The changing bryophyte flora of Chawley Brick Pit, Oxford

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Summary

The bryophytes (mosses and liverworts) of Chawley Brick Pit, Oxford were surveyed in the years 2002 and 2003, and a diverse bryoflora was recorded. Higher plants and soil acidity were also recorded to assist with an understanding of the site. The bryophyte survey added 16 species to the extensive historical list for the pits, including the locally rare liverwort *Pellia neesiana*. The natural succession that has occurred in the pits (1940-2000), from bare soil and acidic pools to woodland, is closely related to the industrial history of the site, and the results are placed in the context of these changes. The site is notable for the regionally and nationally rare bryophytes that have been recorded there, and some of these remain, including *Sphagnum* species. Factors relating to the future of bryophytes at the site are discussed.

Introduction

Although Chawley Brick Pit was well known in the early 20th century for its exposed geology and fossils (Prestwich, 1879; Galton and Powell, 1980), the four pits at the site first drew the attention of bryologists through the colonisation by mosses and liverworts that followed the cessation of commercial quarrying activity. Clay extraction from the pits ceased around 1940 (Dodsworth, 1976) and in the years that followed, a remarkable accumulation of bryophytes developed (Jones, 1986). This was partly related to an unusual natural acidification event (combustion) in 1943 (Jones, 1986). Consequently, throughout the second half of the 20th century, several eminent bryologists visited Chawley to observe and record the mosses and liverworts. All four pits have now undergone a natural succession from bare soil, through colonisation by acidophile plants, to the present day mosaic of bryophytes, higher plants and mixed woodland.

The aims of this survey are to (1) contribute to the continuity of historic recording at the site, (2) monitor further changes in the bryoflora and (3) in view of the rare and unusual bryophytes that have been recorded there, to see whether any conclusions may be drawn as to the site's potential for regaining or restoring its earlier bryological interest. In this study the results are presented in more detail than hitherto and considering the role of acidification in the history of the site's flora, measurements of soil acidity are also presented.

Industrial history

Chawley Brick and Tile Works opened for commercial clay extraction around 1870 and was one of the largest 'farmer brick-maker' enterprises in the region (Bond *et al.*, 1980). The business operated limekilns and made bricks, tiles and land drainage pipes. By 1937 a sawmill had been added. With the onset of the Second World War, brick making was limited by a lack of fuel and by 1940 the brick works had closed. The timber works continued for a further ten years (making clog soles, wheelbarrows, etc.) and was sold off in 1950 (Dodsworth, 1976).

Geo-chemical history

In 1943, shortly after the pit closed, a natural chemical reaction occurred in the Kimmeridge Clay of the quarry face. Exposed deposits of iron pyrites within the clay had become wet in a summer storm and a spontaneous combustion followed, generating very high temperatures for a while, and expelling clouds of steam and sulphurous gasses (Arkell, 1947). Selenite (gypsum), sulphuric acid and oxides of iron were formed by a complex series of oxidizations; as a result, the pools in the pits became highly acidic and toxic to vegetation. The iron pyrite that caused the reaction is largely associated with the fossilization of large quantities of Jurassic fauna (Powell, H.P., 2004, pers. comm.). Similar natural reactions occur in the same Kimmeridgian strata, especially where they are exposed, on the Dorset coast (West, 2003).

Bryological history

Many notable bryologists visited Chawley in the 1950s and 1960s, among them G. Bloom, W.T. Bradnock, J.P.M. Brenan, M.F.V. Corley, A.C. Crundwell, R.A. Finch, J.A. Paton, A.R. Perry, A.J.E. Smith and E.F. Warburg. E.W. Jones visited the site from 1948 to 1956 and later in 1977 and 1985. However, many earlier recorders did not publish their observations of common bryophytes and no full survey was available until E.W. Jones published his comprehensive account in 1986. Jones (1986) also considered the dispersal mechanisms for species to arrive and colonise at Chawley and concluded that most species arrived as spores (some perhaps as gemmae) with inferred distances of 50 km from the next nearest records. At the extreme, the next nearest record of *Sphagnum riparium* was 250 km.

As the acidity of the pits subsided, the first colonising flora was necessarily the most acid tolerant. The first occurrence of rare bryophytes, including *Sphagna*, was noted in 1948. Willow and birch saplings had already established on the slopes of the pits by this time and in the following years to 1977 woodland had become well developed (Jones, 1986). Bryophyte diversity was further increased by erosion of the unconsolidated Greensand, which maintained an unstable substrate suitable for pioneer species.

Two examples of the rarer pioneer mosses are *Ditrichum pusillum* and *Buxbaumia aphylla. D. pusillum* was first found by A.C. Crundwell in 1948 and recorded by W.T. Bradnock and A.J.E. Smith in 1956 and in 1968 by M.F.V. Corley (H. Whitehouse, 1980, letter to BBONT). *B. aphylla* was first recorded in 1956 by A.J.E. Smith and had only been recorded in three other places in southern Britain in the previous 50 years, the nearest to Chawley being at Pishill Bank, Oxfordshire in 1947 (J.M. Campbell, Oxfordshire Biological Records). Although both mosses were observed to produce spores at Chawley and *D. pusillum* is known to produce persistent subterranean tubers, they were unlikely to remain without specifically targeted conservation.

