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The Norfolk & Norwich Naturalists' 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.

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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 £20 per year, which includes all members of a family living at the same address.

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Vegetation development in the Broadland fens

Jo Parmenter

Introduction

The Broadland fens form part of a complex and extensive mosaic of waterways, shallow lakes, grazing marsh, woodland and arable land occupying approximately 300 km^2 (George 1992). This area of land lies in the valleys of three major rivers; the Bure, Yare and Waveney, and their main tributaries, the Ant, Thurne, and Muckfleet. See Fig. 1 for map of Broadland fens.

Over two-thirds of the Broadland landscape is managed as agricultural land; either intensively managed pasture (grazing marsh) or high quality arable land. Much of the remainder is seminatural vegetation or open water. The Broads National Character Area Profile (http://publications.naturalengland.org.uk/publication/11549064) records that over 7,000 ha of land is nationally designated as Sites of Special Scientific Interest (SSSI), with international designations including three Special Protection Areas (SPA), two Special Areas of Conservation (SAC) and two Ramsar sites. Key habitats include grazing marsh (c.12,300 ha) and fen and reedbed (c.10,400 ha), as well as the most extensive tract of wet woodland within eastern England. A number of iconic species are present in the Broads, including 95% of the UK population of Fen Orchid *Liparis loeselii* var. *loeselii*[1] (Mason 2014), and the entire UK population of the Swallowtail butterfly *Papilio machaon* Both of these species are restricted to fen habitat.

Principal environmental and anthropogenic influences upon fen vegetation

Five principal uses have historically been made of the Broadland fens. These were peat cutting, reed cutting, sedge cutting, litter/fodder mowing, and grazing. On the basis of the information available, turbary[2] would seem to be the most economically important and widespread historic land use, followed by the cutting of various types of vegetation (litter, reed, sedge etc.), and lastly, grazing. Turbary was particularly prominent in the medieval period, producing the deep, water-filled basins which dominate the landscape to the present day, but peat cutting continued until the early 20th century. During the medieval and post-medieval periods the demand for litter and fodder is likely to have risen with the increasing population. By the late 18th century, it was possibly as important as peat cutting to the local economy and probably greatly exceeded the importance of reed and sedge cutting.

Peat has been cut for fuel in Broadland for over 1000 years. The increased use of peat as a fuel source from the late Saxon period onwards led to the creation of extensive turbaries in Broadland. A large proportion of the floodplain, and possibly over 75% of the land area in the middle and upper floodplains, has been cut for peat. Many of the fen communities which are found growing over the former turbaries are relatively recent in origin and the great majority of the colonisation of open water by fen vegetation has taken place over the last 175 years. The apparently sudden proliferation of fen communities over the medieval turbaries was in most cases in response to the accumulation of lake mud and sediment to the point when the basin became sufficiently shallow to enable colonisation by swamp species (Lambert 1965).

The shallowest of the former medieval broad basins, at Dilham and Sutton, have already succeeded to fen. Substantial areas of open

1 See Appendix for English names of plants referred to in the text.

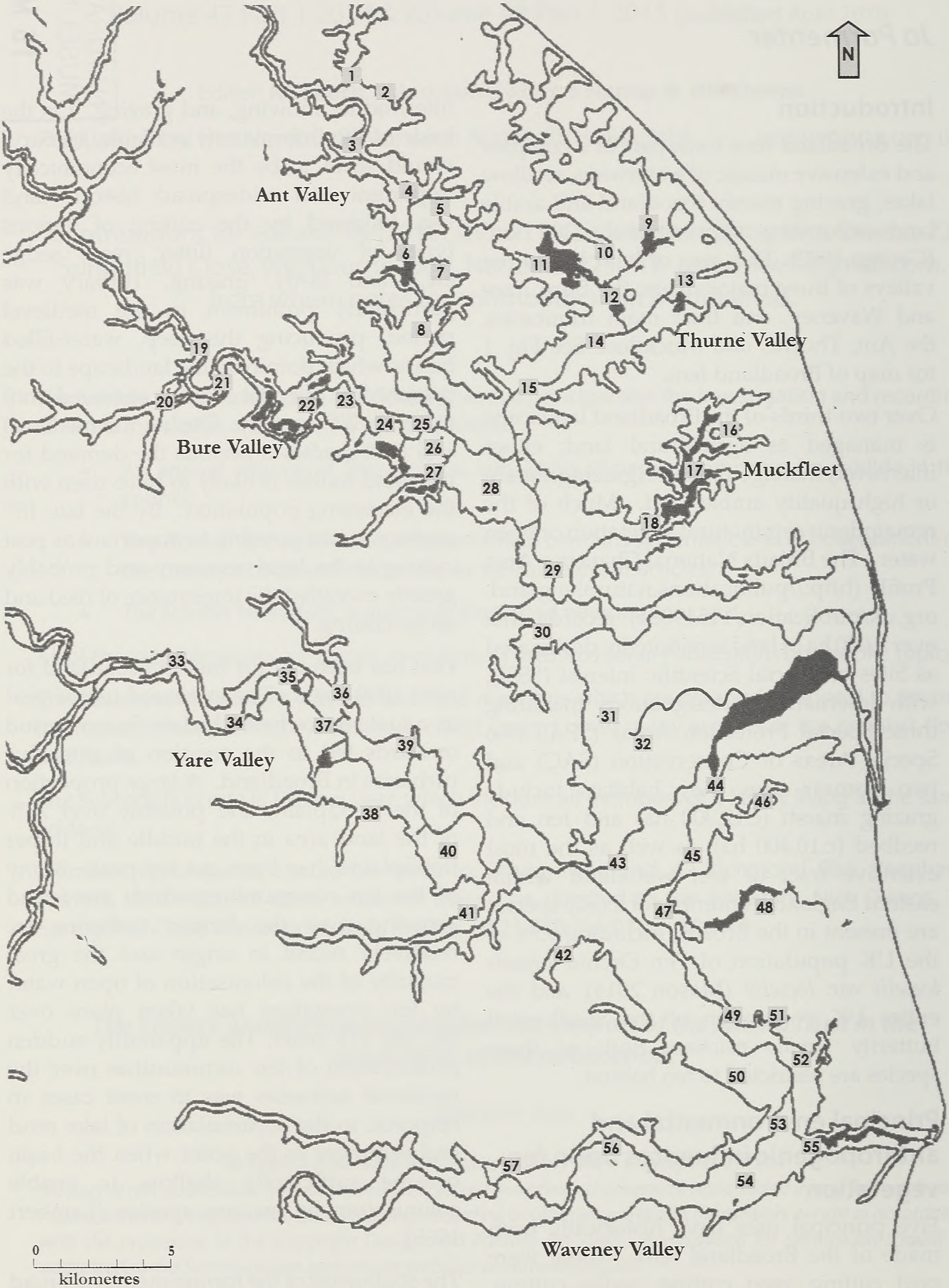

Figure 1. Location of fen sites within The Broads area. Key opposite.

The River Ant Fens

1 East Ruston Common, Honing Common & Dilham Broad

2 South Fen & The Holmes

3 Broad Fen & Smallburgh Fen

4 Barton Fen, Common Fen & Stalham Fens

5 Sutton Fen, Sutton Broad & Hand Marsh

6 Barton Broad Fens & The Heater

7 Catfield Fen

8 Reedham Marshes, Snipe Marsh, Hall Fen & Alderfen

The River Thurne Fens

9 Horsey Mere, Brayden Marshes & Long Gore Marsh

10 Skoyles Marsh, 100 Acre Marsh, Whiteslea & Meadow Dyke (North)

11 Hickling Broad Marshes & Mrs Myhills Marsh

12 Heigham Sound, Meadow Dyke (South) & Sound Marshes

13 Mere Farm Marshes, Starch Grass & Martham Broad Marshes

14 Potter Heigham Fen & Martham Marshes

15 Womack Water Marshes & Shallam Dyke

The Muckfleet Fens

16 Ormesby Common, Ormesby Broad Marshes & Hemsby Common

17 Rollesby Broad Marshes

18 Burgh Common & Filby Broad Marshes

The River Bure Fens

19 Coltishall Marsh & Blackmans Fen

20 Crostwick Marsh & Dobbs Beck Marshes

21 Belaugh, Wroxham & Jubys Farm Marshes

22 Snapes Water, Hoveton Marsh, Sedge Fen & Salhouse Marshes

23 Woodbastwick Marshes & Hoveton Little Broad & The Lows

24 Ranworth Broad Marshes & Horning Church Marshes

25 Horning Hall Marshes & Hulver Ground

26 Ranworth Marshes & Ward Marsh

27 Ranworth Flood, Leists Marsh & South Walsham Fen

28 Upton Fen & The Doles

29 AcleCarrs & FishleyCarrs

30 Decoy CarrAcle

31 Halvergate Marshes

32 Wickhampton Marshes & The Fleet Marshes

The River Yare Fens & Ronds

33 Whitlingham Marshes & Thorpe Marshes

34 Surlingham Church Marshes & Kirby Marshes

35 Surlingham Broad Marshes, Bargate & The Outmeadows

36 Bradeston & Strumpshaw Marshes & Strumpshaw Common

37 Surlingham Marsh, Wheatfen & Rockland Marshes

38 Ducans Marsh & Carleton Broad Marshes

39 Buckenham & Hassingham Carrs & Buckenham Ronds

40 Poplar Farm Marshes, Limpenhoe Marshes & Cantley Ronds

41 Hardley Flood, Chedgrave Common & Loddon Common

42 Thurlton Beck Marshes

43 Reedham Ronds

The River Waveney Fens & Ronds

44 Glebe Marshes & Burgh Castle Ronds

45 Belton Ronds

46 Belton Bog & Bradwell Doles

47 Fritton Ronds

48 Fritton Decoy & Ashby Warren

49 Herringfleet Ronds

50 Wheatacre Marshes

51 Flixton Decoy, Wicker Well & Summerhouse Water

52 Somerleyton & Blundeston Ronds

53 Burgh St Peter & Barnby Ronds

54 Barnby Broad & Marshes, North Cove & Wadehall Marshes

55 Oulton Marshes, White Cast Marshes & Sprats Water

56 Beccles Marshes, Wild Carr & Stanley & Alder Carrs

57 Roos Hall Marshes, Barsham Marshes & Geldeston Marshes

water at Hickling Broad, Ranworth Broad and Heigham Sound have also become grown over. The deeper basins, such as those at Trinity Broads and Fritton Decoy, are still relatively open. The colonisation of the Yare valley broads by swamp and subsequently fen vegetation has progressed much faster than elsewhere in Broadland, apparently because of the ability of Reed Sweet-grass *Glyceria maxima* to colonise quite deep water without the necessity of being rooted in the underlying substrate (Lambert 1965).

Before enclosure, much of the upper valley floodplain was held in common. Common fenland would have been used to supply a variety of commodities, including reed, sedge, litter and peat. The most essential types of fen produce were peat for fuel and fodder for feeding domestic animals, however the management regime had to take into account the differing requirements of a large number of people and common land thus often had to supply a wide range of commodities, giving rise to a mosaic of differing management regimes. Doling[2] enabled individuals to exploit common fenland as they chose. In this respect, the effect of doling on fen management was not dissimilar to the effect of Parliamentary Enclosure.

Parliamentary Enclosure led to a complete restructuring of the landscape of the Broadland fens. Vast tracts of common wetland and heathland were enclosed and drained or otherwise improved. Much of the Broadland floodplain fen was enclosed into private ownership, with small areas designated as poor allotment. The common fenland was divided up into rectilinear parcels using dykes to denote ownership boundaries and to improve drainage. The resulting landscape was more ordered in appearance than that resulting from the earlier enclosures.

Private ownership gave increased control by individuals and enabled those individuals to make choices about the way in which they would manage their land. Enclosure increased exploitation of fenland for mutually exclusive purposes, such as turbary or litter cutting. It also encouraged a much more organised pattern of management and specialisation of land use towards particular marketable fen products such as reed and sedge, rather than continuing to manage one area of land for a number of different purposes. The decision whether to cut peat or whether to harvest fen crops was probably largely an economic one, although the existing vegetation would have to some extent determined the way in which the fen was managed.

Some areas of fen, particularly those which had undergone substantial terrestrialisation or those on solid peat, have been grazed in the past, usually in the drier summer months. It is also likely that animals were encouraged to graze in the areas which were drained to facilitate exploitation of the peat resource, while these areas were not actually being cut (Parmenter 2000). Grazing of fen vegetation results in the suppression of the taller or most palatable species, whilst low growing species and coarse rushes and sedges are favoured. These areas today are sometimes indicated by an increased frequency of rushes and often the presence of the sedges *Carex disticha* and *C. panicea*. *Filipendula ulmaria* and *Calamagrostis canescens* also tend to occur at a higher frequency in these areas. Other species, such as *Phragmites australis*, *Carex paniculata*, *Cladium mariscus* and *Schoenus nigricans* tend to be suppressed or eradicated by long term grazing management and may be reduced in frequency or absent from formerly grazed fen areas.

Superimposed upon the mosaic of concentric bands of successional communities which often occur between the open water and upland margins is a further pattern which is dictated by the presence or absence of 19th

2 Doling was the allocation of strips of common land to a specific person.

century shallow peat cuttings. These have, without exception, virtually completely terrestrialised and the fen surface is usually quite firm, but they support vegetation which is markedly different from that growing over either the former broad basins or on solid peat. *Cladium mariscus* is often abundant in these situations. Several National Vegetation Classification (NVC) types (Rodwell 1995), including S24a and S24e vegetation are almost exclusively found over peat cuttings.

Other former management practices have also altered the fen vegetation to a greater or lesser extent. Traditionally, the open fen areas would have been managed for reed, sedge and marsh hay, with carr and scrub being cut for firewood. Drier areas would have been grazed by livestock. A use seems to have been found for most natural products of the fens and adjoining higher ground and during the 19th century strict bylaws often governed the management and use made of the marsh resources. Bird (1909) wrote of East Ruston Common *"Not only did the rushes which grew there once form the wicks for the only candles then made, but they afforded also the primitive carpets of the clay-floored cottages...The Furze bushes provided kindling for the peat fires, as well as material for effectually walling in the cattle sheds; and the upland turf supplied the place of the present day slates and tiles for roofing purposes ..."*

The decline in the management of areas of fen for crops such as reed and sedge and marsh hay was associated with a move to tile and slate for roofing, the gradual replacement of horses by motor vehicles and the wide availability of straw for animal bedding, coupled with labour shortages in the post war periods. Some areas of fen are still cut for conservation purposes, but the decline in traditional fen management is largely responsible for the present extensive areas of scrub and carr in Broadland.

Many of the abandoned managed reedbeds still support strong populations of *Phragmites australis,* and relict sedge beds usually remain dominated by *Cladium mariscus* because of the ability of these species to resist invasion by woody vegetation to some extent, and to maintain species impoverished, sometimes pure stands. Examples of sedge beds of this type can be found at Brayden Marshes, where, despite an absence of commercial management over several decades, the former commercial sedge beds are still free from scrub and are often extremely species poor. Summer mowing for litter tended to encourage rushes and to suppress *Phragmites australis* and *Cladium mariscus.* Unlike the former *Cladium* beds, however, these litter fen sites have tended to succeed quite rapidly to carr. *Juncus* spp. dominated vegetation, both because of its structure, and the fact that it tends to grow in relatively drier situations, does not have the ability to resist scrub invasion to the same degree as *Cladium mariscus.*

The proportion of drained marshland relative to fen and carr is greatest in the lower reaches of the Yare and Waveney valleys. Historically, land drainage has been more successful in the areas which have extensive deposits of estuarine clay, which is not subject to the shrinking and wastage which usually occurs when peat fen is drained (Ellis 1965). In addition, the clay layer is often rich in minerals and therefore tends to produce better pasture.

In the upper and middle reaches of the river valley, the clay layer is absent or incomplete. Past attempts to drain fen sites upstream have generally ultimately failed due to shrinkage of the peat and the consequent progressive difficulty in draining the land. A proportion of this previously drained land has reverted to fen, and the vegetation is often of a quite different structure and floristic composition to that of the surrounding undrained fen. Reflooded former grazing marsh sites include Bargate and Surlingham Church Marshes on the Yare, Sedge Marsh on the Bure, and Stanley and Alder Carrs on the Waveney. The extensive reedbeds at Ranworth Flood are the result of deliberately flooding an area of wet grazing land for reed culture.

The extent to which the fens are influenced by the chemistry of the river water which irrigates them varies from site to site and from valley to valley (George 1992). In general, sites closest to the main rivers, particularly to the Rivers Yare and Waveney are more nutrient rich and tend to be more alkaline than those closest to the upland margins. Sites which have been formerly drained for agricultural use are often more fertile than those which have been managed as fen, as a result of oxidation of the peat and consequent nutrient release.

The Broadland river system is strongly influenced by tidal fluctuation, both because of the proximity of the sea, and also the very gentle valley gradient, which averages just over 3 cm per kilometre (George 1992). The tidal influence extends for a considerable distance upstream, and even at Norwich, some 25 miles from the sea, the daily fluctuation is commonly between 30 and 60 cm. The tidal effect is much stronger in the Rivers Yare and Waveney than in the corresponding reaches of the Bure and its tributaries.

The influx of saline water into the river system is to some extent limited by fresh water flowing downstream, although in the areas closest to the sea, the salinity is sufficiently high to permit the growth of halophytes. Brackish water tolerant species such as *Samolus valerandi, Schoenoplectus tabernaemontanii* and *Oenanthe lachenalii* are found for a considerable distance upstream, although at some sites, their presence is due to salt water influence derived from non-fluvial sources, such as the presence of an underlying layer of saline estuarine (Breydon Formation) clay. The potential effects of nutrient enrichment are greatest in the case of fen vegetation which is contiguous with the river, or where an open dyke network allows nutrient rich river water to percolate deep into the fen. This latter point is an important consideration in fen ditch management: whilst any adverse effects of nutrient enrichment as a result of increased water penetration from relatively nutrient poor rivers such as the Ant and Thurne into the fens are probably outweighed by the benefits of improved access and the creation of open water habitat in the fen, in the more eutrophic systems, such as the Yare, improved water circulation may result in the proliferation of rank vegetation in previously nutrient impoverished fen areas. In strongly tidal systems such as the Yare and Waveney, water circulation is much higher than in the non-tidal upper Ant. The installation of phosphate stripping equipment at wastewater treatment works in the upper valleys has substantially reduced the availability of this nutrient, however there is still some diffuse phosphate input, and nitrate levels in some rivers remain elevated.

The varying influence of the factors described above on fen vegetation has given rise to a very high degree of heterogeneity in the fen vegetation of The Broads, with each valley system exhibiting unique characteristics (Table 1).

The Ant Valley

The fens of the Ant valley floodplain have long been recognised as being of outstanding importance in Broadland (Wheeler 1978). They support the greatest diversity of fen and mire community types and are also notable for the high number of both nationally rare and scarce species which are found here, including some which are found nowhere else in the Broads.

The main Ant Valley fen sites include Broad Fen, Smallburgh Fen, Barton Fen, Sutton Fen, Sutton Broad, Catfield Fen, Reedham Marshes, Hulver Ground and Alderfen. Together, these sites represent one of the best remaining examples of lowland wet fen habitat, both in Great Britain and in

Table 1. Distribution of open fen habitat types in the Broadland valleys (OHES 2013).

	Total%	ANT%	BUR%	THU%	WAV%	YAR%
Mires and fen meadows	8.3	3.5	11.9	5.3	9.4	14.1
Mesotrophic tall-herb fens	40.7	63.1	60.7	32.4	6.1	18.4
Mesotrophic swamps	7.2	9.6	1.7	17.6	0.0	0.6
Total of 'high-value' fen habitats	**56.2**	**76.2**	**74.3**	**55.3**	**15.5**	**33.1**
Meso-eutrophic reedbeds and fens	13.7	13.6	12.9	16.1	13.2	14.9
Species-poor reedbeds	8.9	5.1	3.4	16.8	11.3	6.0
Eutrophic fens	13.5	3.1	8.4	5.7	18.1	37.8
Brackishfens	4.4	0.1	0.9	3.6	23.8	5.2
Saltmarsh	1.2	0	0	0.2	10.3	1.7
'Contact Communities'	2.1	1.8	0	2.2	8.0	1.4

western Europe (Barendregt *et al.* in prep.)

Several sites stand out as being of particular interest and value. One of these is Sutton Broad, where the fen vegetation demonstrates the hydroseral succession from open water to upland, through swamp, reedbed, tall herb fen, and 'small sedge' fen to marginal fen meadow and carr. Other sites of particular importance are Catfield Fen, which supports one of the three remaining populations of *Liparis loeselii* in addition to an abundance of *Dryopteris cristata*, and Smallburgh Fen, which is of interest for its calcareous mire communities.

Reedham Marshes and Broad Fen are also of very great interest. On the valley scale, the Ant is probably the best example of a diverse floodplain fen in Broadland and almost all of its constituent sites are of exceptional quality, both in terms of species composition and community structure and distribution.

The course of the River Ant has been greatly altered during the medieval and post medieval periods, and formerly discharged into the River Thurne at Cold Harbour, rather than directly into the Bure. The course of the River Ant further upstream has also been modified by four major diversions to facilitate navigation or to improve drainage of the catchment. The original early medieval course of the river is marked today by minor channels which follow the parish boundaries.

Much of the floodplain fen in the Ant valley is irrigated by the river, although a few sites in the northern part of the valley system, including Smallburgh Fen, are fed mainly by calcareous groundwater. In the lower part of the valley, south of Catfield, Breydon Formation clays overlie the Crag and these have an influence upon the vegetation, being both saline and rich in minerals (Pyne 2014).

The water quality in the Ant is generally good in comparison with some of the other main Broadland rivers. In the past, the nutrient discharge into the River Ant was much greater, but the effluent from the waste water treatment works upstream is now phosphate-stripped before discharge. Nitrate levels are comparable to those of the Bure. Nutrient levels generally are considerably lower than those found in the southern rivers.

The Ant valley is notable for a mosaic of closely juxtaposed vegetation community types, a large proportion of which are high quality fen, supporting a diversity of uncommon species. The distribution of the fen communities is linked to a number of factors, such as past and present management, past land use and the spatial position of the vegetation stands within the river valley, which dictates nutrient and salinity levels.

The largest remaining open fen areas in the Ant valley are at Catfield Fen, Sutton Fen, Barton Fen and Reedham Marshes. The majority of the fens in this valley are dominated by varying proportions of *Cladium mariscus, Phragmites australis* and *Juncus subnodulosus.* These fens support populations of almost all of the species which are considered to be nationally rare or scarce fen species: *Thelypteris palustris, Thyselium (Peucedanum) palustre, Sium latifolium* and *Dryopteris cristata* are particularly abundant, and *Carex appropinquata* and *Cicuta virosa* are also quite common. Several locally scarce fen species, however, for example *Thalictrum flavum,* are not found in the Ant fens, and the nationally scarce *Lathyrus palustris* and *Sonchus palustris* are only present at the extreme southern end of the system. *Liparis loeselii* has two out of its three Broadland stations in the Ant valley.

It is possible to distinguish two main groups of fen and mire communities within the Ant Valley; those of the floodplain, which derive a large proportion of their irrigating water from fluvial sources, and the valley mires, which are irrigated by water from springs and marginal seepage zones. Most of the Ant valley fens are of the former type; East Ruston Common, Broad Fen and Smallburgh Fen, however, are of the valley mire type. In addition, the marginal zones of many of the Ant floodplain fens close to the upland receive the majority of their irrigating water from seepage; the River Ant is only weakly tidal and water circulation at a distance from the river is minimal, particularly where the dykes to the river are choked with vegetation or in cases where an internal fen system exists, as at Catfield. The vegetation type of these areas is dictated by the quality of the irrigating water, derived from the groundwater, rather than from a base rich fluvial supply. Calcicole communities are present in some locations, typically dominated by *Molinia caerulea,* often with extensive patches of *Sphagnum* spp. *Erica tetralix* also occurs in this habitat; other species found here include *Calluna vulgaris, Cirsium dissectum, Succisa pratensis* and *Potentilla erecta.* Wetter areas may support communities dominated by the locally scarce *Carex rostrata,* in a form of the M27 community. In some cases, where the irrigating water is most acidic, species assemblages most closely resembling M5 or M6 mire (Rodwell 1988) can be found.

The floodplain fens closer to the river are dominated by *Phragmites australis* and *Cladium mariscus. Juncus subnodulosus* is a common associate, particularly towards the margins of the fen areas on solid peat, where grazing and mowing for litter would have encouraged the spread of this species. *Calamagrostis canescens* is also very frequent in these areas on slightly drier ground. The Ant valley tall herb fen is notable for its wide range of associated forbs, including *Lysimachia vulgaris, Lythrum salicaria, Angelica sylvestris, Thyselium palustre, Ranunculus lingua, Rumex hydrolapathum, Valeriana officinalis* and *Iris pseudacorus. Comarum palustre (Potentilla palustris), Galium palustre, Mentha aquatica, Thelypteris palustris, Hydrocotyle vulgaris* and *Scutellaria galericulata. Salix repens, Schoenus nigricans* and *Carex elata* are often abundant in *Cladium* dominated vegetation where the substrate is of low nutrient status. In the unmanaged fen, scrub, particularly *Salix cinerea, Myrica gale* and at some sites, *Betula pubescens,* are very quick to colonise.

In parts of the valley, notably at Reedham Marshes and Catfield fen numerous oligotrophic nuclei have developed within the mesotrophic fen communities, marked by raised hummocks of Sphagnum, occasionally supporting species such as

Dryopteris cristata, or, where conditions are exceptionally base poor, *Drosera* spp. The W2b *Betula pubescens-Dryopteris cristata* community is more common in the Ant valley, and at Catfield Fen in particular, than anywhere else in Broadland. Similar calcifuge communities are found across the watershed, where the Crag lies adjacent to the fens west of Hickling Broad.

Recent studies at Catfield Fen indicate that the Sphagnum polsters have both increased in frequency and in area: in one small corner of Catfield Fen alone, an area of up to 4000 m^2 is now dominated by sphagnum (Mason 2014). Moreover, some of the rich fen communities described by Giller & Wheeler (1986a, 1986b, 1988) are being replaced by vegetation dominated by the bog mosses *Sphagnum fallax* and *S. squarrosum*, and in the eastern part of the fen system only a few locations now do not support sphagnum (Pyne 2014). At the same time the frequency and abundance of characteristic and rare rich fen species such as *Liparis loeselii* and *Potamogeton coloratus* has reduced (Mason 2014, Parmenter 2014).

A large proportion of the fen area in the Ant valley was formerly worked for peat, either during the medieval period, thus creating Barton, Cromes, Dilham, Sutton, and Alderfen Broads, or during the subsequent phase of shallow excavations which produced the extensive turf ponds which underlie much of the fen area of Reedham Marshes, and Catfield and Sutton Fens. Almost all of the 18th and 19th century cuttings have now terrestrialised, although a few small pools remain in Catfield Fen. The most shallow of the medieval cuttings, for example Sutton Broad, have also become completely terrestrialised. Fen, carr and swamp vegetation have colonised the margins of Barton Broad, Alderfen Broad and Cromes Broad. The terrestrialised turf ponds and broads support a large number of locally and nationally rare and scarce species and communities.

The NVC S24 communities are particularly well represented in the Ant valley. The wide range of habitats found here are thought to have developed into their present diverse forms as a result of the complex pattern of management coupled with local variations in the substratum and hydrological regime.

The fen communities which overlie turbaries are often strikingly different to those which are found over solid peat. *Cladium mariscus* is almost invariably found growing over turf cuttings and several other species including *Sium latifolium, Cicuta virosa* and *Dryopteris cristata* either occur preferentially, or like *Liparis loeselii*, are exclusively found in this situation.

The Ant valley fens are unusual in Broadland for the presence of remnants of open water habitat which have persisted despite turf pond terrestrialisation. These pools and runnels are usually effectively isolated from the eutrophic river water and support a number of locally rare and scarce species including *Utricularia* spp., and the nationally scarce *Potamogeton coloratus*. Several of the broads, for example Alderfen and Barton Broad, support marginal reedswamp, *Typha angustifolia* swamp and S24a *Carex paniculata* tussock fen. These are communities which are much less common in Broadland today than formerly. Open tussock fen at Alderfen has been colonised by various *Sphagnum* spp. and the locally rare sedge *Carex canescens (curta)*, which is probably more frequent in the Ant valley fen system than anywhere else in Broadland.

Several of the terrestrialised turbaries, for example at Broad Fen, Smallburgh Fen, Catfield Fen and Sutton Broad, have developed species-rich small sedge fen communities as a result of hydroseral succession. These areas support a large number of rare and scarce species, including the sedges *Carex diandra, Carex appropinquata* and *Carex rostrata* over a bryophyte carpet dominated by *Calliergonella cuspidata* and *Campylium stellatum*. Other species which seem closely associated with this community type are *Pedicularis palustris, Dactylorhiza traunsteineroides, Dactylorhiza incarnata* and *Liparis loeselii. Carex limosa* has also been recorded from this habitat, but not in recent years.

