The ecological status of ditch systems

An investigation into the current status of the aquatic invertebrate and plant communities of grazing marsh ditch systems in England and Wales

Technical Report Volume 1
Summary of methods and major findings

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Buglife – The Invertebrate Conservation Trust

Little whirlpool ram’s-horn snail (*Anisus vorticulus*) © Roger Key

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Contents

Volume 1

Volume 2 Appendices

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Frogbit and Stonewort © Nick Stewart

Executive summary

1. A major survey of the aquatic vegetation and invertebrate fauna of ditches in coastal grazing marshes in England and Wales was carried out in 2007, 2008 and 2009. The aims were to establish baseline data, assess the extent of and reasons for any observed change in the biota and produce management guidelines for ditches.

2. A standard methodology for surveying the flora and fauna of ditches and assessing their value for nature conservation was produced (Palmer, Drake & Stewart (2010) *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches*).

3. Grazing marshes surveyed in the three years of fieldwork were in Anglesey, the Gwent Levels, the Somerset and Avon Levels and Moors, the Arun valley, Pevensey Levels, Walland Marsh, North Kent, Essex, Suffolk and Norfolk Broadland. 533 ditches were sampled for invertebrates and 546 for plants. 326 target invertebrate species were recorded and 174 plant species were found within the wet zone of the ditches. The data will be passed to the National Biodiversity Network.

4. Plant and invertebrate assemblages and explanatory environmental variables were identified. The environmental variables with the most influence on invertebrate community composition were salinity, geographical location, vegetation structure (principally hydroseral stage), ditch dimensions, water depth and grazing by cattle. Vegetation composition was heavily influenced by salinity, and other explanatory variables were water depth and substrate type.

5. Ten Red List or Near Threatened aquatic plant species were recorded during the survey, five of which are on the UK BAP priority list. Grazing marshes are the British stronghold for Frogbit (*Hydrocharis morsus*-ranae), Tubular water-dropwort (*Oenanthe fistulosa*), Sharp-leaved pondweed (*Potamogeton acutifolius*) and Water soldier (*Stratiotes aloides*).

6. Seventy nationally rare or scarce invertebrates were recorded, 47 of them water beetles. They included nine UK BAP priority invertebrates, one of which, the Little whirlpool ram's-horn snail (*Anisus vorticulus*), is protected under European legislation. The red listed soldierfly *Odontomyia ornata* and the Great silver water beetle (*Hydrophilus piceus*) were among the most widespread and frequent of the nationally rare species, and could be regarded as 'flagship' species for grazing marsh.

7. The invasive non-native plants Nuttall's waterweed (*Elodea nuttallii*) and Least duckweed (*Lemna minuta*) were widespread and abundant. Australian swamp stonecrop (*Crassula helmsii*) was dominant in some ditches in Essex. Three non-native invertebrate species were recorded: the crustacean *Crangonyx pseudogracilis* and two snails: *Potamopyrgus antipodarum* and *Physella acuta.* The latter is a recent arrival in Britain.

8. In order to estimate change over the years, a scoring system for assessing the quality of the ditch biota was devised. The relative abundance of key species found in surveys at different dates was examined. Previous regional vegetation classification systems were applied to data from the Buglife survey and the proportion of ditches in the various vegetation types at different dates was used as a measure of change.

9 For invertebrates, no recent deterioration was detected, but a modest improvement was apparent in species richness and/or in the proportion of rare species in ten of the marshes surveyed. In Somerset and Broadland there appeared to be a reversal of the previously observed trend of continued loss of species-rich freshwater vegetation communities.

10. Brackish ditches are restricted geographically and are an important and distinctive element of the grazing marsh habitat, especially in the east of England. In order to maintain maximum diversity of flora and fauna, it is vital to retain the complete spectrum of brackish and freshwater ditches represented in a marsh or a geographical area.

11. Invertebrate and plant assemblages of ditches are strongly interrelated. In order to maximise the biological potential of a marsh, all stages in the hydrosere should be represented.

12. Analysis of the data collected in this three-year survey suggests that current management practice in protected wetland sites appears to be benefiting the flora and fauna of ditch systems.

13. Recommendations for optimum management of ditch systems for the conservation of ditch flora and invertebrate fauna are presented.

14. Grazing marshes are a valuable resource for nature conservation, but they are threatened by climate change. Marshes in different parts of the country are not equivalent or interchangeable, therefore loss of habitat should be made good at a local level.

Section 1 Introduction

1.1 National context

The ditch systems of grazing marshes are of great importance for biodiversity, and are especially rich in aquatic invertebrates and plants. These networks of channels, although artificial, often act as a refuge for communities typical of previously extensive natural wetland systems. *Coastal and floodplain grazing marsh* is a priority habitat under the UK Biodiversity Action Plan and numerous Biodiversity Action Plan priority species (e.g. the Lesser silver water beetle (*Hydrochara caraboides*), the Little whirlpool ram's-horn snail (*Anisus vorticulus*), Sharp-leaved pondweed (*Potamogeton acutifolius*) and Tubular water-dropwort (*Oenanthe fistulosa*)) are associated with ditch systems.

Grazing marsh ditch systems are found mainly in coastal areas of England and Wales, although some occur in inland areas once occupied by fens and in river valleys. Among the most extensive and species-rich ditch systems on or near the coast are those in Gwent, Somerset and Avon, Sussex, south Kent, the Thames and Medway estuaries, Suffolk and Norfolk Broadland. Many of these coastal grazing marsh systems display a transition from fresh to saline water, which is an important factor in maintaining their biodiversity.

Despite the fact that many of the most important grazing marshes are SSSIs or lie within Environmentally Sensitive Areas, the flora and fauna of ditch systems is thought to be threatened by agricultural pollution, unsuitable management, erratic water supply and rising sea levels. Wholesale mechanical ditch clearance, as practised routinely in some areas, and steep ditch profiles are thought to have a detrimental affect on ditch faunas and vegetation, but evidence has been hard to come by. In order to conserve the biodiversity of these ditch systems it is important to establish whether recent deterioration (or improvement) has occurred and to understand better what constitutes the optimum management regime for the ditches themselves and their immediate catchment areas.

The aim of the EC Water Framework Directive is that all water bodies (large lakes, rivers, transitional waters and coastal waters) should attain at least 'Good Ecological Status' or, if artificial or highly modified, 'Good Ecological Potential'. Ditch systems are classed as artificial water bodies. The Common Implementation Strategy acknowledges the functional importance of wetlands. Water-dependent Natura 2000 Sites (Special Areas of Conservation under the EC Habitats Directive and Special Protection Areas under the Birds Directive) are designated as Protected Areas, to which the Directive's full programme of measures may be applied. Some Natura 2000 sites contain ditch systems. It is hoped that data obtained during the Buglife ditch survey project can contribute to the refinement of assessment methods, as well as providing advice on how best to manage these fragile wetlands.

A project on ditch biodiversity and management is timely because new opportunities for wildlife conservation may arise as a result of the current climate of change in agricultural practice. The information gained during this work could also prove useful in schemes for recreating coastal grazing marshes, which may become necessary to replace habitat lost as a result of rising sea levels.

1.2 Previous relevant studies

In the last three decades numerous surveys of the plant and invertebrate communities of grazing marsh ditch systems have been carried out by the statutory conservation agencies and others, but there has been little attempt to assess overall change or to evaluate the effects of management. The England Field Unit of the Nature Conservancy Council conducted a number of botanical and invertebrate surveys of grazing marsh ditch systems in southern and eastern England in the 1980s (e.g. Glading, 1986; Doarks & Storer, 1990; Drake, 1988). A standard survey method for ditch vegetation (Alcock & Palmer, 1985) has been in use for many years, but a range of methods has been used for sampling invertebrates, making comparison between surveys difficult.

The statutory conservation agencies' *Common Standards Monitoring* protocol (JNCC, 2005) is used for monitoring the condition of ditch systems in SSSIs and Natura 2000 sites. This is a rapid assessment method, concentrating mainly on aquatic vegetation and briefly covering invertebrate, morphological, chemical and hydrological features.

A review of ditch invertebrate surveys was produced by Drake (2004) for English Nature. In preparation for the present Buglife project, a pilot study to produce and test a standard field methodology for monitoring the invertebrate fauna of ditches was undertaken (Drake, 2005). This work was carried out under a Buglife contract funded by the Worldwide Fund for Nature (WWF) and Anglian Water. The main outputs from the study were:

- An examination of management practices for 26 marshes managed by conservation organisations
- A protocol for comparative survey of ditch invertebrate faunas
- Recommendations for assessing the conservation status of ditch invertebrate communities
- Suggested options for a broad survey of the invertebrates of grazing marshes in England and Wales.

The pilot study provided a firm foundation on which the larger project described in this report was based.

1.3 The core project

The Esmée Fairbairn Foundation funded this three-year project, managed by Buglife, to:

- carry out targeted survey of the aquatic invertebrate fauna and flora of ditches in a representative sample of grazing marsh
- assess the extent of and reasons for any observed change in the biota
- obtain information on ditch management procedures, water quality and surrounding land use in the sites surveyed, and define optimum management
- produce management guidelines for land managers, agri-environment scheme advisors and people implementing the Water Framework Directive.

Outputs from the project include:

- a digitised dataset of invertebrate and plant records made between 2007 and 2009, from grazing marshes in Wales and southern and eastern England, made freely available through the National Biodiversity Network
- collated information on environmental data and land and ditch management for the grazing marshes surveyed
- a manual describing standard methods for surveying and assessing the conservation value of ditch flora and invertebrate fauna
- this two-volume technical report, available as hard copy and on the Buglife web site
- leaflets on ditch management, aimed at land and water managers and agricultural advisors.

During the field seasons of 2007, 2008 and 2009, over 500 ditches were sampled in coastal grazing marshes in Gwent, Anglesey, Somerset and Avon, Sussex, Kent, Essex, Suffolk and Norfolk. Both the ditch vegetation and the aquatic invertebrates were sampled.

The project was overseen by a Steering Group that included in its membership staff of Natural England, the Countryside Council for Wales, the Environment Agency, the Broads Authority and the Centre for Ecology and Hydrology (see *Acknowledgements* for the Steering Group membership.) In addition to the main funding provided by the Esmée Fairbairn Foundation, the Environment Agency contributed additional funds in 2007 for a preparatory desk study, a laptop computer and other equipment.

1.4 Companion projects

In addition to the core project, four related ‘companion projects’ on ditch systems were initiated and managed by Buglife. This report does not include details of these but they are given a brief mention here to provide context for the core project. In addition, by providing samples taken during the grazing marsh survey, Buglife has co-operated with the University of Plymouth on a forthcoming project to investigate the genetic diversity of populations of selected grazing marsh invertebrates across western Europe.

1.4.1 Diatom survey

Very little information on water quality was available for the survey areas and a programme of water sampling would have been prohibitively expensive, so it was decided that diatoms should be used as biological indicators of water quality. Diatoms are one of the quality elements used to assess the ecological status of rivers and lakes under the Water Framework Directive, and a predictive tool has been developed for this purpose (Kelly *et al*., 2007).

The project was carried out by Bristol University, under contract to Buglife. It had four aims:

- to extend the present knowledge of diatom communities in ditches
- to explore possible relationships between diatom, macrophyte and invertebrate assemblages in ditch systems
- to act as a surrogate for the programme of water chemistry analysis
- to constitute a pilot study for extending the Water Framework Directive assessment methodology to diatoms of ditch systems.

Diatom films were collected by the botanist from the stems of water plants in 20% of the ditches surveyed for plants. The diatom species present were identified and counted by staff of the University, and the ecological status of the ditches was deduced. Relationships of diatom assemblages to ditch vegetation and environmental factors (e.g. salinity and fertility) were explored. The results are given in a report (Yallop, in prep.) that will be available on Buglife’s web site. This is the first time that a widespread survey has simultaneously covered the macrophytes, invertebrates and diatoms of ditches. The work was funded by the Environment Agency, Natural England, the Countryside Council for Wales, Anglian Water and the Broads Authority.

1.4.2 Bibliography of ditch surveys

A bibliography (Driscoll, 2007) of reports and papers covering grazing marsh ditch surveys in England and Wales between 1878 and 1999 was produced by Rob Driscoll under contract to Buglife. The work was funded by a grant from the Norwich and Peterborough Building Society. An addendum to this bibliography, consisting of references compiled by Martin Drake and Nick Stewart as part of their work on the core Project, covers more recent work. The bibliography is available on Buglife’s web site (www.buglife.org.uk).

1.4.3 Monitoring in the Thurne catchment, Norfolk Broadland

In 1973, 1981/2 and 1997, Rob Driscoll carried out surveys of aquatic invertebrates and plants in 60 ditches in two adjacent, slightly saline areas in the Thurne catchment, Norfolk Broadland. One of these areas (Horsey), owned by the National Trust, remained as grazing marsh throughout, whereas the other (Somerton/Winterton) was ploughed in the 1980s but reverted to grazing marsh in the 1990s. Detailed information on salinity was also collected.

A companion project built on this unpublished monitoring programme by commissioning Rob Driscoll to carry out a further survey of the same ditches in 2009. Data from all four surveys will be analysed to produce a commentary on changes in ditch biota over the 30-year period, in response to changing land use and other environment factors. The report (Drake & Driscoll, in prep.) will be available on Buglife’s web site. The work was funded by the Norfolk Biodiversity Partnership, the Courtyard Farm Trust and Anglian Water.

1.4.4 Digitisation of data from previous surveys of ditch systems in England and Wales

In this project, biological and environmental data from previous grazing marsh surveys were digitised under a contract to Natural England. This information was of use in Buglife's core grazing marsh project and it could potentially contribute to work on Common Standards Monitoring and to a revision of the SSSI selection guidelines for ditch systems.

For invertebrates, information from 34 reports was extracted and records from approximately 1640 ditches were digitised. For ditch vegetation, data on over 6,300 ditches in 58 reports were added to the database.

Section 2 Overview of methods

2.1 Site selection

2.1.1 Selection of sites at the national scale

The area of agricultural land with dense ditch networks in England and Wales is vast. Wet grassland in England alone extends to 220,000ha (Dargie, 1993). The choice of wetlands as study areas for Buglife's ditch survey therefore had to be highly selective and was made using the following constraints:

- marshes should be coastal or in river valleys near the coast; inland floodplain marshes were excluded
- they should contain pasture rather than arable land, but with a few exceptions for purposes of comparison
- previous survey data (botanical or entomological, with an emphasis on entomological data) should be available; invertebrate surveys should cover a range of taxa
- access permission should be straight-forward, which usually meant that the wetland should be SSSI or land in the ownership of conservation organisations.

A large amount of preliminary work was required to search out previous survey data, identify target areas for survey and obtain the necessary permission for visits to sites. A list of previous surveys that were examined is given in Volume 2, Appendix 1. The following sites were chosen for survey in 2007-2009.

Malltraeth Marsh, Anglesey
Malltraeth marsh is an RSPB reserve. Only water beetles had been surveyed, on just one occasion, and one ditch had been repeatedly surveyed for several taxa. Therefore, the selection of ditches was made randomly.

Gwent Levels
About 90 references to invertebrate surveys were located for the Gwent Levels, of which about 60 to 70 mention work on aquatic invertebrates. Despite this apparently large effort, few surveys covered a wide area and most were made in response to heavy development pressure. Only two wide-scale surveys were of value in ditch selection, and one of these concentrated on main reens which were usually of better quality than most field ditches, many of which dry out and are overgrown by tall emergents or hedges. This limitation, combined with difficulties in gaining access permission, resulted in a limited range of ditch morphologies being sampled and most sampling was undertaken from road or track-sides.

The Gwent Levels comprise six contiguous SSSI. The original intention of working just three of these proved impossible since there were too many access constraints. Most samples were taken from Rumney & Peterstone SSSI (Wentlooge Level), Whitson and Redwick SSSI & Llandevenny SSSI (Caldicot Level).

Somerset and Avon Moors and Levels
These marshes have received more high quality invertebrate and vegetation survey than most areas visited. Kenn, Nailsea and Tickenham Moors SSSI in Avon, and seven SSSIs in Somerset were selected, covering both peat and mineral soils. West Sedgemoor is an RSPB reserve and Southlake, King's Sedgemmor and Moorlinch are National Nature Reserves (NNRs). Ten ditches were chosen outside the SSSIs, based initially on those surveyed by the Institute of Terrestrial Ecology in the early 1980s. In practice, some had to be chosen for their convenience (next to roads and tracks) since no access permission had been obtained for sites outside Natural England's jurisdiction.

Arun Valley, Sussex
Amberley Wildbrooks and Pulborough Brooks are RSPB reserves in the Arun valley. Only molluscs had been well surveyed here so most ditches were selected from a single study covering a range of taxa.

Pevensey Levels, Sussex
Few surveys of aquatic invertebrates covered a range of taxa, but molluscs had been well covered owing to the presence of large populations of three BAP priority list species. Ditches in the west of the marsh with Floating pennywort *Hydrocotyle ranunculoides* were avoided, since this invasive plant may have a large impact that swamps the effect of management practices, which was one of the main influences being investigated.

Walland Marsh
Walland Marsh straddles the border of Sussex and Kent. Five isolated blocks of pasture surveyed were SSSIs, nearly all the rest was arable land. All the separate blocks had been surveyed at least once but only four useful invertebrate surveys could be located.

North Kent Marshes
Five marshes near the coast of North Kent were targeted, including Chetney Marsh NNR and several RSPB reserves. The chosen sites had been surveyed once or twice for aquatic invertebrates, and sometimes only for water beetles. Well worked areas that were not chosen were the small Swale NNR, Elmley, which was surveyed for Natural England in 2008 by another contractor, and the Swale crossing bridge area.

Essex marshes
The choice of sites along the north shore of the Thames estuary and East Anglian coast was limited by the paucity of previous invertebrate surveys. The exception was the Inner Thames Marshes SSSI that had been very well worked over a number of years. This SSSI consists of Aveley and Wennington Marshes, which were owned by the MOD but have recently been bought by the RSPB, and Rainham Marsh, a nature reserve managed by Havering Borough Council. Vange Marsh is managed by the RSPB and Essex Wildlife Trust, Hadleigh Marsh is a Local Nature Reserve and Fobbing Marsh is in private ownership. Part of the Fambridge wetlands, in the Crouch Estuary, is owned by the Essex Wildlife Trust and part by Essex County Council. Brightlingsea NNR, in the Colne Estuary, is a National Nature Reserve.

Suffolk marshes
Two contrasting marshes in Suffolk were chosen: Sizewell Belts, a peaty, partly wooded site, and Minsmere Level RSPB reserve, a typical exposed grazing marsh.

Norfolk marshes
These marshes had been well surveyed for plants but not for invertebrates, despite their obvious high quality and large extent. The selection used old invertebrate surveys by Driscoll and two more recent ones, whose overlap limited the choice to four marshes along the Bure and three in the Yare valley. Buckenham and Cantley Marshes, in the Yare valley, and Fleggburgh and Upton Marshes, in the Bure valley, were SSSIs; Limpenhoe Marsh, in the Yare valley, and Oby and South Walsham Marshes, in the Bure valley, were not.

2.1.2 Selection of ditches at the local scale

One of the project's main aims was to detect any change in the aquatic flora and fauna over the last two or three decades. A potential problem when comparing previous work was that the selection of ditches in many old surveys was not random, at least for invertebrate surveys, but was based on several approaches. These included selection based on botanical types, preferences or requirements of the organisation commissioning the survey, or greatest potential conservation value. However the selection was made, it was usually biased towards the more ‘interesting’ ditches. To reduce variation by sampling a new randomly selected suite of ditches, it was decided to revisit those previously surveyed. This approach allowed direct comparison of the past and present quality of each ditch, rather than relying on comparing ‘average’ conditions across a site.

The bibliography of mainly unpublished survey reports by Driscoll (2009) was an important source of surveys prior to 2000 (the cut-off date in this review). Later work was trawled from the files of Natural England and the Environment Agency, and through contact with known surveyors. The old reports used in ditch selection are listed in Volume 2, Appendix 1 of this report.