Sphagnum mosses, which are a genus of bogs and generally acidic wetland habitats (Daniels and Eddy, 1985), are rare in Oxfordshire owing to the paucity of such habitats. Therefore the presence of eight species at Chawley is particularly notable. In the 1980s *Sphagna* were observed to be growing in all four pits (Jones, 1986; Dawe, 1985). A single large tussock of the nationally rare *Sphagnum riparium* was found in

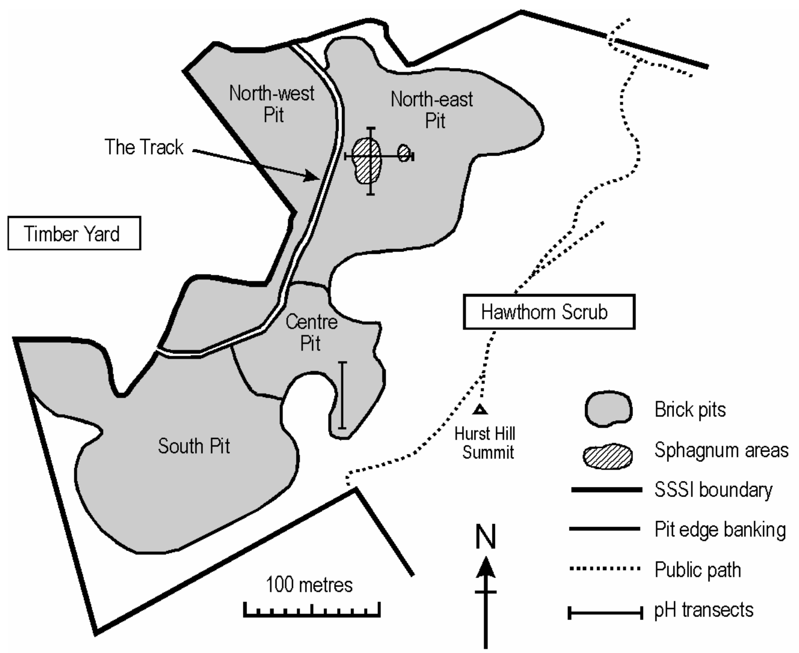
1961 by A.R. Perry and was the only known record south of Yorkshire at that time (Duncan, 1967). Duncan stated that:

> 'This species is now found chiefly in pools or very wet ground, often over 2000 ft., on northern peat moors, with a predominantly northern distribution. It was believed until recently to have become extinct in central and southern England so that its discovery in Berkshire [Chawley: now in Oxfordshire] in 1961 was of great interest.'

Site Description

General

Figure 1. Chawley Brick Pit, Hurst Hill summit and the survey sectors for this study.



Chawley Brick Pit is part of Hurst Hill Site of Special Scientific Interest (SSSI) (English Nature; 1950, 1986) and is situated 4 km west of Oxford: grid reference SP475043. The hill rises to an altitude of 159 m, and is one of the prominences of high ground in the region that constitute the 'Mid Vale Ridge'.

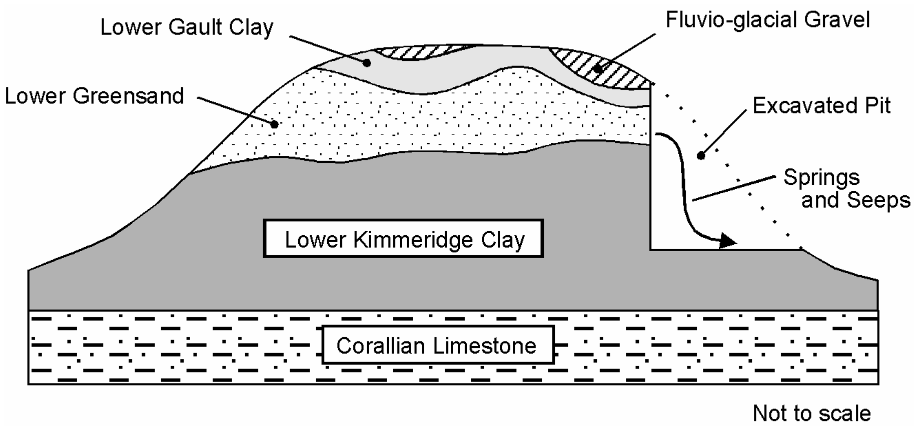
On the excavated west side of the hill there are four well-defined pits (Figure 1) from which clay was extracted for brick and tile manufacture. Since the cessation of quarrying, the original 12 m high quarry faces have slumped to obscure the original contours. Together with the remnant of other workings such as backfill and spoil, the pits now consist of a complex of tiers and banks that link the pit floor areas to the steep upper rim. The area is bounded by pasture fields to the north and south, by hawthorn scrub to the east and a timber yard to the west.

The 7-Ha Brick Pit area was notified as an SSSI in 1950 for its geology, bryophytes and lichens (English Nature, 1950) and was extended in 1986 to include the whole of

Hurst Hill summit (English Nature, 1986). Chawley Brick Pit is currently privately owned and is therefore relatively undisturbed with no official public access.

Geology

Figure 2. Diagrammatic east-west cross section of Hurst Hill geology showing the stratigraphic sequence and the effect of quarrying for brick clay.