The most recently terrestrialised turf pond and broads support semi-swamp communities, with species such as *Typha angustifolia, Cicuta virosa, Sium latifolium, Ranunculus lingua* and *Rumex hydrolapathum* growing in abundance in *Phragmites*-dominated vegetation.

In the southern part of the Ant fen system, at Catfield and Reedham Marshes, the fens closest to the river are underlain by estuarine clay, which has been exposed in places by turbary. These area soften support *Typha angustifolia* or reed-dominated communities, with a number of associated salt-tolerant species, including *Schoenoplectus tabernaemontanii* and *Oenanthe lachenalii*. Similar community types are also found in the lower Bure fens and also at Hickling, although their presence in the latter area is partly due to brackish irrigating water rather than solely to the presence of estuarine clay.

The Ant valley is notable for its diversity of pteridophytes; *Dryopteris dilatata* is abundant throughout, particularly in scrub and woodland communities. *Thelypteris palustris* is also common, as is *Dryopteris carthusiana. Osmunda regalis* occurs quite frequently and is particularly abundant at Sutton and Catfield Fens. The nationally rare fern *Dryopteris cristata* is locally frequent in several of the Ant valley fens, most notably Catfield Fen, where it occurs in association with the acidophilous nuclei described above, alongside the hybrid x *uliginosa*.

Most of the traditional management practices are now no longer carried out, but reed and sedge are still cut commercially on a proportion of the open fen in this area, including Sutton Fen, Reedham Marshes and Catfield Fen.

The Thurne Valley

The fen sites of the Thurne valley occur in an area of low lying land which extends from Catfield Common east to Candle Dyke, and from Candle Dyke north and east to Horsey Mere and Martham Broad. The area is drained by the River Thurne, which has its source less than 2 km from the coast at Somerton and joins the River Bure at Thurne Mouth. There are two main tributaries, the largestof which, Waxham New Cut, drains Brograve Level and Hempstead Marshes in the north of the catchment.

An interesting feature of this catchment is that it is known to have historically drained into the North Sea via a former channel, the Hundred Stream which had an outfall between Winterton and Horsey. The dunes were breached at the site of this channel during the 1938 sea floods. The date of the reversal of flow which resulted in the present southerly course of the River Thurne is not known, but from cartographical evidence it appears that this reversal certainly occurred prior to the 1790s, when the survey work for Fadens 1797 map was carried out and in all likelihood pre-dated the records of the Sea Breach Commissions which were formed from 1609 onwards.

Much of the low-lying land in the catchment has been drained for agricultural purposes; the main fen sites occur in the vicinity of the broads, where drainage was either not attempted or was unsuccessful. The surrounding drained marshland supplies much of the water which enters this fen area and enrichment from fertiliser application, rather than from effluent, is the main source of nutrients in this system. The River Thurne is only weakly tidal upstream of Candle Dyke, but even so, the water levels at Catfield Staithe may rise and fall by around 15 cm under normal tidal conditions, although brackish water only infrequently penetrates the fen dykes in this area.

Much of the land in the Thurne catchment area is used for agriculture, namely arable land and improved grazing marsh. Open fen occupies around 600 ha, which is just over one-fifth of the total land area; the highest proportion of this vegetation type in Broadland. This is the largest area of near-continuous open fen in Broadland, with a relatively small proportion being wooded.

The broads in this area were cut from peat beds which were considerably shallower than at many other sites in Broadland and in places the bottom of Hickling Broad consists of Crag sands and gravels, rather than peat. The remaining uncut peat deposits beneath the fen surface are also very shallow and this may be partly reflected in the abundance of wet heath communities and wet acid grassland communities around the fen periphery, where a thin layer of peat overlies sand and gravel. Towards the south-eastern extreme of this complex of fens and broads, the layer of Romano-British (Breydon Formation) estuarine clay becomes thicker, and there is anecdotal evidence to suggest that part of Heigham Sound may have been dug for its clay resources rather than for peat George 1992).

This area contains a wide variety of fen habitats and a large number of nationally and locally rare and scarce species are found here, including *Dryopteris cristata*, which not infrequent around the margins of Hickling Broad and at Brayden Marshes, and *Sonchus palustris*, which is particularly abundant here growing on spoil by the margins of the broads and major channels as well as being found as an occasional component of reedbed communities. *Cicuta virosa* and *Sium latifolium* are uncommon over much of the catchment and may be intolerant of the often brackish conditions. *Sium latifolium*, is, however, quite abundant in the Martham Broad area, where the salinity is lower than elsewhere in the system. *Thyselium palustre* occurs throughout, and *Lathyrus palustris* is also present. *Thelypteris palustris* and *Carex appropinquata* are scattered throughout the fens of this system, but are by no means frequent. *Althaea officinalis* can be found occasionally growing on dyke spoil. *Schoenus nigricans* is not uncommon in this area as a component of the managed sedge beds, but does appear to have declined from a former abundance, having once been so common that a site near Martham Broad, now commercial reedbed, is called Starch Grass; a corruption of Star Grass, the local name for *Schoenus nigricans*. Further extensive stands of this species are present as *Schoenus nigricans* swamp fen, which is not unknown elsewhere in the county, but has its only Broadland site at Blackfleet Broad, where it has been present for over a century.

Many of the vegetation communities which are found here differ considerably from those in the other valley systems, having a special character, which is in part determined by the water quality of the area, in particular, the relatively high salinity. A large proportion of this area is alluvial marshland, with extensive and often uniform tracts of sedge beds and reedswamp, many of which are still managed on a commercial basis, although large areas of commercially viable reed and sedge are no longer cut. Woodland is less common in this area than in any of the other Broadland fen systems, both in terms of actual area and the proportion of carr relative to open fen. The reasons for this are not certain, but the effects of occasional inundation by brackish water, the long-term effects of the 1938 sea floods and until quite recently, the management of large areas of the fen for reed and sedge, have been proposed as possible explanations.

The entire area is affected by salt water seepage from the North Sea, which lies less than 3 km from the eastern margin of the fen system. The saline water seeps into the dykes which drain the surrounding arable land and grazing marsh and is thence pumped into the river system. This produces brackish conditions in the fens nearest to the broads and channels and the saline influence is reflected in the unusual species composition of many of the fen communities.

The commercial sedge beds, in addition to supporting species such as *Schoenus nigricans, Thyselium palustre, Eupatorium cannabinum, Lythrum salicaria* and *Galium palustre,* also have *Samolus valerandi* and *Oenanthe lachenalii.* Species more typical of upper saltmarshes, such as *Juncus maritimus, Aster tripolium* and *Apium graveolens,* are also present, and are particularly associated with areas where brackish water is able to stand. Many of the reedbeds and *Phragmites* dominated tall herb fen communities support *Schoenoplectus tabernaemontanii.* This makes the Thurne fens of very great importance within a local context as the halophytes present are found elsewhere in Broadland only on the lower ronds, where nutrient levels are very much higher and the vegetation consequently is often coarse and rank. The vegetation communities in the Thurne catchment, which combine species typical of tall herb fen with halophytes, are unique to this area and should be considered as being of very great importance.

The reed and sedge beds are slightly less diverse than those of the Ant and Bure systems, but are nevertheless of great botanical interest, with tall herbs, such as *Eupatorium cannabinum, Lythrum salicaria, Lysimachia vulgaris, Thyselium palustre* and *Ranunculus lingua* being very frequent. *Sonchus palustris* is a common constituent of many of the fen communities in this area, particularly where there has been some disturbance to the substratum, such as occurs during dredging operations. Other species which are frequently found in this habitat are *Carex elata* and *Schoenus nigricans. Carex otrubae* seems to be more common at the western end of Hickling Broad than anywhere else in Broadland, although the reason for this is a mystery.

The broads in this fen system are either non-navigable, or are so extensive, with shallow margins, that boat wash damage appears to be much less here than in many of the other broads. Another factor which appears to contribute to protection of the fringing reedswamp are the extensive beds of aquatic macrophytes, particularly *Myriophyllum spicatum* and *Hippuris vulgaris,* which significantly reduce boat wash. In many areas an intact band of *Typha angustifolia* swamp may be found growing in the deeper water, with successional parallel bands of *Phragmites*-dominated swamp, reedfen, species rich tall herb fen, *Cladium* beds and litter fen behind.

The tidal influence in this catchment is slight and diurnal fluctuations of the fen water table are for the most part insignificant, although there is some water movement in the dykes even as far west as at Catfield Staithe. This has allowed the development of some unusual fen communities, particularly around Hickling Broad. The predominant influence on these fens is an increasing pH gradient from east to west, where the slightly alkaline water of the broad is replaced by base poor water percolating from the Crag aquifer. In addition, there is an increasing salinity gradient operating from west to east. This gives rise to a great variety of vegetation communities, the particular type being dependant upon the position along the gradient. The general pattern is a series of fen meadow and acid wet heath along the upland margin, which grade into *Cladium* or *Phragmites* dominated tall herb fen, and thence *Phragmites* and *Typha angustifolia* swamp at the margin of the broad. Some stands of these vegetation types are more influenced by saline water percolating from the broad than others and where this is the case there are a number of halophytic associated species. The acidophilous communities of the upland margin west of Hickling Broad include a number of species which are rare or scarce in the Broads, including *Juncus acutiflorus, Erica tetralix, Calluna vulgaris, Viola palustris, Carex rostrata, Carex canescens, Potentilla erecta* and *Carex echinata.*Wet heath and acid mire communities are very scarce in Broadland and some of the best examples of this type of vegetation are to be found in the Thurne catchment, particularly at Mrs Myhills Marsh. Similar calcifuge communities are found across the watershed, where the Crag outcrops along the fen margin at Catfield Fen. Invasion by birch and gorse scrub is a problem in the drier stands of the calcifuge communities and it is likely that a considerable area of former mire vegetation has already been lost to woodland.

The Thurne catchment is also notable for floating acidophilous communities over the partially terrestrialised former broad basins, which support *Osmunda regalis* and *Dryopteris cristata.* The most species rich and extensive community of this type is to be found immediately northwest of Horsey Mere, where it has survived for more than 50 years. Another well documented community existed south of Blackfleet Broad, but is now no longer present. Here, *Dryopteris cristata* grew *"... in great abundance, so much so it is impossible to walk in the marsh without crushing the fronds; there are thousands of specimens, from minute plants ... to others two feet six inches ..."* Bennett 1904).

The tall herb fen in the Thurne system is species rich, particularly in those areas which are managed for sedge. However, if the *Cladium* beds are left without management a dense litter layer builds up, preventing the survival of smaller species. This build-up of *Cladium* litter also to some extent prevents scrub invasion. Extensive tracts of sedge dominated fen are quite uncommon in Broadland and the vast area of this type of vegetation which is found at Brayden Marshes should be regarded as one of the most important features of interest at this site.

Brayden Marshes is of particular interest, for the presence of thriving colonies of *Osmunda regalis* and *Dryopteris cristata* which grow on floating rafts of vegetation just above the range of the tidal fluctuations.

Scrub and carr communities are less frequent here than in many other sites in Broadland, the reasons for which have been mentioned briefly above. In recent years, the rate of scrub encroachment, particularly into the open fen meadow areas, has increased greatly, however, and many areas of species rich fen meadow have been lost. This is very noticeable to the west and south of Hickling Broad, which formerly had extensive fen meadow communities.

Together, the Thurne fens comprise one of the more interesting and botanically diverse areas in Broadland, with a unique character which is dependant entirely upon the balance between the saline water percolating from the sea and acid water seeping from the Crag aquifer. Many of the communities found in this catchment are present nowhere else in Broadland.

Most of the traditional fen management practices are now no longer carried out, but reed and sedge are still cut commercially, including at Hickling Broad Marshes, Brayden Marshes and Meadow Dyke. Martham Broad Marshes are managed almost in their entirety for reed and sedge and as a result are virtually scrub free and of higher botanical interest than many of the neighbouring fen areas.

The Muckfleet Valley

The Trinity Broads fen complex, which includes fen meadow vegetation at Burgh Common and Hall Farm Fen, Hemsby, is located at the head of the Muckfleet, which drains into the River Bure. The broads in this group are some of the deepest in Broadland, having been cut down to over 4 m in depth in some places. The sides of the basins shelve steeply, giving little scope for the development of marginal fen communities over the broad basins, although there is a narrow band of reedswamp and where clearance of scrub and carr has taken place, there are some areas of tall herb fen.

The fens in this area have a peat substrate, beneath which are sands and gravels. The Crag appears to be the principle source of groundwater and in the past there were large areas of acidophilous mire vegetation adjacent to the broads, along the springline, supporting a number of unusual or scarce fen species, including *Carex trinervis* and, in areas previously cut for peat, *Tephroseris palustris*. There is no discharge of any effluent into this group of broads, which are protected for public water supply.

One of the more unusual features of this area is the presence of an intact fringe of swamp vegetation around the margins of the broads, with swamp communities dominated by *Cladium mariscus* and *Schoenoplectus lacustris* in addition to the more typical *Phragmites australis* and *Typha angustifolia*. The *Cladium mariscus* dominated communities are more frequent in the southern part of the Trinity complex and are particularly common around the margins of Rollesby Broad. In contrast, *Schoenoplectus lacustris* is very much more abundant in Ormesby Broad, at the northern end of the system. *Schoenoplectus lacustris* is able to grow in deeper water than *Typha angustifolia* and may be found as a distinct pioneer zone in front of the *Typha* dominated swamp communities.

The fen meadow communities at Burgh Common, Hall Farm Fen and Lily Broad are species rich and contain a number of species of interest. These include *Dactylorhiza traunsteineroides, Hydrocotyle vulgaris, Potentilla erecta, Valeriana dioica, Anagallis tenella* and *Succisa pratensis. Menyanthes trifoliata, Comarum palustre, Stellaria palustris* and *Thelypteris palustris* are found in the wetter parts of Burgh Common which are less closely grazed. Lily Broad Marshes is notable for the presence of *Hypericum elodes*, which grows in open fen vegetation, together with *Anagallis tenella, Sphagnum* spp, *Potentilla erecta, Carex canescens* and *Carex echinata.*

Tall herb fen is not particularly abundant in this area, the largest stands being found close to the Muckfleet Drain in the lower lying parts of Burgh Common and behind the swamp fringe around the margins of the broads, where scrub clearance has increased the area of this habitat type. The tall herb fen supports a number of locally and nationally rare and scarce species, which include *Thyselium palustre, Ranunculus lingua, Lathyrus palustris* and *Sonchus palustris* and is typically dominated by *Phragmites australis*, although there are also large areas of *Cladium mariscus* fen both in the lower lying parts of Burgh Common and occurring as 'islands' within the fen meadow.

The largest area of fen vegetation in this valley system is Burgh Common. This site is unlike any of the other valley fens in Broadland because a large proportion of the area is grazed and part of the remainder is mown on a regular basis. This management, combined with the influence of the slightly acidic irrigating water, has led to the development of a series of unique fen meadow community types. Crag outcrops along the western margin of Burgh Common and there are several small sphagnum-dominated calcifuge spring line developments associated with the fen margin. There are also small areas of open tall herb fen and *Cladium* beds closer to the Muckfleet. *Cladium mariscus* also occurs in association with the several small pits which have been dug in the fen, presumably for peat extraction; only the largest of these, the Little Broad, has open water.

The Bure Valley

The River Bure has a catchment which extends across north-east Norfolk. There are four major tributaries in addition to the rivers Ant and Thurne. Water quality in the river is generally good relative to some of the other Broadland rivers. While a large number of waste water treatment works discharge into the River Bure and its tributaries, the majority have had phosphate-stripping equipment installed.

Upstream of Wroxham, much of the open fen area has developed from abandoned grazing marshes and below Wroxham it has been historically maintained as open fen by traditional management practices such as reed, litter and sedge cutting. The main fen areas adjacent to the river are at Woodbastwick, Ranworth and Horning. In addition, there are fen meadows between Coltishall and Belaugh and along Dobbs Beck. There are two isolated fen sites: Upton Fen was separated from the main Bure valley fens through drainage of extensive areas of marshland for agriculture. Decoy Carr lies in a small side valley to the south of Acle.

The open fen area in this valley system has undergone a rapid progression to carr and scrub communities from a formerly extensive open fen habitat of over 1500 ha. Now, only one-third of this area is open fen; the remainder has succeeded to carr. Much of the woodland, however, is itself of great ecological interest, with large areas of alder swamp carr, an unusual community which is virtually restricted to the Bure valley. The Bure valley is unusual in that one of the first woody species to colonise the open fen is *Alnus glutinosa*; in most of the other river valleys *Salix cinerea* is the principle colonist.

The River Bure is one of the less strongly tidally influenced river valleys and is characterised by more species rich fen vegetation than is found in the Yare and Waveney valleys, in places approaching the diversity of the vegetation of the River Ant fens. *Glyceria maxima* is virtually absent, except in some reflooded former pasture sites, and the fens are dominated by *Cladium mariscus, Carex* spp., *Juncus subnodulosus* and *Phragmites australis,* often with abundant *Calamagrostis canescens* on drier ground. *Phragmites australis* is the most commonly occurring dominant. These fens support populations of almost all of the species which are considered to be nationally rare or scarce fen species; *Thelypteris palustris, Thyselium palustre, Lathyrus palustris* and *Carex appropinquata* are particularly abundant. *Sonchus palustris* occurs in the eastern part of the system close to the river and the nationally rare *Liparis loeselii* is found at Upton, albeit in small quantity. *Dryopteris cristata* is quite common in the middle valley. *Potamogeton coloratus* is also found at Woodbastwick growing in the turf ponds and is in addition quite common at Upton. *Pyrola rotundifolia* also occurs quite frequently at Upton Fen. *Thalictrum flavum,* however, is not found in the Bure fens, with the exception of a small colony at Woodbastwick Marshes, which may have been the result of deliberate introduction.

In the least productive, nutrient poor fen areas, the typical dominants *Cladium mariscus* and *Phragmites australis* are, in part, replaced by smaller sedges, such as *Carex appropinquata, Carex nigra, Carex lasiocarpa* and species such as *Schoenus nigricans* and *Eriophorum angustifolium.* Typically, no single species is dominant and low growing species such as *Hydrocotyle vulgaris, Scutellaria galericulata* and *Dactylorhiza* spp. are able to thrive amongst taller vegetation. *Myrica gale* is a frequent colonist of *Cladium mariscus* beds, and some of the fens at Ranworth and Woodbastwick are floristically very similar to those of Sutton Fen.

A large proportion of the fen area in the Bure valley was formerly worked for peat, either during the medieval period, thus creating Wroxham Broad, Salhouse Broad, Hoveton Broads, Upton Broads, Decoy Broad, Malthouse Broad and Ranworth Broad, or during the subsequent phase of shallow excavations which produced the extensive turf ponds which underlie much of the fen area of Woodbastwick Marshes, Horning Hall Marshes and Ranworth Marshes. Almost all of the 18th and 19th century cuttings have now terrestrialised, although a few small pools remain in Woodbastwick Fen at the junctions of dykes. The shallowest of the medieval cuttings, for example Broad Waters at Woodbastwick, have also become completely terrestrialised. Fen, carr and swamp vegetation have colonised the margins of all of the Bure valley broads. The terrestrialised turf ponds and broads support a large number of locally and nationally rare and scarce species and communities.

The NVC S24d, f and g subcommunities are particularly well represented in the Bure valley. The wide range of habitats found here are thought to have developed into their present diverse forms as a result of the complex pattern of management coupled with local variations in the substratum and hydrological regime.

Much of the fen area in the Bure valley has developed upon solid peat, or peat which has been cut down to the brushwood layer for fuel. Downstream of Woodbastwick Marshes an underlying layer of Romano-British marine clay can be found, which usually occurs at about 1.5 m below the fen surface. Where it is exposed by peat cutting, fen communities reminiscent of the brackish *Typha angustifolia* swamp in the Thurne valley fens have developed. These areas support a number of halophytic species, including *Oenanthe lachenalii, Schoenoplectus tabernaemontanii* and *Atriplex* spp., although the lower salinity levels compared with the Thurne system mean that these species are not so widespread or abundant as in the Thurne area.

In areas where the water table is stable relative to the fen surface, sphagnum is able to become established. This provides a suitable habitat for colonisation by birch seedlings, and in places by *Dryopteris cristata*. This species is not as abundant in the Bure valley as it is in the Ant, but strong populations may be found at a number of sites, in particular, Horning Marshes and Woodbastwick Marshes.

The principal aquifer supplying irrigating water to the fens in the middle Bure valley is the Crag, and as a result, the pH in many of the fens is slightly acidic. The exceptions to this are at Crostwick and Dobbs Beck, and the fen meadows upstream of Wroxham, where the Bure has cut down into the Upper Chalk. As a consequence, the fen vegetation in this area receives calcareous spring water from the Chalk aquifer and there are seepage line calcicolous fen meadow communities on some of the steeper slopes. Decoy Carr and Upton Fen also receive water from the Chalk aquifer, and these fens too support a predominantly calciphile vegetation, with strikingly diverse calcareous mire communities at Upton Fen. Upton Fen is also notable for having the only area of open water in the Bure valley with a substantial swamp fringe, the reedswamp at the other Bure valley sites having been lost as a result of erosion and carr encroachment.

Much of the fen vegetation in the River Bure valley is floristically diverse and of high quality. The most important sites from a botanical viewpoint include Upton Fen, Woodbastwick Fens and Marshes, Horning Marshes and Ranworth Marshes. Upton Fen is a spring fed site, isolated from any fluvial influence, and supports a range of calciphile species rich fen and fen meadow communities, including the nationally rare M13c *Schoenus nigricans-Juncus subnodulosus* mire, which has developed over an old decoy pool. There are also large areas of species rich *Cladium mariscus* dominated fen, in which *Schoenus nigricans* occurs abundantly. Until recently, the fen communities north of Upton Broad (Upton Doles) were threatened by progressive scrub and woodland encroachment, and low growing fen species such as *Carex pulicaris* and *Parnassia palustris* were restricted to mown paths. Restoration work has been undertaken and the Doles are beginning to recover some of their former interest.

Woodbastwick Marshes, in contrast, is a well-managed area of *Cladium* and *Phragmites australis* dominated tall herb fen and fen meadow, with large areas which are mown for litter and support species such as *Pedicularis palustris, Carex appropinquata, Epipactis palustris, Schoenus nigricans* and *Salix repens. Dryopteris cristata* is quite abundant.

In the upper Bure fens and marshes, there are several areas of floristically diverse calcareous grassland transitions to fen meadow and fen, with associated spring line communities; the most important of these sites is at Crostwick Marshes, where species such as *Briza media, Carex hirta, Carex pulicaris* and *Valeriana dioica* grow with *Calliergonella cuspidata* in calcareous flushed communities.

Most of the traditional fen management practices are now no longer carried out, but, in addition to conservation mowing, a small proportion of the Bure valley fens are still managed commercially for reed; the main sites for this are at Ranworth Flood, Ferry Road Fens and alongside the river at Horning Marshes, Ranworth Marshes, and Ward Marsh. *Cladium mariscus* is cut commercially on a small scale at Woodbastwick and at Horning Hall Marshes; the largest areas managed for this product are in the Thurne and Ant valleys.

Only 30% of the formerly extensive fen area in the Bure valley is still open; the remainder is now covered by carr woodland or scrub.

The Yare Valley

The Yare valley fens were once regarded as one of the most important and interesting fen areas in Broadland, being the subject of studies by Dr Joyce Lambert (1946), as well as a regular haunt of the local naturalist Dr Ted Ellis, who lived at Wheatfen (Ellis 1935).

The main part of this fen area consists of large areas of floodplain fen lying on either side of the River Yare at Surlingham and Strumpshaw, with smaller areas upstream at Whitlingham and Thorpe, and downstream at Ducans Marsh, Langley, Buckenham and Limpenhoe. A large area was formerly cut for peat, the most extensive cuttings being at Surlingham Broad, Strumpshaw Broad, Wheatfen and Rockland Broad. There were also several smaller broads near Buckenham Carrs and the basin of an extinct broad lies beneath the carr woodland at Carleton.

The River Yare, which flows through these floodplain fens, is the largest river in Broadland. Upstream of Norwich, the Yare, and its tributary the Wensum, cut through beds of Chalk, which is the reason for its relatively high pH. Downstream of Norwich, the Chalk is capped by an increasingly thick bed of Crag, and so much of the seepage along the margins of the mid-Yare floodplain is slightly acidic. The exception to this is Ducans Marsh, a valley fen which is fed by calcium-rich spring water.

The River Yare is tidal in this area and those fens which have not been embanked are regularly inundated by nutrient rich river water and are consequently eutrophic, with levels of nitrate and phosphate which far exceed those found in the other river systems in Broadland. A large proportion of these nutrients originated from the outfall from Whitlingham waste water treatment works. Although phosphate-stripping technology has now been installed at Whitlingham, the expansion of the Whitlingham works is probably the main reason for both the decline in water quality in the River Yare during the 20th century and the decline in the quality of the fen vegetation in the Yare valley.

The area of open fen covers around 470 ha; there are a further c.420 ha of scrub and carr woodland in the Yare valley. An area of former marshland and fen over three times this size has been converted to grazing and arable land, mostly in the lower reaches of the valley. Most of this conversion took place between the 17th and 20th centuries, although further conversion from grazing land to arable land was made following the Second World War.

Across much of the valley below Norwich is a layer of estuarine clay, capped by a thin layer of peat and alluvium; the clay layer becomes progressively thicker and laterally more extensive downstream, ands covers almost the entire valley floor below Buckenham. Downstream of Limpenhoe, where the land is now predominantly either arable or intensively grazed, a long history of agricultural improvements has led to the replacement of the clays and peats at the surface by a layer of loamy soil. The underlying substratum throughout the Yare valley south of Norwich is Crag, which is found at varying depths below the peat and clay. In some places, the peat layer thins and numerous hard bottomed 'islands' of gravel occur in the Strumpshaw and Wheatfen areas (Ellis 1935). At the fen margins, the peat lies adjacent to the exposed Crag.

The peat in both the Yare and Waveney valleys is intercalated with silt as the result of the regular fluvial flooding and is often well mineralised, producing conditions suitable for *Thalictrum flavum*, which is notably absent from the northern river valleys. The more alkaline substrates encourage the invasion of Sallow in the Yare; Alder is more frequent on the Ant and Bure. Acidophilous species such as *Sphagnum* spp. are not generally found in the Yare floodplain fens.

The fen vegetation in this area is very uniform in comparison with some of the other valleys, with only minor community variations, usually resulting from management activities. This was not always the situation here and Ratcliffe (1977) described this valley as being one of the most important areas in Broadland because of its extensive open mixed fen communities. A large proportion of the open fen area is rank and degraded as a result of neglect and the effects of nutrient enrichment. North of the river, at Strumpshaw, embankment of the fen area has mean that exposure to nutrient rich river water is greatly reduced and the vegetation here is of markedly superior quality to that found south of the river. Ironically, it was, and is, the tidal nature of this fen area that is responsible for the unique qualities of the vegetation, but tidal inundation is also responsible for nutrient enrichment and the consequent invasion by nitrophilous species.

Despite the problems caused by eutrophication, the communities which are still present here, although containing few Broadland rarities, are of interest because of the abundance of *Carex riparia* and *Glyceria maxima*. In most of the other valley systems, *Cladium mariscus* and *Phragmites australis* are the most frequently occurring dominants. *Glyceria maxima* is able to grow both as a rooted fen species and also as a floating mat, which in the most strongly tidal parts of the system will rise and fall with the water, and will colonise quite deep water, invading areas beyond the maximum depth tolerated by a rooted swamp community. This is possibly the reason for the advanced stage of swamp colonisation of Surlingham Broad compared to other broads. *Glyceria maxima* is less common in the Yare than it was formerly; large areas having succeeded to mixed tall herb fen, with associated species including *Urtica dioica, Solanum dulcamara, Lythrum salicaria* and *Stachys palustris*. This change is probably due to natural succession and stabilisation of the fen surface, allowing colonisation by other potential dominants such as *Phragmites australis, Phalaris arundinacea* and *Carex riparia*. Another possible explanation for the decline of *Glyceria maxima* in the Yare valley may be the cessation of summer mowing of *Glyceria maxima* for fodder, which may have allowed the proliferation of *Phragmites australis* which was previously suppressed by a summer mowing regime.

Much of the species interest in this valley has declined over the past 75 years; species such as *Cicuta virosa, Sium latifolium, Lathyrus palustris, Carex appropinquata* and *Thyselium palustre* are now rare here, while the nationally rare species *Dryopteris cristata* has been lost altogether.

