabinum						1						
Iris pseudacorus						1						
Persicaria laxiflora						1						
Senecio erucifolius						1						
Ranunculus sardous							1					
Ranunculus sceleratus							1					
Bolboschoenus maritimus							1	+				
Juncus compressus								1				
Juncus gerardii								+				
Carex distans								+				
Carex flacca								+				
Anthoxanthum odoratum									3			
Veronica serpylifolium									2			
Bidens tripartita											1	
Cirsium arvense											1	
Potentilla reptans											1	
Anagallis minima												1
Carex binervis												1
Carex nigra												1
Centaurium pulchellum												1
Euphrasia stricta												1
Hydrocotyle vulgaris												1
Juncus ambiguus												1
Linum catharticum												1
Lycopus europaeus												1
Lythrum salicaria												1
Radiola linoides												1
Trifolium dubium												1
Bare ground approx %	5	1	0			0	0	0	2			20
Height of vegetation (cm)	4	5	3	3	20	15	7	30	5	15	20	2

Appendix 3 Species list for Binsey Green, North Hinksey and Langel Common

North Hinksey Meadow, Oxford - Introduction site; Langel Common, Witney - being restored by A.W. McDonald, C.R. Lambrick, F.H. Watkins and S.E. Erskine.

Binsey Green P = present in field, Assoc = associated with *Apium repens* (1998 whole field only; 2002 associated species only); North Hinksey, Pl = in planted area; Assoc. = associated with surviving Apium repens; P = present in whole field (1998 only associated plants recorded on DAFOR scale); 2003 = DAFOR scale used); Langel Common 2000 P = present in whole field, scrape area DAFOR scale; 2001-4 only scrape area using DAFOR.

	Binsey Green				**North Hinksey**			**Scrape at Langel Common**				
	1998	1999	2000	2002	2002	2003	2004	2000	2001	2002	2003	2004
Achillea millefolium	P	P	P	Assoc								
Agrostis capillaris				Assoc					R			R
Agrostis stolonifera	P	Assoc	Assoc	Assoc	Pl	A	Assoc		A	D	D	D
Alopecurus geniculatus	p	P	P		Assoc.	F	Assoc		O	O		
Alopecurus pratensis								P				R
Angelica sylvatica								P				
Anthriscus sylvestris			P					P				
Apium nodiflorum	P	P	P							R		
Apium repens	P	Assoc	Assoc	Assoc	Pl	F	Assoc					
Arctium lappa							P					
Arctium minus							P					
Arrhenatherum elatius	P							P				O
Atriplex patula			P				P					
Bellis perennis	P		P	Assoc	Pl		P					
Bidens tripartita					Assoc.	O	P					
Bromus commutatus	P											
Bromus hordeaceus hordeaceus	P	P	P									R
Calystegia sepium							P					
Calystegia sylvatica	P											
Cardamine pratensis	P	Assoc	Assoc	Assoc					R			
Carex acutiformis	P											
Carex flacca			Assoc									
Carex hirta		Assoc	Assoc	Assoc				F	F	F	A	A
Carex otrubae			P									
Carex riparia	P	Assoc	P	Assoc								
Centaurea nigra							P	P			R	
Cerastium fontanum	P	Assoc	P					P				R
Cirsium arvense	P	Assoc	Assoc	Assoc			P		R	R	R	
Cirsium vulgare			P									
Coronopus squamatus		P										
Crataegus monogyna							P					
Crepis capillaris	P		P									
Dactylis glomerata	P		P				P	P		R		R
Deschampsia caespitosa	P		Assoc	Assoc				O	R	R		R
Eleocharis palustris	P	Assoc	Assoc	Assoc								
Elytrigia repens		P										
Epilobium ciliatum									O			
Epilobium hirsutum									O	O		
Epilobium parviflorum									R	O		
Epilobium tetragonum						R						
Equisetum palustre								R	F		A	F
Festuca arundinacea			Assoc	Assoc				P				

