Norfolk & Norwich Naturalists' Society

TRANSACTIONS *of the* NORFOLK & NORWICH NATURALISTS' SOCIETY

Volume 42 (Part 1) 2009

TRANSACTIONS OF THE NORFOLK & NORWICH NATURALISTS' SOCIETY

Volume 42 Part 1 2009

Editor: S Harrap Assistant Editor: AR Leech

Published by the Norfolk & Norwich Naturalists' Society

ISSN 0375 7226

Figure 1 Panorama of the Brancaster Managed Realignment saltmarsh, Norfolk, in 2008 (six years after breaching of the sea wall).

Figure 2 The culvert connecting the Brancaster Managed Realignment saltmarsh (foreground) with the 'natural' saltmarshes and the sea.

Figure 3 Halophytic vegetation on the Brancaster Managed Realignment saltmarsh in 2008 (six years after breaching of the sea wall).

Life on the edge: saltmarshes ancient and modern

Anthony J. Davy

Presidential Address delivered to the Society on 18 November 2008

Norfolk can justifiably claim to be a cradle of saltmarsh ecology. The North Norfolk coast, with its shingle banks, sand flats, dunes and saltmarshes has attracted the interest of naturalists for centuries. The extensive tidal marshes between Salthouse in the east and Holme in the west are amongst the most attractive and species-rich in Europe – and the competition from, for example, the Wadden Sea of Denmark, Germany and the Netherlands, the Normandy coast of France, and the estuarine marshes of south-west Spain, is formidable (Davy *et al.* 2009). In East Anglia we have the added value of the largest area of saltmarsh in the UK (3385 ha), including the marshes around The Wash and in the estuaries to our south in Suffolk and Essex. It is the protection afforded from waves and currents by the barrier islands, spits, sand flats and estuaries that has allowed the deposition of tidally-borne silts and clays to form these marshes. There have also been losses of course, many associated with human activity: since Romano-British times, the upper parts of many marshes have been embanked repeatedly to exclude the sea, as the fertile sediments were claimed for agriculture – for grazing or cultivation.

What is the attraction of saltmarshes, apart from the rugged and sometimes bleak beauty of the landscape? As a habitat they issue peculiar challenges to would-be inhabitants. Neither strictly terrestrial nor marine environments, these marshes are literally 'at the edge', as they are swept with tides up to twice a day. Marine algae need to be able to survive regular exposure to the drying atmosphere and the higher plants that colonize most of the marsh area obviously must withstand inundation with salt water. Salinity is a double-edged challenge. On one hand, plants experience the osmotic consequences of a concentrated external solution that in practice tends to limit their ability to take up and retain water, or as Coleridge succinctly put it in *The Rime of the Ancient Mariner:*

> *Water, water, everywhere,*
> *And all the boards did shrink;*
> *Water, water, everywhere*
> *Nor any drop to drink.*

On the other hand, saltmarsh plants must tolerate the potentially toxic effects of the high concentrations of ions, particularly sodium and chloride ions. Few plants have evolved the specialized suite of adaptations that can confer such salt tolerance, in fact only about 1,000 of the more than 275,000 species of flowering plant world-wide. Interestingly, about half of them are found in just two of the hundreds of plant families: the goosefoot family (Chenopodiaceae) and the grass family (Poaceae). Halophytes, as they are known, have invested so much in the paraphernalia of salt tolerance that most cannot survive, or at least cannot compete, in non-saline environments and this alone would be sufficient to explain the distinctiveness of the saltmarsh flora. However, the environmental challenges do not end there; as land plants they can only assimilate carbon dioxide from the atmosphere when actually exposed to it and, perhaps more importantly, they have their roots in more or less waterlogged sediments, with all the limitations on oxygen supply that this entails. The slow rate of diffusion of oxygen in solution, as distinct from in the gaseous state, means that waterlogged soils can rapidly become anaerobic, which in turn leads to them becoming chemically reducing, as specialized microorganisms reduce other oxidized substances in order to derive their energy in the absence of oxygen itself. Anyone who has disturbed the oxidized surface layer of a waterlogged marsh to expose the coal-black underlying sediments will have seen, and smelled, the effects of microbial activity in anaerobic conditions. Ions in the soil become reduced to more toxic forms, for instance sulphate to sulphide or hydrogen sulphide, and ferric to ferrous iron, and these changes are manifested as a lower redox (reduction-oxidation) potential – a measurement that we can conveniently make in the field with an electrode and meter. Plants, including halophytes, vary enormously in their ability to tolerate waterlogged soils (Colmer & Flowers 2008) and this depends to a substantial extent on being able to aerate their roots and rhizomes through porous gas-conducting tissues (aerenchyma) that run continuously from their aerial shoots. In this context, it is important to recognise that a saltmarsh is not a single habitat but a mosaic of many. The depth and duration of tidal inundation increase along the elevational gradient from land to sea, but many features that affect elevation and local drainage are superimposed upon this, such as the creek system with its raised banks (levees), hummocks, and drained or ponded depressions (pans). In addition, the tides vary on lunar and annual cycles, reaching, for example, their greatest amplitude with the equinoctial spring tides and their lowest coverage of the high marsh around the summer and winter solstices. It is clear that saltmarshes are places where the evolutionary selection pressures are intense and variable in both space and time – in short they are a veritable 'field laboratory' for ecologists, where the mechanisms of adaptation and their evolution can be investigated in a specialized flora and fauna.

One of the earliest ecologists who sought to exploit the scientific potential of saltmarshes was Francis Wall Oliver, Quain Professor of Botany at University College London, 1888–1929. After a brief flirtation with the Seine estuary (a series of excursions with his students to the Bouche d'Erquy that started in 1904 (Oliver 1907)) he settled on Blakeney Point in Norfolk. There he established a field station with the purchase of the Old Lifeboat House in 1910. Then he rapidly raised the money to purchase the whole property of some 1200 acres (486 ha) for the National Trust in 1912 and thus established one of the earliest publicly owned nature reserves in Britain. Field courses from University College have been going there ever since and it was on one of these that I had my own first experience of the North Norfolk coast. Professor Oliver's early descriptions of Blakeney Point were published in our Transactions (Oliver & Salisbury 1913) and led to the very first paper ever published in the newly established *Journal of Ecology* in 1913 (Oliver 1913). It is clear from this that Oliver had delegated leadership of the vegetation studies to EJ Salisbury. He had been Oliver's companion on the French excursions and is believed to have penned the following limerick (Anker 2001), which has certain contemporary resonances:

A certain Professor of Botany
To save his class from monotony
Led his students a dance
Round a saltmarsh in France
To develop their brains
If they've got any.

Subsequently, Salisbury had a long and distinguished career, succeeding Oliver as Quain Professor and becoming a Fellow of the Royal Society, Director of the Royal Botanic Gardens, Kew and a Knight of the Realm. Moreover, he was President of this Society 1931-32, with a monumental Presidential Address on 'The East Anglian Flora' running to 72 pages of text and more than 100 maps (Salisbury 1932). Much less fortunate was the man responsible for arguably the most prescient early work on Norfolk saltmarshes, the aptly named AS Marsh. Alfred Marsh was an academically gifted young man who had been trained in AG (later, Sir Arthur) Tansley's Botany School at Cambridge. He organized an ecological excursion to Holme next the Sea in 1914, which resulted in a substantial paper (Marsh 1915). He recognised and mapped the different vegetation communities ('societies'), relating their distribution to sediment depth and the degree of tidal inundation. Having documented the shifting physiography of the coast from historical sources, he also appreciated the dynamic nature of coastal systems and interpreted successional relationships between the plant communities. This classic paper promises further instalments but, sadly, these were not to be: with the outbreak of war he felt duty-bound to volunteer and was commissioned into the 8th Somerset Light Infantry. In the carnage of the trenches his talents were readily apparent and he was quickly promoted to Captain. Contemporary reports say that he was shot through the heart by a sniper at Armentières in January 1916, a month short of his 24th birthday (Tansley 1916). In his short career he is also generally credited with having designed the first competition experiment in plant ecology, although he did not live to see it completed and published (Tansley 1917). I am privileged to say that I recently had the opportunity to pay my respects at his grave in the Cité Bonjean military cemetery in Armentières. We can only speculate on how different the development of saltmarsh ecology over the last 95 years might have been, had he survived.

As it is, the torch of Norfolk saltmarsh ecology was passed to VJ Chapman, a generation later. Also based in Cambridge, he set up long-term studies on Scolt Head Island, which had already become the focus of Professor JA Steers' seminal studies of coastal physiography after being purchased and presented to the National Trust as a nature reserve in 1923 (Steers 1960). Chapman's detailed investigations of tidal regime and its effects on the water table, sediment aeration and drainage (Chapman 1938a), followed by similar work on salinity and the vegetation (Chapman 1939) are the descriptive foundation of much of what we know about Norfolk marshes and their vegetation.

Ancient saltmarshes

The extensive areas of mature, 'upper' marsh in Norfolk are about 6000 years old. We know this because sea levels at the height of the last glaciation, 25,000 years ago, were some 120 m lower than today, rising rapidly as the land-ice melted until shorelines stabilized in approximately their current positions more than six millennia ago (Funnell & Pearson 1989; Allen 2000; Boomer & Horton 2006). Since then there have been smaller fluctuations in sea level but marsh surfaces have slowly accreted to keep pace with an average sea-level rise of 1-2 mm per year. Relative sea levels in the south-east of England are rising for two reasons: the tilting of Britain after the melting of a massive ice sheet in the north (isostatic rebound) and, more recently, the increase in the volume of the oceans associated with climatic warming (eustatic rise). Of course sea level is predicted to rise much faster in the coming century in response to climate change induced by human activity. Boreholes have penetrated the consolidated marine sediments supporting the present-day vegetation to a depth of 8 m below Ordnance Datum (OD) to reach basal peats that have been radio-carbon dated to 8410±50 years BP (Funnell & Pearson 1989).

The conventional wisdom is that marshes form by sedimentation of tidally-borne fine sediments in suitably protected locations, the sedimentation rate depending on the depth of the water column and its sediment load. Hence, areas below the level of the highest astronomical tides will tend to accrete and the marsh will extend seaward until the tidal and wave energies are too great to support net accretion. Chapman recognised that plants play a part in this process and saltmarshes were an early example of 'ecological succession'. For instance, microscopic algae and their gelatinous exudations can help to stabilize the surface, thus reducing erosion (Coles 1979); clearly the roots or rhizomes of early colonists such as glassworts (marsh samphire) *Salicornia* spp. and cord-grass *Spartina* spp. also help to bind the sediments, but their shoots may serve to enhance surface roughness, slowing the tidal flows locally. Such successional processes would also explain the characteristic zonation seen on saltmarshes: the communities of the lower (younger) parts of a marsh are noticeably different from those of the upper (older) areas, and many species tend to occupy more or less distinct elevational ranges on the continuum from sea to land. At Stiffkey marsh, for instance, Long-spiked Glasswort *Salicornia dolichostachya* is confined to the seaward fringe of vegetation but its close relative, One-flowered Glasswort *S. pusilla*, is found mainly on higher, well-drained areas, amongst perennial vegetation. Common Cord-grass *Spartina anglica* is typical of low-lying muddy sediments, whereas Thrift *Armeria maritima*, Sea Arrow-grass *Triglochin maritimum*, Common Sea-lavender *Limonium vulgare* and Sea Plantain *Plantago maritima* come into their own on the upper marsh. Certain species, such as Sea Wormwood *Seriphidium maritimum*, Sea Couch *Elytrigia atherica* and Red Fescue *Festuca rubra*, are only ever found on the highest parts of the marsh profile.

Such relationships were synthesized into Chapman's early 'successional diagrams' (Chapman 1941) which describe succession (in time) in terms of contemporary distribution (in space). This 'space-for-time substitution' is a device that has been much used by ecologists because actual changes with time are often too slow to describe adequately within the lifetime of an observer – think of the successional development of mature oak forest over hundreds or thousands of years from first colonization. However, the approach is not without its dangers. Where there is an environmental gradient (such as is created by elevation in the tidal range) zonation need not necessarily indicate active change, or indeed any change. As the main features of most of the North Norfolk saltmarshes have been in approximately their current positions for at least 6000 years, there is little evidence for major successional change recently, excepting only limited areas where there is active physiographic change. In a sense, we are looking at the 'ghost of succession past'. Furthermore, it is dangerous to make assumptions about the immutability of species on such timescales. *Spartina anglica*, a key early colonist in one of Chapman's two alternative branches, is known to have arisen from a hybridization event in Southampton water in the early 19th century, following the introduction of its maternal-parent species (Smooth Cord-grass *Spartina alterniflora*) in shipping ballast from North America (Gray *et al.* 1991). It might perform the role of colonist now, but it certainly did not when the bulk of current North Norfolk saltmarshes was first formed.

The Norfolk saltmarshes have been the subject of intensive study and many aspects of their ecology have been revealed. On the small scale we have insights into the adaptations of physiology, growth and population biology that enable halophytes to inhabit the remarkably different micro-environments found across the marsh (e.g. Jefferies, Davy & Rudmik 1979, 1981). In particular, the subtle selection pressures that determine local adaptation in populations of very closely-related species of *Salicornia* on the marsh have been investigated through a combination of field-transplantation experiments (Davy & Smith 1985, 1988) and genetic analysis (Noble, Oliver & Davy 1992). Many other studies have addressed a great range of interesting topics, including the roles of fungi (through mycorrhiza, i.e. symbiotic association with plant roots) and seed-predating insects (e.g. Davy *et al.* 2000), not to mention much work on the fauna within the sediments and migrating bird populations in saltmarsh systems. At a larger scale, earlier work on ecosystem processes such as nutrient cycling (e.g. Jefferies 1977; Jefferies & Perkins 1977) is now being taken up again as we seek to understand the consequences of climatic change for the 'ecosystem services' provided by saltmarshes to human society. Other than the processing of nutrients, such services may be extremely varied: striking examples include coastal defence, which we will consider in more detail later, various kinds of support or subsidy for offshore fisheries, and of course the conservation of biodiversity – of paramount value to naturalists.

The huge amount of knowledge of saltmarsh ecology amassed in Norfolk and globally cannot disguise our limited understanding of how saltmarshes form. The fact is that it is possible to investigate saltmarsh formation in real time. Chapman himself predicted relatively rapid rates of succession at Scolt Head, on the basis of measured annual sediment accretion rates and the known elevational ranges of the communities (Chapman 1938b). Later, allowing for subsidence of 30.5 cm per century, he estimated that bare marsh could develop through Salicornietum and Asteretum to the Limonietum late phase of 'General Saltmarsh' in about 180 years. The vegetational transitions he observed on the physiographically dynamic western end of Scolt Head Island, by comparing maps made in 1932/3 and 1957, suggested that even faster development was possible (Chapman 1959). Looking rather further back, a saltmarsh at Berrow in Somerset that arose in around 1910 has been observed somewhat irregularly over some 85 years (Willis 2000); however, its history indicates that change has been driven more by physiographic events than either orderly accretion or the vegetation itself. Returning to Norfolk, we have seen a large, shallow slack behind the dunes at Holkham colonized by saltmarsh halophytes over just the last 30 years or so. Unfortunately events have rarely been recorded in systematic detail or the causes examined rigorously.

Modern saltmarshes

Until recently relative sea-level change has been slow and, unless there was some other substantial perturbation of coastal physiography, there has been little reason for new marshes to form. Such perturbations usually arise from human activity in the form of coastal engineering, perhaps major construction projects or, increasingly, our responses to faster sea-level rise. A good example of the former is a project at Odiel Marshes, on the Atlantic coast of south-west Spain, where I have had the good fortune to collaborate with colleagues from the University of Seville for more than 20 years. The construction of the 15-km Juan Carlos dike in 1977 was designed to protect the navigable channel in the common estuary of the Odiel and Tinto rivers. It bisected low-lying mud flats and created environments favourable for sediment accretion in lagoons on its flanks. This initiated the rapid successional development of saltmarshes, but the reality was rather different from the impression one gets from space-for-time substitution studies based on zonation. The earliest colonist, Small Cord-grass *Spartina maritima*, appeared in isolated clumps (nuclei) on the muddy plain, having probably colonized from rhizome fragments and seed. It is extremely tolerant of highly reducing sediments and long periods of inundation by the sea (Castillo *et al.* 2000). Its clonal tussocks trapped sediment and promoted accretion locally, over the years growing in diameter and elevation. The raised tussocks progressively experienced both shorter periods of daily inundation and better drainage when emerged, factors that together were reflected in increasing sediment redox potential of tussocks within a freely-drained lagoon. These ameliorating conditions allowed the invasion of species less tolerant of flooding and thus *Spartina maritima* can be said to have facilitated the next species, Perennial Glasswort *Sarcocornia perennis*, which colonized the raised centres of the tussocks and then expanded radially. *Sarcocornia* is more competitive under the less reducing conditions at higher elevation and consigned *Spartina* to the edges of the tussocks (Castellanos *et al.* 1994). Between 1984 and

2001, the average elevational increase at the centres of the tussocks was about 60 cm and *Sarcocornia* became dominant. However, further invasions were taking place. As early as 1997, a strange new *Sarcocornia* with much more upright growth had appeared in the centres of many tussocks. Subsequent molecular analysis showed that this is the hybrid *S. perennis* x *S. fruticosa*; *S. fruticosa* is a shrub of the higher, landward margins of the marshes. The hybrid had arisen *in situ* on each tussock as a result of *S. fruticosa* pollen blowing in (Figueroa *et al.* 2003). The hybrid now occupies about 20% of the area of tussocks in one lagoon. More significantly for succession, Sea-purslane *Atriplex portulacoides*, that great dominant of many parts of mature Norfolk saltmarshes, was also first spotted there in 1997; by 2007 its representation had increased to about 70% of tussock area and the original *Spartina maritima* was hardly to be seen, except around the edges. Elevation has increased by more than 70 cm in 23 years. As the tussocks have grown, their perimeters have eventually met and they have begun to coalesce into a more or less continuous marsh surface. It is also now evident that the typically sinuous, branching creek system has formed from the channels left where tussocks almost meet. This sequence of events is one of the few examples of true changes with time that have been documented in detail, illustrating graphically the speed with which morphologically complex marshes can develop when there are adequate supplies of sediment and halophyte propagules.

To return closer to home, we now have increasing opportunity to examine saltmarsh formation, ironically as a result in part of accelerating sea-level rise. Historically, a large proportion of UK saltmarsh area has been converted to agricultural land and further areas are being lost each year to coastal erosion. Land-claim, which began in Romano-British times, has reduced the total area of saltmarsh in the UK substantially (Adam *et al.* 2008; Davy *et al.* 2009). In Essex, for example, an original area of around 30,000 ha has now been reduced to only 2,500 ha (Adam 1990). In addition, climate change is resulting in faster sea-level rise and increased storminess, greatly increasing the cost of coastal defence. Protection of many low-lying areas, particularly old land claims, is now uneconomic. The presence of sea walls and other developments prevents landward migration of many marsh systems in the face of sea-level rise, a phenomenon termed 'coastal squeeze', and this contributes greatly to erosion of marshes in south-east England (Morris *et al.* 2004). The European Union Habitats Directive, incorporated into British law, requires compensatory replacements for saltmarshes damaged by coastal development, and also imposes a requirement on the UK to create approximately 100 ha of marshes a year to replace those lost to erosion. A policy of 'managed coastal realignment' has been developed to allow retreat to a more economically defendable coastline and to meet our obligation to create replacement coastal habitat. Existing sea walls are being breached and new ones built to landward, allowing tidal ingress onto low-lying land (French 2006). More than 30 such managed realignment schemes aimed at saltmarsh creation have been undertaken since 1991.

It was initially assumed that simply reinstating a tidal regime to low-lying coastal land would yield saltmarsh. Recent research at the University of East Anglia suggests, however, on the one hand that the outcomes can be highly variable and, on the other, that these 'restored' marshes may provide valuable insights into the processes limiting marsh development. The two crucial issues are the availability, by dispersal from natural marshes, of propagules of the species of halophyte required, and the provision of suitable habitat niches for their establishment and colonization. As we have seen, elevation within the tidal range is an important determinant of habitat suitability for plants, which suggests that the range of surface elevation present at a particular site before the breaching of the sea wall would affect the development of the vegetation. Interestingly, there are managed-realignment sites with different ranges of elevation that allow us to investigate how this happens. One of the earliest projects was at Tollesbury, Essex, where the sea wall was breached in 1995. Here, shrinkage and consolidation of the soil over the many years since the original land claim had lowered the land surface and it may not have been fully appreciated at the time that it was mainly lower in the tidal range than vegetated saltmarsh outside the sea wall. Hence, although seawater was highly effective in killing the existing vegetation, producing a stark landscape with dead trees and hedgerows, there was little colonization by saltmarsh plants, except near the periphery of the site, on the raised flanks of the sea walls. Admittedly, sediment accreted rapidly within the site but the new sediments have remained wet and unconsolidated. This may be related to both the pace of accretion and demonstrably poor drainage i.e. the absence of a creek system and the development of an impermeable pan (aquitard) in the original soil profile (Crooks *et al.* 2002). In any event, it remains a relatively hostile environment for many halophytes and the development of the vegetation has been disappointing.

In striking contrast to the Tollesbury experience we can look at the managed realignment at Brancaster in Norfolk (Fig. 1, see inside front cover). This 7.5 ha area was re-flooded in August 2002, when a culvert comprising five pipes, each *c.* 1 m diameter (Fig. 2, see inside front cover), was installed in the old sea wall to connect managed marsh with a major tidal creek outside; a further pipe at a lower level was added subsequently to improve drainage. Drainage internally was assisted by the construction of a creek system, albeit of a crude 'herring-bone' design. Remarkably, after four years of flooding, 28 species of saltmarsh plant had colonized, which is equivalent to the number found on natural sites nearby (Mossman 2007) and represents most of the species known to inhabit the marshes of the North Norfolk coast (Beckett, Bull & Stevenson 1998). What is different here? Not only is the elevational range of the marsh surface within the tidal limits that would normally allow the full range of saltmarsh communities (roughly between the levels of high water on a spring tide and high water on a neap tide), but the drainage is also generally better. Despite the gratifying rapidity of this colonization, however, the news is not entirely good, because the relative proportions of the species present (and hence the composition of their communities) remain unlike any natural marsh in the area (Fig. 3, see inside front cover). There is far too much bare ground; furthermore, there is over-representation of early-successional annuals, particularly glassworts *Salicornia* spp. and Annual Sea-blite *Suaeda maritima*, and a real deficit of important perennials, such as Common Sea-lavender, Thift, Sea Aster *Aster tripolium*, Sea-purslane and Common Saltmarsh-grass *Puccinellia maritima* (Mossman 2007). Very few of the samples taken could be referred to any of the nationally recognised British saltmarsh communities (Rodwell *et al.* 2000). This may be a harsh judgement in view of the relative youth of the site, as it will undoubtedly improve with time. Nevertheless, intensive surveys have shown us what some of the limitations are: the areas of bare ground are associated not only with low elevation, as expected, but also independently with low sediment redox potential, indicating that reducing conditions can be a problem even at higher elevation (Brown 2006). This is almost certainly due to insufficient local drainage, relative to natural marshes, and therefore will depend on the composition or consolidation of the sediments and distance from a drainage creek. Furthermore, both the assemblages of plants present and their main component species can be differentiated by their ranges of redox potential and elevation, the unusual combinations of conditions on the managed realignment site allowing discrimination of the effects of these two factors: glassworts *Salicornia* spp.

extend to lower elevations than other species and occupy a wide range of redox potential but Common Saltmarsh-grass, which has a similar range of redox potential, tends to occupy higher elevations; Annual Sea-blite avoids both the lowest redox potentials and elevations; other species such as Sea-purslane and Sea Couch are predominantly distributed at both higher elevations and redox potentials (Brown 2006).

These findings from intensive studies in Norfolk are supported by broader-scale comparisons that introduce a longer time-scale. As well as marshes arising from managed retreat, there are others resulting from accidental breaches of sea walls that were never repaired. Notable examples are the Essex marshes reactivated during the great storm of 1897 (Crooks *et al.* 2002). Hannah Mossman has sampled most of the managed and accidental realignment sites all round the English coast and highlighted the importance of local or site-specific factors in influencing their outcomes. In general, halophytes are quick to arrive at a site after tidal restoration but we consistently observe atypically large fractions of unvegetated ground that can persist for a long time at managed-retreat sites, with the vegetation dominated by pioneer or early-successional species. Accidental retreat sites are more like natural ones than the managed-retreat sites, perhaps because they tend to be older. Despite this, they have, on average, significantly more Sea-purslane than the reference sites and maintained floristic differences from them even 100 years after tidal restoration. Both types of realignment resulted in a deficit of the important mid-marsh species, particularly Common Sea-lavender, Sea Arrowgrass and Thrift. Both were also more prone to domination by particular species, whether Common Cord-grass at lower elevation or Sea-purslane rather higher up; either species might pre-empt space and hinder the establishment of a more diverse flora. Armed with this information we now know some of the important questions we need to answer in order to predict and improve the outcomes of salt-marsh restoration arising from the managed coastal - that are probably inevitable in the coming decades.

Saltmarshes are amongst the most distinctive and least spoilt habitats in Norfolk. In any season of the year they have superb attractions for naturalists and other visitors alike. Beyond that, the Norfolk marshes have played a clearly recognisable role in the developing science of ecology over the century since Oliver established work at Blakeney Point in 1910. As we anticipate an era of more rapid climate change and sea-level rise over the next century, there will be opportunities, as well as challenges, for adaptation on the coast. The saltmarshes will undoubtedly provide many of the opportunities for wild-life conservation and restoration ecology, as we seek to protect this important part of Norfolk's natural heritage.

Acknowledgements

This paper is dedicated to the memory of Professor Robert Jefferies (1936-2009) and Alfred Marsh (1892-1916). I thank many collaborators and students, especially Dr Eloy Castellanos, Dr Jesus Castillo, Professor Enrique Figueroa, Professor Alastair Grant and Dr Hannah Mossman.

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Prof. AJ Davy School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ

Norfolk pingos; their distribution and condition

Andrina Walmsley

Adapted from the report of a project undertaken by Norfolk Wildlife Trust on behalf of the Wetland BAP Topic Group

Periglacial ground-ice depressions

Many parts of Norfolk are characterised by the presence of pits, hollows and depressions. These vary greatly, in size, depth, hydrology and distribution, and may occur in clusters, in isolation, or sometimes spaced quite systematically e.g. one per field. Hollows include both natural and man-made features. The latter include pits dug to extract marl, flint, lime, sand, gravel and brickearth; and to provide watering holes for livestock.