Using data from key entomological and botanical reports for each area, the position of previous samples were plotted on a map and ditches having received most previous effort were selected, with the emphasis on entomological effort. Ditches were selected to cover a range of soil types and give a wide geographic spread across a site. Most sites had so little previous invertebrate survey effort that almost or all ditches were selected but the Somerset Moors and Levels and Gwent Levels were unusual in the amount of previous survey, and here the ditches chosen were nearest to randomly selected grid coordinates within 1km squares. Unfortunately, there was difficulty in obtaining access permission in Gwent, so sampling was mainly in larger IDB drains that could be reached from roads and tracks.

More samples were allocated to large sites but not using any consistent rule, since sites varied so widely in many respects that it was not possible to clearly define a 'site'. For instance, in Somerset there were discrete SSSIs and here the number of ditches selected per 'site' varied from 15 for smaller ones to 25 for large ones, but Pevensey Levels is one large contiguous block of marsh, and here 45 samples were taken. Sampling effort was therefore uneven on a geographic scale.

Most survey information was at least 10 years old, in which time any ditch could have undergone considerable changes, for example in its cleaning regime, hydroseral stage and adjacent land-use. In a few instances, a pre-selected ditch was substituted for another nearby for various reasons, such as the ditch being dry or physical access being difficult or dangerous due to very steep sides or bulls. The selection was regarded as random for the purpose of analysis.

Samples of invertebrates were taken from 531 ditches. Ten ditches in Somerset were sampled in all three years (see Section 8.1). Thus there were 551 invertebrate samples used in the analysis. Two further samples were excluded completely, one being incomplete owing to the surveyor being interrupted by the land-owner who did not want the work to continue, and the other from a burnt reedy ditch next to a rubbish tip (probably the result of arson).

The vegetation of 546 ditches was recorded, including all those surveyed for their invertebrates. Twenty of the ditches in Somerset were sampled in all three years of the project (see Section 7.1).

2.2 Survey coverage

The geographical coverage of survey for plants and invertebrates is shown in Table 2.2. (The repeat surveys in Somerset are not included in this table.) Figure 2.2 shows the distribution of the areas surveyed.

Table 2.2 Marshes surveyed in 2007, 2008 and 2009

Marshes surveyed in 2007	County	No. of ditches sampled	
		Invertebrates	Plants
West Sedgemoor	Somerset	24	24
Kings Sedgemoor	Somerset	20	20
Moorlinch	Somerset	16	16
Chilton, Edington & Catcott Moors	Somerset	25	25
Tadham & Tealham Moor	Somerset	22	22
Pawlett Hams	Somerset	15	15
Kenn, Nailsea, Tickenham Moors	Avon	20	20
Southlake Moor	Somerset	0 (2005 data available)	12
Non-SSSI ditches	Somerset	10	10
Caldicot Level	Gwent	36	36
Wentlooge Level	Gwent	15	15
Total		**203**	**215**

Marshes surveyed in 2008	County	No. of ditches sampled	
		Invertebrates	Plants
River Arun: Amberley Wildbrooks	West Sussex	10	10
River Arun: Pulborough Brooks	West Sussex	10	10
Pevensey Levels	East Sussex	45	45
Walland Marsh (5 pasture blocks, 5 arable areas)	East Sussex/ South Kent	45	45
Thames / Medway estuary marshes: Shorne, Chetney, Grain, Cliffe and Chetney	North Kent	45	46
Malltraeth Marsh	Anglesey	10	10
Total		**165**	**166**

Marshes surveyed in 2009	County	No. of ditches sampled	
		Invertebrates	Plants
Inner Thames Marshes	Essex	15	15
N. Thames: Vange and Fobbing Marsh	Essex	15	15
N. Thames: Hadleigh Marsh	Essex	7	7
Crouch estuary: Fambridge Marsh	Essex	15	15
Colne estuary: Brightlingsea Marsh	Essex	11	11
Orwell estuary: Shotley Marsh	Suffolk	7	7
Sizewell and Minsmere	Suffolk	20	20
River Yare: Buckenham Marsh	Norfolk	9	9
River Yare: Cantley Marsh	Norfolk	11	11
River Yare: Limpenhoe Marsh	Norfolk	10	10
River Bure: Fleggburgh Marsh	Norfolk	9	9
River Bure: Oby Marsh	Norfolk	15	15
River Bure: Upton Marsh	Norfolk	15	15
River Bure: South Walsham Marsh	Norfolk	6	6
Total		**165**	**165**

Figure 2.2 Map showing the location of the areas surveyed

2.3 Field survey methods

The field survey methodology for both invertebrates and plants is described in detail in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010).

Invertebrate sampling took place between late April and early June each year from 2007 to 2009. Each sample was taken from a section of ditch at least 50m long, where the vegetation was moderately similar, and sampling sites were chosen to cover, as far as possible, the full range of vegetation types present in the wetland. The abundance of invertebrate genera was estimated in the field on an approximately logarithmic scale (1-9, 10-99, >100) and noted as 1, 2 or 3. Abundance ratings for individual species were adjusted later when identifications were confirmed in the laboratory.

The vegetation survey was carried out in late summer for the same ditches as the invertebrate survey. The plant survey followed the method originally described in Alcock & Palmer (1985) and recommended in Palmer, Drake & Stewart (2010), which has been used in previous botanical surveys of ditch systems carried out by the statutory conservation agencies (see Section 3) for over two decades. This method involves detailed recording of the species present in representative 20 m. lengths of ditch, followed by observations on extra species found in the remaining parts of the ditch. Relative abundance of plant species is recorded on the DAFOR scale.

A wide variety of environmental variables was measured, nearly half of them for both banks. The same set of variables was measured in both the spring invertebrate and the summer botanical surveys. Variables were grouped in a standard field sheet (Figure 2.3) into classes covering different aspects of the habitat, including land-use, management, structure and cover of vegetation, ditch dimensions and water chemistry (pH, conductivity).

Wildlife & Countryside Act licences were obtained to allow survey of five scheduled invertebrate species: the Medicinal leech (*Hirudo medicinalis*), the Fen raft spider (*Dolomedes plantarius*), the Norfolk hawker (*Aeshna isosceles*), the beetle *Paracymus aeneus*, and the Lesser silver water beetle (*Hydrochara caraboides*). A Habitats Regulations licence was obtained to cover killing and keeping preserved specimens of the Little whirlpool ram's-horn snail (*Anisus vorticulus*). No protected (Schedule 8) plants were to be collected, so no licence was needed for the botanical survey.

2.4 Data storage

In the laboratory, records of invertebrates identified were entered on forms, onto which field records and abundances were also transferred. The data were then digitised using Recorder 3.3. Data were exported to an Excel spreadsheet as a list of records with associated information such as higher taxa, conservation status and scores for other attributes (see Section 6). Environmental variables were entered directly onto an Excel spreadsheet. All characters (e.g. DAFOR abundance values) were converted to numerics that can be handled by statistical programmes.

All the botanical records, together with related environmental information, were also digitised and stored in the form of Excel spread sheets.

The raw data are to be passed to the National Biodiversity Network (NBN) and will be freely available at www.nbn.org.uk. The field sheets and site maps showing the location of the ditches sampled are archived at Buglife's headquarters.

Figure 2.3. Field recording form for ditch survey

Site											**Ditch no.**		**Recorder**	
Grid ref.											**Date**		**Photo**	

ADJACENT LAND USE	**A E/N**	**B W/S**
Improved grassland		
Semi-improved grassland		
Unimproved grassland		
Arable		
Swamp or Fen		
Drove		
Embankment		
Woodland or Carr		
Other		
Cattle/Horse grazed		
Sheep grazed		
Hay/Silage		
Stockproof boundary		
Temporary fencing		
Spoil on bank		

DITCH FEATURES					
Water width (m)	0	1	2	3	4
Banktop width (m)	0	2½	5	7½	10
Freeboard (cm)	0	20	50	100	200
Water depth (cm)					
Silt depth (cm)					
Conductivity (μScm^{-1})					
pH					
Turbidity	Clear				Opaq
Water colour					
Slope bank A	0	15	30	55	70
Slope bank B	0	15	30	55	70
Profile under water A	0	15	30	55	70
Profile under water B	0	15	30	55	70
Soil type	clay	alluv	peat	sand	

VEGETATION COVER	**Abs**	**R**	**O**	**F**	**A**	**D**
Open water surface						
Floating Lemna/Azolla						
Other floating aquatics						
Floating algae						
Lemna trisulca						
Other submerged plants						
Submerged algae						
Open substrate						
Emergent						
Low swamp/Floating mat						
Exposed vegetated						
Exposed mud						
Litter / detritus						
Shaded						
Emergents/floating mat in channel %						

BANK VEGETATION DAFOR	**A E/N**	**B W/S**
Tall grass/reed		
Short grass		
Bare ground		
Tall herbs		
Overhanging vegetation		
Scrub		
Fen		
Woodland ground flora		
Shaded (%)		

D	70-100%
A	30-70%
F	10-30%
0	3-10%
R	<3%

GRAZING/ VEG STRUCTURE	**Bank A (E/N)**				**Bank B (W/S)**			
	none	low	med	high	none	low	med	high
Grazing								
Poaching								
Block formation								
Shelf formation								
Tangledness								
Grassy margin								

Notes

MANAGEMENT				
Years since last cleared	1	2-3	4-10	>10
Water relative to normal		cm (+ above normal, - below normal)		
Cleared to side	A	B		
Benched profile	A	B		
Cleared by	Land manager		IDB	EA

2.5 Classification and evaluation techniques

Several types of statistical analysis were performed on the data. Firstly, Two-way Indicator Species Analysis (TWINSPAN) (Hill 1979) was used to produce separate classifications of the invertebrate and plant samples (see Volume 1, Sections 3 and 4 and Volume 2; Appendices 2 and 3). TWINSPAN has a long history of use and is the basis of two widely used national invertebrate and plant classification schemes (Wright *et al*., 1984**;** Rodwell, 1991).

The relationship of environmental variables to the end-groups recognised in the TWINSPAN classifications was then investigated. It was found that the set of about 60 environmental variables recorded on the field sheets was unwieldy, so the most significant of these were selected to investigate their influence on the composition of the plant and invertebrate assemblages. Soil types were reduced to two: peat or mineral; some variables (e.g. years since last cleaned) were rarely scored or unknown, so these were excluded from analysis.

An assessment of the conservation value of the plant and invertebrate assemblages and of the marshes was carried out, using a series of metrics for each of the taxonomic groups. These metrics were for Species Richness, Species Conservation Status (i.e. rarity), aspects of Habitat Quality (indicators of water quality for plants or fidelity to the grazing marsh habitat for invertebrates) and Naturalness (i.e. presence or absence of non-native species). Their use is explained in detail in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010). The results of their application to the survey results are given in Volume 1, Sections 5 to 8 and Volume 2, Appendices 3 and 4.

Lastly, the distribution and abundance of individual rare species in the TWINSPAN groups and geographical areas and in individual marshes was examined.

2.6 Repeat sampling of ditches in Somerset

One of the main aims of the project was to establish whether there had been any change in the fauna and flora of ditches over the last three or four decades since the earliest surveys were undertaken. One of the methods used to assess the extent of change was comparison of the metrics for Species Richness, Species Conservation Status, Habitat Quality and Naturalness for wetlands at different dates.

An assessment of change in conservation value using these metrics must take into account year-to-year variation (for example due to weather and normal ditch cleaning) that would be expected within an area undergoing no obvious change in management. Moreover, some variation in these values often cannot be explained in terms of changes in management or obvious environmental conditions, and this has to be considered when making comparisons between surveys undertaken many years apart.

To estimate the magnitude of this unexplained variation, a small sample of ditches in Somerset was sampled in all three years of the project, during which time there was no intentional change in management regime. Samples were taken from ten ditches for invertebrates and 20 for plants. The choice was made from stable, well managed sites with no access issues (Natural England-owned NNRs at Southlake, Kings Sedgemoor and Moorlinch, RSPB's West Sedgemoor), and included ditches that had also been sampled for diatoms. Some ditches were cleaned during the project and this was regarded as part of the variation that would be expected.

The four key metrics for plants and invertebrates (Species Richness, Species Conservation Status Score, Habitat Quality Score and Naturalness Score) were examined for average and maximum changes. The aim was not to show whether change had occurred, as it was hoped the selected sites were stable, but to establish the size of variation in the metrics, and to use this as a bar that must be exceeded before any differences between other surveys could be regarded as real

2.7 Investigation of change over time

The methods used to estimate change in the biota of the grazing marshes surveyed and the findings of this investigation are described in Sections 7 and 8 of Volume 1 of this report and in Volume 2, Appendix 5. Data from previous surveys was searched out and digitised to enable comparisons to be made. A list of the surveys used as information sources is given in Volume 1 Appendix 1.

Section 3 Botanical classification of ditches

3.1 Methods

3.1.1 Previous ditch vegetation classifications

All the previous surveys of ditch vegetation have covered only limited geographical areas. A variety of methods has been used for classifying ditch vegetation. Charman (1981) based the first classification, which covered the North Kent Marshes, on two analyses, one of submerged, floating and emergent aquatic species, the other of bank vegetation. Wolseley *et al.* (1984) based the Somerset classification on all the species in the wet part of the ditch, including terrestrial species such as Stinging nettle *Urtica dioica,* and this approach was also used by Glading (1986) for the Pevensey Levels.

In contrast, the method adopted subsequently by the Nature Conservancy Council's England Field Unit (EFU) involved two separate analyses, one for fully aquatic (i.e. floating and submerged) vegetation, the other for emergent vegetation, including species such as Common reed (*Phragmites australis*). The latter approach was used to analyse data from EFU surveys of Exminster Marshes in Devon (Leach *et al.* (1988), North Norfolk (Leach & Reid, 1989), Norfolk Broadland (Doarks & Leach, 1990), the lower Derwent (Birkinshaw, 1991) and the Suffolk and Essex coastal marshes (Wolfe-Murphy *et al.*, 1991). However, Williams and Ware (1997) returned to using aquatics and emergents together in their classification for North Kent Marshes. All except the earliest classification (Charman, 1981) (for North Kent) were carried out using the Two Way Indicator Species Analysis program TWINSPAN (Hill, 1979).

3.1.2 Present vegetation classifications

The TWINSPAN program was used for analysing the Buglife survey data, and to facilitate comparison with the previous analyses mentioned in Section 3.1.1, a dual approach was adopted. The first used all the aquatic and marginal species recorded in the 'wet' zone of the ditches, the second was based on submerged and floating vegetation alone. These two classifications potentially give information on different influences. The open water assemblage is more sensitive to water quality, but inclusion of emergent and marginal species is required to fully describe the condition of ditch vegetation, as well as to provide an adequate habitat framework for comparison with invertebrate assemblages.

Digitised species records from all 586 vegetation samples collected in 2007, 2008 and 2009 were analysed using the 2008 version of TWINSPAN (Hill, 1979). Five 'pseudospecies' were used, based on DAFOR abundance values and ranging from 1 for Rare to 5 for Dominant. Aggregates were used when a significant proportion of records were for the aggregate because plants were not flowering or fruiting at the time of the survey and could not be identified to species. These aggregates were for starworts *Callitriche* species; water-cresses *Rorippa nasturtium-aquaticum* and *R. microphyllum*; bladderworts *Utricularia australis* and *U. vulgaris*; and the water-crowfoots *Ranunculus aquatilis*, *R. peltatus, R.trichophyllus* and *R. baudotii*.

The first suite of species analysed comprised vegetation in the 'wet' zone. This was defined as the parts of the ditch under the water and in the normally inundated zone in ditches where the water level was low, but excluding the ditch banks. The total list amounted to 174 native and non-native species and included plants such as Creeping bent *Agrostis stolonifera* that are by no means restricted to wetland habitats. The 586 samples included 60 from the 20 Somerset ditches that were visited in all three years (see Volume 1, Sections 2 and 7).

For the second analysis, the plant list was reduced to the 48 species that are predominantly found as floating or submerged forms.

3.1.3 Environmental variables influencing the classification

To shed light on the factors shaping the plant assemblages, box plots were produced using the Excel program, to indicate relationships between environmental parameters recorded in the field and the wet zone end-groups.

3.2 Results

3.2.1 Classification of wet zone vegetation

End-groups recognised

Seven major end-groups (A to G) were identified, with three of these subdivided further. The dendrogram showing the main divisions created by TWINSPAN is given in Figure 3.2.1 and in Volume 2 Appendix 2, Figure 2.1a. Information in these can be used to key out any ditch vegetation sample to the appropriate end-group. A constancy table showing the composition of the main end-groups are given as Table 2.1 in Appendix 2.

The first TWINSPAN division separated 75 ditches (group G: Sea club-rush) from the rest. Group G ditches are typified by Sea club-rush (*Bolboschoenus maritimus*) and Fennel-leaved pondweed (*Potamogeton pectinatus*), which are salt tolerant species (Hill *et al.*, 2004). The aggregate water crowfoot, much of which would have been the brackish-water species *Ranunculus baudotii*, is also a prominent constituent of group G.

Common duckweed (*Lemna minor*) and Frogbit (*Hydrocharis morsus-ranae*), the principal indicator species for the remaining end-groups A to F, are obligate fresh water plants (Hill *et al.*, 2004). However, the small end-group A (Common reed group) consists of 32 ditches dominated by Common reed (*Phragmites australis*), which is at home in both fresh and brackish conditions. Group B (floating duckweed group) consists of 103 samples and is typified by a limited number of submerged species and the dominance of surface vegetation consisting of four species of floating duckweed: Common duckweed, Fat duckweed (*Lemna gibba*), Greater duckweed (*Spirodela polyrhiza*) and Least duckweed (*Lemna minuta*), an invasive non-native species. Group C (Flote-grass group) is a small group of 27 samples largely made up of short emergent species typical of shallow water, such as Flote-grass (*Glyceria fluitans*) and Creeping bent (*Agrostis stolonifera*).

The remaining end-groups D (197 samples), E (117 samples) and F (35 samples) are characterised by Frogbit, a free-floating plant, and Ivy-leaved duckweed *Lemna trisulca*, which, unlike the other four species of duckweed, predominantly occupies the zone just below the water surface. Group D (Frogbit / Reed sweet-grass) ditches are usually fringed by Reed sweet-grass (*Glyceria maxima*), but Common reed is the most usual tall emergent in group E (Frogbit-Common reed) ditches. The 35 samples making up group F (the Water-soldier group) are defined by the occurrence of open water species such as Water-soldier (*Stratiotes aloides*) and Broad-leaved pondweed (*Potamogeton natans*).

The composition of further divisions (end-groups B1, B2, D1, D2, E1, E2, G1, G2) is shown in Figure 2.1b and Table 2.2 of Appendix 2. These plant assemblages are all recognisable in the field. Sub-groups G1 and G2, for instance, are both characterised by Sea club-rush, but differ in that G1 ditches often contain Common reed and the open water species Fennel-leaved pondweed and Soft hornwort (*Ceratophyllum submersum*), while G2 ditches lack these three species. The latter tend to be shallower and more likely to dry out during the summer and therefore have a higher cover of non-aquatics such as Creeping bent (*Agrostis stolonifera*) within the ditch. The variants of the duckweed (group B) and Frogbit groups (D and E) are distinguished by their associations with different tall emergent species such as Common reed or Reed sweet-grass (*Glyceria maxima*).

The mean number of species per sample in each wet zone end group in given in Table 3.2.1a below. It is obvious that groups A, G1 and G2, the brackish and Common reed dominated groups, are much more species-poor than the rest. The floating duckweed groups B1 and B2 are less species-rich than the Frogbit and Water-soldier groups.