On the more solid substrate of the reflooded pastures in the Surlingham and Wheatfen area, *Glyceria maxima* tends to be found closer to the river and dykes than other species, occurring most frequently in and along-side the silted-up dykes, whereas *Phragmites australis* appears to prefer the centre zones of the compartments and in general shows an increase in frequency closer to the upland. The marshes closest to the upland margin formerly supported *Juncus subnodulosus* dominated mowing marshes; these are now very limited in extent, having been lost to scrub or *Phragmites australis* colonisation in the absence of mowing (Lambert 1946). Nevertheless, the Yare valley still supports a diverse range of fen meadow communities, the most interesting being at Buckenham, Strumpshaw and Ducans Marsh. The fen meadow flora varies greatly depending upon the management regime, but a number of nationally and locally rare and scarce species occur in this habitat, including *Epipactis palustris, Parnassia palustris, Danthonia decumbens, Cirsium dissectum, Dactylorhiza praetermissa, Dactylorhiza incarnata, Dactylorhiza traunsteineroides* and *Juncus subnodulosus.*

The relatively eutrophic river water is almost certainly the reason for the invasion of rank vegetation into stands which are closer to the river and species which were once common in the Yare valley, such as *Lathyrus palustris, Sium latifolium, Cicuta virosa* and *Thyselium palustre,* are less frequent, but have increased in recent years.

Cladium mariscus, while never as common in the Yare valley as it is in the Bure, Ant and Thurne (Lambert 1953), is now virtually absent from the fens upstream of Carleton Beck. It was previously not infrequent at Surlingham, Strumpshaw and Wheatfen and at Wheatfen, it was once sufficiently abundant to have a marsh named; "Thack Marsh", the local term for *Cladium mariscus*. Downstream of Carleton Beck, it is only found in areas at some distance from the river, for example at Poplar Farm Fen and Buckenham Fen; both sites which are irrigated by groundwater rather than by water derived from a fluvial source. The water movement which is produced by tidal fluctuations results in an exacerbation of the effects caused by the influence of nutrient rich river water. The daily replenishment of the water in the dykes and broads with a steady supply of nutrient rich fluvial water is highlighted by the presence of numerous nitrophilous plants, such as *Urtica dioica* and *Epilobium hirsutum*, in the immediate vicinity of the dyke network.

Traditional management practices such as commercial reed and sedge cutting are now no longer carried out in the Yare valley fens, but some areas are mown for conservation purposes.

The Waveney Valley

The Waveney valley consists almost entirely of grazing marsh, with very little unreclaimed open fen and carr remaining. Of the fen sites present, the most notable are Barnby Marshes, Sprats Water and White Cast Marshes. There are also species rich fen meadow communities at Oulton Marshes. The fen habitats are fragmented and many formerly botanically important sites, for example Wild Carr and Belton Bog, have been lost as a result of neglect, reduced water levels and agricultural reclamation.

The River Waveney has its source at Redgrave and Lopham Fen and joins the River Yare at Breydon Water, although the two rivers are linked further upstream by the New Cut, which was dug in the 1820s to improve navigation. The Waveney also has a link to the sea through Oulton Broad and Lake Lothing at Lowestoft, further down the coast, via Mutford Lock.

The major nutrient inputs to this wetland system are from waste water treatment works, with runoff from the agricultural land in the catchment being a major contributory factor to the total nutrient budget. Recent figures for phosphate and nitrate levels in this river suggest nitrate levels are higher than they are in any other Broadland river except the Yare. This may be due to a higher proportion of nutrients derived from an agricultural source.

The upper Waveney flows through a landscape of chalky boulder clay, and this means that the river water is rich in calcium compared with the northern Broadland rivers. Downstream of Hoxne, the underlying chalk is capped by glacial sands and gravels, which are exposed along many of the side valleys. In the past, a number of small valley bogs, which had a predominantly calcifuge vegetation could be found in these locations, for example, Belton Bog. These bogs have been lost as a result of water abstraction and the cessation of traditional management.

The fen sites on this river are of importance both because of the different character of the fen vegetation compared with the remainder of the Broadland fen system and because Suffolk as a county has few areas of fen. This also affects the value placed on particular species south of the river, with *Cladium mariscus* and *Myrica gale*, both of which are common in northern Broadland, being regarded as rarities in Suffolk.

In general, much of the fen vegetation in the Waveney valley is in places very similar to that found in the Yare valley, with areas often being dominated by *Glyceria maxima.* The peat in this area and in the Yare valley is often mixed with silt as the result of regular fluvial flooding and is well mineralised, producing conditions suitable for *Thalictrum flavum*, which is notably absent from the northern river valleys.

The Barnby Marshes area is of considerable interest both in the Broadland context and also because of the scarcity of botanically interesting rich-fen sites in East Suffolk. Notable species include *Thyselium palustre, Thelypteris palustris, Carex appropinquata, Carex lasiocarpa* and *Parnassia palustris. Drosera rotundifolia* has been found growing on a sphagnum moss raft near the broad. The site is fed mainly by spring water directly from the upland, or indirectly through a system of dykes, and although the marshes closest to the river receive some water from a fluvial source, the influence of river water is minimal. A range of plant communities is present, some of which have only been recorded from this area. Several of the cattle grazed fields near to the Hundred Drain also support an interesting array of species, including *Briza media, Anagallis tenella* and *Anthoxanthum odoratum*. Local surface acidification has resulted in the development of large sphagnum polsters, which seem able to resist the grazing pressure. Close to the upland margin, tall herb fen may be found associated with spring-fed mire vegetation. In this area *Schoenus nigricans, Carex pulicaris* and *Carex appropinquata* occur quite abundantly in low-growing stands of S24a surrounded by S25b *Cladium mariscus* dominated tall herb fen, which also supports a large population of *Myrica gale*, a locally uncommon species.

In contrast, Stanley and Alder Carrs, further upstream, supports a very different flora, being dominated by carr woodland with small areas of coarse tall herb fen vegetation. This part of the Waveney is tidal and this factor has a profound influence on the parts of the site in immediate proximity to the river, which receive nutrient rich, and sometimes quite brackish water. There is a very obvious deterioration in the quality of the vegetation away from the upland margin, although this should be weighed against the interest derived from the tidal nature of the site. The most commonly occurring vegetation at Stanley and Alder Carrs is very wet, semi-mature carr woodland dominated by *Alnus glutinosa*. The areas of open fen are currently managed by mowing and support mixed tall herb fen. The dominant species are *Phragmites australis* and *Phalaris arundinacea*, with *Epilobium hirsutum, Eupatorium cannabinum, Solanum dulcamara, Thalictrum flavum, Scrophularia auriculata, Lycopus europaeus* and *Mentha aquatica*.

Sprats Water and Marshes are on the lower Waveney floodplain, north-west of Carlton Colville. The site comprises areas of mixed *Carex riparia* and *Phragmites australis* fen, open water, alder carr and wet grazing marsh on deep peat. The fen community is of a type that is common in Broadland but which is rarely found in Suffolk. Maintenance of high summer water levels together with seasonal grazing and reed cutting have led to the development of a very rich flora which includes several uncommon species. Despite its small size, this site nevertheless supports an interesting range of fen meadow species and an area of *Carex paniculata* swamp. The areas of fen meadow are showing a tendency towards acidophilous nucleus development. The flora of these areas includes various *Sphagnum* spp. and *Polytrichum commune*, possibly growing in response to the localised occurrence of slightly acid groundwater, or conversely, depleted calcareous groundwater input. The wet grazing marshes in the northeastern part of the site are dominated by *Holcus lanatus* and *Deschampsia cespitosa*, with a variety of rushes and sedges. *Silene (Lychnis) flos-cuculi, Cardamine pratensis* and *Briza media* are common. The tall fen S24d and S26d communities of Sprats Water are dominated largely by *Phragmites australis* and *Carex riparia*. Characteristic associates include *Typha angustifolia, Ranunculus lingua, Glyceria maxima* and *Thyselium palustre*. Other species which occur occasionally include *Menyanthes trifoliata, Cicuta virosa, Sonchus palustris* and *Lathyrus palustris*.

None of the fen in this valley is cut commercially. There is no commercially viable sedge in this valley, and very little reed. Many of the fens in this area were former rough grazing marsh, and have developed into fen as grazing management lapsed; examples include White Cast Marshes and Barnby Marshes.

Conclusions

A large proportion of lowland wetland sites in Great Britain have been lost or damaged over the past 250 years, mainly as a consequence of the continuing process of land reclamation for farming. In Broadland, which lies at the heart of a region important for its agriculture, this change has been particularly dramatic. Despite this, the Broadland wetlands, comprising fenland, carr woodland and drained marshland, the broads themselves and the associated network of rivers, dykes and waterways, still constitute what is arguably the most ecologically valuable lowland wetland system remaining in the United Kingdom.

The Broadland fens appear to be a natural landscape, but are in fact the result of centuries of interaction between humans and environment. The fenland has been managed or exploited in a number of different ways, including extraction of peat for fuel, cutting reed and sedge for thatch, mowing for litter and fodder, and grazing. The use of fen products varied from small-scale domestic use to large-scale commercial exploitation depending upon prevailing socio-economic conditions.

Factors such as enclosure, land reclamation and the subsequent abandonment of agricultural land have all had a profound influence upon the development of different types of fen vegetation. Changes that took place between the early medieval period and the early 20th century have been particularly significant in influencing the development of the fens.

Perhaps the most significant of the anthropogenic factors influencing vegetation development in Broadland are past peat cutting and land reclamation. Peat cuttings, unless very shallow, resulted in a partial or, in some cases, complete re-initialisation of the process of hydroseral succession. Land reclamation, and the subsequent abandonment of this land has given rise to a range of characteristic fen communities, which provide an interesting contrast to the fen which has developed over solid peat or over turbaries.

In the late 19th century, the pattern and nature of management of the fens changed dramatically. Changing socio-economic conditions, in particular industrialisation, led to the abandonment of many of the traditional management practices. While some, for example commercial reed cutting, have continued, many of the Broadland fens are now managed for nature conservation.

Despite the enormous importance of past management in determining the nature of the vegetation in Broadland, natural succession, however gradual, remains the most potent driving force behind vegetation development. It is important to remember that most, if not all, of the Broadland fen communities are transient successional stages and in the absence of management will progress to carr. The Broadland fen communities at the beginning of the 21st century are undergoing adaptation and succession following the cessation of large-scale exploitation. Modern conservation management is, more often than not, only temporarily arresting the process of succession, and many fen sites have reached a successional stage, where, in the absence of management, they will very rapidly proceed to a climax state.

It is evident that no single factor is sufficient to account for the variety and complexity of fen vegetation communities found in Broadland. Rather, it is the combination of past land use and vegetation management, coupled with complex environmental factors, which have been responsible for the development of the present day mosaic of fen communities.

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APPENDIX. English names of plants referred to in the text.

Alnus glutinosa	Alder
Anagallis tenella	Bog Pimpernel
Angelica sylvestris	Wild Angelica
Anthoxanthum odoratum	Sweet Vernal-grass
Apium graveolens	Wild Celery
Aster tripolium	Sea Aster
Betula pubescens	Downy Birch
Briza media	Quaking-grass
Calamagrostis canescens	Purple Small-reed
Calliergonella cuspidata	Pointed Spear-moss
Calluna vulgaris	Heather
Campylium stellatum	Yellow Starry Feather-moss
Cardamine pratensis	Cuckooflower
Carex appropinquata	Fibrous Tussock-sedge
Carex canescens	White Sedge
Carex diandra	Lesser Tussock-sedge
Carex disticha	Brown Sedge
Carex elata	Tufted-sedge
Carex hirta	Hairy Sedge
Carex lasiocarpa	Slender Sedge
Carex limosa	Bog-sedge
Carex nigra	Common Sedge
Carex panicea	Carnation Sedge
Carex paniculata	Greater Tussock-sedge
Carex pulicaris	Flea Sedge
Carex riparia	Greater Pond-sedge
Carex rostrata	Bottle Sedge
Carex trinervis	Three-nerved Sedge
Cicuta virosa	Cowbane
Cirsium dissectum	Meadow Thistle
Cladium mariscus	Great Fen-sedge
Comarum palustre (Potentilla palustris)	Marsh Cinquefoil
Dactylorhiza incarnata	Early Marsh-orchid
Dactylorhiza praetermissa	Southern Marsh-orchid
Dactylorhiza traunsteineroides	Narrow-leaved Marsh-orchid
Danthonia decumbens	Heath-grass
Deschampsia cespitosa,	Tufted Hair-grass
Drosera rotundifolia	Round-leaved Sundew

Dryopteris cristata	Crested Buckler-fern
Epilobium hirsutum	Great Willowherb
Epipactis palustris	Marsh Helleborine
Erica tetralix	Cross-leaved Heath
Eriophorum angustifolium	Common Cottongrass
Eupatorium cannabinum	Hemp-agrimony
Filipendula ulmaria	Meadowsweet
Galium palustre	Marsh-bedstraw
Glyceria maxima	Reed Sweet-grass
Hippuris vulgaris	Mare's-tail
Hydrocotyle vulgaris	Marsh Pennywort
Hypericum elodes	Marsh St John's-wort
Juncus acutiflorus	Sharp-flowered Rush
Juncus maritimus	Sea Rush
Juncus subnodulosus	Blunt-flowered Rush
Lathyrus palustris	Marsh Pea
Liparis loeselii var. loeselii	Fen Orchid
Lycopus europaeus	Gypsywort
Lysimachia vulgaris	Yellow Loosestrife
Lythrum salicaria	Purple-loosestrife
Mentha aquatica	Water Mint
Menyanthes trifoliata	Bogbean
Molinia caerulea	Purple Moor-grass
Myrica gale	Bog-myrtle
Myriophyllum spicatum	Spiked Water-milfoil
Oenanthe lachenalii	Parsley Water-dropwort
Osmunda regalis	Royal Fern
Parnassia palustris	Grass-of-Parnassus
Pedicularis palustris	Marsh Lousewort
Phalaris arundinacea	Reed Canary-grass
Phragmites australis	Common Reed
Polytrichum commune	Common Haircap (moss)
Potamogeton coloratus	Fen Pondweed
Pyrola rotundifolia	Round-leaved Wintergreen
Ranunculus lingua	Greater Spearwort
Rumex hydrolapathum	Water Dock
Salix cinerea	Grey Willow
Salix repens	Creeping Willow
Samolus valerandi	Brookweed
Schoenoplectus lacustris	Common Club-rush
Schoenoplectus tabernaemontanii	Grey Club-rush
Schoenus nigricans	Black Bog-rush
Scrophularia auriculata	Water Figwort
Scutellaria galericulata	Skullcap
Silene (Lychnis) flos-cuculi	Ragged-Robin
Sium latifolium	Greater Water-parsnip
Solanum dulcamara	Bittersweet
Sonchus palustris	Marsh Sow-thistle
Sphagnum fallax	Flat-topped Bog-moss
Sphagnum squarrosum	Spiky Bog-moss
Stachys palustris.	Marsh Woundwort
Stellaria palustris	Marsh Stitchwort
Succisa pratensis	Devil's-bit Scabious
Thalictrum flavum	Common Meadow-rue
Tephroseris palustris	Marsh Fleawort
Thelypteris palustris	Marsh Fern
Thyselium (Peucedanum) palustre	Milk Parsley
Typha angustifolia	Lesser Bulrush
Urtica dioica	Common Nettle
Utricularia spp.	Bladderwort spp.
Valeriana officinalis	Common Valerian
Viola palustris	Marsh Violet

Recent records of marine algae (seaweeds) in Norfolk including species new to the county and a compilation of county records

Dawn Watson

Introduction

It is widely believed that relatively few species of larger marine algae (seaweeds) can be found along Norfolk's coast. Indeed, in the *Seasearch Guide to Seaweeds of Britain and Ireland* (Bunker et al. 2010) the distribution maps for most species show nothing from Kent to Yorkshire. This is often attributed to the lack of hard substrates but, although rocky shores are largely absent in Norfolk, the recent appreciation by naturalists of the extent of the chalk reef lying just offshore is changing this perception (Spray & Watson 2011). Interestingly, Chapman (1937) in his comprehensive 'revision' of Norfolk's marine algae stated that 'many species have been washed up repeatedly at Runton and Cromer indicating that there must be a [large flint] bed offshore similar to that off Scolt Head Island.' However, the paucity of marine alga species in Norfolk must not be overstated as Chapman (1937) reported over 200 species from the county (see Appendix) compared with around 400 for the Isle of Man. The current checklist of British seaweeds (Hardy et al. 2003) lists 642 taxa for Britain. A large number of Chapman's species were collected from the creeks and saltmarshes of north and north-west Norfolk.

The recognition of the offshore chalk reef as an important site of biodiversity, and the suspicion that the paucity of recent Norfolk seaweed records was in part due to under-recording, led to the launch of the Seaweed East exploration.

The Norfolk chalk reef

Traditionally, recreational diving in Norfolk has focused on wrecks, and although local fishermen have known about the offshore chalk, its richness as a habitat had not been appreciated by naturalists until investigations by Rob Spray and Dawn Watson revealed its importance. In 2010 they initiated a survey conducted under the auspices of the Seasearch project to encourage amateur divers to record flora, fauna and habitats.

This survey revealed that the Norfolk chalk reef stretches for at least 20 miles along the North Norfolk coast, from Cley in the west to at least Trimingham in the east. It extends more than three miles out to sea at Cromer and can be seen forming rock pools on the shore at West Runton and Robin's Friend, Sheringham. As a seabed, it varies from a flat plain (often overlaid with cobbles and boulders of flint or a thin veneer of mobile sand) to features up to three metres high. In some areas, such as Overstrand or Cley, there are additional areas of glacial clay which can form dramatic topography.

The varied landscape of chalk provides ideal conditions for a wide range of seaweed species, creating spaces with different current, light and salinity levels, often within a very small area. The large boulders of flint also provide varying light levels and shelter.

Seaweed East

The aim of Seaweed East was to undertake an east coast shore- and sea-based seaweed recording survey using field specialists and local expertise in order to increase the number of records for the otherwise under-surveyed East coast. The programme was coordinated by founding members of Seasearch East, Rob Spray and Dawn

Watson who assembled a team of surveyors and arranged support by experts.

The survey team began in Essex on the Blackwater Estuary on Monday 1 August 2011 and travelled north along the east coast to reach its most northerly destination of Holy Island, Northumberland on 10 August. In total, the team explored 11 locations in 10 days across Essex, Suffolk, Norfolk, Lincolnshire, Yorkshire, Durham and Northumberland

Samples were gathered on dives, by searching the shore and hanging over the edges of marinas, the latter providing most of the alien invasive species. In Norfolk, only attached 'live' seaweeds were recorded to avoid any uncertainty regarding the location of origin, but drift species were recorded in Lincolnshire where sample numbers were lower. Deteriorating weather during the survey meant that only shore samples were taken for Northumberland, which would have had a much higher diversity if diving had been possible. All seaweeds were verified by seaweed expert Dr Lin Baldock in the field then and confirmed by Dr Ian Titley and Professor Juliet Brodie at the Natural History Museum after the survey.

A total of 137 species of alga were recorded, 58 of them in Norfolk. These are listed, with notes, in Tables 1-3. Examples of each species were collected, pressed and scanned to produce the illustrations on pp. Additional illustrations will be found in Watson & Spray (2015).

General descriptions

Seaweeds are traditionally divided into three groups according to their colour: red (Rhodophyta), brown (Phaeophyta) and green (Chlorophyta) although it is now accepted that these groups are not closely related to each other.

Red seaweeds

The red seaweeds are the most diverse and ancient group, with over 350 species known in the UK. The red colour is due to a larger amount of red phycobilin pigments that mask the green of chlorophyll pigments. These pigments absorb the blue and blue-green frequencies of light which penetrate deep water, and allow red algae to carry on photosynthesis at greater depths than other organisms.

Red algae may be bleached by sunlight or turned brown by decomposition once they are no longer attached. It is therefore always worth considering that a specimen might well be a red alga even if it appears brown, green or yellow, but often the original colour will be found nearer the base.

Pink encrusting or 'pink paint' weeds are hard due to the presence of calcium carbonate in the thallus and resemble splashes of pink paint on boulders and pebbles. Two species can exist together in a 'mixed' state which renders them almost impossible to tell apart without DNA analysis. Maerl is a free-living calcified seaweed that looks like pink jacks or twiglets. It forms large loose piles in sheltered areas and is an important habitat in itself, with a range of inhabitants not found elsewhere. The calcified seaweed most widely found in pools on rocky shores is Common Coral Weed which is shaped more like a 'normal' seaweed with branches displaying a herringbone pattern.

Pincer weeds are small, delicate, branching reds attached to rock or other algae in rockpools which appear insignificant until a hand lens reveals their true beauty. Most are striped in red and pink like a pair of cartoon stockings and have the ends of each branch curled inwards to form pincers or love hearts.

Siphon weeds can vary enormously in size, but are usually composed of a large central cell surrounded by a selection of smaller tubular cells, or siphons. The number and arrangement of these is used to separate species and look like tiny flowers if cut into slices and examined with a hand lens.

Feathery reds are the most attractive seaweeds and make the most rewarding

Table 1. Red algae recorded in Norfolk 2011-2015.

Scientific name	English name	Sites in Norfolk	Distribution in British Isles (Bunker et al. 2010) unless stated
Aglaothamnion byssoides (= *A. tenuissimum*)		Hunstanton	Widespread but rarely recorded (Hardy et al. 2003)
Ahnfeltia plicata	Black Scour Weed**	Several sites	Widespread and common
Brongniartella byssoides	Brongniart's Thread Weed**	Sheringham Arches	Widespread and common
Calliblepharis ciliata	Beautiful Eyelash Weed**	Several sites	S and W. Not recorded on E coast N of Kent
Calliblepharis jubata	False Eyelash Weed**	W Runton	S and SW. Not recorded on E coast or W of Hants
Ceramium echionotum	Simply-spined Banded Pincer Weed**	Sheringham shore; E and W Runton	Widespread but overlooked
Ceramium pallidum	Banded Pincer Weed**	Hunstanton Sheraton	W and SW. Rarely recorded and not previously on E coast (Hardy et al. 2003)
Chondria dasyphylla	Diamond Cartilage Weed**	Sheringham Arches and East Runton	Rare on E coast. Previous Norfolk record most northerly on E coast
Chondrus crispus	Irish Moss, Carragheen**	Several sites	Widespread
Corallina officinalis	Common Coral Weed**	E and W Runton	Widespread
Cryptopleura ramosa	Fine-veined Crinkle Weed**	E Runton	Widespread except Lincs and E Anglia where scarce
Cystoclonium purpureum	Purple Claw Weed**	West Runton and Sheringham	Widespread except Lincs and E Anglia where scarce
*Drachiella heterocarpa**	Callused Drachiella	West Runton	S and W. Not recorded between IoW and Northumberland
Erythroglossum laciniatum	Flat Tongue Weed**	Sheringham Arches	Mainly W and S. Pre-190 record from Norfolk
*Furcellaria lumbricalis**	Clawed Fork Weed**	Several sites	Widespread
Gastroclonium reflexum	Reflexed Grape Weed**	E Runton	SW only. No records east of IoW or from E coast
Gelidium cf *pusillum*	Dwarf Gelidium	West Runton	Widespread but often misidentified (Hardy et al. 2003)
Gracilaria gracilis	Slender Wart Weed**	Several sites	Widespread
Gracilariopsis longissima	Long Wart Weed**	Hunstanton	Rarely recorded. Only from Kent on E coast
Griffithsia corallinoides	Mrs Griffiths's Coral Weed**	E Runton and marinas	S and W. No records between Kent and N Scotland
*Gymnogongrus crenulatus**	Norwegian Fan Weed	Several sites	S and W. No records north of Kent.
Halarachnion ligulatum	Sea Spider Weed**	Sheringham Arches	S and W. No records between Sussex and Northumberland
Halurus equisetifolius	Sea Horsetail**	Several sites	Widespread
Halurus flosculosus	Mrs Grifiths's Little Flower**	Several sites	Widespread
Heterosiphonia plumosa	Siphoned Feather Weed**	Several sites	Widespread but Norfolk records were pre-1950

[continued over

Table 1. **Red algae recorded in Norfolk 2011-2015** (continued).

Scientific name	English name	Sites in Norfolk	Distribution in British Isles (Bunker *et al.* 2010) unless stated
Holmsella pachyderma		On *Gracilariopsis* at Sheringham Arches	S and W. Uncommon but under-recorded (Hardy *et al.* 2003)
Hypoglossum hypoglossoides	Under Tongue Weed**	Sheringham Arches	Widespread but Norfolk records were pre-1950
Mastocarpus stellatus	Grape Pip Weed**	W Runton	Widespread but few E Anglian records
*Osmundea oederi**	Brittle Fern Weed**	E Runton	S and W. No E coast records
Phylophora pseudoceranoides	Stalked Leaf Bearer**	E and W Runton	Widespread but Norfolk records were pre-1950
Plocamium cartilagineum	Cock's Comb**	Several sites	Widespread
*Plumaria plumosa**	Soft Feather Weed**	Several sites	Widespread
Polyides rotundus	Discoid Fork Weed**	Several sites	Widespread
Polysiphonia devoniensis	Devon Siphon Weed	Sheringham Arches	S and W. No E coast records. Probably under-recorded
Polysiphonia elongata	Elongate Siphon Weed**	Several sites	Widespread
Polysiphonia fucoides	Black Siphon Weed**	E and W Runton	Widespread
Polysiphonia nigra	Twisted Siphon Weed**	E Runton	Widespread
Polysiphonia stricta	Pitcher Siphon Weed**	Sheringham Arches	Widespread
*Pterothamnion plumula**	Bushy Feather Weed**	Several sites	Widespread
Rhodomela confervoides	Straggly Bush Weed**	Sheringham	Widespread
*Rhodophyllis divaricata**	Leafy Rose Weed	East Runton	Widespread but few E coast records
Rhodothamnionella floridula	Sand Binder**	E Runton	Widespread
Rhodymenia ardissonei	Spiky Rose Weed	Several sites	W and sporadically to Hants. No E coast records
Rhodymenia holmesii	Holmes's Rose Weed**	Sheringham Arches, Cley	Only Kent and Flamborough Head on E coast
Rhodymenia pseudopalmata	Rosy Fan Weed**	Sheringham Arches,	No previous records between Kent and Yorks
*Schottera nicaeensis**	Shaded Weed**	East Runton	S and W. Only Kent and Flamborough Head on E coast
Scinaia furcellata	Southern Scina's Weed**	Sheringham	S and W. Pre-1950 record is only one from E coast
Spermothamnion repens	Dillwyn**	Several sites	Widespread but occasional. (Hardy *et al.* 2003)
Spermothamnion strictum		Sheringham	Rare. S and W only except for single Scottish E coast record (Hardy *et al.* 2003)

* Species not collected during Seaweed East.

** Species illustrated in these Transactions. See Plates 1-8

Note: It was not possible to reliably distinguish Creephorn *Chondracanthus acicularis* from Dwarf Gelidium *Gelidium pusillum* in specimens collected at East8 Runton and West Runton. Neither has been recorded from Norfolk; the former is an uncommon south-western species and the latter is common but, on the east coast, only north of Yorkshire.

Unidentified species of *Ceramium, Gracillaria* and *Porphyria* were also collected together with encrusting coralline species and non-calcareous red crusts.

Table 2. Brown algae recorded in Norfolk 2011-2015.

Scientific name	English name	Sites in Norfolk	Distribution in British Isles (Bunker *et al.* 2010) unless stated
*Ascophyllum nodosum**	Egg Wrack **	Several sites	Widespread
*Chorda filum**	Mermaid's Tresses**	Weybourne	Widespread
Cladostephus spongiosus	Hairy Sand Weed**	Several sites	Widespread
Cutleria multifida (Aglaozonia phase)	Cutler's Many Cleft Weed	E Runton	Widespread. Rare on E coast
Dictyota dichotoma	Brown Fan Weed**	Several sites	Widespread
Fucus serratus	Serrated Wrack**	Several sites	Widespread
Fucus spiralis	Spiralled Wrack**	Several sites	Widespread
Fucus vesiculosus	Bladder Wrack**	Several sites	Widespread
*Halidrys siliquosa**	Sea Oak**	East Runton	Widespread
Ralfsia verrucosa	(encrusting)	West Runton	Widespread but not recorded in E. Anglia (Hardy *et al.* 2003)
Taonia atomaria	Dotted Peacock Weed**	Dominant <5m on reef	S and W. No records between Kent and Yorkshire
*Undaria pinnatifida**	Wakame**	S Norfolk marinas	Invasive, spreading from Solent

* Species not collected during Seaweed East.

