Floristic change in English grazing marshes: the impact of 150 years of drainage and land-use change

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ABSTRACT

Grazing marshes have assumed a significant role in the conservation of British wetlands, but their biodiversity has declined as a result of drainage and land use change. Using as wide a range as possible of published and archive sources from 1840 to the present, changes in species abundance and distribution over 150 years were reconstructed in three English grazing marshes: the Somerset Levels and Moors, the Romney and Walland Marshes and the Idle/Misson Levels. Of 526 species studied, over half showed a decline, which was severe in 123 species. Only 34 species, often aliens or adventives, increased. Published accounts, land use and drainage data, together with knowledge of the species' ecology suggest that drainage has been the most important factor in species decline. Raised bog and fen have experienced the greatest extinction of species. Species of wet grassland and watercourses survive, but often at much reduced abundance.

KEYWORDS: agriculture, drainage channel, grassland, mire, wetland, conservation.

INTRODUCTION

Much attention has been focused on wetland conservation and the relationship between land use change and the survival of particular species and communities. This attention stems from the belief that wetlands are particularly threatened by human activity intended to increase agricultural production or to protect and extend urban areas. Evidence from species decline and extinction supports this view (Ratcliffe 1984).

Concern for the survival of particular species of plants and animals has led ecologists and conservationists to widen their research to include communities which in no sense are natural but which hold populations of vulnerable species. The traditional grazing marshes of Britain represent a stage in the conversion of 'virgin' land into farmland and as such support vegetation that is neither typical of primeval wetland nor of intensive cultivation (Moss 1907; Williams 1970).

Agricultural drainage has been a major factor in the reduced extent of wetlands (Sheail & Wells 1983). The environmental effects of drainage works are many (Hill 1976). They include:

a. Removal or modification of wetland plant communities (reduced species richness and altered diversity).
b. Reduction of breeding (and feeding) areas for animals.
c. Degradation and accelerated loss of organic matter.
d. Higher mineralisation rate, leakage of nitrogen-nitrate to ground-water in the years following drainage and run-off of other nutrients and chemical residues.
e. Change in the local water regime, with impacts on ground-water quantity and quality (channel form, sediment load, water temperature and water chemistry).
f. Increased use of fertilisers and pesticides including aquatic herbicides (for drainage channel maintenance).
g. Reduction of landscape and amenity values.
h. Removal of hedgerows, trees, scrub, small woodlands, ponds, field enlargements, etc. coincidental with drainage works.
i. Drainage effects on land that has itself not been drained, but lies adjacent to such land.

In English grazing marshes, drainage for agriculture and associated land-use change have affected the distribution and abundance of plants through: 1. changes in water-table; 2. peat cutting; 3.

channelisation; 4. changes in water-quality; 5. ditch elimination; and 6. management of the watercourses.

In the present paper, the main objective has been to assess the relationship between drainage and land use change since 1840 and the status of plant species in grazing marshes. The approach has been to marshall the information provided by botanists over the period 1840–1990 and demonstrate changes in species abundance and distribution, a method previously used in Broadland (Driscoll 1982), the Fenland (Sheail & Wells 1980) and Gwent Levels (Wade & Edwards 1980). An aim has been to demonstrate the need for plant ecologists to pay attention to the historical context in which the communities that they study developed (Salisbury 1927).

METHODS

THE STUDY AREAS

Different grazing marshes reflect different stages in the transition from primeval wetland to drained, reclaimed and intensively farmed land. Three areas in England were selected that display the increasing impact of modern agriculture (Fig. 1):

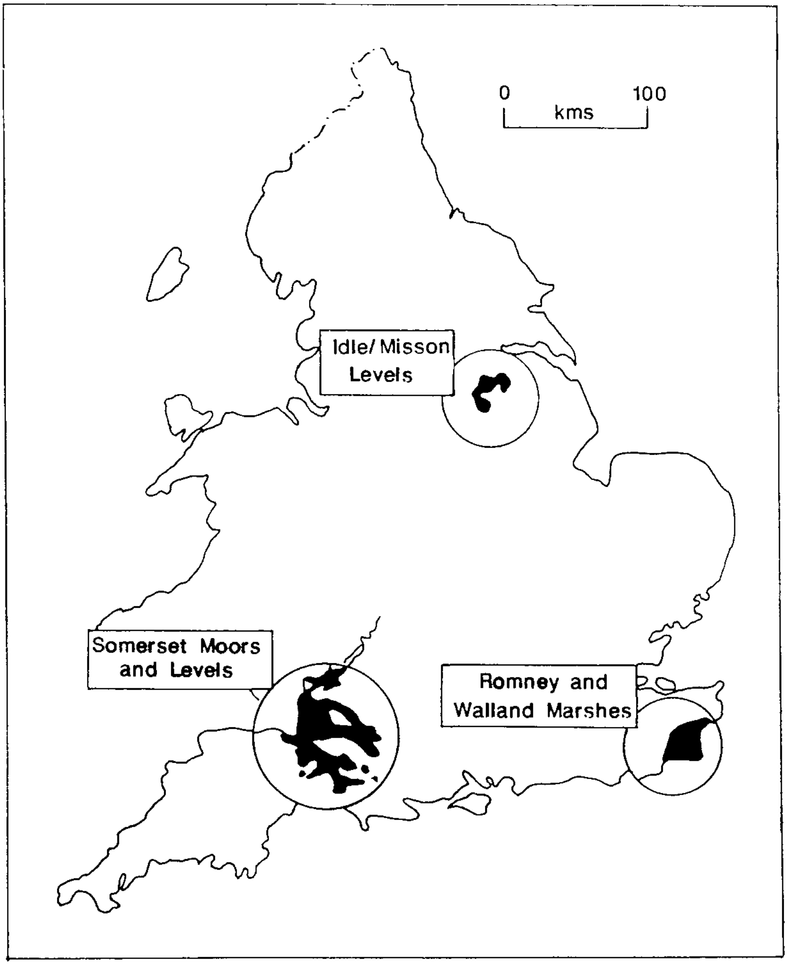

FIGURE 1. Location of three grazing marsh study areas in England. The sites are depicted at twice the base map scale.

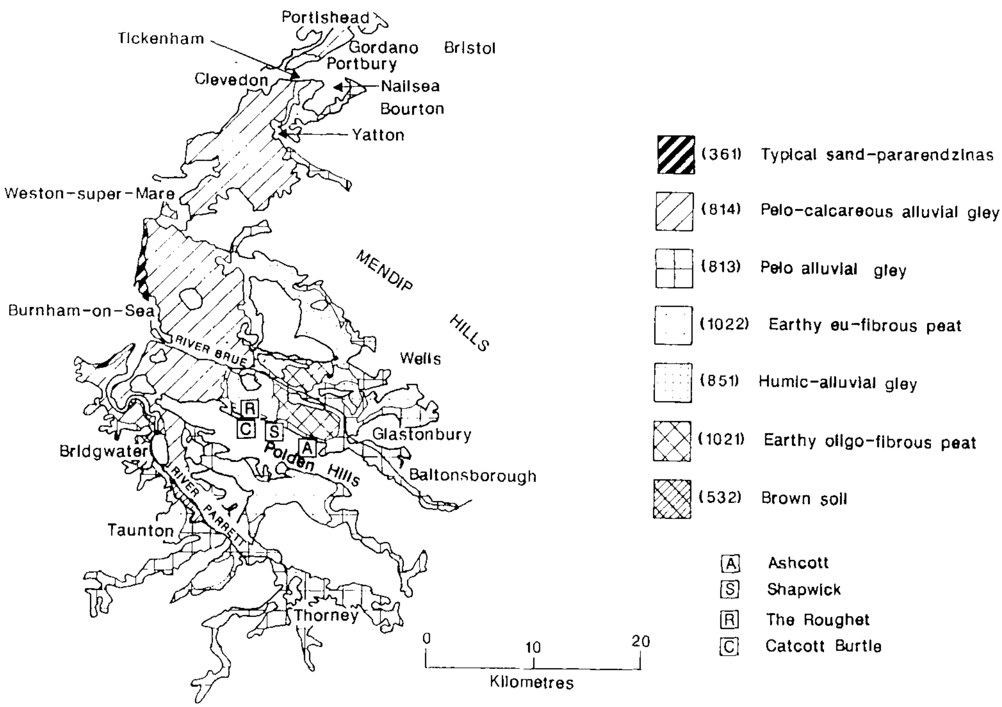

FIGURE 2. The Somerset Levels and Moors – map of study area showing major soil types and localities mentioned in the text. Upland (altitude >10 m) and sea areas left blank. Soil data derived from the Soil Survey of England & Wales (1983).

1. THE SOMERSET LEVELS AND MOORS – chosen as a largely unimproved grazing marsh. The study area takes in all the land on ground-water gley and peat soils between sea level and the 30′ (10m) contour and corresponds with the area defined by the 1:100,000 soil map (Soil Survey 1978) (Fig. 2).