The geology of the high ground near Chawley is unusual in Oxfordshire, having Cretaceous Lower Greensand directly overlying Jurassic Kimmeridge Clay (Horton and Cornwell, 1982). Figure 2 shows a simplified vertical section of the geological sequence at Hurst Hill. The summit of the hill has a shallow and free draining acidic soil formed from remnants of fluvio-glacial gravel and the capping of calcareous Lower Gault Clay. Below this, the coarse rust-coloured Lower Greensand is about 10-15 m thick. The bulk of the hill is 20-25 m of Lower Kimmeridge Clay which is the stratum from which the clay for brick-making was extracted. It is also this stratum that has yielded important Jurassic fossils and the associated biochemical raw materials for the 1943 oxidation event. At the foot of the hill the Kimmeridge Clay levels out onto Corallian limestone.

Hydrology

Water enters the pits as both rainfall and spring flow. The floors of the pits are mostly impermeable clay and semi-permeable clay rubble and support a variety of ponds and damp areas. There is little deep infiltration into the clay floor and most excess water leaves the pits by surface drainage to the ditches and ponds on the north-west side. Surface water does not evaporate readily, as the ventilation of the pits is much reduced in the shelter of the hill and the tall tree canopy. Where the clay is less homogenous, a conventional water table exists and the level of this will have a strong influence on the overall wetness of the pits. The track probably helps to maintain the height of the water table in the North-east Pit.

The juxtaposition of permeable Greensand overlying impermeable Kimmeridge Clay causes many small springs and seeps to flow out around the hill. Rainwater readily percolates into the Greensand aquifer, where it accumulates during wetter periods and is released more gradually throughout the year. This water regulation is important for maintaining dampness and humidity within the pits and contributes significantly to the viability of the bryophyte flora. However, the tall vegetation on the Gault and Greensand capping will reduce spring flow to the pits. Compared to shorter vegetation, the deep rooted hawthorn and oak on the hill will extract and transpire a greater quantity of water and the process of 'rainfall interception' (Ward and Robinson, 1989) on a well ventilated hill top will significantly reduce the amount of rainfall reaching the ground.

North-west Pit

The north end of the pit is closed canopy hawthorn (*Crataegus monogyna*) with minimal herb layer on a dry clay soil. This merges into birch (*Betula* spp.) and sycamore (*Acer pseudoplatanus*) woodland with seasonal pools. Steep banks of Greensand and Gault Clay support a sparse ground flora, including three stems of the calcicole shrub mezereon (*Daphne mezereum*). The long westerly edge has a sunnier aspect than the other three pits and catches the prevailing south-westerly wind, making it comparatively dry. Bryophytes are few under the hawthorn, but become abundant towards the pools and where the substrate changes from clay to spoil heaps of clay and sand.

North-east Pit

The rim of the North-east Pit has now eroded and slumped, such that there are no slopes steeper than about 45°, and it is becoming stabilized by bramble (*Rubus* sp.) and common bryophytes such as *Eurhynchium praelongum* and *Pseudoscleropodium purum.* This rim was once a near vertical cliff of Greensand where many of the earlier pioneer bryophytes were recorded. Both the pit floor and Greensand banks are densely wooded with trees of various ages: mostly birch with some hawthorn, willow (*Salix spp.*) and elder (*Sambucus nigra*). The canopy is about 80% closed when in leaf, with an understorey of young sycamore, oak and hawthorn and a ground layer of bramble and occasional dog rose (*Rosa canina*). A variety of ferns, sedges and grasses have become established, along with wood sage (*Teucrium scorodonia*), wild strawberry (*Fragaria vesca*) and the occasional common spotted-orchid (*Dactylorhiza fuchsii*). *Sphagnum* covers an area of approximately 30 m x 20 m (Figure 1) on the pit floor and there is a small colony in a seasonal pool on one of the lateral raised tiers. Bramble and hawthorn saplings are encroaching upon the areas of *Sphagnum*. There is much bare soil with an abundant and varied bryophyte cover and epiphytic species are present on some of the trees.

Centre Pit

Centre Pit is the smallest of the four pits and has two spring-fed streamlines that remain wet for most of the year. The Greensand banks are very steep and contain an active badger sett, which maintains the disturbance of the sand in places. The predominant trees are birch, with three large aspen (*Populus tremula*) dominating the central area. The canopy is approximately 70% closed when in leaf. The understorey is sparse and includes hawthorn and dog rose. The herb layer includes nettle, bramble, wood sage, enchanter's nightshade (*Circaea lutetiana*) and a patch of small balsam (*Impatiens parviflora*). Three large ash trees (*Fraxinus excelsior*) and the occasional elder support most of the epiphytic bryophytes. Liverworts cover extensive areas of the wetter parts of the pit floor.

South Pit

The north-west section of the South Pit is closed canopy hawthorn scrub and blackthorn (*Prunus spinosa*) with a depauperate herb layer. The remaining part of the pit has the largest of the seasonal pools to be found at Chawley Brick Pit. Near the pools is a small raised knoll of acid Greensand with grasses and broom (*Cytisus scoparius*). The degree of canopy closure is patchy and varies across the pit from about 60% to 70% when in leaf. Willow is more abundant here than in the other pits, with ash and elder throughout. Bryophytes are generally abundant, but nearly absent from the densely shaded area of hawthorn and blackthorn scrub.