** Species illustrated in these Transactions. See Plates 9-10 (pp. 42-43).

*** Banham (2000) reported that *A. nodosum* was displacing *F. vesiculosus* on Wells Harbour walls.

Table 3. Green algae recorded in Norfolk 2011-2015.

Scientific name	English name	Sites in Norfolk	Distribution in British Isles (Bunker *et al.* 2010) unless stated
Blidingia minima		West Runton	Widespread
Bryopsis hypnoides	Variously Branched Mossy Feather Weed**	E Runton	Widespread
*Bryopsis plumosa**	Evenly Branched Mossy Feather Weed	Several sites	
Chaetomorpha linum	Flax Brick Weed**	E and W Runton	Widespread
Cladophora hutchinsiae/ lehmanniana	(Green Branched Weed)** - species not resolved	E Runton	Poorly recorded (Hardy *et al.* 2003)
Cladophora pellucida	Pellucid Green Branched Weed**	Sheringham Arches	Widespread
Cladophora rupestris	Common Green Branched Weed**	W Runton	Widespread
*Derbesia marina**	Silky Thread Weed	Several sites	Widespread but occasional. Only E coast record from Northumberland
Derbesia tenuissima	Thread Weed	Sheringham Arches	Much confused with *D. marina* so distribution unclear (Hardy *et al.* 2003)
Ulva intestinalis	Gut Weed**	E Runton, Hunstanton	Widespread
Ulva lactuca	Sea Lettuce**	Several sites	Widespread

* Species not collected during Seaweed East.

** Species illustrated in these Transactions. See Plates 11-12 (pp. 46-47). Undetermined species of *Cladophora* were also found.

pressings. The branches subdivide into feather, fern and comb shapes, often easily visible to the naked eye in a tray of water. Some, however, are ridiculously delicate and look like red fluff until closely examined. Flat reds generally exist as a simple sheet which can be scalloped, split or further divided.

Brown seaweeds

The brown seaweeds include some of the largest of all the seaweeds with about 150 species around the UK. Their colour is due to the brown pigments fucoxanthin and the olive-green pigment chlorophyll c. Brown seaweeds often have specific niches on the shore and are commonly used to categorise the shore into zones.

Delicate browns make up most of this group, with brown jelly weeds, filamentous browns and others often existing as parasites or epiphytes on their larger cousins. These mostly pass unnoticed on the shore, being either tiny or nondescript.

Wracks are the familiar seashore seaweeds, coating boulders and groynes with slippery fronds, often with air bladders. Wireweed is an invasive alien which outcompetes native species and is spreading around the coast from the south-west. It is very common in Essex, occasional in Suffolk and so far confined to marinas in Norfolk

Kelps are the really big species of algae, with forest kelp growing to over two metres in height. Most are perennial, but some, such as Sugar Kelp, are annuals.

Green seaweeds

The majority of green algae are found in freshwater, but around 100 species can be found in marine and brackish habitats around the UK. Many species exist as single cells, often within the tissues of other plants, but some such as Sea Lettuce can be up to one metre long. Green seaweeds use only chlorophyll pigments and therefore require good levels of light which restricts their distribution to shallow water and well-lit spaces.

Sea Lettuce and gut weeds form the most obvious group on the shore, living as flat sheets, ribbons and tubes only one or two cells thick. They are usually a very bright green and translucent. As the name suggests, they can be eaten, but have a high tolerance for pollution so consumption carries some risk.

Acknowledgements

The North Sea Wildlife Trusts helped to fund and coordinate Seaweed East alongside partners from Norfolk and Suffolk Biodiversity Information Services, The Environment Agency, Durham Heritage Coast, The National Trust, Marine Conservation Society, Hull University, Yorkshire Naturalists' Union, Dove Marine Laboratories and Purling Transport.

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APPENDIX. Provisional checklist of marine algae in Norfolk.

An attempt has been made to bring all Norfolk marine algae records together in this Appendix, compiled by Tony Leech.

In his *Revision of the Marine Algae of Norfolk* in 1937, Chapman included all records for the county known to him at that time, namely those of Geldart (1882), Bloomfield (1908) and Cotton (1929). [See additional references on p. 41.] To these records he added a considerable number made by himself and colleagues in the 1930s. The latter appear to be made mostly by on-shore collection, many on the saltmarshes of the north Norfolk coast. The majority of these have not been recorded since Chapman's time - an opportunity for anyone who wishes to make a contribution without diving. For most of these early records some information about habitat and location is given in Chapman (1937).

There have many taxonomic changes since Chapman's publication and entries in the Appendix are made under the current (December 2015) names given on AlgaeBase, with names used by Chapman where different. Names under which records were originally published are given within square brackets. In the few cases where the name of a taxon used by Chapman is the same as that currently in use but with a different authority, the authorities of both are given.

A *Check-list and Atlas of the Seaweeds of Britain and Ireland*, was published by the British Phytological Society (Hardy & Guiry 2003) and revised in 2006. This publication included maps for the majority of British species at 10 x 10 km resolution. Most of the Chapman records were not, however, included, possibly because of inadequate validation. In order to include as many species as possible known to have been recorded in Norfolk, those for which a Norfolk record exists but were not mentioned in Chapman (1937) have been added (marked Checklist).

New additions to the county list (20 species) made as a result of recent activities by the author, including Seaweed East, have also been added to the table (marked Recent).

Rhodophyta

Acrochaetium endozoicum
Acrochaetium secundatum [*A. virgatulum; A. secundatum*]
Aglaothamnion fasciculatum (noted as needing confirmation) [*Pleonosporium borreri* var. *fasciculatum*]
Aglaothamnion hookeri [*Callithamnion polyspermum*]
Aglaothamnion roseum (Checklist)
Aglaothamnion tenuissimum [*Callithamnion tenuissimum; C. byssoides*]
Ahnfeltia plicata
Apoglossum ruscifolium (Turner) J.Agardh [*A. ruscifolium* Kylin.]
Bangia fuscopurpurea [*B. fusco-purpurea; B.* f. var. *crispa*]
Boergeseniella thuyoides [*Pterosiphonia thuyoides*]
Bonnemaisonia asparagoides
Bostrychia scorpioides (Hudson) Montagne [*B. scorpioides* Kutz.]
Brongniartella byssoides [*B. byssoides*]
Calliblepharis ciliata
Calliblepharis jubata [*C. lanceolata*]
Callithamnion hookeri (Dillwyn) S.F.Gray [*C. hookeri* C.A.Agardh]
Callithamnion roseum
Callophyllis laciniata
Catenella caespitosa [*C. repens*]
Ceramium arborescens
Ceramium deslongchampsii
Ceramium diaphanum [*C. diaphanum.; C. tenuissimum*]
Ceramium echionotum
Ceramium gaditanum [*C. flabelligerum*]
Ceramium pallidum (Recent)
Ceramium rubrum var. pedicellatum
Ceramium shuttleworthianum [*C. acanthonotum*]
Ceramium virgatum (Checklist)
Chondria dasyphylla
Chondrus crispus Stackhouse [*C. crispus* Lyngb.]
Chylocladia verticillata [*C. kaliformis*]
Colaconema daviesii [*Acrochaetium daviesii*]
Compsothamnion thuyoides (Smith) Nägeli [*C. thuyoides* Schmitz]
Corallina officinalis
Corallina rubens Linnaeus [*C. rubens* Ellis & Soland.]
Cryptopleura ramosa [*Acrosorium uncinatum; Cryptopleura ramosum*]
Cystoclonium purpureum (Hudson) Batters[*C. purpureum* Kutz.]
Delesseria sanguinea
Dilsea carnosa [*D. edulis*]
Drachiella heterocarpa (Recent)
Dumontia contorta [*D. incrassata; D. i.* var. *crispata*]
Erythroglossum laciniatum [*Porphyra umbilicalis* var. *laciniata; Polyneura gmelini*]

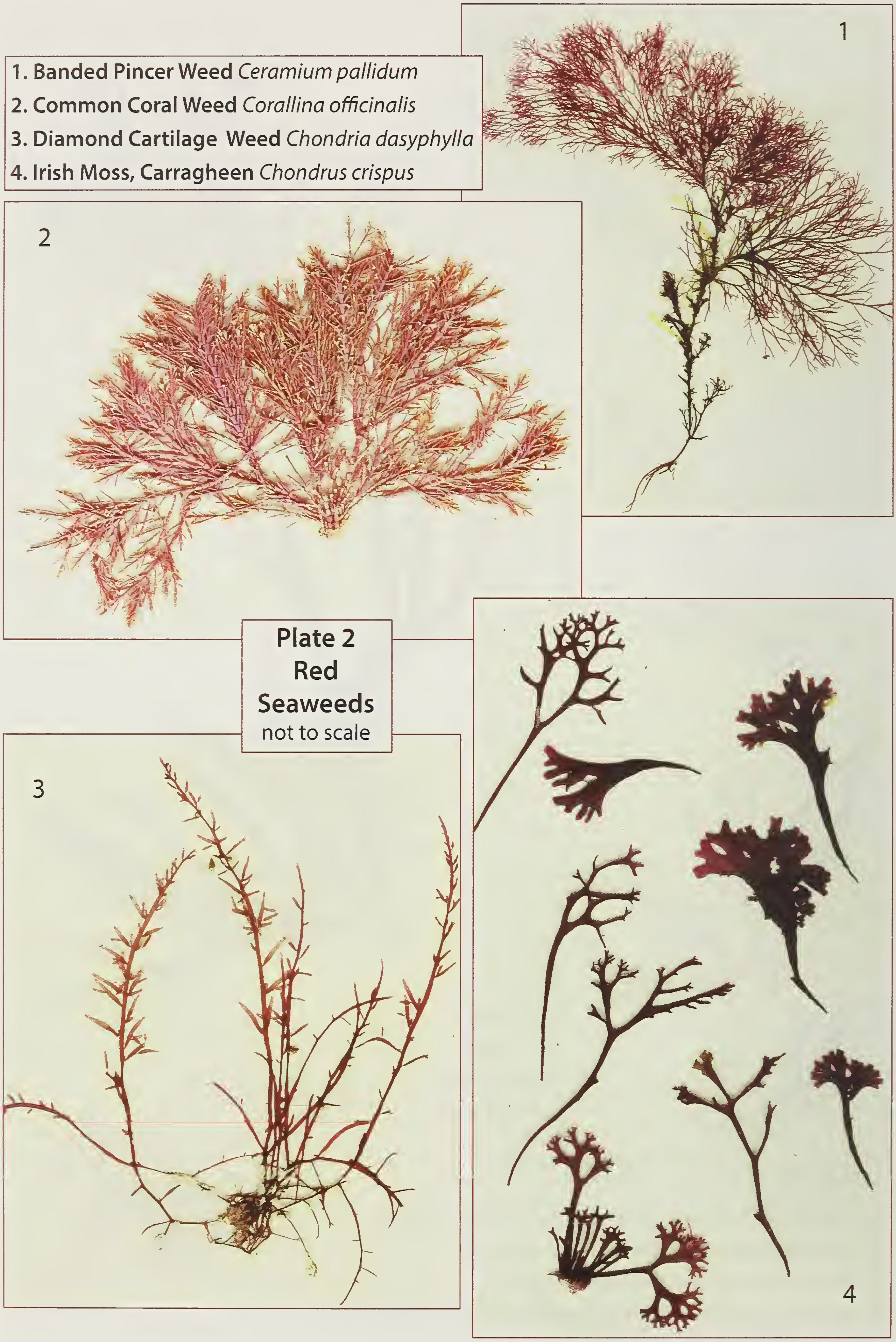
Erythrotrichia carnea [*E. carnea*]
Furcellaria lumbricalis [*F. fastigiata*]
Gastroclonium ovatum [*Chylocladia ovata*]
Gastroclonium reflexum (Recent)
Gelidium corneum
Gelidium crinale (Hare ex Turner) Gaillon [*G. crinale* J.G.Agardh]
Gelidium cf *pusillum* (Recent)
Gracilaria gracilis (Recent)
Gracilariopsis longissima [*Gracilaria confervoides*]
Griffithsia corallinoides (Recent)
Gymnogongrus crenulatus (Recent)
Halarachnion ligulatum (Recent)
Halopithys incurva [*H. incurvus*]
Halurus equisetifolius
Halurus flosculosus [*Griffithsia flosculosa*]
Heterosiphonia plumosa
Hildenbrandia rubra [*H. prototypus*]
Holmsella pachyderma (Recent)
Hydrolithon farinosum [*Melobesia farinosa*]
Hypoglossum hypoglossoides (Stackhouse) Collins & Hervey [*H. woodwardii* Kylin.]
Lomentaria articulata
Lomentaria clavellosa
Mastocarpus stellatus (Recent)
Membranoptera alata (Hudson) Stackhouse [*M. alata* Kylin.]
Naccaria wiggii [*N. wigghii*]
Nitophyllum punctatum
Osmundea hybrida [*Laurencia hybrida*]
Osmundea oederi (Recent)
Osmundea pinnatifida [*Laurencia pinnatifida*]
Peyssonnelia dubyi [*Cruoriella dubyi*]
Phycodrys rubens [*Phyllophora epiphylla*]
Phyllophora pseudoceranoïdes [*P. membranifolia*]
Phymatolithon lenormandii [*Lithothamnion lenormandii* f. *typica*]
Pleonosporium borreri
Plocamium cartilagineum [*P. coccineum*]
*Plumaria plumosa**
Polyides rotunda (Hudson) Gaillon [*Polyoides rotundus* Grev.]
Polysiphonia atlantica [*P. macrocarpa*]
Polysiphonia devoniensis (Recent)
Polysiphonia elongata
Polysiphonia fibrata
Polysiphonia fibrillosa (Dillwyn) Sprengel [*P. fibrillosa* Grev.]
Polysiphonia fucoides [*P. nigrescens*]
Polysiphonia furcellata (C.Agardh) Harvey [*P. furcellata* Hook.]
Polysiphonia nigra
Polysiphonia stricta [*P. urceolata*]
Porphyra linearis (Checklist)
Porphyra umbilicalis [*P. umbilicalis* var. *vulgaris*]
Pterothamnion plumula [*Antithamnion plumula*]
Ptilothamnion pluma
Rhodochorton purpureum [*R. rothii*]
Rhodomela confervoides [*R. subfusca*]
Rhodomela lycopodioides
Rhodophyllis divaricata [*R. bifida*]
Rhodothamniella floridula [*Rhodocorton floridula*]
Rhodymenia ardissonei (Recent)
Rhodymenia holmesii (Recent)
Rhodymenia palmata
Rhodymenia pseudopalmata [*R. palmetta*]
Rubrointrusa membranacea [*Rhodocorton membranaceum*]
Schmitziella endophloea
Schottera nicaeensis (Recent)
Scinaia furcellata (Turner) J.Agardh [*S. furcellata* Bivona.]
Spermothamnion repens [*S. turneri*]
Spermothamnion strictum (Recent)
Stylonema alsidii [*Goniotrichum elegans*]
Vertebrata lanosa [*Polysiphonia fastigiata*]

Phaeophyta

Acinetospora pusilla [*A. pusilla* var. *crinita*]
Alaria esculenta
Arthrocladia villosa
Ascophyllum nodosum
Asperococcus fistulosus
Bifurcaria bifurcata [*B. tuberculata*]
Chaetopteris plumosa
Chorda filum
Chordaria flagelliformis
Cladostephus spongiosus
Cladostephus verticillatus
Colpomenia sinuosa
Cutleria multifida
Cystoseira baccata [*C. fibrosa*]
Cystoseira foeniculacea [*C. discors*]
Cystoseira tamariscifolia [*C. ericoides*]
Desmarestia aculeata
Desmarestia ligulata
Desmarestia viridis
Dictyota dichotoma
Ectocarpus fasciculatus
Ectocarpus hincksiae
Ectocarpus siliculosus [*E. confervoides*]
Ectocarpus siliculosus var. subulosus [*E. confervoides* var. *subulatus*]
Elachistea fucicola [*Elachista fucicola*]
Elachistea scutulata [*Elachista scutulata*]
Eudesme virescens [*Castagnea virescens*]
Fucus ceranoides
Fucus guiryi [*F. spiralis* var. *platycarpus*]
Fucus serratus
Fucus vesiculosus [*F. vesiculosus* var. *divaricatus; F.v.* var. *sphaerocarpus*]
Fucus vesiculosus var. *linearis* [*F. vesiculosus* var. *evesiculosus*]
Halidrys siliquosa
Halopteris filicina (Checklist)
Halopteris scoparia [*Stypocaulon scoparium*]

Plate 1
Red Seaweeds
not to scale

1. **Black Scour Weed** *Ahnfeltia plicata*
2. **Brongniart's Thread Weed** *Brongniartella byssoides*
3. **Beautiful Eyelash Weed** *Calliblepharis ciliata*
4. **False Eyelash Weed** *Calliblepharis jubata*
5. **Simply-spined Banded Pincer Weed** *Ceramium echionotum*



1. Banded Pincer Weed *Ceramium pallidum*
2. Common Coral Weed *Corallina officinalis*
3. Diamond Cartilage Weed *Chondria dasyphylla*
4. Irish Moss, Carragheen *Chondrus crispus*

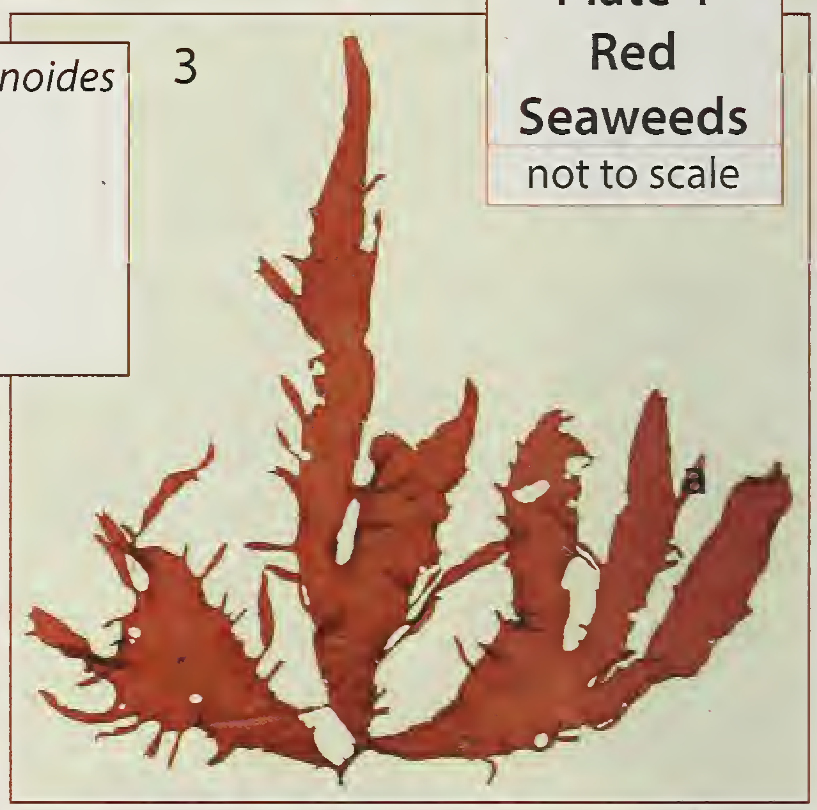
Plate 2
Red
Seaweeds
not to scale

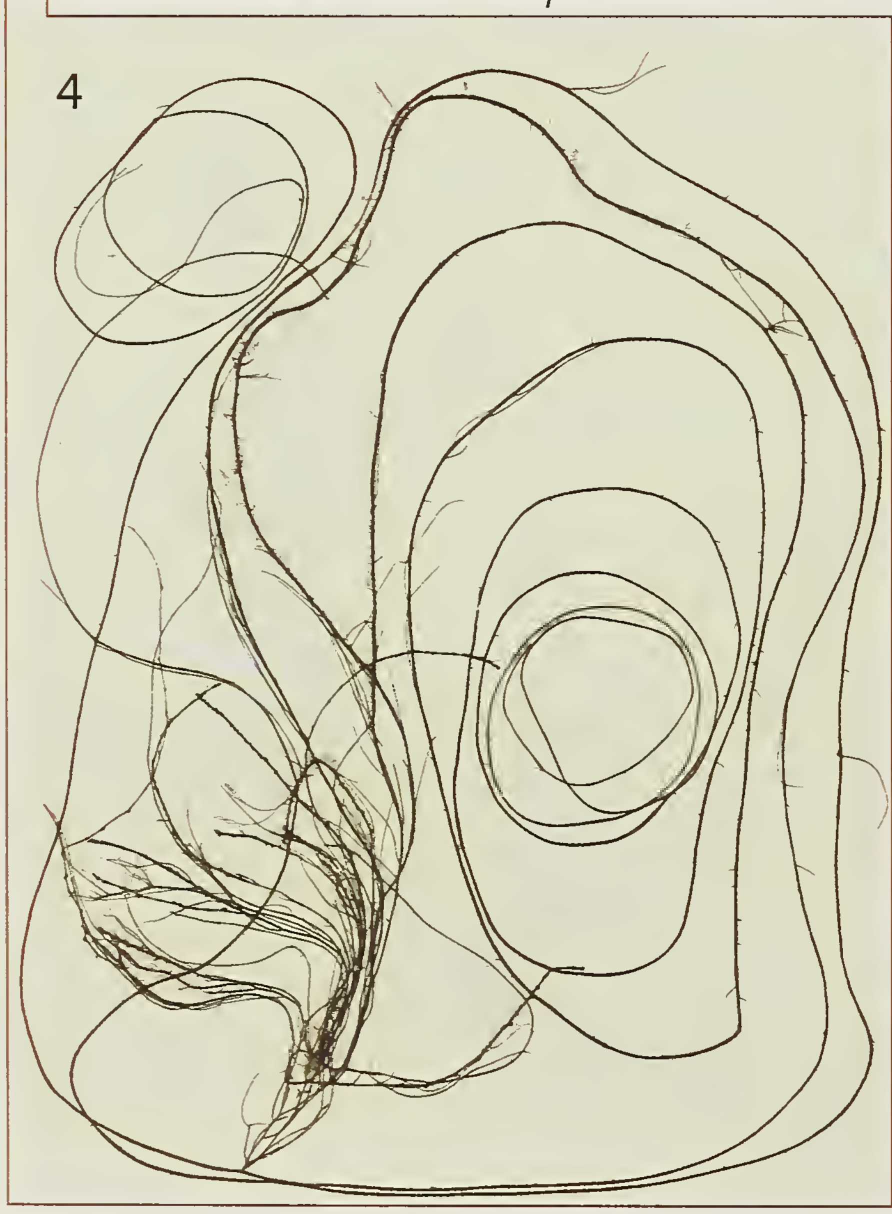
Plate 3
Red Seaweeds
not to scale

1. Clawed Fork Weed *Furcellaria lumbricalis*
2. Flat Tongue Weed *Erythroglossum laciniatum*
3. Reflexed Grape Weed *Gastroclonium reflexum*
4. Fine-veined Crinkle Weed *Cryptopleura ramosa*
5. Purple Claw Weed *Cystoclonium purpureum*

Plate 4
Red Seaweeds
not to scale

1. **Mrs Griffiths's Coral Weed** *Griffithsia corallinoides*
2. **Slender Wart Weed** *Gracilaria gracilis?*
3. **Sea Spider Weed** *Halarachnion ligulatum*
4. **Long Wart Weed** *Gracilariopsis longissima*
5. **Sea Horsetail** *Halurus equisetifolius*





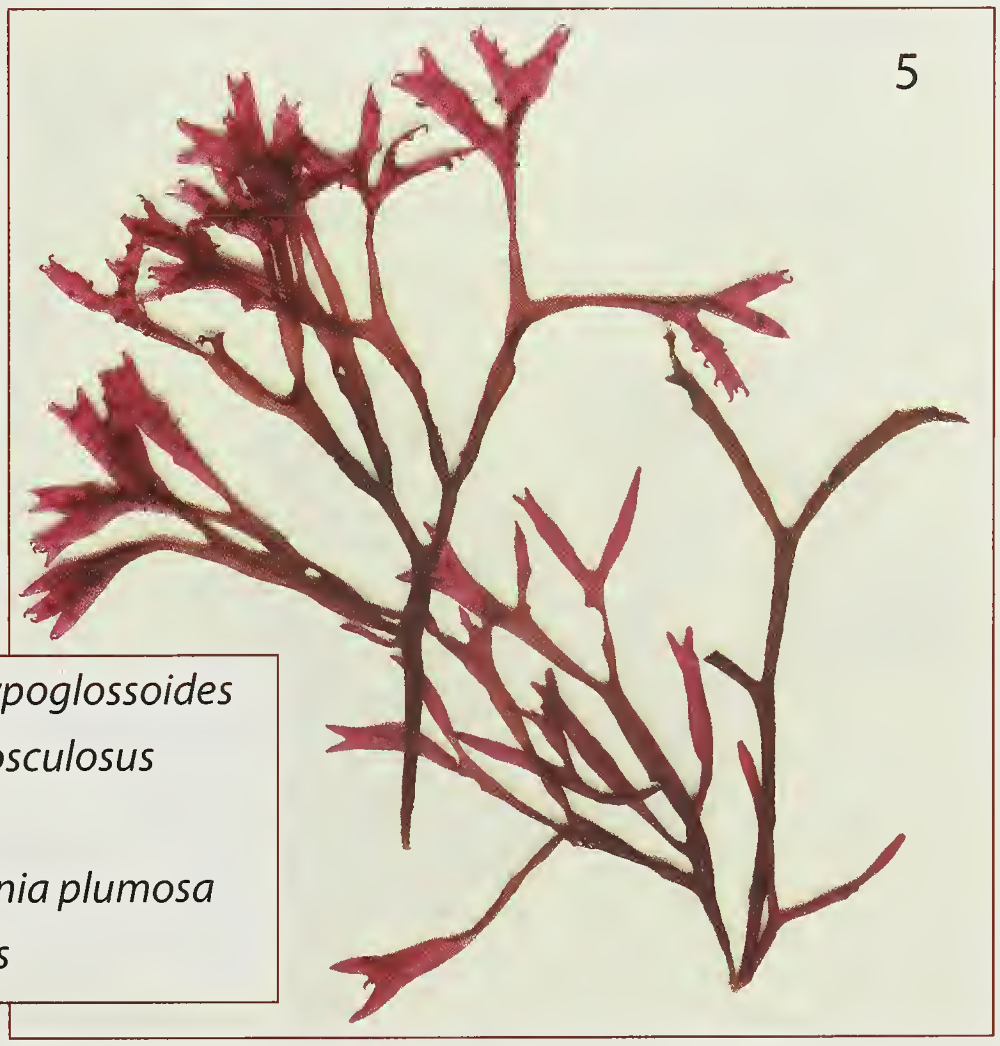


Plate 5
Red
Seaweeds
not to scale

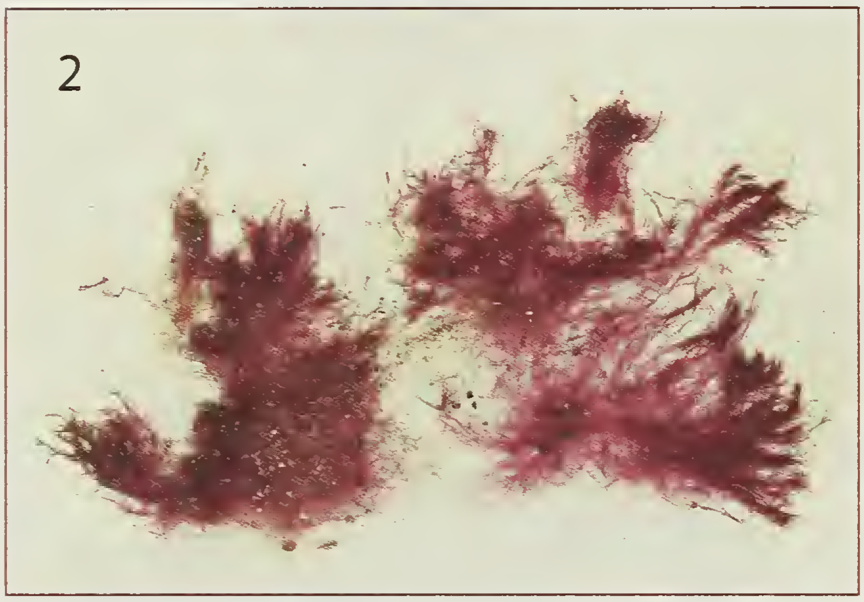
1. Under Tongue Weed *Hypoglossum hypoglossoides*
2. Mrs Grifiths's Little Flower *Halurus flosculosus*
3. Brittle Fern Weed *Osmundea oederi*
4. Siphoned Feather Weed *Heterosiphonia plumosa*
5. Grape Pip Weed *Mastocarpus stellatus*

