ESTABLISHMENT OF WETLAND GROUND FLORA: AN ANALYSIS OF PLANTING METHODOLOGIES

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Abstract

National and local Biodiversity Action Plan targets for wetlands have identified the requirement for the creation of new wetland habitats throughout the UK. However, a brief review of current literature has highlighted a need for the quantification of the range of accepted wetland vegetation establishment techniques for ground flora. This project aims to provide a quantification of these techniques for various wetland habitats. To enable this a cost/benefit analysis of the establishment techniques utilised within a series of experimental sites will be developed. This will involve the analysis of the comparative costs of each of the techniques used and the development of 'success criteria' to provide a quantifiable 'benefit' for each of the planting methods. The comparison will inform a cost/benefit matrix for the establishment of wetland nature reserves.

Keywords: biodiversity, reedbeds, wetland habitat, wet woodlands

I. Introduction

Wetland habitats have undergone an extensive decline in distribution and cover over the last 60 years. In Europe, lowland wetlands have been extensively drained for agriculture and urban development. River engineering schemes for flood control and navigation, towering of water tables; power generation, ground w ater abstraction, waste disposal, pollution and mining have all contributed to wetland loss (Bardsley *et al.* 2001).

Within the UK, the United Kingdom Biodiversity Group (UKBG) has developed a series of national Biodiversity Action Plans (BAP) providing targets for the protection, restoration and creation of wetland habitats. Combined with changes in attitudes to wetland conservation during the past decade this has led to the creation of new wetland habitats, restoration of debilitated systems, efforts to halt and reverse the decline in existing wetland habitat, and the prevention of the loss of associated flora and fauna

This research project aims to develop success criteria for selected planting techniques of wetland ground flora vegetation. By combining these criteria with the costs recorded during the planting of experimental sites a cost/benefit analysis will be created for the methods trialed. The research will only examine clay based wetland systems and does not include peat based habitats.

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Within clay based wetland systems a mosaic of habitats is often found. These habitats include wet woodland, wet grassland, sedge bed and seedbeds. Wet grassland establish ment has been extensively researched and has been excluded from this project.

Of the remaining wetland habitats, seedbed and wet woodland are priority habitats with dedicated Habitat Action Plans (HAP) in response to the UKBG (UKBG. 1995 and UKBG, 1998 respectively). Table 1 details the relevant restoration/creation targets as de tailed in the relevant HAP for these habitats. Sedge bed has not been selected as a prior ity habitat by the UKBG. and therefore no restoration/creation targets have been published.

Action	Area (ha)	Completion Date
Create seedbed on land of low nature conservation interest	1,200	2010
Wet Woodlands		
Complete restoration of former native wet woodland on ancient woodland sites	1,600	2010
Comptete restoration of former native wet woodland on ancient woodland sites	1.600	2015
Complete establishment on unwooded sites or by conversion of ptantation	3,750	2010
Complete establishment on unwooded sites or by conversion of ptantation	3,750	2015

Initial research has shown that for some wetland habitats there are a number of accepted techniques for the establishment of the vegetation (e.g. for seedbed. Hawke and Jose, 1996). There are also texts detailing establishment methods for wet woodland canopy species (e.g. Rodwell & Patterson. 1994), however. there is a lack of information with respect to the establishment of wet woodland field layer vegetation. In addition, the available literature does not describe success criteria for the various planting techniques withm newly created wetland sites.

Broad habitat types (e.g. grassland, woodland etc) have long been described in more detail (e.g. inesotrophic grassland, calcareous grassland, oak/ash woodland, alder can). Within Britain the National Vegetation Classification (NVC) (Rodwell, 1991) has been adopted as the definitive system for the classification and description of vegetation com munities. This system was developed through extensive surveys of habitats throughout the British Isles, and provides community descriptions and species lists for each. The NVC system has been utilised within the research to select appropriate experimental sites and the plant species to be used.

2. Selection Criteria for Experimental Sites

The selection criteria for the experimental sites were determined by designed habitat type [target NVC Community). extent. canopy species planting date (wet woodland) and envi-roiunental variables (slope, aspect. hydroperiod etc.). In addition. the permission of the landowner for the establishment of experimental areas was required. Potential experimental sites must have an adequate extent of appropriate environmental conditions to enable replicates of samples in order to ensure the statistical significance of the findings.

2.1. Wet Woodland

With respect to the environmental variables. an ideal wet woodland site should be located within the floodplain of a riparian system, or the flood zone of a waterbody, to ensure periodic inundation (annual winter inundation, summer inundation at 1 in 5 year interval) and wet soils. The sites should be relatively macro-topographically flat. with areas of sufficient size to allow installation of experimental blocks with little change in slope and aspect. These conditions will reduce variables within the experiment providing data that can be assessed effectively.

The chosen NVC community for research into the establishment of wet woodland *field* layer vegetation is W6 *:Albus glutinosa- Urtica dioica* community. This habitat was selected as a result of discussions with the Forestry Commission. Woodcock (2000) stated :hat within the Midlands Region of the UK, floodplain habitat restoration will primarily xcur within ex-arable land and plantation sites, where W6 commu likely target habitat due to the high nutrient levels within the soils.

To facilitate investigation of the effect of canopy species on the establishment of the ground flora, the research requires a variation in age of canopy species – ideally a newly planted site and a site with tree species providing an almost closed canopy,

2.2. Sedge Bed

The selected NVC community for research into the establishment of sedge bed is 56 *Carex riparia* Swamp. This community was selected as a representative of the swamp communities not dominated by *Phragmites australis.* and being characteristic of wet or water-logged, mesotrophic or eutrophic, circumneutral mineral soils alongside standing or slowmoving waters. These characteristics will be common for many wetland creation projects and therefore knowledge of this community will be valuable to future wetland restoration schemes.

An experimental site for research into the establishment of sedge bed flora should contain areas subject to periodic inundation to a depth of 200 mm. The site should be predominantly flat to remove topographical influence on variation in establishment success. The aspect of the site should remain constant throughout the experimental area. again removing the potential influence of aspect on variation in establishment success.

2.3. *Reedbed*

Dense stands of *Phragmites australis are* classified as S4 *Phragmites australis* Swamp. To facilitate quantification of the cost/benefit analysis of the various planting methodologies for this community experimental sites must contain areas subject to appropriate environmental conditions, particularly permanent inundation of between 200 mm and 1,000 mm. This depth of water will reduce colonisation of most other wetland vegetation types, ensuring the S4 community is preserved for research.