The Track

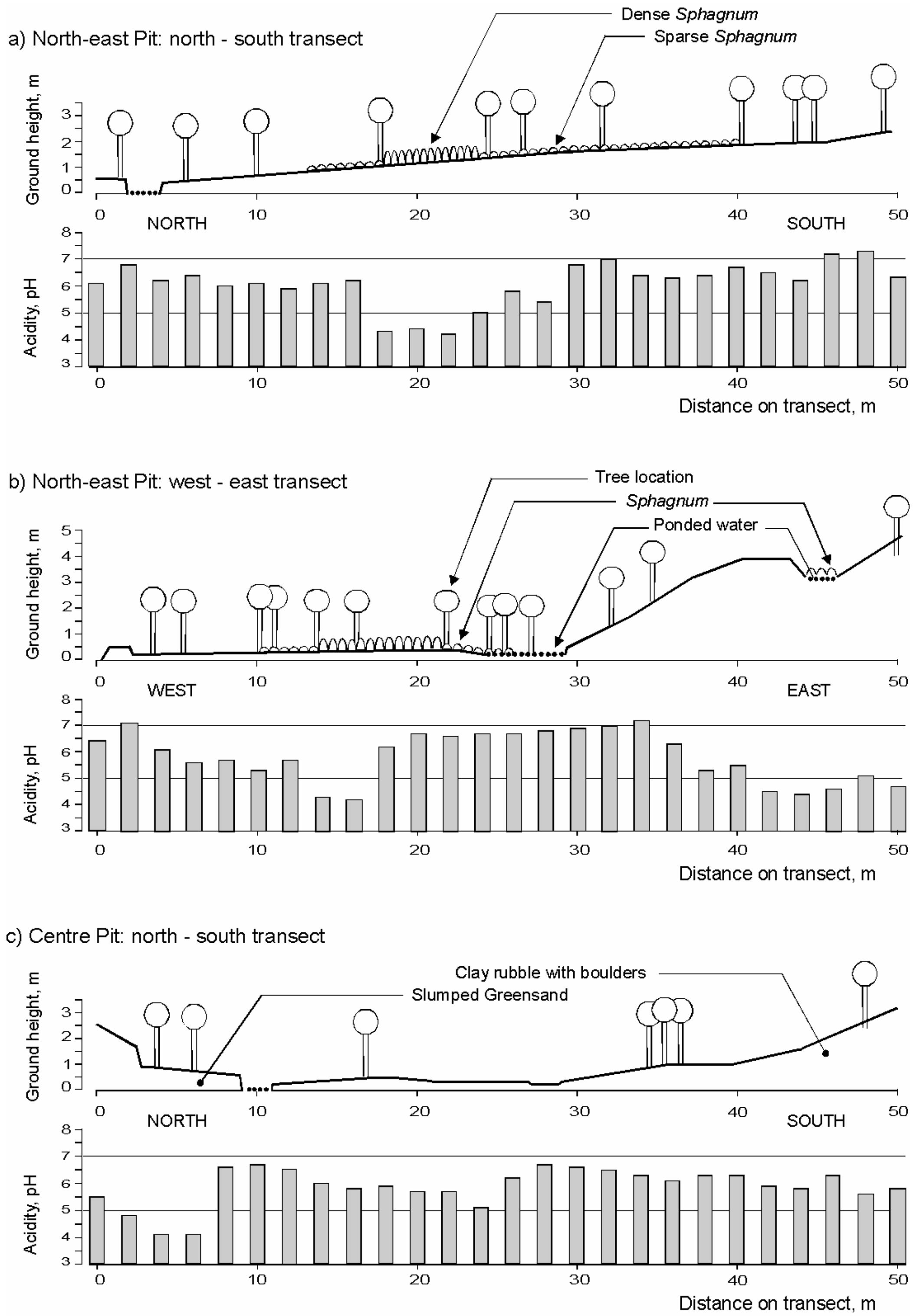
A 6 m wide track leads through the pits for about 300 m. Most of the track surface is brick and limestone rubble mixed in with the varied soils of the locality. The north end of the track is water logged clay, with a variety of sedges and rushes, and maintains its wetness for most of the year. The south end supports a varied flora of bracken (*Pteridium aquilinum*), colt's-foot (*Tussilago farfara*), ploughman's spikenard (*Inula conyza*), common spotted-orchids and broad-leaved helleborine (*Epipactis helleborine*). The track is maintained as a firebreak by mechanical scraping and the removal of perennial growth and in 2003 some of the topsoil was removed exposing the gravel substrate. As this soil removal necessarily restarts the succession of bryophyte colonisation, English Nature requested that the work be undertaken during the summer months to allow winter ephemerals to complete their life cycle and for pioneer species to establish in the following winter months (R.D. Porley, 2002, pers. comm.).