2. THE ROMNEY AND WALLAND MARSHES – chosen as an area where marked changes in drainage and land use occurred after 1940. The study area includes the land south-east of the Royal Military Canal, with Shirley Moor and the Rother Levels west to Potman's Heath (Fig. 3).

3. THE LOWER IDLE VALLEY AND MISSON LEVELS – chosen to study the effect of a long period of intense cultivation on the plants of pasture and drainage channels. The study area was defined as that to benefit from the location of new pumps at West Stockwith, where the R. Idle joins the R. Trent (i.e. between Epworth and Bawtry, and up the R. Idle to Mattersey) (Fig. 4).

SELECTION OF SPECIES

Over 500 species of vascular plant and Charophyte were included in an archive search. The species chosen met one or more of the following habitat criteria, growing: 1. in standing or flowing fresh water; 2. in mire vegetation at altitudes <300 m; 3. in mesotrophic grasslands below 300 m; 4. in flood-plain or fen woodland; 5. on the banks of water-courses; 6. associated with occasionally flooded sites, muddy ground, or where compaction of the soil leads to transient standing water; and 7. in or by brackish water or where saltmarsh gives way to freshwater communities.

SOURCES OF FLORISTIC DATA

In order to trace changes in the distribution and abundance of species since 1840, as complete a set of sources as possible was used to build up a picture of the history of individual species in each study

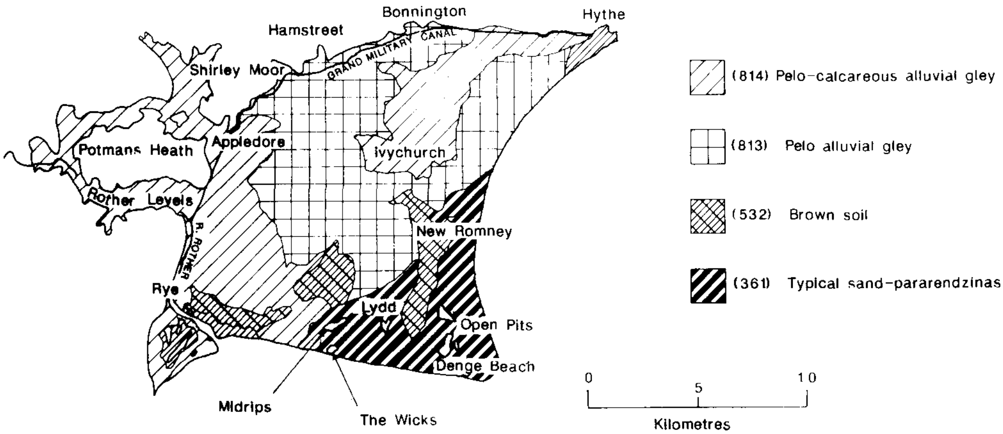

FIGURE 3. The Romney and Walland Marshes – map of study area showing major soil types and localities mentioned in the text. Upland (altitude >10 m) and sea areas left blank. Soil data derived from the Soil Survey of England & Wales (1983).

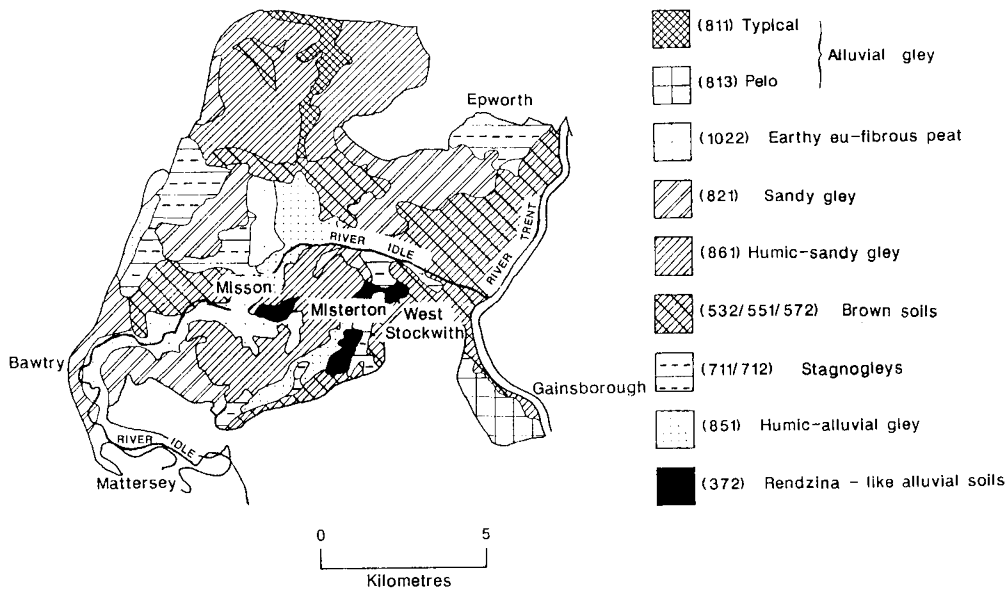

FIGURE 4. The Lower Idle valley and Misson Levels – map of study area showing major soil types and localities mentioned in the text. Upland (altitude >10 m) and sea areas left blank. Soil data derived from the Soil Survey of England & Wales (1983).

area. The sources used in the study areas are set out in Appendix 1. There is great variation in the detail and comprehensiveness of the earlier county or regional Floras. Recent plant atlases record information systematically but often omit local detail useful in interpreting species distribution.

The journals of naturalists' societies contain site-specific data, providing the detail required to evaluate accounts in Floras and plant atlases. Manuscript data (card indices, etc.) were consulted both in private hands and in herbaria, where accompanying specimens may be used to substantiate the accuracy of records. When these sources were prepared by authors of (or contributors to) Floras, they clarify and amplify the published accounts.

Many botanists have kept notebooks or annotated maps detailing their finds and the notes referring to a single visit may be enough to reconstruct the contemporary vegetation. Such sources were traced through the recorder network of the Botanical Society of the British Isles.

Both the national Biological Records Centre at Monks Wood and local centres provided species distribution data and were consulted extensively in all three study areas. Local centres may also store material on a site basis, giving an insight into floristic change at particular locations.

English Nature (formerly the Nature Conservancy Council) commissioned inventories of watercourse vegetation for each of the study areas between 1978 and 1982. These accounts provided detail on specific sites and a valuable baseline from which to measure change.

RECONSTRUCTION OF FLORISTIC CHANGE: THE EXAMPLE OF GOLDEN DOCK (*RUMEX MARITIMUS* L.)

The range and quality of material used can be demonstrated by a detailed example. Appendix 2 reproduces the information gathered about the Somerset distribution of *Rumex maritimus*. From such material, trends in the distribution and frequency of *R. maritimus* can be discerned:

To 1900, it was common on the peat-moors, and also scattered by the R. Parrett and its estuary, with outlying records near Wells and at Portishead.

Between 1901 and 1940, the dock may have spread further up the R. Parrett and near the R. Tone also. It maintained its abundance on the peat-moors.

Between 1941 and 1975, *R. maritimus* was not seen in the Parrett valley (except on the coast and a transient site at Thorney). It was present on the peat-moors but recorded only from *specific* sites rather than described as generally 'plentiful'.

After 1975, it was only found in a small area at the centre of the peat-moor between Catcott Burtle and the R. Roughet.

There is a strong suggestion that *R. maritimus* declined on the Somerset Levels and Moors, surviving only on the peat moors (the core of its former range) where peat cutting and ditch clearance created the open, bare, wet conditions where the dock could germinate, flourish and seed.

A similar marshalling and assessment was undertaken for each of the 500 species covered by the archival search, though for the commonest taxa there may only be summary data. Judgement had to be exercised in the interpretation of a wide range of disparate sources. Any trends identified in the abundance of species might be 1. marked, 2. moderate but unambiguous or 3. slight and based upon data of doubtful quality (Mountford 1994). Species with similar environmental needs which show consistent population or distribution changes were grouped together. Where the abundance or distribution of a species changed between 1840 and 1990, the extent of its preferred habitat can often be shown to have changed also. When species from one habitat show similar changes, there is circumstantial evidence that the cause of the change is some alteration to that habitat. Land-use and drainage data were examined to test whether any changes in the habitat had occurred. Changes in the study areas are described in detail elsewhere (Sheail & Mountford 1984; Mountford & Sheail 1989).

RESULTS

MAJOR TRENDS IN PLANT DISTRIBUTION AND ABUNDANCE

Trends in distribution are summarised in Tables 1–5, which list all taxa for which the sources used provide some evidence of change 1840–1990 (References and Appendix 1). Over half the taxa showed a population change in one or more area.

SPECIES SHOWING NO CHANGE IN POPULATION OR DISTRIBUTION

There were 206 species for which no convincing evidence of population change could be found. This total included:

- Species where the published sources differed in precision (giving an impression of change), e.g. *Carex pilulifera* L.