3. Selected Sites

In reality it is almost impossible to satisfy all ideal selection criteria within available experimental sites. but efforts must be made to ensure that they are met as far as possible.

With this in mind, two research sites were identified for the investigation of groundflora establishment, the Leam Valley Local Nature Reserve (LVLNR), on the River Leam at Leamington Spa. Warwickshire. and The Burton Mail Centenary Woodland (BMCW). on the River Trent at Burton-on-Trent, Staffordshire (Fig.I).

Fig I. Experimental site locations.

3.1 . The Leam Valley Local Nature Reserve

The primary selection criterion for the project, that of appropriate target communities, was satisfied at the Learn Valley Local Nature Reserve (LVLNR) through the Warwickshire Wildlife Trust's choice of target habitats during its design phase. The site is approximately 4.6 ha in size. with newly created areas of wet woodland. sedge bed and reedbed habitat (Fig. 2). Sufficient areas of each habitat are available to contain experimental planting blocks that experience the same environmental conditions.

The wet woodland canopy species had been planted in November 2000, and the LVLNR therefore represented a newly planted site. However. the wet woodland area is located on a slope that varies from 10 to 20°, and as a consequence, the top of slope and base of slope experience different hydroperiods. This rendered it less than ideal for the wet woodland component of the research. With respect to tile environmental variables. although located within the floodplain of the River Learn. the LVLNR site is ideal for sedge bed and reedbed research.

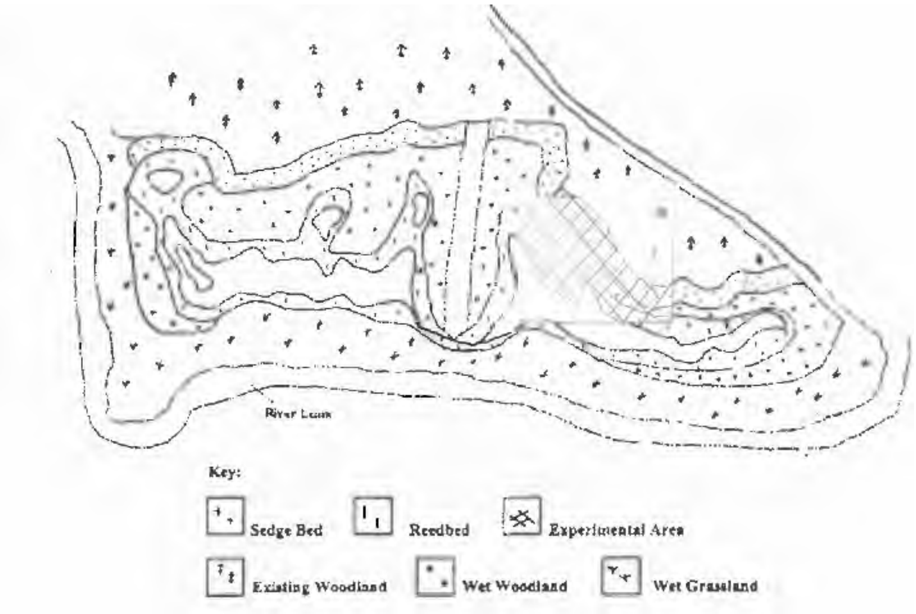


Fig. 2. Leam Valley Local Nature Reserve and experimental site location

3.2. The Burton Mail Centenary Woodland

The Burton Mail Centenary Woodland (BMCW) site was designed as floodplain woodland. Therefore, there are no opportunities for studying sedge bed and rcedbed habitats. Within the mosaic of floodplain. woodland planting at the BMCW, an area of *Salix spp.* of sufficient size (> 350 in²) to accommodate the experimental filed layer planting was located. This area is representative of the W6 target community (Fig. 3), and since canopy species were planted in 1998 it has developed a more mature canopy than the LVLNR site with greater shade to the field Layer.

With respect to the environmental variables, the BMCW is located within the flood-plain of the River Trent and is predominantly macro-topographically flat. The site therefore provides an ideal experimental area with very Little variation in slope and aspect across the planting blocks.

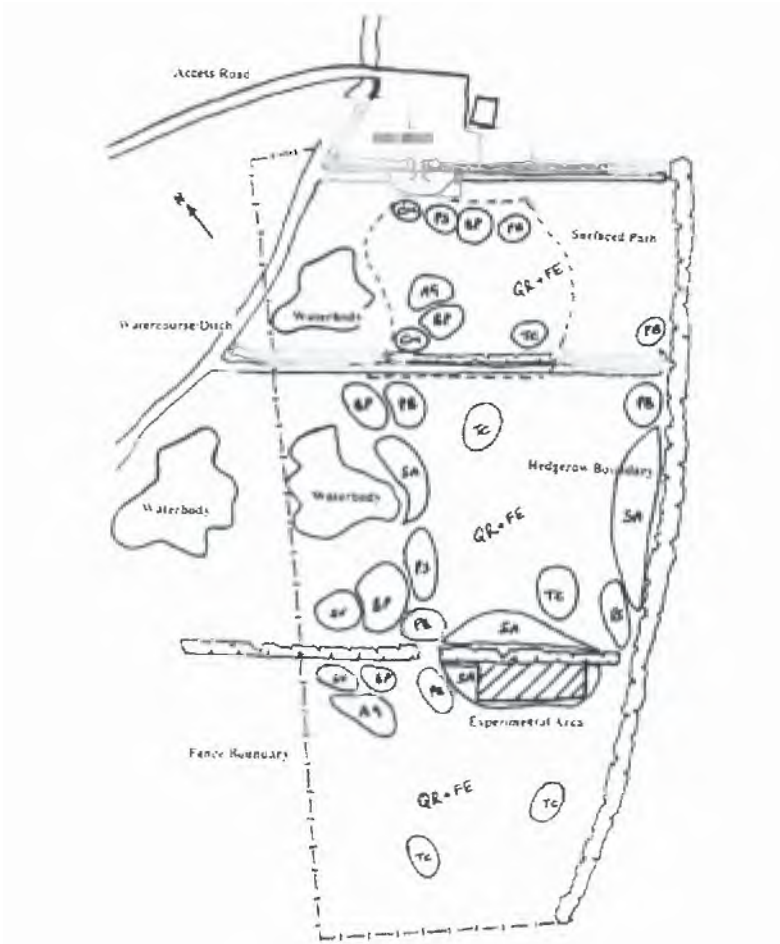


Fig. 3. Burtun Mail Centenary Woodland experimental site location Key: CM- *Cralaegus monogyna,* PS - *Pinus spinosa. HP-Betula pendula, PB Populus nigra var betulifolia. AG - Albus glutinosa. TC-Tiliacordata. SA -Salixalba*

4. Planting Methods

The range of possible planting methods are summarised in Table 2. The actual planting techniques adopted (Table 3) were chosen to provide a practical representative selection, whilst ensuring that experimental blocks of adequate size could be accommodated within the available sites, and the financial resources were utilised effectively.