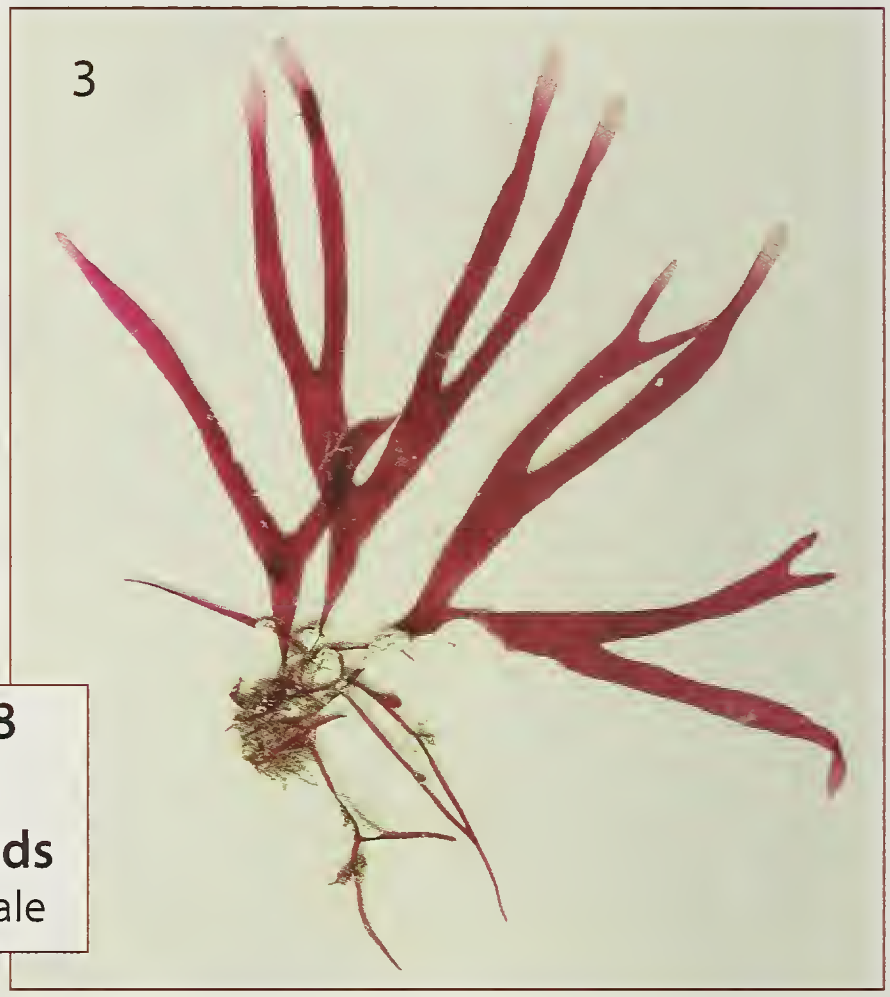
1. **Stalked Leaf Bearer** *Phylophora pseudoceranoides*
2. **Black Siphon Weed** *Polysiphonia fucoides*
3. **Cock's Comb** *Plocamium cartilagineum*
4. **Soft Feather Weed** *Plumaria plumosa*
5. **Discoid Fork Weed** *Polyides rotundus*

Plate 6
Red Seaweeds
not to scale

1. Elongate Siphon Weed *Polysiphonia elongata*
2. Pitcher Siphon Weed *Polysiphonia stricta*
3. Laver *Porphyria* sp.
4. Twisted Siphon Weed *Polysiphonia nigra*
5. Straggly Bush Weed *Rhodomela confervoides*

Plate 7
Red
Seaweeds
not to scale





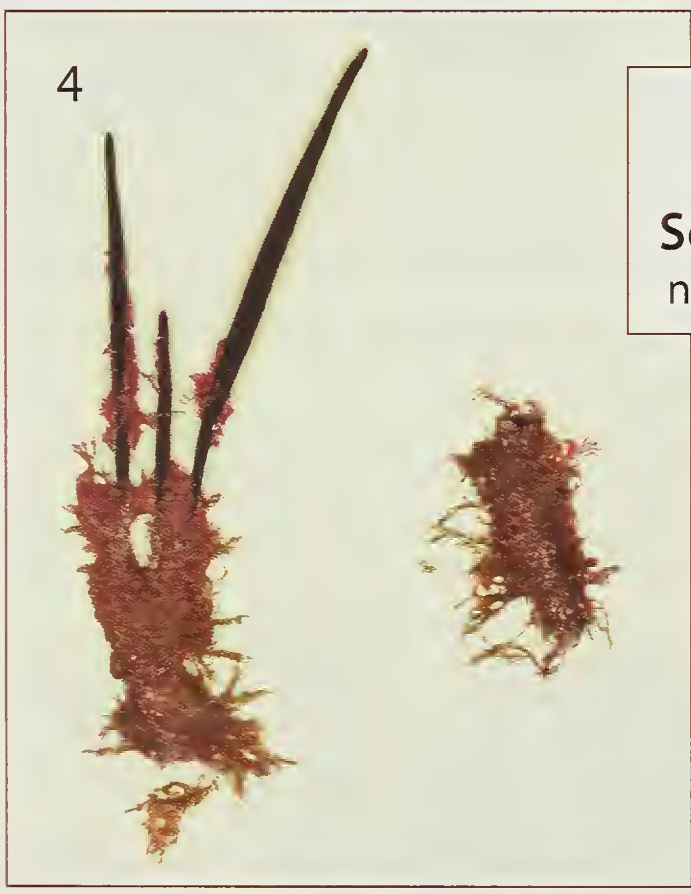
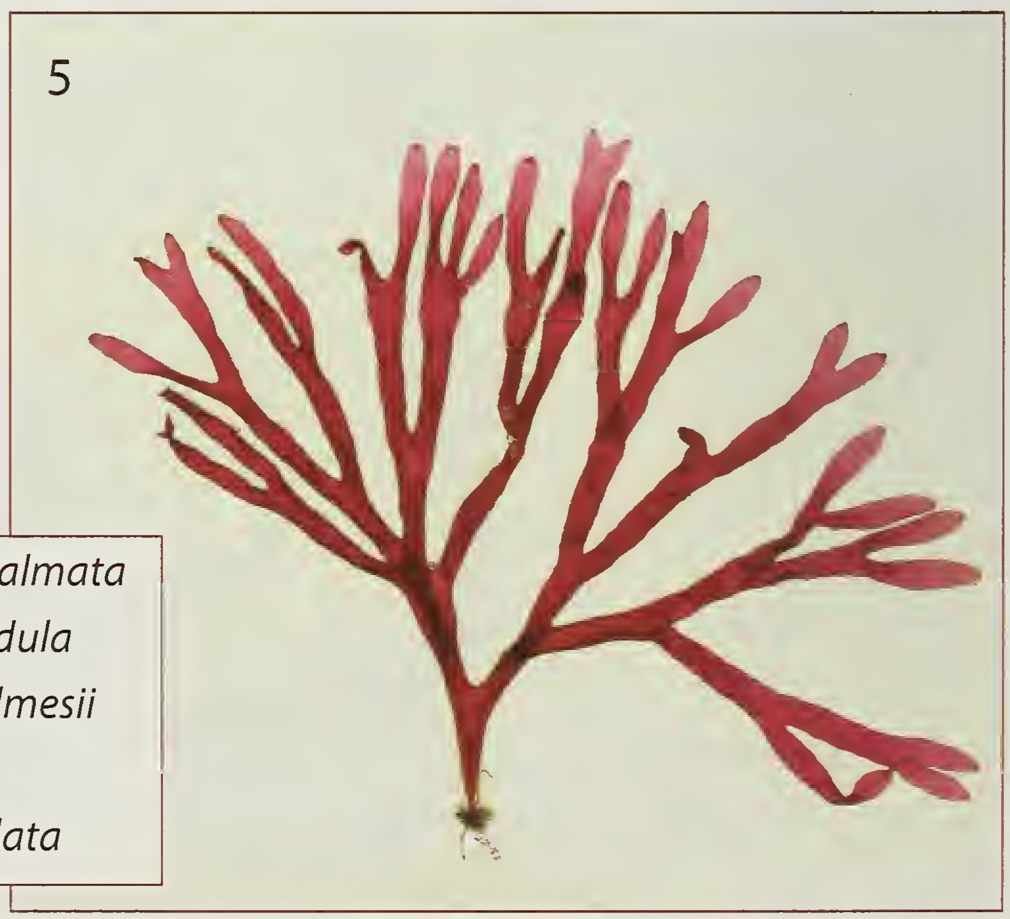


Plate 8
Red Seaweeds
not to scale



1. **Rosy Fan Weed** *Rhodymenia pseudopalmata*
2. **Sand Binder** *Rhodothamnionella floridula*
3. **Holmes's Rose Weed** *Rhodymenia holmesii*
4. **Dillwyn** *Spermothamnion repens*
5. **Southern Scina's Weed** *Scinaia furcellata*

Himanthalia elongata [*H. lorea*]
Hincksia granulosa [*Ectocarpus granulosus*]
Leptonematella fasciculata [*Leptonema fasciculatum*]
Myrionema strangulans
Myriotrichia clavliformis [*M. filiformis*]
Pelvetia canaliculata
Petalonia fascia [*Phyllitis fascia*]
Petaloia zosterifolia [*Phyllitis zosterifolia*]
Pilinia rimosa (Checklist)
Protohalopteris radicans [*Sphacelaria radicans*]
Punctaria latifolia
Punctaria plantaginea
Pylaiella littoralis
Ralfsia verrucosa (Recent)
Saccharina latissima [*Laminaria saccharina; L. s.* var. *phyllitis*]
Scytosiphon lomentaria [*S. lomentarius*]
Sphacelaria cirrosa [*S. cirrhosa* var. *pennata*]
Sphacelaria cirrosa var. fusca [*S. cirrhosa* var. *fusca*]
Spongonema tomentosum [*Ectocarpus tomentosus*]
Sporochnus pedunculatus
Stictyosiphon griffithsianus [*Phloeospora brachiata*]
Stragularia clavata [*Ralfsia clavata*]
Striaria attenuata
Taonia atomaria
Tilopteris mertensii
Undaria pinnatifida (Recent)

Chlorophyta

Acrosiphonia arcta [*Cladophora arcta; C. lanosa*]
Blastophysa rhizopus
Blidingia marginata [*Enteromorpha micrococca*]
Blidingia minima [*Enteromorpha minima*]
Bryopsis hypnoides
Bryopsis plumosa
Chaetomorpha aerea
Chaetomorpha ligustica [*C. tortuosa; Rhizoclonium kochianum* var. *arenicola; R. arenosum*]
Chaetomorpha linum
Chaetomorpha litorea
Chaetomorpha melagonium
Cladophora albida [*C. albida; C. neesiorum* var. *humilis*]
Cladophora flexuosa [*C. gracilis*]
Cladophora fracta [*C. fracta* var. *flexuosa*]
Cladophora glomerata
Cladophora hauckii [*C. fracta* var. *marina*]
Cladophora lehmanniana [*C. utriculosa*]
Cladophora pellucida
Cladophora refracta
Cladophora rupestris
Cladophora sericea [*C. glaucescens*]
Cladophora utriculosa var. *diffusa*
Cladophora vagabunda [*C. expansa*]
Derbesia marina (Recent)
Derbesia tenuissima (Recent)
Enteromorpha chartacea
Enteromorpha compressa f. *subsimplex*
Enteromorpha flexuosa subsp. *pilifera* [*E. prolifera* f. *capillaris*]
Enteromorpha intestinalis f. *flagelliformis*
Enteromorpha intestinalis f. *microphylla*
Enteromorpha prolifera f. *trichodes*
Enteromorpha ramulosa f. *tenuis*
Epicladia perforans
Gayralia oxysperma [*Monostroma crepidinum; M. orbiculatum*]
Gayralia oxysperma f. *wittrockii* [*Monostroma wittrockii*]
Gomontia polyrhiza
Monostroma grevillei
Monostroma latissimum
Monostroma oxyspermum var. laceratum [*M. laceratum*]
Percursaria percursa
Pilinia rimosa
Prasiola stipita
Rhizoclonium riparium [*R. implexum*]
Rhizoclonium tortuosum (Checklist)
Saccharina latissima [*Ulva lactuca* var. *latissima*]
Spongomorpha aeruginosa (Checklist)
Ulothrix flacca [*U. flacca; U. pseudoflacca*]
Ulothrix speciosa
Ulothrix subflaccida
Ulva clathrata [*Enteromorpha clathrata; E. clathrata* f. *gracilis; E. clathrata* f. *prostrata; E. crinita*]
Ulva compressa [*Enteromorpha compressa* f. *complanata*]
Ulva flexuosa [*Enteromorpha intestinalis* f. *tubulosa*]
Ulva flexuosa subsp. *paradoxa* [*Enteromorpha erecta*]
Ulva intestinalis [*Enteromorpha intestinalis* f. *genuina; maxima*]
Ulva intestinalis f. *cornucopiae* [*Enteromorpha intestinalis* f. *cornucopiae*]
Ulva lactuca
Ulva linza [*U. linza* var. *lanceolata*]
Ulva prolifera [*Enteromorpha salina* var. *polyclados*]
Ulva ralfsii [*Enteromorpha ralfsii*]
Ulva torta [*Enteromorpha torta*]
Urospora penicilliformis [*U. isogona*]

Ochrophyta

Gloeocystis adnata [*Phaeococcus adnatus*]
Vaucheria coronata
Vaucheria intermedia (Checklist)
Vaucheria sphaerospora var. *synoica*
Vaucheria submarina [*V. dichotoma* var. *submarina*]
Vaucheria synandra
Vaucheria velutina [*V. thuretii*]

No modern names have been established for the following taxa recorded in Chapman (1937): *Ceramium rubrum* var. *corymbiferum, Enteromorpha compressa* f. *genuina, E. compressa* f. *intermedia, E. intestinalis* f. *crispa, E. paradoxa* f. *tenuissima, E.prolifera* f. *tuberosa, E. ramulosa* f. *uncinata, E. ramulosa* f. *robusta, Polysiphonia violacea.*

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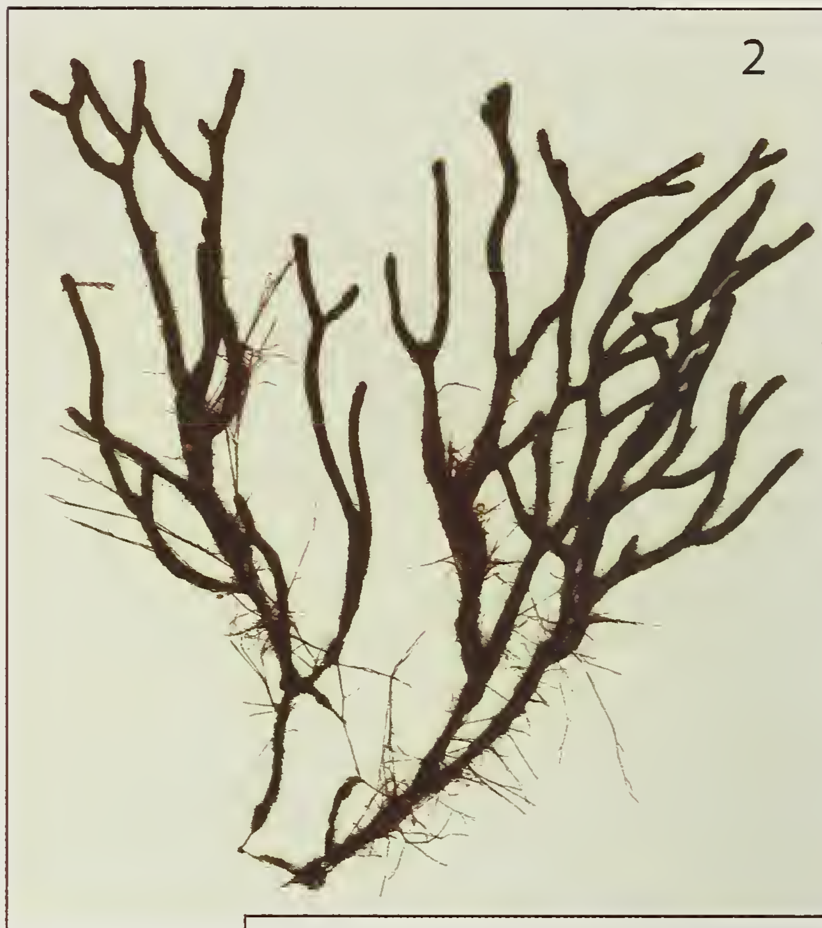


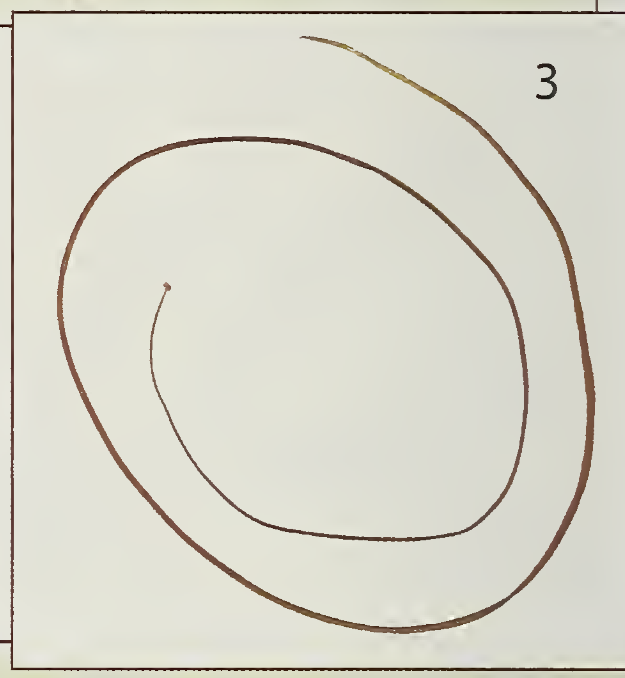
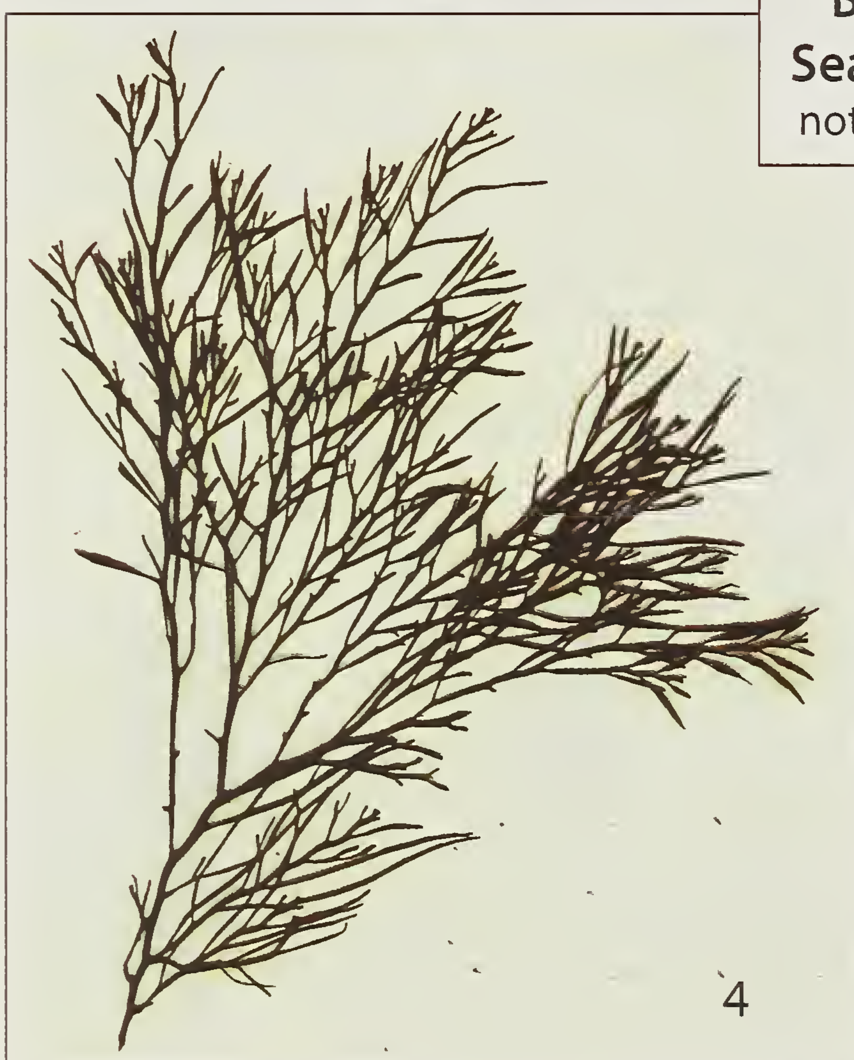


Plate 9
Brown
Seaweeds
not to scale



1. **Egg Wrack** *Ascophyllum nodosum*
2. **Hairy Sand Weed** *Cladostephus spongiosus*
3. **Mermaid's Tresses** *Chorda filum*
4. **Sea Oak** *Halidrys siliquosa*
5. **Brown Fan Weed** *Dictyota dichotoma*

Plate 10
Brown Seaweeds
not to scale

1. Spiralled Wrack *Fucus spiralis*
2. Dotted Peacock Weed *Taonia atomaria*
3. Bladder Wrack *Fucus vesiculosus*
4. Serrated Wrack *Fucus serratus*

The Antlion *Euroleon nostras* at Holkham, Norfolk

Andrew Bloomfield

Introduction

Antlions are insects belonging to the order Neuroptera, a group that also includes the more familiar green and brown lacewings (Chrysopidae and Hemerobiidae). The antlion family, Myrmelenidae, is found throughout much of the world in temperate and warm regions, and in Europe alone 41 species occur, mainly around the Mediterranean (Chinery 1993). In Britain only one species, *Euroleon nostras*, has established itself as a resident and is thought to be a relatively recent addition to our fauna from the near continent. Even more recently, in 2013, a second species, *Myrmeleon formicarius*, has been noted on the Isle of Wight.

The adult Antlion *Euroleon nostras* (referred to below as Antlion) resembles a frail and dainty damselfly or an elongated lacewing, but is seldom seen, being mainly nocturnal. The actions of Antlion larvae are, however, much more likely to catch attention and have long been a subject of great interest due to their fascinating behaviour. See Plate 13, p. 50 for photographs.

The adult Antlion lives most of its short life around the canopy of pine trees, usually descending to the ground only at night to lay its eggs in the sand. From the egg hatches the larva that gives the creature its name. Although measuring just 5-17 mm in length it has proportionally very large jaws protruding from its head, giving the insect its fearsome appearance.The larva forms a small conical pit in the sand using backward movements. Small invertebrates, such as ants, woodlice and spiders, frequently stray into the pits whilst passing. As these are in loose sand, a mini-avalanche of fine sand is triggered and the harder the insect tries to escape, the more sand is disturbed. This ensures that the prey loses its footing, while also alerting the Antlion larva at the bottom of the pit. Once it becomes aware that potential prey is present, it vigorously flicks up more sand, adding to the avalanche effect and further hindering the escape of its prey. If the prey item falls right to the bottom of the pit, then the large jaws of the larva swiftly snatch it and pull it under the sand to be devoured. This involves injecting enzymes which break down its tissues into a fluid that is then extracted to leave the exoskeleton which is discarded. Antlion larvae have evolved forward-facing spines on their legs and bodies, which, whilst limiting their forward motion, enable them to anchor into the ground when any prey items are attempting to escape.

The pits measure up to 25 mm in diameter, but some may appear only as a slight depression in the sand with a steeper forward-facing edge. Usually more than one pit can be found in an area where Antlions are present and these colonies in the sand can easily be found once an observer is aware of what to look for. Not all species of antlion adopt the pitfall trap as part of their behaviour.

It is thought that as the Antlion larvae grow, they pass through at least three instars before making a silk cocoon covered in sand granules that resembles a tiny sandy pea, and finally emerge as adults after about two months. The whole life cycle is generally thought to last two years (Plant 1999).

When adult Antlions emerge from their cocoon in the sand they need to spend time stationary, drying and hardening their wings, much as a dragonfly or damselfly does; this involves them clinging onto the nearest vegetation above their colony. This is the only time when a daytime observation of an adult Antlion is likely and is most likely to happen throughout August into early September during late afternoons and early evenings following a warm day. The problem for the newly emerged adult is that it is initially quite slow and helpless in its movements, sometimes leading to it becoming a victim of its own kind, being dragged into a pit and devoured by a neighbouring larva! Sometimes egg-laying females suffer the same fate (Plant 1999). If this does not happen, and the adult successfully takes to the wing, it soon flutters up in a rather weak damselfly-like flight into the tops of nearby pines, where it then remains, switching to a vegetarian diet of pollen. Sightings are then virtually unheard of as it becomes nocturnal, only venturing low to lay eggs in the sand. The adult is said to live for only approximately 24 days.

British status

Although reports of Antlions in Britain date back to 1781, there seems to be much debate about whether the old records were reliable. Many eminent Victorian naturalists concluded that the species was not actually present and it was not until September 1931 that one was found and collected in a torpid state at Gorleston, although it was not identified correctly as *Euroleon nostras* until 1996 when it was examined at Ipswich Museum. Thereafter the insect remained unrecorded until one was seen and photographed at Corton in Suffolk in 1988, and then in 1994 three adults were found at Minsmere, also in Suffolk. It was not, however, until 1996 that the first larval pits were found when up to 1000 were counted around Minsmere, confirming that the Antlion was a resident British species, albeit possibly a recent colonist. Subsequent reports and a greater awareness showed that pits had actually been present around Dunwich and Thorpeness in 1986 and 1992. Since then, dedicated searching revealed that the species was present along much of the coastal heathland of the Suffolk Sandlings. Moth trappers in Suffolk have frequently caught adult Antlions and in July 2010, one was caught at Yarmouth and was incorrectly heralded at the time in the local press as being the first example to be found in Norfolk as at that time the discovery of a breeding colony at Holkham NNR was not widely known.

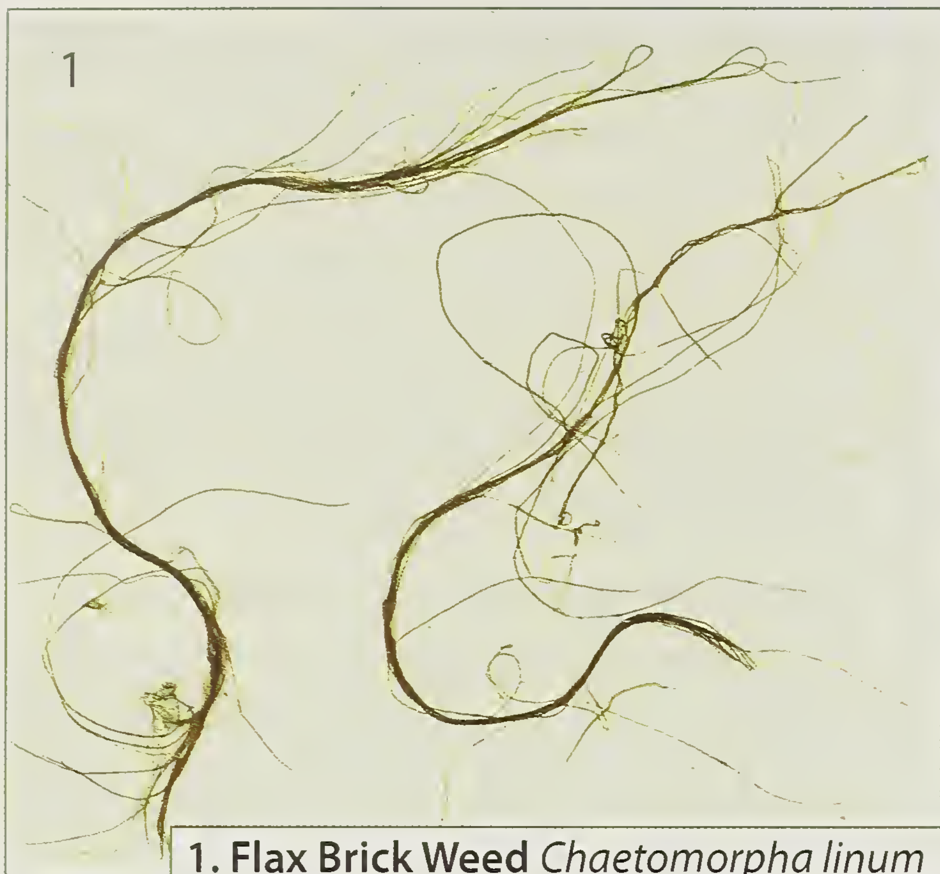
The Antlion at Holkham NNR

With Suffolk remaining the UK's sole region for Antlions during the remainder of the 20th century it was perhaps rather surprising when three larval pits made by an Antlion species were discovered at in the coastal pinewoods of Holkham NNR in 2005 by visiting naturalist Roger Northfield. Although the precise species was not known it was greeted by local naturalists as a most exciting find. The situation remained relatively quiet thereafter until 2008 when a dedicated search and survey began to determine the exact population size, distribution, habitat requirements and also the species of Antlion. As far as reserve staff were aware at this stage, no one had yet seen or positively identified an adult. Work carried out by the author in July-August 2008 established that the species was, as suspected, *Euroleon nostras* following a daytime sighting of an adult on August 23. A surprising total of 719 pits was counted in the year of the first full survey. Table 1 shows the number of Antlion pits counted at Holkham NNR during Natural England/Holkham Estate surveys in July of each year.