It is widely believed, however, that many depressions and hollows that occur in Norfolk are the result of natural processes which occurred at the end of the last glaciation when temperatures were very low. For example, analysis of pollen profiles found in organic sediments in some depressions in West Norfolk (Sparks et al. 1972) has dated them to the last (Devensian) ice age, suggesting that they originated in periglacial conditions, when the expansion of freezing groundwater heaved the ground's surface into ice-cored mounds. When warmer conditions finally returned and the ground ice melted, distinctive landforms, often in the form of circular, water-filled depressions, sometimes with raised ramparts around the rims, were often left behind. Many of these features are still visible today.

Occurring in clusters, sometimes at a density of one hundred per square kilometre, these landforms are widely referred to as 'pingos'. The term pingo is of Inuit origin and means 'small hill'. It actually describes a very specific landform type, which formed in certain contexts and conditions (see below) and the term may not accurately describe the full range of periglacial hollows which occur in the county. For this reason, the generic phrase 'ground-ice depressions' is used in preference.

In Norfolk, ground-ice depressions are typically found in the eastern margins of the Fens and the Breckland valleys, and are characteristic features at sites such as Thompson Common, East Walton and Adcock's Common and Foulden Common. Other sites with similar landforms occur in north, west and central Norfolk, and a few are located to the north of Norwich. Few, if any, of these other sites have been investigated in detail, but similarities in form and landscape context suggest a parallel origin with better-known sites.

Regardless of the processes which formed them, many of these sites support a range of important wetland habitats, in particular fen communities which are similar to valley and basin mires (Wheeler & Shaw 1992). Several are considered to be of outstanding national importance because of their assumed geological and obvious biological interest (Lambley 2005) and have been designated as SSSIs. Others have been notified as County Wildlife Sites (CWS) on the basis of their botanical interest but, in about 90% of cases, their potential geological interest has not previously been recognised. It is likely that other sites in Norfolk have still to be discovered and these may be particularly vulnerable to unsympathetic management, neglect or destruction.

Periglacial landforms In Norfolk

The Devensian glaciation

The most recent glacial stage in Britain, the Devensian, ended approximately 10,000 years ago. This glaciation is divided into three substages, the Early, Middle and Late Devensian (26000-10000 years before present, or 26-10 ka BP). Less is known about the Early and Middle substages, which are generally dated at 122-26 ka BP.

The Late Devensian substage is further divided into three units: the Dimlington Stadial (26-13 ka BP); the Windermere Interstadial (13-11 ka BP) and the Loch Lomond Stadial (11-10 ka BP). The last of these represents the final episode of severe periglaciation to have affected Great Britain.

At its maximum extent, the Late Devensian ice sheet covered two thirds of Great Britain as it is today. At its south-easternmost limit, it covered what is now the Lincolnshire coast and a very small area of the coast in north-west Norfolk. To the south and east of this, during the Dimlington Stadial, the land was subject to periglacial conditions.

The term periglaciation refers to conditions around the edge of the ice sheet where the climate is very cold but temperatures are not low enough to allow glacier ice to persist at the surface. Water in the underlying rocks and soil, however, is typically frozen (a condition known as permafrost), although the surface layers may melt in summer and refreeze in winter, producing a succession of freeze-thaw cycles.

Permafrost is used to describe ground in which the temperature remains below 0°C for at least two consecutive years. Ice is not necessarily present in the soil, although in moisture-retentive, fine-grained sediments, permafrost may be very rich in ground ice. 'Continuous' permafrost occurs in zones where the climate is very severe, usually at high latitudes and altitudes. Where there are lateral breaks in the continuity of the permafrost, caused by insulating features such as river valleys, vegetation, etc, the permafrost is described as 'discontinuous', and becomes increasingly so in more southerly latitudes. Seasonal warming thaws the topmost layer of soil (for this reason known as the 'active layer'), so permafrost only occurs at the surface where it is protected by ice from seasonal thaw.

Landforms associated with periglaciation

Groundwater can freeze in different ways, depending on a variety of factors including the landscape and hydrological context.

- **Pore ice** Formed when the water in the soil and sediment pores freezes, cementing the frozen sediment into a hard, rock-like mass. Pore ice can occur in both seasonally frozen ground and in permafrost.
- **Wedge (or vein) ice** Caused by water entering vertical contraction cracks within frozen ground and freezing into a vertical, tapering wedge.
- **Segregation ice** The gradual freezing of groundwater in saturated, usually fine-grained, sediments to produce an ice lens. Water is gradually drawn from the surrounding substrate, via a process known as cryosuction, into the expanding lens of ice, forming very ice-rich permafrost. A significant volume of ice may accumulate, resulting in upward movement of the ground. On thawing, segregation ice produces a super-saturated active layer, which is subject to flow, even on gentle slopes. The difference between segregation ice and pore ice is determined by soil water content (French 2007).
- **Injection ice** Often formed at sedimentological boundaries, as a result of water freezing under artesian pressure.

In a periglacial environment, distinctive landforms can result from repeated cycles of freezing and thawing. Those potentially relevant to Norfolk include the following:

Thermokarst (cryokarst) hollows These are formed as a result of the differential development of ice lenses (segregation ice) in waterlogged soil, causing uneven heaving of the ground's surface. During seasonal thawing of the active layer during the summer months, surface material partially melts and is shed from the tops of the mounds into the intervening hollows. On re-warming of the climate, the melting ice lenses leave small depressions, while the sloughed material remains in relief, resulting in a 'hills and holes' topography.

Surface solution dolines Where the underlying bedrock is calcareous and close to the surface, chemical weathering (solution) of the calcium carbonate content may occur. Solubility of this mineral increases with a decrease in temperature (subject to precipitation rates), and solution rates may therefore be considerably greater in periglacial and glacial climates, leading to chalk 'denudation' or loss. In areas of permafrost, groundwater and solution may be limited to the active layer, allowing the development of a series of shallow depressions (French 2007), rather than deeper features, such as sinkholes or limestone karsts.

Closed-system (hydrostatic) pingos These pingos form by the eventual freezing and expansion of an underground body of water (or talik) expelled in front of advancing ground ice during permafrost development. They typically occur in lake beds or river channels and may involve a significant proportion of segregation ice. As further water freezes, the pingo grows in height and stress cracks in the covering material, or regolith, appear. These dilate to expose the ice core to melting and the mound starts to subside. On eventual re-warming of the climate, the core melts, leaving a depression surrounded by a rampart of shed material, a so-called pingo 'scar'. Closed-system pingos have been found to occur at a density of fewer than eight pingos per km^2 (Pissart 2000; Stager 1956)

Open-system (hydraulic) pingos This type of pingo is formed by the development of injection ice ie the freezing of groundwater rising under artesian pressure, such as a spring or seepage, usually at the base of slopes. In the surrounding frozen ground, the water is forced upwards as it freezes, pushing up a dome of ice below the surface. Surface tension cracks and seasonal thawing of the exposed ice core result in the regolith being sloughed from the top of the dome.

Over time, the shed material forms a ring, or rampart, around the mound, which may be further elevated by compression as the ice core continues to grow. A ridge encircling a shallow depression is left behind when the climate warms and the ice melts.

While the forms are often broadly circular or slightly elongate, superimposition of ground-ice mounds developed during a succession of cold stages may result in overlapping 'vermiform' patterns with discontinuous and confused ridges. Many fossil pingos in Norfolk, such as those at East Walton Common, display this vermiform rampart formation, and are believed to be the remains of open-system pingos as they are associated with spring activity.

Pingo scars occur in a range of sediment types and are often located on plains, valley floors and lower valley sides where groundwater seepage takes place.

Palsas These are similar to closed-system pingos, and are also formed by segregation ice, but they occur in peat bogs. They commonly occur in areas of discontinuous permafrost, and in some areas it may be only the palsas which remain permanently frozen (Gurney 2001). Fossil forms of palsas may be difficult to recognise, as the former surface of the peat is largely restored when the ice mound melts and collapses (Washburn 1973).

Patterned ground (cryoturbation) Patterned ground is caused by repeated freezing and thawing of the active layer in ice-rich permafrost, which causes fine-grained sediments to migrate downwards, while coarser material rises to the surface. Water movement during summer thawing of the surface creates flow patterns in the surface sediments, typically producing circles, polygons and nets on flatter ground, and stripes on steeper slopes. This patterning often covers large areas.

Patterned ground, where differentiated by vegetation cover, is easily visible from the air. Parts of West Norfolk and Breckland display sizeable areas of patterned ground, known locally as 'Breckland stripes'.

Characterisation of ground-ice depressions in Norfolk

Despite the apparent distinctiveness of individual landform types, research has shown that ground-ice mounds do not always fall neatly into separate categories depending on how the core ice formed. Hybrid or transitional forms, containing a combination of ground-ice types, have also been found, blurring the distinctions between categories (Ross 2005). Further difficulty is caused by the fact that, on melting, different types of ground ice often leave behind landforms which, although of different origin, may appear superficially very similar (Bryant & Carpenter 1987); and there is a lack of certainty, even among specialists, concerning key diagnostic criteria for identifying different landform types (Ballantyne & Harris 1994).

For these reasons, the interpretation of relict landforms on the basis of surface topography is not possible. Accurate classification of individual features requires detailed analysis of its internal structure, including both the organic infill and the structure of the hollow which holds the infill. However, even detailed geological investigations of internal structure and sediments are not always conclusive (West 1987).

Fieldwork carried out recently at a range of sites in Wales (Ross 2005) proved that features at a number of sites, long held to be pingos, were formed via a completely different process. Using high-resolution near-surface geophysics (electrical resistivity, seismic refraction) and detailed analysis of sediment layers obtained from boreholes and trenching, the researchers found that many of the features were in fact the result of sub-glacial (i.e. formed below the ice sheet) rather than periglacial processes. As the ice sheet during the Devensian barely reached into Norfolk, sub-glacial features would not have formed during this period, although they might have formed during earlier, colder periods.

Based on research that has taken place to date, it appears likely that Norfolk contains examples of thermokarst hollows, hydraulic and hydrostatic pingo systems and chalk solution features such as surface solution dolines. Patterned ground is widespread in Breckland and parts of west Norfolk. Palsas or closed-system pingos may also have occurred in the area now known as Fenland (Ballantyne & Harris 1994) and in other low-lying peatland areas, although the longevity or visibility of relict palsas is uncertain (Washburn 1973; Gurney 2001).

Sparks et al. (1972) considered a number of potential explanations for hollows found in East Anglia. They analysed rampart cores taken from features at East Walton Common, and found they contained inverted sediment layers, indicative of material shed from 'an updomed form'. This seemed consistent with pingo formation and proof of likely periglacial origin. Chalk solution they considered unlikely as this would have left behind insoluble residues, of which there was no evidence in the deposits they examined.

They also investigated a section that had been exposed by a gas trench cut through a series of dry hollows in the south part of the common. Pollen analysis of organic sediments at different levels in the horizon suggested two superimposed stages of development, the lower depression dating to the Dimlington Stadial (Full Glacial); and the one above it formed during the Loch Lomond Stadial (Late Glacial). This appeared to suggest that ground-ice depressions in Norfolk developed over at least two periods. They found the older 'subdued' forms to be more widespread, occurring at slightly higher levels, and consistent with the more severe climate and 'more thorough saturation of the ground' associated with the Dimlington. The newer 'fresh' forms were more limited in their distribution, restricted to areas of springs near the Fenland edge, and were thought to have been formed in areas of shallower permafrost than the older forms.

The authors also compared the landscape context of similar, but unramparted depressions near Marham. The lack of springs in this location led them to conclude that these might be thermokarst hollows, formed in waterlogged conditions.

West (1987) described detailed studies of a series of permanently and seasonally water-filled depressions at Beetley gravel pit, and a site at Wretton. Analysis and configuration of organic sediments contained within two of the hollows at Beetley, and the deep level of the chalk below their bases, led him to conclude that they were the result of chalk collapse as a result of solution. He was unable to determine whether ground-ice had played a role in their formation, but believed that, even if it had, there would have been insufficient volume of ice to produce ramparts around the feature. The origins of a third hollow in the same area were more difficult to determine. The hollow and its margins appeared to be the result of a series of interrelated but separate processes none of which could be proved without further detailed geological survey. The hollow itself he thought might be a thermokarst lake; or possibly a solution feature of the type associated with ice-wedge polygons, a theory supported to some extent by the presence very close by of a wedge-cast (the fossil remains of wedge ice, where a wedge-shaped fissure in the ground created by ice fills with sediment when the ice melts). The hollow at Wretton appeared to have formed as a result of ground-ice freezing under hydrostatic pressure within a channel system to produce a closed-system pingo. West concluded that all of the hollows could be associated with 'processes of Devensian age', and noted that all except the hollow at Wretton were at sites where springs are still present.

Prince (1962) attempted to identify the origins of depressions found across Norfolk by comparing and interpreting maps of different ages, and looking at the historical evidence for practices, such as marling, which produced pits on a widespread scale. He counted over 27,000 hollows on 1:25000 Ordnance Survey maps; noting that most occurred in areas where glacial drift deposits exceeded three feet in depth. Mineral workings appeared to be almost ubiquitous, with the exception of the Fens and the Broads. He cited evidence, however, that many hollows might have been dug at sites already containing shallow depressions, possibly chalk solution hollows or thaw sinks formed under glacial or periglacial conditions. He concluded that many natural depressions might have originated under periglacial conditions and been enlarged by chemical weathering.

Importance of ground-ice depressions for biodiversity

Vascular plants

The present day character of ground-ice depressions is highly variable and includes permanent spring-fed basins, temporary pools, seasonally wet/damp hollows, and depressions which are dry all year round. This variety gives rise to a wide-ranging vegetation, which may itself be more or less diverse depending on the degree to which the site is actively managed. Very many sites are now located in woodland, and may support little vegetation other than woody emergent species, such as sallow or alder scrub. Where depressions occur in a more open context, however, in a well-buffered site, and particularly where management helps to retain a habitat mosaic, they can be extremely diverse, with a wide range of aquatic, emergent, marginal, fen and grassland species.

Much of the overall floristic value of these systems arises from variations in substrate and hydrology, and the habitat mosaic which they support. Even the pH value of the water in different hollows may vary quite significantly (G Nobes, pers. comm.; Watts & Petch 1986), providing a range of aquatic habitats. The raised chalk rims on some ramparted depressions can support a species-rich calcareous flora, often abundant in Cowslips *Primula veris*, particularly where the site is kept open and competitive species are controlled through regular management such as grazing. Neutral grassland and scrub may also develop in and around the depressions. Where water levels within the hollows fluctuate, vegetation may be unable to establish for long periods, and bare mud on the drawdown zones can provide opportunities for species which need low levels of competition.

High quality calcareous fen communities may develop in peat-filled basins fed by calcareous springs, or ponds which drain down to damp mud during the summer months. Characteristic species include Blunt-flowered Rush *Juncus subnodulosus*, Black Bog-rush *Schoenus nigricans*, Fibrous Tussock-sedge *Carex appropinquata*, Lesser Tussock-sedge *Carex elata*, Marsh Helleborine *Epipactis palustris*, Fen Fragrant-orchid *Gymnadenia conopsea*, Southern Marsh-orchid *Dactylorhiza praetermissa*, Grass of Parnassus *Parnassia palustris*, Butterwort *Pinguicula vulgaris* and Marsh Lousewort *Pedicularis palustris* (Lambley 2005). At Thompson, Watts & Petch (1986) found abundant populations of Water Violet *Hottonia palustris*, Bogbean *Menyanthes trifoliata*, Water Forget-me-nots *Myosotis laxa*, and *M. scorpioides*, Lesser Spearwort *Ranunculus flammula* and Greater Spearwort *R. lingua*, with species such as Cuckoo-flower *Cardamine pratensis*, Marsh Bedstraw *Galium palustre*, Marsh Pennywort *Hydrocotyle vulgaris* and Water-mint *Mentha aquatica* at the slightly drier margins. Permanent pools are important for species such as Water Plantain *Alisma plantago-aquatica*, Water Dropwort *Oenanthe fistulosa* and Water-cress *Nasturtium officinale*.

Bryophytes

Although no moss species in Norfolk appear to be specifically confined to such sites, they may often retain pockets of bryophyte species which are generally poorly distributed across the county, (R Stevenson, pers. comm.). Typical moss species include *Plagiomnium elatum*, *Campylium stellatum* and *Calliergonella cuspidata*.

Water beetles (Coleoptera)

The outstanding invertebrate fauna associated with many water-filled ground-ice depressions is attributed to the stability of these habitats over very long periods, and the range and mosaic of habitats frequently present (Lambley 2005). In particular, there are unusually high populations of Red Data Book (RDB) species in pingo systems. Foster (1993) observed that the pingo systems of Norfolk are dominated by nationally rare water beetle species, 'the remnants of early postglacial biota', probably because they are often still fed by the same groundwater source that created them. He found that the four best-known pingo systems in Norfolk, at Thompson Common, Foulden Common, East Walton Common and East Harling Common, support 125 species of water beetle in total, of which 104 occur at Thompson alone (Foster 1993).

Because many of the ponds are dry in the summer months, early spring breeding species dominate, while those which require permanent water tend to be scarce. More recently (2007), a survey of the pingos at The Wilderness, north of Norwich, identified three RDB3 (Nationally Rare) species and seven Nationally Scarce species (G Nobes, pers. comm.); while at East Harling Common, 94 species of water beetle have been recorded from the site between 1983 and 2005, although repeat surveys have shown a decline in the number of RDB species present over the same period (Nobes 2005).

Dragonflies (Odonata)

Water-filled ground-ice depressions may not have a specific importance for dragonflies and damselflies for any reason other than their inherent value as ponds and pools which are shallow, and therefore able to warm up quickly. However, species such as the rare and local Scarce Emerald Damselfly *Lestes dryas* favour temporary pools, and this characteristic of some pingo sites may make them of particular value for this species, which is regularly associated with pingos (P Taylor, pers. comm.). One of the greatest threats to *L. dryas* is over-abstraction resulting in lowering of the water table, especially at sites where they breed in temporary pools, suggesting that some pingo sites may be at particular risk. In 1987, Thompson Common was ranked as one of the top sites in the county for dragonflies, with seventeen species recorded from the site (Irwin 1987).

Snail-killing flies (Sciomyzidae)

The larvae of these species are parasitic on freshwater and terrestrial snails, eventually killing them. Snail-killing flies are an outstanding feature at many pingo sites, particularly Thompson Common, where 25 of the 65 British species (several of them Nationally Scarce) were found to occur in 1987 (Irwin 1987). Irwin assumed that the remarkable richness of the sciomyzid fauna was attributable either to the 'antiquity of the habitat'; or to the particular combination of basic grassland alongside pools of varying character. Another key factor may be the fluctuating water levels, which expose snails to a greater degree to predation by the flies (Irwin 1987).

Molluscs (Mollusca)

Pingo systems at two sites in Norfolk are amongst a limited number of sites nationally, and only a handful of sites within the county, which support the nationally rare Desmoulin's Whorl Snail *Vertigo moulinsiana* (Killeen 2003). Listed as a Red Data Book (RDB3, or 'rare') species, the snail has its Norfolk stronghold in the Broads, but also lives in fen habitat in and around the pingos at East Walton Common and Thompson Common, and is known from sites in the Nar Valley and at Guist and Hempton, all of which are areas believed to contain relict periglacial features. Desmoulin's whorl snail was more widely distributed in Britain in early postglacial times than it is now, its retreat possibly due to climatic cooling over the past 5000 years (Killeen 2003).

Thompson Common also supports the rare Shining Ram's-horn Snail *Segmentina nitida*, now classified as Endangered. The snail's stronghold in Norfolk is in the Broads. Irwin (1987) noted that, while a relatively small number of freshwater and terrestrial snails had been recorded from Thompson Common, including *S. nitida*, different species tended to have colonised different pingos, with a limited range in each pool (Irwin 1987).

Amphibia

Thompson Common supported the last population of the northern-clade Pool Frog Rana lessonae which became extinct in the 1990s (Irwin 1987; Beebee & Wycherley 2001), although it is not known whether these were descendents of a native population or the result of more recent introductions as they were only rediscovered at the site during the 1960s (Gent 1996). Fossilized bone material found in deposits dating to the Hoxnian period, before the Devensian ice age, suggest that the northern-clade Pool Frog is native to East Anglia (Gent 1996), having possibly colonised Britain from Scandinavia via the land bridge which linked Britain to the continent until about 8500 years ago.

It is believed that Pool Frogs may have existed at a number of sites in East Anglia, although it is unclear whether they were present, or widely distributed outside of the region. Drainage of the Fens, loss of breeding ponds, lowering of water tables as a result of water abstraction and loss of habitat through lack of management are thought to have been the major factors in the collapse of the native population (Beebee & Wycherley 2001). The Pool Frog was reintroduced to a pingo site in Norfolk in 2005, using northern-clade frogs from Sweden.

Great-crested Newts *Triturus cristatus* require water (typically, but not always, ponds) for breeding and feeding; while terrestrial habitat, such as undisturbed grassland, scrub, woodland and hedgerows, is essential for feeding, refuge, dispersal and hibernation. A range of pond types may be used, provided they are well-vegetated, not too shaded, and have areas of shallow water. Pond clusters with good connectivity between them provide the best habitat, and will support the largest populations (Foster 2001). Many pingo sites in Norfolk offer ideal conditions for Great-crested Newts and other newt species, and Great-crested Newts records for the county show them to be present at a large number of sites, particularly within the Stanford Training Area (STANTA).

The Norfolk pingo mapping project

Rationale

Despite the obvious biodiversity and geological value of these sites, until now no detailed, county-wide map showing the overall distribution of sites with ground-ice depressions has been compiled, although a few of the SSSI sites have been mapped in detail and are very well- documented. Furthermore, no overall assessment of site condition and status has been undertaken. Although similar landforms occur in Wales, East Anglia and the Thames Basin, and as far north as Cumbria and the Isle of Man (Ballantyne & Harris 1994), they are relatively rare on a national scale.

To address some of these issues, and as a follow-up to the Norfolk Fen Assessment Project carried out in 2005/6, the 'pingo mapping project' was established in 2007 to:

- Map the locations of sites with depressions potentially formed by ground ice;.
- Assess the overall condition of as many as possible, and identify those at particular or immediate risk from damaging activities or succession.
- Produce a list of sites that would benefit from restoration.
- Identify previously unknown sites, for future survey/designation as CWS where appropriate.
- Ensure that appropriate protective measures and conservation strategies are put in place for relevant sites by making the resulting work available to relevant organisations.
- Identify potentially important sites for Great-crested Newt and other important fauna.
- Provide a basis for further research into the origins of these features.

Data sources

Because pingos and other similar periglacial features are formed where porous bedrock, frequently chalk, lies close to the surface mantled by only shallow drift deposits, the search for sites in Norfolk was focused on areas where this is the case, and particularly in those areas where depressions are already known to occur, e.g.

- Parts of West Norfolk, (including Gayton, Walton, Hiborough, Boughton, Methwold).
- Large areas of Breckland (including Thompson, Stanford, Stow Bedon, Merton, Harling).
- Parts of western North Norfolk (particularly the Fakenham and Helhoughton areas).
- A small area north of Norwich (particularly Horsford, Horsham, Hevingham).

The following data sources were used to identify potential sites:

Aerial Surveys Aerial photography allows rapid coverage of large areas and, in some cases, is ideal for a county-wide survey. Unusual formations and soil marks can show up clearly when seen from the air, and pingos and other depressions in open sites are easily visible. Adjacent to these sites, ploughed (but uncropped) land frequently displays very distinct, chalky white 'swarms' of marbling patterns, which merge into the semi-natural areas suggesting that the ploughed land might once have contained similar landforms. Semi-natural sites within these swarms may contain relevant landforms and are worth closer investigation. Use of aerial photographs makes it possible to track the full extent of these swarms of soil marks over large areas, something which it would be impossible to do on the ground, not least because soil marks are only clearly visible from the air.

The 1946 and 1999 aerial surveys of Norfolk were analysed to identify areas with heavily marked ground. Areas of 'patterned ground' (ie cryoturbated or frost-sorted ground) were also noted as evidence of localised periglacial activity, although these were not digitally mapped because of their extensive nature.

Areas with known ground-ice depressions were also identified on the aerial survey so that their appearance could be compared with unknown sites and used as a benchmark. Using this method, it was possible to identify a number of semi-natural sites with potentially relevant features. Wooded and other sites which lay within the patterned 'swarms', but which were not visible from the air because of canopy cover or shadow, were also captured.

Limitations to using aerial surveys include poor visibility of the terrain within wooded and heavily scrubbed sites and the potential for misinterpreting crop and soil marks and unusual land formations e.g. archaeological remains, impact craters and other features may appear very similar from the air. There is also the possibility that significant changes in land-use (especially cultivation) could have occurred since the survey was carried out

The 1946 survey was used because it shows sites with ground-ice depressions which have since been ploughed out and once-open sites with ground-ice depressions which now have a canopy cover

The 1999 survey was used alongside the earlier one to provide more recent land-use data, and because the use of two surveys helps to overcome visibility problems caused by low cloud, shadow and mature crops, all of which can conceal soil marks. Locations with soil-marks or hummocky terrain which appeared relevant were marked onto OS maps.

County Wildlife Site System The Norfolk County Wildlife Site database was used to compile a list of sites both known to contain ground-ice depressions or with reference to potentially relevant (but unidentified) features eg clusters of depressions, hollows or ponds.

Ordnance Survey Maps OS maps (1:25,000 Explorer Series) were used in conjunction with aerial photographs to mark areas with relevant soil marks, differentiating between cultivated and non-cultivated sites. Cartographical marks showing closely-grouped water bodies (unless obviously of man-made origin) and contour lines indicating clusters of dry depressions were also used as indicators for potential sites.

Geological Maps A digital layer showing the underlying geology and drift deposits against which identified sites could be directly compared was not available. Instead, British Geological Survey (BGS) solid and drift geology maps were used, where available, to provide geological data for many sites. (Maps of two key areas, in Breckland and north of Norwich, are currently out of print.)

Field work

Ground-truthing To try to assess the reliability of the information obtained from the aerial photographs, a large number of sites were 'ground-truthed'. This was also necessary to ascertain current land-use where this was not clear from current maps, or where maps and photographs did not agree. For speed, ground-truthing was generally confined to areas accessible from adjacent roads or footpaths, but was also used wherever possible for sites where interpretation of the aerial photographs was difficult.