	Binsey Green				North Hinksey			Scrape at Langel Common				
	1998	1999	2000	2002	2002	2003	2004	2000	2001	2002	2003	2004
Festuca gigantea							P					
Festuca pratensis				Assoc				P	O	F	R	O
Festuca rubra	P		Assoc	Assoc			Assoc	F				O
Filipendula ulmaria	P	P	P					P				R
Fraxinus excelsior							P					
Galeopsis tetrahit							P					
Galium palustre		P										
Geranium dissectum	P	P	P							R		R
Geranium molle		P						P				
Geranium pyreniacum	P	P							R			
Glechoma hederacea	P		P	Assoc			P					
Glyceria maxima		P	P									
Heracleum sphondylium	P		P				P	P				
Holcus lanatus	P	P	Assoc	Assoc				O	R	O		
Hordeum murinum	P	P	P									
Hordeum secalinum	P	P									R	O
Humulus lupulus							P					
Impatiens glandulifera							P					
Isolepis setacea		P										
Juncus acutiflorus			P									
Juncus articulatus		Assoc	Assoc	Assoc		R			O	A	F	F
Juncus bufonius	P		P						O			
Juncus compressus		P								R		O
Juncus effusus										R		
Juncus inflexus	P		Assoc	Assoc						R	O	F
Lactuca seriola	P											
Lamium album							P					
Lathyrus pratensis								P				
Leontodon autumnalis			P		Pl		Assoc	P		R	R	
Leotodon saxatile			P									
Leucanthemum vulgare		P										
Lolium perenne	P		Assoc	Assoc	Pl		Assoc	F	R	O		
Lotus corniculatus			P				P					
Lycopus europaeus					Pl	R				R		
Lythrum salicaria							P				R	R
Matricaria discoidea			P									
Mentha aquatica	P		Assoc		Pl		P		R	R		
Mentha arvensis											R	
Myosotis scorpioides	P	P	P	Assoc								
Myosoton aquaticum			P				P			R		
Odontites verna					Pl	F	Assoc					
Oenanthe fistulosa			P									
Persicaria amphibia		Assoc	Assoc	Assoc		F	Assoc	P				
Persicaria hydropiper	P		P				P					
Persicaria maculosa					Assoc.		P		R			
Persicaria mitis (=laxiflora)							P					
Phalaris arundinacea			P									
Phleum pra. bertolonii	P		Assoc						R		R	
Phleum pra. pratensis	P	P	P	Assoc				O	O	O		0
Picris echioides	P	P	P									
Plantago lanceolata	P		P		Pl	F	P	P				
Plantago major	P	Assoc	Assoc	Assoc	Assoc.	A	Assoc	P	O	O	R	
Poa annua	P		P		Assoc.	F	Assoc					
Poa pratensis		P	P									R
Poa trivialis							Assoc		O	O		R
Polygonum aviculare			P	Assoc					R	R		
Potentilla anserina	P	P	Assoc	Assoc	Assoc.			P	F	F	F	F

	Binsey Green				North Hinksey			Scrape at Langel Common				
	1998	1999	2000	2002	2002	2003	2004	2000	2001	2002	2003	2004
Potentilla reptans	P	P	Assoc					O				
Prunella vulgaris		P					P					
Pulicaria dysenterica					Pl		P					
Ranunculus acris	P	Assoc	P	Assoc					R		R	R
Ranunculus aquatilis	P								R			
Ranunculus bulbosus				Assoc								
Ranunculus flammula	P	P	P									
Ranunculus repens	P	Assoc	Assoc	Assoc	Assoc.	D	Assoc	F	A	A	F	F
Ranunculus sceleratus	P											
Rorippa nasturtium-aquaticum	P	P	Assoc									
Rorippa palustris									A			
Rorippa sylvestris					Assoc.					R		
Rubus fruticosus agg							P					
Rumex acetosa								P				
Rumex conglomeratus				Assoc	Assoc.	O		P		F		O
Rumex crispus	P	P	P				Assoc		O		R	O
Rumex obtusifolius	P		P	Assoc	Pl		P		R			
Rumex pulcher											R	
Salix alba							P					
Salix caprea									O			R
Salix cinerea										O	O	O
Salix fragilis							P			O	R	
Salix rubens												R
Salix viminalis												O
Senecio jacobea	P		P	Assoc								
Senecio erucifolius					Pl		P					
Senecio vulgaris	P								R			
Silaum silaus												
Solanum dulcamara	P						P					
Sonchus asper		P	P						R			O
Stachys palustris							P					
Stellaria graminea	P											
Stellaria holostea	P											
Stellaria media	P	P	P			R						
Symphytum officinale					Pl		P	P				
Taraxacum agg	P	P	Assoc	Assoc	Assoc.			F	F	O	O	O
Torilis japonica	P		P									
Tragopogon pratensis		P										
Trifolium dubium		P				R						
Trifolium fragiferum			P	Assoc								
Trifolium pratensis	P	P	Assoc	Assoc				P			O	O
Trifolium repens	P	Assoc	Assoc	Assoc	Assoc.	F	Assoc		R	O	O	LA
Urtica dioica dioica	P		P				P		R			
Urtica dioica galeopsifolia		P	P									
Veronica beccabunga		P								R		
Veronica catenata		P							A	O		
Veronica scutellata		P	P	Assoc					R	O		
Total no. of spp. in field	62	54	69				51	32				
Species associated		14	25	36	11	19	14					
Number in scrape								10	36	37	26	34