Table 1. Number of Antlion pits counted each year.

Year	2008	2011	2012	2013
No. pits	719	1905	1254	848

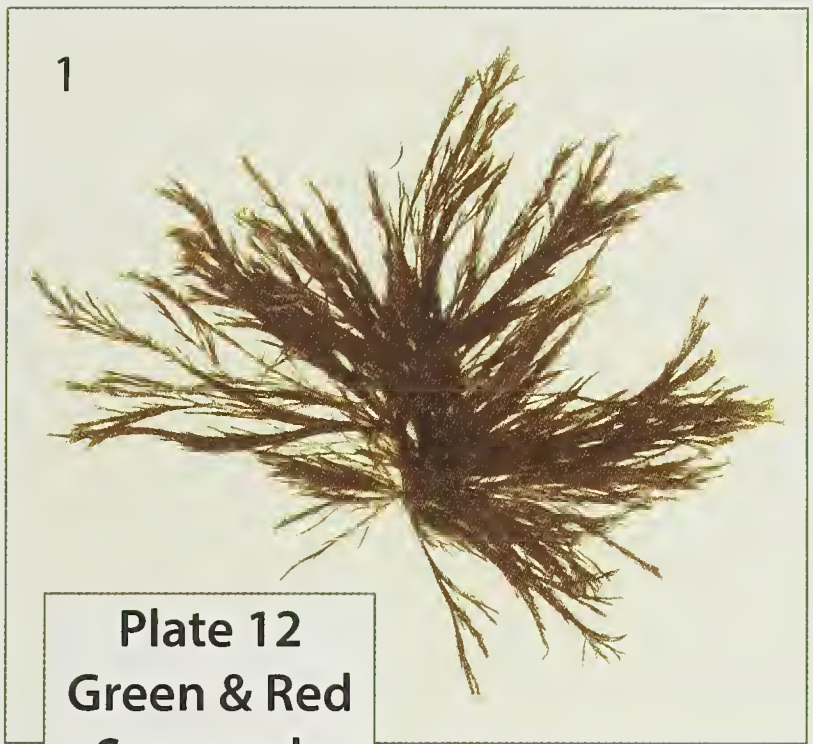
Whilst the numbers recorded in 2012 and 2013 were lower, they both followed cold winters. Summer rainfall was also prevalent prior to the 2012 and 2013



1. Flax Brick Weed *Chaetomorpha linum*
2. Variously-branched Mossy Feather Weed *Bryopsis hypnoides*
3. Wakame *Undaria pinnatifida* [BROWN]
4. a Green Branched Weed *Cladophora hutchinsiae/lehmanniana*

Plate 11
Green & Brown Seaweeds
not to scale

Plate 12
Green & Red Seaweeds
not to scale



1

2

3

4

5

1. Common Green Branched Weed *Cladophora rupestris*

2. Gut Weed *Ulva intestinalis*

3. Sea Lettuce *Ulva lactuca*

4. Pellucid Green Branched Weed *Cladophora pellucida*

5. Shaded Weed *Schottera nicaeensis* [RED] surveys. Both could have had an impact on the population size and hence numbers counted. These counts indicated that the Antlion had become firmly established as a resident but, as in Suffolk, the question remains as to whether the Antlion is a recent addition to the area or was present and undiscovered until an enthusiast who knew what he was looking for stumbled across it.

Individual colonies vary from only a single pit to over 300, making what might seem a sizeable population quite vulnerable. In recording, a single colony is defined as a distinct spot within the wood/dune edge where a 'cluster' of pits is found. These colonies might be as close as a few yards apart (i.e. two neighbouring trees) while others have been as far away as 300 metres from the nearest colony.

The Antlion's habitat at Holkham

The pinewoods at Holkham were planted between 1870 and 1890 in an attempt to stabilize the coastal sand dunes thus adding to the sea defence system and prevent flooding on the reclaimed arable land to the south. The dominant species is Corsican Pine *Pinus nigra* but there are also significant numbers of Maritime Pine *P. pinaster*, Monterey Pine *P. radiata* and Scots Pine *P. sylvestris*, whilst a secondary scrub layer includes birches, willows, oaks, Sycamore and, increasingly, Holm Oaks *Quercus ilex*. Clear patterns emerged when surveying began and the precise needs of Antlions at Holkham soon became apparent.

Sand is an obvious requisite. It is needed for the adults to lay their eggs and for the larvae to make their pitfall traps in. The sand needs to be firm enough for pits to be made, but fine enough for the 'avalanche' effect to be easily generated by struggling prey. Many of the trees in the wood are surrounded by shed pine needles and cones while others are surrounded by thick grass which make them unsuitable sites for pits. The fact that the larval pits are in fine sand also means they are easily disturbed by heavy rain. A visit to a colony after, or during, a wet spell may well result in seeing no evidence at all of Antlions. Most of the colonies are situated on slopes with a southerly aspect; some may face south-west or south-east but very few are actually facing north. An obvious advantage to this is that with more sunlight able to penetrate, the sand in which the colonies are made dries out far more quickly following heavy rain. At Holkham there are many seemingly suitable spots on the north side of the woods that are completely devoid of Antlions. Similarly, much of the interior of the woodland is also unsuitable, being too dense for sunlight to penetrate as freely as it does on woodland edges or clearings where most of the Antlions are found. The very few colonies that do face north are actually within the wood (thus retaining a degree of shelter) in very suitable sand banks and are very close to more established and more typical open south-facing ones.

For Antlion larvae to survive they must make their pits under, or close to, an overhanging object and usually on sloping terrain to enable insect prey to fall in. Success is increased if there is either a natural slope or an obstruction that guarantees a regular source of falling prey. Fallen logs, exposed root plates and the fine sand at the base of large tree trunks are all attractive locations for pits. Similarly, small sandy banks that resemble cliffs in miniature underneath scrub or grass are equally favoured, providing there are trees nearby. With only a few exceptions, the colonies were underneath or very close to Corsican or Maritime Pine trees.

Most of the sites with overhangs and cavities also had spider webs and it was not unusual to find pits immediately below a web. Such a position undoubtedly ensures that any insect lucky enough to escape a web and fall to the ground would ultimately perish at the bottom of an Antlion pit. Spiders themselves are also a regular prey item.

Another seemingly important factor of the Antlion's habitat is disturbance created by man's activities. Some disturbance seems almost essential but too much and the effects are detrimental. Obviously Antlion colonies cannot become established in the middle of a well-walked path but the edges seem ideal. Some man-made objects have even provided the stimulus for Antlion pit formation including a lump of abandoned war-time concrete, the steps of a building and a standing post. So whilst the Holkham Antlion population seems healthy and more widespread than when they were first discovered, the activities of unknowing visitors could have a serious impact on their continued presence as can the activities of rabbits making their burrows in the sand.

Conclusion

With some of the Suffolk colonies containing large numbers of pits (6070 pits were counted in 1998 by Plant (1999)) it seems there is still much room at Holkham for further expansion. Plant's findings were that females lay an average of 20 eggs and that the complete life cycle takes up to two years. With that in mind it could be that Holkham's totals might be the work of just a small number of adults. This could be due to the species recent colonization and it will be interesting to see just how quickly the population increases, if indeed it does. Since the last full survey was carried out in 2013 it seems that the population has slowly begun to expand out into the peripheries of the favoured habitat. Bare patches of loose earth at the edge of rabbit burrows and below bramble bushes in the mid-section of the Meals (where none were recorded in the past) have been colonized by a very small number whilst sheltered south-facing spots under marram grass in the open 'yellow dunes' 200 metres away from the nearest tree have also produced small numbers of pits for the first time in 2015.

With numbers being lower than in Suffolk, the Antlion at Holkham could be described as being a very rare insect in need of regular monitoring and sensible protection efforts. As the Antlion is now firmly established along the Suffolk coast and at Holkham it remains to be seen if it is present at any other sites along this coast. In August 2012, a fresh adult was seen along the coast on an open path beside the marsh edge at Burnham Deepdale. Such a record was perplexing as there would appear to be no suitable breeding habitat nearby.Was it a pioneering adult from Holkham, some three-and-a-half miles to the east? Holme, with a similar habitat to Holkham, would seem an obvious possibility for future colonisation.

Acknowledgements

Thanks must go to the following for their help and enthusiasm in all aspects of the Antlion survey work carried out at Holkham and in the writing of this paper: Jeremy Bishop, Victoria Egan, Sarah Henderson, Tony Leech, James McCallum, Nick Owens, Baz Scampion and Michael Rooney.

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See *www. antlion pit. com* for more information about Antlions.

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1. *(left)*. Adult Antlions can be seen in the daytime when they emerge from pupation before living a short nocturnal life in the canopy of pine trees. See p.44.

2. *(above)*. Note the relatively huge jaws of the larva and its spines, adapted to anchor it in the sand when grappling with its prey.

Plate 13 Antlions at Holkham.

3. *(above)*. Typical antlion habitat within Holkham Meales; open south facing, sandy and undulating terrain amidst mature pine woodland.

5. *(below)*. Pits occupied by Antlion larvae.

4. *(above)*. Antlion larvae live at the bottom of sandy depressions known as 'pits'.

6. *(below)*. What looks like a sand-encrusted pea is actually the discarded pupal case of an Antlion - often seen at colonies in the early autumn. [*Photos*: Andrew Bloomfield]

Plate 14 Great Tachinid. See p. 52.

1. *(above).* **Great Tachinid *Tachina grossa*,** Horsey. *Photo:* Neil Marks.

2. *(below).* **Great Tachinid *Tachina grossa*,** Sheringham Common. *Photo:* Francis Farrow.

Two moths new to Norfolk in 2013. See p. 73.

3. *left).* **Box Moth *Diaphania perspectalis*.** *Photo:* M. Casey.

4. *(right).* **Dotted Chestnut *Diaphania perspectalis.*** *Photo:* K. Puttick.

The Great Tachinid *Tachina grossa* in Norfolk

Francis Farrow

The Tachinids are a group of parasitic flies and the Great Tachinid *Tachina grossa* (Linnaeus, 1758) is the largest. Being the size of a bumblebee, black, bristly and with a yellow face, it is fairly unmistakable. See Plate 14 p. 51.

Tachinids are known parasites of moth larvae, such as the large hairy caterpillars of the Fox Moth *Macrothylacia rubi* and Oak Eggar *Lasiocampa quercus*. As with most parasites this is particularly gruesome as the host usually becomes the food for the parasite's larval stage. *T. grossa* lays an egg in the caterpillar and on hatching the larva will eat the caterpillar's non-vital parts from the inside, allowing the caterpillar to survive long enough to pupate. The fly

Table 1. Notes on the appearance of the Great Tachinid at Waxham and Horsey.

Date	Place	Notes
18/07/2013	Waxham Cut	1 on Angelica *Angelica sylvestris*.
31/07/2013	Waxham Cut	1 on Bracken *Pteridium aquilinum*
06/08/2013	Waxham Cut	1 on Hemp Agrimony *Eupatorium cannabinum*.
07/08/2013	Waxham Cut	1 on Hemp Agrimony
08/08/2013	Waxham Cut	1 on Hemp Agrimony
08/08/2013	Horsey Gap	Hundreds on umbellifers and Hemp Agrimony. The flies were confined to an area of ca.150 x 4 m with 1-6 individuals present on most flower heads. An approximate 'block' count gave a total of at least 100. The condition of the flies varied from very worn with frayed wings to hardly a bristle missing.
09/08/2013	Horsey Gap	Fewer than previous day but still several dozen
10/08/2013	Horsey Gap	20 plus on an overcast, cooler, breezy day.
11/08/2013	Horsey Gap	A few singletons on umbels along the track to the car park but most still concentrated along a 200 m strip near to the pill box.
12/08/2013	Horsey Gap	As above
15/08/2013	Waxham Cut	1 near telegraph pole.
19/08/2013	Horsey	Flowers seeded and only four at main site. About half a dozen on the track to the car park
22/08/2013	Waxham Cut	1 on Hemp Agrimony
28/08/2013	Waxham Cut	1 on Hemp Agrimony
29/08/2013	Top of Waxham Cut	1 on Hemp Agrimony
	Horsey	Still 6 or so dispersed on Heather *Calluna vulgaris* and Hemp Agrimony.
04/09/2013	Horsey Gap	2 on Heather, 1 on Hemp Agrimony and 1 on Perennial Sowthistle *Sonchus arvensis*.

larva also pupates and overwinters within the now dead host's pupa before emerging as an adult.

I have met with this fly on only two occasions on Beeston Common and once last year on the adjoining Sheringham Common. Each time I have only seen singletons and most historical records that I have seen refer to a single individual. I was very surprised when in 2013 I received an email from Neil Marks informing me that he had just seen 'hundreds' of these flies at Horsey.

Neil first spotted these flies on his local patch at Waxham and compiled Table 1.

I was away at the time but Neil kept me informed of his observations and on August 29 I managed to meet up with him and visit Horsey. In the space of an hour or two I had counted around seven individuals - more than half of the total of previous records held at the Norwich Castle Museum.

The paucity of records, especially from East Norfolk, makes the Horsey 'swarm' that much more of a phenomenon. The species is not known to be migratory therefore the assumption is that they all hatched locally and must have had a dramatic if not catastrophic effect on the local host moth population. Such numbers seem unprecedented and as far as I can tell there had been no other such record from Norfolk. In 2014, however, Tony Irwin posted on the Norfolk Wildlife Facebook Group that he had seen a solitary *T. grossa* at Winterton on 28 June and later a post from Tim Hodge indicated that there might be another 'swarm' as he had found 14 at Horsey on 31 July. As far as I know, however, there were no further reports.

Table 2. Historical and other recent records of *T. grossa* in Norfolk.

Location	Date	Recorder
King's Lynn (within 10 miles?)	1915	Morley & Atmore
Roydon Common	21/08/1957	Ken Durrant
Winterton	20/08/1962	Ken Durrant
Lolly Moor	16/05/1979	Tony Irwin
Foulden Common	29/07/1992	Ken Durrant
West Harling	03/08/1993	Ken Durrant
Beeston Common	30/08/2000	Francis Farrow
Beeston Common	2010	Francis Farrow
Flordon Common	24/08/2010	Stuart Paston
Sheringham Common	03/08/2013	Francis Farrow
Holme	04/08/2013	Andy Brown

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My thanks go to Neil Marks who allowed me to use his observations and for alerting me to this exceptional population explosion and to Tony Irwin who undertook to research the historical specimens that are part of the Norwich Castle Museum collections.

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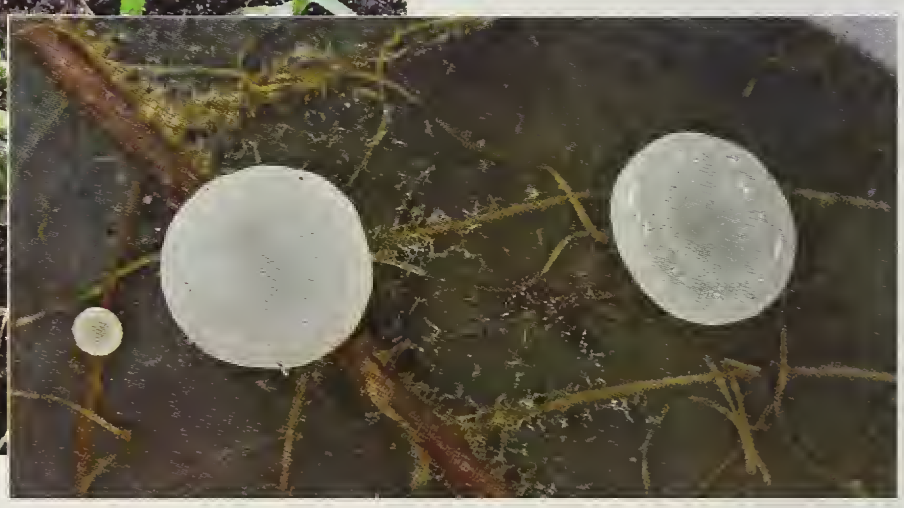
Plate 15 Fungi. See p. 79.

1. *(above left)* ***Amanita inopinata*****.** West Beckham.

2. *(top right)* ***Coprinopsis kubickae*****,** Cranwich Pits, 2013. *Photos:* Tony Leech.



3. *(above left)* **The spindes of *Typhula phacorrhiza* in a garden at Edgefield.** *Photo*: Simon Harrap

4. *(above)* **Sclerotia of *T. phacorrhiza* on an Ash leaf at Beeston Common.** *Photo:* Francis Farrow.

5. *(left)* ***Hymenoscyphus fraxineus*****, the causative agent of ash dieback disase. Foxley Wood, 2013.** *Photo:* Neil Mahler.

Plate 16. Pollination of *Epipactis* spp.

1. ***Dolichovespula sylvestris* male taking nectar from Broad-leaved Helleborine.** Swanton Novers Great Wood, 6 August 2012. *Photo:* Nick Owens.

2. **Hoverfly with parts of pollinia on its head takes nectar from yellow callus on epichile before entering flower (the remaining pollen was subsequently nearly all groomed off).** *Photo:* Nick Owens.

3.***Colletes hederae*.** Beaune, France. *Photo*: Nick Owens. See p. 70 (vol 48).

Some preliminary observations of insect visitors to Broad-leaved Helleborine *Epipactis helleborine* and Marsh Helleborine *Epipactis palustris* orchids in Norfolk

N.W. Owens

Cross-pollination and outbreeding are thought to be essential for the maintenance of genetic diversity and the ability of plants to adapt to changing environments. It is therefore important to know which pollinators are associated with our local orchid populations in order to ensure their conservation and long term survival. This article describes pollinator behaviour for two species of *Epipactis* orchids in Norfolk, based on field observations.

Epipactis helleborine

Introduction

Broad-leaved Helleborine orchids at a site in Swanton Novers Great Wood, Norfolk were observed over four seasons and found to be pollinated largely by male *Dolichovespula* wasps. Brodmann *et al.* (2008) demonstrated that Broad-leaved Helleborine flowers release chemicals which mimic the scents produced when phytophagous insects chew leaves, thereby attracting worker wasps seeking prey. The worker wasps are thought to discover the nectar in the orchids and act as pollinators. The observations of a preponderance of male wasps visiting the orchids in Swanton Novers Great Wood in this study are therefore unexpected, since male wasps do not seek prey.

Figure1. *Dolichovespula sylvestris* worker leaving Broad-leaved Helleborine flower with pollinia attached to its clypeus. Swanton Novers Great Wood, 6 August 2012.

Figure 2. *Dolichovespula* sp. male with multiple pollinia on its clypeus. Swanton Novers Great Wood, 6 August 2012.

Observations

On 6 August 2012 the author was shown some Broad-leaved Helleborine orchids flowering by the edge of a ride in Swanton Novers Great Wood, Norfolk. Almost immediately it was apparent that the flowers were being visited by social wasps. Photographs of the wasps were obtained, all but one of which proved to be males of *Dolichovespula* spp., several with one or more orchid pollinia attached to their clypeus (Figs. 1 & 2). Males were distinguished by their longer antennae (13 segments rather than 12) and longer abdomens (7 visible segments rather than 6). On 9 August 2012, twelve orchids were in bloom along on the ride edge over a distance of about 20 m. At least ten different male *Dolichovespula* wasps were visiting the orchids, moving from one plant to the next in sequence along the ride and not visiting other plant species. The wasps were taking nectar from within the flowers and also sometimes reaching in from the outside of the petals rather than landing on the labellum. Up to three wasps were visiting each orchid at a time. Movement was generally upwards on the raceme but with occasional movements from higher to lower flowers. No workers were seen.

Many of the wasps had pollinia on their clypeus. The pollinia were in pairs held together in a wishbone shape by the viscidium, and tending to point upwards. The pollinia were not released when visiting another flower, but remained stuck on the clypeus despite wasps' attempts to remove them with the front legs from time to time while settled on leaves. Up to seven or eight pollinia were present on some wasps. Only the top three or four flowers on each raceme retained their pollinia by about mid-day, the lower ones all having had them removed. (Flowers open in sequence starting at the base.) There were up to 38 flowers on each plant. It seemed likely that the flowers had their pollinia removed by wasps on the day they opened, assuming suitable weather. Flowers with pollinia removed developed a browner colour than the newly opened ones. Wasps with pollinia attached presumably placed dabs of pollen on the stigmas when seeking nectar from these older flowers.

Table 1. Fruits and flowers in Broad-leaved Helleborine orchids, August 18 2012.

Orchid number	No. of fruits	No. of flowers
1	14	0
2	22	0
3	14	0
4	26	0
5	38	3 open
6	27	3 faded
7	9	0
8	25	3 faded
9	23	5 faded

By the next day (10 August), most of the flowers had dried up and seed pods were developing. Only one wasp was seen visiting the orchids (a male). However, several wasps were seen visiting angelica *Angelica sylvestris* flowers nearby, and many of these had orchid pollinia still attached. Four wasps with pollinia were taken for identification (key by Else, 1994). Two were *Dolichovespula sylvestris* males and two were *D. saxonica* males.

A further visit was made on August 18 2012. No wasps were seen on the orchids. Most orchids had gone to seed with just a few with flowers at the very top. Nine orchids were inspected along the side of the ride. Table 1 shows the number of fruits set and the number of flowers still present on each plant. This evidence suggests that pollination was very effective and largely complete by this date. The only other insects seen visiting these orchids during about five hours total observation time were ants (*Formica* sp.) which crawled into the flowers to gain nectar. No ants were seen with pollinia attached.

The orchids were observed again on 8 August 2013. Once again, only male wasps were observed visiting the orchids; ten wasps were collected from the orchids and found all to be *D. saxonica* males. Six had pollinia on their clypeus. A further visit on 29 July 2014 found 10 orchids in flower. Three had already set fruit on the whole inflorescence, the others having flowers at the top only. A *D. saxonica* male was present on one plant at 08.15h with old pollinia on its clypeus. An hour later the same wasp possessed fresh pollinia. One other *Dolichovespula* male was observed patrolling the ride. No other wasps were seen near the flowers. On 2 August 2015 the orchids were visited by one *D. saxonica* male and one Hornet *Vespa crabro* worker. On 16 August 2015 one *D. media* male visit was recorded.

These observations indicate that the visitors to these orchids in Swanton Novers Great Wood are largely male *Dolichovespula* wasps.Only one worker wasp (and one worker hornet) was observed at the orchids over four seasons, but at least 23 different males. The only other visitors seen were ants, which did not acquire pollinia and one hoverfly *Episyrphus balteatus* which was feeding on dislodged pollinia. The flowering period of the orchid appears to coincide with the emergence of male *Dolichovespula* wasps.

Discussion

These observations conform with the comment in Harrap & Harrap (2005), that pollination in Broad-leaved Helleborines is carried out by wasps, 'especially long-headed wasps of the genus *Dolichovespula*'. These authors also state that 'other insects, including short-headed wasps, bees, hoverflies and beetles, may visit the flowers but are the wrong size or shape to act as efficient pollinators'.

Broad-leaved Helleborine flowers seem 'made to measure' for social wasps: the wasp's hind legs touch the two lower sepals whilst it grips the lip of the orchid with front and middle legs (See Plate 16, p. 55). Unlike Marsh Helleborine orchids, the lower lip (epichile) is rigid. The structure of the flower allows the wasp to reach nectar inside the cup formed by the inner lip (hypochile). When it adopts this posture in a newly-opened flower, the viscidium touches and sticks to the wasp's clypeus and the wasp pulls out the pollinia as it drops backwards out of the flower (Fig 1). Darwin 1877 describes 'the common wasp *Vespa sylvestris*' (presumably *Dolichovespula sylvestris*) as being attracted to some *Epipactis* species. He comments on the surprising lack of other types of insects on wasp-visited *Epipactis* species. Broad-leaved Helleborine flowers show characteristics of 'wasp flowers' which include some Figworts *Scrophularia* spp. and *Cotoneaster* spp., being (usually) a dull purple-brown colour (Proctor & Yeo 1973). Honeybees *Apis mellifera* and several Hornets *Vespa crabro* have also been observed visiting this orchid and carrying pollen in the Netherlands (Claessens & Kleynen 2014).

As mentioned above, Manfred Ayasse and his team at the University of Ulm, Germany, using *Vespula germanica* and *Vespula vulgaris* (workers) in captivity, demonstrated the attraction of wasps to scents released by flowers of Broad-leaved Helleborine and Violet Helleborine *Epipactis purpurata* (Brodmann *et al.* 2008). Analysis showed that these scents share some components with volatile chemicals released from leaves when phytophagous insects feed on them, these chemicals being termed 'green leaf volatiles' (GLVs). The antennae of wasps produced electrophysiological responses to GLVs, and the wasps also turned preferentially towards GLVs in a Y-maze. Worker wasps also visited samples of sugar solution containing GLVs more than they visited sugar solution without GLVs. The orchids are believed to mimic GLVs, tricking wasps into visiting them. Once arrived at the orchid the wasps are thought to detect nectar and enter the flowers. This mechanism will only function with female (worker) wasps, whereas in the present study the orchids were visited almost exclusively by males.

Claessens & Kleynen (2011) report observations by Veenendaal (2010) at Epe in the Netherlands who recorded 37 pollinators of *E. helleborine,* all of which were *D. saxonica,* comprising 33 males and four females. Their own observations at Wijlre comprised four male *D. saxonica,* three male *D. sylvestris* and one female *V. vulgaris*. Manfred Ayasse (pers. com.) points out that male wasps will be attracted by the nectar in the orchids and their presence does not invalidate the GLV mechanism. Ayasse and various other observers have noted female (worker) wasps visiting this orchid species (e.g. Müller 1988). Roy Sexton (pers. com. Dec. 2015) reports his recent studies at several *E. helleborine* sites in Stirlingshire where 71 visiting wasps were collected for study. Of these, 67 were workers and only four were males. However, the major role of male wasps at some sites is striking and further field observations would be of interest.

Epipactis palustris

Introduction

The lower lip (epichile) of a Marsh Helleborine flower hinges loosely on the upper lip (hypochile). If the epichile is flicked with a finger it bounces up and down. Darwin suggested that the weight of a visiting insect would cause the epichile to hinge downwards. Once the insect had moved onto the hypochile, the epichile would swing back up to its original position, forcing the insect's body against the pollinia. Darwin thought that the pollinia would be pulled out as the insect backed upwards and outwards from the flower. Darwin did not himself observe insects visiting this orchid species, though he reports visits by Honeybees *Apis mellifera* witnessed by his son William, on the Isle of Wight. Since Darwin's time some doubts have been expressed about the so-called springboard mechanism and there is still no consensus about its exact function. This paper gives some further observations of pollinators of this orchid, in France and in Norfolk, and reviews the literature on the subject.

Description of the flower

The epichile of a Marsh Helleborine flower forms an ideal landing place for insects and bears a protrusion or callus with a yellow border which secretes nectar. Claessens & Kleynen (2011) describe these yellow marks as 'pseudo-pollen'. Brantjes (1981) was the first to demonstrate that nectar

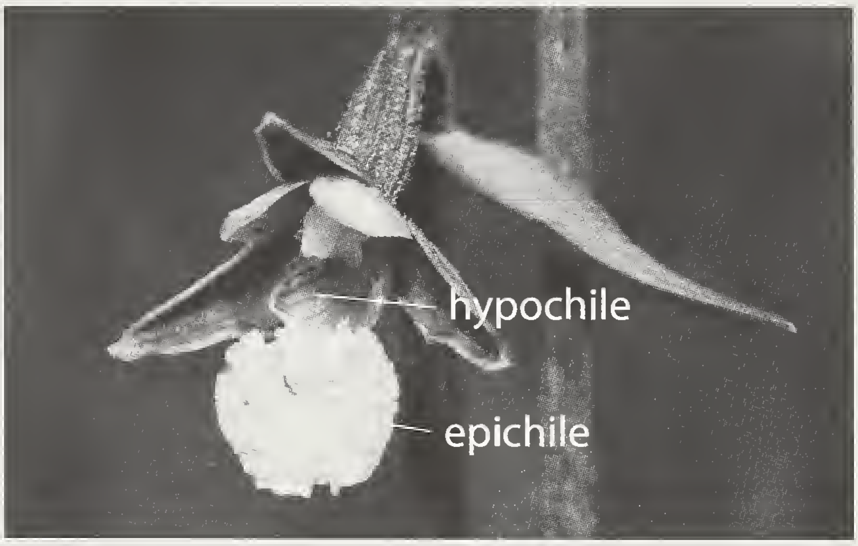


Figure 3. ***Epipactis palustris*** **flower showing yellow callus on the upper epichile with a groove above it (both nectar-producing). The inside of the hypochile bears pinkish guidelines converging on the base of the column where there is further nectar.**

is released by the epichile as well as the hypochile, using Glucostix test strips[1] to test for glucose. Just above the yellow border is a groove containing more nectar which was described by Brantjes (1981) as a nectar guide. He suggested that the nectar guide leads the insect into the hypochile with the correct orientation. The hypochile bears converging pinkish lines leading to more nectar at the base of the column (Fig. 3). Histological details of the nectaries are given by Kawalkowska *et al*. (2014).