Site assessment Identified sites were prioritised for visit based on the likely presence of ground-ice depressions. In no particular order, this was assessed on:

- likely interest based on existing site descriptions;
- likely interest, suggested by aerial photography;
- proximity to other well-known ground-ice depression sites;
- size (sites of less than one hectare were not prioritised, although small sites were visited if adjacent to a road);
- ease of access (e.g. availability of ownership information or public accessibility).

SSSI sites were not prioritised because many of these sites are already well-researched and documented, and their condition and management are under ongoing review.

Site assessments were carried out at 73 sites, Site condition, management status and apparent threats were also noted for each site.

Outputs

Access database A database of sites was compiled using Access 2003. A full list of the data fields is shown in Appendix 1.

Digital map Sites were digitally mapped (MapInfo 5.5) showing their known or likely extent. Contiguous but differently-designated sites were mapped and listed separately. Separate pingo 'zones' within the same large site (particularly extensive SSSIs) were mapped and listed separately to distinguish between them. Sites were also differentiated by colour according to whether they were known ('extant') or believed ('unverified') to contain ground-ice depressions. The map is linked to the database so that all datafields are shown for each site on the GIS layer.

Copies of both the Access database and the digital map (Appendix 2) have been deposited at Norfolk Wildlife Trust, Norwich.

Observations

Overview

A total of 215 sites were listed and mapped. Of these:

- 124 sites (58%) are in Breckland District;
- 49 (23%) are in West Norfolk;
- 29 (13%) are in North Norfolk;
- 11 (5%) are in Broadland

Of the total list, 39% (84) of the sites are known to contain depressions which might be of periglacial origin, with the balance of the sites unvisited.

Of all the sites in the database, 13 are SSSI or part of SSSIs; 41 are designated County Wildlife Sites (CWS), including one which is also a registered common; and one is a potential CWS. The remaining 160 sites are currently unprotected, including 29 sites where hollows/depressions are known to occur.

Habitat

The sites were broadly categorised according to 'matrix' type, and sub-categorised where information was available. Approximately half of sites are within a mainly wooded context; one quarter of sites are within grassland; approximately one fifth are within a habitat mosaic, and only 4% within fen.

Site condition and management

Condition was determined at a total of 73 sites, on the basis of factors such as vegetation quality, levels of scrub encroachment, nutrient levels, appropriateness of management such as grazing, damaging activities such as drainage, cultivation, keepering etc

Of visited sites, 34% were classified as in favourable condition, 30% as declining, 27% as unfavourable and 7% as variable/recovering. One site had been destroyed.

Two thirds of the sites visited were being managed privately, fewer than one fifth by government agencies such as Natural England, the Ministry of Defence or the Forestry Commission, and just over one tenth by conservation organisations.

Threats to sites

Threats (or perceived threats) to the 93 individual sites assessed fell into eight broad categories, listed below in order of the number of sites affected (in brackets). In addition, water abstraction is a significant, or even the greatest threat at many sites, with ponds now drying up during minor droughts and taking longer to recharge (G Nobes, pers. comm.) but this was difficult to establish on the basis of single visits undertaken during the course of this study.

Scrub encroachment (33) This threatens the highest number of sites, although 11 of these are unmanaged and type of management (if any) was unclear in a further six cases. Nine of the sites were grazed, four by cattle (3) or sheep (1), and the balance by unspecified livestock. Nineteen of the sites are designated CWS (including one registered common), and seven are part of SSSIs. The remaining sites are undesignated.

Cultivation (19) Potentially a significant threat although difficult to assess based purely on observation. Two of the sites within this group are CWS.

Inappropriate management (16) Of this group, six sites are managed primarily for shooting and fishing, and three for forestry.

Inappropriate grazing (13) Only two sites appeared under-grazed, while more than half were over-grazed or heavily poached. Livestock in 46% of cases were horses, in 38% of cases were cattle, and in 15% of cases, sheep. Five of the sites are CWS.

Disturbance (5) At all affected sites this was attributed to forestry operations.

Neglected (3) One of these sites was forested and the other two unmanaged.

Development (2) A major threat at just two sites, one at Roudham where planning permission was recently refused for a site containing a small pingo. This site has since been designated a CWS, so is hopefully more secure. Another site at Hainford, although not visited, appeared from aerial photographs to be potentially at risk from encroaching development.

Siltation (2) was frequent in wooded sites, but was noted as the main threat in only two such sites.

Follow-up action has been recommended for 84% of sites, which have been allocated a priority rating based on a range of factors including site quality, site condition, and proximity to other key sites.

Survival of ground-ice depressions

It is probably correct to assume that many of the extant relict pingo sites in Norfolk have never been cultivated because the topography and, more importantly, the presence of active springs and water bodies would have made draining of the land too difficult and uneconomic. Wheeler & Shaw (1992) observed that a number of botanically rich fen sites in East Anglia had escaped cultivation precisely because the land was nutrient-poor with strong spring activity. In many parishes these marginal sites, regarded as unfit for any other purpose, were given over to the poor who were allowed to graze animals, and cut peat and wood for fuel. This low level of management fortuitously helped to protect and shape many sites, enabling them to survive largely intact to the present day (although loss of traditional 'management' means that many are now in decline).

Sites with pingos and other water-filled depressions would have been even more challenging to drain and cultivate, and the best-preserved pingo sites in Norfolk today are those which occur on common (or former common) land. Several are notified as SSSIs or SACs, namely East Walton Common, Foulden Common, Thompson Common and East Harling Common. A great many others are used for pasture, some designated as County Wildlife Sites. A large number have been planted with conifers in the last 80 years, and are managed by the Forestry Commission. Notable 'pingo' sites in afforested land include Hills and Holes, Frost's Common and Fox Covert in Breckland; Spring Covert in West Norfolk; and The Wilderness in Broadland. The pingos at many of these sites are not managed in their own right, and many are in unfavourable condition, shaded or blocked with encroaching scrub and fallen trees.

Aerial surveys show that, where there is underlying chalk, there are extensive areas, now cropped, which once also contained periglacial landforms of some kind. The 'ghosts' of these largely-destroyed features show up very clearly as swarms of soil-marks in ploughed land, although they are more difficult to detect, both from the air and on the ground, with standing crops. At ground level, these features often appear as subdued, gently-contoured depressions, often bowl- or saucer-like, without ramparts, but often damp or wet in the bottom. Whether these depressions were once more pronounced, or habitually held water, is not generally known. However, as land would presumably have been cultivated only where drainage was viable and cost-effective, it seems unlikely that the majority of these depressions represent the remains of spring-fed pingos, and are more likely to be attributable to other processes not dependent on the presence of springs, such as chalk solution or thermokarst activity. Alternatively, if water tables increasingly lowered by abstraction gradually reduced the flow of springs, previously wet hollows might have dried to the point where cultivation was deemed feasible. It would be necessary to excavate a trench across some of these features to test this theory.

Cropped fields at sites in Thompson, Hockham and Northwold contain the remains of what were clearly once water-filled depressions, and remain very wet in the bottom to the extent that harvesting of crops in some years has not been possible (K Stone, pers. comm.). In some cases, the ploughed features are known to have been pingos and after heavy rainfall and in the winter months may habitually be water-filled.

Acknowledgements

This study was funded by the Norfolk Biodiversity Partnership, Breckland District Council and Natural England. Many experts in the field have given their time generously to this project, helping to locate articles and literature and giving the benefit of their advice. I am particularly indebted to Tim Holt-Wilson and Robin Stevenson, both of whom have been enormously helpful, particularly with technical aspects; and to Geoff Nobes for his help with invertebrate information. I would also like to thank Professor RG West and Dr Steve Boreham for their help and explanations, and Geoff Nobes, Robin Stevenson and Rob Yaxley for kind permission to reproduce their photographs.

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A Walmsley Choppins Hill Cottage, Spring Lane, Coddenham, Suffolk IP6 9TW

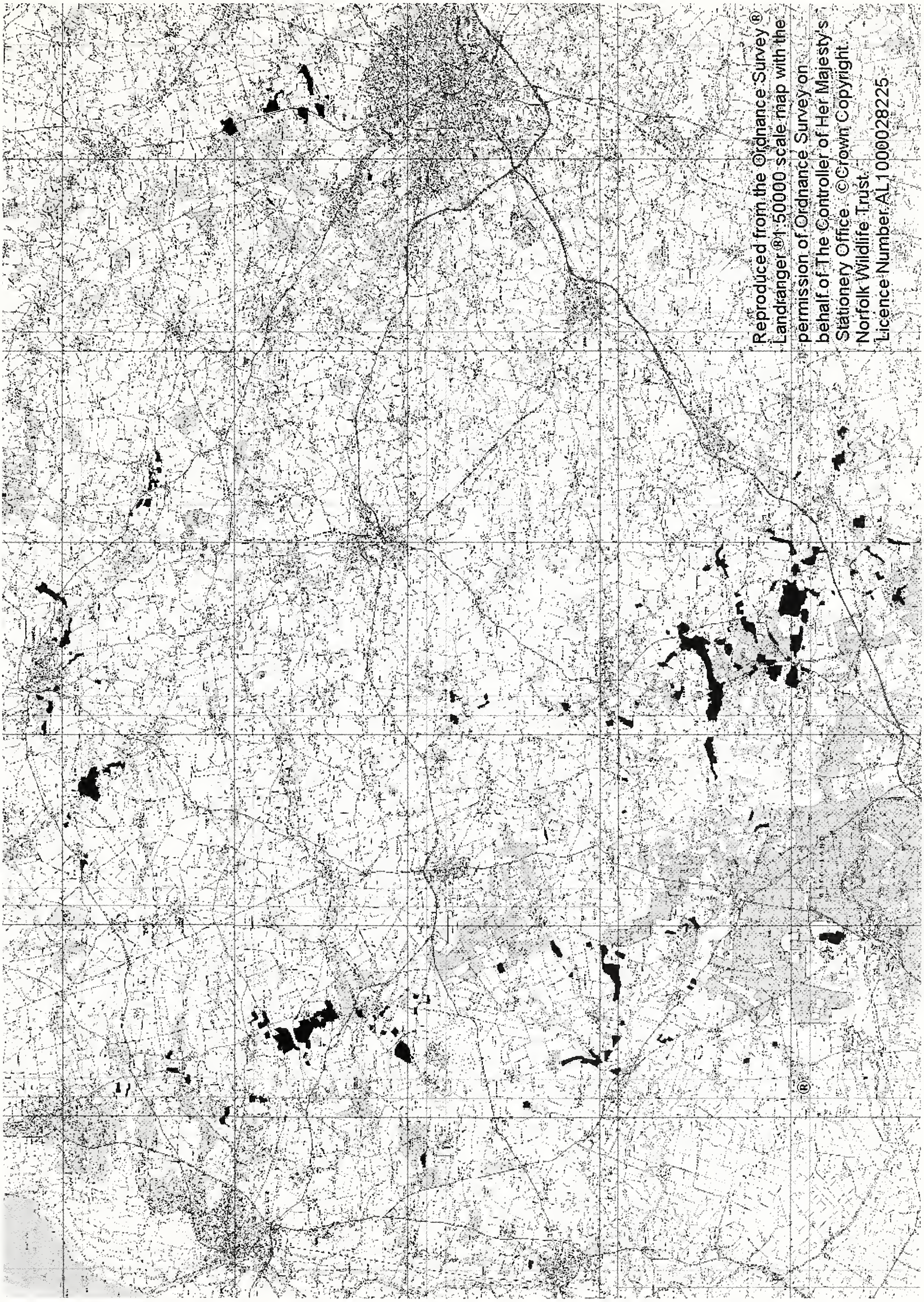
APPENDIX 1 Data recorded

Field Name	Description
GIS ID	Unique identifier to match database record to map polygon
Site designation	Details whether site is a SSSI, CWS, registered common, or undesignated
Site name	Either the given name, or a descriptive term for unnamed sites
District	The local authority area within which the site is located
Parish	The county parish within which the site is located
Grid reference	The grid reference given in standard format (eg TG 222152)
Grid square	The grid square, or hectad, reference (eg TG)
Easting / northing	Two fields providing the east and north Cartesian coordinates of the site (eg 622200 and 315000)
Site status	Indicates whether depressions are extant at the site, or if this is unknown ('unverified')
Feature type	Indicates nature of depressions eg ponds, shallow depressions, damp hollows, etc
Formation	Indicates whether features within a site are closely grouped, scattered, etc
Number of features	Provides broad estimate of number of depressions within the site (ie 1-10, 11-20 etc)
Feature size	Indicates whether features within a site are broadly uniform or of a variable size
Hydrology	Indicates water retention within features eg wet all year, damp, winter wet, variable etc
Landscape context	Gives location of site at landscape scale ie valley bottom, mid-slope, top of slope etc
Metres AOD	Gives approximate height above sea level (Ordnance Datum)
Vegetative status	Describes vegetation within features in broad terms eg woody emergent, poor fen, damp grassland etc.
Geomorphology	Describes whether features have obvious ramparts, partial ramparts, no obvious ramparts, etc

continued

Field Name	Description
Soil type	Provides soil code for site, based on Soil Association descriptions
Matrix	Provides broad description of landscape context in which site is located eg woodland, grassland, etc
Potential for Great Crested Newt	Estimates likely value of site as suitable habitat for Great Crested Newt, and contains notes on existing records for this species
Protected status	Indicates whether site is protected via a designation such as SSSI, or (to a lesser extent) CWS, whether it is a registered common, or whether it is unprotected
Geology	Based on the British Geological Survey maps of Norfolk, this field provides the bedrock and drift deposit type for each site. Information unavailable for some sites
Joint Character Area	The JCAs are Natural England categories which define different regions of the UK based on inherent landscape character
Overall condition	Using the standard condition categories: Favourable, Declining, Recovering, Unfavourable, Destroyed, with the addition of Variable and Unknown
Main threats	Indicates the primary perceived threat eg scrub encroachment, over-grazing, cultivation etc
Current manage ment	Indicates the way in which a site is currently being managed, where known, or where there are non-deliberate factors influencing the condition of the site, such as rabbit-grazing
Managed by	Provides generic information about 'who' manages a site eg Ministry of Defence, farmer, private estate
Recommended action	Suggests the next, most appropriate course of action for individual sites based on site quality, site requirements, proximity to other sites, etc.
Priority for action	Sites are prioritised for further action based on a range of factors.

APPENDIX 2 Distibution of sites with presumed ground-ice depressions in Norfolk (in black)



The distribution and identification of earthstars (Fungi: Geastraceae) in Norfolk

Tony Leech, Trevor Dove & Jonathan Revett

All of the 18 species of earthstar recorded in Britain occur, or have occurred, in Norfolk. This may be due to the fact that many of them prefer the light sandy soils found widely in the county, but it is an accepted fact that the known distributions of fungi reflect the distribution of those who study them and Norfolk has generated many mycologists with an interest in these striking fungi.

The county's first claim to earthstar fame may well have been the discovery of *Myriostoma coliforme* near Bungay in 1782. The fact that, nearly one hundred years later, every one of the nine species of earthstar recorded by CB Plowright in his list of Norfolk fungi (1872-3) was illustrated, but only four of the remaining 800 species of fungi were so favoured, gives some indication of his fascination with the earthstars.

GJCooke in that part of his Norfolk county list of fungi dealing with gasteromycetes (1937) adds just one further species, the now widespread *Geastrum triplex*, although a number of others had occurred unknown to him. By this time EA (Ted) Ellis had begun recording and is indeed credited by Cooke for his help in indexing the older records. Ellis subsequently added *G. minimum* to the Norfolk list and published a thorough account of early records (Ellis 1981). Only one species (*G. campestre*) has been added since then and the present paper seeks to update that of Ellis with the addition of more recent records; appropriately in the centenary year of his birth. We are pleased to be able to reproduce the drawings by Ted Ellis (and his brother Martin) that illustrated his 1981 paper as Figures 1, 2 and 3.

The nature of earthstars

Earthstars are essentially puffballs in which the outer layer of the fungus fruit body splits radially into segments that open outwards and which may bend downwards to separate the fruit body from its subterranean mycelium. The resulting star-shape is eye-catching and distinctive; Plowright wrote that 'the sight [of *Myriostoma coliforme*] would gladden the heart of the most lethargic fungologist' (1872). They are often, however, surprisingly difficult to find as their muted colours blend into the background. Set against this, to the benefit of the earthstar hunter, most of the fruit bodies dry naturally and can be found well after they have emerged.

Sixteen of the British earthstars belong to the genus *Geastrum* (earlier spelled *Geaster*), a Latin 'translation' of earth star. *Myriostoma coliforme* belongs to the same family (Geastraceae) but the remaining species, *Astraeus hygrometricus*, is more closely related to the earthballs and is placed in the Astraeaceae. All belong to what were formerly the Gasteromycetes but are now better referred to as gasteroid fungi since members of the group are not closely related to each other. In gasteroid fungi spores are produced on basidia (as in other basidiomycetes) but are not actively discharged. Moreover, in earthstars, as in most gasteroid fungi, the fertile surface remains enclosed within the fruit body during development.

Earthstar fruit bodies develop as spherical or onion-shaped objects at, or just below, the soil surface. As they mature the outer layers, forming the exoperidium, split and turn downwards to reveal the endoperidium, the layer which forms the endoperidial body (or spore-sac). In some species, the 'arms' formed as the exoperidium splits are

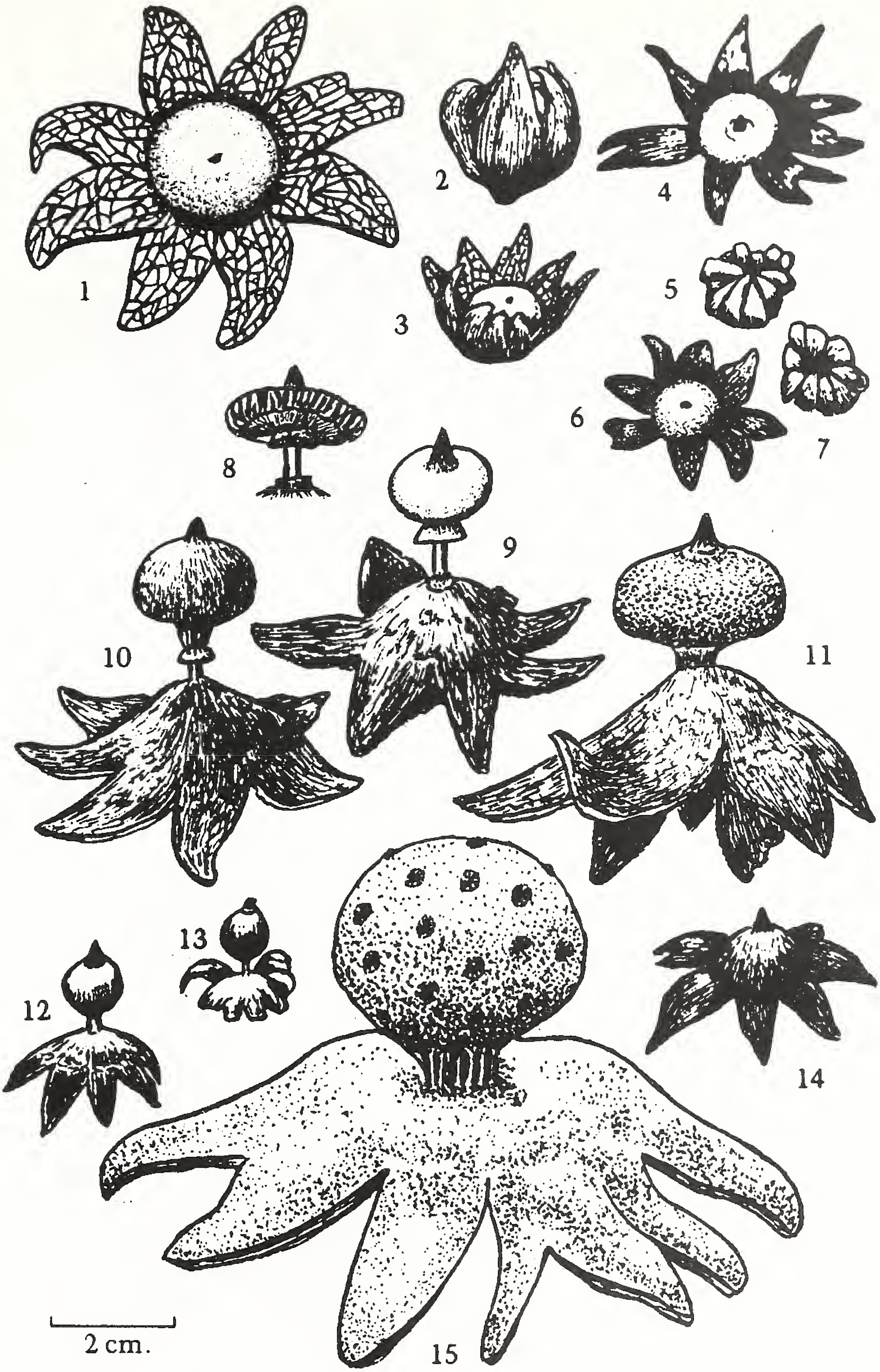


Figure 1. Earthstar fruit bodies (1). 1,2,3 *Astraeus hygrometricus.* 4,5 *Geastrum corollinum.* 6,7 *G. floriforme.* 8,9 *G. striatum.* 10 *G. pectinatum.* 11 *G. berkeleyi.* 12 *G. schmidelii.* 13 *G. minimum.* 14 *G. elegans.* 15 *Myriostoma coliforme.* Nomenclature updated. Drawn by E.A. Ellis (1981).

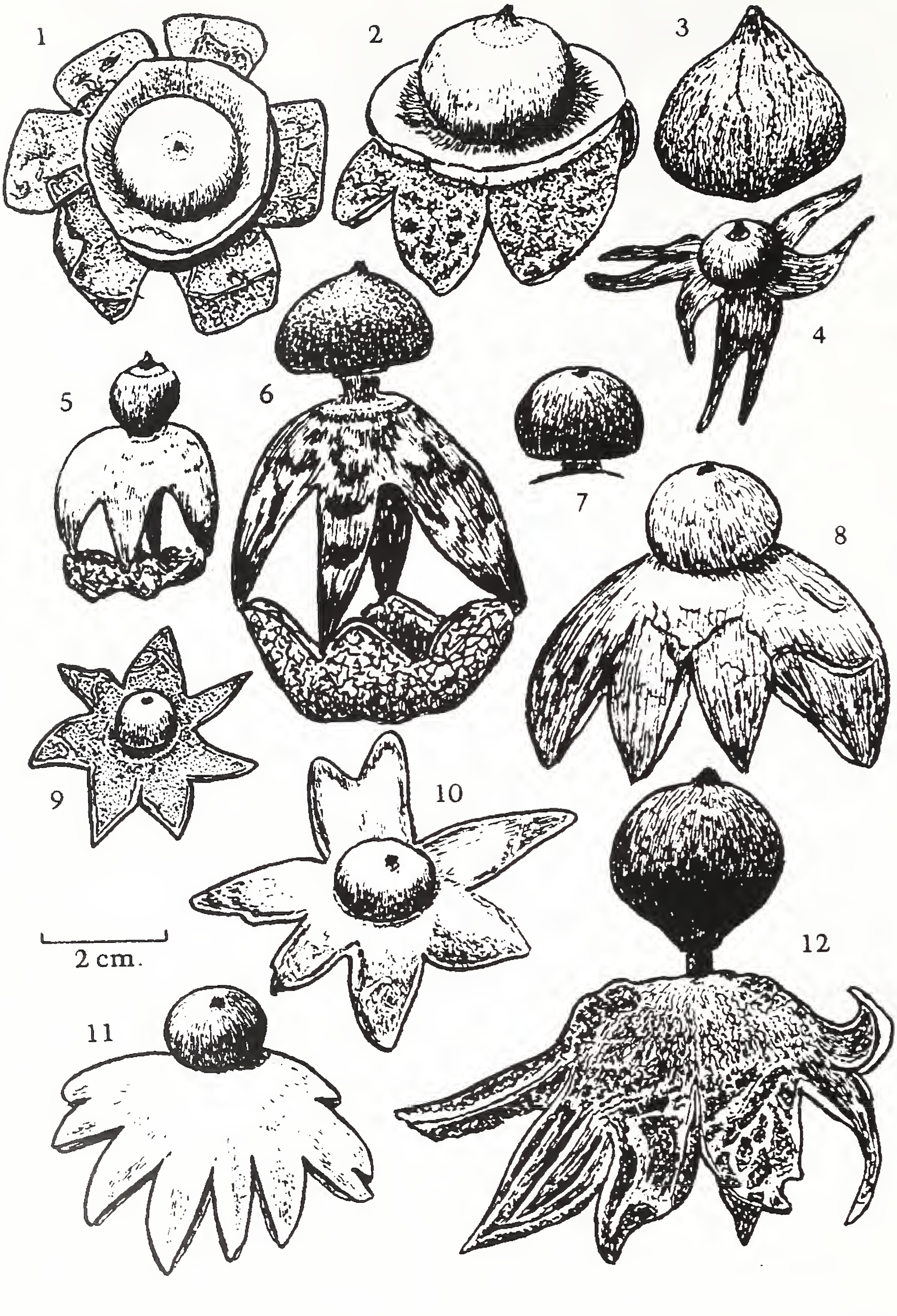


Figure 2. Earthstar fruit bodies (2). 1,2,3 *Geastrum triplex*. 4 *G. lageniforme*. 5 *G. quadrifidum*. 6 *G. fornicatum*. 7,8 *G. rufescens*. 9,10 *G. fimbriatum*. 11,12 *G. coronatum*. Nomenclature updated. Drawn by E.A. Ellis (1981).