Survey Description

Topography

Figures 3a, b and c show transects from within two of the brick pits (x axes) and were laid out as follows (see also Figure 1): North-east Pit, north/south and west/east transects passing through *Sphagnum*; Centre Pit, north/south transect (no *Sphagnum*). The ground height (above an arbitrary datum) and pH are shown on the y-axes. Figures 3a, b and c also show the location of the *Sphagnum* in relation to the seasonally ponded water and the positions of mature trees within 50 cm each side of the transect**.**

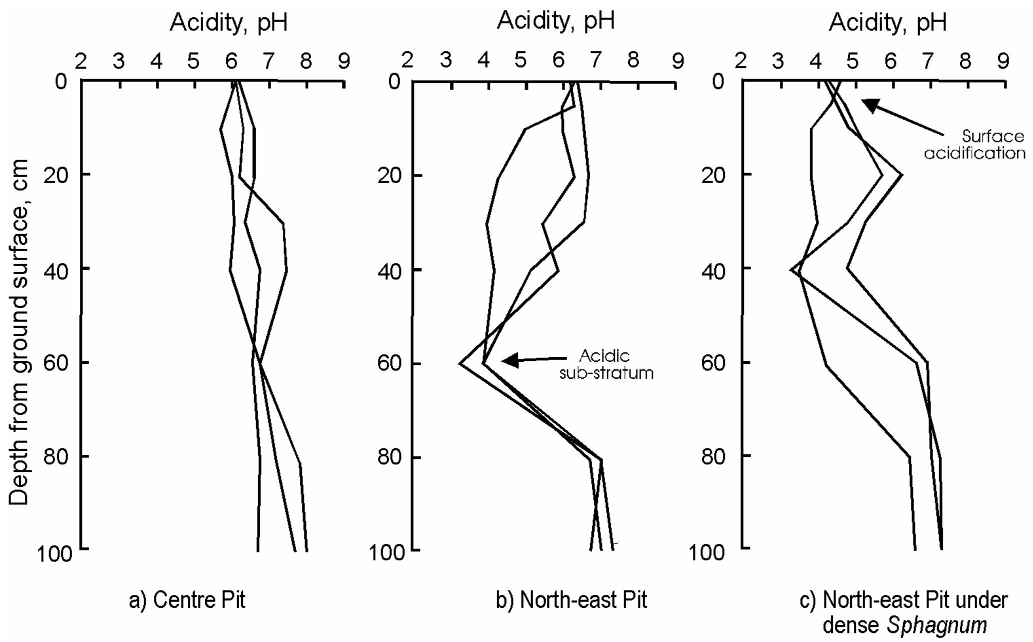
Figure 3. Transects of the North-east Pit and Centre Pit (see also Figure 1) showing the distribution of the *Sphagna* and near-surface soil acidity (bars). Also shown are ground height (above an arbitrary datum) and the locations of ponded water and mature trees.



Soil acidity

Soil pH was measured to compare the surface and subsurface acidity of areas both with and without *Sphagnum*. At 2 m intervals along each transect (Figure 3), three samples of soil were taken from within 2 cm of the soil surface, after removing any loose organic material. The pH values presented here are the mean of the three samples. Vertical profiles were augered to a depth of one metre to observe the subsurface pH as follows: three from the floor of Centre Pit; three from the North-east Pit where the *Sphagnum* is absent; and three from the North-east Pit where the *Sphagnum* forms a dense carpet.

Figure 4. Vertical profiles of acidity (pH) (3 samples for each) from the North-east Pit and Centre Pit showing (3a) an even gradient with depth in the Centre Pit, (3b) acidic sub-strata in the North-east Pit and (3c) the influence of *Sphagnum* on the surface soil acidity in the North-east Pit.



Bryophytes

The 5 survey sectors were visited regularly in 2002 and 2003, choosing bright days in the winter and spring when capsules are most likely to be present. Bryophyte abundance was recorded using the DAFOR scale (Shimwell, 1971) and a vascular plant survey carried out to provide a context for the bryophytes.

Results

The general surface pH on the wet clay floor of the pits is slightly acidic and typically in the range pH = 6.0 – 7.0 (Figures 3a, b and c). However, it can be seen that most of the denser *Sphagnum* has had an acidifying influence on the surface soil and reduced the pH to around 4.0. This acidification results from the ability of *Sphagnum* to access minerals in exchange for hydrogen ions (O'Neill, 2000). Figures 3b (east end) and 3c (north end) also show the lower pH (typically 4.0 - 4.5) associated with the acidic Greensand that outcrops at the sides of the pits. The more alkaline clay rubble with boulders at the southern end of the Centre Pit transect (Figure 3c) does not show the same low pH values.

Figures 4a, b and c show sample profiles of soil pH in the Centre Pit and North-east Pit. Observations during sampling showed that the top metre of soil was consistently different between the two pits. In the North-east Pit most of the profile was of homogenous dense grey Kimmeridge Clay, whereas in the Centre Pit the profile was a more complex mix of clay, small stones and Greensand, possibly backfill or 'spoil'. Therefore it is likely that the Centre Pit has a more free-draining profile, at least in places, compared to the extensive areas of impeded drainage in the North-east Pit.

All profiles appear to stabilise to a neutral pH at 80 cm depth and below. In the Centre Pit (Figure 4a), the generally uniform gradient of pH is consistent with a free draining profile. In contrast to this, the impermeable Kimmeridge Clay of the North-east Pit shows marked stratification, with particularly acidic sub-strata at 60 cm (Figure 4b) and 40 cm (Figure 4c). Figure 4c clearly shows the near-surface acidification under the dense *Sphagnum* of the North-east Pit.

Bryophyte Survey

In 2002-3, 55 species of moss and 14 liverworts with various abundances were recorded in 'The Pits' area of Hurst Hill SSSI, including the Track (Appendix: List 1). Sixteen species are new records for The Pits but five of these (*Bryum rubens, Didymodon insulanus, Tortula truncata, T. acaulon and Ulota phyllantha*) had been previously recorded elsewhere in the SSSI in 1995 (Porley, 1996). When combined with the additional records of Porley (Appendix: List 2), 64 mosses and 15 liverworts have been recorded in recent years (1995-2003) of which 36 had not been previously recorded. Of the 100 species recorded between 1948 and 1985 (Jones, 1986; British Bryological Society Database) (Appendix: List 3) 57 species have not been refound by the two more recent surveys. Three species of *Sphagnum* were found in this survey. *Sphagnum squarrosum* is the dominant species, with *S. fimbriatum* and *S. subnitens* occurring in small quantities.