- Taxonomically difficult plants, identified by very few botanists, producing insufficient data from which to infer trends, e.g. *Rorippa* × *anceps* (Wahlenb.) Reichb.
- Species where opposing pressures (some favourable, others unfavourable) balanced, resulting in no perceptible change, e.g. *Phragmites australis* (Cav.) Trin. ex Steudel.
- Species whose habitat requirements limited them to a few sites from 1840–1990, e.g. *Potamogeton coloratus* Hornem.
- Ubiquitous species occupying habitats which were as widespread in 1990 as 1840, e.g. *Agrostis stolonifera* L.

SPECIES SHOWING AN INCREASE IN ABUNDANCE AND DISTRIBUTION

50 species showed evidence of spread in at least one study area, although 16 of these declined in another of the three areas (Tables 1 & 2). Of the remaining 34, there is some doubt attached to the quality of the data for 18 (due to taxonomic problems or unevenness of coverage). Only seven spread markedly *and* unambiguously – *Azolla filiculoides* Lam., *Chamerion angustifolium* (L.) Holub, *Elodea canadensis* Michaux, *E. nuttallii* (Planchon) H. St John, *Impatiens glandulifera* Royle, *Nymphoides peltata* Kuntze and *Puccinellia distans* (Jacq.) Parl. Table 1 includes many aliens and colonists (species introduced into grazing marshes from other habitats or parts of Britain). Increasing abundance might be presumed for some species whose preferred habitat became more widespread between 1840 and 1990, but cannot be demonstrated from the sources. These species were classified as unchanged in abundance.

SPECIES INCREASING IN SOME AREAS AND DECREASING IN OTHERS

In most cases, presumed causes of population change and the resulting trends in species were similar in all study areas (Table 6). However, 16 species showed conflicting trends in distribution when the study areas are compared (Table 2). Wade & Edwards (1980) note several species in the Gwent

TABLE 1. SPECIES SHOWN TO HAVE INCREASED IN POPULATION SIZE OR DISTRIBUTION FROM 1840 TO 1990

(a) In all three study areas	
Elodea canadensis	*Potamogeton berchtoldii*?
Elodea nuttallii	*Ranunculus trichophyllus*?
Populus alba?	*Rorippa microphylla*?
(b) In two of the study areas (absent/unchanged in third)	
Azolla filiculoides	*Mimulus guttatus*
Callitriche platycarpa?	*Myriophyllum spicatum*?
Carex acuta?	*Nymphoides peltata*
Chamerion angustifolium	*Petroselinum segetum*
Festuca arundinacea?	*Potamogeton pusillus*?
Glyceria declinata?	*Salix triandra*?
Impatiens glandulifera	*Veronica catenata*?
Lemna gibba	
(c) In one study area (absent/unchanged in other two)	
Alopecurus bulbosus	*Leucojum aestivum*
Barbarea stricta	*Myosurus minimus*?
Chara globularis	*Nitella mucronata*?
var. *annulata*?	*Potamogeton pectinatus*
var. *virgata*?	*Puccinellia distans*
Eleocharis uniglumis?	*Rorippa* × *sterilis*?
Elodea callitrichoides	*Salix viminalis*?
Leersia oryzoides	

Notes: i. Where a question mark follows the species name, there is some doubt about the trend. Data may be inadequate, there may be some taxonomic problem, etc. ii. Where a species has clearly changed in one area, but in one or both the others there is some doubt, no ? is marked. iii. Some species have only ever been recorded in one or two of the study areas. iv. Nomenclature follows Stace (1991) for vascular species, Moore (1986) for Charophytes and local sources (Appendix 1) for some infraspecific taxa.

TABLE 2. SPECIES SHOWN TO HAVE INCREASED IN POPULATION SIZE OR DISTRIBUTION IN ONE OR MORE STUDY AREAS, AND TO HAVE DECREASED IN THE OTHERS FROM 1840 TO 1990

Althaea officinalis	*Potamogeton trichoides*
Bromus commutatus	*Ranunculus baudotii*
Carex vesicaria	*Ranunculus circinatus*
Carex viridula subsp. *viridula*?	*Rorippa amphibia*
Chara hispida subsp. *hispida*?	*Schoenoplectus tabernaemontani*
Epilobium tetragonum subsp. *tetragonum*	*Symphytum officinale*
Persicaria bistorta	*Tolypella nidifica*
Potamogeton natans	*Wolffia arrhiza*

Notes: see Table 1.

Levels whose distribution trends differ from those observed in the present study, reflecting the importance of local factors in determining floristic change.

SPECIES SHOWING A DECREASE IN ABUNDANCE OR DISTRIBUTION

Just over half the species included in the archive search underwent an apparent contraction in range or decline in frequency after 1840 (Tables 3 & 4). Of these, 123 species declined markedly, 94 becoming extinct in at least one, and 23 in two or all study areas (Table 4). In all areas, many more species declined from 1840–1990 than increased (Tables 5 & 6).

The sources used note plants that decreased during the lifetime of the botanist, frequently suggesting reasons for that decline. Most of the causes advanced involve the activities of a burgeoning human population (especially agricultural improvement), but some natural changes were also suggested as factors in species decline. Suggested causes include:

Drainage: the commonest factor proposed as a cause for species loss in wetlands, e.g. *Myrica gale* L., *Parnassia palustris* L., *Ranunculus lingua* L., *Lythrum salicaria* L., *Narthecium ossifragum* (L.) Hudson and *Vaccinium oxycoccos* L. (Gibbons 1975); *Thelypteris palustris* Schott, *Dryopteris cristata* (L.) A. Gray, *Drosera rotundifolia* L., *Empetrum nigrum* L., *Viola persicifolia* Schreber and species of the Misson "fenny fields" (Howitt & Howitt 1963); *Valeriana dioica* L. and *Carex pulicaris* L. (Roe 1981); *Althaea officinalis* L. (Hanbury & Marshall 1899); *Cyperus longus* L. (White 1912).

Peat-digging: e.g. *Hypericum elodes* L. (White 1912; Sandwith files; Roe files); *Andromeda polifolia* L. (Roe 1981); *Rhynchospora fusca* (L.) Aiton f. (Murray 1896; Roe 1981).

Flooding acid peat and alkaline water: *Utricularia minor* L. (Storer 1985 and files; Roe, pers. comm. 1982).

Enclosure and grazing: e.g. *Vaccinium myrtillus* L. (Lees 1888); *Juncus effusus* L. (Raine 1980).

Cultivation (fertilisers, liming, ploughing or reseeding): e.g. *Colchicum autumnale* L., *Orchis morio* L. and *Primula veris* L. (Roe 1981); *Genista tinctoria* L. (White 1912); *G. anglica* L. and *Rhinanthus minor* L. (Lees 1888); *Botrychium lunaria* (L.) Sw. and *Sanguisorba officinalis* L. (Gibbons 1975).

Watercourse management and pollution: e.g. *Hottonia palustris* L. and *Rumex hydrolapathum* Hudson (Gibbons 1975); *Stratiotes aloides* L. (Roe files); *Rorippa sylvestris* (L.) Besser, *Valeriana officinalis* L. (Gibbons 1975) and submerged aquatics especially pondweeds – herbicide (Howitt day-book); *Ranunculus fluitans* Lam. – colliery effluent (Howitt & Howitt 1963).

Sea defences: e.g. salt-tolerant species at the Midrips and Wicks, Kent (N. W. Moore, pers. comm. 1981).

Industrialisation and urbanisation: e.g. *Blysmus compressus* (L.) Panzer ex Link (White 1912; Roe files); *Cladium mariscus* (L.) Pohl and *Carex elata* All. (Roe files; Sandwith files); *Salix aurita* L. (Howitt & Howitt 1963).

Deliberate eradication or collection: e.g. *Colchicum autumnale* (Roe 1981); *Lychnis flos-cuculi* L. (Willis & Jefferies 1959); *Osmunda regalis* L. (White 1912); Pteridophyta (Gibbons 1975).