Appendix 4 Frequency of species growing on Port Meadow 1981 and 1996-2004

Port Meadow 1981 - 2004. Col. 1 = species names; cols 2 - 3 = 1981 stands; Cols. 4 - 12 = North population; cols. 13 - 20 = South population.

	37	40	1996N	1997N	1998N	1999N	2000N	2001N	2002N	2003N	2004N	1996S	1998S	1999S	2000S	2001S	2002S	2003S	2004S
Glyc flu	100	96	93	10	3	48	38	21	17	7	0	33	7	0	20	13	7	13	87
Oena fis	100	100	79	83	41	21	10	7	14	0	0	93	27	13	0	0	0	7	13
Agro sto	100	84	100	100	45	62	66	48	66	79	100	100	13	93	53	20	93	100	100
Ment aqu	100	100	97	93	31	34	59	28	45	62	76	93	0	27	13	20	20	40	47
Junc art	88	76	0	66	0	3	0	0	0	21	3	87	0	0	33	0	7	0	100
Myos sco	92	100	93	90	52	55	55	41	34	59	66	93	0	20	7	7	40	47	73
Eleo pal	0	96	97	90	97	86	86	90	83	76	93	100	100	100	100	93	93	100	27
Pote ans	0	96	93	93	97	72	93	69	55	62	66	93	100	100	93	80	87	93	20
Ranu rep	0	4	34	31	45	21	52	59	14	41	7	47	7	20	0	20	20	13	47
Gali pal	68	44	41	21	7	10	10	0	0	0	10	0	0	0	0	0	0	0	0
Alop gen	88	0	93	93	31	14	7	7	10	3	24	100	67	93	7	13	87	80	93
Trif rep	0	0	28	90	38	10	7	24	0	48	0	73	0	13	0	0	0	27	60
Vero scu	76	28	17	38	7	34	86	79	17	28	10	33	0	93	0	0	40	0	67
Ranu aqu	0	0	48	21	72	48	69	28	17	0	14	7	0	79	36	29	93	86	29
Ranu fla	48	48	55	31	28	24	3	14	14	7	10	93	0	13	0	0	13	0	60
Card pra	16	32	7	41	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Care pan	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stel pal	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa tri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Care hir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agro cap	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiu nodi	0	0	7	0	0	3	0	0	0	0	0	13	0	0	0	0	0	0	0
Myos dis	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa pra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Call spe	0	12	0	0	0	0	0	3	0	0	0	0	13	27	0	7	0	0	0
Crep bie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trig pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rume cri	0	0	0	3	21	10	3	0	3	0	0	67	20	40	13	20	67	40	33
Equi pal	8	0	3	7	7	10	3	7	3	10	10	0	0	0	0	0	0	0	0
Plan maj	0	0	31	93	93	97	90	83	21	93	3	93	73	60	7	93	93	93	27
Junc buf	0	0	90	38	93	90	100	83	34	21	0	13	73	60	0	87	87	80	20
Apiu rep	**0**	**0**	**14**	**24**	**69**	**24**	**59**	**55**	**31**	**45**	**55**	**13**	**0**	**7**	**0**	**0**	**7**	**33**	**47**
Pers amp	0	0	0	3	55	79	90	90	31	0	3	0	0	0	0	0	0	0	0
Chen rub	0	0	0	0	72	90	90	45	0	41	0	0	0	0	0	73	27	60	13
Ranu aqu	0	0	48	21	72	48	69	28	17	0	14	7	73	33	27	87	80	27	7
Vero cat	0	0	62	7	86	83	7	10	7	17	21	47	0	13	0	0	27	0	20
Seedlings	0	0	0	0	0	34	62	0	66	0	7	0	0	0	0	0	0	0	0
Poly avi	0	0	0	7	31	14	21	34	14	14	0	33	7	7	0	73	80	80	0
Rori nas	0	0	28	0	24	21	21	10	7	0	3	7	0	27	0	7	0	0	47