Observations

The author and his wife observed insects visiting Marsh Helleborines in the Jura region of France in July 2014. Further observations were made at Beeston Common, Norfolk shortly afterwards, with additional observations by Francis Farrow.

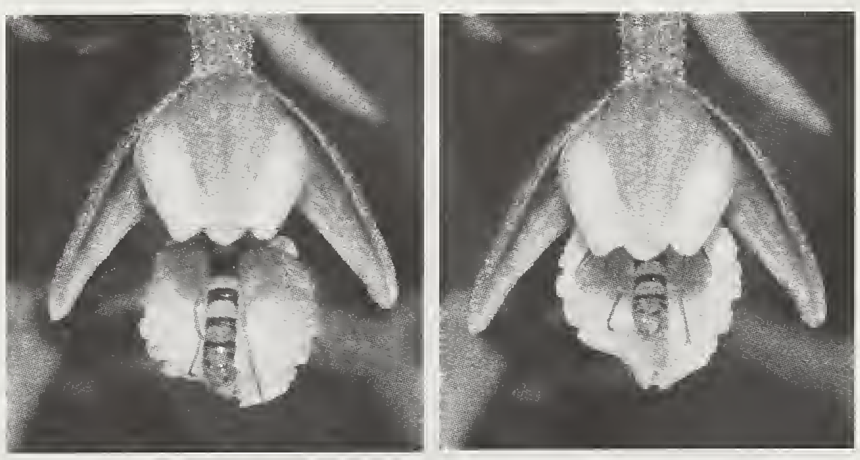


Figure 4 (left). Epichile hinged down: Figure 5 (right) epichile hinged up.

1 Manufactured by Bayer Schering Pharma.

In France a male hoverfly (*Sphaerophoria scripta)* was seen landing on the epichile. This is a relatively small and light hoverfly species. It then moved forwards, presumably seeking nectar under the base of the column. As its weight was transferred partly onto the hypochile, the epichile was seen to hinge up and down several times (Figs. 4, 5 & 6). The insect emerged almost immediately with pollinia attached to its thorax. Over the next 15 minutes the hoverfly rested on the petals and pedicel of the flower and attempted to groom off the pollen using its legs, but was unable to do so (Fig. 7).

A visit by a second hoverfly, a female *Sphaerophoria* sp., followed a similar pattern, except that the epichile hinged upwards once, suddenly, pitching the hoverfly into the flower. The insect immediately emerged with pollinia on its head, partly covering its eyes (Figs. 8 & 9). It was able to groom these off almost completely (Fig. 10), though it did enter a second flower before all the pollen had been removed, potentially pollinating it (Figs. 11 & 12; Plate 16.2, p. 55).

Figure 6. Hoverfly with weight partly transferred to the hypochile: epichile hinged up. The insect's middle legs are inserted round the front edge of the epichile, assisting the forward and upward projection of the insect as the epichile hinges upwards.

Figure 7. Hoverfly attempts to groom pollinia from its thorax, but is unable to do so.

Figure 8. Hoverfly enters flower. The epichile is on the point of moving upwards.

Figure 9. Immediately afterwards, the hoverfly emerges with pollinia on its head. Epichile hinged down again by weight of the insect.

Figure10. Hoverfly rotates its head allowing its legs to remove pollen from the eyes and frons.

Table 2. Insects recorded visiting Marsh Helleborine flowers in Norfolk.

Insect visitor		Recorder	Date	Location	Pollinia present	Position
Apis mellifera	Honeybee	K. Durrant	1958	Scarnn Fen	Yes	Head
Zygaena filipendulae	6-Spot Burnet	K. Durrant	1958	Scarnn Fen	Yes	Tongue
Banchus volutatorius	Ichneumon	K. Durrant	1958	Scarnn Fen	Yes	
Cryptopimpla errabunda	Ichneumon	K. Durrant	1958	Scarnn Fen	Yes	
Phaeonia incana	Fly	K. Durrant	1958	Scarnn Fen	Yes	
Scopeuma (Scathophaga) stercoraria	Dung fly	K. Durrant	1958	Scarnn Fen	Yes	
Neoascia dispar (tenur)	Hoverfly	K. Durrant	1958	Scarnn Fen	Yes	
Tropidia scita	Hoverfly	K. Durrant	1958	Scarnn Fen	Yes	
Zygaena filipendulae	6-Spot Burnet	K. Durrant	1998	BeestonCommon	Yes	Tongue
Zygaena trifolii	5-Spot Burnet	K. Durrant	1998	BeestonCommon	Yes	Tongue
Helophilus pendulus	Hoverfly	K. Durrant	1998	BeestonCommon	Yes	
Trichopsomyia flavitarsis	Hoverfly	K. Durrant	1998	BeestonCommon	Yes	
Neoascia dispar (tenur)	Hoverfly	K. Durrant	1998	BeestonCommon	Yes	
Strangalia (Rutpela) maculata	Longhorn beetle	K. Durrant	1998	BeestonCommon	Yes	
Rhagonycha lignosa	Soldier beetle	K. Durrant	1998	BeestonCommon	Yes	Thorax
Rhagonycha fulva	Soldier beetle	K. Durrant	1998	BeestonCommon	Yes	Thorax
Episyrphus balteatus	Hoverfly	F. Farrow	07.07.2014	BeestonCommon	Yes	Head
Lasioglossum calceatum (f.)	Solitary bee	N. Owens	16.07.2014	BeestonCommon	No	
Lasius niger	Ant	N. Owens	16.07.2014	BeestonCommon	No	
Ichneumon sp.1	Parasitic wasp	N. Owens	20.07.2014	BeestonCommon	No	
Ichneumon sp.2	Parasitic wasp	N. Owens	20.07.2014	BeestonCommon	Yes	Thorax + leg
Fly sp. ?Muscidae	Fly	N. Owens	07.07.2015	BeestonCommon	No	
Paragus haemorrhous	Hoverfly	N. Owens	07.07.2015	BeestonCommon	No	
Sphaerophoria scripta	Hoverfly	N. Owens	07.07.2015	BeestonCommon	No	
Oedemera lurida	Beetle	N. Owens	07.07.2015	BeestonCommon	Yes	Elytra
Oedemera nobilis male x 2	Beetle	N. Owens	07.07.2015	BeestonCommon	Yes	Thorax
Fly sp Dolichopodidae	Fly	N. Owens	07.07.2015	BeestonCommon	Yes	Thorax
Paragus haemorrhous	Hoverfly	N. Owens	07.07.2015	BeestonCommon	Yes	Head
Bombus pascuorum	Bumblebee	N. Owens	12.07.2015	BeestonCommon	No	
Bombus terrestris	Bumblebee	N. Owens	12.07.2015	BeestonCommon	No	
Oedemera lurida	Beetle	N. Owens	12.07.2015	BeestonCommon	Yes	Elytra
Spaerophoria scripta	Hoverfly	N. Owens	12.07.2015	BeestonCommon	No	
Lasius niger x 2	Ant	N. Owens	15.07.2015	Holkham	Yes	Thorax
Lasius niger	Ant	N. Owens	15.07.2015	Holkham	No	
Myrmica rubra	Ant	N. Owens	15.07.2015	Holkham	No	
Spaerophoria scripta	Hoverfly	N. Owens	26.07.2015	BeestonCommon	Yes	Thorax?
Bombus pascuorum worker x 2	Bumblebee	N. Owens	28.07.2015	BeestonCommon	No	
Episyrphus balteatus	Hoverfly	N. Owens	28.07.2015	BeestonCommon	No	
Halophilus pendulus	Hoverfly	N. Owens	28.07.2015	BeestonCommon	No	
Herina frondescentiae	Ulidiidae	N. Owens	28.07.2015	BeestonCommon	Yes	Thorax
Oedemera nobilis female x 3	Hoverfly	N. Owens	01.08.2015	BeestonCommon	No	
Tropidia scita	Hoverfly	N. Owens	01.08.2015	BeestonCommon	No	
Vespula germanica work.	Social wasp	N. Owens	01.08.2015	BeestonCommon	Yes	Clypeus

Figure11. Hoverfly moves into flower taking nectar from groove above yellow callus.

Figure 12. Hoverfly moves into flower, allowing the pollinia to touch the stigma. On this occasion the epichile was not observed to move.

Table 2 lists insect visitors recorded on Marsh Helleborines in Norfolk, including those recorded by Durrant (1958, 1998). Pollinia were readily released and attached to any part of the insect's body which brushed against the viscidium. Those attached to the thorax appeared to be difficult for insects to remove, whereas those attached elsewhere could be groomed off. For example an ichneumon was observed with two pairs of pollinia on its thorax which were dried and old, whereas when it acquired new pollinia on its leg (by entering sideways) it was able to groom them off immediately. It should be noted that on several visits to Beeston Common, few or no insects were observed on the flowers. The best times seemed to be when the sun emerged after rain, or in the early morning as the day warmed up. It seems likely that nectar would have accumulated at such times. Brantjes (1981) states that, in Holland, there were few insect visitors in the afternoon.

Seed set

Photographs of 20 Marsh Helleborine racemes were taken at Beeston Common in July 2014. Excluding flowers still open or newly faded at the top of the racemes, over 95% of the flowers had swollen with developing seeds. See Table 3.

Discussion

The observations described above support Darwin's idea that the hinged epichile assists in pushing an insect towards the pollinia. Darwin noted that larger insects, such as Honeybees, were able to acquire pollinia without entering the flower, and states that 'the upward movement (of the

Table 3. Fruits and flowers in Marsh Helleborine plants. July 27 2014.

Orchid number	No. of fruits	No. of undeveloped fruits	No. of Flowers
1	11	2	4
2	6	0	3
3	3	0	4
4	7	0	0
5	5	0	1
6	12	0	0
7	6	0	7
8	7	1	3
9	5	3	0
10	7	0	1
11	8	1	2
12	10	0	0
13	10	0	0
14	7	0	3
15	7	0	0
16	7	0	3
17	7	0	2
18	9	1	0
19	6	1	0
20	5	1	2
Total	**145**	**10**	**35**

epichile) may not be so necessary in all cases as I had supposed'. Darwin suggested that the springboard mechanism might also be important for pollen deposition, since it could help to prevent the pollinia being brushed off by the edges of the petals as an insect, carrying pollinia, enters a flower. However, in the one instance a pollen-bearing insect was observed to enter a flower in this study, the epichile was not seen to move. It is possible that the hinge mechanism of the flower functions most effectively in the topmost flowers of the raceme where the anthers are intact. This could explain why the springboard mechanism has apparently not regularly been observed and described.

Nilsson (1978) recorded 431 insect visitors to Marsh Helleborines across twelve sites in southern Sweden. Hymenoptera and diptera comprised 49.7% and 40.8% of visitors respectively. He suggested that the flowers are most closely adapted to (male) eumenid wasps, since these insects have a suitable body size/shape and tongue length to reach the nectar below the column while striking their head on the rostellum. As *Eumenes pedunculatus* depressed the epichile, the wasp was seen to curl its abdomen under the flower. It then moved forwards, allowing the epichile to move upwards. As it backed out of the flower the epichile moved downwards again, causing the wasp to 'partially lose its balance and tip backwards' striking its head on the rostellum and releasing the pollinia. *Eumenes* were not frequent visitors but carried the highest average number of pollinia of all visitors. In the British Isles, *Eumenes*is confined to the southern counties and does not occur in Norfolk.

Nilsson considered some hoverflies, such as *Syritta pipiens*, to be too light to depress the epichile. However, this species is of similar size to *Sphaerophoria* spp. which was observed to depress the epichile in this study. Nilsson found that small insects received pollinia further back on their bodies compared with larger insects (usually on their thorax rather than the head). Very small insects tended to get stuck in the flower or weighed down by the pollinia. Insects with very long tongues, such as *Bombus* spp. were able to take nectar without releasing the pollinia. He calculated that effective pollination was brought about by insects whose tongues reached the nectar while their clypeus and frons were 1.5-4.0 mm above the surface of the hypochile and therefore pressed against the stigma. In Nilsson's study, out of 48 species of insect visitors, 33 species received pollinia on their head area and 23 species on the thorax.

Brantjes (1981) found that ants, smaller hoverflies and honeybees were the most effective pollen vectors at a semi-natural site in the Netherlands and provides detailed descriptions of their behaviour. These agree with the author's observations that insects start by licking the yellow edge of the callus on the epichile before moving to the hypochile. However, agreeing with Nilssen, he notes that the main hoverfly pollen vectors, *Syritta pipiens* and *Lejogaster mettalina*, did not depress the epichile. Brantjes also records that these hoverflies groomed off pollinia only when they were on the eyes, but not from the vertex. Honeybees groomed off most of the pollinia from their heads and placed it in their pollen baskets, but some pollen generally remained on their clypeus and could effect pollination. However, Anna Jakubski-Bussa (pers. com.) has images of Honeybees in Poland with multiple pollinia of Marsh Helleborine on the clypeus. The epichile was seen to move upwards on two occasions when the flowers were visited by small hymenoptera, potentially assisting pollen transfer, but in neither case were pollinia attached.

Talalaj & Brzosko (2008) list colletidae (solitary bees), eumenidae (solitary wasps), vespidae (social wasps) and syrphidae (hoverflies) as pollinators of Marsh

Helleborine in NE Poland. Jakubska-Busse & Kadej (2011) list the insect species recorded visiting Marsh Helleborine in their own studies in Poland and by other authors.

Jacquemyn *et al.* (2014) provide a literature review of all aspects of the biology of *E. palustris,* including the pollination mechanism. They list 10 coleoptera, 45 diptera and 55 hymenoptera species recorded visiting the flowers of the orchid by various authors. At a site in the Netherlands, diptera comprised 76% of insect visitors (Verbeke & Verschueren 1984), while in Germany Müller (1988} reported hymenoptera to be the main visitors, especially bees of the genus *Lasioglossum* (both cited Jacquemyn *et al.* 2014). Jacquemyn *et al.* relate the doubt of some authors about the validity of Darwin's springboard mechanism and say that 'it may be more plausible that when the insect backs out of the flower, both depression of the epichile and maintenance of the insect's foothold on the outside of the hypochile ... induce a stretching of its body that brings its head into contact with the rostellum'.

Wilcox 2010 provides a detailed account of almost 50 visitors to *E. palustris* in the Vendées and dunes of France. The main pollen vectors were *Polistes* wasps, *Oedemera nobilis* beetles, halictid bees, ants and tachinid flies. Twenty insect species/groups collected pollinia on their heads, 12 on the thorax and four on the abdomen. Syrphidae sometimes depressed the epichile, triggering the springboard mechanism. Some were able to avoid rupturing the viscidium and ingested pollen, whereas others acted as pollen vectors.

Claessens & Kleynen (2011) state 'our observations underline the importance of the upward movement of the epichile when returning to its original position. The visitors are pushed towards the anther, just as Darwin (1877) described it'. These authors present sequential images (p. 107) of a soldier fly (Stratiomyidae) entering a Marsh Helleborine flower and eliciting the springboard action of the epichile. Their list of all pollinators identified to species in the literature comprises 10 coleoptera, 46 diptera and 57 hymenoptera.

Pollination is not always essential for fruit set in Marsh Helleborines; some populations of this orchid have been found to form fruits when the inflorescences are bagged before the flowers open, though not all populations show this ability (Talalaj & Brzosko 2008, Brantjes 1981). Talalaj & Brzosko found very little fruit set in bagged flowers of Broad-leaved Helleborines, indicating a greater dependence on insect pollinators for seed formation in that species. Regardless of the ability to self-pollinate, cross pollination is of major importance in generating the genetic variation needed for adaptation and long term survival, including adaptation of flower morphology in response to changing insect populations. It is possible that migratory hoverflies, such as *Sphaerophoria scripta* and *Episyrphus balteatus,* can lead to occasional pollen transfer between different populations of orchids.

Conclusions

From the author's observations and those of a small number of other observers, the springboard mechanism appears to have validity, and apparently functions as Darwin surmised when suitable insects visit the flower. The most effective pollen vectors seem to be insects of intermediate size, including hoverflies, soldier flies, smaller solitary wasps and solitary bees. Insects of suitable size land on the lower part of the epichile and take nectar from the yellow callus. They are enticed into the flower by the channel of nectar just above the callus. The pink converging lines inside the hypochile lead the insect to the base of the column where there is more nectar. As it enters, the epichile hinges up (or up and down repeatedly). This springboard mechanism nudges the insect upwards and forwards towards the pollinia. The attachment of pollinia when the viscidium ruptures appears to disturb the insect, causing it to retreat from the flower. Pollinia may be attached to the head or thorax of the insect vector, or in some cases the abdomen. Pollinia on the head area or legs may be at least partially removed by grooming. Larger insect visitors, such as Honeybees, may strike the viscidium as they leave the flower, and a role for the springboard mechanism has been claimed based on insects 'losing their balance' or being propelled upwards as they take off.

The very wide range of insect visitors to *E. palustris* contrasts strongly with *E. helleborine* which is closely adapted to social wasps. *E. palustris* usually grows in sunny situations whereas *E. helleborine* generally grows in shade (Summerhayes 1951) which may partly account for the greater variety of insect visitors to the former species. A further factor is that *E. palustris* has a longer flowering season. At any one site 50 or more insect species may visit the flowers of *E. palustris*. A good proportion of these will not be of ideal size, shape or behaviour to act as pollen vectors, and not all will elicit the springboard movement of the epichile. However, this does not mean that the mechanism does not work well enough for the purposes of the orchid. It is not necessary or to be expected for the orchid to be perfectly adapted in this way. There may be little or no selection pressure for more specific adaptations to particular insects, especially since the spectrum of insect visitors will vary from site to site and season to season. The springboard mechanism needs only to increase the chances of pollen transfer by vectors and/or reduce the probability of pollen stealing by non-vectors. Similar arguments apply to *E. helleborine* where the attraction of males does not invalidate the GLV mechanism: there are many constraints on perfection in adaptation (e.g. Dawkins 1982). In both *Epipactis* species seed set was effective, again suggesting little selection pressure for more specialised floral adaptation (though in *E. palustris* autogamy may have occurred). In the future however, climate change may result in mismatches between orchids and their pollinators (Robbert *et al.* 2014), leading to further adaptive change.

Hybridisation does not seem to occur in *E. palustris* despite its wide range of pollen vectors but *E. helleborine* sometimes produces fertile hybrids with Dark-red Helleborine *Epipactis atrorubens* and Violet Helleborine *Epipactis purpurata* (Harrap and Harrap 2005). The potential loss of adaptation through the formation of hybrid swarms may act as a selection pressure for specialisation to particular pollen vectors: social wasps in this case.

There are surprisingly few descriptions of the mechanism of the epichile despite the many studies of this orchid. The following questions need further investigation:

- Which species of insects elicit the springboard mechanism?
- Does the epichile have a function during the receipt as well as the removal of pollen?
- To what extent is pollen removed by grooming from different parts of an insect's body?

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Weather Report 2013

Norman Brooks

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

Monthly accounts

January 2013 Very cold from the 14th-25th inclusive, with the screen minimum of -13.2°C at Buxton, Norfolk on the 16th, the lowest reading recorded in the British Isles throughout the month.

Snow fell on 11 days and lay on 13, with a maximum level depth of 20 cm on the 21st. A sudden thaw at the end of the month peaked on the 29th with the maximum of 14°C, very close to the East Anglian record. Rainfall was near average.

Jan. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	0	1	2	1	1	10	2	2	12

February 2013 A bleak month with snow falling on 12 days but never accumulating to any significant depth.

Only a single day achieved a maximum in excess of 10°C. Very dry air in mid-month caused static electricity to produce a tingling sensation when a metal object was touched and blue-tinged sparks to 'dance' over clothes! Rainfall was average.

Feb. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	0	8	5	2	2	1	2	5	3

March 2013 Coldest since 1962 with a nearly continuous feed of frigid air from Scandinavia and western Russia. Snow fell on 13 days and lay on 5 mornings. The average temperature was identical to that of February and there was a single warm and spring-like day, the 5th, with a maximim of 14.7°C The rainfall total of 79.8 mm was 170% of average.

Table 1 Monthly summaries for 2013

Month	Total rainfall (mm)	Percentage of average rainfall	Days air frost	Days ground frost	Monthly mean temperature (°C)	Deviation from mean (°C)
January	63.6	110%	17	20	2.9	-1.1
February	43.8	101%	11	21	3.1	-0.7
March	79.8	171%	16	24	3.1	-2.8
April	23.4	48%	10	17	8.3	+0.7
May	63.5	140%	3	9	10.7	-0.6
June	20.1	38%	0	1	14.2	-0.1
July	10.2	18%	0	0	18.9	+2.4
August	42.0	82%	0	0	18.3	+1.9
September	63.2	116%	0	0	14.3	0.0
October	97.1	167%	0	0	12.7	=1.7
November	60.2	86%	2	14	6.3	-0.4
December	41.8	69%	4	14	5.8	+1.0

Mar. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	2	12	9	2	0	1	1	1	3

April 2013 Very dry; the rainfall total of 23.4 mm was barely 50% of average. Frosts were a feature with 10 air frosts and 17 ground frosts, but two spells of warmth, 14th-17th and 23rd-25th caused the mean temperature of the month to be slightly above normal. Spring growth was very retarded, with Bluebells delaying flowering until the 29th.

April wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	3	8	2	0	0	11	1	5	0

May 2013 A cool and wet month whose rainfall total of 63.5 mm was 140% of average, dispelling any fears of an impending drought. A preponderance of cold nights caused the average temperature of the month to be signficantly below normal. Northerly winds were more frequent than usual.

May wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	8	0	1	4	2	6	4	6	0

June 2013 Extremely dry - the driest June since 2000. The rainfall total of 20.1 mm was only 38% of average. Only six days had maxima above 21°C, with many days reminiscent of early autumn. The 8th and 9th only just exceeded 13°C and there was even a ground frost on the 4th.

June wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	3	4	0	4	1	9	1	8	0

July 2013 Another very dry month. The rainfall total of 10.2 mm a mere 18% of average and no rain at all falling between 3rd and 22nd inclusive. (By contrast, in July 2012, 124.2 mm was recorded, 220% of average.) High summer at last; maxima exceeded 25°C on 19 days, with 31.9°C attained on the 22nd.

July wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	0	9	0	4	5	8	3	0	2

August 2013 The rainfall total of 42 mm was barely 80% of normal with the aggregate total rainfall for the three month summer season showing a deficit of nearly 50%. There were signs of approaching drought in the countryside. Maxima exceeded 25°C on seven days and 31.1°C was recorded on the 1st.

Aug. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	1	3	1	1	5	12	7	1	0

September 2013 There was some recovery in the parched landscape but rainfall was unevenly distributed across the county with 63.2 mm measured to the west of Norwich and 49.8 mm to the east.

Maxima in excess of 21°C were recorded on 6 days, and the 29.4°C attained on the 5th was accompanied by thunder and torrential rain. (A feature of recent years has been the lack of thunderstorms.)

Sept. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	0	1	4	2	2	5	5	4	7

October 2013 Notably warm and wet with rain falling on 19 days yielding a total of 97.1 mm, 167% of average. Unusually, the month was virtually frost-free and there was a complete absence of crisp, calm autumn weather. The St Jude storm on the 28th caused wind speeds 67 mph at Caister St. Edmund, 60 mph at Norwich Airport and 53 mph at Weybourne.

Oct. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	1	1	0	6	4	10	3	2	4

November 2013 Although rain fell on 24 days, the total in the Norwich area, of between 60 and 63 mm, was less than 90% of average. Only two air frosts were recorded but ground frost formed on 14 days. There was a total absence of sleet or snow. A fire rainbow or circumzenithal arc was observed mid-afternoon on the 26th.

Nov. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	1	2	0	1	2	2	6	7	9

December 2013 Frequent mild days caused the mean temperature to be 1°C above normal. With a preponderance of rain-bearing south-westerly winds the rain-shadow effect allowed Norfolk to be drier than average. Rainfall totals of between 34 and 42 mm in the Norwich area were little over half the average.

There was a total absence of sleet or snow. The wind reached gail-force on the 5th, 24th and 27th.

Dec. wind	N	NE	E	SE	S	SW	W	NW	Calm
Days	0	0	0	1	6	11	5	3	5

Annual summary 2013

Total rainfall	608.8 mm (94% of average)
Wettest day	3 Mar, 23.2 mm
Days with rain recorded	168
Days with sleet or snow	37
Days with snow lying	19
Highest maximum temperature	31.9°C 22 July
Lowest maximum temperature	- 0.5°C 16 Jan
Highest minimum temperature	18.6°C 2 Aug
Lowest minimum temperature	-11.5°C 16 Jan
Lowest grass min. temperature	-15.5°C 16 Jan
Air frosts	63
Ground frosts	120
Days with hail	4
Days with thunder	8
Days with gales	4
Longest period with no measurable rain	20 days (3rd -22nd July inclusive)
Mean cloud cover at 09.00 hrs	68%
Wind direction at 09.00 hrs (days):	
North	19
North-east	49
East	24
South-east	28
South	30
South-west	86
West	40
North-west	44
Calm	45
Annual mean maximum temp.	14.0°C
Annual mean minimum temp.	5.9°C
Annual mean temperature	9.9°C

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Dragonflies

Pam Taylor

Note: Wildlife Reports that cover both 2013 and 2014 begin on p. 59, Volume 48.

The 2013 dragonfly season started slowly with a late spring. The first **Large Red Damselfly** *Pyrrhosoma nymphula* was seen on 14 April, but there were only two more reports before the end of the month. Thankfully May then brought a flood of observations of both this and other spring species. Despite the slow beginning, the year was overall a good one for our commoner dragonflies and the only species to show any ill effects from the early cold spell was the aforementioned Large Red Damselfly whose shortened main flight period meant it was missed at many sites.

Willow Emerald Damselfly *Chalcolestes viridis.* The first sighting of the year on 6 August was made by Jon Mee at Cringleford on the River Yare. This was a new site for this recent colonist, but by the end of that month it was clear that a substantial colony was in the process of establishing itself there. The maximum count at the site in late August was of over 20 individuals, with at least six pairs ovipositing into the overhanging branches. Elsewhere the initial Norfolk colony at Strumpshaw Fen continued to survive, with a single female also seen at nearby Surlingham Church Marsh on the opposite side of the river on 24 September. At Wheatfen, directly across the river from Strumpshaw Fen, singles were reported by Nick Elsey on 3 September and David Nobbs on 24 October.

Southern Emerald Damselfly *Lestes barbarus.* This species first arrived in mainland Britain in 2003. Since then small numbers have been seen in most years at Winterton Dunes, suggestive of a persistent colony. In 2013 the first individual was seen there on 26 July and sightings continued until early September. The maximum count during this period was of six individuals, including a pair and an ovipositing female. Despite the small numbers involved, ovipositing was witnessed on a total of four occasions.

Scarce Emerald Damselfly *Lestes dryas.* Continues to thrive at its main site of Thompson Common in the Brecks. Elsewhere a small colony persists on a private farm at Briston thanks to the pond conservation initiatives of its owner Richard Waddingham. On 20 August a single very tatty looking male was observed by Bernard Dawson near Bodham. More surprisingly, a small colony was found and identified by Andrew Bloomfield at Overy Marsh on the Holkham estate where three breeding pairs were present on 16 August. This site is well away from its usual Breckland areas, so could stem from migrant individuals reaching our coast.

Small Red Damselfly *Ceriagrion tenellum.* Only one site in the county, but 2013 proved to be bumper year for sightings. No fewer than nine reports were received from Scarning Fen between early June and late July. The maximum count came on 2 July when David Ruthven saw at least 150 at the site. Mating pairs were seen on at least four occasions, although ovipositing was not observed.