TABLE 3. SPECIES SHOWN TO HAVE DECREASED IN POPULATION SIZE OR DISTRIBUTION FROM 1840 TO 1990

(a) In all three study areas

Alnus glutinosa
Anagallis tenella
Apium inundatum
Baldellia ranunculoides
Bidens cernua
Caltha palustris
Carex diandra
Carex pulicaris
Chara globularis subsp. *globularis*?
Chara vulgaris var. *longibracteata*?
Dactylorhiza praetermissa
Eriophorum angustifolium
Galium uliginosum
Hydrocotyle vulgaris
Juncus squarrosus
Menyanthes trifoliata
Myriophyllum verticillatum
Nymphaea alba
Ophioglossum vulgatum
Orchis morio
Osmunda vulgaris
Pedicularis palustris
Potamogeton alpinus
Potamogeton polygonifolius
Potentilla palustris
Primula veris
Ranunculus lingua
Rumex maritimus
Rumex palustris
Sium latifolium
Sparganium natans
Stellaria uliginosa?
Veronica scutellata

(b) In two of the study areas (absent/unchanged in third)

Achillea ptarmica
Acorus calamus
Apium graveolens
Briza media
Butomus umbellatus
Callitriche truncata
Carex curta
Carex disticha
Carex divisa
Carex echinata
Carex elongata
Carex hostiana
Carex pallescens
Carex viridula subsp. *brachyrrhyncha*
Catabrosa aquatica
Chara vulgaris
  var. *papillata*?
  var. *vulgaris*?
Cirsium dissectum
Cirsium palustre
Cladium mariscus
Coeloglossum viride
Colchicum autumnale
Dactylorhiza incarnata subsp. *incarnata*
Dactylorhiza maculata
Drosera intermedia
Eleocharis quinqueflora
Epipactis palustris
Erica cinerea
Erica tetralix
Eriophorum vaginatum
Frangula alnus
Groenlandia densa
Hippuris vulgaris
Hottonia palustris
Hydrocharis morsus-ranae
Juncus bulbosus
Juncus effusus?
Lathyrus palustris
Lotus glaber
Lychnis flos-cuculi
Mentha pulegium
Molinia caerulea
Montia fontana?
Myrica gale
Myriophyllum alterniflorum
Narcissus pseudonarcissus
Narthecium ossifragum
Nuphar lutea
Pedicularis sylvatica
Persicaria laxiflora
Persicaria minor
Peucedanum palustre
Platanthera bifolia
Potamogeton gramineus
Potamogeton lucens
Potamogeton perfoliatus
Radiola linoides
Ranunculus flammula?
Ranunculus hederaceus
Ranunculus peltatus
Ranunculus penicillatus?
Rhinanthus minor s.l.
Rhynchospora alba
Sagittaria sagittifolia
Sagina nodosa
Salix aurita
Salix repens?
Schoenus nigricans
Senecio aquaticus
Spirodela polyrhiza
Stachys × *ambigua*
Stachys palustris
Stellaria palustris
Succisa pratensis
Thelypteris palustris
Utricularia minor
Utricularia vulgaris s.s.

TABLE 3. *cont.*

Vaccinium oxycoccos
Valeriana dioica
Valeriana officinalis
Veronica anagallis-aquatica?
Viola canina
Viola palustris

(c) Clearly declined or extinct in one study area (absent or unchanged in other two)

Alopecurus aequalis +
Alopecurus pratensis
Antennaria dioica +
Aster tripolium
Bidens tripartita
Blechnum spicant
Blysmus compressus +
Blysmus rufus +
Bupleurum tenuissimum
Calluna vulgaris
Carex distans
Carex elata
Carex extensa +
Carex laevigata
Carex limosa +
Carex nigra
Carex panicea +
Carex paniculata
Carex pseudocyperus
Carex rostrata +
Ceratophyllum submersum
Chenopodium chenopodioides
Danthonia decumbens
Deschampsia cespitosa
Dryopteris carthusiana
Dryopteris cristata +
Eleocharis multicaulis +
Eleogiton fluitans
Empetrum nigrum +
Euphrasia arctica
Galeopsis segetum +
Genista anglica +
Gentiana pneumonanthe +
Geum rivale
Gnaphalium uliginosum
Gymnadenia conopsea
  subsp. *conopsea*
  subsp. *densiflora*
Hammarbya paludosa +
Hordeum marinum
Huperzia selago +
Hypericum maculatum
Iris pseudacorus
Isolepis setacea +
Juncus gerardi
Juncus subnodulosus
Lactuca saligna
Lepidium latifolium +
Limosella aquatica +
Lycopodiella inundata +
Lycopodium clavatum
Lysimachia thyrsiflora +
Lysimachia vulgaris
Lythrum salicaria
Mentha × *verticillata*
Mimulus moschatus +
Nardus stricta
Oenanthe lachenalii +
Ononis spinosa
Orchis ustulata
Petasites hybridus
Peucedanum ostruthium +
Pinguicula lusitanica
Potamogeton compressus +
Potamogeton × *lintonii* +
Potamogeton × *salicifolius* +
Potamogeton × *sparganifolius*
Prunus padus
Puccinellia fasciculata
Puccinellia maritima
Pyrola minor +
Ranunculus fluitans
Ranunculus omiophyllus +
Ranunculus sardous
Ranunculus tripartitus +
Rhynchospora fusca +
Ribes rubrum
Rumex hydrolapathum
Ruppia cirrhosa
Ruppia maritima
Salicornia ramosissima
Sanguisorba officinalis
Saxifraga granulata
Scheuchzeria palustris +
Schoenoplectus lacustris
Scirpus sylvaticus +
Selaginella selaginoides +
Sparganium angustifolium +
Suaeda maritima
Taraxacum palustre +
Thalictrum flavum
Triglochin maritimum
Triglochin palustre
Utricularia australis
Veronica beccabunga
Viola persicifolia +
Wahlenbergia hederacea
Zannichellia palustris

(d) Possibly declined or extinct (?) in one study area (absent or unchanged in other two)

Angelica sylvestris
Berula erecta
Calamagrostis canescens
Callitriche hamulata
Carex remota
Carex vulpina s.s.
Ceratophyllum demersum
Chara pedunculata
Chara vulgaris
  var. *crassicaulis*

TABLE 3. *cont.*

Eupatorium cannabinum	*Nitella translucens*
Filipendula ulmaria	*Oenanthe crocata*
Glyceria maxima	*Persicaria hydropiper*
Hypericum tetrapterum	*Potamogeton praelongus*
Juncus acutiflorus	*Ranunculus aquatilis*
Juncus ambiguus	*Salix purpurea*
Juncus bufonius s.s.	*Scrophularia auriculata*
Juncus conglomeratus	*Scutellaria galericulata*
Juncus × *diffusus*	*Sison amomum*
Lotus pedunculatus	*Tolypella intricata*
Luzula pallidula +	*Tolypella prolifera*
Mentha × *smithiana*	*Utricularia intermedia*
Myosotis scorpioides	*Viburnum opulus*

Notes: Where a species has become extinct in one study area, but is unchanged or unrecorded in the others, it is marked as +. (Species which have become extinct in more than one study area are included in Table 4.) See also Table 1.

TABLE 4. SPECIES SHOWN TO HAVE BECOME EXTINCT IN MORE THAN ONE STUDY AREA BEFORE 1990, WITH DATES OF LAST RECORD IN EACH STUDY AREA

(a) In all three study areas	
Littorella uniflora (S 1895, R 1899, I 1876)	
Myosotis secunda? (S 1960, R 1960, I 1888)	
Scutellaria minor (S 1914, R 1829, I 1880)	
Stratiotes aloides (S 1976, R 1875, I 1855)	
(b) In the Somerset Levels and Moors and Romney Marsh	
Cyperus longus (S 1896, R c. 1830)	*Juncus squarrosus* (S 1912, R c. 1850)
Eleocharis acicularis (S 1907, R c. 1900)	*Potamogeton friesii* (S 1914, R 1909)
(c) In the Somerset Levels and Moors and Idle/Misson Levels	
Andromeda polifolia (S 1920, I 1833)	*Parnassia palustris* (S 1782, I 1847)
Botrychium lunaria (S 1955, I 1955)	*Pinguicula vulgaris* (S 1928, I c. 1905)
Carex dioica (S 1855, I 1840)	*Potamogeton alpinus* (S 1881, I 1944)
Cicuta virosa (S 1888, I 1850)	*Rhinanthus angustifolius* (S 1918, I 1960)
Drosera longifolia (S 1970, I 1893)	*Trichophorum cespitosum* (S 1972, I 1905)
Hypericum elodes (S 1914, I 1896)	*Vaccinium oxycoccos* (S 1919, I 1815)
(d) In the Romney Marsh and Idle/Misson Levels	
Anagallis tenella (R 1959, I 1855)	*Oenanthe silaifolia* (R 1839, I 1930?)
Drosera rotundifolia (R ?, I 1959)	

Note: Numbers in brackets after species name are the dates of the last record, annotated with the appropriate study area: S (Somerset Levels and Moors), R (Romney Marsh) and I (Idle/Misson Levels).

Succession: "upright-leaf and floating-leaf formations" (Moss 1907); *Sparganium natans* L. (Storer files).

Drought: e.g. *Drosera longifolia* L. (Gibbons 1975); *Schoenus nigricans* L. (White 1912); *Stratiotes aloides* (Roe files).

For most species, contemporary accounts do not suggest the cause of observed population changes. Table 7 groups species that have declined in at least one of the study areas according to their habitat and the probable cause of their decline. Species are allotted to a group when archive sources (Appendix 1) indicate a link with some environmental change or where they are typical of the plant community affected by this change (Ellenberg 1988; Rodwell 1991a, 1991b, 1992, MSS).