Table 3.2.1a. Mean number of plant species per sample in wet zone groups

Wet zone group	A	B1	B2	C	D1	D2	E1	E1	F	G1	G2	All
	Common reed	Floating duckweeds		Flote-grass	Frogbit / Ivy-leaved duckweed				Water-soldier	Sea clubrush		
No. of samples	32	34	69	27	85	112	69	48	35	54	21	586
Mean no. of plant species per sample	5	10	13	16	18	17	16	16	17	8	7	14

Geographical distribution of wet zone end-groups

The distribution of the end-groups (Table 3.2.1b) indicates a geographical bias. Because of the over-riding influence of salinity on the classification, most of the samples in group G are in North Kent and Essex. Groups B and D are strongly associated with the west (Gwent Levels and Somerset); group E ditches lie predominantly in the south (Pevensey Levels and Walland Marshes) and the east (Suffolk and Norfolk); and a large majority of group F ditches are in Norfolk. Samples in groups A and C are widely distributed, but a majority of the ditches sampled in Anglesey fall into group C.

Table 3.2.1b. Geographical distribution of wet zone vegetation groups

Group	A	B1	B2	C	D1	D2	E1	E2	F	G1	G2	All
Malltraeth, Anglesey	-	-	2	**6**	2	-	-	-	-	-	-	10
Gwent	4	**11**	**29**	-	6	-	1	-	-	-	-	51
Somerset/Avon	1	9	**33**	4	**54**	**94**	3	6	-	-	-	204
Arun Valley	-	-	2	3	**15**	-	-	-	-	-	-	20
Pevensey Levels	2	1	-	6	2	2	**16**	7	9	-	-	45
Walland	6	2	-	3	4	1	2	**17**	-	8	2	45
North Kent	4	3	-	1	-	1	8	4	-	**20**	5	46
Essex	**11**	4	-	3	-	2	3	7	-	**20**	**13**	63
Suffolk	-	1	1	-	-	1	**13**	4	1	5	1	27
Norfolk Broadland	4	3	2	1	2	11	**23**	3	**25**	1	-	75
All samples	32	34	69	27	85	112	69	48	35	54	21	586

In contrast to the findings for invertebrates (Volume 1, Section 4), the geographical bias shown by the vegetation assemblages is not thought to be due to differences in the distribution of plant species, but rather to the predominance of brackish conditions in the east of England. The one exception is group F, which lies mainly in Norfolk and is typified by Water-soldier, which is native only in Broadland. No satisfactory reason could be found for the high incidence of floating duckweed vegetation in the west, especially in Gwent.

Figure 3.2.1 Wet zone groups

Group 1 (N = 586)
Hyd m-r | Bol mar
L minor |
0 -- 1

Group 2 (N = 511)
Phr aus4 | Spa ere
| Hyd m-r
| L minut
-1 -- 0

Group 3 (N = 75)
Pot pec | Agr sto3
Cer sub | Gly flu
Phr aus | Bol mar3
| Rum con
1 -- 2

Group 4 (N = 32)
End Group A
Phragmites

Group 5 (N = 479)
L minut3 | L tris2
L gib | Hyd m-r2
L minor2 | Men aqu
| Spa ere2
-1 -- 0

Group 6 (N = 54)
End Group G1
Bolboschoenus/P. pectinatus

Group 7 (N = 21)
End Group G2
Bolboschoenus

Group 10 (N = 103)
Phr aus3 | Gly max
L tris2 | Spi pol
| Pha aru
| Cer dem
| Per amp
0 -- 1

Group 11(N = 376)
Jun eff | Phr aus
L minor2 |
Pha aru |
-1 -- 0

Group 20 (N = 34)
End Group B1
Lemna/Phragmites

Group 21 (N = 69)
End Group B2
Lemna/Glyceria maxima

Group 22 (N = 224)
Agr sto3 | L tris3
Gly flu3 | Hyd m-r2
Ele pal | L minor2
-1 -- 0

Group 23 (N =152)
L minor | Str alo
L minuta | Elo can
| Gly max
| Pot nat
0 -- 1

Group 44 (N = 27)
End Group C
Agrostis/Glyceria fluitans/Eleocharis

Group 45 (N = 197)
Equ flu | Ber ere2
Elo nut | Jun sub
| Bol mar
| Car rip
0 -- 1

Group 46 (N = 117)
Phr aus2 | Spa ere2
Car rip | Bol mar
L minor2 | Cer sub
-1 -- 0

Group 47 (N = 35)
End Group F
Hydrocharis/Stratiotes/
Pot. natans/Glyceria maxima

Group 90 (N = 85)
End Group D1
Hydrocharis/Spirodela/Glyceria maxima

Group 91 (N =112)
End Group D2
Hydrocharis/Juncus effusus

Group 92 (N = **69)**
End Group E1
Hydrocharis/Phragmites

Group 93 (N = 48)
End Group E2
Hydrocharis/algae

3.2.2 Classification of submerged and floating vegetation

A TWINSPAN classification was produced for the submerged and floating aquatic species alone. This was to facilitate comparison with the EFU classification for Norfolk Broadland. Table 2.3 in Appendix 2, Volume 2 lists the 48 submerged and floating species recorded in the ditches. They were recorded in 565 of the 586 samples in the complete dataset.

End-groups recognised

Figures 2.2b and 2.2b in Volume 2, Appendix 2 are dendrograms showing the results of the TWINSPAN analysis. Tables 2.4 and 2.5 in Appendix 2 are the resulting species constancy tables for the end-groups.

The first TWINSPAN division resulted in a single sample in the Pevensey Levels being split off because it was the only ditch where White water-lily (*Nymphaea alba*) occurred alone. Seven main end-groups (AqA to AqG) were then recognisable. The next major division separated off 75 samples (end-group AqG) characterised by Fennel-leaved pondweed (*Potamogeton pectinatus*). AqG is obviously the equivalent of brackish Group G in the analysis of the wet zone vegetation. As in the wet zone analysis, the next major division was based on the dominance of surface floating duckweeds on the one hand and Ivy-leaved duckweed (*Lemna trisulca*) and Frogbit (*Hydrocharis morsus-ranae*) on the other.

Seven ditches in Essex formed a tight group AqA because of the presence of the invasive non-native Australian swamp stonecrop (*Crassula helmsii*) to the exclusion of most other species apart from duckweeds. Group AqB (76 samples) is similar to wet zone group B, being composed of ditches dominated by floating duckweeds, including the non-native Least duckweed (*Lemna minuta*).

The three largest groups AqC, AqD and AqE (387 samples in total) are characterised by Frogbit, together with Ivy-leaved duckweed, and appear somewhat similar in composition. AqC ditches tend to have more abundant floating duckweed than those in the other two groups, and AqD ditches more frequently support *Elodea* species (see Volume 2, Appendix 2, Tables 4 and 5). The 19 ditches in group AqF are equivalent to those in wet zone group F, having high constancies of both Frogbit and Water-soldier (*Stratiotes aloides*).

Further divisions of AqC (AqC1, AqC2) and AqD (AqD1, AqD2) were poorly differentiated.

Geographical distribution

The geographical distribution of the aquatic end-groups is shown in Table 3.2.2 Again, the over-riding influence of salinity on the classification is illustrated by the majority of samples in North Kent and Essex being in the brackish group AqG. The samples from Gwent are mainly in the floating duckweed group AqB. The Australian swamp stonecrop group AqA was only found in Essex and the great majority of group AqF ditches are in Norfolk. The rest of the groups are more widely spread throughout the regions.

Table 3.2.2 Geographical distribution of floating and submerged vegetation groups

Group	AqA	AqB	AqC1	AqC2	AqD1	AqD2	AqE	AqF	AqG	All
Malltraeth, Anglesey	-	2	1	-	-	-	2	3	2	10
Gwent	-	**33**	2	9	1	4	-	-	-	49
Somerset/Avon	-	**30**	**55**	**32**	6	**42**	**38**	1	-	204
Arun Valley	-	-	4	2	-	8	3	1	-	18
Pevensey Levels	-	3	3	-	2	**22**	11	-	2	43
Walland	-	2	4	-	8	7	11	-	12	44
North Kent	-	2	2	1	3	4	9	-	**24**	45
Essex	**7**	2	4	-	2	-	12	-	**25**	52
Suffolk	-	1	4	1	1	7	7	-	6	27
Norfolk Broadland	-	1	11	3	6	9	**24**	**14**	4	72
All samples	7	76	90	48	29	103	117	19	75	564

Like the wet zone classification, the floating/submerged species classifications showed the overwhelming influence of salinity on the composition of the vegetation, detected an important difference between freshwater ditches dominated by floating duckweeds and those containing Frogbit, and pointed to the distinctive character of ditches with Water-soldier. However, the floating/submerged species classification proved to be difficult to apply because nearly 70% of the samples ended up in three 'frogbit' groups (AqC, AqD and AqE) that lacked distinctiveness. The wet zone analysis was more useful because different tall emergent plant species served to characterise the individual 'frogbit' groups.

3.3 Explanatory environmental variables and vegetation characteristics

Figure 3.3a illustrates the associations of the most influential environmental variables with the wet zone end-groups.

The brackish nature of group G ditches was confirmed by the high conductivities, and the presence of some brackish ditches in group A was also confirmed. Groups A, C and G2 obviously contain ditches that tend to dry out in summer. Groups B2, D1 and D2, all predominantly easterly in distribution, are associated with peaty soil.

The general characteristics of the vegetation in the wet zone end-groups is shown in Figure 3.3b. The extent of the vegetation types was categorised on a DAFOR scale, which gives the box plots a stepped appearance, but the trends for the different end groups are still clear. The values used in calculating medians for the DAFOR scale were 5, 4, 3, 2 and 1.

Figure 3.3b shows the predominance of floating duckweeds in groups B1 and B2, together with a marked lack of floating algae. The reverse is apparent in the brackish groups G1 and G2. Floating duckweed is more prevalent in the D (predominantly western) groups than in the E (more easterly) groups, for reasons that are not clear. The D, E and F groups, as might be expected, have a high proportion of other floating species (mainly Frogbit) and of Ivy-leaved duckweed. Ditches in groups A, C and G2 are predominantly at a stage late in the hydrosere, with high cover of emergents in the channel. This presumably reflects a late stage in the cleaning cycle or a low maintenance regime. High cover of emergents goes along with lack of submerged plant cover in group A but not in groups C or G2. The groups with the highest average submerged vegetation cover (excluding ivy-leaved duckweed) are E2, which is centered on Walland Marsh, and F, the 'Norfolk' group.

Figure 3.3a Associations of key environmental variables with wet zone end-groups

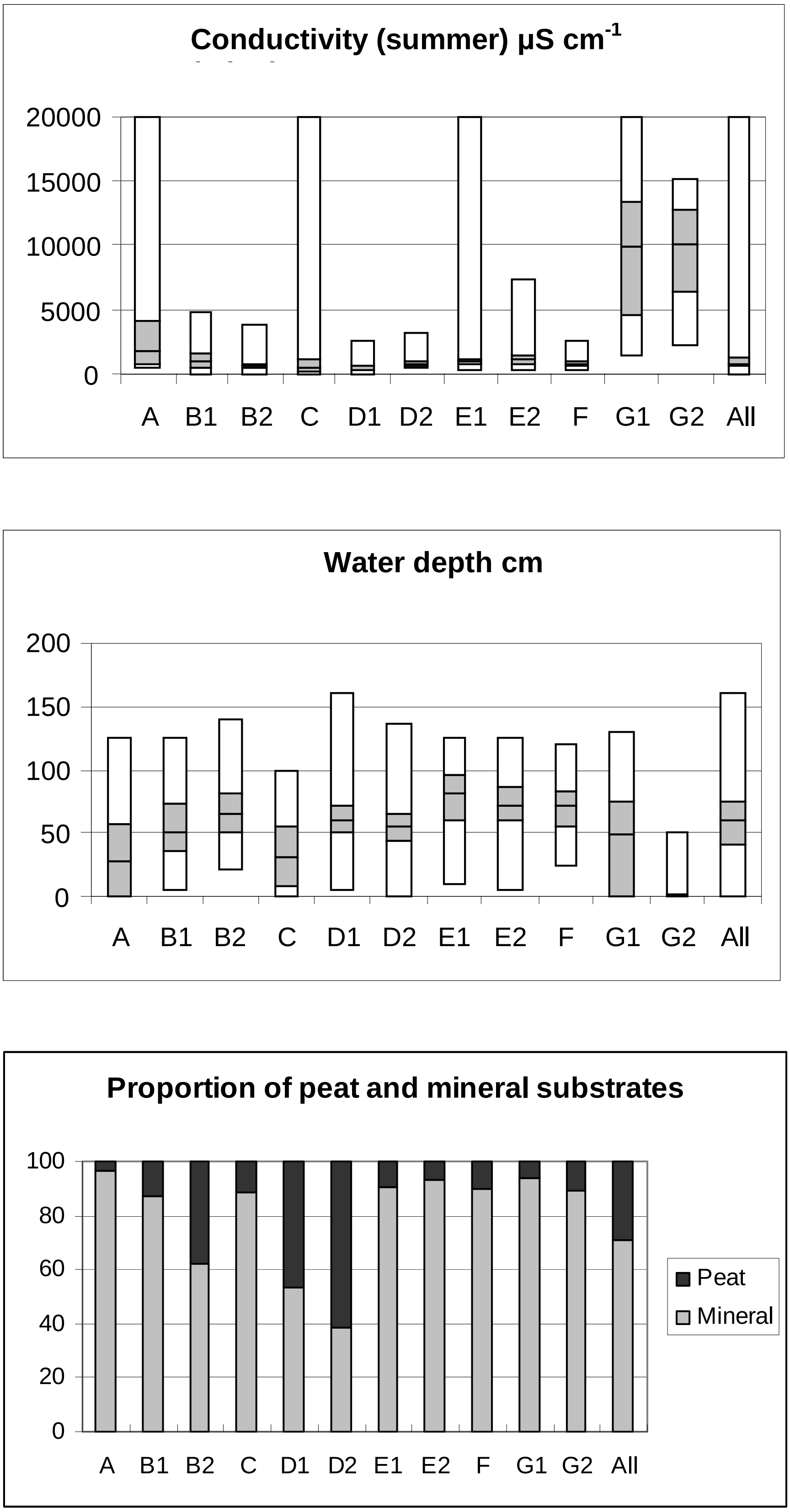
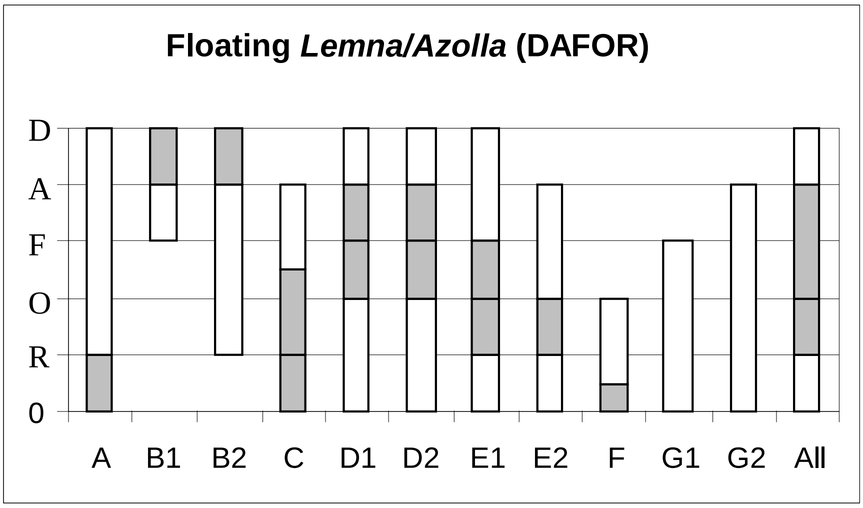
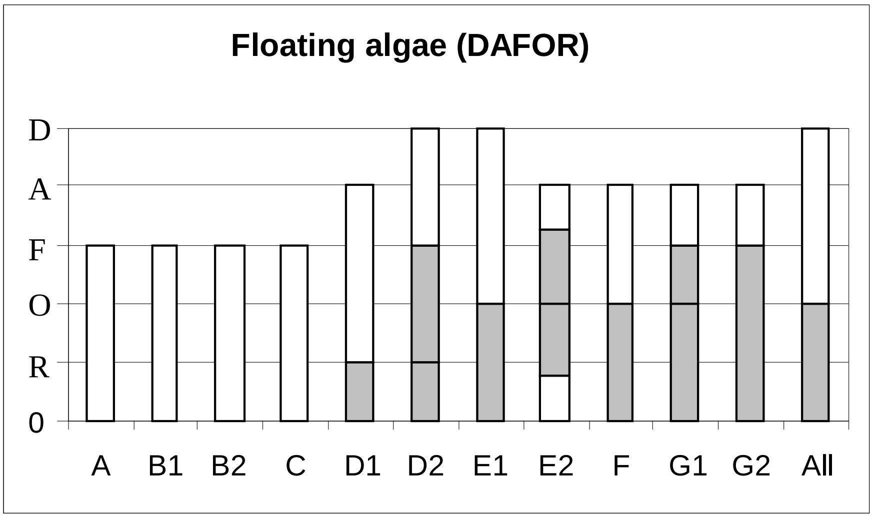
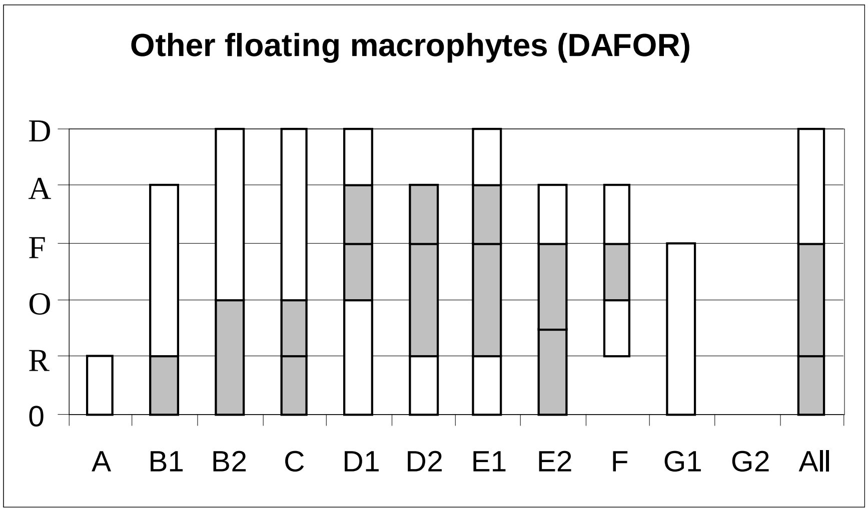
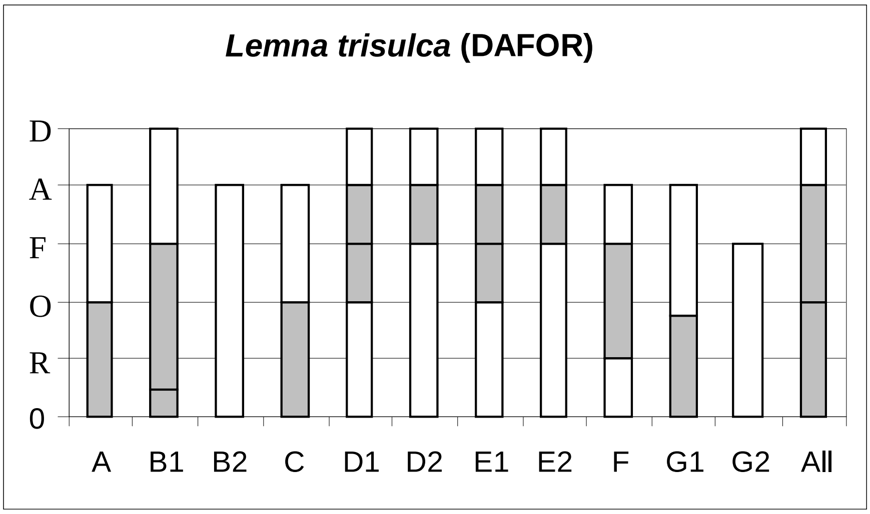