The totals of recorded bryophytes in the individual pits are summarised in Table 1 together with the distribution of epiphytic species. For the purposes of this study, epiphytes are defined as those bryophytes that are predominantly, rather than strictly, found on trees.

Table 1. Bryophyte diversity of the individual survey areas.

Survey Area	Total moss species	Total liverwort species	Total Bryophytes (total epiphytic species)
North-west Pit	18	4	22 (3)
North-east Pit	34	9	43 (13)
Centre Pit	24	5	29 (5)
South Pit	12	5	17 (7)
Track	17	4	21 (0)
All areas	55	14	69 (16)

A thriving community of *Pellia neesiana* was found extending for several metres along the streamline of the Centre Pit. Fertile thalli of both male and female plants were plentiful. *P. neesiana* is a dioecious liverwort favouring marsh and wet flush habitats and neutral to slightly acidic substrates (Hill, *et al.*, 1991). There is only one other record of *Pellia neesiana* for the Vice County (VC22, Berkshire) from near Newbury in 1964 (Bates, 1995); it has not been recorded in VC23, Oxfordshire (J.M. Campbell, 2004, Oxfordshire Biological Records; Perry and Jones, 1998), and is rare in south-east Britain.

An established patch (6 m x 5 m) of *Rhytidiadelphus loreus* was found on a raised Greensand bank within the North-east Pit, with further plants scattered over an extensive area on a higher terrace. A patch of this moss had been noted in previous surveys and almost certainly in the same place (Jones, 1986; Porley, 1996). *R. loreus* is not at all common in the mid and south-east regions of Britain.

As a result of the removal of topsoil from the Track sector in 2003, the colonising bryophytes were typical of an arable/pioneer community (Watson, 1981). However, these species are colonisers of neutral substrates (rather than acidic) and are not among those acidophiles that colonised in the 1940s. Consequently many of the Track species are common bryophytes but new records for the SSSI, including *Barbula convoluta, B. unguiculata, Bryum rubens*, *Eurhynchium hians*, *Tortula truncata* and *T. acaulon*.

Discussion

Pit hydrology

For the Chawley Brick Pit to sustain its current bryophyte diversity, humidity and surface wetness would need to remain stable and factors that are drying the pits need to be objectively evaluated. For example, although the taller trees within the pits will export some water, this loss may not be significant when compared to other water movements. Furthermore, the tree canopy plays an important role in maintaining a humid microclimate within the pits and in preventing excessive light penetration to the ground in summer. Both high humidity and some degree of shading are necessary for a diverse bryoflora at Chawley and thinning of the canopy trees would need careful consideration.

The more significant influences causing the pits to become drier are likely to be associated with the pit's surroundings, either increasing the drainage from the area or reducing the spring flow to it. The year-round spring flow and seepage into the pits from the permeable hill strata (Figure 2) are particularly important in maintaining dampness throughout the year. Yet by transpiration and reduced rainfall efficiency (Ward and Robinson, 1989), the development of mature woody scrub on the hilltop will have greatly reduced the spring flow from the Greensand capping. It is possible that these processes have reduced spring flow into the pits to the least amount since they were dug. Plans to return large areas of mature hilltop scrub to shorter vegetation would undoubtedly increase spring flow and seepage into pits to the benefit of the bryophytes.

A change of use, or development, of the timber yard could alter the drainage from the North-west and South Pit by lowering the water table, especially if the existing ponds were drained or the complex flow along the west boundary was modified. However, clay bunds could be created to permanently raise, or at least maintain, the water table in parts of the pits for the benefit of the bryophytes. The Track probably already provides such a barrier to water for the North-east Pit.

Bryophytes

Although 69 species of bryophyte were recorded in this survey, the highest number recorded in any one of the five survey sectors was considerably less (17 to 43: see Table 1). Furthermore, 36 species (52%) occurred exclusively in any one sector and this suggests that the survey areas are quite different in character.

The pits with the greatest diversity of bryophytes were those that were wettest and had species preferring a more acidic substrate: North-east Pit and Centre Pit. The development of epiphytic species in the North-east Pit and South Pit would appear to be associated with the dampness and the competitive success of suitable host trees such as birch, elder, ash and willow. Areas where the succession was similarly advanced but drier have become dominated by a monoculture of hawthorn and were depauperate in bryophytes. However, the dense hawthorn does contribute to the sheltered microclimate for the abundance of bryophytes nearby.

The scraped Track sector would be expected to have a different bryophyte flora to the less disturbed and wooded pits. Half of the Track species were not recorded in the pit areas. The North-east Pit had the most epiphytic bryophytes (13 species), which can be attributed to the presence of mature birch, willow and elder. In the drier South Pit there were fewer epiphytes (7 species), notwithstanding the frequency of suitable willow. The North-west Pit and Centre Pit had the least number of epiphytes (3 – 5 species) mostly on a few large and well-colonised ash trunks.