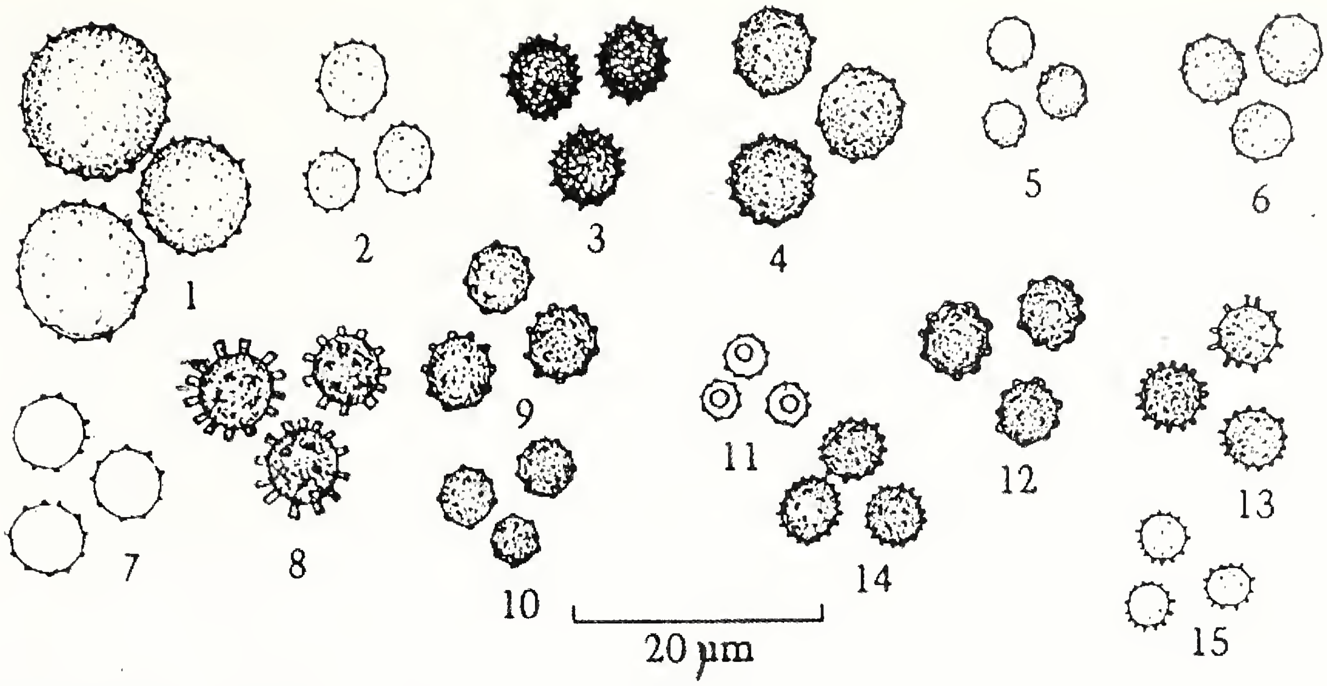


Figure 3. Earthstar spores. 1 *Astraeus hygrometricus.* 2 *Geastrum elegans.* 3 *G. coronatum.* 4 *G. floriforme.* 5 *G. fornicatum.* 6 *G. minimum.* 7 *G. schmidelii.* 8 *G. pectinatum.* 9 *G. quadrifidum.* 10 *G. corollinum.* 11 *G. fimbriatum.* 12 *G. striatum.* 13 *G. triplex.* 14 *G. rufescens.* 15 *G. lageniforme.* Nomenclature updated. Drawn by M.B. Ellis (Ellis 1981).

hygroscopic, that is, when dry they close round the spore-sac but in damp weather the rays open out and become recurved. In members of the genus *Geastrum* a central pore, surrounded by a conical peristome, allows the mature spores to escape. Features of the peristome, whether plicate (pleated), or fibrillose (fibrous) and fimbriate (fringed), are important characters for the separation of species, as is the presence or absence of a clear boundary (peristome delimited or not) around this feature. In *M. coliforme* there are several pores which, although slightly fringed, lack a true peristome. In *A. hygrometricus* the spores escape through an irregular tear in the endoperidium. Some of these features are illustrated in Figure 4.

The changes which take place during the development of an earthstar can be interpreted as adaptations to spore dispersal. The peeling back of the thick exoperidium reveals the thin-walled spore-sac which is readily disturbed by, for example, rain drops, falling debris or animals, to release the spores. Any elevation of the spore-sac will assist dispersal as the spores are more likely to be released into faster moving air and are more likely to clear surrounding obstacles. The development of a stalk and the reflexing of the rays both serve to elevate the spore-sac. In two species (*G. fornicatum* and *G. quadrifidum*) the mycelial layer under the rays splits off and pushes downwards to

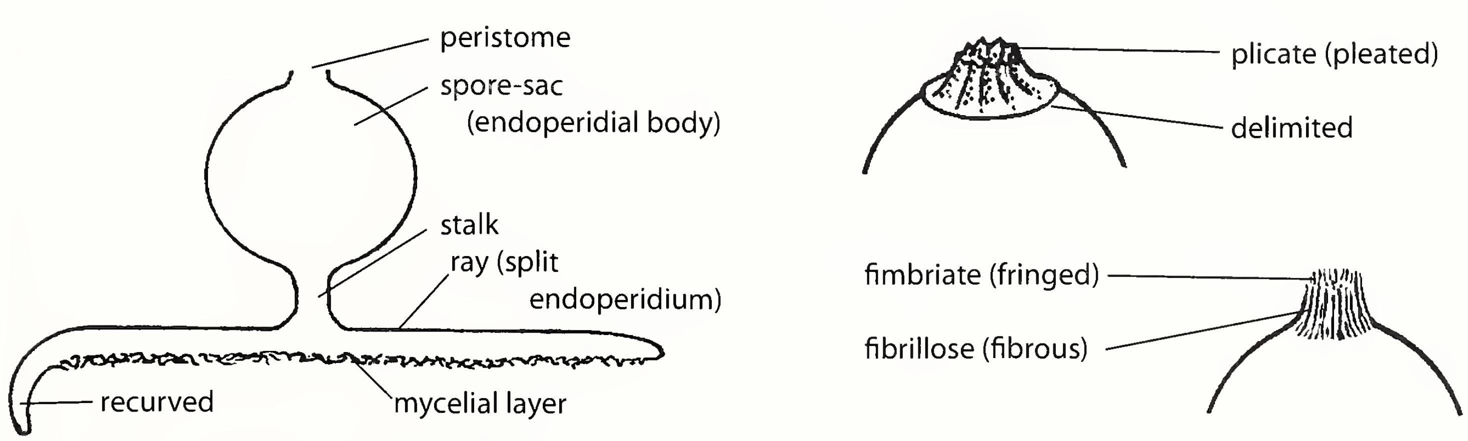


Figure 4. Terms used to describe earthstar fruit bodies.

raise the spore-sac even higher.

Identification

In common with almost all other groups of fungi, earthstars cannot usually be unambiguously identified from photographs of the entire fruit body because of variation in their overall appearance. Nevertheless, references to photographs in some of the more accessible and comprehensive fieldguides are given in Table 1, together with some of the synonyms used in the literature on Norfolk earthstars. Photographs of most species are to be found between pages 16 and 17. If attention is directed towards certain critical features and it is possible to identify normal specimens of all species without the need for microscopic examination. A dichotomous key is the usual means of achieving this and the one in Pegler *et al.* (1995) works well. An alternative approach is to tabulate these features (Table 2) and to assign letters for 'present' or 'absent' characters so that each species can be described by a code of up to seven letters (Table 1). It may be possible to gain support for a putative identification by comparing the dimensions of the specimens with the ranges given in Figures 4-7. These tables and figures are based on information in Pegler *et al.* (1995). If a microscope is available, spore size and structure may provide confirmatory evidence (Figure 8). It should be noted, however, that occasionally specimens will be found which have abnormal features, for example *G. minimum* occasionally lacks a stalk and young *G. triplex* lack the collar.

The standard reference work on this group

Table 1. Synonyms, code assignments (from Table 2) and sources of illustrations.

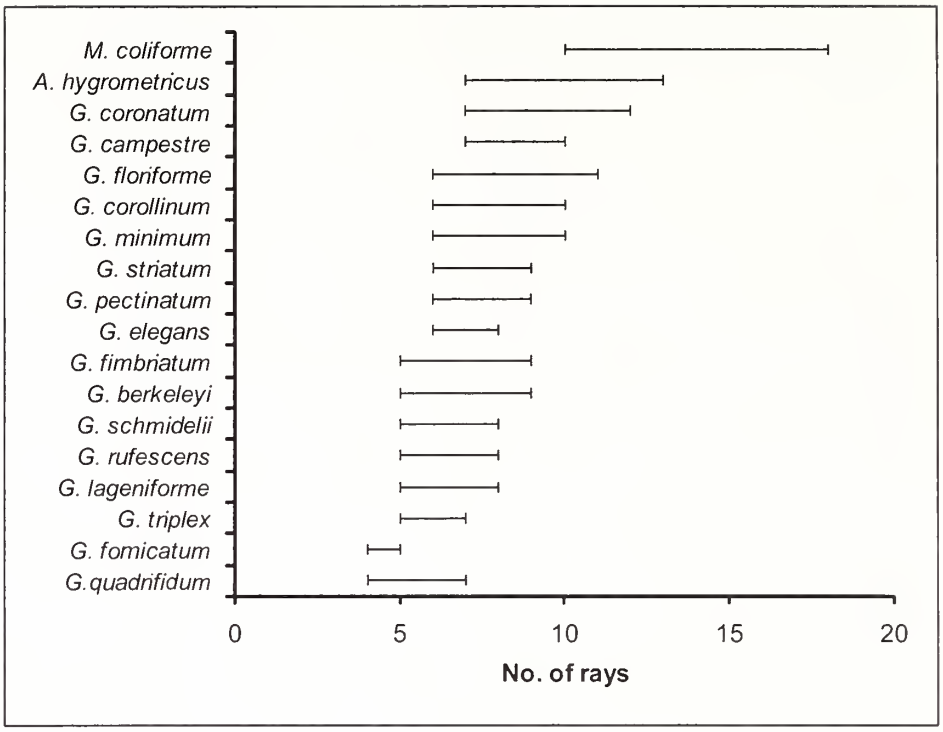
Name	Synonym	Code letters in Table 2	Illustrations Phillips 1981	Phillips 2005	Jordan 1995	Sterry & Hughes 2009
Astraeus hygrometricus (Pers.) Morgan			p.254	p.336	p.365	p279
Geastrum berkeleyi Massee		ABD				
Geastrum campestre Morgan		ABDE				p.273
Geastrum corollinum (Batsch) Hollós	*G. recolligens*	CDE				
Geastrum coronatum Pers.		ACF	p.253	p.336	p.359	
Geastrum elegans Vittad.	*G. badium*	BD				
Geastrum fimbriatum Fr.	*G. sessile*	C	p.252	p.334	p.359	p.271
Geastrum floriforme Vittad.		CG				p.271
Geastrum fornicatum (Huds.) Hook.		AC(D)FG	p.254	p.334	p.359	p.271
Geastrum lageniforme Vittad.	*G. saccatum*	CD				
Geastrum minimum Schwein.		ACDF				p.341
Geastrum pectinatum Pers.		ABD	p.254	p.336	p.360	p.273
Geastrum quadrifidum Pers.		ACDFG	p.253	p.335	p.360	p.271
Geastrum rufescens Pers.	*G. vulgatum*	ACF	p.253	p.335	p.360	p.271
Geastrum schmidelii Vittad.	*G. nanum*	ABD	p.253	p.336	p.361	p.341
Geastrum striatum DC.		ABD			p.361	p.273
Geastrum triplex Jungh.		CD	p.253	p.335	p.361	p.271
Myriostoma coliforme (With.: Pers.) Corda			p.252	p.334	p.362	p.339

Table 2. Identification features of earthstar species.

Species	Spore-sac		Peristome (mouth)			Rays		Mycelial layer		Other features
	Stalked	Surface[1]	Grooved	Fibrous and fringed	Delimited[2]	Hygroscopic[3]	Recurved[4]	Sticks to debris	Separates downwards	
Code letter (see Table 2)	**A**		**B**	**C**	**D**	**E**		**F**	**G**	
Astraeus hygrometricus	×	felty	irregular opening			✓	×	(✓)	×	reticulate pattern on rays
Geastrum berkeleyi	✓	finely warty	✓	×	✓	×	×	×	×	
Geastrum campestre	✓	finely warty (smooth)	✓	×	✓	✓	✓damp	×	×	
Geastrum corollinum	×	smooth (powdery)	×	✓	✓	✓	✓damp	×	×	
Geastrum coronatum	✓	almost smooth	×	✓	occ	×	(✓)	✓	×	
Geastrum elegans	×	smooth (powdery)	✓	×	✓	×	✓	×	×	
Geastrum fimbriatum	×	minutely downy	×	✓	×	×	✓	×	×	
Geastrum floriforme	×	scurfy	×	✓	×	✓	✓damp	×	×	
Geastrum fornicatum	✓	finely hairy	×	✓	(×)	×	×	✓	✓	ray margins incurved
Geastrum lageniforme	×	minutely downy to smooth	×	✓	✓	×	(✓)	×	×	
Geastrum minimum	✓	(powdery)	×	✓	✓	×	(✓)	✓	×	
Geastrum pectinatum	✓	smooth (powdery)	✓	×	✓	×	(✓)	×	×	
Geastrum quadrifidum	✓	powdery	×	✓	✓	×	×	✓	✓	
Geastrum rubescens	✓	minutely downy	×	✓	×	×	(✓)	✓	×	rays slightly pinkish
Geastrum schmidelii	✓	smooth	✓	×	✓	×	(✓)	×	×	
Geastrum striatum	✓	finely striate when rubbed	✓	×	✓	×	(✓)	×	×	spore-sac with basal collar
Geastrum triplex	×	smooth	×	✓	✓	×	(✓)	×	×	fleshy collar around spore-sac
Myriostoma coliforme	✓	warty and pitted	many openings			×	(✓)	✓	×	

Features in brackets are less reliable. **Note 1** Spore-sac surface tends to loses features and becomes smoother with age. **Note 2** Distinct zone around peristome; can be surrounded by a ridge. **Note 3** When dry, rays close round spore-sac; when damp, rays open out. **Note 4** As an earthstar ages, arms are more likely to recurve.

Figure 4. Ranges of earthstar ray numbers.



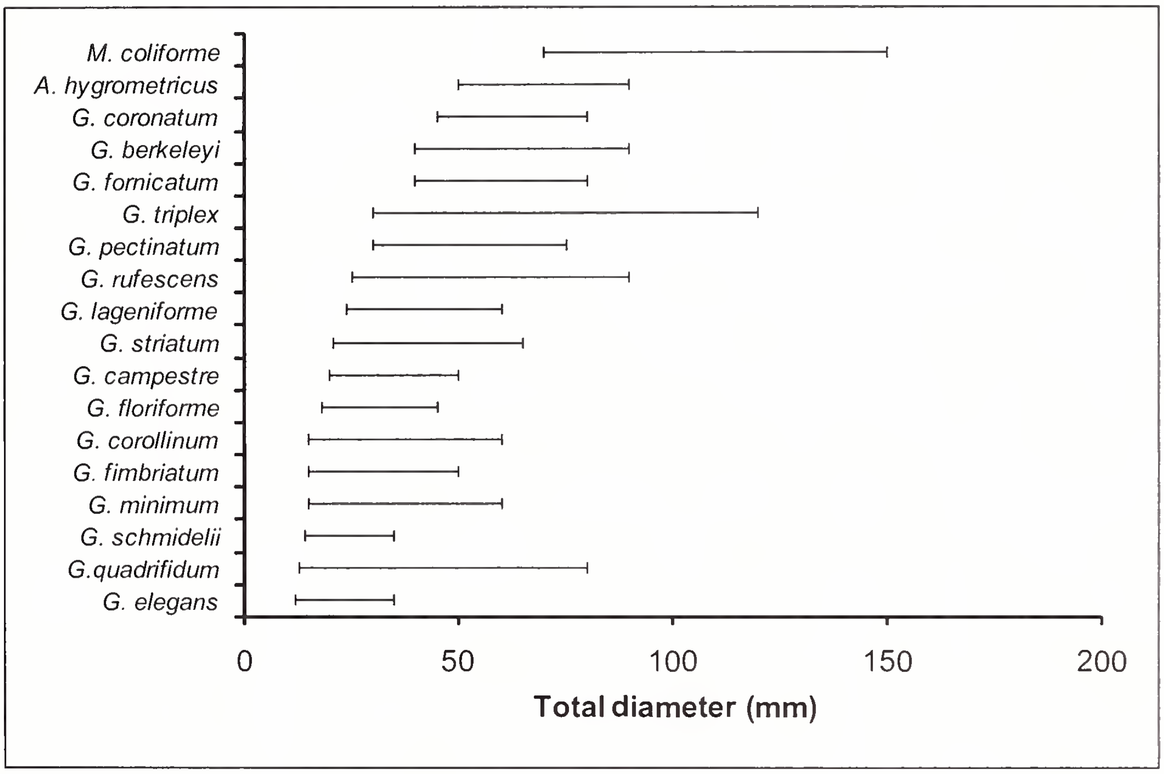
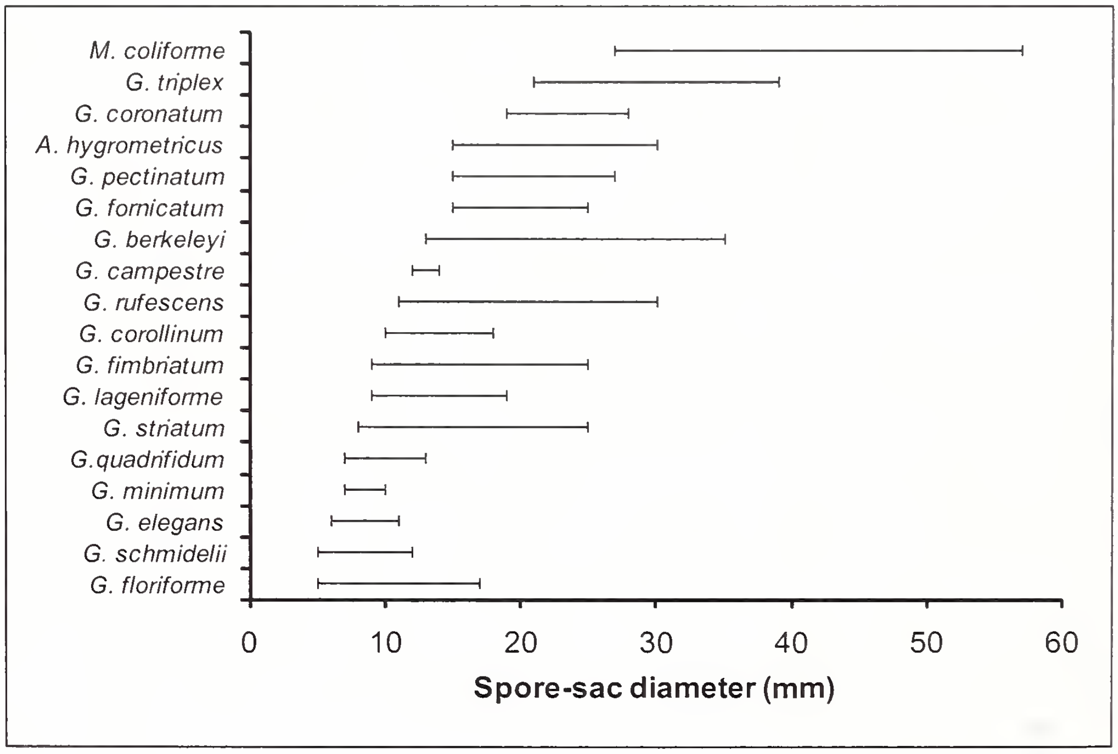


Figure 5. Ranges of earthstar total diameters.

Figure 6. Ranges of earthstar spore-sac diameters.



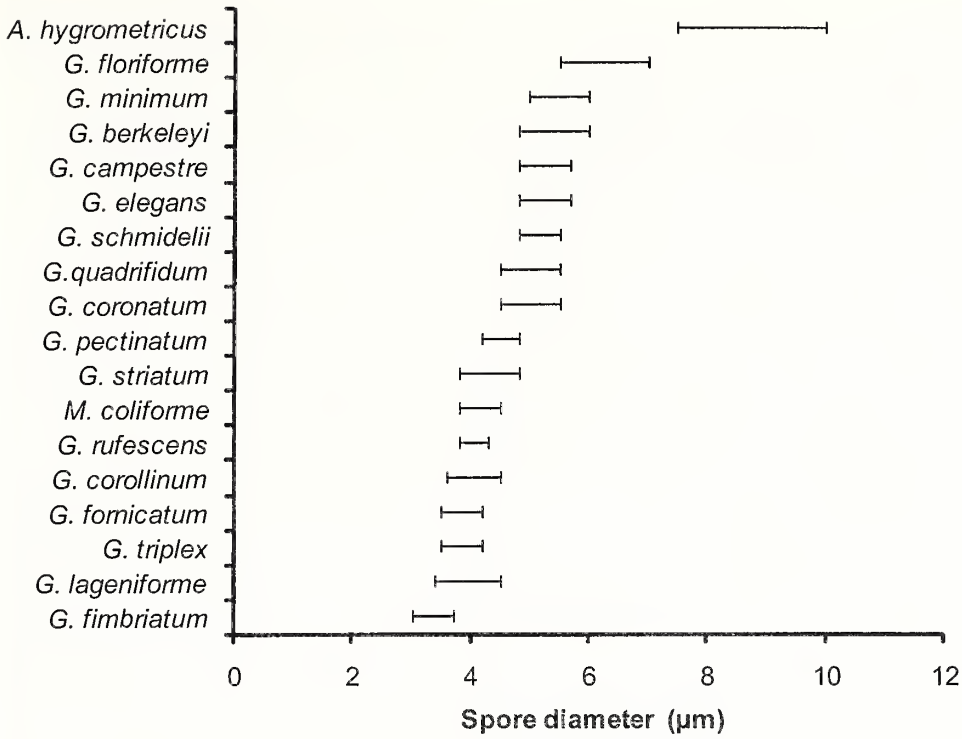


Figure 7. Ranges of earthstar spore diameters.

is Sunhede (1989) but for British species the monograph on the gasteroid fungi by Pegler *et al.* (1995) is considered authoritative.

Distribution

Most of the early Norfolk records are taken from Ellis (1981) or the Fungus Record Database of the British Isles (FRDBI) maintained by the British Mycological Society and accessible at http://www.fieldmycology.net. Recent Norfolk records are from Richard Shotbolt's Norfolk Fungus Database which is held at the Norfolk Biodiversity Information Service, or have been supplied by personal communication. Information about national distributions is from Pegler *et al.* (1995) or the FRDBI.

Grid references in the form, ~TG 0434 are given as an approximate indication of location but were not supplied with the original record. They were obtained from Driscoll & Hewitt (1999) and refer to the 1 km square in which the initial letter of the place name appears on the Ordnance Survey 1:25000 First Series maps. A plus sign after a year (e.g. 2000+) indicates that the fungus was seen in the same location at some time during the succeeding five years. Where known, the

Table 3. Full names of recorders referred to in Tables 4-9.

Initials	Name	Initials	Name	Initials	Name
ALB	AL Bull	GJC	GJ Cooke	RGB	RG Betts
ARD	AR Disney	GM	G Massee	RHS	RH Sewell
BI	B Ing	HLJ	H Lindley Jones	RJC	RJ Colman
(BMS)	Brit. Mycological Soc.	HW	H Williamson	RK	R Key
CAB	CA Blenkiron	JJR	JJ Revett	RMSB	RMS Brown
CB	C Bryant	JML	JM Lambert	RPBO	RP Bagnall-Oakeley
CBP	CB Plowright	JP	J Palmer	RWT	RW Turner
CPP	CP Petch	JS	J Sowerby	THP	T Hyde Parker
CR	C Rea	KT	K Trimmer	TJW	TJ Woodward
DAB	DA Boardman	MN	M Nichols	TWD	TW Dove
EAE	EA Ellis	MP	M Pett	WEHF	WEH Fiddian
EM	E Mountford	MW	M Wright		
GCHC	GCH Chandler	REE	RE Evans		

Table 4. **Records of *Geastrum corollinum*.**

Year	Place	Grid	Name	Year	Place	Grid	Name
1782			CB	1896+	Hillington	~TF 7125	CBP
1794	Earsham	~TM 3289	TJW	1938	Hellesdon	~TG 2010	HLJ
1794	Ditchingham	~TM 3292	TJW	1983	Wortwell	TM 2080	EAE
1861	Crostwick	~TG 2515	KT	2006	Edgefield	TG 0934	TWD

names of identifiers take precedence over finders and finders over reporters. The full names of those responsible for records are given in Table 3.

Astraeus hygrometricus Barometer Earthstar

This large and distinctive earthstar was first recorded in Norfolk by the Rev. K. Trimmer in 1866 from a sandy bank at Rackheath (~TG 2714). Trimmer never published his records but made them available to C.B. Plowright who did (beginning in 1872). The second find was from King's Lynn (~TF 6218) in 1897 (reported by C Rae) and the third was by CP Petch in December 1927 from Holt (~TG 0838). Some sixty years later M.A. Brewster found it near Saxthorpe (TG 1131), where a small colony was observed along the edges of a sandy track through mixed woodland between 2000 and 2004 by TWD. This earthstar is uncommon in Britain and largely restricted to the southern counties although there are early records from Yorkshire and a recent one from Nottinghamshire.

Geastrum berkeleyi Berkeley's Earthstar

This genuinely rare earthstar appears to have occurred in Norfolk but once, at Blakeney Brecks (~TG 0243) in 1925 or 1926, a record attributed to F Yeo. This record is given by Ellis (1981) without further details but is not referred to by Cooke (1937). Its designation as possibly extinct in Britain (Pegler *et al.* 1995) was premature as there were subsequent records from Worcestershire in 1996; Herefordshire in 1999 and Hampshire in 2001.

Geastrum campestre Field Earthstar

This species was added to the Norfolk list as recently as 2006 when Paul Sterry found 'an old eroded specimen with only slight hygroscopic activity' at Holkham Meals (TF 8845); its identity was confirmed by Brian Spooner at Kew. Pegler *et al.* (1995) considers it to be introduced to Britain, although they state that it occurs throughout Europe. As with so many rare earthstars there has been a flurry of recent records: Surrey in 2001; Wiltshire in 2005 and Hampshire in 2007.

Geastrum corollinum Weathered Earthstar

The rays of this far-from-common species are often recurved and lose their mycelial layer with age. The first British record was from Norfolk in 1782, although the locality is not known. Since then it has occurred spasmodically with the most recent, and curious, record in 2006 from a greenhouse near Edgefield, identified by TWD. (Table 4). Its more usual habitat is hedge-banks or deciduous woods on well-drained base-rich soils. British records are scattered across the eastern half of England (with just a handful from North Wales). Pegler *et al.* (1995) point out that some of the relatively few records from the twentieth century require confirmation; the species is similar to *G. floriforme* but the latter is even rarer.

Geastrum coronatum Crowned Earthstar

This species is much commoner than the above and is more widespread in Britain but with, again, the greatest concentration of records from East Anglia, where in recent

Table 5. Records of *Geastrum coronatum*.