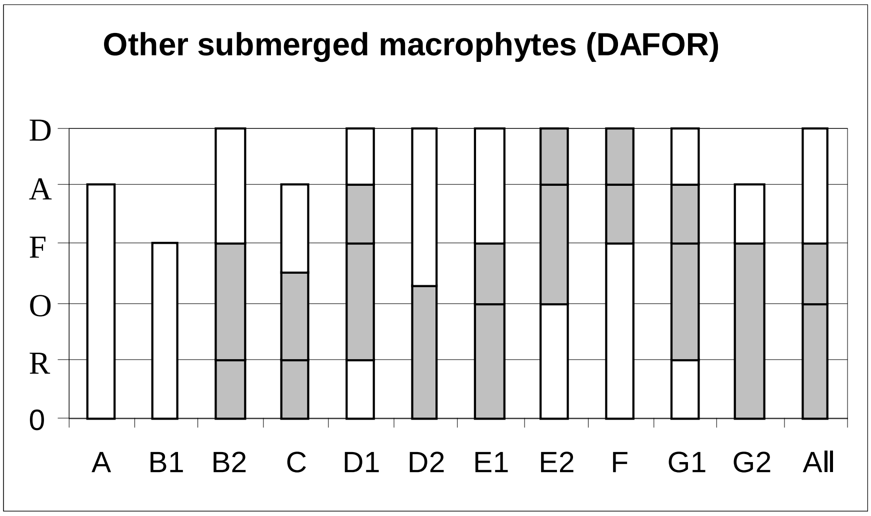
Figure 3.3b Vegetation structure in the wet zone end-groups

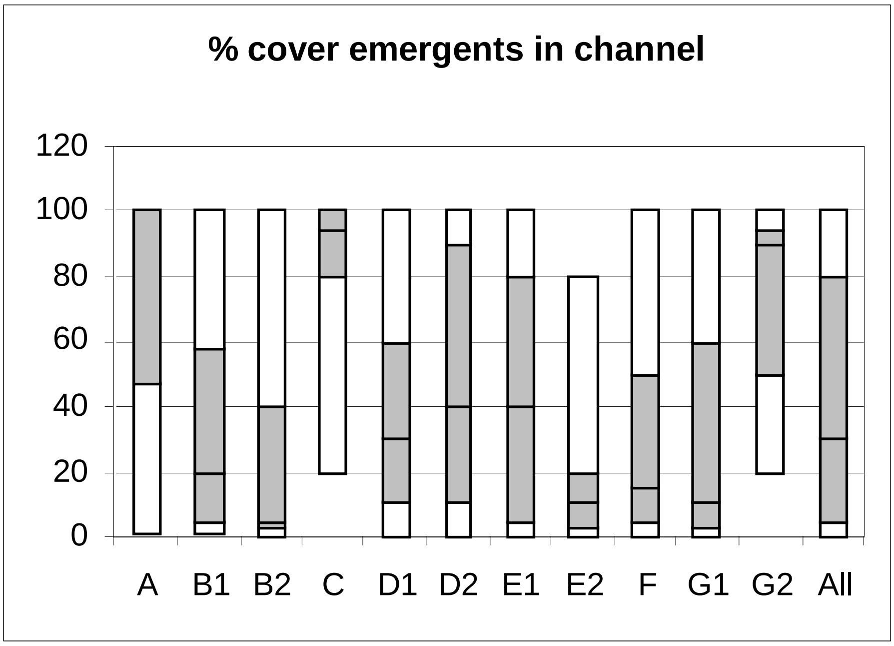







Lemna trisulca (DAFOR)
D
A
F
O
R
0
A B1 B2 C D1 D2 E1 E2 F G1 G2 All


Other submerged macrophytes (DAFOR)
D
A
F
O
R
0
A B1 B2 C D1 D2 E1 E2 F G1 G2 All


% cover emergents in channel
120
100
80
60
40
20
0
A B1 B2 C D1 D2 E1 E2 F G1 G2 All

Each wet zone group is influenced by a different combination of environmental variables that determines its predominant vegetation structure. These combinations are summarised in Table 3.3.

Table 3.3 Broad characteristics of wet zone plant assemblages

Wet zone plant group	A Common reed dominant	B Floating duckweeds dominant	C Flote-grass Shallow	D Frogbit / Ivy-leaved duckweed	E Frogbit / Ivy-leaved duckweed	F Water-soldier	G Sea club-rush
Hydroseral stage	Late	Early to mid	Late	Mid to fairly late	Early to fairly late	Early to mid	Early to late
Fresh / Brackish	Brackish & fresh	Fresh	Fresh	Fresh	Fresh	Fresh	Brackish
Water depth	Shallow	Deep	Shallow	Deep	Deep	Deep	Deep & shallow
Predominant substrate	Mineral	Peat & mineral	Mineral	Peat & mineral	Mineral	Mineral	Mineral
Focus of distribution	Eastern	Western	General	Western	Eastern & southern	Norfolk	Eastern

3.4 Comparison with previous ditch vegetation classifications

Previous ditch vegetation classifications for five of the areas surveyed in the Buglife project are summarised below.

3.4.1 North Kent Marshes

Charman (1981) worked on data from marshes in North Kent before TWINSPAN was widely used, and classified samples of both aquatic and bank vegetation from whole ditch length using Sørensen's Coefficient of Similarity. Three main groups of ditches were recognised:

- a species-rich freshwater assemblage dominated by Common duckweed (*Lemna* minor) and Ivy-leaved duckweed (*Lemna trisulca*) in association with Sea club-rush (*Bolboshcoenus maritimus*) and Common reed (*Phragmites australis*), with Frogbit (*Hydrocharis morsus-ranae*) occasionally represented
- a species-rich intermediate type with duckweeds, Common spike-rush (*Eleocharis palustris*), Sea club-rush, Soft hornwort (*Ceratophyllum* submersum) and Fennel-leaved pondweed (*Potamogeton pectinatus*) prominent
- a suite of species-poor brackish ditches (conductivity between 2,200 and 9,500 μScm^{-1}) dominated by Sea club-rush combined with submerged species such as fennel-leaved pondweed, Soft hornwort or Brackish-water crowfoot (*Ranunculus baudotii*).

The first group has affinities with Buglife wet zone groups D and E; the last is equivalent to Buglife group G.

Williams & Ware (1997) identified four main assemblages based on aquatic and emergent species and five assemblages of bank vegetation. The aquatic/emergent assemblages were:

- a brackish water type characterised by Sea club rush (*Bolboschoenus maritimus*), subdivided into those with significant submerged aquatic vegetation (principally Fennel pondweed (*Potamogeton pectinatus*) and those without, often because they frequently dry out in summer.
- a Common reed (*Phragmites australis*) dominated type

- a weakly brackish water type characterised by Soft hornwort (*Ceratophyllum submersum*) and Fennel Pondweed (*Potamogeton pectinatus*) but with distinctly freshwater elements such as Duckweeds (*Lemna minor* and *Lemna trisulca*) and Common spike rush (*Eleocharis palustris*)
- a freshwater type, subdivided into a more species-rich group characterised by Watercress (*Rorippa nasturtium-aquaticum* agg) and more species-poor group characterised by Common reed (*Phragmites australis*)

The first three assemblages have affinities with groups G, A and E2 of the Buglife wet zone groups respectively. The fourth covers all of the remaining Buglife groups and the make-up of this classification reflects the strong predominance of brackish water ditches in the North Kent Marshes.

3.4.2 Suffolk and Essex Marshes

Wolfe-Murphy *et al.* (1991) described a similar range of ditch vegetation types in the Suffolk and Essex coastal marshes. Using TWINSPAN, they identified eleven aquatic (submerged and floating) vegetation types and twelve separate emergent vegetation end-groups. The eleven aquatic vegetation groups (five freshwater and six brackish) were:

- two Ivy-leaved duckweed groups with hornworts and Frogbit (showing affinities to AqC, AqD and AqE)
- a starwort (*Callitriche*) group
- a Fat duckweed (*Lemna gibba*) group (with elements of Buglife group AqB)
- a species-poor freshwater Common duckweed group (similar to Buglife group AqB)
- two ‘oligohaline’ groups (conductivity 2,000 to 10,000 μScm^{-1}) with species such as Brackish-water crowfoot (*Ranunculus baudotii*) and Spiked water-milfoil (*Myriophyllum spicatum*)
- one ‘mesohaline’ group with Fennel-leaved pondweed (nearest to AqG)
- three ‘mesohaline’ groups (conductivity generally above 10,000 μScm^{-1}) containing Gutweed (*Enteromorpha*), Beaked tasselwort (*Ruppia maritima*) or marine algae.

3.4.3 Somerset / Avon Moors and Levels

Wolseley *el al.* (1984) produced a TWINSPAN classification of ditch vegetation in the ‘Somerset Levels and Moors’ (before the administrative area of Avon was formed) that included all the aquatic and marginal species in the wet zone of 512 samples and recognised 17 end-groups. The Buglife survey of this area consisted of 204 samples, including 40 that were repeats in 2008 and 2009 of 20 ditches sampled in 2007.

The first TWINSPAN division in the Wolseley analysis produced a distinctive group comprising dry land species, which does not have an equivalent in the Buglife wet zone classification because dry ditches were avoided in the survey. However, two of the four swamp vegetation groups in the Wolseley classification do have equivalents in the drier end of the Buglife spectrum:

- a Common reed group (represented by Buglife group A)
- a Flote-grass/ Creeping bent grass group (Buglife group C).

In the Wolseley classification no brackish group was identified, and no Buglife samples from Somerset are included in saline groups G or AqG. In the earlier classification, three end-groups were isolated because of the preponderance of algae, but in the Buglife classifications algae are spread more evenly throughout the groups. Common reed occurs at more than 20% constancy in only one Wolseley end-group, but in the Buglife classification it is prominent in a wide range of groups (A, B, E, F and G).

Otherwise, the major divisions in the Wolseley and the Buglife wet zone classifications tell similar stories. Both Wolseley and Buglife classifications recognise the important distinction between assemblages with different combinations of duckweed species. There are:

- four Wolseley groups dominated by floating duckweeds, which are similar to Buglife groups B and AqB, except that Frogbit is present at a higher constancy in the Wolseley classification
- five Wolseley end-groups typified by Ivy-leaved duckweed with Frogbit at high constancy, which are similar to Buglife groups D, E, AqC, AqD and AqE.

3.4.4 Pevensey Levels

Glading (1986) produced a classification of floating, submerged and emergent aquatic plants for ditches in the Pevensey Levels, Sussex. Three end-groups dominated by emergent plants are:

- a Common reed group (equivalent to Buglife group A)
- a Common bent / Flote-grass group (similar to Buglife group C)
- a Branched bur-reed (*Sparganium erectum*) / Reed sweet-grass (no clear equivalent in the Buglife classification)
- three groups defined by Ivy-leaved duckweed and Frogbit (parallels in Buglife groups D and E)
- two groups of large drains with algae but few submerged species (these do not match well with any Buglife group).

3.4.5 Norfolk Broadland marshes

The EFU classification of 627 samples of aquatic (submerged and floating) vegetation, collected in 1988-89 from ditches throughout Broadland (Doarks & Leach, 1990), produced ten end-groups. The Buglife survey looked at 75 ditches in the valleys of the Rivers Yare and Bure, so covered a much smaller area.

In both EFU and Buglife floating/submerged classifications the first TWINSPAN division separated brackish samples with Fennel-leaved pondweed from the rest, producing two end-groups in the EFU classification and group AqG in the Buglife one. Frogbit characterises some of the freshwater groups in the EFU classification, as in the Buglife one. However, the lower divisions of the two classifications diverge, with very different combinations of species making up the individual groups. The EFU classification, for instance, tends to separate ditches with Frogbit from those containing Rigid hornwort (*Ceratophyllum demersum*), whereas these species are in combination in groups AqC and AqD. Buglife group AqF, characterised by Water-soldier, Broad-leaved pondweed and Frogbit, has affinities with the more species-rich 'meso-eutrophic' groups in the EFU classification.

3.5 Affinities with the National Vegetation Classification

The National Vegetation Classification (NVC) (Rodwell, 1995) recognises 24 aquatic communities and 23 swamp communities.

The indicator species for NVC communities that are present at a constancy of over 20% in the wet zone groups are shown in Volume 2 Appendix 2, Table 2.6. These species are prominent components of ditch vegetation, so their occurrence implies that the equivalent NVC communities are well represented. The table clearly shows the lack of diversity in the saline groups G1 and G2 and in groups A and B1, both of which are dominated by Common reed.

At least twelve NVC aquatic communities are well represented. The indicator species for three more are present in the dataset at a frequency too low to appear as constants in the table. In addition, Pond water-crowfoot (*Ranunculus peltatus*) (indicating the A20 community) probably occurred, but because of problems with the identification of water crowfoots this cannot be confirmed.

Eleven swamp communities are easily recognisable in the wet zone groups. The main indicator species for another ten were recorded in the sites surveyed in 2007 to 2009.

Botanical classification: key points

- Two TWINSPAN classifications (one for all species in the wet zone, the other for floating and submerged species) were produced using botanical data from 546 ditches surveyed in grazing marshes in Wales and southern England.
- Seven main assemblages were recognised for each classification.
- Salinity had an over-riding influence on both classifications.
- Brackish ditches occurred predominantly in the North Kent and Essex marshes.
- There was a clear distinction between vegetation dominated by floating duckweed species and the more species-rich vegetation typified by the presence of Frogbit (*Hydrocharis morsus-ranae*) and Ivy-leaved duckweed (*Lemna trisulca*).
- Ditches dominated by floating duckweeds were found predominantly in the western marshes of Gwent and Somerset.
- A distinctive vegetation type centred on Norfolk Broadland and containing Water-soldier *Stratiotes aloides* was recognised.
- The principle environmental variables influencing ditch vegetation types were identified. These are salinity, water depth, substrate and hydroseral stage.
- Comparisons were carried out between the new botanical classification and previous ditch vegetation classifications for the North Kent Marshes, Suffolk and Essex Marshes, Pevensey Levels, Somerset Levels and Norfolk Broadland.
- Affinities with the National Vegetation Classification were identified.

Section 4 Classification of invertebrate assemblages

4.1 Methods

Details of the application of analytical techniques and the results obtained are given in Volume 2, Appendix 3 of this report.

4.1.1 The 'national' classification

The final dataset consisted of 551 samples that contained a total of 335 target aquatic invertebrates species. Assemblages were classified using the TWINSPAN program (Hill, 1979). This was run using a series of different combinations of data, to determine which were the most robust classifications and whether the results were similar for all species combined and for the two major taxonomic groups, beetles and molluscs, separately. Results using presence-absence data were compared with results using abundance data on a three-point logarithmic scale.

Statistical tests were applied to test the validity of TWINSPAN groups and to investigate the relationship of environmental variables with the invertebrate assemblages identified. The statistical packages used were Brodgar version 2.6.5 by Highland Statistics, CAP v.4.0 (Community Analysis Package) by Pisces Conservation and the Analyse-it version 1.67 add-in to Excel.

4.1.2 Regional analyses

The TWINSPAN analysis of the entire dataset from all sites in England and Wales showed that geographical location is important in determining the major divisions of the classifications of all taxa and of beetles and molluscs taken separately. Consequently, it was necessary to examine assemblages at a local level to determine which environmental factors had the greatest influence on assemblage structure. Separate ordinations were therefore carried out for sites grouped into geographic regions where the national classification indicated low species turnover between sites.

The 'national' classification showed that there was little consistent similarity between locations when different taxa were considered, so it was not sensible to amalgamate samples except for those from the two Norfolk catchments and from the brackish greater Thames Estuary and Essex marshes (including the small group of Colne samples). Gwent, Somerset, Pevensey and Walland marshes were kept separate, despite some being similar, since there was a large number of samples in each area. These six large groups were analysed separately, and this had the advantage that any real effects should recur. Malltraeth, Arun and Suffolk marshes were not analysed separately as they each had rather few samples.

TWINSPAN analyses were run for Norfolk, greater Thames, Somerset and Walland samples separately and the species composition of each end-group was then related to environmental trends.

4.1.3 Environmental variables

The analyses started with around 60 explanatory environmental variables, which were reduced to a more manageable number by excluding those that were infrequently recorded, strongly correlated or produced multicollinearity. Final subsets usually contained 25-30 variables, but the suite differed for each geographic area depending on how they were correlated and therefore which had to be excluded prior to ordination. Those for Somerset and Avon Moors and Levels are shown in Table 4.1.3.

Table 4.1.3 Environmental variables examined for Somerset and Avon data

Open water	pH (summer)	Hay/Silage
Soil type	Silt depth	Tall herbs
Litter	Freeboard	Last cleared
Floating mat	Short grass	Grassy margin
Improved grass	Cattle-grazed	Poaching
Floating aquatics	Turbidity	Water depth
Unimproved	pH (spring)	Grazing
Conductivity	Floating duckweeds	Exposed mud
Submerged plants	Submerged algae	Tangled
Water width	Margin profile	Bare ground
		Spoil on bank

Once the dataset had been trimmed in this way, ordinations were carried out separately for each of the large geographical areas, to determine which environmental factors explained significant amounts of the variation in the invertebrate data.

4.2 Results

Detailed results of all the analyses are given in Volume 2, Appendix 3. A summary of the main findings is given below.

4.2.1 Abundance and presence/absence data

For the classification of all invertebrate species and beetles, there was more variation in the analysis using presence-absence data than abundance data, although this was less distinct for the mollusc classification. This suggested that classifications based on abundance data more accurately reflect underlying environmental conditions, so abundance data were subsequently used as the basis for the classification.

4.2.2 The 'national' TWINSPAN classifications

Seven major assemblages of invertebrates were identified in the TWINSPAN classification using the complete dataset. Figure 4.2.2a shows how the samples divided initially on the basis of salinity. The next major division for freshwater ditches was between 'early' and 'late' stage ditches, which were recognised by a suite of variables that appeared to distinguish more open (early) ditches from more densely vegetated (mid to late stage) ones. The final divisions related to geographical location.

The beetle and mollusc assemblages behaved differently, which meant that amalgamating all taxa may lead to artefacts. Recurring patterns were the similarity of:

- Gwent and Somerset for beetles and molluscs but not for all taxa
- Pevensey and Walland for all taxa and beetles but not for molluscs
- Greater Thames estuary marshes of North Kent, Thames and Crouch, with the possible inclusion of Colne for all taxa and beetles
- Yare and Bure in Norfolk, with the inclusion of Suffolk for beetles and molluscs but not for all taxa.

These groupings were unremarkable as they involved adjacent marshes separated by about a county's width (less than 100km).

There were two unexpected similarities using all taxa: Malltraeth, Arun and Colne marshes, and Suffolk with Pevensey and Walland. Both cases were probably strongly influenced by beetles, which showed the same combinations (excluding the Colne in the first case), whereas molluscs showed no sign of these geographically widely separated assemblages being similar.

The assemblages identified for beetles (Figure 4.2.2.b) show the same initial division on the basis of salinity, the major environmental factor at a national level; subsequent divisions are based on location. For molluscs, species-poor brackish and probably ephemeral or very shallow ditches formed recognisable faunas at one end of the ordinations, but the mass of samples from fresh ditches were less clearly separated and form a continuum that TWINSPAN cannot distinguish well (Figure 4.2.2.c).

Beetle and mollusc assemblages followed a similar pattern of occurrence. This suggested that groupings for beetles and molluscs have similar underlying ecological drivers.