Table 2. Available planting methods.

Planting Method
Turf Translocation
Soil Translocation
Seeding
Plug Planting
Pot Planting
Rhizome Segment Translocation (reeds)
Stem Cuttings (reeds)

Table 3. Selected planting methods

Method	Wet Woodland	Sedge Bed	Reedbed
Natural Regeneration/Colonisation	✓	✓	×
Turf Translocation	✓	×	×
Soil Translocation	×	×	×
Seeding	✓	✓	×
Plug Planting	✓	✓	✓
Pot Planting	×	×	×
Rhizome Segment Translocation	×	×	✓
Stem Cuttings	×	×	✓

4.1. Natural Regeneration/Colonisation

This technique was selected as it represents the non-intervention approach. Odum (1987) stated that whilst an exact target community is unlikely to be achieved this may be the most cost effective technique fox wetland vegetation establishment.

Natural regeneration/colonisation has been adopted for the wet woodland and sedge bed experiments, as both habitats are exposed to potential seed/plant input from external sources. However, since no external sources of *Phragmites* are available to the LVLNR research site, this methodology was rejected for the reedbeds. Usually there are no establishment costs associated with this approach. However, for this research the natural regeneration areas were subject to the same ground preparation works as the remainder of the trial plots and so a small cost was incurred.

4.2. Turf Translocation

As W6 communities contain many ubiquitous plants that are generally not commercially available. the translocation of plains front an existing habitat is potentially an attractive option. It was employed for wet woodland ground flora, but as no sources of sedge bed turf could be found, it was not possible to include it for the sedge bed research. In addition. although this method is one option for reedbed establishment, the decision was made to opt for rhizome segment translocation as it was judged to be the most appropriate alternative. Soil translocation was rejected due to its similarity to turf translocation and the fact it is often excessively time consuming and hence too costly for many organisations.

4.3. *Rhizome Segment Translocation*

Hawke & Jose (1996) state that translocation of reed rhizomes can be a highly effective technique. As sources of rhizome arc usually readily available from local donor sites ; as discussed above, this method was adopted. The selected approach is simple rhizome fragment (without stems attached) translocation.

4.4. Seeding

The use of native seed broadcasting is a widely utilised establishment technique for many habitat creation schemes. However. its effectiveness and cost/benefit for weet woodland ground flora and sedge bed is poorly understood, and for these reasons seeding was included in the research programme,

Where seed was used in the research project it was sourced from a commercial supplier using their recommendation of proportions for the selected species. As different species of plant produce seed of different size and weight the seed mix was designed to provide the same number of seeds from each species. A sowing rate of 4 g m^{-2} has been utilised. With respect to *Phragmites* the poor viability of seed and low germination and survival of seedlings indicates that this technique is non-viable (Hawke & Jose 1996), and therefore has not been utilised for the reedbed areas.

4.5. *Plug Planting*

Plug planting *is* generally the most costly approach to vegetation establishment in terms of capital outlay and initial planting costs. However, the instant effects provided by the inclusion of young plants into a planting scheme means that it is often used in vegetation establishment where finances permit. To provide a direct comparison with seeding. and to facilitate the cost/benefit analysis of the planting methods plug planting has been selected.

Planting plugs as a species mix increases the labour element of the planting, and would introduce additional variables to the research. To facilitate comparison between species and to replicate the drift planting approach adopted by practitioners. plug planting was undertaken in single species blocks at 9 m^{-2}.

Pot Planting was rejected from the research due to the similarity to plug planting and the high cost of purchasing pot plants.

4.6. *Stem Cuttings*

As this technique is very simple and has no capital costs associated with it. it is a very

attractive technique for reedbed establishment for many organisations. and was therefore included within the research.

5. Selection of Species

To provide continuity across the experimental sites and comparison throughout the various planting methods under investigation, specific species were selected for each of the three vegetation communities; wet woodland (W6). sedge bed (S6) and reedbed (S4).

With respect to wet woodland and sedge bed, the species were selected from the species tables provided in the published NVC descriptions (Rodwell, 1991. 95). The selection process included the rejection of highly competitive species and grasses as these plants were deemed inappropriate for the experiment due to their competitive natures. In addition, bryophyte species were rejected due to the difficulty in sourcing the plants commercially. All the species selected were commercially available both as seed and plugs.

The species selected for the wet woodland and sedge bed planting are detailed in Tables 4 and 5 respectively. *Phragmites australis* was adopted as the only experimental plant for the reedbed habitat.

Table 4. Selected wet woodland species

Common Name	Latin Name
Meadowsweet	*Filipendula ulmaria*
Wild angelica	*Angelica sylvestris*
Creeping buttercup	*Ranunculus repens*
Flag iris	*fria psuedacorus*
Red campion.	*Silene dioica*

Table 5. Selected sedge bed species.

Common Name	Latin Name
Glaucous sedge	*Carex flacca*
Son rush	*Juncus effusus*
Sneezewort	*Achillea ptarmica*
Hemp agrimony	*Eupatorium canabinum*
Branch bur-reed	*Sparganium erectum*

6. Experimental Site Layout

The layout of the experimental planting blocks within each site was designed to ensure that each technique is subject to the same environmental variables (slope, aspect, shade, soil type etc), and that all experimental blocks have sufficient areas to provide sample replicates. In addition, financial considerations relating to the purchase of plugs and seed, together with the available space, dictated the extent of the planting blocks for each method.

6.1. Leam Valley Local Nature Reserve

The wet woodland component of the Leam Valley Local Nature Reserve (LVLNR) wetland creation project was designed as a 10 m wide fringe between the existing plantation woodland and the sedge bed (see Figure 2). Although the wet woodland experimental planting blocks are contained within the wet woodland, the requirement for minimal change in slope and aspect placed constraints on the layout of the planting design.

The sedge bed and reedbed research areas have been designed to form a contiguous experimental area with the wet woodland component (Fig. 4).