Urtic dio	0	0	0	0	48	24	31	0	0	0	0	0	0	0	0	0	0	0	0
Loli per	0	0	3	17	21	3	14	3	0	7	0	0	0	0	0	0	0	0	0
Pers mac	0	0	0	0	0	0	0	0	0	41	45	0	0	0	0	0	0	0	0
Cirs vul	0	0	0	0	28	10	7	0	0	10	0	0	0	0	0	0	0	0	0
Pers lap	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	53	47	73	93
Rori pal	0	0	0	10	62	76	93	90	41	82	41	0	0	0	0	0	7	0	0
Sonc asp	0	0	0	0	10	14	7	0	3	3	0	0	0	0	0	0	0	0	0
Chen alb	0	0	0	0	0	0	0	24	0	0	0	0	13	7	0	53	7	0	93
Atri pat	0	0	0	0	0	0	3	14	0	0	0	0	0	0	0	0	7	0	0
Stel gra	0	0	17	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa ann	0	0	0	0	0	7	3	7	0	3	0	0	0	0	0	0	0	0	0
Trif fra	0	0	7	0	0	0	3	0	0	0	0	0	0	0	0	13	0	0	33
Dact glo	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tara off	0	0	0	3	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Barb vul	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poly are	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Pote rep	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senec vul	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stel med	0	0	0	0	0	0	0	0	0	3	7	0	0	0	0	0	0	0	0
Bell per	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cera fon	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chen bon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	13
No. of spp.	15	15	27	30	36	34	34	29	25	29	23	22	14	21	11	19	23	18	24

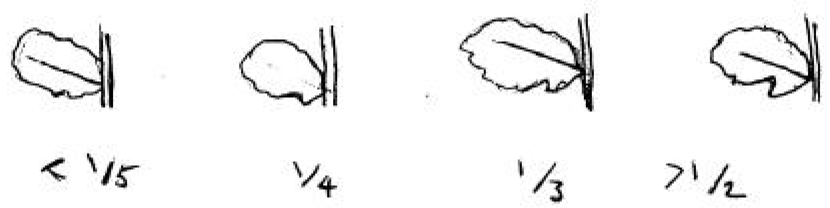
Appendix 5 Proforma for recording *Apium repens* on Port Meadow

Port Meadow *Apium repens* Population. Date .....\\......\\

Recorders . . . . Time start . . . . Finish . . . . . .

AB long	AC short	Seedl \lobing	Ped. length	Bract no.	Grey

Third leaflet up from base, or largest leaflet



Appendix 6 UK guidance on conservation objectives for monitoring designated sites

Interest feature: ***Apium repens*** **(Creeping marshwort)**

The plant occurs in short, grazed mesotrophic, inundated grassland (primarily, MG13) where a degree of trampling and/or summer flooding causes disturbance, providing open ground where the runners can root.

It is best to visit in July-August when they are potentially suffering drought. Consult sects. 5-7 before making a final selection of appropriate direct attributes for the site, spatial targets may be advisable. All indirect attributes are mandatory. If any indirect attribute fails, the feature is not in a favourable condition.

Direct attributes	**Targets**	**Method of assessment**	**Comments**
Presence/absence	Species should be present	Identification of species	If all other targets are met but the species cannot be found then the feature should be referred to the Country Agency botanical specialists.