Scarce Blue-tailed Damselfly *Ischnura pumilio.* Following the discovery of immigrant Scarce Blue-tailed Damselflies at Winterton Dunes in 2012, a small colony appears to have established itself on private land not far away at Hempstead Marshes near Sea Palling. In 2013 the first male was seen there on 1 July, followed by another adult and an immature *aurantiaca* form female on 4 July. Eight days later at least one adult, three tenerals and two more *aurantiaca* females were seen. The last reported sighting was of a single male on 1 August.

Common Hawker ***Aeshna juncea.*** Following a plea for records after the 2012 season, I received several reports of Common Hawker being seen at Winterton Dunes during August 2013, including notes of emergence. Adults were also seen at other known sites including Upton Fen and Potter Heigham Marshes. Of more interest were the four observed on the coast at Blakeney Point by Ajay Tegala on 6 August and the single male seen by Andrew Bloomfield at Holkham ten days later. These latter sightings could indicate migrants arriving on our shores in the same way that immigration many years ago could account for the long-established breeding colony at Winterton Dunes.

Norfolk Hawker ***Aeshna isosceles.*** A larval survey conducted by the author in May and early June 2013 produced positive results in marshes at Ludham, Upton and Thorpe. Following this, flying adults were reported from all the usual broadland locations. Of greater note were the two adults seen hunting over farmland well away from water at Ludham Airfield on 16 June and an out-of-range sighting by Phil Davidson near Buxton Heath on 29 June. A wandering adult was seen by David Boulton in his Sprowston garden on 5 July and other wanderers were encountered by Adrian Riley at Lenwade on 20 June and Thompson Water on 16 July. These travellers away from their expected locations may go some way to explaining how this usually quite sedentary species recently reached new breeding sites in Cambridgeshire and Kent. Later in July Helen Smith reported an adult from Little Fen within the larger complex of Redgrave and Lopham Fen near the River Waveney.

Scarce Chaser ***Libellula fulva.*** Now plentiful in its main stronghold in the Broads around Strumpshaw Fen, Rockland Marshes, Surlingham and Wheatfen. It is also to be expected along stretches of the River Waveney at Geldeston and elsewhere, although no such reports were received for 2013. Scarce Chaser has spread in recent years and within Norfolk this year wandering individuals were observed by Peter Dolton at Lynford Water and John Curd at Ludham Bridge, both on 30 June. In the far south-west of the county Scarce Chaser was seen on watercourses in both the Hockwold Fens and Feltwell Fens.

Keeled Skimmer ***Orthetrum coerulescens.*** Now has several established sites in Norfolk. The original colony at Holt Lowes, as well as others at Buxton Heath, Dersingham Bog, Roydon Common and Beeston Common all produced a number of sightings this year. Elsewhere presumed migrants were seen at Burnham Overy Marshes by Andrew Bloomfield on 1 August and at Winterton Dunes. At the latter site at least two males were present on 3 August and 18 August; reported by Phil Heath and Greg Bond respectively.

Interestingly there were no reports of **Lesser Emperor** ***Anax parthenope*****, Red-veined Darter** ***Sympetrum fonscolombii*** or **Yellow-winged Darter** ***S. flaveolum*** during 2013.

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Moths

Jim Wheeler

According to records received, a staggering 1280 species of moth were recorded in Norfolk in 2013. Listed below and in Table 1 is a selection of notable records from 2013, including eight species new for Norfolk, plus four new for Vice-county 28 (West Norfolk) and three new for Vice-county 27 (East Norfolk). The list also includes several species recorded in 2013 that were last noted in Victorian times by the great Charles Barrett.

Dotted Chestnut *Conistra rubiginea* The first Norfolk specimen was trapped at Hockwold in West Norfolk on 24 April by Katherine Puttick. A very local species, occurring mainly in the south and south-east of England. The moth overwinters as an adult, flying again in the spring. Photo: Plate 14.4, p.51.

Scythris picaepennis This Nationally Scarce (Nb) micro moth was discovered at Cranwich Heath VC 28 where a single male was netted and determined by examination of genitalia on 18 June by Ian Barton and Kathleen Rosewarne, with further specimens netted at the site in 2013.

Parornix carpinella New for Norfolk. Leaf-mine on leaf of Hornbeam *Carpinus betulus* found at Hoveton Hall gardens in Norfolk VC27 in July (S. Wright).

Yponomeuta irrorella New for Norfolk. Cley-next-the-Sea VC27, 30 July (I. Walker). A scarce and local species, occurring in southern and south-eastern England.

Ectoedemia sericopeza New for Norfolk. Mines found in samaras from Norway Maple *Acer platanoides* at Lynford Arboretum VC28, with an adult hatching in August (I. Barton, K. Rosewarne).

Small Chocolate-tip *Clostera pigra* Found in the Norfolk Broads in late July by Mark Crossfield. Not seen in Norfolk for many years, thought possibly locally extinct until this year!

Ground Lackey *Malacosoma castrensis* A single record of a female trapped in a Norwich garden on 1 August by Alan Dawson. The origin of this coastal saltmarsh species remains a mystery. It is not thought that this is from a hidden Norwich colony(!), but possibly either bred, hitched a ride from Suffolk, carried on the wind or caught in a thermal during the extreme hot weather.

Maize Moth *Spoladea recurvalis* A rather worn out visitor, trapped at Walcott (M. A'Court, 4 August). The first for East Norfolk. A scarce autumn migrant from the tropics, first recorded in Britain in Surrey and Dorset in September 1951. The Norfolk county first was on 13 October 2011 at Holme in West Norfolk.

Tree-lichen Beauty *Cryphia algae* This rare migrant was recorded at Holme-next-the-Sea on 13 August 2013 by Sophie Barker. The first for VC28 West Norfolk and the second for Norfolk.

Jersey Tiger *Euplagia quadripunctaria* A single specimen was photographed in a garden at Castle Acre, West Norfolk, on 17 August 2013 (Nick Ford). How it got there remains a mystery!

Phyllonorycter comparella The first for Norfolk was of mines on Grey Poplar *Populus*x *canescens* found at Weeting Heath on 18 August 2013 (I. Barton, K. Rosewarne).

Box Tree Moth *Diaphania perspectalis* Two specimens of this Asian moth were taken at light in a garden trap at Costessey, Norwich, on 3 October. (M. Casey). This is the first record in Norfolk of this Asian species. The moth is a pest of box *Buxus* spp. and was first recorded in the UK and Germany in 2007. Recent records from a handful of counties in the UK, are all thought to originate with accidental importation on box plants. Photo: Plate 14.3. p.51.

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Table1. A selection of notable records in 2013 (listed by date recorded)

Date 2013	Taxon	No.	VC	Location	Recorder	Stage	Comment
01/01	*Duponchelia fovealis* Dark Marbled Tabby	1	28	Watton	Chris Pye	Adult	New VC28
24/04	**Dotted Chestnut** *Conistra rubiginea*	2	28	Hockwold	Katherine Puttick	Adult	**New Norfolk**
23/04	*Acleris literana* Lichen Button	1	27	Overstrand	Greg Bond	Adult	(Previous VC27 rec. 1998)
18/05	*Coleophora pennella* Bugloss Case-bearer	1	28	Hockwold	Jon Clifton	Larval (Bred)	Several in 2013 (previously rec. 1999)
31/05	**Lace Border** *Scopula ornata*	1	27	confidential	Matthew Casey	Adult	Post-Victorian VC27 (1 of 2 at new site)
10/06	*Coleophora trochilella* Verge Case-bearer	3	28	Weeting Heath	Ian Barton/ Kathleen Rosewarne	Cases (Bred)	2nd Norfolk record (previous 1974)
11/06	*Tinagma ocnerostomella* Bugloss Spear-wing	1	27	Aldeby	Tony Prichard	Larval	New VC27 (several VC28 in 2013)
18/06	*Scythris picaepennis* White-dusted Owlet	1	28	Cranwich Heath	Ian Barton/ Kathleen Rosewarne	Adult	**New Norfolk** (1 of 6 adults swept)
20/06	*Mompha locupletella* Red Cosmet	1	27	Hoveton Hall	Stewart Wright	Adult	5th Norfolk record
26/06	*Cochylis molliculana* Ox-tongue Conch	1	28	Snettisham	Dick Jones	Adult	3rd Norfolk record (also at Haddiscoe, B. Jones)
29/06	*Pammene opulana* Pygmy Piercer	1	28	Sandringham	Jim Swalwell	Adult	5th Norfolk record
30/06	*Dichrorampha aeratana* Obscure Drill	1	27	Overstrand	Ben Murphy	Adult	New VC27 (also at Swanton Novers, J.Clifton)
30/06	*Epiblema grandaevana* Great Bell	1	27	Trimingham	Bill Urwin	Adult	2nd Norfolk (1 of 2 at same site in 2013)
03/07	*Parornix carpinella* Hornbeam Slender	1	27	Hoveton Hall	Stewart Wright	Mine	**New Norfolk**
09/07	**Shaded Fan-foot** *Herminia tarsicrinalis*	1	27	West Caister	Brian Jones	Adult	1 of 2 new sites in 2013 also Winterton (M. Crossfield)
13/07	*Prochoreutis myllerana* Small Twitcher	+	27	Repps-with-Bastwick	Stewart Wright	Larval + Adult	Post-Victorian 1st ? (several at site in 2013)

Date 2013	Taxon	No.	VC	Location	Recorder	Stage	Comment
20/07	*Epinotia nanana* Small Spruce Bell	1	28	Repps-with-Bastwick	Stewart Wright	Adult	Post-Victorian 1st
21/07	*Leucospilapteryx omissella* Mugwort Slender	3	28	Weeting Heath	Ian Barton/ Kathleen Rosewarne	Mine	New VC28
22/07	*Oncocera semirubella* Rosy-striped Knot-horn	1	27	Overstrand	Greg Bond	Adult	5th Norfolk record
22/07	*Batrachedra pinicolella* Pine Cosmet	1	27	Bawdeswell	Dave Appleton	Adult	Post-Victorian 1st (1 of 3 in 2013)
23/07	*Epinotia signatana* Black-brindled Bell	1	27	Bawdeswell	Dave Appleton	Adult	5th Norfolk record
23/07	*Evergestis limbata* Dark Bordered Pearl	1	25	Herringfleet Hills	Brian Jones, Keith Knights	Adult	(VC25 Suffolk) Just over the border!
27/07	*Trifurcula immundella* Broom Pigmy	1	28	Lynford	Stewart Wright	Adult	Post-Victorian 1st
28/07	*Ectoedemia sericopeza* Norway-maple Pigmy	1	28	Lynford	Ian Barton/ Kathleen Rosewarne	Mine (bred)	**New Norfolk** (1 of 5 at site in 2013)
30/07	*Mecyna flavalis* Yellow Pearl	1	27	Barnham Broom	J & J Geeson	Adult	Post Victorian 1st
30/07	*Yponomeuta irrorella*	1	27	Cley	Ian Walker	Adult	**New for Norfolk**
31/07	**White-mantled Wainscot** *Archanara neurica*	1	27	confidential	Brian Jones et.al	Adult	2nd Norfolk (1 of 2 in 2013)
31/07	**Small Chocolate-tip** *Clostera pigra*	18	27	Broads	Mark Crossfield	Adult	18 adults in 2 days at 1 site (prev record 1993)
01/08	**Ground Lackey** *Malacosoma castrensis*	1	27	Norwich	Alan Dawson	Adult	Norfolk 1st - unknown origin.
02/08	*Nemapogon wolffiella* White-speckled Clothes Moth	1	27	Bawdeswell	Dave Appleton	Adult	3rd Norfolk (1 of 2 at site in 2013)
03/08	*Hysterophora maculosana* Bluebell Conch	+	27	Hindolveston	Jon Clifton	Larval	4th Norfolk
04/08	*Spoladea recurvalis* Maize Moth	1	27	Walcott	Mick A'Court	Adult	New VC27 (2nd Norfolk)
13/08	**Tree-lichen Beauty** *Cryphia algae*	1	28	Holme	Sophie Barker	Adult	New VC28 (2nd Norfolk, 1 of 2 in 2013)
17/08	**Jersey Tiger** *Euplagia quadripunctaria*	1	28	Castle Acre	Nick Ford	Adult	**New Norfolk!** Unknown origin.
18/08	*Phyllonorycter comparella* Winter Poplar Midget	5	28	Weeting Heath	Ian Barton/ Kathleen Rosewarne	Mine (bred)	**New Norfolk** (several mines in 2013)
26/08	*Phyllonorycter quinqueguttella* Sandhill Midget	+	27	Winterton Dunes	Stewart Wright	Mine	2nd modern record (last recorded 1992)

Date 2013	Taxon	No.	VC	Location	Recorder	Stage	Comment
05/09	**Orache Moth** *Trachea atriplicis*	1	27	Edingthorpe Green	Mick A'Court	Adult	2nd VC27 (3rd modern record)
08/09	*Leucoptera lotella* Little Bent-wing	+	27	Shotesham Common	Andy Musgrove	Mine	Also at Catfield (S. Wright) Last rec. 1993
21/09	*Caloptilia semifascia* Maple Slender	2	28	Lynford	Ian Barton/ Kathleen Rosewarne	Mine (bred)	First confirmed VC28 ? (Unknown VC28 ref in MBGBI)
21/09	*Ectoedemia hannoverella* New Poplar Pigmy	10	28	Cranwich	Ian Barton/ Kathleen Rosewarne	Mine	3rd Norfolk
21/09	*Phyllonorycter lantanella* Viburnum Midget	+	28	Lynford	Stewart Wright	Mine	New VC28. (Unknown VC27 ref. in MBGBI)
24/09	*Ypsolopha sylvella* Wood Smudge	+	28	Costessey (30/09) Dersingham	Matthew Casey Dick Jones	Adult	Post-Victorian VC27 2nd modern day VC28 (1 of 2)
03/10	*Diaphania perspectalis* Box Tree Moth	2	27	Costessey	Matthew Casey	Adult	**New Norfolk** (2 of 4 in 2013)
30/11	*Ectoedemia turbidella*	4	28	Hockwold	Ian Barton/ Kathleen Rosewarne	Mine	**New Norfolk**

Hoverflies

Stuart Paston

2013 was notable for the hottest summer for seven years and some insect groups such as butterflies responded with a noticeable increase in populations. Whilst there was no evidence of a similar upsurge in hoverfly numbers, the year produced some noteworthy records that included three new species for the county.

Species new to Norfolk

The arrival of ***Cheilosia caerulescens***, a pest of houseleeks *Sempervivum*, was reported by the author in Natterjack, May 2014, with an appeal for records. The two 2013 records, from Brundall (Tim Strudwick) and Norwich (Elizabeth Grimes), related to sightings of adults confirmed from photographs. The first occurrence of this species in the UK came from a garden in South Croydon, Surrey in 2006 (Collins & Halstead 2008) and there have since been further records from Surrey as well as Bedfordshire.

Another addition to the County list arose from a collecting session undertaken by attendees of a hoverfly course at Holt Hall in July. Conditions for hoverfly activity hardly seemed auspicious with an overcast sky and persistent light rain putting the summer heat on hold but, amid a dozen or so recorded species, Nick Owens swept two male *Platycheirus* that were subsequently identified as ***Platycheirus europaeus.*** This was confirmed by the author.This species, which belongs to the clypeatus group, was first recognised in 1990 (Speight & Goeldlin 1990). Nationally it has been found widely in a variety of habitats including afforested Breck heathland in Suffolk. It seems to prefer the damper parts of sites where sedges tend to occur and it is thought the larva may be associated with aphids on sedges *Carex* spp. The Holt location was long grassland close to the lake, TG075398.

The third newcomer is ***Syrphus nitidifrons***, a female found at flowers of Box *Buxus sempervirens* on 2 May 2013 at Lynford, TL818933, by Ivan Perry. The first UK record came from Dorset in 2010 (Parker 2010) with another from the New Forest in the following year and there have been other recent unpublished records. This species, which was included in Stubbs & Falk 2002 in anticipation of its likely colonisation of the UK, is an inhabitant of woodland that was thought to be associated with conifers but there have been records from sycamore woodland (Perry 2014). There is potential for this spring species to occur widely in Norfolk.

Notes on other species

In all I received records for 97 species. ***Volucella inflata***, highlighted in last year's report, was found at Beeston by Francis Farrow and, for the second year running, at Stoke Holy Cross by Nick Elsey.

Naomi Dalton undertook a PhD project at Cantley marshes to assess the effect of Greater Water Parsnip *Sium latifolium* on pollinator communities and a stand-out record from the resulting Syrphid data was ***Lejogaster tarsata.*** This species is scarce nationally with a mainly coastal distribution. It was identified by David Gibbs.

Amid a lengthy list from his local patch at Shotesham, Andy Musgrove recorded both ***Cheilosia fraterna*** and ***Sphaerophoria taeniata***, the latter representing only the fourth Norfolk record this century. Both these species occur on damp meadowland. Nick Owens' list included ***Cheilosia longula*** from Kelling Heath and Weybourne which are the first Norfolk records this century

This species is mainly associated with acidic woodland and heathland sites.

Other species warranting a special mention are ***Arctophila superbiens*** from Beeston (Francis Farrow) and ***Cheilosia griseiventris*** from the Cut-off Channel in west Norfolk (Nick Owens).

Sericomyia silentis seems to have had a good year with some sightings from gardens. Males are known to wander some distance from wetland breeding sites and several were found at Ivy *Hedera helix* blossom in Earlham Cemetery, Norwich, the first observations the author has made of this species here since 2002. He also recorded a male ***Xanthandrus comtus*** hovering high in woodland at the UEA, Norwich, in July. No other records were received for this migratory species.

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Fungi

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Ash dieback – an unwelcome arrival

In other circumstances, the finding of a fungus new to Britain might be something to celebrate but the discovery of *Chalara fraxinea* in Ashwellthorpe Lower Wood, near Wymondham, Norfolk [TM 1397] in October 2012 was not welcome since it was the first time this causative agent of ash dieback had been found in Britain in a mature woodland.

Although the symptoms of the disease can be readily recognised, the fungus causing them is microscopic and, in this form, lacks any kind of 'fruiting body'. It belongs to a large group of fungi which lack the ability to reproduce sexually and which has been given many names including Fungi Imperfecti, deuteromycetes and mitosporic fungi. However, many of these do indeed have a sexual form (teleomorph) but this is very different in appearance from the asexual form (anamorph). Matching the asexual form (anamorph) with the sexual form (teleomorph) requires much detective work and for many anamorphs, corresponding teleomorphs have not been found, or may not even exist. It was 14 years after ash dieback was first recognised in Europe (in Poland, 1992) that the causative agent was given the name *Chalara fraxinea*, and only in 2010 was its sexual stage recognised as a discomycete (cup fungus) and named *Hymenoscyphus pseudoalbidus*. Since then, a ruling by the *International Code of Nomenclature for Algae, Fungi and Plants* has stipulated that each fungus species can have only one name, and the name *Hymenoscyphus fraxineus* has now been accepted (superceding both *C. fraxineus* and *H. pseudoalbidus*). A very similar species, *H. albidus*, is well-known and widespread in Britain. Both species fruit on the midrib (rachis) of fallen Ash *Fraxinus excelsior* leaves from mid-summer into autumn. However, *H. albidus* appears to have become much rarer in Britain since the arrival of *H. fraxineus*.

In some ascomycetes, sexual and asexual stages alternate, or at least both are involved in an annual lifecycle. This appears to be the case with *H. fraxineus*. Spores from the discomycete on the fallen leaf stalks are blown on to growing leaves where the germinating fungus enters, grows and spreads into the twigs. Eventually it reaches the stem of the tree, causing damage which is ultimately fatal. When infected leaves fall to the ground, asexual spores are produced but these seem incapable of re-infection. However, those from different mating strains (analogous to different sexes) can undergo a fertilisation process which leads to the formation of the discomycete fruiting bodies which release spores which can infect new hosts.

It was appropriate for two reasons that the first discovery of the discomycete form of *H. fraxineus* in Britain was made by Anne Edwards at Ashwellthorpe Lower Wood (2 June 2013). The first is that this site was where ash dieback was first seen in Britain in self-set trees, and the second is that, Anne, a research scientist, had begun working on the molecular biology of the fungus at the John Innes Centre, Norwich. Through genome analysis she was able to confirm that the fungus was indeed *H. fraxineus*. Just a few weeks later, Neil Mahler found and photographed numerous specimens at Foxley Wood [TG 0522] Photo: Plate 15.5 p.54. It is now widely found on Ash leaves which have fallen during the previous year, especially if lying on wet ground.

Typhula phacorrhiza - a master of disguise

Anne Edwards' professional interest extends to all fungi on Ash leaves so she kindly agreed to examine the white button-like structures found by Francis Farrow on a fallen Ash leaf on Beeston Common [TG 1642] in 2013. Although apparently fungal, the buttons, 2-4 mm in diameter had a firm, almost rubbery, texture and lacked any evidence of reproductive structures Some of the leaves also bore similar dark brown 'buttons'(see photo: Plate 15.4, p.54).

Sequencing part of the 18S ribosomal RNA gene revealed that both the white and the brown 'buttons' were sclerotia *of Typhula phacorrhiza,* a spindle fungus. After the results were published (Edwards *et al.* 2014), a mycologist from Norway informed us that she had puzzled over the identity of these structures for seven years! Sclerotia are perennating structures which allow the fungus to remain dormant but then grow rapidly in the next season. Ted Ellis recorded this fungus (in its spindle form) at Wheatfen in the 1940s but it was not recorded in Norfolk again until 2003 when it occurred in Simon and Anne Harrap's garden at Edgefield (see photo: Plate 15.3, p.54). Earlier this year Rob Shepherd found *T. phacorrhiza* in his garden near Dereham.

Amanita inopinata - the unexpected

If ever a fungus was well-named it is *Amanita inopinata* (see photo: Plate 15.1, p.54). It has no English name but when Derek Reid described it in 1987 he chose the specific epithet '*inopinata*' meaning 'unexpected'. It was unexpected in at least two ways: first it was a surprise that such a distinctive fungus should have remained undiscovered until 1981 (in Kent) and, secondly, that such a strange amanita should exist at all. Equally unexpected has been its recent appearance in a North Norfolk garden, extending its range northwards by over 100 km.

During a fungus foray organised by the Norfolk Group of Plant Heritage in the large garden of John and Judy Wilson at West Beckham [TG 1339], Pauline Davies emerged from the shrubbery with a chunky gilled fungus and a tentative 'is this anything interesting'. With peach-coloured gills, a scaly cap and no apparent volva,the fungus did not at first reveal itself as an amanita. Indeed its identification involved several blind alleys.

Amanita inopinata is not thought to form mycorrhizal associations with any tree species but most of the finds have been with introduced conifers, particularly, as in this case, *Chamaecyparis*. Its association with habitats influenced by man, and its recent appearance and subsequent spread, suggest that it might have been introduced. After a description of *Amanita inopinata* was published, it was reported that an identical (but then unnamed) fungus had been previously found in several locations in New Zealand, but again with non-native conifers in man-made habitats (Ridley 2000). One explanation is that it has indeed been inadvertently introduced but to both Britain and New Zealand from a third centre, as yet undiscovered.

Oak Polypore returns

The Oak Polypore *Piptoporus quercinus* is one of only four species of fungus on Schedule 8 of the Wildlife and Countryside Act 1981, making it illegal to pick or destroy the bracket. Its second British record was from West Norfolk in 1871 but after that it was very rarely recorded anywhere in Britain until the 1990s when Martyn Ainsworth had a contract from English Nature to locate the fungus. Since then he has found a remarkable number of specimens, all of them on oak trees that are at least 200 years old. The bracket usually appears in early summer on wounded surfaces or on the ends of large fallen branches. In 2005, Martyn Ainsworth was being driven from a meeting in Brancaster to King's Lynn to catch a train back to London. As he passed close to Castle Rising, he recognised the name as the locality where Charles Plowright had collected the fungus in 1871 and suggested that a brief detour might be made. From the village, Martyn looked across the fields towards a row of ancient oaks in a field boundary and observed that this was the sort of place that the bracket might occur. He walked over to the trees – and promptly found an Oak Polypore on the end of a large fallen branch! Good fortune does indeed favour the prepared mind. Remarkably, during 2013 the Oak Poylpore was found twice in Norfolk. Tracy Money and Andy Gardiner found the fungus on an a mature oak tree in the grounds of Wymondham College [TM 0798] and Anne Crotty found it at Whitlingham - on an old fallen branch and on a stub of a live veteran oak nearby. Ironically the highly protected status of the fungus makes it difficult to confirm finds!

And finally, a Yorkshire record with Norfolk connections. Joseph Hubbard, an active member of the Norfolk Fungus Study Group, on holiday with his family, visited Helmsley Castle where he spotted a bracket fungus growing on a large oak beam over a window in the roofless keep. Martyn Ainsworth later confirmed it as Oak Polypore - making it the first record of the fungus on worked timber.

Sclerogaster compactus – a smelly truffle

The name truffle is given to any fungus with a fruiting body which develops beneath the soil surface. Over 80 species have been recorded in Britain, from a diverse range of fungal groups. Most are small and inedible, and are not commonly recorded. In December, Jonathan Revett entered his greenhouse in Welney and wrote:

> "The thing that alerted me was a strong smell of garlic which was odd as there were no plants in there, only sawdust, woodchips and other organic debris to encourage fungi. A quick poke around revealed several small (3-5 mm diameter),

Table 1. New county records of fungi (excluding those referred to in the text).

Species	Place	Collector [Identifier if different]	Habitat
Agarics			
Coprinellus pusillulus	Watermill Broad, Cranwich TL 7795	Tony Leech	Sheep dung
Coprinopsis kubickae *(Photo: Plate 15.2 p.55)*	Watermill Broad, Cranwich TL 7795	Lee Barber [Tony Leech]	Reed stem
Coprinopsis tigrinella	Watermill Broad, Cranwich TL 7795	Lee Barber [Tony Leech]	Reed stem
Hygrocybe aurantiosplendens	Brinton Hall TG0335	Alex Prendergast	Lawn
Hygrophorus penarius	Little Plumpstead Wood TG 3110	[Tony Leech]	Woodland
Leccinum melaneum	Gresham's School, Holt TG 0839	Tony Leech	Lawn (birch)
Jelly fungi			
Mucronella flava	Holt Country Park TG 0837	James Emerson	Conifer log
Discomycetes (cup fungi)			
Ascobolus hawaiiensis	Watermill Broad, Cranwich TL 7795	Tony Leech	Sheep dung
Ascobolus stictoideus	Watermill Broad, Cranwich TL 7795	Tony Leech	Deer dung
Coprotus sexdecimsporus	Watermill Broad, Cranwich TL 7795	Tony Leech	Rabbit dung
Peziza fimeti	Watermill Broad, Cranwich TL 7795	Tony Leech	Deer dung
Saccobolus citrinus	Watermill Broad, Cranwich TL 7795	Tony Leech	Deer dung
Other ascomycetes			
Hypoxylon petrinae	Pigney's Wood TG 2932	Neil Mahler	Ash log
Sordaria macrospora	Blakeney Point TG 0046	Tony Leech	Hare dung
Trichodelitschia munkii	Blakeney Point TG 0046	Tony Leech	Hare dung

very downy, white sub-globose structures, partially buried amongst the woody debris. There were also lots of mycelial cords amongst the debris which may or not have been part of this species.Cutting through the fruitbodies displayed a slimy, green, gelatinous interior with several chambers. The garlic smell was not as prominent. The spore shape and size, coupled with the macroscopic features, agreed with the description of *Sclerogaster compactus* in Pegler et al. (1993) although I can find no reference in this or in other literature to the garlic smell."

There are no previous records for this fungus from Norfolk and only six from Britain, the most recent in 1964.

Fungal hot spots

On most forays large numbers of widespread species are recorded but occasionally, when time and place are right, a cluster of more unusual species is encountered. One such foray took place at the Greenacres Woodland Burial Park, Colney [TG 1608] in October. The highlight was the first Norfolk record of *Lepiota cortinarius*, found by a small girl at the start of the foray. This was followed by *Amanita betulae*, Dark Honey Fungus *Armillaria ostoyae*, *Cystolepiota hetieri*, Golden Bootleg *Phaeolepiota aurea*, *Pholiota tuberculosa* and Piggyback Rosegill *Volvariella surrecta*, all rarely recorded in the county. The latter is a medium-sized agaric which grows on the collapsing remains of Cloud Funnel *Clitocybe nebularis*. A week later, an opportunity for the Norfolk Fungus Study Group to visit Sutton Broad Wood South [TG 3723], on the RSPB Sutton Fen Reserve, revealed Girdled Webcap *Cortinarius trivialis*, *C. cinnamomeoluteus*, *C. uliginosus*, *Lactarius lacunarum*, Orange Oak Bolete *Leccinum aurantiacum*, and the cup fungus *Peziza limnea*.

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