Sphagnum

In view of the historical and regional importance of *Sphagna* at Chawley, it is unfortunate that the abundance has declined considerably over the years. Whereas *Sphagna* were observed in all four pits in the 1980s, they are now confined to only the North-east Pit.

However, the diversity of *Sphagnum* may not necessarily have declined to quite the same extent. S*phagnum papillosum* (nationally common) and *S. riparium* (nationally rare) were both likely to die out as the habitat became more shaded, but in contrast to these, the six species present in 1995 require a less acidic substrate (especially *S. palustre* and *S. subnitens*) and are tolerant of woodland shade (Hill *et al.*, 1992). Also, *Sphagnum palustre, S. fimbriatum, S. subnitens* and *S. squarrosum* are quick to colonise when the circumstances are suitable and are often found together in damp woodland habitats (Daniels and Eddy, 1985; Hill *et al.*, 1992). Although *Sphagnum angustifolium*, *S. fallax* and *S. palustre* were not identified in this survey, it is considered likely that these species remain in the North-east Pit (R.D. Porley, 2004, pers. comm. and A.R. Perry, 2004, pers. comm.).

Figures 3a and b show that where the dense *Sphagnum* occurs the pH of the surface soil has been lowered to values of around pH = 4 - 5, which undoubtedly helps the *Sphagnum* to dominate over less acid-tolerant flora. Furthermore, the considerable areas of sparse *Sphagnum* surrounding these denser patches appear stable and healthy on a less acidic substrate (pH = 6 - 7). The greatest immediate threat to the remaining

Sphagnum would appear to be drying of the pits, which weakens the competitive advantage of the *Sphagnum* and hastens the encroachment by bramble and hawthorn saplings. In places, the accumulation of leaf litter may also have an influence in providing nutrients to the competitive advantage of other plants.

The influence of *Sphagnum* on the pH can be seen to persist for at least 10 cm into the clay soil of the North-east Pit floor (Figure 4c) and at greater depths other influences within the soil (not investigated here) are maintaining strongly acidic sub-strata. Consequently, soil disturbance at this site, be it light (e.g. dealing with invasive flora) or more traumatic (e.g. a soil scrape, or fallen tree) is likely to assist the spread and colonisation of acidophile bryophytes. This colonisation would include *Sphagnum* as long as the drying of the pits was reversed.

Conclusions

The mosses and liverworts of Chawley Brick Pit remain exceptionally diverse for a small site in Oxfordshire and make a significant contribution to regional biological diversity. This survey has added 16 species, including the locally rare *Pellia neesiana*, and at least three species of *Sphagnum* remain in the North-east Pit. The existing bryophytes would seem to be in reasonable balance with the current habitat, and the extant species of *Sphagnum* are suited to the pit's dappled shade and generally mild acidity. Most of the bryophytes that have gone from the site are those that would be expected to diminish with a succession to woodland, or those acidophile species that were specifically associated with the unusual geo-chemical events of the 1940s. Trees and shrubs now provide a substrate for a good diversity of epiphytic bryophytes. Observations of soil acidity have shown that conservation effort that disturbs the ground on either a small or medium scale is more likely to encourage bryophyte diversity than suppress it.

A key factor for the management of Chawley Brick Pit for bryophytes is to maintain or increase the wetness. Also required is an understanding of the contribution by the trees and shrubs to the microclimate and diversity of substrata for bryophyte growth. However, the future of the site and the diversity of its flora may be decided, for better or worse, by external and larger scale influences on the overall hydrology of the hill. Although the pit habitats seemed to be relatively stable at the time of surveying, without intervention the pits will continue to become drier and the bryological interest diminish. Changes to the surrounding land use could be rapid and detrimental (such as building development) or slowly beneficial (such as increased infiltration on the hill). In the meantime, the required intervention to maintain the Brick Pit for bryophytes is not beyond reasonable resources.

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Appendix

List 1. Species of bryophyte recorded in this survey, including substrate and abundance.

Nomenclature follows Paton (1999) for liverworts and Smith (1978) for mosses with amendments from Blockeel and Long (1998).

† Species newly added by this survey
* epiphytic species

'DAFOR' codes (Shimwell, 1971) are as follows:

D Dominant
A Abundant
F Frequent
O Occasional
R Rare

NB: Ratings relate to abundance in the pits, not national abundance.