Figure 4.2.2a. TWINSPAN groups using all invertebrate species and abundance data

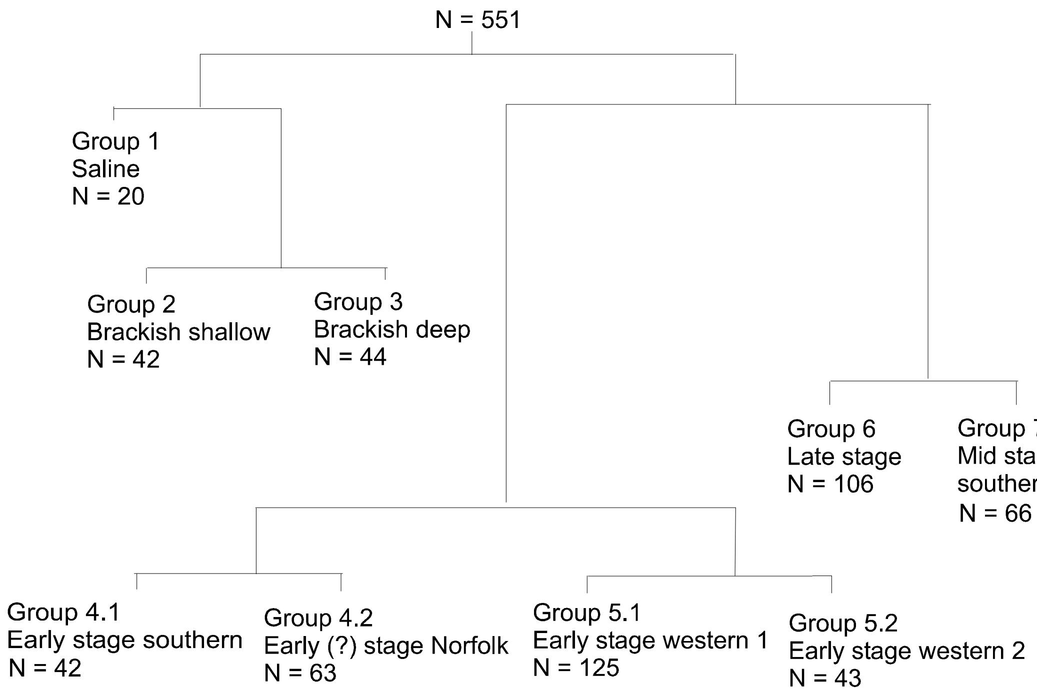


Figure 4.2.2b. TWINSPAN divisions for beetles.

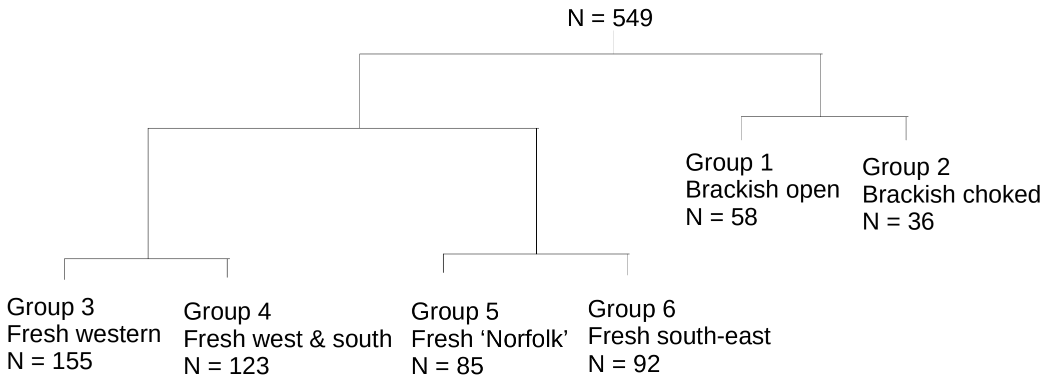
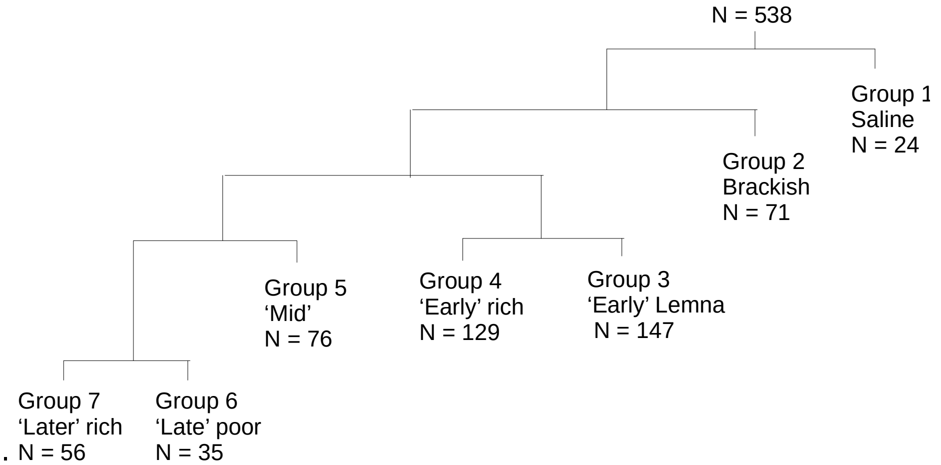


Figure 4.2.2c. TWINSPAN divisions for molluscs



4.2.3. Brackish groups (groups 1, 2 and 3) in the classification of all taxa

The 106 brackish ditches were mainly eastern in their distribution. Three brackish groups were distinguished, one being exceptionally saline ditches and the other two less so. Group 1, comprising the twenty most saline ditches, had a very distinctive fauna that was species-poor, especially for beetles and molluscs, and often dominated by crustaceans. Many of the invertebrates that characterise this group are regarded as obligate brackish-water species. They include the isopod crustaceans *Gammarus duebeni* and *G. zaddachi*, the prawn *Palaemonetes varians* and the beetle *Enochrus halophilus*. Other frequently occurring near-obligate halophils in the groups were the water-boatmen *Sigara stagnalis* and the beetles *Gyrinus caspius*, *Hygrotus parallelogrammus* and *Helophorus alternans*. The salinity was reflected in very high conductivity readings for the water, which also had high pH and turbidity. The ditches tended to be wide, open-water fleets or borrow-dykes with low covers of most types of vegetation.

Most of the invertebrates found in group 2 and 3 ditches have an affinity either to brackish water or strong coastal connections, even if they are not dependent upon brackish conditions. Species associated with strongly saline water were markedly less frequent than in group 1. Brackish-water species were the isopod *Gammarus duebeni* and the beetles *Enochrus halophilus*, *Graptodytes bilineatus*, *Gyrinus caspius* and *Hygrotus parallelogrammus*. The Scarce emerald damselfly (*Lestes dryas*), although not confined to brackish water, was found exclusively in the brackish groups. 'Coastal' species that preferred these groups were the beetles *Berosus affinis*, *B. signaticollis* and *Limnoxenus niger*, and the soldierfly *Stratiomys singularior*.

The main environmental difference between the groups 2 and 3 was water depth. Species that indicated the separation of the shallow or choked ditches of group 2 from the deeper or more open group 3 were the snail *Anisus leucostoma*, which prefers ditches that dry out, and the brackish-associated beetles *Agabus conspersus*, *Helophorus alternans* and *Ochthebius viridis*, along with common species of choked conditions such as the beetles *Agabus bipustulatus* and *Colymbetes fuscus*. For both groups 2 and 3, species-richness was slightly lower than in the equivalent shallow and deep freshwater ditches, due largely to the scarcity of mollusc species. As with the very saline group 1, there was a high frequency of species with high fidelity to grazing marshes.

As well as conductivity being moderately high, pH was also noticeably higher in the brackish ditches than in the freshwater ones. Groups 2 and 3 had the highest ranking for grassy margins and very low covers of floating aquatics and floating duckweeds. Land-use lent slightly towards unimproved pasture and sheep. Group 2 (shallow) ditches tended to have gently sloping banks and low covers of submerged vegetation. These features accounted for the ditches being regarded as not having been cleaned for many years, and they ranked with the saline group 1 ditches as being the least disturbed by maintenance. Group 3 ditches were scarcely distinguishable from freshwater groups on environmental variables, other than those already mentioned.

4.2.4 Freshwater groups in the classification of all taxa

The separation of groups 4 and 5 from groups 6 and 7 was a major ecological division into 'early' and 'late' successional stage ditches. 'Late' stage ditches, although not necessarily in a choked, end-of-succession state, had higher covers of emergents or floating vegetation mats and less open water and submerged vegetation than 'early' stage ditches. The faunal difference was marked. Invertebrates preferring the early-to-mid groups 4 and 5 included many species of more open conditions, especially where there is both open surface water (mainly as a result of little floating *Lemna* cover) and a good mix of submerged and fringing emergent vegetation – a typical mid-stage ditch. These species included the snail *Bithynia tentaculata*, the molluscs *Planorbis carinatus*, *Lymnaea stagnalis* and *Musculium lacustre*, the beetles *Graptodytes pictus*, *Gyrinus substriatus*, *Haliplus lineatocollis*, *Hydrophilus piceus*, *Laccobius colon*, *Laccobius minutus*, *Limnoxenus niger* and *Peltodytes caesus*, the bugs *Ilyocoris cimicoides*, *Plea minutissima* and *Sigara dorsalis*, the mayflies *Caenis robusta* and *Cloeon dipterum*, the swimming caddis *Triaenodes bicolor*, the soldierfly *Odontomyia ornata*, and the Blue-tailed damselfly (*Ishnura elegans*).

The 'late' stage (groups 6 and 7) ditches were typified by several species characteristic of either densely vegetated shallow water, dense emergents or even perhaps conditions of low oxygen rather than merely choked conditions. These are the crustaceans *Asellus aquaticus*, *A. meridianus* and the introduced *Crangonyx pseudogracilis*, the molluscs *Pisidium* spp and *Valvata cristata*, and the beetles *Cymbiodyta marginella*, *Helophorus obscurus*, *Hydraena riparia* and *Liopterus haemorrhoidalis*.

Further division of the 'early' stage freshwater ditches was based on geographic location rather than local effects. The split of group 4 from 5 was a good example of species distribution over-riding any ecological distinction. Table 4.2.4 lists some species used to separate these two groups and which show fairly strong east-west preference in their national distribution.

Table 4.2.4. Species with a pronounced east-west preference in their national distribution and their occurrence in groups 4 and 5

Numbers in brackets are the number of ditches occupied in group 5 and group 4 out of the totals given for each group.

Group 5 (168 samples) - western	**Group 4** (105 samples) - eastern
Anacaena lutescens (104, 11)	*Gyrinus marinus* (2, 40)
Hydaticus transversalis (63, 1)	*Hygrotus impressopunctatus* (6, 34)
Hydroporus striola (36, 1)	*Noterus crassicornis* 1 (3, 102)
Hydroporus tessellatus (86, 3)	*Rhantus suturalis* (14, 62)
Bathyomphalus contortus (96, 19)	*Sigara fossarum* (3, 22)
Physella acuta (43, 1)	*Asellus meridianus* (5, 57)

Separation of groups 6 and 7 (and subdivision of group 6) was also based largely on geographic location. Group 6 ditches had a scattered distribution, whereas over half the samples in group 7 were from Pevensey Levels

4.2.5. 'Early' stage freshwater ditches in the eastern group (group 4)

Further division of group 4 was based almost entirely on geographic location, although environmental variables may have related partly to deeper-sided ditches with denser submerged plants (both macrophytes and algae) suggesting a slight effect due to vegetation development.

Within the eastern group 4, two assemblages were identified: 'southern' and 'Norfolk'. All but eight of the 63 ditches in group 4.2 were in Norfolk, whereas the 42 ditches in group 4.1 came from a wider range of sites, from the Arun valley to Norfolk, with a preponderance in Walland Marsh. Among the less common species more strongly skewed to the ‘Norfolk’ group were the beetles *Hydrophilus piceus*, *Rhantus grapii* and *Ochthebius dilatatus*, the soldierfly *Odontomyia tigrina* and the damselfly *Lestes sponsa*. TWINSPAN identified many other nationally common species preferring this group, including several snails occurring in large numbers. Uncommon species preferring the ‘southern’ group were the beetles *Hydrochus elongatus*, *Hydrovatus clypealis* and *Porhydrus lineatus* and the bugs *Cymatia coleoptrata* and *Hesperocorixa moesta*. Scarcely any environmental variable distinguished these two groups, which must therefore be considered as merely geographic variants.

In terms of species-richness, group 4.1 was unremarkable compared to other freshwater groups, having a slightly lower complement of molluscs and beetles but more bugs than in many other freshwater groups. Group 4.2, by contrast, was the most species-rich group. Some of the Norfolk Broadland ditches in this group had remarkably high numbers of species, reaching a maximum of 83 in one at Upton. There were on average more species of beetle and among the highest counts of molluscs, crustaceans and caddisflies. Nearly a third of ditches had 15 or more species of molluscs, and a fifth had 30 or species of beetles, which are values well above the upper quartile for most groups. Group 4 ditches as a whole supported a relatively high number of species ‘faithful’ to grazing marshes, as compared to other freshwater groups.

Because group 4.1 ditches were mainly in Walland Marsh there was a high incidence of sheep grazing in this group, contrasting with the high proportion of cattle grazing in 4.2 ditches, which were mainly from Norfolk. The preponderance of Walland ditches may also account for the slightly higher conductivities in group 4.1. Groups 4.1 and 4.2 were very similar in water depth and width. Minor differences included Group 4.2 having smaller freeboards (perhaps due to deliberately raised water levels) but steeper profiles under water at the margin, tendencies for less emergent cover and more submerged and floating aquatics, and a slightly greater score for ‘tangledness’ of the vegetation. None of these seemed sufficiently important to be responsible for differences between invertebrate assemblages.

4.2.6 ‘Early’ stage freshwater ditches in the western group (group 5)

The main distinction between early to mid-stage western ditches was location, with the 125 group 5.1 ditches mostly in Somerset and the 42 group 5.2 ditches mostly in Gwent. Uncommon species that were clearly more frequent in the ‘Somerset’ group were the beetles *Hydaticus transversalis*, *Hydrophilus piceus*, *Hydroporus striola* and *Limnoxenus niger*, the soldierflies *Odontomyia ornata* and *Stratiomys singularior*, and the snails *Bathyomphalus contortus* and *Bithynia leachii*. No uncommon native species showed a marked preference the ‘Gwent’ group. However, the non-native snail *Physella acuta* was notably more frequent there, in moderately high numbers. Differences in large invertebrate taxa were trivial, with the exception of molluscs and caddis which were notably less species-rich in group 5.2.

Soil type was the main variable showing a strong difference between the groups, with group 5.1 mostly on peat and 5.2 mostly on clay. The remaining environmental variables that appeared to separate the groups were the markedly different land-use and historical ditch management of the Gwent Levels and the Somerset Moors. Thus group 5.1 (mainly Somerset) were on average slightly shallower and narrower, and had smaller freeboards, more shallowly sloping banks and a shallower underwater profile at the margin.

4.2.7 ‘Mid to late’ stage freshwater ditches (groups 6 and 7)

The ‘later’ stage groups 6 and 7 were distinguished by water depth and geographic position. Group 6 ditches were generally shallower, with greater floating duckweed cover and less submerged vegetation, although the distinction was not clear.

The large, widely scattered group 6 (106 samples) was characterised by the absence of unusual species and by the presence of common species of closely vegetated ditch margins, especially those of grassy edges. These included the beetles *Anacaena globulus*, *Hydroporus palustris*, *H. tessellatus*, *Ilybius ater*, *I. quadriguttatus* and rather large numbers of *Anacaena lutescens*, *H. planus* and *H. pubescens*. The soldierfly *Odontomyia tigrina* and the mussel *Musculium lacustre* were frequent in the group. This suite of species would be expected in smaller, shallower and perhaps rather mundane ditches. It was also characterised by the absence of some very common species found widely in the freshwater groups but scarce in these choked ditches, such as the bugs *Gerris odontogaster*, *Ilyocoris cimicoides*, *Notonecta glauca* and *Plea minutissima*.

In the southern group 7, in which over half the 66 samples were from Pevensey Levels, there was a large number of nationally scarce and rare species. However, many of the species found in this group of ditches are also found in most other freshwater groups, so the assemblage is not as distinctive as that in the more choked group 6 ditches. The rare species that are well represented in group 7 are the beetle *Hydrochus elongatus*, the water measurer *Hydrometra gracilenta*, and the rare Shining ram's-horn snail (*Segmentina nitida*) and the Large-mouthed valve snail (*Valvata macrostoma*), which were both sometimes moderately numerous. Although all were found in other groups, they were more frequent in group 7. These ditches were markedly more species-rich than group 6 ditches for nearly all groups (molluscs, bugs, caddis, crustaceans, leeches), but beetles had similar richness in both groups. Group 6 ditches had the lowest median score for marsh fidelity of any group.

Environmental variables that separated groups 6 and 7 from the early-stage freshwater ditches (groups 4 and 5) included a higher cover of emergents and less open water and submerged plants, near absence of floating algae, often a higher amount of litter and less recent cleaning. Variables separating group 6 from 7 were a tendency for group 6 ditches to be shallower and narrower, although with a steeper underwater profile at the margin, and more floating *Lemna* at the expense of other floating aquatics and open water. Group 7 ditches tended to have higher grazing pressure and consequently shorter grass on the banks.

4.2.8 Associations of invertebrate groups with plant groups

The main associations of invertebrate groups with wet zone plant groups (see Section 3) are shown in Table 4.2.8. The strongest associations are indicated at the top of the third row. These show where over 40% of the invertebrate samples in the group was found in ditches of the relevant botanical group. Figures in parenthesis are for >20% to 40% occurrence of invertebrate samples in a plant group. The comparison emphasises the major influence of salinity, hydroseral stage and location on both classifications.

Table 4.2.8 Main associations of invertebrate and plant TWINSPAN end groups

Wet zone plant group	A	B	C	D	E	F	G
	Common reed dominant	Floating duckweeds dominant	Flote-grass	Frogbit / Ivy-leaved duckweed		Water-soldier	Sea club-rush
Hydroseral stage of plant group	Late	Early to mid	Late	Early to late		Early to mid	Early and late
Fresh / Brackish	Brackish & fresh	Fresh	Fresh	Fresh		Fresh	Brackish
Focus of plant group distribution	Eastern	Western	General	Western	Eastern & southern	Norfolk	Eastern
Associated invertebrate group	- (2)	5.2 -	- -	5.1 (5.2) (6) (7)	4.1 and 7 (4.2) (6)	- (4.2)	1 2 3 -

4.3 Regional analyses: explanatory environmental variables

Ordinations of data from the six geographic areas with an adequate number of samples indicated that the following environmental variables were the most important drivers shaping invertebrate assemblages:

Significant findings from data analysis at a local level are summarised as follows:

- The degree of pasture improvement appeared to be unimportant. However, this was partly due to the difficulty of deciding in the field on the correct category of grass type (improved, semi-improved, unimproved) and because at Pevensey and Walland marshes the grass appeared to be nearly all one type. In Somerset, the Thames and Essex and Norfolk marshes, where the pasture was distributed more evenly between at least two classes, land-use did appear as an important variable. In the Thames and Essex marshes, unimproved grassland was associated with older ditches, and in Somerset, improved ditches were associated with mineral soils and deeper-sided ditches. These opposing effects, although expressed in different areas, suggested that unimproved pasture was more likely to have less frequently cleaned ditches and a fauna of later stage ditches.

- Factors strongly related to cattle, such as poaching and short vegetation on ditch banks, were usually important. This was reinforced by the absence of any effect at Walland, which was almost exclusively sheep-grazed; at other marshes cattle were present next to at least half of the ditches. The direct effect on aquatic invertebrates was presumably mediated through reduction of marginal shading by tall vegetation and by poaching.

- Marginal vegetation structure or the similar effect produced by mat-forming vegetation was usually important and was often related to cattle effects. 'Tangledness' was less important than had been expected but was often excluded during analysis as it effectively summarised several other features such as the grassy margin, floating mat and emergent fringe.

- Physical features of the ditch, especially water width and underwater profile at the margin, were nearly always highly significant. Water depth, width and the amount of open water surface were usually well correlated with each other so it is not possible to identify any one of them as the key factor. These factors summarise the overall size and openness of the water body. While size of the water body may have been important to a few species (e.g. whirligigs on open water surfaces), it was thought that size was perceived by the invertebrates as closely related to hydroseral succession, since a marked TWINSPAN division followed this trend in all four regional analyses. Larger ditches tended to have higher Species Richness in Walland, North Kent, Thames, Essex and Norfolk marshes (but not in Somerset), but had no effect on Species Conservation Status Score except for higher values in Walland marshes.