Year	Place	Grid	Name	Year	Place	Grid	Name
1864	Attlebridge	~TG 1316	KT	1980	Intwood	TG 1904	EAE
1867	Skeyton	~TG 2425	KT	1998	Harford, Norwich	TG 2105	JJR
1880	Hillington	~TF 7125	CBP	1998	Norton Subcourse	TM 4098	TWD
1938	Drayton	~TG 1813	RMSB	1999+	Holt Country Park	TG 0838	TWD
1939	East Wretham	~TL 9190	JML	1999	Brundall Gardens	TG 3108	TWD
1940	Blofield	~TG 3309	THP	2000	Earsham	TM 3290	TWD
1945	Eaton	~TG 2006	GJC	2000+	Marston Lane	TG 2205	TWD
1945+	Upper Hellesdon	~TG 2111	EAE	2000	Gayton	TF 7419	TWD
1946+	Surlingham	~TG 3006	EAE	2000+	Cockley Cley	TF 7804	JJR
1948+	Claxton	~TG 3303	RHS	2000	Keswick Old Hall	TG 2004	TWD
1951	Halvergate	~TG 4106	RK	2000	Saxthorpe Woods	TG 1132	TWD
1953	Ingham	~TG 3825	ARD	2001	Ipswich Rd., N'ch	TG 2207	TWD
1971	West Bradenham	~TF 9108	Tubby	2003	Wortwell	TM 2785	TWD
1978	New Costessey	~TG 1710	CAB	2003	Holkham Meols	TF 8845	TWD
1979+	Rockland St Mary	TG 3204	MN	2007	Holkham Gap	TF 8944	RGB

years it has been found relatively frequently (Table 5). It is most likely to occur on hedge-banks, often under hawthorn or oak and occasionally under beech.

Geastrum elegans Elegant Earthstar

The first British record for this earthstar was from Norfolk by JT Palmer at Great Massingham (~TF 7922) in 1882. Strangely it was not reported by CB Plowright whose interest by that time had moved on to the rust fungi. It appears to be genuinely rare with only seven further British records through the twentieth century, not all of them confirmed, from East Lothian to the Isles of Scilly and from Anglesey to East Suffolk. After a gap of 120 years an old specimen was found by M Rotheroe and ARL. in the spring of 2002 under pines at Holkham (TF 8845) and was identified by BM Spooner. During autumn of the next year SE Evans reported finding a fresh specimen in the same area.

Geastrum fimbriatum Sessile Earthstar

Tracing early records for this species is hampered by nomenclatural uncertainties as the name *G. rufescens* has also been used for this species. It is apparent from spore descriptions that Ellis (1981) uses the name in this way and refers to what is now accepted as *G. rufescens*, as *G. vulgatum*. *G. fimbriatum* is comparatively widespread through England and southern Scotland and is one of the few earthstars to occur widely in Ireland. It appears to be getting commoner in Norfolk and is typically found on hedge-banks and along the edge of woods, both coniferous and deciduous (Table 6).

Geastrum floriforme Daisy Earthstar

Although it might be getting commoner, with around a dozen British records since it was first found in Lancashire in 1952, this is still a rare fungus which favours the east of England. It was added to the Norfolk list by EA Ellis who found it at Heacham (TF 6737) in 1981 and at nearby Old Hunstanton (TF 6840) in the following year. In Norfolk it is a coastal species, growing on bare sand between patches of well-grazed turf in exposed sites. Very recently (2009) a third site was located when four specimens were found by P Amies and G Hibberd at

Table 6. Records of *Geastrum fimbriatum.*

Year	Place	Grid	Name	Year	Place	Grid	Name
1872	Castle Rising	~TF 6624	CBP	1987	Santon Downham	TL 8187	REE
1902	Cromer	~TG 2141	CR	1990	Grimes Graves	TL 8189	REE
1948	Norwich	~TG 20	GJC	1990	Lynford Hall	TL 8194	REE
1952	Mousehold Heath	TG 2410	EAE	1993	Croxton Heath	TL 8690	REE
1954	Holt	~TG 0838	GCJ	1998+	Emily's Wood	TL 7989	REE
1956	Hingham	TG 0301	EAE	1999+	Holt Country Park	TG 0838	TWD
1958	Holkham Dunes	~TF 8944	EAE	2000	Cranworth	TF 9804	REE
1977	Bacton Woods	~TG 3130	EAE	2001	Norwich	TG 2216	TWD
1980	East Harling	~TL 9986	EAE	2001	Sheringham Park	TG 1441	TWD
1983	Bacton Woods	TG 3131	REE	2002	Bridgham Picnic Site	TL 9683	JJR
1985	Bridgham Picnic Site	TL 9683	REE	2002	Weeting Heath	TL 7688	TWD
1985	Felthorpe Woods	TG 1416	REE	2003	E. Walton Common	TF 7316	ALB
1986	Emily's Wood	TL 7989	REE	2003	Croxton Heath	TL 8690	ALB

Holme (TF 7144), barely 3 km from the 1982 record.

Geastrum fornicatum Arched Earthstar

This earthstar gets its intriguing specific name from the Latin *fornix,* meaning arch, as it is one of the two British species in which the mycelial layer separates from the exoperidium and reflexes downwards while remaining attached to the rays at their tips. It is not common in Britain and like so many earthstars it has a predominantly south-eastern distribution. Half of the Norfolk records have been made in the last decade (Table 7).

Table 7. Records of *Geastrum fornicatum*

Year	Place	Grid	Name	Year	Place	Grid	Name
1815	North Elmham	~TF 9820	JP	2000+	Forncett St. Mary	TM 1694	TWD
1872	Billingford	~TG 0120	KT	2000+	Cockley Cley	TF 7804	JJR
1924	East Dereham	~TF 9912	MP	2001	Narborough	TF 7711	TWD
1937	Crown Point	~TG 2506	RJC	2002	Ringland	TG 1415	TWD
1954	Sprowston	~TG 2411	WEHF	2003	Cockley Cley	TG 8005	JJR
1974	Norwich	TG 2310	EAE	2006	Pott Row	TF 6921	JJR
1983	Narford Hall	TF 7613	REE	2007	Frettenham	TG 2418	TWD
1999	Itteringham	TG 1431	TWD	2007	Raveningham	TM 3896	TWD
2000+	Forncett St. Mary	TM 1694	TWD				

Geastrum lageniforme Flask Earthstar

Although still nationally rare, this earthstar is being recorded increasingly frequently but has not been found in Norfolk for nearly 100 years. The first record for the county is that by the Rev. K Trimmer in, or near, Norwich in 1873. C Rae recorded it at Cromer in 1902 and GJ Cooke at Earlham, also in Norwich, in 1912. A difficulty here is that this species is very similar to specimens of *G. triplex* that have failed to develop the characteristic collar, a not unusual phenomenon. There are microscopic differences but spore size is not one of them (according to


Beaked Earthstar *Geastrum pectinatum*


Rayed Earthstar *Geastrum quadrifidum*


ıyed Earthstar *Geastrum quadrifidum* (fleshy form)


Rosy Earthstar *Geastrum rufescens*


Striate Earthstar *Geastrum striatum*


Collared Earthstar *Geastrum triplex* (young)


Collared Earthstar *Geastrum triplex* (mature)


Pepper Pot *Myriostoma coliforme*

All photos by Jonathan Revett except *G. floriforme* (Gary Hibberd), *G. campestre* (dried) (Tony Leech) and *G. triplex* (mature) (Tony Leech).

All photos are of Norfolk or Suffolk specimens except *Myriostoma coliforme* (foreign).

Top: **A pingo at NW Thompson Commor** (Photo: Rob Yaxley)

Left: **A more shaded pingo pool** showing *Carex elata*. (Photo: Robin Stevenson)

Bottom left: **Marsh Lousewort *Pedicular palustris*,** a characteristic plant of ground-ice depressions. (Photo: Geoff Nobes)

Bottom right: **Scarce Emerald Damselfly *Lestes dryas*,** a specie associated with ping ponds. (Photo: Geoff Nobes)

op: **Male Adders 'dancing'.**
Photo: Bernard Dawson)

'ight: **Juvenile Adder** bask-
ng on an unsloughed male.
Photo: Bernard Dawson)
ee p. 40

Bottom left: **Orchard Crust**
arcodontia crocea on ap-
ple tree at Bergh Apton.
Photo: Tony Leech)

Bottom right: ***Hydnangium***
arneum at Bergh Apton.
Photo: Tony Davy)
ee p. 68

Barometer Earthstar *Astraeus hygrometricus*

Field Earthstar *Geastrum campestre* (dried)

Weathered Earthstar *Geastrum corollinum*

Crowned Earthstar *Geastrum coronatum*

Sessile Earthstar *Geastrum fimbriatum*

Daisy Earthstar *Geastrum floriforme*

Arched Earthstar *Geastrum fornicatum*

Tiny Earthstar *Geastrum minimum*

Pegler *et al.* 1995) despite a suggestion to the contrary in Ellis (1981). A further complication is that *G. saccatum*, the name under which Ellis describes this species, is recognised as a distinct species in the USA and Europe but not in Britain.

Geastrum minimum Tiny Earthstar

If any earthstar can be thought of as Norfolk's own, *G. minimum* is that species. It is not quite a Norfolk endemic in the British Isles as it has been found on the Cumbrian coast at Ravenglass (Legon & Henrici 2005), although this record does not appear on the FRDBI. A record for it from the Isle of Man is unsupported by voucher material. It was first found in Britain at Holkham, by EA Ellis in 1958, and confirmed by JT Palmer, the expert on gasteroid fungi. Its stature alone cannot be used to establish its identity as half a dozen species can be less than 20 mm in total diameter (Figure 4). The spore-sac is normally dusted whitish and is typically stalked, although sessile specimens have been found.

During the 1990s specimens were collected at Holkham by a number of people including A Harrap in 1993 and by MJ Telfer and L Gresser in 1995 (Telfer *et al.* 2000). Monitoring work by the Norfolk Fungus Study Group (particularly by TWD, JJR and T Money) since 2000 has established that there are a number of small populations within a few kilometres of each other. In a very detailed survey, supported by Plantlife International in 2009. AM Ainsworth found over 300 fruit bodies in 21 patches in this area Most are on sloping ground near the seaward edge of belt of Corsican Pine *Pinus nigra* where small patches of bare sand occur amongst rabbit-grazed turf with a high percentage of moss cover. The dunes are visited by large numbers of people, but although trampling and erosion have eliminated it from one vulnerable site, in general the earthstar appears to be thriving. Colonies also occur on the dunes to the west of the pines.

Geastrum pectinatum Beaked Earthstar

G. pectinatum bucks the trend by being rather commoner elsewhere in England than Norfolk, with just one locality in the county. This may be because it favours limestone under spruce, a habitat not found in Norfolk. When mature the spore sac of this species is normally a leaden grey. It was first found in 1954, also at Holkham Dunes, by TJ Wallace and in 1958 by EA Ellis and JT Palmer. In 1987 it was re-found by RE Evans in what might well have been the same site (TF 9045) but it has not been seen since despite this being a well-studied area.

Geastrum quadrifidum Rayed Earthstar

G. quadrifidum is distinctly less common than our other arched earthstar (*G. fornicatum*), both in Norfolk and in Britain. It was not found in Norfolk until 2000 when JJR collected it from a remarkable roadside bank at Cockley Cley (TF 7804); remarkable because it is a site not only for the rare Sandy Stiltball *Battarraea phalloides* but for six more species of *Geastrum*! Moreover the specimens found annually at this site are quite different from the normal form of this earthstar: they are at least two or three times larger, have up to six rays and the peristome does not sit on a flattened 'saucer'. L Jalink (pers. com.) notes that he has seen this form several times in the Netherlands but sees no reason to rank it as a subspecies or variety. Fresh young specimens can appear on casual observation to be *G. berkeleyi.*

A second Norfolk site was discovered in 2002 at Pratt's Hill, Surlingham (TG 3107) only about 2 km from the late Ted Ellis's home at Wheatfen, and a third, at Stoke Holy Cross in 2008, both by TWD. In the spring of 2009, D McNeil found a specimen under Yew *Taxus baccata* in Rushford churchyard (TL 9281).

Geastrum rufescens Rosy Earthstar

The rays of this earthstar can have a pinkish tint but this is rarely as marked as its names might suggest. It is one of the more widely reported species in England (rarely reach-

Table 8. **Records of *Geastrum rufescens***

Year	Place	Grid	Name	Year	Place	Grid	Name
1794	Trowse	~TG 2406	JS	1958	Honingham	TG 1010	EAE
1861	Drayton	~TG 1813	KT	1973	Briston	~TG 0632	HW
<1872	Hellesdon	~TG 2010	KT	1974	Weeting Heath	~TF 7587	(BMS)
<1872	Earlham	~TG 1808	KT	1974	West Harling Heath	TL 9784	EAE
1874	North Wootton	~TF 6424	JP	1994+	Lynford Arboretum	TL 8294	JJR
1936+	Sheringham	~TG 1442	GJC	1998	Emily's Wood	TL 7989	TWD
1936	Cromer	TG 2241	EAE	1998	Holkham Dunes	TF 9045	JJR
1938	Sparham Pools	TG 0718	EAE	1999	Stoke Holy Cross	TG 2301	TWD
1938	Earlham Park	TG 1907	EAE	1999+	Mousehold Heath	TG 2410	TWD
1952	Mousehold Heath	TG 2410	EAE	2000	Bridgham Picnic Site	TL 9683	JJR
1956	Surlingham	TG 3107	EAE	2001	Gressenhall Old Carr	TF 9717	REE
1956	Hingham	~TG 0202	EAE	2007	Lynford Arboretum	TL 8294	TWD
1958	Holkham Gap	TF 9045	EAE				

ing Scotland) and one of the commonest in Norfolk (Table 8). It has no coastal pretensions and although typically found on leaf litter also occurs in grassy places.

Geastrum schmidelii Dwarf Earthstar

Although the FRDBI gives the first Norfolk record as that of J Palmer at Winterton in 1874, Ellis (1981) states that this species is clearly illustrated in *Flora Londiniensis* (ca 1819) by WJ Hooker with the comment that it was 'common at Yarmouth Denes'. This small sand-loving species is not often met with in Norfolk and has not enjoyed the flush of recent records which have characterised some of its relatives (Table 9).

Geastrum striatum Striate Earthstar

Were it not for the basal collar projecting downwards from below the spore-sac this species would be hard to distinguish from *G. pectinatum*, although there are small microscopic differences. It is occasional to locally common in Norfolk (Table 10), where it occurs in woods and especially along their boundaries. It is one of the commoner earthstars and although it has been found farther north than any earthstar in Britain (on the south side of the Moray Firth) it is very much more abundant in East Anglia and the Home Counties.

Geastrum triplex Collared Earthstar

It is interesting that this distinctive earthstar, which is now by far the commonest in Norfolk and in Britain, was not mentioned by Plowright in any of his publications. It

Table 9. Records of *Geastrum schmidelii*

Year	Place	Grid	Name	Year	Place	Grid	Name
1874	Winterton	~TG4920	JP	1979	Burnham Overy	~TF8442	CPP
1874	Caister	~TG5111	JP	1984	Holkham Dunes	TF9045	REE
1880	Yarmouth	~TG50	GM	1987	Holkham	TF8745	REE
1949	Scolt Head Island	~TF8146	DAB	1990	Breckland		
1977	Holkham	~TF9045	BI				

Table 10. Records of *Geastrum striatum*

Year	Place	Grid	Name	Year	Place	Grid	Name
1849	East Carleton	~TG 1702	KT	1954	Upper Hellesdon	~TG 2111	EAE
1867	North Wootton	~TF 6424	CBP	1971	Aldeby	TM 4493	EAE
1890	Shotesham	~TM 2499	KT	1973	Mundford	~TL 8093	RPBO
1905	Swanton Abbott	~TG 2625	EM	1978	Cranworth	TF 9804	REE
1935+	Eaton	~TG 2006	GJC	1983	Bridgham Picnic	TL 9683	REE
1937	Stoke Holy Cross	~TG 2302	GCHC	1998	Itteringham	TG 1431	REE
1943	Mangreen	~TG 2103	GJC	2001	Harford Hills	TG 2205	TWD
1946	Claxton	~TG 3303	RHS	2002+	Holkham Gap	TF 8745	JJR
1948	Rockland St. Mary	~TG 3104	EAE	2002	Ringland	TG 1413	TWD
1950	Barford	~TG 1107	RWT	2003	West Norfolk		
1953	Surlingham	TG 3107	EAE	2005	South Walsham	~TG 3613	TWD

would seem that he had not personally encountered this species although Ellis (1981) reports that it is clearly figured by Bryant (no reference given), showing that it was present in the Norwich area in the 18th century. We must wait until Cooke (1937) for more formal records: by himself at Horsford Heath (~TG 1818), 1910 to 1914, and then nothing until 1932 (T Petch at Holkham Gap (~TF 9045) followed by seven more records in the next three years. Cooke comments that it appears to be becoming increasingly common in Norfolk and that trend has continued; the Norfolk Fungus Record Database contains 124 records for *G. triplex* from 62 sites between 1938 and 2007 (map see Figure 8), although still not widely reported from the Broads or from West Norfolk. It

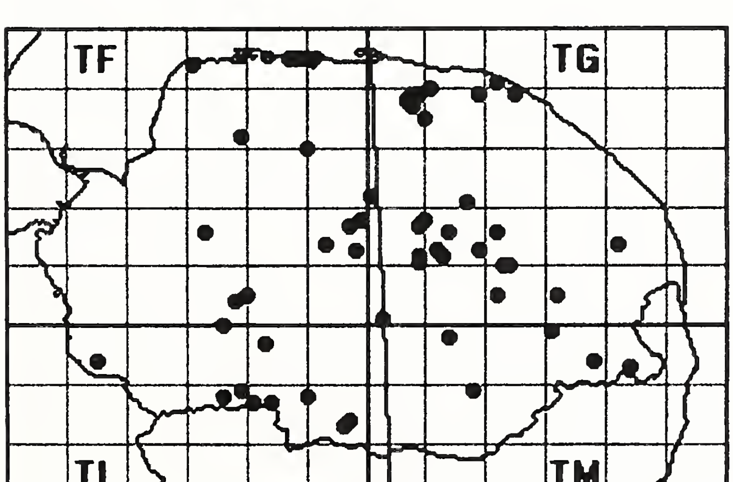


Figure 8 Records of *Geastrum triplex* since 1938

is abundant most years in Thetford Forest in the thick mossy needle litter below the pines but, although it may favour humus-rich soil, it can also occur on sandy soils beneath trees. Note that the 'collar' is formed by a cracking of the thick inner layer of the exoperidium as the fungus matures so is not apparent on young specimens.

Myriostoma coliforme Pepper Pot

This distinctive earthstar, with its multiple stalks and openings, is the Holy Grail of Norfolk mycology, the more so since it was found in Suffolk in 2006 (on a sandy bank under oak)! It was first collected in Norfolk by TJ Woodward in 1794 from Earsham (~TM 3289) and Gillingham (~TM 4091), two localities near Beccles on the Norfolk side of the county boundary. He also collected it from two nearby localities just south of the Waveney. Plowright (1881) reports that at about this time it was found near Norwich by Sowerby but the record was never formalised. On 25th September 1880 CB Plowright was therefore very excited when four fruit bodies of this earthstar were brought to his house in King's Lynn, having been collected by Mr Philip Higben at nearby Hillington (~TF 7125) (Plowright 1881). They had been found 'growing upon a hedge-bank in a green lane (called the

Swaffham Road) amongst a large clump of nettles'. About three weeks later Plowright collected further specimens from the same location but in a withered state. These were the last collections of the species in the British Isles until the Suffolk record once again confounded the premature statement of its extinction in Britain by Pegler *et al.* (1995). *Myriostoma coliforme* occurs in Europe and in the 1990s was recorded from Jersey where it occurs on a sandy bank along a track leading to the sea. On a visit to the site, TWD found *G. fornicatum* and *G. pectinatum* on the same bank.

Suffolk earthstars

The original paper by Ellis (1981) was entitled *Earth-stars (Geastraceae) in Norfolk and Suffolk*, and the latter county is almost as rich in earthstars (13 have occurred there according to FRDBI). We prefer to leave a detailed account to our colleagues in Suffolk; a Suffolk Fungus Group now exists and a County Recorder has been appointed. Nevertheless, mention should be made of the earthstars in Brandon Country Park just over the border, where JJR has recorded no fewer than eight species (*G. coronatum, coronillum, fimbriatum, fornicatum, quadrifidum, rufescens, striatum* and *triplex*) and a ninth, *G. pectinatum*, has been reported.

Earthstar 'hotspots'

Whilst it is true that mycologists visiting the site of a rare fungus with their eyes open are more likely to spot new species, it is inescapable that a 'family' preference for particular habitats is shown by many groups of fungi. The association in Brandon Country Park is a remarkable example, now matched by Holkham Meals, a 4 km length of pine-covered dunes, with *G. campestre, coronatum, elegans, minimum, pectinatum, rufescens, schmidelii, striatum* and *triplex*. (Note that the statement by Leech *et al.* (2008) that there were only eight species at Holkham was erroneous; records had been entered under a number of different place names for the site.) In many ways an even more remarkable example of this clustering is at Cockley Cley, where a narrow road-side verge, no more than 150 m long, with scattered Scot's Pine, produces *G. coronatum, fimbriatum, fornicatum, quadrifidum, rufescens, striatum* and *triplex*.

Acknowledgements

We are grateful to John Ellis for the kind permission to reproduce his father's line illustrations and to Richard Shotbolt for making available the Norfolk Fungus Database which he set up.

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AR Leech 3, Eccles Road, Holt , Norfolk NR25 6HJ leech@dialstart.net

TW Dove 2 Kirklees, Tuckswood, Norwich NR4 6LP

JJ Revett Wigston Villa, Welney, Wisbech, Cambs PE14 9QA

The Adders of Holt Lowes; a decade of recording

Bernard Dawson

In 1999 I became aware that a major management programme was due to start on Holt Lowes. I knew that the site was a good one for the Adder *Vipera berus* and, in order to see if the management was beneficial for these beautiful creatures, I decided to find as many spring basking areas as possible and to monitor the number of Adders utilising these areas. As the Adder is usually very faithful to these sites, which are generally close to their hibernacula, data gathered on these aggregations of Adders should prove a good indicator as to their welfare.

There is a common requirement for dry ground with a southerly aspect and adjacent thick vegetation. The Lowes has a good mixture of habitat and an ideal topography but the large area to be covered (*c.* 50 ha) was daunting and initially the number of Adders being found was disappointing. However, as I gained an improving understanding of their requirements, the number being recorded increased and by 2006 I had started to record 100+ individual adults in a mornings visit, providing the weather conditions were ideal.

Figure 1 shows the maximum morning count of adult Adders for each of the years 2000 to 2009. The steady rise in the number of Adders being recorded was undoubtedly due to the increasing number of basking areas being found, from nineteen in 2000 to forty in 2009. The fall in 2005 was due to my inability to carry out full surveys in that year.

Figure 2 shows the mean count per basking area over the same period and is calculated by dividing the total number of adult Adders recorded by the number of basking areas. The dip in 2001 was due to access problems during the Foot and Mouth outbreak, that of 2005 as mentioned above.

Whereas Figure 1 shows a continuing rise in the number of adult Adders being recorded, Figure 2 shows a slight decline in the mean count per basking area from a peak in 2007. This fall-off in the mean count per basking area could be the result of one of several factors, or most likely a combination of them.

1. Although I try to keep the individual basking areas in reasonable condition (minor management over the winter period) the rapid growth of vegetation sometimes makes this impossible and they can quickly become unsuitable for use.

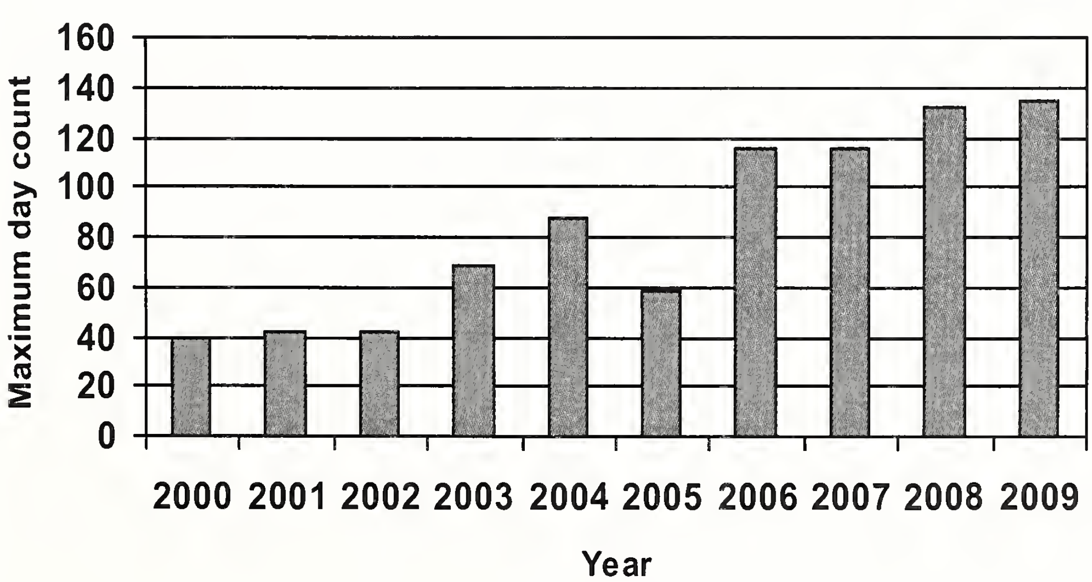

Figure 1. Maximum counts over time.