	Substrate	Track Sector	North-west Pit	North-east Pit	Centre Pit	South Pit
LIVERWORTS						
Cephaloziella divaricata	birch			R		
Chiloscyphus polyanthos	soil			O	O	
*Frullania dilatata**	willow		R	R		
Lophocolea bidentata	soil/birch	O		A	F	O
Lophocolea heterophylla	soil/birch	O	F	F	O	
Lunularia cruciata†	brick	O	R			
*Metzgeria fruticulosa**	willow					O
*Metzgeria furcata**	birch/willow			R	F	O
Metzgeria temperata†*	willow					R
*Microlejeunea ulicina**	willow			R		
Pellia endiviifolia	soil		R			
Pellia epiphylla	soil	R		R		
Pellia neesiana†	soil				A	
*Radula complanata**	elder/oak			R		R
MOSSES						
Amblystegium serpens	elder		R			
Atrichum undulatum	soil		O	O	F	O
Barbula convoluta	soil	R				
Barbula unguiculata†	soil	O				
Brachythecium rutabulum	soil	O	F		O	
Brachythecium velutinum	soil/brick		R		R	
Bryum capillare†	elder		R	R	R	
Bryum rubens	soil	O				
Calliergon cordifolium	soil			R		
Calliergonella cuspidata	soil	F	R			O
Ceratodon purpureus	soil	R				
Cratoneuron filicinum†	soil	O		O		
*Cryphaea heteromalla**	elder/willow			R	R	
Dicranella heteromalla	soil				R	
Dicranella varia†	soil	O				
*Dicranoweisia cirrata**	birch			F	O	
Dicranum scoparium	birch			F	O	
Didymodon insulanus†	soil	R				
Eurhynchium praelongum	soil		A	A	A	A
Eurhynchium striatum	soil		O	A		O
Eurhynchium hians†	soil	O				
Fissidens bryoides	soil		F	O		
Fissidens taxifolius	soil				R	
Hypnum andoi	birch/willow			F	O	F
Hypnum cupressiforme var. cupressiforme	birch		A	F	F	F
Hypnum resupinatum	birch			R		
Leptodictium riparium	soil				R	
Mnium hornum	soil		O	O	O	O
Orthodontium lineare	rotting log			R	R	
*Orthotrichum affine**	ash/elder		O	O	A	F

	Substrate	Track Sector	North-west Pit	North-east Pit	Centre Pit	South Pit
*Orthotrichum diaphanum**	elder		R	R	R	
Plagiomnium rostratum	soil				R	
Plagiomnium undulatum	soil	F	F	F	F	F
Plagiothecium nemorale†	rotting log				R	
Plagiothecium undulatum	birch			R		
*Platygyrium repens**	birch			R		
Polytrichum formosum	soil			O	R	
Pseudoscleropodium purum	soil	O	F	A	F	
Pseudotaxiphyllum elegans	soil			R		
Rhizomnium punctatum	soil			R		
Rhynchostegium confertum†	ash		R		R	
Rhytidiadelphus loreus	soil			O		
Rhytidiadelphus squarrosus	soil	O		A		
Sphagnum fimbriatum	soil			R		
Sphagnum squarrosum	soil			A		
Sphagnum subnitens	soil			R		
Syntrichia laevipila†*	elder			R		
Thuidium tamariscinum	soil	R	A	A	O	O
Tortula acaulon†	soil	R				
Tortula muralis†	brick	O	R			
Tortula truncata†	soil	O				
*Ulota bruchii**	willow			R		
*Ulota crispa**	oak/willow			R		O
Ulota phyllantha†*	willow					R
*Zygodon viridissimus var. viridissimus**	elder			R		

List 2. Bryophyte species recorded in the survey sectors of this study by R.D.Porley in 1995 (pers. comm., 2004; Porley, 1996), but not seen during the surveying for this study.

LIVERWORTS

Lepidozia reptans

MOSSES

Brachythecium rivulare
Dicranella schreberiana
Dicranella staphylina
Ditrichum cylindricum
Plagiothecium curvifolium
Polytrichum commune
Sphagnum angustifolium
Sphagnum fallax
Sphagnum palustre

List 3. Bryophyte species that have not been re-recorded since the survey of Jones in 1986 or before; most recent record in brackets.

LIVERWORTS

Aneura pinguis (1951)
Blasia pusilla (1951)
Calypogeia muelleriana (1985)
Cephalozia bicuspidata (1985)
Cephalozia bicuspidate ssp. lammersiana (1948)
Cephaloziella hampeana (1951)
Gymnocolea inflata (1985)
Jungermannia gracillima (1952)
Jungermannia hyalina (1951)
Lophozia bicrenata (1951)
Lophozia capitata (1951)
Lophozia excisa (1969)
Lophozia ventricosa (1951)
Lophozia ventricosa var. silvicola (1951)
Nardia geoscyphus (1951)
Nardia scalaris (1951)
Riccardia chamedryfolia (1955)
Riccardia multifida (1955)
Scapania compacta (1948)
Scapania irrigua (1949)
Scapania nemorea (1949)
Tritomaria exsectiformis (1951)

MOSSES

Aulacomnium palustre (1952)
Barbula reflexa (1955)
Brachythecium albicans (1985)
Bryum argenteum (1985)
Bryum intermedium (1951)
Bryum pallens (1952)
Bryum subapiculatum (1985)
Bryum subelegans (1985)
Buxbaumia aphylla (1969)
Calliergon giganteum (1985)
Climacium dendroides (1948)
Dicranella cerviculata (1985)
Ditrichum pusillum (1968)
Drepanocladus aduncus (1985)
Fissidens viridulus (1985)
Hypnum jutlandicum (1985)
Isothecium myosuroides (1985)
Philonotis fontana (1952)
Plagiomnium affine (1985)
Plagiothecium denticulatum var. denticulatum (1985)
Plagiothecium succulentum (1968)
Pleurozium schreberi (1985)
Pogonatum urnigerum (1985)

Pohlia annotina (1977)
Pohlia nutans (1985)
Pohlia proligera (1954)
Polytrichum juniperinum (1956)
Polytrichum piliferum (1969)
Racomitrium canescens (1951)
Racomitrium lanuginosum (1950)
Sphagnum papillosum (1962)
Sphagnum riparium (1971)
Tortula modica (1979)
Tortula subulata var. angustata (1957)
Zygodon conoideus (1985)