Indirect attributes	**Targets**	**Method of assessment**	**Comments**
Niche availability	Sufficient area of suitable habitat to maintain the population(s). See comments. No loss in extent of suitable habitat.	Mapping (area)	The assessment on Port Meadow can take additional information into account concerning the extent and coverage of populations NB There can be year on year variation as to the extent of the niche available on account of weather condieirons and this needs to be taken into account when thinking about trendts
Vegetation structure: sward height	Average sward height 2-10 cm	Measure with ruler or drop disc if possible as results with ruler not sufficiently consistent	Short turf to be maintained throughout the year. Currently and historically grazed by cattle and horses at high densities.
Vegetation structure: Bare ground	1-20% bare ground present	By eye	
Positive indicators: Vegetation composition	Presence of all: *Ranunculus flammula*, *Agrostis stolonifera*, *Alopecurus geniculatus*, *Potentilla anserina*, *Juncus articulatus*, *Ranunculus repens*, *Festuca rubra* within niche	Identify indicator species, it is not essential to find *every* species at *every* assessment point	These species provide evidence of a high seasonable water table. *Ranunculus flammula* and *Juncus articulatus* indicate that it remains damp throughout the year, while *Eleocharis pal* and Veronica (?) indicate winter flooding
Negative indicators: pollution	Nettles and other species associated with eutrophication absent from niche	Visual assessment	*A. r.* is vulnerable to pollution and eutrophication. This is not an issue on Port meadow as nettles are absent from the A. repens area due to winter flooding.
Negative indicators: Invasive species	Invasive species such as Crassula should be absent.	Identification of species	Early removal of the threat.

Appendix 7 Latin and English names of species mentioned in the text

Achillea millefolium	Yarrow
Agrostis capillaris	Common bent-grass
Agrostis stolonifera	Creeping bent-grass
Alisma plantago-aquatica	Water plantain
Alopecurus geniculatus	Marsh foxtail
Alopecurus pratensis	Meadow foxtail
Anagallis minima	Chaffweed
Anthoxanthum odoratum	Sweet vernal grass
Anthriscus sylvestris	Cow parsley
Apium nodiflorum	Fool's-watercress
Apium repens	Creeping marshwort
Arctium lappa	Greater burdock
Arctium minus	Lesser burdock
Arrhenatherum elatius	Tall oat-grass
Atriplex patula	Common orache
Barbarea vulgaris	Winter-cress
Bellis perennis	Daisy
Bidens tripartita	Trifid bur-marigold
Blysmus compressus	Flat sedge
Bolboschoenus maritimus	Sea club-rush
Bromus hordeaceus hordeaceus	Soft brome
Callitriche agg.	Starwort
Calystegia sepium	Bindweed
Calystegia silvatica	Large bindweed
Cardamine pratensis	Cuckooflower
Carex acutiformis	Lesser pond-sedge
Carex binervis	Green-ribbed sedge
Carex distans	Distant sedge
Carex disticha	Brown sedge
Carex ericetorum	Rare spring-sedge
Carex flacca	Glaucous sedge
Carex hirta	Hairy sedge
Carex nigra	Common sedge
Carex oederi	
Carex otrubae	False fox sedge
Carex panicea	Carnation sedge
Carex riparia	Greater pond-sedge
Centaurea nigra	Common knapweed
Centaurium pulchellum	Lesser centaury
Cerastium fontanum	Common mouse-ear
Chara sp.	Stonewort
Chenopodium album	Fat-hen
Chenopodium bonus-henricus	Good King Henry
Chenopodium rubrum	Red goosefoot
Cirsium arvense	Creeping thistle
Cirsium palustre	Marsh thistle
Cirsium vulgare	Spear thistle
Coronopus squamatus	Swine-cress
Crassula helmsii	Australian swamp stonecrop
Crataegus monogyna	Hawthorn
Crepis biennis	Rough hawk's-beard
Crepis capillaris	Smooth hawk's-beard
Cynosurus cristatus	Crested dog's-tail
Dactylis glomerata	Cock's-foot
Deschampsia cespitosa	Tufted hair-grass
Eleocharis palustris	Common spike-rush
Eleocharis uniglumis	Slender spike-rush
Elytrigia repens	Couch grass
Epilobium ciliatum	American willow-herb
Epilobium hirsutum	Great willow-herb
Epilobium parviflorum	Hoary willow-herb
Epilobium tetragonum	Square-stalked willow-herb
Equisteum arvense	Field horsetail
Equisetum palustre	Meadow horsetail
Eupatorium cannabinum	Hemp-agrimony
Euphrasia stricta	Eyebright
Euphrasia tetraquetra	Eyebright
Festuca arundinacea	Tall fescue
Festuca gigantea	Giant fescue
Festuca pratensis	Meadow fescue
Festuca rubra	Red fescue
Festulolium	
Filago uliginosum	Marsh cudweed
Filipendula ulmaria	Meadowsweet
Fraxinus excelsior	Ash
Galeopsis tetrahit	Common hemp-nettle
Galium palustre	Common marsh-bedstraw
Geranium dissectum	Cut-leaved crane's-bill
Geranium molle	Dove's-foot crane's-bill
Geranium pyreniacum	Hedgerow crane's-bill
Glechoma hederacea	Ground ivy
Glyceria declinata	Small sweet-grass
Glyceria fluitans	Floating sweet-grass
Glyceria maxima	Reed sweet-grass
Heracleum sphondylium	Hogweed
Holcus lanatus	Yorkshire fog
Hordeum murinum	Wall barley
Hordeum secalinum	Meadow barley
Humulus lupulus	Hop
Hydrocotyle vulgaris	Marsh pennywort
Impatiens glandulifera	Indian balsam
Iris pseudacorus	Yellow iris
Isolepis setacea	Bristle club-rush
Juncus acutiflorus	Sharp-flowered rush