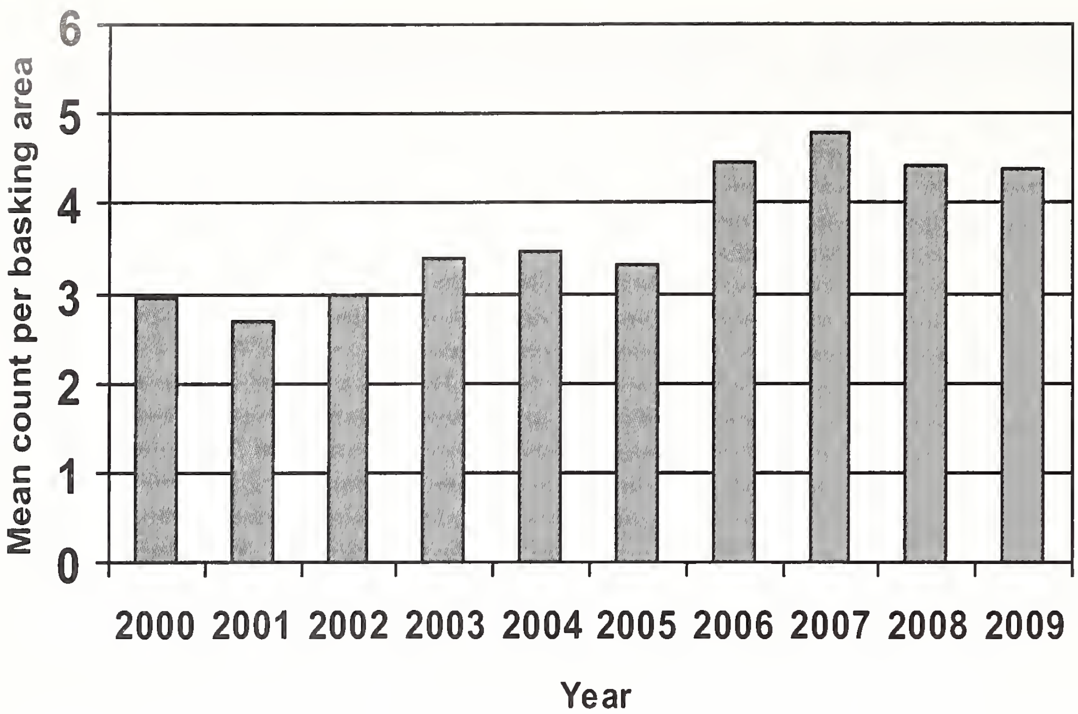

Figure 2. Mean counts over time.

2. Major management over the years has steadily opened up more of the Lowes, allowing easier access to more and more of the site, and this can lead to disturbance, especially by dog walkers. Dogs have a natural tendency to patrol along the 'hard' edges checking for signs of other dogs, and where management opens up new areas this means that dogs and Adders are utilising the same space. On many occasions I have given up counting when dogs have preceded me, as any counts have become meaningless.

3. In 2008 there were definite signs of persecution at several of the basking areas. On 10 April 2008 there was a lot of activity in one of the basking areas but on 11 April this area was deserted; I eventually found a single female with blood on it and assumed that the area had been 'thrashed'. I had a similar experience earlier the same year when a good sub-site was suddenly deserted and I found a length of chestnut paling close by. On another occasion I advised an elderly lady that her small dogs were about to blunder through a good basking area. She then picked up her dogs and went off muttering. The next day this very reliable area was deserted and remained so for the remainder of the season.

4. Management outside the hibernation period undoubtedly cause fatalities. On the Lowes it is not unusual for good numbers of Adders to be out from about mid-February onwards and yet major management, including forage-harvesting on the dry heathland, often does not start until after this date. I have occasionally come across Adders showing signs of having been hit by machinery. On 22 October 2009 I found a dead Adder that had obviously been killed by forage-harvesting the previous day; a few Adders were still basking at this time.

5. Fires, even minor ones, can have a devastating effect. Happily, the huge fires of the 1970s and 1980s have not been repeated in recent years, but large fires do still occur. For example, both the fires of April 2003 in the north-east of the Lowes, and of May 2004 near the Norwich Road, affected known basking areas, although by May the Adders should have dispersed.

One factor that is hard to quantify is breeding success. It is almost impossible to find newly born Adders due to the large swathes of Bracken *Pteridium aquilinum* that cover the majority of the basking areas during the summer months, and I rely on spotting juveniles basking in the following Spring (see photo opposite p.37). It may be the case that insufficient juveniles are reaching maturity to replace those adults that are being lost. The Bracken is also a problem in the autumn as this can prevent basking prior to re-entering hibernation. All of these factors can cause the number of adults in the various aggregations to fluctuate but the overall apparent decline is disturbing.

The winter of 2009-2010 saw the start of further extensive management. Large swathes of scrub were cut by hand from the wet areas, as well as the usual annual forage-harvesting on the dry heath. Significant clearance of birch woodland is scheduled to take place during the winter of 2010-2011. As already indicated, management is a very necessary tool in keeping basking areas open and there is a need to create new suitable sites to replace those that have become overgrown. To allow for any expansion of the Adder population it is also necessary to increase suitable habitat but it is essential not to lose sight of the need to protect hibernacula, retain hunting territories and ensure that some areas remain free from public pressure. I have passed details of my counts to the Holt Lowes Trustees and to the Norfolk Wildlife Trust, and great eforts will be made to protect hibernacula and basking areas in future management.

Holt Lowes is currently an excellent site for the Adder, indeed may well be one of the best in the country, and one can only hope that the following decade will prove equally successful, and that the careful observer will be able to continue to enjoy the spectacle of male Adders 'dancing' (see photographs opposite p.37), surely one of the highlights of watching wildlife in Norfolk.

B Dawson 15 Barrett Road, Holt, Norfolk, NR25 6EQ

Ferrissia wautieri (Mirolli), an alien limpet in Norfolk

Roy Baker & Derek Howlett

Ferrissia wautieri (Mirolli) is an alien species to the UK fauna. It is currently believed to be to be extending its distribution in the UK and this spread is, in all probability, a consequence of the activities of man, especially through the aquarium trade. Some authors argue that it is of North American origin but others point to North Africa as a more likely source.

Nomenclature

Anderson (2005) notes that the name applied to this taxon is contentious. In the European Clecom List (Falkner *et al.* 2001) it is considered to be synonymous with *Ferrissia clessiniana* (Jickeli); Anderson (2005) follows Glöer (2002), however, in naming it *Ferrissia wautieri* (Mirolli). In this report we have used Anderson's name.

Status

Ferrissian wautieri is listed as an alien species by Natural England.

Description

Ferrissia wautieri (Figure 1) is often difficult to detect because the shell is coated with algae and/or detritus. Even when a clean shell is discovered it remains inconspicuous because it is nearly transparent. It is often confused with the Lake Limpet *Acroloxus lacustris* (L.) (Figure 2), but can be distinguished by its flatter profile and, while *Acroloxus* has a sharp apex turned to the right when viewed from behind, *Ferrissia* has an apex reflected to the left. The apex is also flatter and possesses a large number of very fine radial ridges. Adult limpets attain a size range between 4 mm and 6 mm.

Ecology

Ferrissia wautieri inhabits shallow ponds, small ornamental lakes, canals and a large, slow-flowing river. It has been found several times in greenhouse tanks in botanic gardens (see below). The limpet attaches itself to firm surfaces (usually the leaves, stems and rhizomes of aquatic plants) in well-vegetated, stagnant or slowly moving water. Kerney (1999) noted that it is said to be tolerant of seasonal desiccation, but this has not been confirmed in the UK.

Figure 1 *Ferrissia wautieri* Great Ouse.

Figure 2 *Acroloxus lacustris* Great Ouse.

Current distribution

The first record for *Ferrissia wautieri* in mainland Europe came from central France

(Calas 1944) and this was soon followed by further discoveries in France, Italy, northern Germany, Austria, Czechland, Slovakia, Hungary, Romania and the former Yugoslavia (Wautier 1974). Mirolli (1960) described both the structure and ecology of the species in Italy. Some authors think that there may be more than one species of *Ferrissia* in Europe, but the current consensus is that a single species is involved.

In the UK *Ferrissia wautieri* was first recorded in hothouse tanks in the Royal Botanic Gardens in Glasgow in 1931 and subsequently in greenhouse tanks in botanic gardens in London (Kew) and Edinburgh. It was first detected in an open habitat by Brown (1977) in Hampshire and by David Holyoak (1978) from a small pool of stagnant water in an area of poor fen with a stream running through it in Sussex. Norris (1982) and Turk *et al.* (2001) recorded it from canals. In 2006 Geraldine Holyoak and Derek Howlett collected large specimens from water-lily leaves in an ornamental pond in Cornwall. The limpets were covered in debris and were numerous on the leaves.

Norfolk distribution 2008

Preece and Wilmot (1979) collected 'recently dead' shells from sediments in the middle of the River Great Ouse at Hilgay. The question arises as to whether or not these shells had been washed down from sites further upriver and as such are not truly a record for Norfolk.

The authors examined marginal river sediments and the leaves of aquatic plants from a number of sites on the Great Ouse and Little Ouse from June to late October 2008. Sediments were finely sieved and the samples examined under a microscope. Marginal vegetation was pulled out of the river and examined on site and in some cases also under a microscope in the laboratory.

The first record of the limpet came from sediments taken from just beyond the marginal vegetation at Brandon Creek on the River Little Ouse, and involved recently dead shells. Examination of the leaves of water-lilies and Branched Bur-reeds *Sparganium erectum* failed to discover living limpets. A planned detailed survey of the marginal vegetation in October of the Norfolk side of the river was aborted because the riparian owner had built extensive moorings stretching for over 1km along the bank. The Cambridge bank remains untouched so it is highly probable that the limpet survives there.

At the Brandon Bank in the hamlet of Little Ouse no evidence of *Ferrissia wautieri* was found.

Extensive collections along the River Great Ouse from June until October failed to discover either dead shells or living specimens until a revisit to a site below the junction with the Little Ouse in late October produced the first living limpets. These specimens were discovered attached to the rhizomes of bur-reed amongst the marginal vegetation. They were all juveniles less than 1mm in size. The numbers were small.

The water-lilies and bur-reed collected from the margins held numerous Lake Limpets and it was only when some of the material was examined later under the microscope that *Ferrissia wautieri* was discovered. The fact that the shells soon become covered in algae and/or debris makes them very difficult to see in the field. This is the first record of living material from Norfolk.

In the UK *Ferrissia wautieri* is considered to be under-recorded. This is likely to be the case in Norfolk where the construction of artificial garden ponds has been a feature of housing developments within the county over the last four decades. These ponds are normally planted with aquatics from garden centres and many of the plants have been imported from Europe. From a conservation viewpoint these garden ponds remain relatively self contained so the spread to other natural sites will be limited.

Acknowledgements

The authors would like to thank the Norfolk

Biodiversity Partnership for sponsoring this survey as part of a wider review of alien species in Norfolk and Mr Bertrand Lézé of the School of Environmental Sciences UEA for the SEM photographs.

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Dr R Baker 126 Pelican Way, Norwch Road, Tacolneston, Norfolk NR16 1AL

DJ Howlett 6 New Inn Hill, Rockland St. Mary, Norfk NR14 7HP

How far does a bee fly? Some observations of bumblebee dispersal in Norfolk

Nick Owens

The ability of bumblebees and other insects to disperse is crucial to their survival and this is increasingly the case as suitable habitats become fragmented. It can be difficult, however, to determine the ability of insects to move from place to place. It therefore seems worth recording some recent observations of queen bumblebees *Bombus* spp. moving along the Norfolk coast in spring and of male bumblebees dispersing later in the year.

Whilst looking for bumblebees on Blakeney Point on 6 April 2009, Richard Porter, Chris Wheeler and I noticed a movement of queen bumblebees along the beach. The first bees were noticed at 11.30 near the lifeboat station. Over the next hour and a half, at least eleven queens were observed moving eastwards in direct flight, usually within 1-2 m of the ground. The wind was blowing from the east-northeast at force 3-4 – in other words the bumblebees were flying into a gentle wind. Frankie Owens on Weybourne cliffs, about 10 km to the east, noted a similar movement of bumblebees at about the same time, all heading eastwards. The warden of Blakeney Point, Eddie Stubbings, later informed me that these movements continued most of the day on the Point, all in the same direction, and Chris Wheeler noted one bumblebee moving directly north and out to sea beyond binocular range on the same afternoon.

A check at Weybourne beach the following day (7 April) showed that bumblebees were continuing to move. All were queens except for one worker. Twelve bumblebees were observed passing along the beach in 45 minutes from 12.45. The wind was coming from the south-west at force 4. Two of the bumblebees moved eastwards, seven westwards, two south-westwards and one southwards.

These dispersing bumblebees were queens in all cases but one, presumably recently emerged from hibernation. It was not possible to identify all individuals, but at least five were *B. terrestris*, one was *B. lucorum* and one was *B. lapidarius*. It is not clear whether the movements described were confined to the coast or whether it was part of a more general bumblebee dispersal, with bumblebees meeting the beach and the being channelled along it. In either case, it appeared that queen bumblebees were dispersing some kilometres. Whilst watching bumblebee movements at Weybourne, I noticed one *B. terrestris* queen by the coastal path, buzzing close to the ground and landing to inspect possible nest sites. This suggests that a proportion of queens was dispersing while others were already searching for nest sites.

Dispersal by male bumblebees also appears to take place, as indicated by the appearance of males of various species a good distance from their known breeding sites. In August 2007, Ash Murray and Neil Lawton recorded three *B. monticola* males on Scolt Head Island, and the author found another on Kelling Heath in September 2009. The nearest known colony of this species is in Derbyshire, although it is possible that there are nearer populations. A single male of *B. muscorum* was recorded near Cley by David Richmond in July 2009 and by me at Weybourne in August 2009. The nearest extant colonies of *B. muscorum* are on Scolt Head Island, over 20 km to the west (although until recently there was a small colony a little nearer, at Stiffkey (Ash Murray, pers. comm.). Summer dispersal of females may also occur, but is difficult to detect. A female cuckoo bumblebee, probably *B. vestalis*, emerged from a host's nest in my garden and flew directly out over a cornfield for at least 1 km.

Bumblebee dispersal can also be quantified by the spread of *B. hypnorum*, which appeared in southern England in 2001. Presumably at least one queen managed the 32 km cross-channel flight, although it is possible that it had assistance. The first record for Norfolk was at Earlham Cemetery, Norwich, in 2008 (Paston 2008). In June 2009, *B. hypnorum* was recorded by Francis Farrow at Beeston Common (at least three individuals), and I found singles at Kelling Heath and Holkham Beach. The Kelling Heath individual was a worker with loaded pollen baskets, so was clearly from a nearby nest. These sightings suggest that *B. hypnorum* spread across Norfolk in the space of one or two years. Similarly, the cuckoo bumblebee, *B. rupestris*, was not recorded in Norfolk from 1963 until the 21st century (Richmond 2001). This species has been spreading from surviving populations in the south of England and is now appearing at various sites in Norfolk, mostly in the north of the county. In 2009 I counted over 20 males and one female on the flower-rich field margins on the Holkham Estate, again indicating that bumblebees can disperse and rapidly colonise new areas when conditions allow.

There is very little in the literature about the dispersal of bumblebees. Goulson (2003) emphasises the importance of bumblebee dispersal in reversing local extinctions and reducing inbreeding. He cites a Scandinavian study by Mikkola (1984) which reports bumblebee queens moving in streams along the coastline in spring, with up to 900 *B. lucorum* queens passing through a coastal strip 150 m wide in one hour. This appears to be the only previous reference to bumblebee movements on the coast, although clearly on a much larger scale than those described here. In a review of the possible reasons for such behaviour Vepsäläinen and Savolainen (2003) suggest that the movements are related to vole population cycles. When vole numbers are at a maximum there are few empty vole holes available for bumblebees to nest in. This triggers bumblebees to move away to distant areas where the vole cycle is in a different phase (i.e. to where there are fewer voles and more available bumblebee nesting sites).

It is possible that the movements seen in Norfolk in 2009 were unusual, perhaps related to vole cycles, high population levels, high numbers of inquilines (cuckoo bumblebees) or the deterioration of habitats. There is clearly more to be discovered about bumblebee movements and I would be very grateful to hear of any further observations of this kind.

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Dr N Owens 22 Springfield Close, Weybourne, Holt, Norfolk NR25 7TB

Brachyopa insensilis – an overlooked Norfolk hoverfly

Stuart Paston

The occurrence in Norfolk of the hoverfly *Brachyopa insensilis* Collin, predicted by Roger Morris of the National Hoverfly Recording Scheme (pers. comm.), was confirmed on 29 May 2009 when I took a male hovering in front of a sap-run on the trunk of a Horse-chestnut *Aesculus hippocastanum* on the south side of an avenue in Earlham Cemetery, TG 211089. The discovery was the outcome of a planned search, the cemetery, close to my home, being an obvious candidate to support a species that 'should occur wherever there are Horse-chestnuts with sap runs, including suburban parks and roadsides where this tree is frequently planted' (Stubbs & Falk 2002). *B. insensilis* is distinguished from the other UK *Brachyopa* species by the absence of a sensory pit on the inner surface of the third antennal segment and the identification was confirmed by Tony Irwin using Stubbs & Falk (2002).

The genus *Brachyopa* is represented by four species in the UK and the larvae are reliant on sap for their development. Assessment of the status of the respective species is hindered by the resemblance of the adults, with their grey thorax and orange abdomen, to certain anthomyiids and muscids, which means they are all too easily overlooked by hoverfly recorders. The orange abdomen shows up well when the flies are seen hovering in sunlight but this is not so apparent when the insect is at rest as it is obscured beneath the long wings. In order to address the problem of under-recording and to provide fieldcraft expertise to would-be recorders, Morris (2008) has published guidance on finding adult *Brachyopa*.

B. insensilis is not restricted to Horse-chestnut, having been recorded from other trees including elm species, Ash, lime species and Beech, but the known strong association with Horse-chestnut particularly helpful in aiding detection as my discovery in Earlham Cemetery makes clear. Further searches in the cemetery and elsewhere in south and west Norwich failed, however, to produce sightings, with no evidence of sap runs that would provide potential breeding sites.

The distribution as presented by data on the National Hoverfly Recording Scheme website (www.hoverfly.org.uk/portal.php) is of a very widespread species, with isolated records from the far north of Scotland, but one which is sporadic in occurrence over much of its range. The largest concentration of records is in the London area but more pertinent to its likely status throughout eastern England is a strong cluster of mostly recent records from Cambridgeshire and Lincolnshire; these highlight the value of focussed searching by experienced recorders. It is probable, therefore, that *B. insensilis* is found widely in Norfolk.

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S Paston 25 Connaught Road, Norwich NR2 3BP

The occurrence of *Chrysolina coerulens* (Scriba) (Carabidae: Chrysomelidae) in Norfolk

Bryan Sage

The discovery of this striking chrysomelid beetle in Norfolk has been recorded in detail elsewhere (Sage 2009), but, in view of the fact that it is not only new to Norfolk but also only the second record for Great Britain, it is important that the details are published in this journal.

The morning of 15 June 2008 was fine and sunny with a temperature of 25°C and a visit was made to Swanton Novers Great Wood, where the grassy rides at the southern end of the wood (TQ 0130) are floristically the richest (Sage 2008). In the course of sweeping the vegetation in ride 68 only a small number of beetles was found, but amongst them was a large metallic-blue chrysomelid with which I was not familiar. Later, on referring to Joy (1932), it keyed easily to the genus *Chrysolina* but did not really fit any of the species therein. At this point it became evident that it was a species not currently on the British list, so reference was made to Warchalowskii (2003). Here it eventually keyed through to Auxilary Group J of the genus *Chrysolina*, and then to *C. coerulens* or possibly a related species. The specimen was sent to Martin Collier for his opinion and, after examining photographs on various web sites, he concluded that it did seem close to *C. coerulens*. The beetle was then passed to the Natural History Museum in London where Max Barclay kindly determined it as *C. coerulens*. It is a species associated with mints (*Mentha* spp.), a genus of plants not represented in the habitat where the beetle was collected.

Although not listed in the main section of the latest British checklist (Duff 2008), it is included in the section on Non-established Introductions. The species is also mentioned in Cox (2007), and this refers to a live example found on bare soil on a traffic island beside the main A20 road out of Dover, Kent, by Peter Brash on 6 August 2003. This specimen is now in the Natural History Museum collection. It was considered to be a casual introduction which may have arrived on a motor vehicle from the continent. The distribution of this species extends from Central France, northern Germany and Poland to the Balkan Peninsula and eastwards into Central Asia (Warchalowskii 2003). Its appearance in an ancient woodland in Norfolk, about 14 kilometres south of the nearest point on the coast, is not easy to explain. Any form of human-aided transport is very improbable and the most likely explanation is that it was windblown. The relevant weather records show that during the two weeks preceding 15 June there were winds from the north-east on 2 June, from east-south-east on 4 June, the east on 5 June and again from the north-east on 9 June.

Acknowledgements

I am grateful to Martin Collier for his assistance, and to Max Barclay for his expert determination of the specimen.

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Dr B Sage Waveney House, Waveney Close, Wells-next-the-Sea, Norfolk NR23 1HU.

The fate of woodland plants: a critical look at the survival and travel of our woodland plants

Gillian Beckett

For all plants, the most critical factor in their survival and spread is efficient seed dispersal, germination and the successful development of seedlings. In this respect no plants are more limited than many of those which inhabit large areas of woodland. For trees the matter is simple; most either produce fruits which are light and winged, and thus easily transported by the wind – birches *Betula* spp., maples *Acer* spp. and Ash *Fraxinus excelsior* fall into this category – or they offer a lure to animals or birds to gather the fruits and carry them away from the parent tree, be it large fruits, as with Hazel *Corylus avellana* and oaks *Quercus* spp., or juicy fruits, such as Rowan *Sorbus aucuparia*. Of non-woody plants, some are climbers and these can then use the trees' methods; Honeysuckle *Lonicera periclymenum* has succulent fruits while those of Traveller's-joy *Clematis vitalba* are adapted to travel far in the wind. It is the herbaceous woodland plants that have the most serious problems, and they have overcome these in a number of ways.

Of all the ground plants, the most efficient in the work of spreading their seeds must be the orchids. With their millions of tiny seeds they have an almost limitless propensity for spreading, but on the down side need the right conditions to germinate and thrive, these include the presence of a particular soil fungus which helps the plant absorb nutrients from the soil. All orchids are erratic in their appearances and occasionally turn up in surprisingly isolated sites. A few years ago an Early Purple Orchid *Orchis mascula*, a true woodlander, was even noted growing on the side of a dike of a reclaimed wheat field near the southern shore of the Wash! A chance seed, but a plant certainly not destined to last long, though it had remarkably reached flowering size. No other woodland plant has quite such an ability to spread its seeds. Of the other herbaceous plants, some have hooked seeds, enabling them to hitch a lift on the coats of browsing animals, though remarkably few have this obvious adaptation. Of those that do, Enchanter's-nightshade *Circaea lutetiana* and Wood Avens (or Herb Bennet) *Geum urbanum* are by far the most successful, being found in many woods, old and new. The species which have the greatest problems are the low, ground dwelling plants which have no obvious means of dispersal, and can only rely on insects or a mechanical method to prevent their seeds from simply falling to the ground beneath the parent plant and being stifled out of existence. These plants can move only short distances at a time and have a very slow rate of dispersal. There are also a few plants which thrive best in the denser parts of a wood and are almost never seen away from a normally heavily shaded habitat; they are often at their best in coppiced woodlands, where light is present for the few years after cutting, allowing them to flower and fruit. This is the favoured habitat of Herb Paris *Paris quadrifolia*. In truly natural woods, plants must wait until the fall of a tree near their place of growth gives them the necessary light. Bluebells *Hyacinthoides non-scripta* remain dormant if conditions are not to their liking and a clump dug up (try this in a garden, not the wild) will always be found to have a number of bulbs which show no sign of growth. Wood Sorrel *Oxalis acetosella*, Lily-of-the-valley *Convallaria majalis*, Dog's

Mercury *Mercurialis perennis* and Ramsons *Allium ursinum* are rhizomatous perennials with strong underground growth. All can create large colonies, especially Ramsons, which can form immense colonies when not disturbed. At Castle Rising, one such area is found in an ancient wood just by a bend in the old road (now bypassed) which was known locally as Onion Corner. In the days when buses passed it regularly, no one was ever in any doubt how it got its name if the windows were left open!

Plants which are not adapted to be as long-lived as the deep rooted perennials tend to grow nearer the edges of woods and around clearings and rides. Here will be found Wood Anemone *Anemone nemorosa*, Primrose *Primula vulgaris*, Goldilocks Buttercup *Ranunculus auricomus*, Nettle-leaved Bellflower *Campanula trachelium* and other free-flowering species. These, whilst typical of old woodland, are able to spread happily into damp areas adjacent to woods. In the boulder clay region of south-east Norfolk many woodland plants can be found along ditches and even the edges of meadows where the longer vegetation of early summer gives them a little shade, for shade is the essential factor in their survival. This is why removal of hedges has so often caused their disappearance, not always because the plants themselves cannot stand being dry, but because their seedlings need moisture to become established and propagate themselves. Some plants have requirements we do not fully understand, an example being one of the rarest plants of coppice woods in Norfolk, the Crested Cow-wheat *Melampyrum cristatum*. At present it is occasionally to be found on the verge outside one wood in central Norfolk, having lost its original habitat in the 1960s when much of the wood was planted with conifers, a frequent fate of woodland in that period. In the 1800s it was recorded in woods at Gressenhall, Colkirk, Godwick, Testerton, Litcham and Horningtoft, and also Wayland Wood - all of these sites except the last are within fifteen miles of each other. Whether it grew at other sites in Norfolk we shall probably never know, but no other record has yet turned up in any Herbarium or in the literature and it seems as if it has been confined to this small area of central Norfolk for several centuries.

The long list of woods that can be compiled by trawling through early accounts of parishes has been seriously depleted throughout the last 500 years, often by the complete removal of the wood. In a number of areas, however, especially where the soil was rather acid and cultivation less profitable, the woodland was adapted to the be used for grazing cattle, the trees being pollarded, that is lopped above the browse line of cattle. In time the regularly pollarded trees developed heads made up of many spreading branches, giving large areas of shade. As the whole area reverted from wood to heath, these provided a refuge for any woodland species which had survived, notably those with a good underground reserve. Lily-of-the-valley, a successful survivor, is capable of thriving in surprisingly dry surroundings as long as it has shade. It still grows strongly under modern conifer plantations at Santon on the south Norfolk border, at Grimston and near Sandringham, and is also found in several old woods on the acid soils within 10 miles of the north coast from Swanton through to Felbrigg, all of which were associated with grazing. This combination of grazing and often pollarded trees is known as wood pasture. It is a habitat that is difficult to trace on old maps as it is rarely differentiated from any open land, but it is typical of ground at the edge of heaths and acid commons, often representing the remains of woodland where cutting had been badly managed or over grazing was permitted. Mousehold Heath is the county's best-known area; in the early Middle Ages it was productive woodland but was first turned into wood pasture and later became heathland as it lost its remaining trees. The main culprit was the growing population of Norwich with its demand for firing and grazing. In central Norfolk the large area of Stock Heath, which extended westwards from Holt for many miles, seems also to have had its stands of pollards, a fascinating row of which has survived at Thursford (although much of this part of the old heath is now conifer plantation).