TABLE 5. TOTAL NUMBER OF SPECIES INCREASING OR DECREASING IN POPULATION AND DISTRIBUTION IN THREE ENGLISH GRAZING MARSHES – 1840–1990

I. Species increasing in population and distribution (35 species)			
	Pronounced increase	Moderate increase	Data poor
Three study areas	2	0	4
Two study areas	4	3	8
One study area	1	7	6
Totals	7	10	18
II. Species increasing in some and decreasing in other study areas: 16			
III. Species decreasing in population and distribution (269 species)			
	Pronounced decrease	Moderate decrease	Data poor
Three study areas	19	14	4
Two study areas	53	39	8
One study area	51	47	34
Totals	123	100	46
IV. Species with no change in population and distribution: 206			

DISCUSSION

The importance of documenting the declining status of species was realised as early as the nineteenth century (Sheail 1982) and the value of artificial habitats such as grazing marsh ditches for "substituted plant associations" identified by Moss (1907) long before the contribution of these modified wetlands was generally accepted. Written records, herbaria and published accounts have been used to reconstruct the past vegetation pattern. Such sources contribute to an assessment of the scale and speed of environmental change over the past 150 years. Broad trends can be identified and, following comparison with knowledge of the species' ecology and present distribution, inferences made as to the cause for such trends (Table 7).

SPECIES INCREASING IN ABUNDANCE AND DISTRIBUTION

Aliens and denizens showed the clearest evidence of increased abundance. Such species were often absent from the study areas in 1840. Some were deliberately introduced later as ornamentals (e.g. *Nymphoides peltata* and *Populus alba* L.) or as crops (e.g. *Rorippa* × *sterilis* Airy Shaw and *Salix* spp.). Others escaped from gardens (e.g. *Impatiens glandulifera* Royle and *Mimulus* spp.) or from aquaria and ponds (e.g. *Azolla filiculoides* Lam. and *Elodea nuttallii*).

Amongst native species, some increased because their preferred habitat became more extensive e.g. drainage for peat-cutting combined with burning created a dry, disturbed soil favouring *Chamerion angustifolium*. Others were favoured by particular management, enabling them to compete effectively e.g. increased dredging, resulting in more deep water, may explain the increase of *Potamogeton berchtoldii* Fieber. Field survey showed *P. berchtoldii* was typical of newly dredged ditches both in the study areas and in Gwent (Wade & Edwards 1980).

Changes in water quality contributed to the spread of certain species. *Lemna gibba* L. and *Potamogeton pectinatus* L. tolerate eutrophic, polluted water (Ellenberg 1988). Once rather rare and largely coastal in the Somerset Levels, *L. gibba* is now common throughout the area, especially in managed drains with high nutrient levels. Reduced salinity (by improved sea defences and flood control) alters water quality. Some plants may have spread into the coastal levels from which they were previously excluded by salinity e.g. *Myriophyllum spicatum* L. (Scotter *et al.* 1977).

Locally increased salinity led to the spread of some plants. In the Romney Marsh, *Puccinellia distans* was once confined to coastal salt-marshes and a few sites inland with saline ground-water in

TABLE 6. NUMBERS OF SPECIES SHOWING A CHANGE IN ABUNDANCE IN EACH OF THREE ENGLISH GRAZING MARSHES OVER THE PERIOD 1840–1990
(Modified after Mountford & Sheail 1989)

(a) Somerset Levels and Moors

Increase in abundance and/or distribution				Decrease in abundance and/or distribution				
+++	+	?	Total	†	—	–	?	Total
6	12	18	36	31	48	43	31	153

(b) Romney and Walland Marshes

Increase in abundance and/or distribution				Decrease in abundance and/or distribution				
+++	+	?	Total	†	—	–	?	Total
4	2	14	20	37	25	55	40	157

(c) Idle/Misson Levels

Increase in abundance and/or distribution				Decrease in abundance and/or distribution				
+++	+	?	Total	†	—	–	?	Total
2	3	15	20	53	30	53	15	151

Increases: +++ = marked; + = moderate; ? = trend slight or doubtful.
Decreases: — = marked; – = moderate; ? = trend slight or doubtful; † = extinct.

TABLE 7. SPECIES DECREASING IN POPULATION SIZE AND DISTRIBUTION IN AT LEAST ONE OF THREE ENGLISH GRAZING MARSHES, CLASSIFIED IN TERMS OF TYPICAL HABITAT AND SUSPECTED CAUSE OF DECLINE, 1840–1990

Preferred habitat or vegetation type	Suspected cause of decline	Total number of species
Wet woodland	Felling and drainage	21
Acid bog and heath	Peat cutting and drainage	76
Rich fen and tall wet meadow	Drainage and conversion to pasture or arable	60
Old wet grassland	Drainage and conversion to intensive grassland or arable	55
Grazing marsh ditches and pools	1. Regrading conversion to trapezoidal section 2. Overgrowing, increased shade and siltation 3. Elimination due to field rationalisation	73
Open water	Aquatic herbicides	28
Open water	Pollution and increased turbidity	39
Bare wet mud and peat	Fencing of ditches and control of water-levels	13
Saline habitats	Tidal control and sea defence improvement	17
Varied	Urbanisation and industrial development	17
Varied	Weed control and collection by botanists	8
Varied	No clear cause	7

peaty layers (Green 1968). In recent years it has increased along those more important roads that receive regular de-icing salt during the winter (Philp 1982).

SPECIES DECREASING IN ABUNDANCE AND DISTRIBUTION

1. Drainage: water-table change and plant community structure. Community composition may be in equilibrium with a particular water-regime, such that either drainage or flooding can change that composition (Thibodeau & Nickerson 1985). Wetland drainage may influence community structure not only through changes in water-table, but also through altered inputs of dissolved nutrients (Meade & Blackstock 1988). Those species requiring high water tables and oligotrophic peat are the first to disappear, followed by those needing wet pasture, fen and open water (Sheail & Wells 1983).

a. Decline due to drainage and felling of wet woodland. 21 species which prefer wet alder woodland with birch and willow declined in the study areas. Most are typical of waterlogged soils that are nitrogen-deficient or mesotrophic (Ellenberg 1988). Those present in the study areas are mainly planted and were not extensive: birch and osiers on peat in Somerset (Moss 1907) or pine on sand and gravel near the R. Idle. In recent years, woodland has been cleared and the water-table lowered for extraction of gravel. The Idle/Misson woods on sand were vulnerable to drying out following the upgrading of the Stockwith pump, and though the total wooded area did not diminish from 1840 to 1990, the older woods were felled and new plantations have not acquired a shade flora. There are no woods on the Romney Marsh, though woodland plants occur on overgrown drain banks.

b. Decline due to drainage and peat cutting on acid bog. Peat-cutting for fuel or horticulture and reclamation for farming have greatly reduced the area of raised bog (Goode 1981; Limbert 1988), though new mire communities may develop on abandoned cuttings (Giller & Wheeler 1986; Smart *et al.* 1986). Wet heath and bog species grow in permanently wet, acid sites poor in nitrogen and many are typical of the oceanic fringe of Europe (Ellenberg 1988).

Peat cutting is the single most important cause of species extinction in the study areas, particularly Somerset and the Idle valley. Of the 76 species typical of wet heath and bog to have declined, almost 30 have become extinct. This scale of extinction was also observed at Holme Fen in Huntingdonshire (Sheail & Wells 1980). All but one of the 33 wetland species to have become extinct at Holme Fen since 1800 also show a serious decline in one or more of the study areas. The turbary peats of the Brue valley in Somerset have been cut for many years and those species which require an actively growing raised bog surface have been exterminated (Hope-Simpson & Willis 1955). When the peat surface was lowered, calcifuge species were displaced as the bog became flooded by alkaline water from the adjacent limestone uplands.

c. Decline due to drainage and cultivation/grazing of fen. Primevally, fens were extensive in all three areas, notably Somerset (Moss 1907; Williams 1970). Fens occur on peaty soils and are minerotrophic wetlands, dominated by tall grasses, sedges and rushes (Wheeler 1983). Fen species are typical of moist to permanently wet sites, on weakly acid or basic soils that are nitrogen-deficient (Ellenberg 1988). Fen peat shrinks and oxidises rapidly following drainage. The consequent lowering of the land surface puts pressure on the capacity of pumps to remove water and may necessitate the installation of more powerful pumps (Hutchinson 1980). 60 plants of rich fen and tall wet meadow declined in one or more study area. In contrast to the many extinctions in acid bog, most fen species showed only a moderate decline, surviving in fragmented wetlands or on ditch banks in the grazing marsh (Moss 1907). Early drainage and cultivation converted much fen into grassland. Typical tall fen species survived in wet hay meadow but were eradicated from pasture.