Juncus ambiguus	Frog rush
Juncus articulatus	Jointed rush
Juncus bufonius	Toad rush
Juncus compressus	Round-fruited rush
Juncus effusus	Soft rush
Juncus gerardii	Salt-marsh rush
Juncus inflexus	Hard rush
Lactuca seriola	Prickly lettuce
Lamium album	White deadnettle
Lemna major	Greater duckweed
Leontodon autumnalis	Autumn hawkbit
Leontodon saxatile	Lesser hawkbit
Leucanthemum vulgare	Oxeye daisy
Linum catharticum	Fairy flax
Lolium perenne	Perennial ryegrass
Lotus corniculatus	Bird's-foot trefoil
Lycopus europaeus	Gypsywort
Lysimachia nummularia	Creeping Jenny
Lythrum salicaria	Purple-loosestrife
Matricaria discoidea	Water-mint
Mentha aquatica	Water-mint
Myosotis discolor	Changing forget-me-not
Myosotis laxa	Tufted water forget-me-knot
Myosotis scorpioides	Water forget-me-not
Myosoton aquaticum	Water chickweed
Odontites vernus	Red Bartsia
Oenanthe fistulosa	Tubular water-dropwort
Oenanthe aquatica	Fine-leaved water-dropwort
Oenanthe lachenalii	Parsley water-dropwort
Persicaria amphibia	Amphibious bistort
Persicaria hydropiper	Water-pepper
Persicaria lapathifolia	Pale persicaria
Persicaria maculosa	Redshank
Persicaria mitis (=laxiflora)	Tasteless water-pepper
Phalaris arundinacea	Reed canary-grass
Phleum bertolonii	Smaller cat's-tail
Phleum pratensis	Timothy
Phragmites australis	Common reed
Plantago intermedia	
Plantago lanceolata	Ribwort plantain
Plantago major	Great plantain
Poa annua	Annual meadow-grass
Poa pratensis	Smooth meadow-grass
Poa trivialis	Rough meadow-grass
Polygonum arenastrum	Equal-leaved knotgrass
Polygonum aviculare	Knotgrass
Potentilla anserina	Silverweed
Potentilla reptans	Cinquefoil
Pulicaria dysenterica	Fleabane
Prunella vulgaris	Self-heal
Radiola linoides	Allseed
Ranunculus acris	Meadow buttercup
Ranunculus aquatilis	Common water-crowfoot
Ranunculus batrachium	
Ranunculus baudotii	Brackish water-crowfoot
Ranunculus bulbosus	Bulbous buttercup
Ranunculus flammula	Lesser spearwort
Ranunculus repens	Creeping buttercup
Ranunculus sardous	Hairy buttercup
Ranunculus sceleratus	Celery-leaved buttercup
Rorippa islandica	Northern yellow-cress
Rorippa nasturtium-aquaticum	Water-cress
Rorippa palustris	Marsh yellow-cress
Rubus fruticosus agg	Bramble
Rumex conglomeratus	Clustered dock
Rumex crispus	Curled dock
Rumex obtusifolius	Broad-leaved dock
Rumex pulcher	Fiddle dock
Sagina procumbens	Procumbent pearlwort
Salix alba	White willow
Salix caprea	Goat willow
Salix cinerea	Grey willow
Salix fragilis	Crack willow
Salix rubens	Hybrid crack-willow
Salix viminalis	Osier
Samolus valerandi	Brookweed
Schoenoplectus tabernaemontani	Grey club-rush
Senecio erucifolius	Hoary ragwort
Senecio jacobea	Ragwort
Senecio vulgaris	Groundsel
Silaum silaus	Pepper saxifrage
Solanum dulcamara	Bittersweet
Sonchus asper	Annual sow-thisle
Stachys palustris	Marsh woundwort
Stellaria graminea	Lesser stitchwort
Stellaria holostea	Greater stitchwort
Stellaria media	Common chickweed
Stellaria palustris	Marsh stitchwort
Symphytum officinale	Common comfrey
Taraxacum officinale agg.	Dandelion
Torilis japonica	Upright hedge-parsley
Trifolium dubium	Lesser trefoil
Trifolium fragiferum	Strawberry clover
Trifolium pratense	Red clover
Trifolium repens	White clover
Triglochin palustre	Marsh arrowgrass
Typha latifolia	Reedmace
Urtica dioica dioica	Stinging nettle
Urtica dioica galeopsifolia	Stingless nettle
Veronica beccabunga	Brooklime
Veronica catenata	Pink water-speedwell
Veronica scutellata	Marsh speedwell
Veronica serpyllifolia	Thyme-leaved speedwell