Where soils were both dry and of a free draining nature, as in much of the higher parts of West Norfolk, the land was perfect for periodic cultivation and sheep grazing and suffered a serious loss of woodland in the Middle Ages. Few ancient woods survived in this area beyond about 1600 and close grazing by sheep proved to be a sure way of eliminating woodland plants. The only places left in sheep country for trees and their associated ground flora were within the villages themselves and under pollards and scrub on the commons. The main sheep-rearing areas extended southwards from north-west Norfolk to the Suffolk border, yet a glance at a map of plant distribution shows that this area is by no means lacking in woodland plants. How they came to be in isolated, planted woods needs a bit of thought: deliberate introduction is possible for attractive or useful plants or for those with herbal or culinary uses, but unlikely in the case of a plants which had no such value, and Dog's Mercury immediately comes to mind as an example. Its smallish seeds are ejected from the seed pod explosively but are not able to travel much more than a foot at a time and certainly not across open sheep-grazed terrain. The occurrence of this plant must indicate centuries of the presence of continuous shade in one form or another. In recent years it has become fashionable to doubt the validity of using this plant as an indicator species for any sort of old woodland, but it is difficult to imagine how it can ever have spread to completely new areas away from a source of seed if there was no shade available to form a corridor. Certainly it is not an indicator of ancient woodland in the sense of the boulder clay woods with which we are familiar, but where the land is dry and open it seems that it owes its existence to the presence of pollard trees. A remarkable example of the survival of Dog's Mercury in hedges on a relatively dry soil is at Great Massingham where it grew freely along hedgerows, including those of the Peddars Way. These mark the former boundaries of Harts Wood, which appears to have been largely cleared at the time of the dissolution of the local monastery. Recent clearance of the much of the hedge has sadly removed much of its interest.

A large number of the extensive commons of this same area survived until the Enclosures (mostly in the 18th and early 19th centuries), when they were ploughed and any remaining trees and scrub removed. In a few areas, however, especially on estates where pheasant shooting was becoming established as a fashionable sport, new plantations were quickly established to provide cover and safety for young birds, and some seem to have been sited to include a few of the remaining pollards, perhaps using them to give the necessary cover before the new wood grew to maturity. This seems likely to be the explanation for the surviving patches of woodland plants and occasional ancient pollards that occur in what appears otherwise to have been heath or grazing land. The former lands of the Houghton Estate in the north-west of the county took in most of what had been Bircham Heath: some of the plantations have good colonies of Dog's Mercury, together with Wood Sorrel, Barren Strawberry *Potentilla sterilis* and, in one case, Bluebells, while others have little other than brambles and nettles. The ones with botanical interest were largely planted on former common land. The same probably also happened on Grimston Common, where at least one 19th century plantation has a large pollard oak on its edge together with an undergrowth of Dog's Mercury and good dark Red Campion *Silene dioica*; neither plant occurs again within a radius of several miles. It is worth making a note of pollards in this sort of isolated site and checking for any woodland survivors, especially when they are on dry soils. Where commons have survived into the 21st century, trees, including pollards, can often still be found near their boundaries and again it is worthwhile looking at the ground flora for woodland survivors. At Swannington Common, Dog's Mercury and Wood Sorrel are among the plants which can be found in such a site, but here damp ground has helped them. The pollards mentioned as being associated with the former Stock Heath at Thursford also have Dog's Mercury and Wood Sorrel beneath them.

Dog's Mercury may not be an indicator of ancient woodland, but I am quite confident that it can identify centuries of continuous shade and so has its uses in discovering past land uses. Plants and their distribution still have much to tell us.

G Beckett Bramley Cottage, Stanhoe, King's Lynn, Norfolk PE31 8QF

A review of some new discoveries and recent trends in the Norfolk flora 1999-2008

Bob Ellis

It is exceedingly rare (by definition, I suppose) that new native species are discovered in a county such as Norfolk that has been well botanised for over two centuries, other than apomictic microspecies of brambles *Rubus* and dandelions *Taraxacum*. In recent years there have, however, been four discoveries that might make that claim.

Laurie Hall found Leafy Rush *Juncus foliosus* in Felthorpe in 1999 (confirmed by Dr TA Cope). It has subsequently been found at Swanton Novers, at Dersingham and in a second tetrad in Felthorpe. It was, however, only separated from Toad Rush *Juncus bufonius* as recently as 1959, initially as a subspecies but then as a full species from 1978. Thus, although it would appear to be predominantly a western species in the British Isles, it is quite possible that it is native to Norfolk. A search of herbarium specimens labelled '*Juncus bufonius*' might just possibly reveal an earlier occurrence.

Again it was Laurie who discovered Smooth-stalked Sedge *Carex laevigata* in 2002, also at Felthorpe, followed by a second colony in 2007. This is another plant with a predominantly western distribution. Both colonies have a number of plants with a range of ages and have presumably been there for some time. They occur in an area of forestry, however, and so might have been brought in with tree stock from another part of the country.

In 2003 Paul Stanley deliberately searched for, and discovered, Early Meadow-grass *Poa infirma* in Great Yarmouth and Cromer. It is considered to be native in south-west England, but may be naturally extending its range or may just have been here all along, just waiting to be found. Few botanists are out hunting small grasses in February, which is the best time of year to search for it, and it is usually dried up and gone by May.

In 2008, Colin Dunster and the Flora Group found a single plant of Rock Samphire *Crithmum maritimum* at Scratby on the east coast. There is an old record from nearby in Nicholson's 1914 Flora: 'Said to have been found at Hemsby in 1781 by L Wigg (P.)'. The 'P.' refers to Sir James Paget, but it is not clear why doubt was attached to the record. Small colonies have long been known from the Suffolk coast and it is unlikely the 2008 Norfolk specimen arrived other than by natural means. Maybe this is a new native species for the county, or the re-appearance of one discovered in the 18th century, or perhaps just an accidental arrival that will not persist for very long.

The re-appearance or rediscovery of native species in the county as a whole is almost as rare as the discovery of a new species but there has been one recent instance. (*The Vice-County Census Catalogue of Vascular Plants* (2003) distinguishes between species recorded before and after 1970, and that year is used as the basis for this brief report.) In July 2008, Mike Crewe found Mudwort *Limosella aquatica* in a recently re-excavated pond on Beeston Regis common. It had not been seen in the county since at least 1914, when Nicholson's Flora was published.

Taking the two vice-counties separately there have been five more re-discoveries. Thin-spiked Wood-sedge *Carex strigosa*, well known from Foxley Wood in East Norfolk, was discovered in West Norfolk at Wood Rising by Chris Roberts in 2007. Prior to this the most recent record for the vice-county was by the Rev. Kirby Trimmer (i.e. before 1866) 'In a bushy ditch by the road leading from East Dereham to Yaxham'. In 2008, Slender Club-rush I*solepis cernua* was found literally just a couple of hundred metres into West Norfolk at Mattishall Moor during an October bryological excursion. Petch and Swann (1968) cite records from Scarning Fen in 1915 and from Potter's Fen some time before 1968.

For East Norfolk, Petch and Swann listed four records of Wall Bedstraw *Galium parisiense*, the most recent being in 1957. In 2001 Ken and Gillian Beckett reported it growing on a wall at Kenninghall churchyard (note that the East Norfolk dot on the map in the last Flora is thought to be an error). In 2005 Greater Broomrape *Orobanche rapum-genistae* was discovered at Mundesley in East Norfolk and reported in Natterjack by Mike Crewe. This is the first time it has been seen in the vice-county since the 19th century. Nicholson (1914) listed nine localities in East Norfolk, the first being attributed to Sir JE Smith at Thorpe in 1778. In May 2007 a few plants of Lemon-scented Fern *Oreopteris limbosperma* were discovered at Westwick. Petch and Swann (1968) list two rather mysterious 'Maps Scheme records' (i.e. records for the 1962 Atlas of the British Flora), further to the south-east, in TM49 and TG40.

Hybrids are much more likely to be added to the county list – they are far harder to spot and most of them need critical determination, so they are usually under-recorded. Furthermore, short-lived sterile hybrids are inevitably ephemeral. Some hybrids, however, are long-lived and some spread vegetatively, and these are worth a brief mention here. Of particular note, and new to West Norfolk, is *Carex ×rotae* (*C. appropinquata × paniculata*), designated as Vulnerable in the latest Red Data List (2005). This was found in two places at Sculthorpe Moor in 2008 and confirmed by Mr M Porter.

The hybrid horsetail *Equisetum ×rothmaleri* (*E. arvense × palustre*) was recorded for the first time in the county on slumped cliffs at Overstrand in 2003. Identification was confirmed by Dr CN Page. The hybrid Shore Horsetail *Equisetum ×litorale* (*E. arvense × fluviatile*) was confirmed by Dr H McCaffie from a collection made at Wheatfen, Surlingham, by Clive Jermy in 2008. It has subsequently been found at three other sites in East Norfolk; Swannington Upgate Common, Strumpshaw Fen and Roydon Fen. Though it appears to be new to East Norfolk, there are a couple of earlier records in West Norfolk, from Blo Norton Fen and Cranberry Rough (both 1938). This hybrid is almost certainly under-recorded and is worth looking out for in similar fen habitats.

Rosa ×pseudorusticana (*R. arvensis × stylosa*) is a hybrid rose new to Norfolk. It was found at Sustead in 2006 by Bob Leaney and confirmed by Mr R Maskew. Another is a rediscovery: *Rosa ×scabriuscula* (*Rosa canina × tomentosa*) was found at Felthorpe in 2007 by Laurie Hall and also confirmed by Mr R Maskew. It was previously recorded as *Rosa tomentosa* var. *scabriuscula* by Rev. EF Linton (1848-1928) at Rackheath and Ellingham.

Non-native species fall into a number of categories ranging from short-lived annuals that have appeared in pavement cracks below hanging baskets, through garden throw-outs that may survive for a few years or in some cases become well established, to deliberate introductions including planted trees and shrubs. Furthermore, it is also often difficult to decide if a particular occurrence falls into the rather vague concept of 'in the wild'. Whether or not to include a record in the county list is, therefore, often moot. Since 1998 there have been well over a hundred non-native vascular plants that might be considered for addition to such a list – far too many to include here. It is, however, perhaps worth exploring a few themes and taking a look at some species that seem to be spreading. In the following paragraphs, figures in square brackets refer to the number of additional tetrads since the 1999 Flora and the % figure to the number of new tetrads since 1999 as a proportion of the 1987-2008 total. Although more than 160,000 records have been added to the database since 1998, recent recording activity has not aspired to systematic coverage of the county so the figures can only be used as an indication of recent changes, not a scientific measure of change.

The casual weed Niger *Guizotia abyssinica* used to be recorded on rubbish tips in the 1960s and 1970s when there was something of a vogue for botanising on tips (and it was still possible to do so). There were no records in the last Flora but it has now been reported from eight tetrads and no doubt there have been many more occurrences in gardens under bird-feeders. Presumably from the same source, occurrences of Ragweed *Ambrosia artemisiifolia* seem to have increased [7, 54%]. Another species that turns up near bird-feeders that used to be recorded on tips is the grass Cockspur *Echinochloa crus-galli* [57, 77%], and this is also a contaminant of game-cover crops, especially maize and sorghum. Yellow Bristle-grass *Setaria pumila* [20, 57%] is also a game-cover contaminant and can become a remarkably persistent weed. Of the other bristle-grasses recorded in the county, Green Bristle-grass *Setaria viridis* [15, 58%] is encountered less frequently and Rough Bristle-grass *S. verticillata*, recorded three times from rubbish tips in Petch and Swann (1968), is a recent rediscovery by Robin Stevenson in King's Lynn in 2006.

Whilst we are out in the arable fields, the last ten years has seen an escalation in the use 'wildlife mixes', pollen-and-nectar mixes and the like under countryside stewardship schemes and other environmental initiatives, and there is also an ever-wider variety of game-cover crops in use. This has led to an increase in the number of records of several other species such as Phacelia *Phacelia tanacetifolia* [18, 69%]. Many new records of Ribbed Melilot *Melilotus officinalis* (known as 'yellow sweet clover' in the agricultural world), Lucerne *Medicago sativa*, Chicory *Cichorium intybus* and White Mustard *Sinapis alba* probably also originate from such mixes, either from spillage or as volunteers the following year. Also under stewardship, some grass margins and reversions are 'enhanced' with broad-leaved plants, particularly Ox-eye Daisy *Leucanthemum vulgare*, but also with clovers, including Alsike Clover *Trifolium hybridum* and Hop Trefoil *Trifolium campestre*, Black Medick *Medicago lupulina*, Bird's-foot Trefoil *Lotus corniculatus* and Salad Burnet *Sanguisorba minor*. The last two are usually the cultivated versions, namely *Lotus corniculatus* var. *sativus* and *Sanguisorba minor* subspecies *muricata*.

Saltmarsh plants continue to spread inland on our roadsides: Danish Scurvy-grass *Cochlearia danica* [178, 52%]; Lesser Sea-spurrey *Spergularia marina* [42, 19%]; Reflexed Saltmarsh-grass *Puccinellia distans* [42, 11%]; Grass-leaved Orache *Atriplex littoralis* [45, 8%]; Hard-grass *Parapholis strigosa* [10, 23%] and Sea Fern-grass *Catapodium marinum* [16, 36%], the last of which now has records as far inland as Norwich and Beetley. These have been joined by Sea Wormwood *Seriphidium maritimum*, seen on the A11 at Hethersett by Bob Leaney and Mary Ghullam in 2008 and at Wymondham by Bill and Carol Hawkins. Just one clump was recorded during the survey for the last Flora, by Alec Bull on the side of the A47 at East Tuddenham.

In our rivers, streams, ponds and ditches, aquatic non-native species are still spreading and many are generally considered to be undesirable. Least Duckweed *Lemna minuta* [74, 40%], New Zealand Pigmyweed *Crassula helmsii* [20, 40%], Parrot's Feather *Myriophyllum aquaticum* [12, 80%] and Nuttall's Waterweed *Elodea nuttallii* [20, 24%] still appear to be expanding their ranges. Those that have been with us a little longer, perhaps less so: Canadian Pondweed *Elodea canadensis* [13, 5%] and Water Fern *Azolla filiculoides* [6, 11%]. There are three newcomers. Floating Pennywort *Hydrocotyle ranunculoides* has been reported from five tetrads since 2003, though there are probably more. It is potentially very invasive. One plant of American

Skunk-cabbage *Lysichiton americanus* was seen by Mary Ghullam on the bank of the River Bure near Blickling in 2008 and Water-lettuce *Pistia stratiotes* was seen in King's Lynn by Robin Stevenson in 2007. However, Water-lettuce is not frost-hardy and is unlikely to persist (yet).

Some species, usually those of disturbed ground, are rapidly becoming a familiar part of our flora. They often start off in our ports or come in along the railway lines and then slowly establish before their proliferation accelerates. Lesser Swine-cress *Coronopus didymus* is a good example. Nicholson reported two localities, Great Yarmouth and King's Lynn, both in the 19th century. Petch and Swann described it as uncommon in 1968 and cited thirteen records. By the time of the latest Flora it was recorded in 460 tetrads and in the last ten years that has increased to 580 – so there is no real sign of it slowing down. Guernsey Fleabane *Conyza sumatrensis* was just beginning to appear during the last Flora – three tetrads – two in King's Lynn (the first in 1993), then one in Great Yarmouth. It has now been reported in 33 tetrads spread across all but the most central parts of the county. Two recent additions may well follow the same pattern of colonisation. Another fleabane, Bilbao Fleabane *Conyza bilbaoana*, new to the county, was found outside factory gates at Wicklewood in 2007 and recently also in central Norwich. Narrow-leaved Ragwort *Senecio inaequidens* was reported from Great Yarmouth by Graham Peck soon after the last Flora was published. It is now well-established there and has been found in small quantities in three more tetrads.

Some well-established garden relics and throw-outs are still spreading. Winter Heliotrope *Petasites fragrans* [32, 11%] is beginning to appear on roadside verges well away from habitation, possibly spread as fragments by grass-cutting. Where it is established it is forming some very large colonies indeed. Others species of this ilk include the creeping garden comfreys *Symphytum grandiflorum* [13, 59%] and *Symphytum* 'Hidcote Blue' [16, 84%], the variegated garden form of Yellow Archangel *Lamiastrum galeobdolon* subsp. *argentatum* [72, 28%] and Yellow-flowered Strawberry *Duchesnia indica* [14, 74%].

Finally, while on the subject of garden 'escapes', the discovery of a new hybrid plant most certainly deserves to be mentioned. 'Norfolk Comfrey', *Symphytum ×norvicense* RM Leaney & CL O'Reilly, has recently been named and a description published. The putative parents are *S. asperum* and *S. orientale* and it probably arose from a horticultural selection. Bob Leaney first found it at Intwood in 1999 and it has since been recorded from four other tetrads, the largest colony occurring at Sustead.

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RW Ellis 11 Havelock Road., Norwich NR2 3HQ

Weather Report 2008

Norman Brooks

Observations were made with approved Meteorological Office instrumentation, and in accordance with standard Metereological Office practice, at Old Costessey, Norfolk. Monthly figures are presented in Table 1.

Monthly accounts

January 2008 An extraordinarily mild month, with a mean temperature nearly 3°C above normal. Much of the month was dominated by a succession of depressions sweeping off the Atlantic with the maritime influence providing unusual warmth, a small range of temperatures and above average rainfall. The first January in my records (which commenced in 1954) devoid of a single air frost. A few flakes of snow fell on 3 January.

February 2008 Another mild month, with the average daytime maxima over 4°C above normal and the night-time minima nearly 1°C below average. No fewer than 26 days were warmer than average. The coldest day, with a maximum of 5.9°C, compares with the reading of 4.3°C that was the highest temperature recorded throughout the very cold February of 1986. Norwich was the sunniest locality in the British Isles with a sunshine total of 156 hours. Slight snowfall on 1 February.

Many localities in Norfolk were shaken just before 01.00 hrs on 27 February by earth tremors emanating from an earthquake centred near Market Rasen in Lincolnshire. Apart from some broken crockery and pictures displaced on walls there was little damage reported. The low rumbling sound that accompanied the tremors was of great interest.

March 2008 Very wet, with near-average temperatures (although it is noteworthy that the month's mean temperature was lower than January 2008). The first fortnight was mild, allowing the soil temperature

Table 1 Monthly summaries for 2008

Month	Total rainfall (mm)	Percentage of mean rainfall	Days air frost	Days ground frost	Monthly mean temperature (°C)	Deviation from mean (°C)
January	91.8	158%	0	11	6.9	+ 2.9
February	28.9	67%	15	20	5.6	+ 1.8
March	103.3	215%	6	14	6.5	+ 0.6
April	56.9	116%	5	16	8.7	+ 1.1
May	60.3	133%	0	4	13.3	+ 2.0
June	55.4	104%	0	0	15.1	+ 0.7
July	50.8	90%	0	0	17.6	+ 1.0
August	111.5	218%	0	0	17.5	+ 1.5
September	72.4	133%	0	0	13.9	- 0.4
October	79.2	137%	3	8	9.7	- 1.3
November	105.3	166%	5	9	7.1	+ 0.4
December	38.8	64%	14	22	3.5	- 1.3

to pass the threshold when spring growth can resume in earnest. A suden change on 16 March brought air of Arctic origin over our region and the first snowfalls since the winter of 2006-2007. Snow fell on seven days and lay from 23-25 March, with an accumulated total of 9 cm. The close of the month witnessed a remarkable recovery in temperatures, the maximum on 31 March being 16.6°C.

April 2008 Slightly warmer and wetter than average. A typical spring month, with slight snow on three days and ground frosts on 16 nights, causing the usual rise in temperature to be slowed, but with sudden warmth in the final week. The maximum of 22°C on 26 April was notable.

On 17 and 18 April an easterly wind wafted over our region the honest smell of pig manure recently spread over north German farmland.

May 2008 Warm and wet – this combination allowed the 'spring flush' to be particularly luxuriant by the month's close. Together with May 1992 it was the warmest May in central England since 1848. Air frosts were absent and thunder was noted on three days, with a brief hailstorm on 1 May. The maximum of 27.7°C on 10 May was notable.

June 2008 Although the average temperature was slightly above normal, it was the coolest June since 1999. A cool period mid-month, caused by northerly winds from the Arctic, made central heating necessary and gardeners had a narrow escape on the night of 16 June when the ground temperature just managed to remain above freezing. There was a total absence of thunder, but on 22 June gale-force winds caused some damage to crops.

July 2008 Mediocre weather until the final week of the month when a surge of warmth allowed the maximum on 27 July to reach 29.9°C. Very slight thunder was heard on three days, continuing the trend of recent summers to be reasonably free of significant thunderstorms. In the 1950s and 1960s summer storms could be expected on about a dozen days each season, but a sharp decline since 1990 has reduced the average to below six.

August 2008 The warmest August since 2004, largely due to the preponderance of warm nights. Rain fell on 20 days, yielding a total of 111.5 mm. A localised rainfall deposited 43.2 mm in less than three hours on 12 August at Old Costessey. Considerable erosion was evident on exposed sloping ground, one fresh gully being 35 cm deep. The most sunless August since the terrible August of 1912. A minor tornado caused slight damage at Wortwell, Mendham and Honersfield (all south-west of Bungay) on 12 August.

September 2008 The coolest and dullest September since 2001, with no significantly colder September since 1993. Only five days had a maximum temperature in excess of 21°C; on 11 September the maximum of 23.7°C at Buxton was the highest temperature recorded in the British Isles throughout the month. Slight thunder heard on two days.

October 2008 Quiet and sunny with a plunge of Arctic air at the close of the month. Norfolk escaped the most widespread and severe October snowfall event to afflict southern England since 1880, with 7 cm of lying snow at Whipsnade on 28 October.

November 2008 A dull and wet month, the preponderance of cloudy nights allowed the mean temperature to be slightly above normal. There was a total absence of gales and serious fogs. A widespread snowfall on 22 and 23 November gave accumulations of lying snow in excess of 7 cm to the west of Norwich, the most significant November snowfall since 1969. Even coastal locations such as Sheringham reported depths in excess of 4 cm.

December 2008 The coldest December since 2001, with an excess of sunshine. Frequent, but not severe, frosts, and a total absence of gales. Slight snow was observed on five days, but there was below average rainfall.

Annual summary 2008

Total rainfall	854.7 mm 132% of mean
Wettest day	4 October, 31.3 mm
Days with rain recorded	200
Days with sleet or snow	20
Days with snow lying	7
Highest maximum temperature	29.9°C 27 July
Lowest maximum temperature	2.3°C 30 December
Highest minimum temperature	16.6°C 6 August
Lowest minimum temperature	-7.5°C 17 February
Lowest grass minimum temperature	-9.6°C 17 February
Air frosts	48
Ground frosts	104
Days with gales	1 12 March
Days with thunder	17
Longest period with no measurable rain	11 days (3-14 May inclusive)
Days with hail	12
Days with fog (09.00 hrs)	14
Mean cloud cover at 09.00 hrs	63%
Wind direction at 09.00 hrs (days):	
North	9
North-east	30
East	24
South-east	28
South	17
South-west	71
West	75
North-west	50
Calm	62
Annual mean maximum temp.	14.6°C
Annual mean minimum temp.	6.3°C
Annual mean temperature	10.5°C

NWK Brooks 1 The Croft, Old Costessey, Norwich NR8 5PT

Wildlife Report 2008

Butterflies

Andy Brazil

2008 was a much better year for butterflies than 2007 and there was also a welcome increase in records: 13,618 covering 500 tetrads from 135 recorders. My thanks to them all.

The most noticeable issue arising from the data is the decline in Dingy and Grizzled Skippers. These are now the most endangered species in Norfolk, with Dingy recorded from just two sites (Narborough Railway Line and Foulden Common) and Grizzled from six (Narborough Railway Line, Foulden Common, Middle Harling Heath, Adcocks Heath, Northwood and Wretton). It is sobering to reflect that the Victorians considered these species to be 'uncommon but widespread'.

Species Accounts

Note that whenever a figure or date is given, the 2007 equivalent is given in parentheses.

Brown Argus Recorded from only 24 tetrads (49) - a decline mirrored in other counties this year. Earliest 10 May, last seen 14 September (18 April, 4 October).

Chalkhill Blue Seen again at Warham Camp this year, with a maximum of ten insects seen at any one time in the period 1-4 August by five separate observers. No further sightings were received, although at least one recorder was there on 11 August. The source of this illegal introduction remains a mystery.

White Admiral Recorded from 44 tetrads (26), a significant increase. First seen on 22 June, the first brood finished on 5 August. Sightings from the second brood totalled eight, a strong showing, and all were at Holkham. The first was on 18 September and the season would have finished on 8 October but for the remarkable find of a grounded, but still alive, individual on 18 October. This is believed to be the latest live sighting ever recorded in the UK.

Dark Green Fritillary Recorded from 12 tetrads (13) with an early first sighting on 16 June and very early last record on 11 August (20 June, 31 August). This species seems to have shifted its flight season forward in the year compared to historical data – the earliest date recorded in the 1980s was 11 July. Two separate reports from Holt Lowes, both on the 23 July, were the first there since 1997 and the only inland sightings this year.

Grayling Recorded from 29 tetrads (28) Sculthorpe Airfield produced good numbers (over 200 estimated across the whole site), and there were two records from the Brecks (Cranwich and Harling heaths), the first since 2006.

Migration

There was an influx of Small Tortoiseshells (as detailed below), but Painted Lady was relatively scarce (as were Silver-Y and Hummingbird Hawkmoth) and numbers of other migrant butterflies were exceptionally poor.

Small Tortoiseshell A significant migration of Small Tortoiseshells occurred in late August and early September. For much of the year reports of this species had, for the most part, involved one to three individuals, with highest count being ten from Upton Fen. Then on 28 August some 15 were observed on the beach at Caistor, and 'D' (i.e. 30-99 individuals) estimated at Ludham. The next day 63 were seen at the coast near King's Lynn, 15 at Scolt Head and 105 along the River Bure behind Caistor, while similar reports arrived from Suffolk coastal locations. The next day, 30 August, nearly 200 were along the Bure while 18 were at Ditchingham and 13 at Upton; on the 31 there were over 250 along Breydon Water south wall. Then, on 13 September the Norfolk Flora Group reported 'thousands' on Sea Aster at Terrington St Clement. Coastal numbers slowly decreased over the next few days but there were elevated counts from gardens across Norfolk throughout September, with the peak coming later in the month the further the garden was from the coast. It is clear that a significant number of insects migrated into Norfolk - several thousands at least.