Fen fragments survived in Somerset in 1990, especially on Altcar soils at the edge of the turbary moors or where cutting has removed acid peat. Fen meadows are more widespread, both on Altcar and Midelney soils. In the nineteenth century, fens survived in the Romney Marsh by 'fleets' (creeks), near the south coast and, in a modified form, in the >700 ha of rough grazing. By 1980, some fleets had been eliminated or affected by farming; improvements to sea defences and drainage had altered coastal wetlands, and rough grazing had been reduced to under 400 ha (M.A.F.F. 1968; Latimer 1980). Near the R. Idle, washlands, fens and fen meadows occurred widely in the nineteeth century. The land downstream of Misson was still ". . . a sea of *Glyceria maxima* . . ." in 1955

(Howitt day book – 21 July). The fen meadows were drained in the 1950s, and the washes converted to arable in the 1970s after the upgrading of the Stockwith pump (Howitt & Howitt 1963; Severn-Trent Water Authority 1974). By 1980, most of the area was intensive arable land with fen vegetation present largely confined to a few ditch banks.

d. Decline due to drainage of old wet grassland, followed by reseeding or conversion to arable agriculture. Traditional management of grazing marsh grassland involved either year-round sheep-grazing or a summer hay cut and aftermath grazing, followed by waterlogging in winter. Agricultural improvement, with increased use of fertiliser and pesticides, resulted in the conversion of pasture to arable or increased stocking rates which altered grassland composition. In most grazing marshes, much grassland was converted to arable in the twentieth century. For example, in 1930, all Broadland marshes were under grass, but by 1984, 37% of the area was tilled (Driscoll 1985) whilst in East Essex, coastal grazing marsh declined by 82% after 1938 (Williams & Hall 1987). The composition of the wet grassland flora overlaps with that of fens but grassland species are more light-loving, typical of warmer conditions and soils that are somewhat more acidic (Ellenberg 1988). Nitrogen mineralisation can increase 5–10 fold in meadows following lowering of the water-table. Thus drainage (with no other agricultural improvement) can also reduce species richness (Grootjans *et al.* 1985).

In the study areas, most of the grassland species which have declined are typical of moist meadows, though some are associated with manured meadows, fairly dry calcareous or poor swards. Wet grassland species may have spread during the early phase of drainage when mires were reclaimed for grazing, but with the expansion of arable land, they became restricted to farms practising traditional grazing. 55 species of wet grassland have declined in one or more of the study areas, 70% showing only a slight decline. In Somerset, permanent grass is the main land use, but much of this has been improved resulting in the loss of the old grassland flora (Bradford 1978). Fertiliser use suppresses sedges, rushes and low-growing wetland forbs (Mountford *et al.* 1993). In the Romney Marsh, the proportion of permanent grass fell from 81% in 1939 to 35% in 1980 (M.A.F.F. parish returns). In the R. Idle area, old grassland is less extensive than in the other study areas and much rarer than formerly, only surviving near Bawtry, locally elsewhere on the Idle washlands and around the Misson Line Bank (Mountford & Sheail 1985).

2. *Open water: grazing marsh ditches and pools.* Mires naturally include areas of open water but when they are reclaimed, grazing marshes, ditches for drainage and ponds for watering stock are created. This open water may be further modified as the needs of agriculture change.

a. Decline due to the altered management of ditches and pools. The ability of drainage ditches to act as refuges for wetland plants was affected by the methods used to manage them. After 1840, the ditches and ponds of grazing marshes underwent two changes. On the one hand, with improvement of main channels, pump and under-drainage, some field ditches became redundant and were either filled in or allowed to silt up, losing their aquatic vegetation through succession. In contrast, the remaining ditches were liable to more intense management to ensure effective removal of excess water.

There are rather few quantitative data on ditch removal. In Broadland, 33.5% of dykes were lost between 1973 and 1981 when old grassland was ploughed for arable farming (Driscoll 1983, 1985). In similar circumstances in the Pevensey Levels, the loss of dyke habitat was 40% (Palmer 1986). From 1908 to 1986 in Hatfield Chase, the length of ditch managed by farmers decreased by 36% (Wingfield & Wade 1988). In Gwent, still mainly pastoral, the loss of ditch length between 1882 and 1975 was only 14% (Wade 1977).

Much of the Somerset Levels remained under grass after 1840, with little under-drainage. Consequently, few ditches became redundant, overgrown or were eliminated. In contrast, there is ample evidence of ditch elimination in the Romney Marsh, particularly where grassland has changed to arable (Latimer 1980; Mountford & Sheail 1982). Field survey of the Idle valley in 1983 indicated that 25% of ditches had been destroyed since 1950 (Mountford & Sheail 1985).

Ditches or natural streams are often regraded during drainage schemes, to accommodate increased run-off of water. Aquatic and bankside vegetation are removed (Hill 1976). If there is no further dredging, however, most species will return within two years (Haslam 1978). Channel maintenance and weed control can have a profound effect on the vegetation of ditches (Mitchell 1974). Ditch maintenance methods changed after 1950, with mechanical and chemical techniques replacing manual ones (Newbold *et al.* 1989). The intensity of management varies, from more than once each year in main channels to less than once in ten years in field ditches. Floristic composition depends both on the management method used (Beltman 1984, 1987) and the frequency and date of the last maintenance (Wade 1978).

Changes in the extent or management of watercourses were involved in the decline of 73 species. Most were typical of well-lit sites, but representing the wide range of aquatic and swamp communities present in grazing marsh ditches (especially *Lemnetea*, *Potamogetonetea* and *Phragmitetea*, but also, locally, three other classes and three alliances (Ellenberg 1988)).

A particular method of ditch maintenance (chemical weed control) may be partly responsible for the decline of 25 flowering plants and three genera of stonewort (*Chara*, *Nitella* and *Tolypella*). Aquatic herbicide use is usually confined to drains managed by the National Rivers Authority or Internal Drainage Boards. Herbicides have short-term effects on aquatic habitats and longer term impacts dependent on the degree of habitat destruction and herbicide persistence. Different species have differing susceptibilities (Newbold 1975). Although implicated in the decline of some species (Howitt, pers. comm. 1983), Wade & Edwards (1980) thought it unlikely that herbicide use had been responsible for the extinction of any macrophyte in Gwent where there was little evidence of long term change in the ditch flora. In contrast, all the present study areas showed a decline in aquatic macrophytes.

b. Decline due to pollution of ditches and pools. Drainage of wetlands and farmlands alters water chemistry through: 1. increased nitrate nitrogen derived from fertiliser; 2. increased release of calcium, magnesium and potassium; 3. reduced phosphorus transport due to reduced surface run-off; 4. soluble pesticides; and 5. oxidation of iron pyrites to colloidal iron hydroxide ('iron ochre') in acid sulphate soils (Hill 1976; Marshall 1981, 1984; Swales 1982). Increased nutrient loads lead to an increase in the biomass of some macrophytes, whilst others decline (Boar *et al.* 1989). Overall, eutrophication reduces species diversity, alters the dominants, increases turbidity and the rate of sedimentation and causes anoxic conditions to develop (Mason 1981).

In all study areas species whose decline is associated with pollution include those typical of nitrogen-poor sites (N indicator value <4) (Ellenberg 1988). In addition, in the Romney Marsh and Somerset, other *submerged* species have declined, with wider nutrient tolerance but vulnerable to the reduced light levels following increased turbidity. This may explain the observed spread of *Potamogeton pusillus* L. in Broadland and the decline of *P. perfoliatus* L. (Driscoll 1982).

c. Decline due to fencing or penning of water levels. Open wet soil occurs where water levels are allowed to vary naturally in response to weather or where stock trample the margins. Conversion to arable or fencing halts bank poaching (Driscoll 1984) and control of water level (penning in summer to maintain wet fences or pumping down) eliminates wet mud or alters its seasonal occurrence. The filling in of redundant farm ponds, once intensely grazed and trampled, has further contributed to the reduction of the wet mud habitat.

A well defined group of 13 declining species was typical of herbaceous vegetation in this habitat including wet, often winter-flooded, depressions, newly flooded sites and peat cuttings. The species are mostly annuals of well-lit sites, over a wide range of soil acidity, but with some trend toward sites richer in available nitrogen (Ellenberg 1988).

3. *Coastal and other habitats*. Grazing marshes are usually coastal in Britain, created as a late stage in the impoundment and reclamation of saltmarsh. Certain species have declined in the study areas but their reduced population has been caused by factors other than, or additional to, drainage and watercourse management.

a. Decline due to tide control and improved sea defences. Impoundment leads to decreased salinity and less exchange between marsh water and estuarine water, both in nutrients and biota (Montague *et al.* 1987; Wade & Edwards 1980). In Gwent, main drains were much less saline than the less frequently dredged minor channels (Wade 1978) whilst in Broadland, saline ground-water seeped into ditches from the adjacent water-table after drainage (Driscoll 1985).