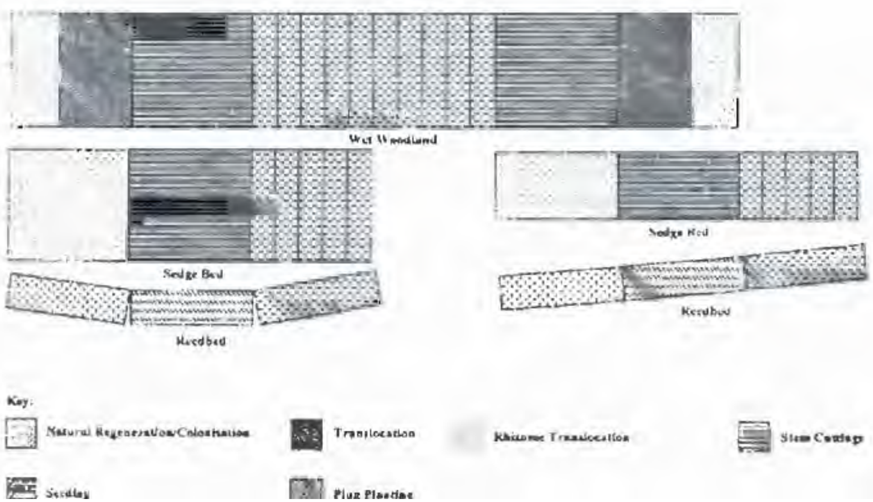


Fig 4 Leam Valley Local Nature Reserve Experimental Planting Layout

6.2. Burton Mail Centenary Woodland

All experimental planting at the Burton Mail Centenary Woodland (BMCW) has been designed to be contained within a stand of White Willow *Salix alba* (Fig. 3) to provide comparability with the LVLNR site. The size of the White Willow planting area placed a constraint on the layout of the planting design (Fig. 5).

7. **Experimental** Site Set-up

7.1. Site Preparation

Prior to implementing the selected planting methods both sites were pre-treated using the same technique to provide an appropriate planting medium. To create an appropriate plant-

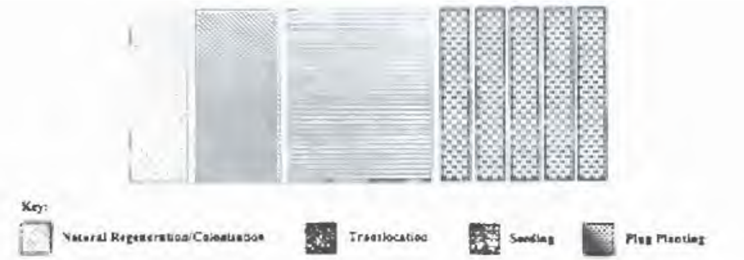


Fig. 5. Burton Mail Centenary Woodland Experimental Planting Layout.

ing medium and reduce early competition from existing field layer vegetation the experimental areas were rotovated to a depth of approximately 100 mm. The planting blocks were subsequently marked out.

The LVLNR Research Site is a newly created wetland mosaic. Creation of the wetland site involved reduce level excavation across the site to achieve the design ground levels. This activity effectively removed the topsoil layer and associated vegetation from the site. In addition, a post and wire netting fence was erected around the experimental site to reduce potential grazing damage from waterfowl.

The BMCW Research Site was created in 1998. and a well-established, closed sward ground flora had developed between and underneath the canopy tree species. To assist rotovation the dry dead vegetation was raked off.

7.2. Planting

The arrangement of the planting, seeding and translocation plots are detailed in Figure 4 for the LVLNR and Figure 5 for the BMCW respectively.

8. Monitoring

The monitoring methodology for the experimental sites is based on the standard techniques described by Rodwell (1991), and involves the use of 2 m x 2 in quadrants to survey vegetation communities.

To facilitate monitoring and to provide replicate data 2 permanent quadrants have been installed within each planting block. Monitoring of the quadrats is undertaken by setting a 2 m x 2 m string quadrant over permanently located quadrat pegs. Within the quadrants all species are recorded in terms of the percentage cover of each, together with the proportion of bare ground/free water surface area. In addition, the vegetation height is monitored in each corner and at the centre of the quadrat.

Percentage cover is assessed by eye as a vertical projection on to the ground of all the live, above-ground parts of the plant within the quadrat (Rodwell 1991). The percentage cover methodology can be criticised as being subjective, however, as the same surveyor undertakes the monitoring this subjectivity should remain standardised across the results. Monitoring is undertaken monthly throughout the first year of each experimental site and every 3 months from then on. Experimental data will continue to be collected until November 2005.

9. Preliminary results for Wet Woodland ground flora

This section describes the data collected to date for the establishment of wet woodland ground flora. To provide a simple graphical representation of the results. a degree of manipulation has been required. Data from each quadrat within a given planting method has been combined (e.g. all quadrats within the single species plug planting). and the mean percentage ground cover calculated. Where cover is less than 1%. the standard Recording technique is to express this as 1 individual or few individuals. However, as this is not conducive to the mathematical operations required to provide mean cover values, all such records have been given a value of 0.5%.

Due to the overlapping of the various vegetation species, the total percentage ground cover often totals more than 100 %. Therefore, in order to facilitate the graphical representation of the results. all data has been scaled to a maximum of 100 %. In addition, the species recorded within each quadrat have been separated into 8 data series for representation within the graphs:

- Grasses;
- Forbs (non-experimental broad-leaved flowering plants):
- The 5 Planted Species:
  - Creeping buttercup *Ranunculus repens;*
  - Yellow flag *Iris pseudocorus;*
  - Meadowsweet *Filipendula ulmaria;*
  - Red campion *Silene dioica;*
  - Wild angelica *Angelica sylvestris;* and
- Bare ground

It should be noted that the percentage cover attributed to forbs includes all broad-leaved flowering plants. with the exception of the five species selected for planting and seeding. This cover includes species present within the translocated turf.

9.1. Leam Valley Local Nature Reserve

Data recording has been ongoing since January 2002, with monthly monitoring visits until November 2002, and 3 monthly monitoring visits from then on. Graphical representations of the data are provided in Figures 6 to 9.