- 'Chemistry' was a major factor. Conductivity was expected to be prominent since the degree of salinity was the most important factor in the classification of all taxa and of beetles and molluscs taken separately. By contrast, the significant effect of pH was unexpected but it was often strongly correlated with conductivity and may not have been a causal factor. Brackish sites were often turbid, so turbidity was also a significant factor.

- Many variables related to the openness of vegetation structure described the extremes of the hydroseral succession. The dominant and often highly significant ones were the amount of open water, leaf litter and emergent vegetation. Variables that might be expected to reflect intermediate stages in the hydrosere, for example the amounts of floating mat and submerged vegetation, were almost never significant. However, the amount of floating aquatics did appear to be significant in Gwent and Somerset, which may have reflected the fact that mid-stage ditches with low cover of floating *Lemna* are attractive to a suite of invertebrates that are less tolerant of duckweed carpets.

- The significance of algae to invertebrates was obscure, but the abundance of algae was unexpectedly shown to be an important variable in Somerset and Norfolk.

- A variety of soil types (peat or clay + alluvium) was present only in Gwent, Somerset and Norfolk. Soil type had an impact on the invertebrate assemblages at the two western marshes but the imbalance of samples with and without peat cast some doubt over its importance; only four of 50 Gwent samples were on peat, and most Somerset ditches clay were the outlying Kenn and Pawlett marshes.

Classification of invertebrate assemblages: key points

- TWINSPAN classifications were produced for all 335 target invertebrate species in 551 samples, and for beetles and molluscs separately.
- Salinity, hydroseral stage and geographical location were the main factors associated with major divisions of the classifications.
- The relationship between plant and invertebrate classifications broadly supported this conclusion.
- The invertebrate classifications were influenced by the pronounced east-west preference of some species in their national distribution.
- It was not possible to derive a classification of aquatic invertebrates that is robust for the entire spectrum of ditch types at a ‘national’ scale.
- Because location was as important as successional stage, analysis was carried out at the local level to determine which environmental factors had the greatest influence on assemblage structure.
- The most influential variables were water chemistry (conductivity, pH), ditch dimensions, water depth, vegetation structure, the presence/absence of algae and grazing.
- The brackish-water fauna is species-poor but these species assemblages have high fidelity to the grazing marsh habitat.
- Brackish systems are restricted geographically and reach their best expression in North Kent and Essex.

Section 5 Evaluation of plant assemblages and wetlands

5.1 Methods

The relative conservation value of the plant assemblages of ditches is measured using four metrics:

- **Species Richness -** Number of native aquatic plant species recorded, based on a check list of target species
- **Species Conservation Status** (SCS) **Score** - average score per target native taxon, based on scores for threat and rarity
- **Habitat Quality Score –** average score per target species, based on water quality (fertility, as indicated by nitrogen requirement) as a surrogate
- **Community Naturalness Score -** the sum of threat scores for introduced species, expressed as a negative value

For each species on the check list of target aquatic plants, scores have been allotted for each of the last three attributes. These scores and the application of the metrics for evaluating and ranking plant assemblages and marshes is explained in detail in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010). The metrics are best expressed as averages for the samples in a marsh or a wider area, but they may also be applied to complete species lists for sites.

The four metrics were calculated for each marsh and geographic area, and the marshes and areas were ranked for each attribute.

5.2 Salinity

Because salinity is such an important explanatory variable for the composition of plant assemblages (see Section 3) fresh and brackish marshes should not be compared without giving a statement about the relative proportions of fresh and brackish ditches present.

Figure 5.2a (repeated in Section 6 as Figure 6.2) shows the proportions of fresh and brackish ditches in each of the survey areas, using conductivity of 2000μS cm^{-1} as the threshold for separating fresh from brackish ditches. It is obvious that marshes in the east of the country are much more brackish than those in the west.

Table 5.2 gives the mean of the species metrics for all the freshwater and brackish samples in the dataset. These figures can be used as yardsticks against which to judge individual samples or sites. It is obvious from the table that Species Richness, SCS Score and Habitat Quality Score are lower in brackish than in freshwater ditches, but Naturalness Score is higher.

A biological salinity index may also be used, based on the salinity tolerance of each plant species. These scores are given in Palmer, Drake & Stewart (2010) and range from 0 for species confined to fresh water to 4 for species that are tolerant of salinity. The plant salinity index for a sample is the mean of the salinity scores for all the species present. Figure 5.2b shows the relationship between conductivity and this salinity index.

Figure 5.2a Number of fresh and brackish ditches in the areas surveyed

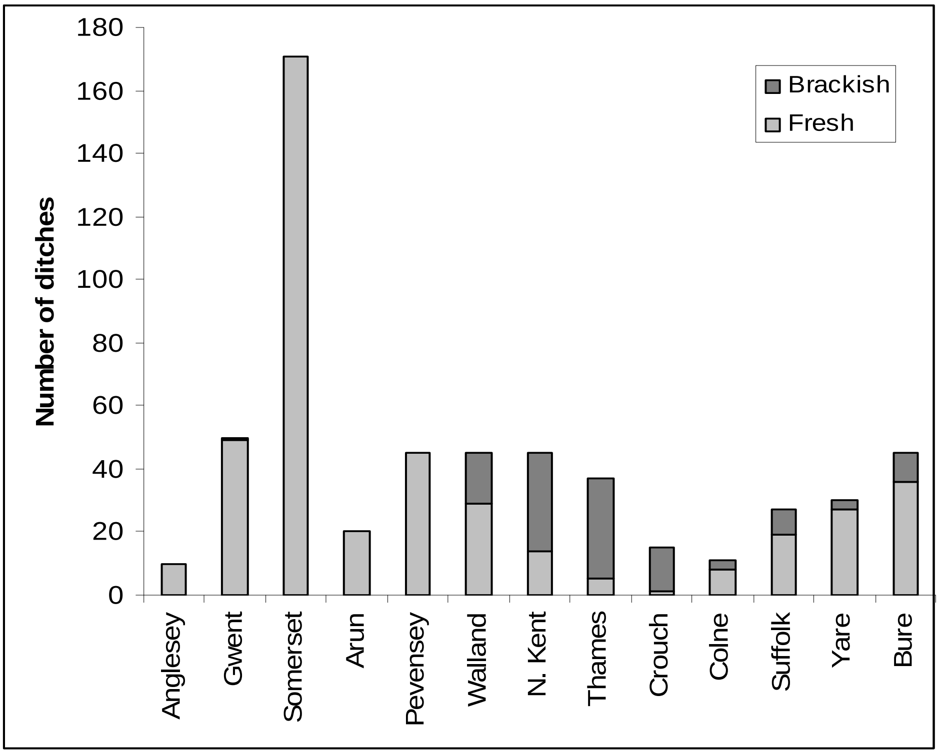
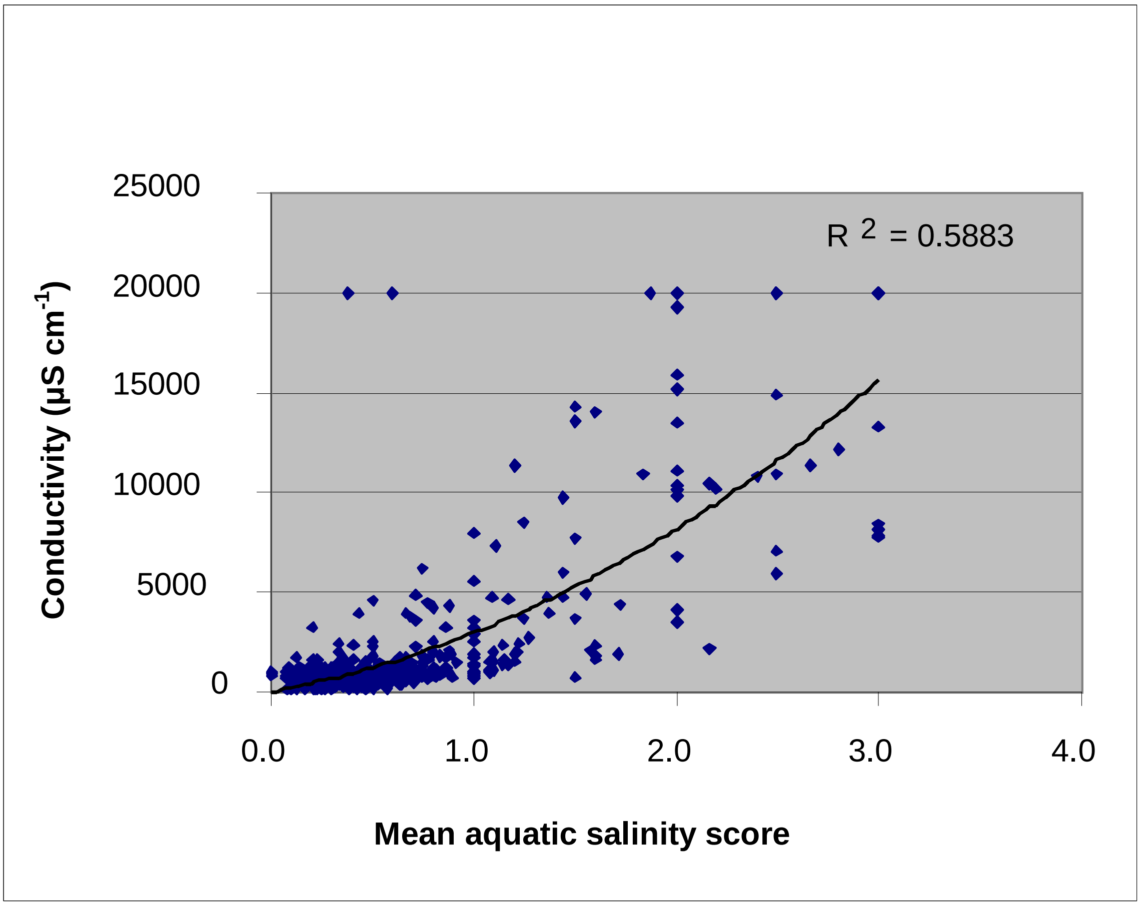


Table 5.2 Mean species metrics for all freshwater and brackish samples in the dataset, using 2000µS cm^{-1} as the threshold

	No. of samples	Mean Species Richness	Mean SCS Score	Mean Habitat Quality Score	Mean Naturalness Score	Mean plant salinity index
All ditches	586	10.6	1.3	1.6	-3.0	0.7
Fresh ditches	462	11.9	1.4	1.7	-3.4	0.5
Brackish ditches	85	6.5	1.1	1.4	-1.4	1.6

Figure 5.2b Regression of summer conductivity against plant salinity index for all the samples in the dataset



5.3 Results: evaluation using metrics

5.3.1 Evaluation of TWINSPAN end-groups

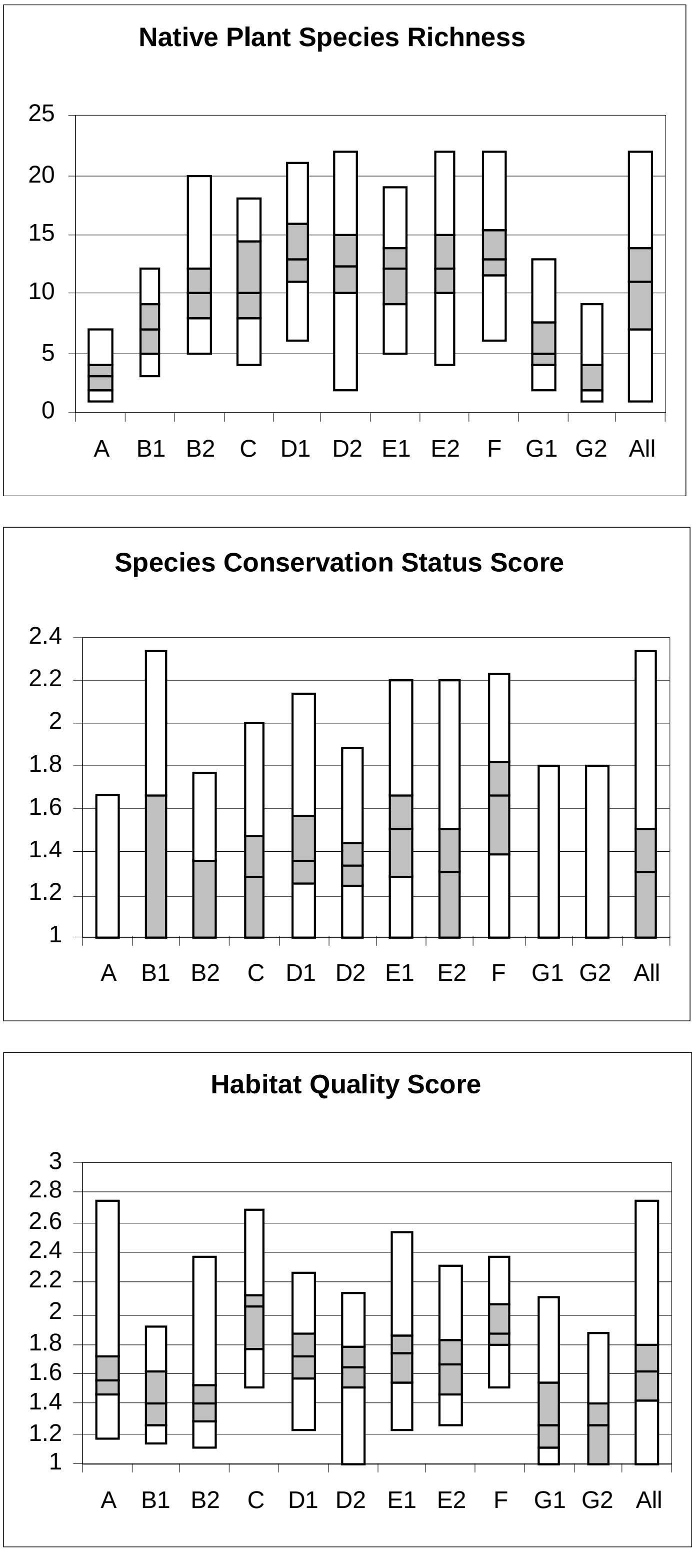
The metrics were applied to each of the wet zone end-groups. Table 5.3.1 shows the mean values per sample. The brackish nature of the G groups and, to a lesser extent, the Common reed group A, is indicated by the salinity index. It is clear that the D, E and F groups are the most species-rich and groups A, G1 and G2 the most species-poor. The group with the highest proportion of rare species (a high SCS Score) is F, the Water-soldier group. Habitat Quality Score is highest in the small Flote-grass group C, which contains the majority of the ditches from the relatively nutrient-poor ditches on Anglesey, and it is below average in the saline G groups and the floating duckweed groups B1 and B2. The more saline ditches contain the lowest proportion of non-native species, as shown by their high Naturalness Score.

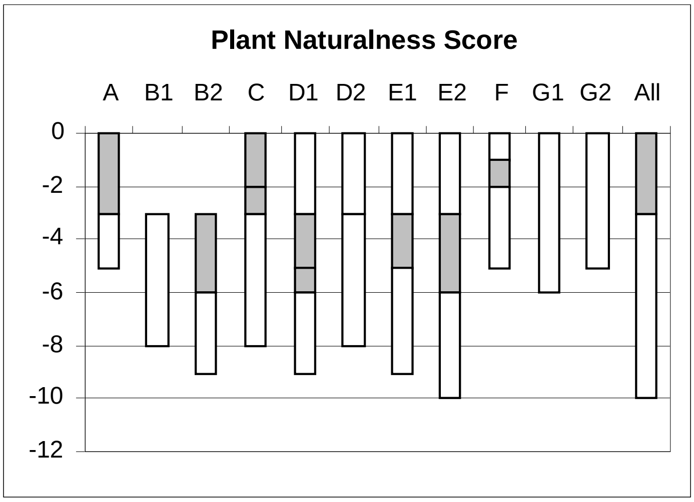
Table 5.3.1 Mean values of metrics for samples in the wet zone end groups

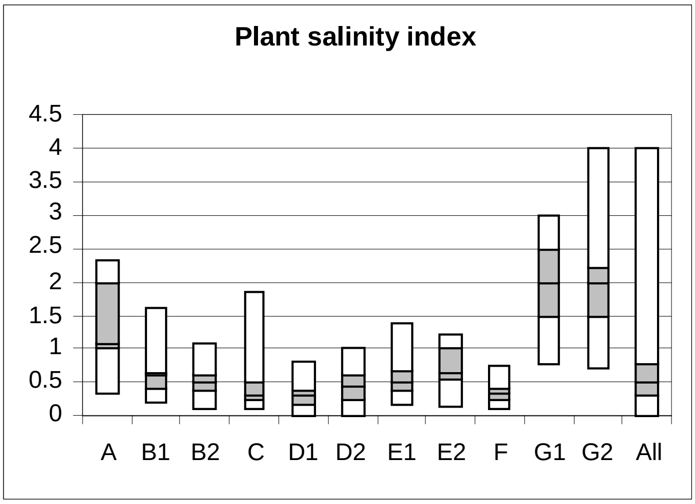
	A	B1	B2	C	D1	D2	E1	E2	F	G1	G2	All
No. of samples in group	32	34	69	27	85	112	69	48	35	54	21	586
Mean scores												
Native Species Richness	3.3	7.1	10.6	10.9	13.3	12.7	11.7	12.4	13.5	5.9	3.9	10.6
SCS Score	1.0	1.3	1.2	1.3	1.4	1.3	1.5	1.3	1.6	1.1	1.1	1.3
Habitat Quality Score	1.6	1.4	1.4	2.0	1.7	1.7	1.7	1.7	1.9	1.3	1.3	1.6
Naturalness Score	-0.9	-3.5	-4.0	-2.1	-4.4	-3.2	-3.5	-3.8	-1.7	-0.8	-0.5	-3.0
Plant salinity index	1.3	0.6	0.5	0.4	0.3	0.4	0.5	0.7	0.3	2.0	1.9	0.7

Median values of the metrics for each end-group are shown in Figure 5.3.1. The upper and lower quartiles are indicated. This figure indicates the same trends as those discussed for Table 5.3.1.

Figure 5.3.1 Native Plant Species Richness for each end-group







5.3.2 Evaluation of areas surveyed

The four metrics were applied to the individual areas surveyed. The means of the values for all the samples in each geographical area are shown in Table 5.3.2a.

These indicate than on average, samples from the Yare marshes were the most species-rich and those from the brackish Essex marshes were the most species-poor.

Pevensey Levels had the highest Species Conservation Status Score and the samples from Essex and the Orwell estuary marsh had a mean score of 1.0 for SCS because of the lack of rare plant species.

Habitat Quality Scores show up the relatively nutrient-poor freshwater Malltraeth Marsh, with the Arun Valley, Pevensey Levels and Sizewell / Minsmere in Suffolk close second. The brackish North Kent and Essex marshes had low Habitat Quality Scores, as might be expected, but the score for the Gwent Levels was surprisingly low, given that almost all the ditches sampled were fresh. This implies that ditch systems in Gwent are more polluted than in the English sites. However, this may be a false impression caused by the fact that in Gwent few small ditches were sampled because many were dry or could not be surveyed because of access problems, so the samples were predominantly from large drains.

By far the lowest Naturalness Score was for the Colne estuary, where some of the ditches were infested with Australian swamp stonecrop (*Crassula helmsii*).