Clouded Yellow Only three records were received from just two locations – Marsham and Middleton, all between 30 July and 2 August (25 from 18 tetrads in 2007).

Camberwell Beauty Just five records this year (17). Two in March, at Sutton Fen on 14 and Hoveton Hall on 29, both likely to have over-wintered. In the autumn singles at Yarmouth Cemetery on 14 September, Salthouse on 25 September and Upton Fen in 'early October'.

Red Admiral 56 in Yarmouth cemetery on 16 September, perhaps indicating reverse migration back to the continent.

Peacock A remarkable record of over 70 Peacocks found hibernating in a pillbox near Salthouse on 25 August.

A Brazil 68 Albany Road, Great Yarmouth, NR31 0EE

Dragonflies

Pam Taylor

2008 was a relatively uneventful year for dragonflies. The weather was highly variable, but often wet, and although species diversity seemed unaffected, abundance levels appeared to be down on recent years. On a more positive note, some species continued to spread, colonising new sites, while others consolidated their position in relatively new colonies.

Small Red Damselfly *Ceriagrion tenellum*. Hanging on by its claw tips in the county, but again seen on several occasions in its only Norfolk location at Scarning Fen, Dereham.

Black Darter *Sympetrum danae*. Recorded in good numbers from four sites in West Norfolk, which is one more site than in the past. Established sites are Dersingham Bog, Roydon Common and Grimston Warren. The new site is within the same general area of West Norfolk and up to 20 individuals were on the wing in 2008, following ovipositing observed there in 2007.

Keeled Skimmer *Orthetrum coerulescens*. This species had another successful season at its two well-established colonies at Holt Lowes and Buxton Heath. There are signs that it is now spreading to two further sites. At Dersingham Bog singletons were seen in 2004 and several times in 2007, then in 2008 a pair, plus two other males, were observed by Stuart Spalding on 24 July. At Beeston Regis Common the sighting of one male in 2002 has been followed by low numbers each year from 2006 to 2008. Sadly there were no 2008 records from the Roydon Common-Grimston Warren complex, so it appears the wanderers in that area have failed to establish themselves.

Downy Emerald *Cordulia aenea*. This species is currently confined to one breeding site in Norfolk, but wanderers were seen at two separate locations in the Broads during 2008. Two were observed on a fen beside the River Ant on 28 May and a single specimen was at Sutton Fen on 31 May; both sightings being supported by photographic evidence.

Banded Demoiselle *Calopteryx splendens*. This species continued to be recorded from an ever wider range of sites and certainly appears to be increasing its range.

Norfolk Hawker *Aeshna isosceles*. This species had a good season throughout its Broadland range and should be boosted in the future by Norfolk Wildlife Trust's purchase of more land at Upton Marshes. This new land holding is at one of the species main breeding sites and will extend the area of grazing marsh under suitable management.

Migrants

Wandering dragonflies from further afield were in short supply, and there were no records at all of Yellow-winged Darter *Sympetrum flaveolum* or Southern Migrant Hawker *Aeshna affinis*.

Lesser Emperor *Anax parthenope*. A single 2008 record from Lound Waterworks close to the Suffolk border on 22 June. The species was first seen here in 2003 and was reported several times in 2007.

Red-veined Darter *Sympetrum fonscolombii*. There were just two records in 2008. One was seen at Scolt Head Island NNR on 1 July and one at Belton Common on 6 August.

During 2008 there was a significant addition to the Norfolk list which took the county total to 35 species. Six male and a few female Scarce Blue-tailed Damselfly *Ischnura pumilio* were found in West Norfolk on 6 August. This sighting was followed by further observations at the same site later in the month, when up to eight individuals were seen, but there were no records after that time.

Recording

Recording continues for both a new national atlas, due for publication in 2013, and for a revised Norfolk atlas. If you have any dragonfly records please send them to me as County Recorder (BDSPamTaylor@dragonflysoc.org.uk). We are currently targeting under-recorded areas and I can supply details of these on request.

Dr P Taylor Decoy Farm, Decoy Rd., Potter Heigham, Norfolk NR29 5LX

Wildlife Report 2008

Orthoptera

David Richmond

A cold year with a wet summer provided poor conditions for orthoptera recording in 2008. With summer temperatures generally less than 20ºC, the author did not undertake many searches for Roesel's Bush-cricket to check for its spread in remote parts of the county; instead he concentrated on Long-winged Conehead, the county's other new-comer, which, in his experience, stridulates more reliably at lower temperatures.

Figure 1 shows the distribution of new 10km square records in 2008.

Updated distribution maps for all species can be viewed under the 'species guides' section of the Society's website (www.nnns.org.uk)

Oak Bush-cricket *Meconema thalassinum*
A female beaten from an oak tree at Pygney's Wood, North Walsham TG 23 was a new 10km square for this under-reported species.

Dark Bush-cricket *Pholidoptera griseoaptera*
Two tantalising records from the extreme

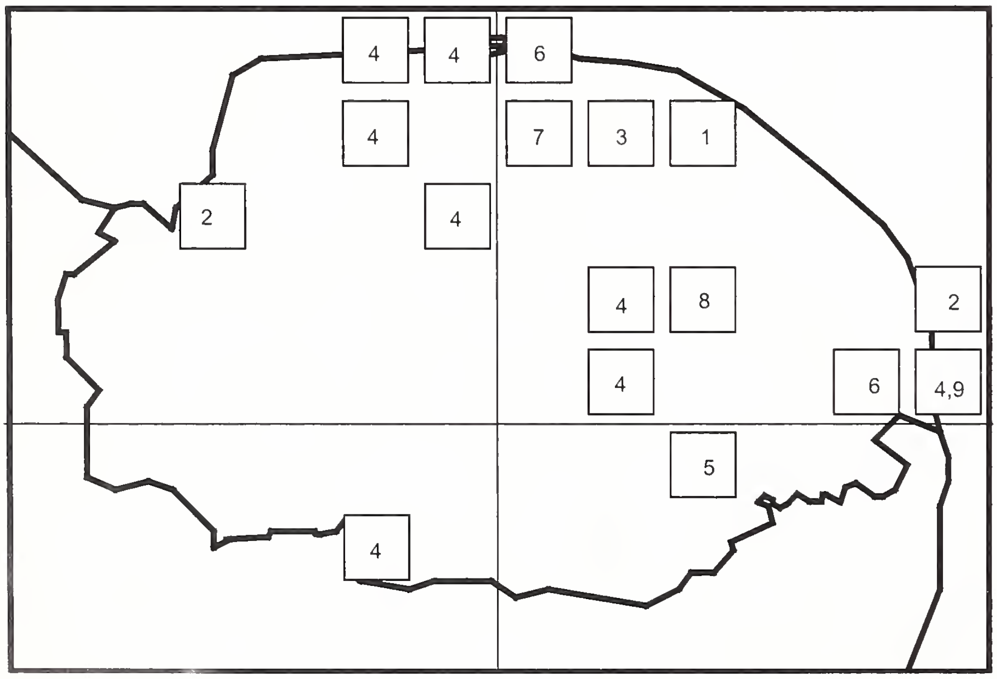

Figure 1 New 10km square records in 2008.

1 Oak Bush-cricket
2 Dark Bush-cricket
3 Roesel's Bush-cricket
4 Long-winged Conehead
5 Short-winged Conehead
6 Meadow Grasshopper
7 Lesser Marsh Grasshopper
8 Stripe-winged Grasshopper
9 Mottled Grasshopper

west and east of the county added to our limited knowledge of this species outside of its stronghold in the 'ancient countryside' of central and south Norfolk: Karl Charters reported it from Lynn Point TF 62 and Ken Saul had a specimen brought to him from West Caister TG 51 – both new 10km squares.

Roesel's Bush-cricket *Metrioptera roeselii*
The only new 10km square record was from Matlaske TG 13, though it was reported from eighteen other new tetrads within its established range.

Long-winged Conehead *Conocephalus discolor*
This was reported from thirty new tetrads, including eight new 10km square records (see Figure 1). It seems that this species has become widespread across the county in less than ten years, with most of the expansion being since 2003. The remaining gaps in the 10km square distribution must surely reflect lack of recording effort rather then the species absence.

Short-winged Conehead *Conocephalus dorsalis*
G Edgar sent a sound recording of this species distinctive stridulation from Shotesham Common TM 29, a new 10km square record. The author found it in four new tetrads along the River Bure in the Buxton area, and from Marston and Eaton Marshes alongside the River Wensum on the west side of Norwich.

Meadow Grasshopper *Chorthippus parallelus*
There were two new 10km square records for this species. Tim Gardiner reported it from Fritton TG 40, and John Widgery (former national recorder) found it at Glandford TG 04.

Lesser Marsh Grasshopper *Chorthippus albomarginatus*
A roadside verge record from North Barningham was a new 10km square record for TG 03. The author had an interesting observation of 24 individuals (mainly females) crowded together in one square foot of unvegetated south-facing bank near the North Hide on Cley beach.

Stripe-winged Grasshopper *Stenobothrus lineatus*
Jit Thacker reported this species from Mousehold Heath, Norwich TG 21 in August 2008. This provides further evidence of range expansion for this species, once considered typical of chalk grassland. It will be interesting to see if it can consolidate its presence in the new areas of the county occupied in the early years of the 21st century.

Mottled Grasshopper *Myrmeleotettix maculatus*
Tim Gardiner reported this species from sand dunes and cliff vegetation at Hopton TG 50 – a new 10km square record in the extreme east of the county.

Early and late dates

A cold and wet start to the year with snow on 23 and 24 March meant there were no early dates for nymphs. The author did not see Dark Bush-cricket nymphs until 5 May (compared with five April dates in the period 2001-8) nor Speckled Bush-cricket nymphs until 23 May (the author's latest date in this period). No adult grasshoppers or bush-crickets were seen or heard until July (matching the position in 2005 and 2007). At the tail end of the season, the author did not record any grasshopper species surviving into November, but Dark Bush-cricket did survive until 15 November at Reepham, and Speckled Bush-cricket until 20 November, after which wintry showers on 21 November and snow on 22 November brought the season to a close.

DI Richmond 42 Richmond Rise, Reepham, Norfolk NR10 4LS

Spiders

Peter Nicholson

A survey to discover the whereabouts of the Fen Raft Spider *Dolomedes plantarius* (Clerk) in the United Kingdom was started in 2008 and continued through 2009. We are fortunate to have one of the three known UK populations of this charismatic spider in Norfolk, as well as its close relative *Dolomedes fimbriatus*. The survey aims to establish whether there are any *D. plantarius* populations that have been overlooked or misidentified as *D. fimbriatus*. The spin-off from these surveys in Norfolk was the chance for local spider recorders to find other species in areas not often visited.

It was through the endeavours of Dr Helen Smith, a leading researcher of *D. plantarius*, that these surveys have been undertaken, supported by keen local arachnologists all over the country. The Dolomedes website (http://www.dolomedes.org.uk/) explains the *D. plantarius* monitoring and recovery programme, funded by Natural England (formerly English Nature), which has been operating at Redgrave and Lopham Fen NNR since 1992. Helen now runs the translocation programme on behalf of Natural England - whether or not translocations go ahead is based in part on establishing positively or negatively the possibility of any other resident populations. So far these surveys have revealed no new *D. plantarius* sites in Norfolk but those of you venturing out again next year in Norfolk are asked to be vigilant for the possibility of its presence in the Broads. To help those not sure of what they are looking for, the Broads Authority has produced small ID cards which can be obtained by emailing Helen Smith via the Dolomedes website.

Recent surveys may not have turned up *D. plantarius* but in August 2008 *Clubiona juvenis* was found by David Hewitt west of the Catfield Hall Estate in an area owned by Butterfly Conservation. This was a pleasant surprise as this spider is generally thought to be rare and confined to a very few marshy localities in the south and east of England, including the Norfolk Broads and Fens. It is also remarkable that it was not found during the surveys undertaken in previous years on the Catfield Hall Estate given its proximity and the similar habitat. The results of this survey were celebrated in the Society's latest Occasional Publication *A Natural History of the Catfield Hall Estate* (2008).

Sutton Fen also came under scrutiny during the year where Pip Collyer found *Philodromus collinus* in the lower branches of mature oak trees. This is uncommon in Britain but has been recorded from sites in the south and south-east. It has also been recorded in Norfolk pre-1983, mainly in the Santon Downham area on heathland, but also at Thompson Common and Weeting Heath.

Another species of interest that is rare in Britain but frequently found in the fens and broads of East Anglia was *Marpissa radiata*, a member of the family Salticidae, commonly known as jumping spiders. These are to be found in the flower heads of Common Reed *Phragmites australis* which require careful examination before the spider reveals itself.

The Wasp Spider *Argiope bruennichi* has been drawing comment over the last few years as it has moved north along the coast from Suffolk. Although few actual records have been received it seems to be building a presence in the county. There are healthy populations as far round as Horsey Mill on the coast of Norfolk, with single records of individuals found at the inland sites of Narborough and Cranwich Camp.

A visit to RSPB Strumpshaw Fen at the invitation of Tim Strudwick, Senior Warden, resulted in *Meta bourneti* being recorded from their macerator. It is the rarer of two members of the Tetragnathidae that are often confused, the other being *M. menardi*. Both draw attention to themselves by being 12-15 mm in length and both are associated with the total darkness found in sites such as the deep interior of caves, culverts, sewers and Nissen huts. These two species are often recorded incorrectly due to arachnologists assuming that specimens are *M. menardi* rather than examining them critically.

Strumpshaw Fen also turned up another species not often recorded by arachnologists due to its unique lifestyle, the Water Spider *Argyroneta aquatica*. This species spends most of its time submerged and is not normally found skating on the water's surface; it is most likely to be found when pond-dipping or when clearing weed from ponds and dykes. Please pass the records on, with a photo, if you see this species.

An incidental record passed to me by Shane Allen, a vigilant observer, was *Ero tuberculata* in the Fakenham area. This species is uncommon in Britain and there are only four records for Norfolk, all pre-1991, from Grimes Graves, Scole and Catfield Common. This attractive creature is a member of the family Mimetidae which is represented by only four species, all in the genus *Ero*, in Britain. They are commonly referred to as 'pirate spiders' for they prey on other spiders in their own webs.

Lastly, thanks to a Dolomedes survey on the Waveney marshes near Barnby, just over the border in Suffolk, Pip Collyer and Helen Smith discovered *Enoplognatha tecta*, a very rare and under-recorded species that has only two British records (both from Dorset, in 1888 and 1974). A report of this discovery is being published in the British Arachnological Society Newsletter this autumn.

To finish I would like to welcome back to Norfolk (from France) the well-known and distinguished arachnologist Eric Duffey.

PJ Nicholson 9 Stalham Road, Hoveton, Norwich NR12 8DG

Wildlife Report 2008

Bryophytes

CR Stevenson & Mary Ghullam

The last account of progress in the study of the Norfolk mosses and liverworts (Stevenson 2007) covered the period from 2002 to 2006. The present account brings that story up to date. As always, most interest centres on the discovery of new species, but the notes below also take account of other observations of interest. The nomenclature follows Hill *et al.* 2008.

Aneura (Cryptothallus) mirabilis New to VC27: growing under *Sphagnum squarrosum*, in alder carr under Downy Birch *Betula pubescens*, Catfield Hall (TG 3725 2137), 20 September 2007, NBG.

Anthoceros agrestis New to VC28: damp sandy loam by side of wood, Bawsey, King's Lynn (TF 6579 1937), 25 July 2008, CRS.

This plant was regarded as rare by Burrell (1914) and had not been seen for many years until re-discovered by John Mott in 1998 at Alderfen Broad. Since then Mary Ghullam has found it at several other localities in East Norfolk. A notably large colony was found in February 2007 at Blickling (TG 1829), where it was growing in company with the Red Data Book species *Sphaerocarpos* *texanus* in barley stubble by the western edge of Tollands Wood.

Sciuro-hypnum (Brachythecium) populeum Second record for VC28: growing as an epiphyte on old pear trees, Myrtle House Farm, Terrington St. John's, 7 February 2008, CRS.

Cirriphyllum crassinervium New to VC28: on the roots of a Beech tree, near the lake, Holkham Park (TF 8828 4356), 14 August 2008, CRS.

This is only the second record of this species from the county as a whole. The only other occurrence was on imported limestone in the rockery of Earlham Hall.

Cololejeunea minutissima New to VC28: crevices in bark of *Salix* sp., by the lake, Bawsey Country Park, King's Lynn (TF 6785 1942), 30 January 2008, CRS. New to VC27: epiphytic at the base of sallow, Sutton Broad Fen (TG 3744 2342), 18 October 2008, RM.

This tiny epiphyte is one that has been spreading across England in recent years.

Conocephalum salebrosum VC28: on the side of a dyke, Thompson Common (TL 9347 9607), 24 March 2007, NBG; Lolly Moor (TF 992103), 6 October 2007, NBG; by the side of a stream, The Collects, Dersingham (TF 6929), 3 January 2007, CRS.

First reported in 2006, this species has since been found at several other localities. It may prove to be quite frequent in the county.

Didymodon nicholsonii New to Norfolk and VC27: growing on a shaded concrete farm track, together with *Syntrichia ruralis, Bryum capillare, Brachythecium rutabulum,* etc., on the edge of Billingford Wood, Upper Street, SE of Dickleburgh (TM 1754 8017), 30 September 2008, CRS.

This rather undistinguished small species occurs in neighbouring counties and has been long sought for in Norfolk. Its apparent rarity is puzzling, since its habitat requirements occur frequently enough.

Diplophyllum obtusifolium New to VC28: shady sandy bank, near Cat's Bottom, Sandringham (TF 666276), 1 March 2008, CRS.

Only the second record from the county as a whole, the previous one being from Weybourne Heath in 1970.

Encalypta streptocarpa VC28: shaded bank on Leziate Fen (TF 7057 2018), 16 March 2007, CRS.

Not a new record, but a first from a previously unknown site. The main stronghold for the species is in Breckland and it appears to be in decline – possibly as a result of increased nitrification?

Fossombronia incurva First and second records for VC28: growing on the sides of shallow pool in an old sand pit, Wolferton (TF 665278), 1 March 2008, MG; on sand by the side of a lake, RSPB Reserve, Leziate (TF 6856 1955), 4 January 2008, MG.

It was necessary to grow this tiny liverwort on to produce mature capsules, before it could be accepted as a new vice-county record.

Lophozia capitata VC28. Growing in damp ground by a lake, at Bawsey Country Park, King's Lynn (TF 6671 1973), 15 October 2007; on bare sand by side of a lake, RSPB Reserve, Leziate (TF 6856 1955), 4 January 2008, NBG.

This Red Data Book species used to be found at several places around King's Lynn, in old sand and gravel pits. It appeared to have disappeared, however, so these re-discoveries are very welcome.

Riccardia incurvata Second record for VC28: on damp sand by the side of a lake, RSPB Reserve, Leziate (TF 684 195), 4 January 2008. NBG.

This rather inconspicuous little liverwort is possibly overlooked.

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CR Stevenson 111, Wootton Road, King's Lynn, Norfolk PE30 4DJ

M Ghullam 5, Beech Drive, North Walsham, Norfolk NR28 0BZ

Wildlife Report 2008

Fungi

Tony Leech

Although old news, the discovery of a fungus in Norfolk which is not only new to Britain but new to science deserves a mention in this journal; even if it is a microscopic parasite on another fungus. In the autumn of 2003, the British Mycological Society held its Autumn Foray in Holt. During the week, a visit was made to Swanton Novers NNR (TG 03) where, in the Great Wood, Martyn Ainsworth collected a specimen of what at first appeared to be *Corticium roseum*, a pinkish-buff resupinate (encrusting) fungus, from a dead attached willow branch. This species is widespread but uncommon in Britain, with four records from Norfolk, all by Reg Evans. Some unusual microscopic features of the fungus, however, enabled Martyn to determine that the specimen was actually the first European collection of *Laetocorticium simplicibasidium*. Yet further examination resulted in Peter Roberts (Royal Botanic Gardens, Kew) recognising that this 'species', originally described from a specimen collected in Arizona, USA (Lindsey & Gilbertson 1977), was in fact a combination of a sterile host (*C. roseum*) and a parasite. This meant that the parasite had not been properly described as a species, and Peter Roberts therefore went on to describe *Celatogloea simplicibasidium*, erecting a new genus for the purpose (the name coming from *celatus*, the Latin for 'concealed', and *gloea*, the Greek for 'glue') (Roberts 2005). The *Ceratogloea* remains within the host and is not visible to the naked eye. It consists of hyphae which possess haustoria to extract nutrients from the host mycelium and basidia which typically bear single spores (in contrast to most species of basidiomycete fungus, in which each basidium produces four spores).

'Truffle' is a name given to any of the 60 or so fungus species in Britain in which the fruit bodies mature below ground, but it is the true truffles (*Tuber* spp.) which generate the most interest since some species are highly sought after for culinary purposes. Eleven species have been recorded in Britain but none are found commonly. In September a woman digging in a flowerbed close to a mature oak in the Wymondham area (TG 10) collected what she suspected were truffles and passed them, via Anne Edwards, to Tracy Money who provisionally identified them as the Large-spored Truffle *Tuber macrosporum*, an identification subsequently confirmed by Brian Spooner (Royal Botanic Gardens, Kew). This was the first record for Norfolk and only the fourth for Britain, with the previous one from Warwickshire in 1911.

A quite unrelated (and probably inedible) false truffle, *Hydnangium carneum*, was found in some abundance in the garden of Bill and June Boardman at Bergh Apton (TG 3002) in December under *Eucalyptus* sp. This flesh-pink truffle fruits with just its upper surface visible above ground and is thought to have been introduced from Australia with its mycorrhizal partner. It was first recorded from Britain in 1875 but has not hitherto been reported from Norfolk. See photo opposite p. 37.

Another 'first' for Norfolk revealed itself in the Boardmans' garden, this time on an old apple tree. Orchard Tooth *Sarcodontia crocea* is a striking fungus, both in appearance and smell; it forms an ochre, waxy crust with numerous tooth-like projections cascading down the split trunk, and has a very strong aroma, combining apple and cheese. With only 25 records on the national fungus record database, this parasitic fungus has the Red Data Book designation of Vulnerable B and may be getting scarcer as old orchards disappear. See photo opposite p. 37.

Several hundred fungus species exploit herbivore dung as their sole food source although their fruit bodies appear but rarely as the dung often dries out. Incubating the dung in containers at home can therefore be an interesting way of obtaining new records. Pellets of Brown Hare dung collected from Blakeney Point (TG 0046) on 9 August produced funnel-shaped fruit bodies of the cup fungus *Peziza fimeti* after about ten weeks. Although this fungus is widespread in Britain it has not previously been recorded in Norfolk.

Woodchips continue to produce interesting records and on 21 October a heap at Whitlingham Cemetery (TG 2507) attracted the attention of Paul Bachelor who found growing on it clusters of *Agaricus rufotegulis*, a red-staining mushroom only recently (Surrey in 2003) recorded from Britain and still, apparently, restricted to the south-east.

In Leech *et al.* (2008) reference was made to fungi which, although generally considered to be restricted to old nutrient-poor grassland, had made an appearance on areas relatively recently reclaimed from agriculture. A further observation can now be added; the appearance of numerous fruit bodies of the earthtongue *Geoglossum umbratile* on the front lawns of three adjacent 1980s-bungalows in Holt (TG 085382).

A further new county record was provided by *Cortinarius parvannulatus* under birch on Holt Lowes (TG 0837), 25 September.

Corrigenda

After publication of new Norfolk fungus records 2000-2007 (Leech *et al.* 2008), Alick Henrici, a mycologist working in the Fungus Herbarium at the Royal Botanic Gardens, Kew and co-author of the *Checklist of the British & Irish Basidiomycota* (2005), supplied the following comments and corrections.

Records queried without dried material for verification: *Cheilymenia cadaverina*, *Cheimonophyllum candidissimum*, *Datronia stereioides*, *Galerina terrestris* (now named *G. minima*), *Hohenbuehelia reniformis*, *Mycena rosella*, *Mycena septentrionalis*, *Pholiota lubrica*, *Typhula sclerotioides* and *Typhula sphaeroidea*. The Kew Herbarium welcomes dried material of scarce species and those on unusual hosts.

Changes in name not appreciated (by ARL) which resulted in the following species erroneously noted as 'new to Norfolk': *Armillaria bulbosa* (actually *A. gallica*, correctly noted as a recent record) and *Coprinopsis jonesii* (formerly known as *Coprinus lagopides*, a fairly common species).

Species for which there exists some taxonomic doubt: *Lepiota clypeolarioides* and *Clavaria kriegelsteineri*.

Finally, we apologise to Martyn Ainsworth for reporting his initials as MAA rather than AMA.

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Dr AR Leech 3 Eccles Road, Holt, Norfolk NR25 6HJ leech@dialstart.net

NORFOLK & NORWICH NATURALISTS' SOCIETY

The County's senior natural history society has as a principal aim the investigation and recording of Norfolk's wildlife and to this end it publishes:

- An annual volume of *Transactions*, consisting of papers and notes on wildlife in the county.
- The *Norfolk Bird and Mammal Report* which contains systematic lists of observations on the county's birds and mammals, as well as relevant articles.
- *The Norfolk Natterjack*, a quarterly illustrated newsletter.

All of these publications are free to members, as are *Occasional Publications* on specific topics.

The Society also arranges lectures and field meetings which are planned to appeal to anyone interested in natural history. More specialist groups cover many aspects of the county's flora and fauna.

The subscription rate is £15 per year, which includes all members of a family living at the same address. Group affiliation is available at £15 per year.

Membership enquiries should be made to: David Paull, 8 Linford Drive, Eaton, Norwich NR4 6LT.

All other enquiries should be directed to the Secretary, Dorothy Cheyne, Wood House, Free Lane, Ditchingham, Bungay NR25 2DW. Tel 01986 894277.

NOTES FOR AUTHORS

The Editor will be pleased to receive proposals for papers and notes from anyone and will be pleased to advise authors on the production of material and the appropriate form in which to submit text and artwork.

Editor: Simon Harrap, 1 Holt Road, Edgefield, Melton Constable, Norfolk NR24 2RP Tel 01263 58736 Email: harrap@onetel.net.

The Society gratefully acknowledges the support of the Sarnia Trust in the production of this publication.

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Cover: Collared Earthstars *Geastrum triplex*. Photo: Jonathan Revett

£5.00 to non-members

Printed by Barnwell's of Aylsham