9.1.1. Single Species Plug Planting

With respect to the experimental plants (see Section 5), creeping buttercup *Ranunculus repens* has established well, increasing in ground cover from 3% to a maximum of 7% during 2002. However, it experienced a slight decrease in ground cover during 2003 to 6%. Over the study period, the ground cover of Meadowsweet *Filipendula ulmaria* has increased from 0,3% to 1.2%, whilst Red campion *Silene dioica* ground cover has decreased from 2.3% to 1.1%. Wild angelica. *Angelica sylvestris* has reduced from 112% ground cover to 0.1%, with

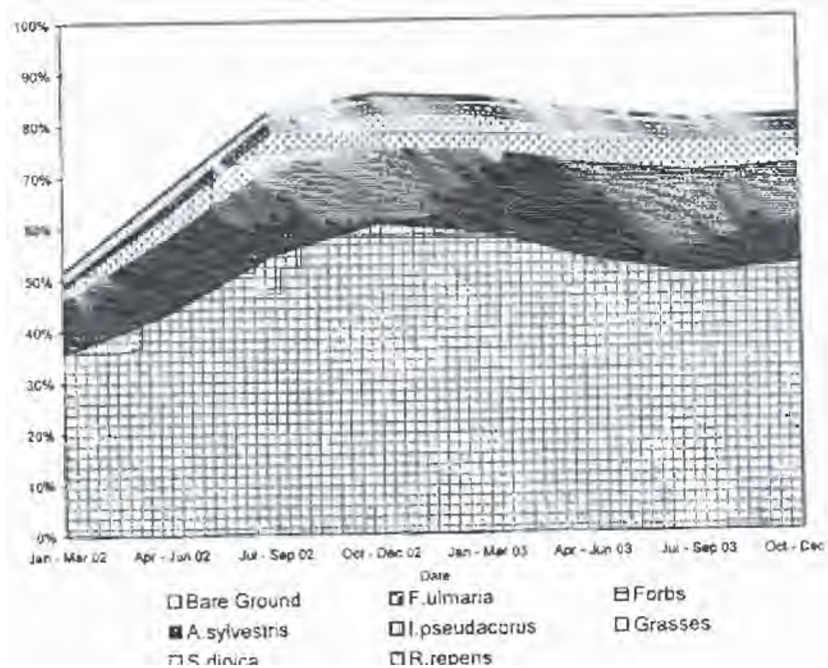


Fig 6. Single Species Plug Planting at LVNVR

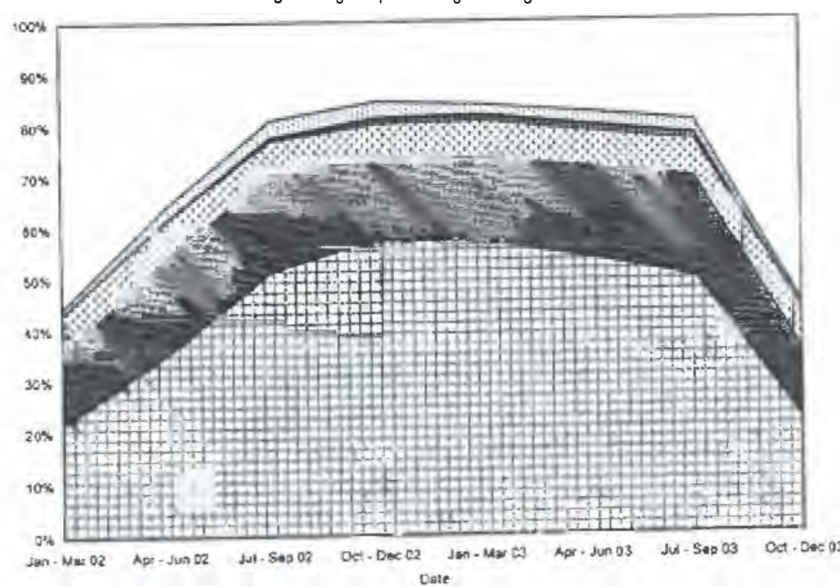


Fig 7. Mixed species seeding at LVNVR (key see above).

Yellow flag *Iris pseudocorus* increasing from 0.3% to 0.6%.

During 2002 the ground cover attributable to grasses increased from 35% to a maximum of 60%. but there was a reduction through 2003 down to 50 %. Forb species have increased in ground cover from some 10% to 20%. To compensate for the vegetation growth, bare ground has reduced from 50% to 20%.

9.1.2. Seeding

Within the seeded plots, creeping buttercup *Ranunculus repens* has remained relatively constant at 8% ground cover. Meadowsweet *Filipendula ulmaria* originally increased from 0% ground cover to a maximum of approximately 0.5%. However. its ground cover area during 2003 appears to be reducing. Red campion *Silene dioica* ground cover has increased from 1.1% to a maximum of 3.3%. however this species has since shown a decline to approximately 1.1%. Wild angelica *Angelica sylvestris* has not established successfully from seed. but the ground cover of Yellow flag *Iris pseudocorus* has gradually increased to approximately 1%.

The ground cover attributable to grasses increased from 21% to a maximum in 2002 of 57%. but reduced through 2003 down to 22 %. Forb species within this planting area have increased in ground cover from 13% to 20%. Bare ground reduced from 55% to a minimum of approximately 15%. However, a seasonal increase in bare ground resulted in a return to approximately 55% at the end of 2003.

9.1.3. Turf Translocation

Due to difficulties in gaining access to the donor site in 2003, turf translocation was undertaken until April 2003, and therefore. data recorded prior to this date does not reflect the status of translocated plants. However. these records have been retained since the translocated turf was placed into the environment represented by this data.

With respect to the experimental plants, the ground cover of creeping buttercup *Ranunculus repens* remained relatively constant at 8% up to the introduction of the translocated turf. At this point it exhibited a reduction to a minimum of 5.5% before rising to 8% once more. No other of the selected experimental plants have been recorded within the translocation area.

The grasses increased from 30% ground cover to a maximum of 60% during 2002, but subsequently there was reduction throughout 2003 ending at 30 %. Forb species gradually increased in ground cover from 9% to 22% up to the third quarter of 2003, when there was a seasonal reduction in ground cover back down to 9%.

9.1.4. Natural Regeneration/Colonisation

Creeping butteraup *Ranunculus repens* has remained present within these experimental plots throughout the experiment. Although ground cover of this species has reduced from 8% to a minimum of 3%. a recent increase has been recorded. and it has returned to 8%. A small number of meadowsweet *Filipendula ulmaria* plants were recorded within Natural Regeneration/Colonisation area during the third quarters of both 2002 and 2003, with ground cover rising to a maximum of 0.7%.

Since the experiment commenced, grasses have increased from 33% to a maximum ground cover of 61%. with a subsequent reduction back to 33% during 2003. Over the same period, the ground cover of Forb rose from 12% to 25%, but has ended at 12% due to seasonal dieback at the end of 2003.