Table 5.3.2a Mean values of metrics for samples in the survey areas

Areas surveyed	No. of ditches sampled	Species Richness	Sp. Cons. Status Score	Habitat Quality Score	Natural-ness Score
Gwent Levels	51	10.7	1.3	1.4	-3.7
Malltraeth Marsh	10	12.1	1.1	2.0	-2.1
Somerset & Avon	184	12.1	1.3	1.6	-3.8
Arun valley	20	11.9	1.3	1.9	-3.5
Pevensey Levels	45	11.9	1.6	1.8	-3.3
Walland Marsh	45	9.3	1.4	1.7	-2.6
North Kent marshes	46	7.2	1.2	1.4	-2.0
North Thames Essex	37	5.6	1.0	1.4	-1.8
Crouch estuary	15	4.0	1.0	1.3	-0.6
Colne estuary	11	5.5	1.0	1.4	-6.3
Orwell estuary	7	5.9	1.0	1.3	-1.3
Sizewell / Minsmere	20	12.8	1.4	1.8	-2.5
Yare marshes	30	13.5	1.4	1.7	-2.2
Bure marshes	45	10.5	1.4	1.8	-2.4
All areas	586	10.6	1.3	1.6	-3.0

Table 5.3.2b shows the same metrics calculated for the total species lists from the survey areas. The values for Species Richness and Naturalness are much more effort-dependent than the mean for each sample shown in Table 5.3.2a, but nevertheless it useful to know how many target species were recorded from an area and to have a measure of the overall threat posed by non-natives.

The values for SCS Score were very even, apart from those for Essex and the Orwell, because many of the rare species were ubiquitous. The Habitat Quality Score again showed up the good water quality at Malltraeth Marsh and Sizewell / Minsmere and reflected the brackish conditions in the Essex marshes.

The application of the plant metrics clearly indicated differences in four separate attributes of the vegetation, both between end-groups in the classification and between geographical areas. All four metrics were regarded as useful measures for evaluating ditch vegetation and so are included in the guidance set out in the *Manual* (Palmer, Drake & Stewart, 2010).

Table 5.3.2b Values of metrics calculated for the total species list in the survey areas

Areas surveyed	No. of ditches sampled	Species Richness	Sp. Cons. Status Score	Habitat Quality Score	Natural-ness Score
Gwent Levels	51	56	1.4	1.6	-9
Malltraeth Marsh	10	42	1.3	2.3	-5
Somerset & Avon	184	74	1.3	1.9	-9
Arun valley	20	44	1.4	1.9	-9
Pevensey Levels	45	62	1.3	1.8	-15
Walland Marsh	45	58	1.4	1.8	-11
North Kent marshes	46	53	1.2	1.7	-13
North Thames Essex	37	39	1.0	1.5	-14
Crouch estuary	15	26	1.0	1.4	-3
Colne estuary	11	24	1.0	1.5	-8
Orwell estuary	7	24	1.0	1.5	-3
Sizewell / Minsmere	20	56	1.2	2.1	-6
Yare marshes	30	59	1.4	1.9	-7
Bure marshes	45	61	1.2	1.8	-9
All areas	586	105	1.4	2.1	-22

5.4 Rare and threatened species

The second approach to evaluation is a description of the rarer elements of the flora of each plant assemblage, marsh or area.

Grazing marsh ditches are remarkable for the number of nationally threatened plants strongly associated with them. This habitat is a British stronghold for some of these species. The most widespread is Frogbit (*Hydrocharis morsus-ranae*), which is rated as Vulnerable on the British Red List (Cheffings & Farrell, 2005) but occurred in over half the ditches sampled. Tubular water-dropwort (*Oenanthe fistulosa*), also Vulnerable, occurred in almost a quarter of the ditches surveyed.

Other Red List plants recorded less frequently during the Buglife survey are Whorled water-milfoil (*Myriophyllum verticillatum*) (Vulnerable), Sharp-leaved pondweed (*Potamogeton acutifolius*) (Critically Endangered), Greater water-parsnip (*Sium latifolium*) (Endangered), Cut-grass (*Leersia oryzoides*) (Endangered) and Rootless duckweed (*Wollfia arrhiza*) (Vulnerable). Plants regarded as Near Threatened (i.e. near to being included on the Red List) are Lesser water plantain (*Baldellia ranunculoides*), Pillwort (*Pilularia globulifera*) and Water-soldier (*Stratiotes aloides*). Pointed stonewort (*Nitella mucronata*) is Nationally Scarce (i.e. not red listed but occurring in Britain in 16 to 100 10x10 km squares).

Five of these plants are on the Biodiversity Action Plan priority list and Cut-grass is also specially protected by inclusion in Schedule 8 of the Wildlife and Countryside Act 1981. Water-soldier and Sharp-leaved pondweed are now largely restricted in Britain to ditch systems (Preston & Croft, 1997).

The occurrence of the Red List and Nationally Scarce species in ditches of individual wet zone groups is shown in Table 5.4a. These figures include records from the bank as well as the wet zone, so they incorporate a few records that were not included in the samples analysed by TWINSPAN. Frogbit could be regarded as the 'flagship species' for ditch systems of southern England.

Table 5.4a Percentage occurrence of nationally threatened and scarce species in ditches of wet zone groups

	A	B1	B2	C	D1	D2	E1	E2	F	G1	G2	All
No. of samples in group	32	34	69	27	85	112	69	48	35	54	21	586
% occurrence of species												
Baldellia ranunculoides	0	0	0	0	1	0	0	0	0	0	0	0.2
Hydrocharis morsus-ranae	3	32	35	22	78	75	75	56	87	0	0	51.7
Myriophyllum verticillatum	0	0	1	0	5	2	9	4	23	2	0	4.1
Nitella mucronata	0	0	0	0	0	0	0	2	0	0	0	0.2
Oenanthe fistulosa	3	15	4	52	20	33	39	31	46	11	10	24.4
Pilularia globulifera	0	0	0	4	0	0	0	0	0	0	0	0.2
Potamogeton acutifolius	0	0	0	0	11	1	13	0	20	0	0	4.4
Sium latifolium	0	0	0	0	0	1	0	0	0	0	0	0.2
Stratiotes aloides	0	0	0	0	0	2	4	2	40	0	0	3,4
Wolffia arrhiza	0	6	15	0	12	0	10	15	0	0	0	6-1

Table 5.4a clearly shows the relative importance of groups D, E and F for rare species.

The geographical distribution of records of the plants of most concern is given in Table 5.4b. The tables include records from both inside and outside the 20m sample sections. (When a whole ditch is walked after a section is recorded, on average two extra wetland species and three extra aquatic species are added to the plant list.)

Table 5.4b. The distribution of records of Red Listed, Near Threatened and Nationally Scarce plants in the survey areas, 2007-2009

Area	Aquatic plant species	Status	No. of records
Gwent Levels	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	21
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	2
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	17
	Rootless duckweed (*Wollfia arrhiza*)	Vulnerable	8
Malltraeth Anglesey	Whorled water-milfoil *(Myriophyllum verticillatum*)	Vulnerable	1
	Pillwort (*Pilularia globulifera*)	Near Threatened, BAP	1
Somerset and Avon	Lesser water-plantain *(Baldellia ranunculoides*)	Near threatened	1
	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	123
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	3
	Pointed stonewort (*Nitella mucronata*)	Nationally Scarce	1
	Tubular water-dropwort *(Oenanthe fistulosa*)	Vulnerable, BAP	30
	Rootless duckweed (*Wollfia arrhiza*)	Vulnerable	12
River Arun	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	14
	Cut-grass (*Leersia oryzoides*)	Endangered, BAP, Sched 8	1
	Fringed water-lily (*Nymphoides peltata*)	Nationally Scarce	1 Introduced
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	5
	Sharp-leaved pondweed (*Potamogeton acutifolius*)	Critically Endangered, BAP	9
Pevensey Levels	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	24
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	1
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	38
	Sharp-leaved pondweed (*Potamogeton acutifolius*)	Critically Endangered, BAP	19
	Water-soldier (*Stratiotes aloides*)	Near Threatened	4 Introduced
	Rootless duckweed (*Wollfia arrhiza*)	Red List Vulnerable	8
Walland Marsh	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	17
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	3
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	24
	Sharp-leaved pondweed (*Potamogeton acutifolius*)	Critically Endangered, BAP	1
	Greater water-parsnip (*Sium latifolium*)	Endangered, BAP	2
	Rootless duckweed (*Wollfia arrhiza*)	Vulnerable	14
North Kent Marshes	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	13
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	8
Essex			No records
Suffolk	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	15
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	5
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	5
Norfolk: River Yare	Frogbit (*Hydrocharis morsus-ranae*)	Vulnerable	25
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Vulnerable	13
	Tubular water-dropwort (*Oenanthe fistulosa*)	Vulnerable, BAP	7
	Sharp-leaved pondweed (*Potamogeton acutifolius*)	Critically Endangered, BAP	5
	Greater water-parsnip (*Sium latifolium*)	Endangered, BAP	1
	Water-soldier (*Stratiotes aloides*)	Near Threatened	11
Norfolk: River Bure	Frogbit (*Hydrocharis morsus-ranae*)	Red List Vulnerable	35
	Whorled water-milfoil (*Myriophyllum verticillatum*)	Red List Vulnerable	3
	Water-soldier (*Stratiotes aloides*)	Near Threatened	11

A number of Red Listed wetland plants, which are not in the target list of aquatic species, were also recorded during the survey. These include Small water-pepper (*Persicaria* minor), Milk-parsley (*Peucedanum* palustre), Marsh stitchwort (*Stellaria* palustris) and the salt-tolerant Divided sedge (*Carex divisa*).

5.5 Non-native species

Invasive non-native species encountered frequently during the survey were Least duckweed (*Lemna minuta*), Canadian waterweed (*Elodea canadensis*), Nuttall's waterweed (*Elodea nuttallii*), Water fern (*Azolla filiculoides*) and New Zealand swamp stonecrop (*Crassula helmsii*). Floating Pennywort (*Hydrocotyle ranunculoides*) was recorded in two samples in the Pevensey Levels and was also observed in the North Kent Marshes, although not in a ditch that was sampled. Sweet flag (*Acorus calamus*) and water lily cultivars (*Nymphaea x marliacea* agg.), which are long-established and less invasive than the other non-natives species, were also present. Water-soldier (*Stratiotes aloides*) and Fringed Water Lily (*Nymphoides peltata*), both native only in the east of England (Preston *et al.,* 2002), were recorded in a few ditches in Pevensey Levels as an introduction. *Elodea canadensis* was first recorded in Britain in 1842 and *E. nuttallii* much more recently, in 1966; *Azolla filiculoides* was first found in 1886 and *Crassula helmsii*, in 1956. *Hydrocotyle ranunculoides* was first recorded in the wild in Britain in 1990 and *Lemna minuta* was first recognised in 1977 (Preston & Croft, 1997), but may have been introduced some years earlier.

The distribution of all these species in the wet zone groups is given in Table 5.5a. Both *Elodea* species were well established in a wide range of freshwater ditch types, with *Elodea nuttallii* being almost twice as common as *Elodea canadensis*. *Lemna minuta* was present in 60% of the ditches sampled, including all ditches in the floating duckweed groups (B1 and B2), and was often co-dominant with native duckweed species. The dominance of *Crassula helmsii* in a number of ditches in Essex is a worrying feature.

Ditches in parts of the Pevensey Levels known to badly affected by the recently established Floating pennywort were deliberately avoided as sampling sites. This was because the study was looking principally at the effects of standard management, and to target ditches known to be infested by non-natives would have introduced another variable, which would best be examined in a dedicated study. Nevertheless, Floating pennywort was recorded in two of the surveyed ditches.

Table 5.5a Percentage occurrence of non-native species in ditches of wet zone groups

	A	**B1**	**B2**	**C**	**D1**	**D2**	**E1**	**E2**	**F**	**G1**	**G2**	**All**
No. of samples in group	32	34	69	27	85	112	69	48	35	54	21	586
% occurrence of species												
Acorus calamus	0	0	0	0	0	0	1	0	0	0	0	0.2
Azolla filiculoides	3	3	10	0	6	4	6	8	0	4	0	4.8
Crassula helmsii	0	3	0	7	0	1	3	0	0	2	0	1.2
Elodea canadensis	0	0	4	7	20	2	13	4	57	0	0	9.4
Elodea nuttallii	6	3	19	7	48	8	17	35	6	6	0	17.4
Hydrocotyle ranunculoides	0	0	0	0	0	0	0	2	0	0	0	0.2
Lemna minuta	6	100	100	33	68	81	70	67	11	7	5	60.1
Stratiotes aloides (as intro.)	0	0	0	0	0	1	1	2	0	0	0	0.6

Fringed water-lily and *Nymphaea x marliacea* agg. were not recorded in any 20 metre survey samples, so do not appear in Table 5.5a.

The numbers of records of non-native species in the areas surveyed is shown in Table 5.5b. This illustrates the ubiquitous nature of these invasive plants, especially *Lemna minuta.*

Table 5.5b Numbers of records of non-native species in the areas surveyed

Area	Total no. samples	Non-native plant species	No. of records
Gwent Levels	51	*Azolla filiculoides* *Elodea canadensis* *Elodea nuttallii* *Lemna minuta*	5 6 8 48
Malltraeth, Anglesey	10	*Elodea canadensis* *Lemna minuta*	3 5
Somerset and Avon	184	*Azolla filiculoides* *Elodea canadensis* *Elodea nuttallii* *Lemna minuta*	12 14 49 143
River Arun	20	*Azolla filiculoides* *Elodea canadensis* *Elodea nuttallii* *Lemna minuta*	1 5 10 12
Pevensey Levels	45	*Azolla filiculoides* *Elodea canadensis* *Elodea nuttallii* *Hydrocotyle ranunculoides* *Lemna minuta* *Nymphoides peltata* *Stratiotes aloides*	3 9 14 2 25 1 4
Walland Marsh	45	*Azolla filiculoides* *Elodea nuttallii* *Lemna minuta*	1 14 24
North Kent Marshes	46	*Azolla filiculoides* *Elodea nuttallii* *Hydrocotyle ranunculoides* *Lemna minuta*	6 9 1 15
Essex	63	*Azolla filiculoides* *Crassula helmsii* *Elodea nuttallii* *Lemna minuta*	3 10 5 23
Suffolk	27	*Elodea canadensis* *Elodea nuttallii* *Lemna minuta*	6 1 15
Norfolk	75	*Acorus calamus* *Azolla filiculoides* *Elodea canadensis* *Elodea nuttallii* *Lemna minuta* *Nymphaea x marliacea* agg.	1 3 26 2 35 2

5.6 National Vegetation Classification communities

Of the 24 aquatic communities in the National Vegetation Classification (NVC) (Rodwell, 1995), two are confined to running water and five to nutrient-poor, mainly upland situations. As shown in Table 6 of Appendix 2, at least twelve of the seventeen aquatic NVC communities of relatively nutrient-rich, lowland standing waters are well represented in the suite of ditches surveyed. The other five are all probably present at low frequency (see also Section 3.5).

Eleven of the 23 NVC swamp communities are easily recognisable in Table 6 of Appendix 2 and the indicator species for another ten were recorded in 2007 to 2009.

This means that almost all the NVC aquatic and swamp communities of relatively nutrient-rich habitats of lowland Britain were represented in the grazing marsh ditches surveyed in 2007 to 2009. This is another indication of the richness of this habitat.

Evaluation of plant assemblages and wetlands: key points

- Seven Red List, three Near Threatened and one Nationally Scarce aquatic plant species were recorded during the survey.
- Frogbit (*Hydrocharis morsus-ranae*) (Vulnerable) occurred in over half the ditches sampled and Tubular water-dropwort (*Oenanthe fistulosa*) (Vulnerable) in about a quarter of them.
- Most, if not all of the National Vegetation Classification aquatic and swamp communities of relatively nutrient-rich habitats in lowland Britain are represented in grazing mash ditches.
- The invasive non-native plants Water-fern (*Azolla filiculoides*), Canadian waterweed (*Elodea canadensis*), Nuttall's waterweed (*Elodea nuttallii*) and Least duckweed (*Lemna minuta*) were widespread and abundant. Australian swamp stonecrop (*Crassula helmsii*) was dominant in some ditches in Essex.
- The plant assemblages of the marshes were evaluated and ranked, using four metrics for Species Richness, Species Conservation Status (SCS), Habitat Quality and Naturalness.
- The end-groups dominated by Frogbit and Water-soldier were the richest in species and held the largest proportion of rare plants.
- Brackish ditches were poor in species and rarities, but less heavily infested with non-native species.
- Samples from the Yare marshes were on average the most species-rich and samples from Pevensey Levels had the highest SCS Scores.

Section 6 Evaluation of invertebrate assemblages and wetlands

6.1 Methods

The faunal interest of each marsh and each major geographic area was summarised by metrics for the following attributes: Species Richness, Species Conservation Status, Habitat Quality and Naturalness. Their application is fully explained in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010). They are:

Native Species Richness – the number of native taxa recorded, based on a check list of target aquatic species

Species Conservation Status (SCS) Score – a Species Quality Index (SQI) based on threat and rarity: an average score per native taxon

Habitat Quality (habitat fidelity):
3 = species confined to grazing marsh or very scarce in other habitats
2 = species particularly widespread in some grazing marsh systems but with good populations in other wetland habitats
1 = species with no preference for grazing marsh.
The Habitat Quality Score for a sample is the mean of scores for the species present,

Naturalness (presence or absence of non-native species):
Species scores range from 1 to 5, according to the perceived threat they pose to the native invertebrate fauna. The three non-native species recorded in this survey were:

		Threat score
Crangonyx pseudogracilis	An amphipod crustacean	3
Physella acuta	A bladder snail	2
Potamopyrgus antipodarum	New Zealand mud snail / Jenkin's spire snail	2

The Naturalness Score for a sample is the sum of scores for the non-native species, expressed as a negative value.

In addition, a salinity index was used, based on the salinity tolerance (scored on the scale 0, 1, 2) of each species. The salinity index for a sample is the sum of the salinity scores for all the species present.

Each of the metrics was estimated as the mean and median for each marsh and geographic area, and as the value for the whole species list for all ditches combined. Median values are given for comparison with the national standards because extreme values can be usefully compared with the lower and upper quartiles.

Single marshes and areas were ranked using the metrics. These are not amalgamated into a single score, as they indicate different attributes. Each of the metrics was estimated as the mean and median for the ditches sampled in each marsh or geographic area, and as the value for the whole species list for all ditches combined. Detailed results are given in Volume 2, Appendix 4 of this report and results for individual areas are presented and discussed in Section 6.3 of this volume. Rather than simply relying on the Naturalness Score, the three non-native species are mentioned individually, although it is not known whether they cause conservation problems.

As well as applying the metrics, lists of all the nationally rare and scarce species found in individual marshes and areas are also given in Volume 1, Appendix 4. A commentary on many of these species is given in the area accounts in Section 6.3.

6.2 Salinity

A conductivity of 2000µS cm^{-1} was chosen to separate fresh from brackish ditches. Samples from marshes west of Kent were almost entirely from fresh ditches, and those from the greater Thames estuary marshes were mainly from brackish ditches; a mixture of both types was sampled in the remaining areas (see Figure 6.2).

The overall influence of salinity on the metrics, when applied to the whole dataset, is shown in Table 6.2. More detailed analysis (see Volume 2, Appendix 4) showed small declines in species richness at both high and low conductivities. Low species-richness at low conductivities may have been partly an artefact of inadequate sampling in the Gwent Levels during flooding, when rainwater was probably responsible for low conductivities, but small values were also recorded at the freshwater Malltraeth and Arun Marshes. Average values also disguised different responses by major taxa to increasing salinity. Beetles had the same mean species-richness in fresh and brackish ditches and their response to changing conductivity was mild and declined only slightly in species-richness in the more brackish marshes, whereas molluscs showed an unambiguously marked decline in richness above the 2000µS cm^{-1} threshold.

As Species Richness (especially of molluscs) generally decreases and SCS Score, Habitat Quality Score and Naturalness Score increase with conductivity, freshwater and brackish-water samples or wetlands should not be compared without acknowledging these differences. Table 6.2b gives average values for freshwater and brackish-water ditches, which can be used as yardsticks against which to judge values for each marsh.