There is salt water adjacent to all the study areas, but sea-floods and tidal rivers are now much more carefully controlled than formerly, reducing the saline input. Hence, 17 coastal species declined from 1840 to 1990. Such species once occurred not only where coastal vegetation gave way to grazing marsh but also further inland (Green 1968).

b. Decline due to urbanisation and industrialisation. Human habitation and industry greatly expanded from 1840 to 1990, and within the study areas, became particularly extensive near the coast. Certain species, often coastal or halophytic, once mainly occurred in those areas since urbanised. Such development often cannot be distinguished from the improvement of sea defences as the cause of their decline. Contemporary accounts record how housing and industry destroyed notable plant localities, both in the study areas (see Results) and elsewhere (Wade & Edwards 1980).

Increased human population has had indirect effects on the flora. Disposal of urban or industrial waste puts pressure on wetlands, e.g. pulverised fuel ash in Gordano. Improved transport systems were built to accommodate traffic, damaging adjacent sites. Sand and gravel extraction is a feature of the Idle valley, but was not cited as a cause of species decline, and indeed subsequent flooding of the pits may have increased the diversity of wetlands. However, gravel dredging near Camber destroyed a site for *Ruppia cirrhosa* (Petagna) Grande (Hall 1980).

c. Decline due to terrestrial weed control and collection. Some plants are identified by graziers as poisonous weeds in pasture and removed, e.g. *Colchicum autumnale*. Weed control and the drainage or destruction of grassland may be confounded as causes of species decline. A few wetland species were also arable weeds and were the target of improved cultivation. Direct effects of herbicides on the wet grassland were noted in Gordano (Willis & Jefferies 1959). Enthusiasm for plants, every bit as much as antipathy, may lead to them being removed deliberately. The Victorian fern craze led to the decline of many species, including several from the grazing marshes.

The cause of decline in seven species is unclear. These include taxonomically difficult plants that may now be overlooked and cultivated species that could require continued reintroduction to ensure survival in the wild.

CONCLUSIONS

Drainage and land use change modified or destroyed large areas of wetland in England. The resultant decline and local extinction of many wetland species was recognised by Salisbury (1927) who showed that the decrease of wetland species was both more pronounced and more comprehensive than in any other major habitat. If data on species decline since 1930 are examined at a national scale, the most significant decrease is observed in wetland and grassland species (Ratcliffe 1984).

This study of three English grazing marshes not only confirms the broad trend, but demonstrates that between 20 and 33% of declining wetland species have become locally extinct, even over as large an area as the Somerset Levels and Moors. The decline has been most severe in mires, particularly raised bogs. There is evidence that the watercourses have become a major refuge for plants, and that the decline in macrophytes was less marked (Moss 1907; Mountford & Sheail 1989). However, even in drainage channels, there is ample evidence of reduced populations and distribution, in which respect the study areas contrast with the relative lack of long-term change in Gwent (Wade & Edwards 1980). Despite the choice of study areas to reflect differing degrees of agricultural impact, comparable large declines were observed in all three. Only in the case of extinction did the intensively farmed Idle/Misson levels show the markedly greater effect that was predicted. The dependence of the present upon the past in community structure and conservation can clearly be observed in the flora of grazing marshes.

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SOIL SURVEY OF ENGLAND & WALES (1983). *1:250,000 Map of England and Wales: six sheets and legend*. Harpenden.
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STORER, B. Card indices, files and notes. [Consulted at owner's residence.]
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WHEELER, B. D. (1983). British fens: a review, in MOORE, P. D., ed. *European mires*, pp. 237–281. London.
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WILLIAMS, G. & HALL, M. (1987). The loss of coastal grazing marshes in South and East England, with special reference to east Essex, England. *Biological Conservation* **39**: 243–253.
WILLIAMS, M. (1970). *The draining of the Somerset Levels*. Cambridge.
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WINGFIELD, M. & WADE, P. M. (1988). Hatfield Chase: the loss of drainage channel habitat. *Naturalist* **113**: 21–24.

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APPENDIX 1: FLORISTIC HISTORY – SOURCES OF INFORMATION CONSULTED

OLD COUNTY FLORAS AND THE NINETEENTH CENTURY

I. Somerset Levels and Moors

SWETE, E. H. (1854). *Flora Bristoliensis*. London.
CLARK, T. (1856). Catalogue of the rarer plants of the Turf Moors of Somerset. *Proceedings of the Somerset Archaeological Society* **7**: 64–71.
WHITE, J. W. (1886). *Flora of the Bristol coalfield*. Bristol.
MURRAY, R. P. (1896). *The flora of Somerset*. Taunton.
WHITE, J. W. (1912). *The flora of Bristol*. Bristol.
MARSHALL, E. S. (1914). *A supplement to the Flora of Somerset*. Taunton.
[Marshall's own annotated copy of the supplement (held by his great grandson, Dr E. J. P. Marshall) was examined.]

II. Romney and Walland Marshes

ARNOLD, F. W. (1887: 1st ed.; 1907: 2nd ed.). *Flora of Sussex*. London.
HANBURY, F. J. & MARSHALL, E. S. (1899). *Flora of Kent*. London.
WOLLEY-DOD, A. H. (1937). *The flora of Sussex*. Hastings.

III. Idle valley and Misson Levels

DEERING, C. (1738). *Catalogus stirpium, &c. or a catalogue of plants naturally growing and commonly cultivated in divers parts of England, more especially about Nottingham*. Nottingham.
ORDOYNO, T. (1807). *Flora Nottinghamiensis or a systematic arrangement of the plants growing naturally in the county of Nottingham with their Linnean and English names, generic and specific characters in Latin and English, places of growth and time of flowering*. Newark.
HOWITT, G. (1839). *The Nottinghamshire flora*. Nottingham.

LEES, F. A. (1888). *The flora of West Yorkshire.* (*Botanical Transactions of the Yorkshire Naturalists Union* **2**.) London.
WOODRUFFE-PEACOCK, E. A. (1909). *A check-list of Lincolnshire plants.* Lincoln.
CARR, J. W. (1909–39). Manuscript 'Flora of Nottinghamshire'. [Copy held at Wollaton Hall Museum, Nottingham.]

MANUSCRIPTS AND INDICES, C. 1915–1960
I. Somerset Levels and Moors
1. J. W. White?: note-book (1918) entitled 'Brue Plants' [held by Prof. A. J. Willis of Sheffield University].
2. N. Y. Sandwith: Notes and files belonging to Sandwith [held by Prof. A. J. Willis]. Including: a. Complete series of '*Bristol Botany in 19—*' (*Proceedings of the Bristol Naturalists' Society*); b. Card index for period 1912–1965, including (all?) published records and data from other workers (e.g. I. M. Roper and H. S. Thompson); c. Annotated copy of White (1912).
3. Capt. R. G. B. Roe: Notes and files, including all the sources of records he could trace for the period between the first Flora writers and his own survey, e.g.: a. Card index begun by W. D. Miller (1919–1933), continued by Dr W. Watson (1933–1952), A. D. Hallam (1952–c. 1960) and Roe (c. 1960 onward); b. Transcriptions of data from County Museum, Taunton and other herbaria by Roe and Dr P. M. Wade.

II. Romney and Walland marshes
1. Dr F. Rose: manuscripts and field note-books including: a. Manuscript 'Ecological Flora of Kent', for period from 1942 to late 1960s; b. Note-books (especially 1954–1960 when most work on the Romney Marsh was done).
2. Maidstone Museum (E. G. Philp): both pre-1970 records for Kent and herbarium specimens.

III. Idle valley and Misson Levels
1. R. C. L. & B. M. Howitt: Note-books, files and maps covering Nottinghamshire: a. Day-books: record of botanical excursions, 1951–1978; b. Division files (essentially a manuscript Flora); c. 6-inch Ordnance Survey maps annotated with locations of rare species.
2. E. J. Gibbons: Files and day-books for Lincolnshire, from c. 1920 onward. [Similar to Howitt.]

ATLAS OF THE BRITISH FLORA AND *CRITICAL SUPPLEMENT* (1962 AND 1968)
Covers all three study areas. The maps depict the known distribution of species in the middle part of the present century with an indication of changes from earlier times. During the preparation of the *Atlas* more or less complete vice-county lists were supplied for East Kent by Dr F. Rose and North Lincolnshire by E. J. Gibbons. Other recorders who contributed records to the *Atlas* were A. D. and O. M. Hallam, R. C. L. & B. M. Howitt, Capt. and Mrs R. G. B. Roe and N. Y. Sandwith.

BIOLOGICAL RECORDS CENTRE
Data gathered during the B.S.B.I. Maps Scheme formed the nucleus of the Biological Records Centre (B.R.C.) at Monks Wood. The original data have been supplemented with records (grid reference, locality, date, recorder, vice-county). Printouts of B.R.C. data were searched.

MODERN COUNTY FLORAS, AFTER THE *ATLAS OF THE BRITISH FLORA*
I. Somerset Levels and Moors
ROE, CAPT. R. G. B. (1981). *The flora of Somerset.* Taunton.
[The card index that formed the basis of the *Flora* and annotated since publication, includes tetrad maps for the period 1960–1980. Though not published, these data are very detailed and were transcribed fully.]