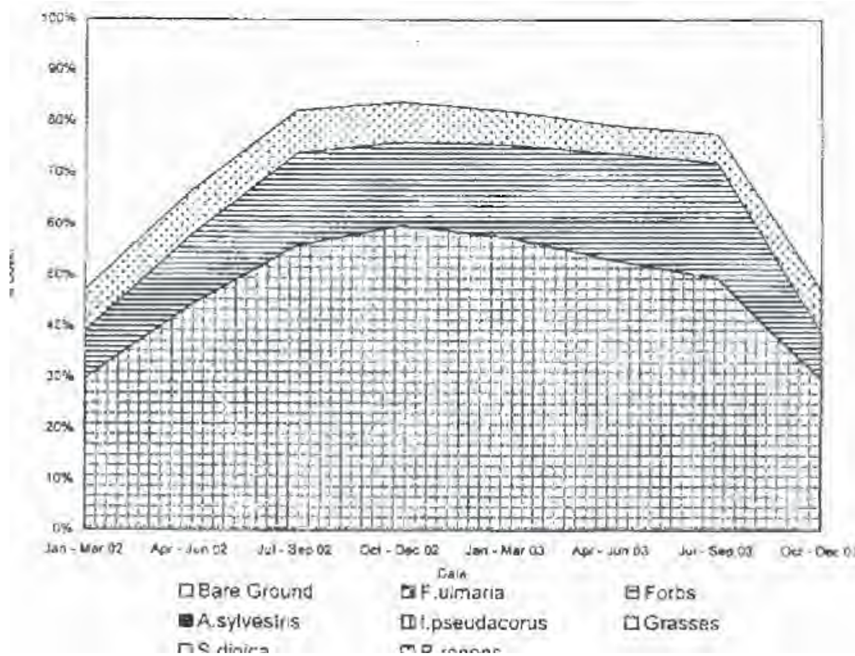


Fig 8. Translocation at LVLNR.

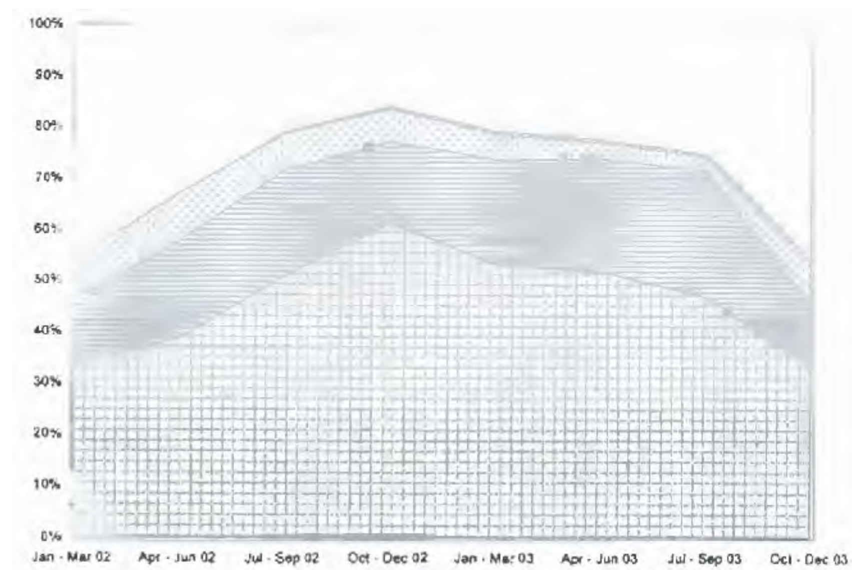


Fig. 9. Natural regeneration:Colonisation at LVLNR (key see above).

9.2. Burton Mail Centenary Woodland

Data recording has been ongoing since April 2003, with monthly monitoring visits to November 2003, and 3 monthly monitoring visits thereafter. Graphical representations of the data are provided in Figures 10 to 13.

9.2.1. Single Species Plug Planting

The predominant pattern for the experimental species within the plug planting has been a reduction in ground cover (creeping buttercup, yellow flag & meadow sweet). Red campion initially increased in ground cover from 1.3% to a maximum of 1.6%, there was subsequently a reduction to 1.1% during the third quarter of 2003. The exception is wild angelica, which has exhibited a marked increase in ground cover from 1.8% up to 3.3%.

Ground cover attributable to both grasses and forb species have increased from 22% to 74%. and from 7% to 22% respectively over the study period. Conversely, as should be expected, bare ground has reduced from 63% down to 0.2%.

9.2.2. Seeding

Within the seeded area initial growth of the experimental plants was promising (with the exception of flag iris), however, these plants did not survive through the monitoring period with all species having disappeared by the third quarter of 2003. In the seeded plots, grass cover has increased from 21% to 69%, whilst forb species have increased from 9% to 30%. This is at the expense of bare ground, which has reduced from 67 % to 0.4%.