Research Information Note

English Nature Research Reports, No. 706

***Apium repens* creeping marshwort**
Species Recovery Programme 1995-2005

Report Authors: A.W. McDonald and C.R. Lambrick
Ashmolean Natural History Society of Oxfordshire Rare Plants Group
Date: September 2006
Keywords: Creeping marshwort, Oxfordshire, Walthamstow Marshes, Species Recovery Programme

Introduction

Apium repens (Jacq.) Lag., Apiaceae, is a small, creeping perennial which is listed under the Habitats Directive because of its scarcity and decline in Europe. The one site known in the UK in 1995 is now designated part of the Oxford Meadows Special Area for Conservation. A Species Action Plan was drawn up in 1995 and English Nature funded the Rare Plants Group of the Ashmolean Natural History Society of Oxfordshire to carry out field work under the Species Recovery Programme. This report covers the work undertaken from 1995-2005.

What was done

The autecology of the plant and the threats it faces were little understood in 1994 so that the plant was placed on the Species Recovery Programme. Initially it was recorded from one site but it is now recorded from four sites including a recent population found at Walthamstow Marshes SSSI, Essex, by Brian Wurzell in 2002. Collaborations have been undertaken with European colleagues and some research projects carried out.

Results and conclusions

Apium repens requires plenty of light, including high levels of summer sunshine, and soil moisture. It tolerates winter- flooding but is killed by soil anoxia during early summerflooding. However any increase in bare ground allows *A. repens* to germinate and spread. The water-table on Port Meadow is freely connected to the gravel aquifer rather than to the river level giving a complex flooding pattern. Grazing keeps down competing vegetation and favours *A. repens* which generally grows below the level of grazing.

Threats

Summer flooding causes loss of *Apium repens* but is also beneficial because it opens the sward and provides germination sites. However, too many of these events may deplete the seed-bank. Grazing is essential to maintain a low sward with trampled areas and provide plenty of light. The invasive alien *Crassula helmsii* is a potential threat.

Conservation and research

- Continuation of the current hydroecological study and further study of the population dynamics and flowering of *Apium repens*.
- Further monitoring of the restoration site at Langel Common, to be followed, if *Apium repens* does not reappear, by reintroduction at a third site.

- The eradication of *Crassula helmsii*.
- Further international collaboration following the workshop held in Oxford in September 2005.

Environment Agency became involved to develop a Water Management Plan and assessed whether water abstraction licenses were having significant impacts on *Apium repens*. They then funded a hydroecological study of Port Meadow by David Gowing, of Cranfield and the Open Universities. This work has greatly extended the understanding of the hydrology and vegetation types of the area, and is partially discussed in the ENRR and in Gowing and Youngs (2005). The study also recommended further research on the effects of hydrology on *Apium repens*

English Nature's viewpoint

English Nature is committed to the conservation of this rare speceis which features among the top five English priorities but recognises that the conditions requried to retain this plant rely on sympathetic management and further investigations. The report includes an excellent summary of the work undertaken, results and directions for future work.

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English Nature is the Government agency that champions the conservation of wildlife and geology throughout England.

This is one of a range of publications published by:
External Relations Team
English Nature
Northminster House
Peterborough PE1 1UA

www.english-nature.org.uk

Cover printed on Character Express, post consumer waste paper, ECF.

ISSN 0967-876X

Cover designed and printed by Status Design & Advertising, 2M, 5M, 5M.

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Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
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