II. Romney and Walland Marshes
HALL, P. C. (1980). *Sussex plant atlas.* Brighton.
PHILP, E. G. (1982). *Atlas of the Kent flora.* Maidstone.

III. Idle valley and Misson Levels
HOWITT, R. C. L. & HOWITT, B. M. (1963). *A Flora of Nottinghamshire.* Privately published.
GIBBONS, E. J. (1975). *The flora of Lincolnshire.* Lincoln.
GIBBONS, E. J. & WESTON, I. (1985). *Supplement to the Flora of Lincolnshire.* Lincoln.

THE NOTE-BOOKS AND FILES OF CONTEMPORARY BOTANISTS
I. Somerset and Avon Levels
1. B. Storer: Data gathered during and after publication of *The natural history of the Somerset Levels* (1972); 2nd ed., 1985: a. Card index for parts of National Grid square ST/3.3; b. Detailed account of Catcott and Westhay Heaths in note-books; c. Maps, annotated with new records.

2. Prof. A. J. Willis: as well as data and indices inherited from earlier workers, his files include: a. Reprints of '*Bristol Botany*' since 1965; b. Scientific papers with data on Gordano, Shapwick and Catcott Heaths (Willis & Jefferies 1959; Hope-Simpson *et al.* 1963; Willis 1967; Hope-Simpson & Willis 1955, 1973).
3. Dr P. M. Wade: species lists made in 1975 in Somerset.

II. Romney and Walland marshes
1. Mrs L. B. Burt: day-books and summary of distribution of wetland plants in the area.
2. Dr F. Rose: note-books with accurate locations.
3. E. G. Philp: Manuscript maps for *Atlas*.

III. Idle valley and Misson Levels
1. Doncaster Museum (local B.R.C. for South Yorkshire, etc.): Site files and species maps on a 1-km square basis.
2. Nottingham Museum (Wollaton Hall – local B.R.C.): Site files and individual species data.
3. Scunthorpe Museum (local B.R.C.): Site files, especially L.N.R.s, S.S.S.I.s, etc. Records made after 1970 were noted.
4. Nature Conservancy Council (East Midlands office – Grantham): S.S.S.I. files.
5. Dr J. G. Hodgson (Unit of Comparative Plant Ecology, University of Sheffield): rare species and site data on detailed data base.

NATURE CONSERVANCY COUNCIL (N.C.C.) COMMISSIONED DITCH AND WETLAND STUDIES

I. Somerset Levels and Moors

SECCOMBE, P. (1977). *Report on the botanical evaluation of the Rhyne system.* N.C.C. (Somerset Wetlands Project [S.W.P.])

[Areas of conservation interest only.]

BRADFORD, R. (1978). *A report on the botanical evaluation of the meadows and other nature conservation interests in the Somerset Levels, 1977–8.* N.C.C. (S.W.P.)

RAINE, P. (1980). *The flora of drainage ditches – an ecological study of the Somerset Levels.* Unpublished M.Sc. thesis, University College, London.

[North, Southlake and both Salt Moors.]

WOLSELEY, P. A., PALMER, M. A. & WILLIAMS, R. (1984). *The aquatic flora of the Somerset Levels and Moors.* Huntingdon, N.C.C.

[All S.S.S.I.s and P.S.S.S.I.s.]

II. Romney and Walland Marshes

PHILLIPS, N. J. A. (1975). *Dykes of Romney Marsh.* Unpublished M.Sc. thesis, Wye College, University of London.

LATIMER, W. (1980). *A survey of the dyke flora of the Romney Marsh.* Taunton, N.C.C. [S.S.S.I. only.]

III. Idle valley and Misson Levels

PAGE, S. E. (1980). *River Idle Carrs: Botanical survey of Dykes.* Huntingdon, N.C.C. (East Midlands Region).

[Areas of conservation interest only.]

WINGFIELD, M. & WADE, P. M. (1988). Hatfield Chase: the loss of drainage channel habitat. *Naturalist* **113**: 21–24.

[Overlaps with northern part of study area.]

APPENDIX 2: *RUMEX MARITIMUS* L. – FLORISTIC HISTORY IN SOMERSET

Information given as provided in each source.
I. Nineteenth and early twentieth century records
1. White (1886)
In marshes. "Wedmore . . . June 1843. G. H. K. Thwaites", **herb. Stephens.** "Mouth of the Parrett; Steart Marsh. J. C. Collins, MSS", *New Botanist's Guide.* Frequent on the peat moors still further south.
2. Murray (1896)
Rare and very local in marshes. District 3 at the mouth of the Parrett and at Steart Marsh, J. C. Collins. District 8 ". . . in a bit of marshy ground SE of Tor Hill, Wells, several plants", Miss Livett; plentiful in many parts of the peat moor and abundant near Shapwick Station, Murray. District 9 (8?) at Wedmore, Thwaites; Knowle Bridge near Wells, Miss Livett; near Portishead, S. Rootsey.
3. White (1912)
Typical of peat. Rare and local in marshes in the southern portion of area. On the beach at Portishead, c. 1852, J. N. Duck. "Said to have been found at Portishead by S. Rootsey", *Fl. Som.* Several plants in 1884 in a marsh on

Tor Hill, E. of Wells; and at Knowle Bridge, Wookey, Miss Livett. Wedmore, 1843, *Thwaites* in **Herb. Stephens.** Salt-marshes near Highbridge, Sole, MS. Mouth of Parrett and Steart, J. C. Collins, MSS, in *New Botanist's Guide*. Plentiful on the peat moors after any fresh cutting of peat.
4. Marshall (1914)
District 3: by the towing-path of the canal below Maunsel, 1908, Marshall. District 5: Langport, W. Watson. District 8: salt-marshes near Highbridge (Sole, MS), *Fl. Bristol* (Wedmore locality is probably in this division).
5. White? (1918)
In marshes at Wedmore and on the moors.

II. Mid-twentieth century records
1. Sandwith files, etc.
Bank of a rhine on the Kenn side of Nailsea Moor, 1941, C. I. & N. Y. Sandwith, *Bristol Botany in 1941*. Annotated copy of White (1912) confirms status on the peat-moors.
2. Roe files, card indices, etc.
District 3: on the banks of the Parrett at Bridgwater, 1915, H. S. Thompson; between the bridge and the docks, Bridgwater, *H. S. Thompson* in **TTN**; North Newton, *Marshall*, **herb. Druce & Hanbury**; by a pool on the edge of West Sedgemoor below Burton Pynsent, 1918, W. Watson.
District 4: Thorney Moor, 1923 – rare H. Downes in *Proceedings of the Somersetshire Archaeological and Natural History Society* [*Proc. SANHS*].
District 5: on banks of the Parret, Bridgwater, 1915, H. S. Thompson; small pool, close to Wills Works, right bank of Parrett, *H. S. Thompson* in **TTN**; near Weston Zoyland, *C. E. Salmon* in **LSR**.
District 8: near Edington Junction, 1915, *J. Bot.*; in some quantity N. of Shapwick Station, 1926, *Bristol Botany in 1926*; by the sides of a rhine near the station, 5 July 1951, *Proc. SANHS*; Ashcott Moor, 27 July 1928, *H. J. Gibbons* in **LSR**; specimens from Shapwick dated 1933, **herb. J. E. Lousley** and *H. S. Thompson* in **LSR**. [Roe quotes W. Watson as suspecting that the plants at Tor Hill may have been *R. palustris*.]
District 9: specimen on the bank of a rhine on the Kenn side of Nailsea Moor, 1941, C. I. & N. Y. Sandwith; at Tickenham Moor, 1930, *H. J. Gibbons* in **LSR**.
3. *Atlas of the British flora* (1962)
Recorded before 1930 in ST/2.4, 3.3, 3.4, 4.2, 4.3, 4.4, 4.7, 5.4. No post-1930 records.

III. Records since 1960
1. Roe files, card indices, etc.
District 8: on old peat cuttings, the Roughet – rapidly appeared in quantity in 1969 after ditches had been cut across, *J. K. Hibberd* det. F. Rose [Roe noted there was very little at this site in 1970]; plentiful in some peat cuttings in Catcott Burtle in 1970, H. W. Boon in *Proc. SANHS*; several in old peat cuttings, Shapwick Heath in 1980, R. S. Cropper in *Bristol Botany in 1980*.
2. Roe tetrad maps (notation as Philp 1982) [100-km square ST]
2.3Y (1910s); 2.4Y (1950s); 3.2S (1910s), 3.2T?; 3.3D (1910s); 3.4D (1930s); 4.2G (1920s); 4.3P (1920s); 4.4A, 4.4B, 4.4F (all 1970s onward); 4.7F (1940s).
3. Roe (1981)
In marshes. Very rare and only seen recently in old peat cuttings on the moors near Shapwick and Westhay (District 8). Formerly more widespread on the levels in districts 3, 4, 5 and 9 also.
4. Mountford field work (1982–88)
Not recorded.