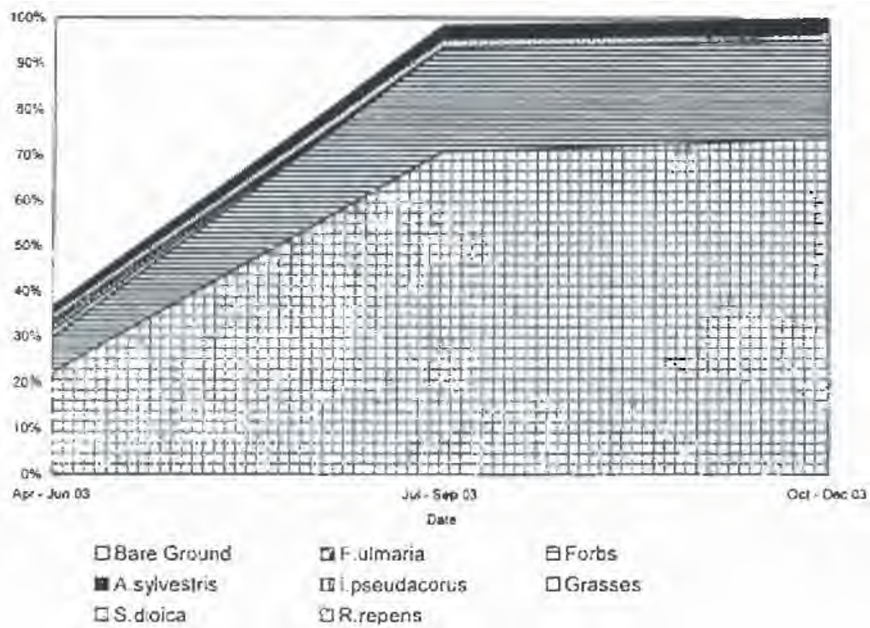
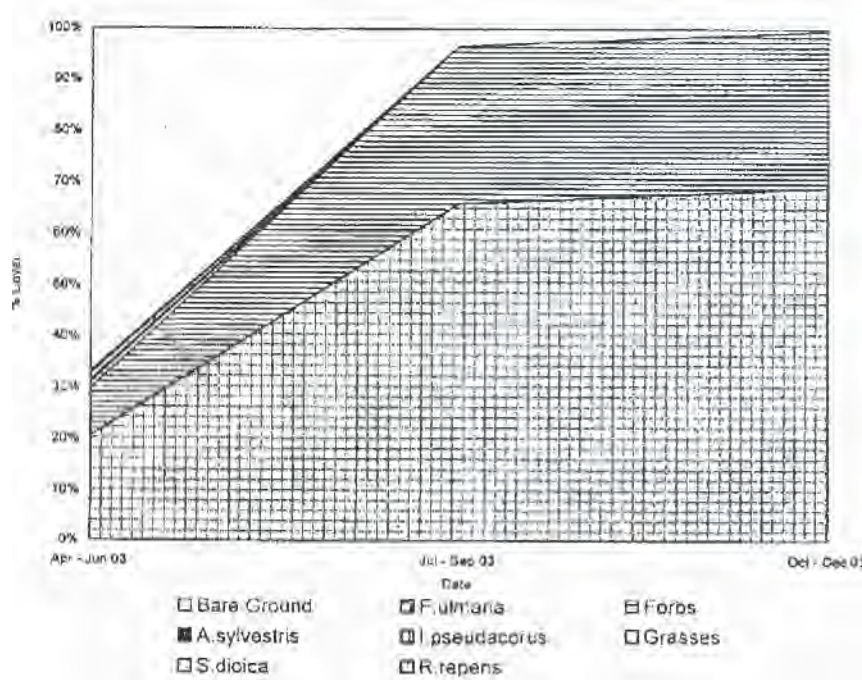


Fig. 10. Single species plug planting at BMCW



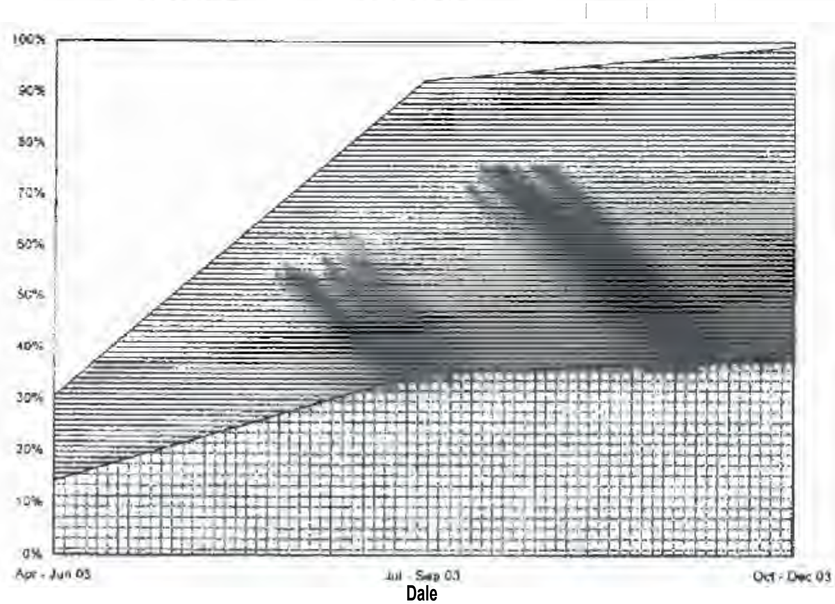


Fig. 12. Turf translocation at BMCW (key see above)

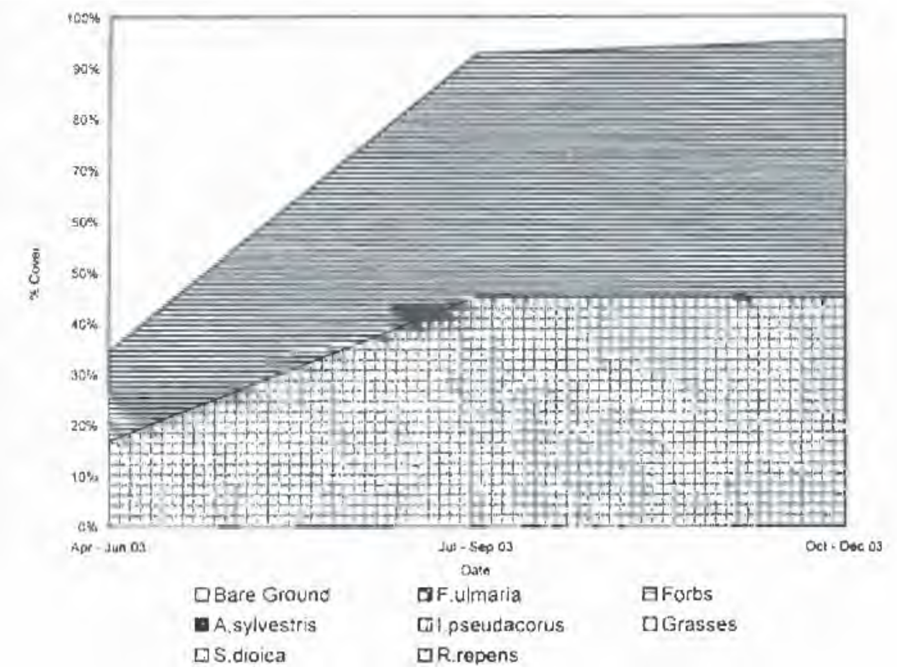


Fig 13. Natural regeneration/colonisation at BMCW.

9.2.3. Turf Translo cation

None of the five chosen plants have been found within the turf translocation areas. However, some of the species translocated from the donor wet woodland (e.g. cleavers *aparine:* chickweed *Stelaria holoslea)* have established well. Unlike at the seeded plots, forb species now dominate having increased from 16% to 61%, whilst grass cover has increased from 14% to 38%. Over this period, the bare ground has reduced down to 0.8%.

9.2.4. Natural Regencration/Colonisat ion

The development of cover within the natural regeneration/colonisation experimental plots has been similar to that found for turf translocation. No evidence of the selected species has been found within this area. Grass cover has increased from 17% to 45%. but forb which was originally 18% by the end of 2003 had reached 50%, with the remaining 5% being bare ground.

10. Conclusions

During the first two years of this research project a Literature review has been undertaken, the experimental design has been formulated, experimental sites have been selected and established. and monitoring has commenced.

The literature review highlighted the need for research into the varying benefits and `success' rates of the available planting techniques with respect to wetland ground flora. The experimental design, the development of selection criteria for experimental sites, and the choice of appropriate plant species and planting methods have all been informed by the literature review.

Two experimental sites have been established to enable the establishment of wetland ground flora to be studied. The first, at the Leam Valley Local Nature Reserve is a wetland, representing conditions experienced at a creation scheme, whilst the second is within the Burton Mail Centenary Woodland, and simulates wet woodland regeneration.

Permanent quadrats have been established within the experimental planting areas, and monitoring has commenced to provide data for comparison of the various planting methodologies. This is due to continue until November 2005.

Some initial analysis of the data collected to date for wet woodland ground flora has been undertaken. A comparison of the data for the four planting methods employed (Figures 7 to 13) indicates some distinct differences between the experimental sites. Within the LVLNR bare ground has remained a noticeable component of the experimental plots throughout the monitoring period, whereas within the Burton Mail Centenary Woodland (BMCW) bare ground has reduced to a small percentage within the first year.

With respect to the experimental plants there have been marked differences in recorded ground cover between the species and between the sites. Creeping buttercup *Ranunculus repens* has remained a constituent of all quadrats at the LVLNR site. whereas this species has all but disappeared from the BMCW site. Wild Angelica *Angelica sylvestris* has not established well within the LVLNR site, whereas the plug planted specimens at the BMCW have established well with ground cover of this species increasing threefold. To date, the single species plug planting has proved the more successful establishment technique.

It is apparent from the graphical representation of the data that whilst an increase in bare ground cover was recorded within the Learn Valley Local Nature Reserve site during the winter of 2003, no such increase was noted during the winter of 2002. In addition, no increase in bare ground cover was recorded at the Burton Mail Centenary Woodland in winter 2003. At present no probable explanation for this increase in bare ground during the second winter of the LVLNR site is available, however it is noted that neither site showed an increase in bare ground cover during the first winter following planting.

It is important to note the distinct differences in character of the two sites (see Section 3). The LVLNR site has a marked slope to the wet woodland, with the lower portion of the slope prone to winter flooding, whilst the BMCW site is predominantly flat, with little difference in elevation between the quadrats. In addition, the BMCW Site has existing *tree* cover, whilst the LVLNR has little shade since the trees were newly planted.

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DISCUSSION

Kadlec: I am thinking in terms of wetlands that are created for water quality improvement. Some of the issues that are faced in these projects are following. What is the influence of the time of the year that you select for establishment on the survival of the plants? What I am thinking is if you plant in spring, great, the plants are happy and it is their lime to start to grow. But should we plant in October? Is that cost-effective or should we wait until the next spring?

Ireland: It is a very valid question. Obviously, there is the best practice element to any form of what is effectively horticultural practice. With something like seeding it may actually be beneficial to plant in October. Then winter frosts activate the seeds. With certain things like planting of seedlings or plant parts it may actually be quite damaging to plant in late autumn and be subject to frost. It may also be a very poor practice to go with planting in the beginning of summer if you have no ability to water the plants. Obviously, in that situation you would have to take into account the costs associated with that high level of post-planting aftercare. Otherwise it is not comparable methodology.

Kadlec: The second question comes up. When is that wetland going to be ready to do its job?

Ireland: I think with respect to treatment wetlands you are looking for much more instant effect. Generally, you wouldn't be necessarily planting to create a wetland that you did not actually want to start using as a treatment wetland for several years or decades. When we talk about a purely biodiversity-based project we can look much longer term. We can have a much broader view. And that allow us to try approaches that would take years to establish. Particularly as we are looking at community development rather than specific plant or species development and we are generally not looking at water quality improvement but improved biodiversity.

Kadlec: A question on custodial costs. Sometimes people establish things but then there is an invasion of exotics or more aggressive plants. Have you included or thought about including custodial costs in your calculations?

Ireland: Currently we have rejected the inclusion of custodial costs. We felt that if we included that, and we can develop obvious costs very easily. when somebody would open our best practice guide, it would say immediately "by-the-way you have to look after that in a very intensive fashion for three years to get these results. It would probably turned out to be a "dust gatherer" rather than the best practice guide. In addition, we are not providing any custodial or post-planting care for the experiment, as we felt this was likely to be the reality of a lot of biodiversity related projects, and for those reason we have currently ignored the management costs.

Tonderski: I am wondering about management of water immediately after the establishment of the planting. because we have seen in many plants that they are dependant on appropriate water levels. This could also be a way of keeping invasive plants away. How are you going to manage this?

Ireland: Neither of our experiment sites currently have facilities to manage water levels. That is why I want to bring the soil moisture content monitoring because we do not have the capacity to manage for an ideal water regime. We want to be able to examine the actual water regime and see how it impacts the plant establishment. I think that your point is very valuable as some plants have shown ten fold improvement of survival ability from putting 20-30 mm of water across the field immediately after the planting and some plants have showed exactly the opposite. But at the moment we do not have facility to examine that within our sites.

Kvet: When you talk about reed beds. do you really mean only beds of common reed *(Phragmites australis)* or do you also include other reed-like plants that form similar communities like *Typha, Scirpus* or others?

Ireland: Very briefly, we worked purely with eommon reed. We are being a bit selective because of problems with the invasive nature of *Typha* and *Scirpus* species in the UK.

P. Cooper: This is a follow up to the last question. When you plant *Phragmites*, how many plants do you put in each square meter? The reason why I am asking *is* because when we first started to design reed beds for wastewater treatment, *the* big problem was growing reeds. We got the Institute of Terrestrial Ecology to do a study involving growing seedling, planting seeds, rhizomes sections and clump sections and we have major problems with the last two. Finally, how much do you pay for each plain? Because it looks like a high cost to me.

Ireland: We are planting 9 plants per square meter. The cost per plug is about 25 pence per unit. We are buying relatively small volumes so we do not necessarily get a very good bulk discount.

Bavor: There is quite a lot of work that looked at a range of different planting types and especially with *Phragmites* most types depended on water regime, i.e. water depth and frequency of flooding. And competing species were also very important. Sometimes they provide ground cover that allowed common reed time to develop. So it is very much more complex than just water depth.