Figure 6.2. Number of fresh and brackish ditches in each area surveyed

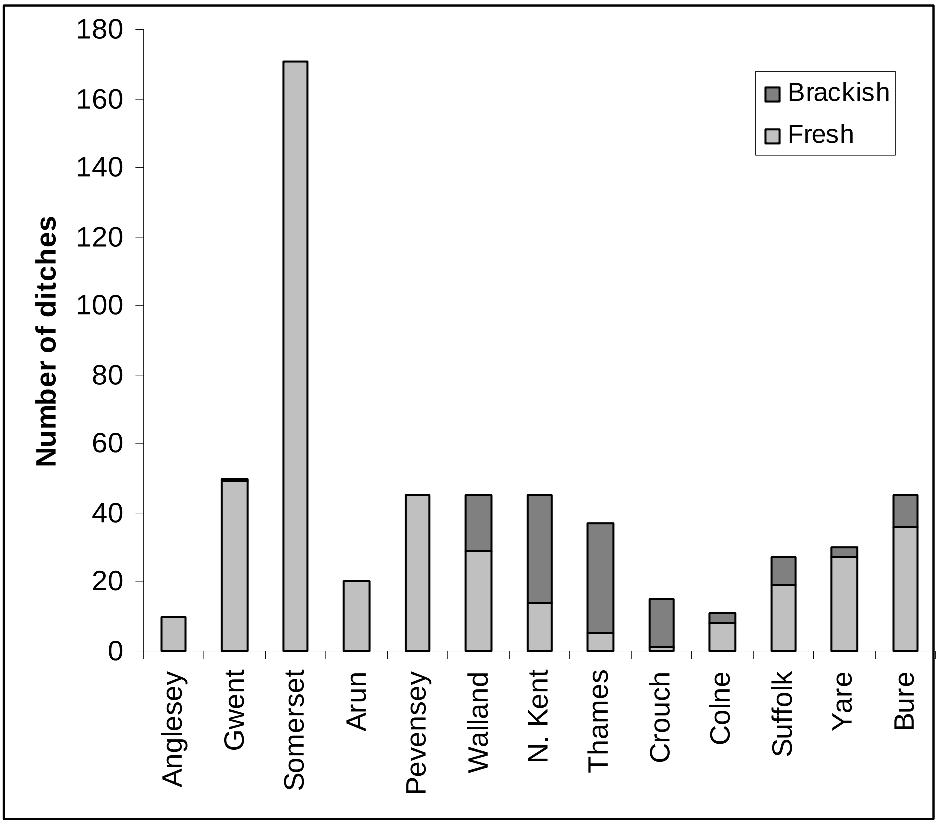


Table 6.2 Mean and median of species metrics for all freshwater and brackish samples, using 2000μS cm^{-1} as the threshold.

Medians are given with lower and upper quartiles.

	Species Richness			**SCS Score**	**Habitat Quality Score**	**Naturalness Score**
	All taxa	Beetles	Molluscs			
Mean						
Fresh	45.9	19.5	10.2	1.393	1.15	-3.22
Brackish	37.7	19.1	3.6	1.520	1.21	-2.41
Median						
Fresh	47 (40 – 53)	19 (16-23)	10 (7-13)	1.39 (1.31-1.48)	1.15 (1.10-1.20)	-3 (-3_-3)
Brackish	39 (29-46)	19 (14-25)	3 (1-5)	1.501 (1.41-1.62)	1.20 (1.13-1.27)	-2 (-3_-2)

6.3 Results: evaluation of marshes using metrics

Table 6.3 (p. 63) gives mean and median Species Richness, Species Conservation Status Score and Habitat Quality Score for samples in each of the main areas. The Naturalness Score is not included because experience showed that it was more useful to comment on the few non-native species present, rather than to rely on the metric. Metrics for individual marshes are given in Volume 1, Appendix 4.

6.3.1 Malltraeth Marshes, Anglesey

Site characteristics
This is a freshwater marsh, which is managed by the RSPB. Only ten ditches were sampled.

Metrics
The ten ditches had similar mean Species Richness (43 species) to most other freshwater marshes, but considerably lower SCS (1.20) and Habitat quality (1.08) Scores. The low Species Richness Score may have reflected the small sampling effort here compared to that spent at most areas, but it did not explain the SCS and Habitat Quality Scores, which were also very low compared to averages for the whole dataset. Almost no species associated with brackish-water were recorded.

Non-native species
The amphipod crustaean *Crangonyx pseudogracilis* was ubiquitous and the snail *Physella acuta* was found in most ditches, giving a low naturalness score (-4.4).

Species of note
Only five nationally uncommon species, all beetles, were recorded. Two beetles, *Hydrochus brevis* (Near Threatened) and *Paracymus scutellaris* (Nationally Scarce) were recorded at this site and nowhere else. While it is possible that *H. brevis* may be found in Norfolk marshes (it is found in fenland ditches here), *P. scutellaris* is normally associated with acidic seepages rather than coastal grazing marshes.

6.3.2 Gwent Levels

Site characteristics
Fifty ditches were sampled in Wentlooge and Caldicot, almost all of them freshwater. Owing to the difficulty of getting access permission for field ditches, sampling concentrated on larger IDB drains that could be reached from roads and tracks so the sample was biased towards frequently cleaned ditches. It is not known whether this had an effect on the species metrics, although these did not differ significantly from earlier surveys that covered more field ditches.

Metrics
Average Species Richness was the lowest of the freshwater marshes surveyed (36 species), and SCS Score (1.27) was also low compared to other fresh marshes. The median values were below the lower quartile for freshwater marshes. The SCS Score for the entire species list was rather poor for

such an extensive site with high sampling intensity, and this suggested that there was a limited number of rare species here. The average Habitat Quality Score, although low (1.12), implied that a reasonable number of grazing marsh specialists were found.

Non-native species
Crangonyx pseudogracilis was found in most ditches and *Physella acuta* was present in nearly half of them, and represented a very considerable increase for both species since 1985. The snail *Potamopyrgus antipodarum* was relatively infrequent (12% of ditches) compared to 1985 (28%). Mean Naturalness Score was low on Wentlooge (-4.29) but similar to the national average at Caldicot (-3.28).

Species of note
Six threatened or scarce beetles species and four rare or scarce soldierflies were recorded, of which the diving beetle *Hydaticus transversalis* and the soldierfly *Odontomyia ornata* were widespread. Several of these species are regarded as good indicators of the grazing marsh habitat. The absence of the Nationally Scarce soldierfly *Stratiomys singularior*, if real, represents a significant loss, although under-sampling of field ditches may be reason for not finding it.

6.3.3 Somerset Levels

Site characteristics
This complex of marshes received considerably more effort than given to other areas in the project. Seven discrete moors and ten ditches outside SSSIs were sampled. All the ditches were fresh, including those on the coastal Pawlett Hams.

Metrics
More species (224) were found in Somerset than in other areas, which is unsurprising because sampling effort was high here, but the averages per individual wetland for Species Richness (45 and 46), SCS Score (1.39) and Habitat Quality Score (1.16 and 1.17) were identical to those for all freshwater ditches. Taken as a whole, the Somerset Moors rated as 'average' on a national scale.

Mean Species Richness did not differ significantly between the moors or the two non-SSSI suites of ditches, although the non-SSSIs had the lowest values (40-41 species) and Tadham / Tealham and West Sedgemoor had the highest (48 species).

SCS Score varied significantly between the sites; the higher values were from the non-SSSI peat sites (1.48), Kings Sedgemoor (1.44), the Catcott complex and West Sedgemoor (both 1.40). The lower values were from the non-SSSI ditch on clay (1.29) and the Kenn complex (1.31). This was a relatively small range, and it is likely that only the extreme values were significantly different, suggesting that there was little to differentiate the quality of most moors. The representation of uncommon species seems to be well reflected in SCS Scores. Habitat Quality scores also differed significantly between the moors and the ranking largely mirrored that for species conservation scores, although in this case Pawlett Hams had the highest score.

Non-native species
Crangonyx pseudogracilis was found in nearly all ditches except at Pawlett Hams, where it was less frequent, and this represented a recent expansion of range. *Physella acuta* was present in a few ditches on several moors but was more frequent at Tadham and Tealham Moors; this appeared to be a recent colonisation. *Potamopyrgus antipodarum* is very scarce in the Somerset wetlands. Apart from a lower score for Pawlett Hams, the Naturalness Scores for each marsh were near the national average.

Species of note
The total list of 22 uncommon species (fifteen beetles, five flies and two snails) was rather short considering the large sampling effort on a varied suite of marshes. The most frequent species included species with moderate to strong affinity to grazing marshes (e.g. the beetles *Hydrophilus piceus* and *Limnoxenus niger,* the soldier-flies *Odontomyia ornata, O. tigrina* and *Stratiomys singularior*). The Lesser silver water beetle (*Hydrochara caraboides*) (Near Threatened) and the Large-mouthed valve snail (*Valvata macrostoma*) (Vulnerable) appeared to have retained their

localised populations. The record for the Endangered Shining ram's-horn snail *Segmentina nitida* represented only the third for Somerset.

6.3.4 Arun Valley

Site characteristics
The ditches sampled at Pulborough Brooks and Amberley Wildbrooks were on land managed by the RSPB. They are entirely freshwater sites that occasionally flood when the Arun over-tops its banks (as happened just before sampling in early June 2008). Water quality tended to remain high except during these flooding events.

Metrics
None of the metrics differed between the two sites so they are here treated as a single unit. Species Richness (42 and 44.5) was 'average' for freshwater marshes but SCS Score (1.21 and 1.18) and Habitat Quality Score (1.05) were the lowest recorded on any marsh and the medians were well below the lower quartile. These values were similar to those recorded for Malltraeth Marshes.

Non-native species
Crangonyx pseudogracilis was found in all ditches but no non-native snails were found. Consequently the naturalness score was exactly 3 – the score allocated to *C. pseudogracilis* - thus highlighting a limitation of this score.

Species of note
Nationally uncommon species recorded in the Arun Valley included three beetles, two soldierflies, one bug and the Critically Endangered Little whirlpool ram's-horn snail (*Anisus vorticulus*), which is protected under the Habitats Directive. Most uncommon species that were also grazing marsh specialists, and many uncommon species that were widespread on other marshes, were not found. In contrast, the most widespread rare species, the beetle *Hydrochus elongatus* (Near Threatened), was relatively uncommon on other marshes. The mismatch in the uncommon species in both the Arun Valley and Malltraeth Marshes compared with most large freshwater coastal marshes suggest that these two river valley marshes represent a somewhat different habitat from the rest.

6.3.5 Pevensey Levels

Site characteristics
No attempt was made to separate the different parts of these levels, for instance the NNR or the Sussex Wildlife Trust reserve, even though there were probably some large differences in management between these areas and privately managed pasture. All sampled ditches were fresh, despite their proximity to the sea.

Metrics
Mean Species Richness (51) was among the highest recorded, surpassed only by the Norfolk marshes. The median was almost at the upper quartile for the whole set of fresh ditches. Mean SCS Score (1.54) was the highest of all freshwater marshes, and noticeably greater than the Norfolk marshes. The median was well into the top quartile. Habitat Quality Score (1.16) was similar to most freshwater marshes and, unlike the previous two metrics, not remarkable. This reflects the low occurrence of coastal marsh specialists here.

Non-native species
Crangonyx pseudogracilis was found in all ditches and was abundant in about two thirds of them. No other non-native species were recorded. Again, this resulted in the mean Naturalness Score being exactly 3.

Species of note
The reason for the high SCS Score is evident when the 22 scarce and rare species are examined. Several very rare species were widespread at Pevensey, including the beetle *Hydrochus elongatus*, the water measurer *Hydrometra gracilenta*, the Fen raft spider (*Dolomedes plantarius*) and the Shining ram's-horn snail (*Segmentina nitida*) and the Large-mouthed valve snail (*Valvata macrostoma*). None of these species was frequent at other marshes, and collectively they make Pevensey a remarkable marsh. The Critically Endangered Little whirlpool ram's-horn snail (*Anisus vorticulus*), which is protected under the Habitats Directive, was recorded in three ditches. The rather

average score for Habitat Quality compared with the exceptional SCS Score may reflect the low occurrence of most coastal marsh specialists.

6.3.6 Walland Marsh

Site characteristics
Five blocks of pasture within SSSIs, mainly grazed by sheep, and five ditches next to arable land were sampled. Cheyne Court was managed primarily as a private nature reserve but all other areas were working farmland. One third of the ditches were classed as brackish and few of the 'fresh' ditches had conductivities below 1000µS cm^{-1} (mainly at Broomhill). Fairfield has saline intrusion, despite its distance from the sea, and a few ditches are dominated by the brackish water crustaceans *Palaemonetes varians*, *Gammarus duebeni* and *G. zaddachi*.

Metrics
Comparison of mean values of the metrics with national averages was potentially complicated by the split of ditches into fresh and brackish, but the four species metrics were not significantly different (using a Mann-Whitney test). The two groups of ditches did have a significant difference in the number of species of molluscs and in their salinity.

Species Richness and SCS Score for sub-sites on Walland Marsh, including the five arable ditches treated as a unit, differed significantly but there was no difference in Habitat Quality Scores. The arable ditches were noticeably poorer than most SSSI marshes.

When compared with the national averages for brackish and fresh ditches, each of the species metrics behaved slightly differently. Mean Species Richness (45) was close to the average for fresh ditches but high for brackish ditches, mean SCS Score (1.51) was average for brackish but high for fresh ditches, and the mean Habitat Quality Score (1.17) was low for brackish but average for fresh ditches. This confusing result was taken to mean that in general brackish ditches were more species-rich but without a concomitant increase in uncommon or marsh-faithful species compared with brackish marshes on the Thames and Essex coasts. The exceptions at Walland were Broomhill and Cheyne Court, which had notably high SCS Scores. Conversely, when compared with fresh ditches, those at Walland were at least as good as most freshwater marshes. The two groups of ditches were significantly different in the number of mollusc species present, with fewer in the more saline ditches.

Non-native species
Crangonyx pseudogracilis was widespread but abundant only at some ditches on The Dowels. *Physella acuta* was found only in two ditches, at Fairfield. *Potamopyrgus antipodarum* was frequent only at Fairfield, where it was probably responding positively to the unusually brackish conditions here. The Naturalness Scores for each SSSI marsh fell between -2.1 and -3.2, whereas the arable ditches scored -3.8.

Species of note
Nineteen scarce or threatened beetles were recorded, which was more than on most freshwater marshes. Five uncommon flies and three scarce bugs were also recorded. Three widespread beetles at Walland Marsh were scarce or absent on marshes further west: *Graptodytes bilineatus*, *Hydrovatus clypealis* and *Noterus crassicornis*. Among the soldierflies, the large population of *Odontomyia ornata* was noteworthy. Medicinal leech (*Hirudo medicinalis*) is well known from these marshes and still present. The scarcity of most of these species in the five arable ditches sampled was pronounced.

6.3.7 North Kent Marshes

Site characteristics
The survey included several blocks along the coast, and adjacent marshes are treated as single units here although some were under different management and were probably in separate hydrological units. Five blocks were recognised. About one third of the ditches were freshwater, mostly in Shorne and Seasalter and Graveney. The pasture was grazed by cattle at most sites and by sheep at Graveney. RSPB managed Shorne, Halstow and Seasalter Marshes; Chetney Marsh is an NNR, and the remainder were in private ownership as working farmland. Shorne and Graveney and Seasalter Marshes were freshwater, the rest were brackish.

Metrics
There was no significant difference in mean Species Richness and SCS Scores between freshwater and brackish ditches, but the Habitat Quality Score was higher (1.28) in the 45 brackish ditches than in the fresh ones (1.18). There were far fewer molluscs and more brackish-water species in the brackish ditches, but there was no difference in the number of beetle species. Comparisons with national values for Species Richness and SCS Scores were therefore made with those for brackish ditches alone.

All metrics differed significantly between the five blocks of marshes, so local variation needed to be taken into consideration when the whole of the North Kent marshes were compared with other areas. These differences included low Species Richness at Chetney Marshes, high SCS Score and Habitat Quality Scores at Grain and Allhallows Marshes and low values of both these metrics at Graveney and Seasalter.

When the North Kent Marshes were taken as a single unit, mean Species Richness (37) was normal for brackish marshes, although Chetney with 25 species was very poor and the mainly freshwater Shorne (46) had the normal number for freshwater marshes. SCS Score (1.58) was also normal for brackish marshes but in Grain and Allhallows (1.82) it was exceptionally high, and in the mainly freshwater Graveney and Seasalter (1.37) it was normal for freshwater marshes. Habitat Quality Score (1.24) was normal for brackish marshes, and again Grain and Allhallows (1.37) had a very high score and Graveney and Seasalter (1.10) had a normal score for freshwater marshes

Non-native species
Crangonyx pseudogracilis was scarce or absent on the brackish sites and only moderately widespread on the more freshwater marshes, where it was sometimes abundant. *Physella acuta* was found in just a few freshwater ditches; *Potamopyrgus antipodarum* was widespread but infrequent, and abundant in only a few ditches. These differences in the tolerance of *C. pseudogracilis* and *P. acuta* to saline conditions showed up in the Naturalness Scores, which were between -0.83 and -1.37 for the three more brackish sites, and -3.7 and -4.43 for the two mainly freshwater marshes.

Species of note
The marshes supported many uncommon species: 22 beetles, three soldierflies, two bugs, the caddisfly *Leptocerus lusitanicus* (Vulnerable) and the Near Threatened Scarce emerald damselfly *Lestes dryas*. Beetle species with a strong association with brackish water were widespread, and included *Agabus conspersus, Hygrotus parallellogrammus, Rhantus frontalis, Helophorus alternans, Enochrus halophilus* and *Limnoxenus niger.* These species were particularly frequent at the more brackish Cliffe and Halstow and Grain and Allhallows Marshes. Although Chetney Marsh was also strongly brackish, it supported only a few of these saline indicator species and rather few uncommon species altogether. Brackish-water species were also noticeably scarce at the predominantly freshwater Shorne and Graveney and Seasalter Marshes, where there was a slightly higher representation of species more usually associated with freshwater marshes, such as the Great silver water beetle (*Hydrophilus piceus*) and the soldierfly *Odontomyia ornata*. Although many uncommon species were found, they included only a few with strong affinities to grazing marshes.

6.3.8 Thames and Essex Marshes

Site characteristics
These marshes are treated together as they were similar in many respects, although widely separated. Three marshes in the Thames estuary were surveyed: the Inner Thames Marshes SSSI, Vange and Fobbing Marshes, and Hadleigh Marsh. An account of their management is given in section 8.3.1. As most of these marshes are now nature reserves, water levels were high for this water-stressed part of the country. Except in the RSPB's Rainham reserve, most ditches appeared not to have been cleaned for at least ten years. Nearly all the ditches were brackish except Rainham, which remained a predominantly freshwater marsh, as it had been historically. At Brightlingsea a large range of conductivities was recorded.

Metrics
Species Richness did not differ significantly between the five marshes, but the remaining metrics did differ. SCS and Habitat Quality Scores were low at Rainham and Brightlingsea compared with the other three sites. While noting that the Species Richness values did not differ significantly, it was worth pointing out that Hadleigh and Vange & Fobbing, each with 39 species, had rather higher

values than those at the other sites (31-34 species). Taking all the metrics into account, Rainham and Brightlingsea were consistently poorer than Hadleigh, Vange and Fobbing or Fambridge Marshes.

These local variations needed to be taken into account in comparison with national averages. However, the mean Species Richness for the three Thames marshes together (36) was close to the average for brackish sites, but those for Fambridge (34) and Brightlingsea (32) were somewhat below this. SCS and Habitat Quality Scores were average for the Thames and Fambridge Marshes but low for Brightlingsea, whose scores were closer than expected when compared with the national average for freshwater sites. It appeared that Brightlingsea, however it was viewed, was a notably poorer site than the other Thames and Essex marshes.

Non-native species
Crangonyx pseudogracilis was widespread, although rarely abundant. *Physella acuta* was also widespread, but uncommon except at Brightlingsea, where it was clearly becoming well established and was abundant in one ditch. *Potamopyrgus antipodarum* was widespread and abundant in a few ditches. These distributions were reflected in the mean Naturalness Scores that were between -2.2 and -3.27 for Thames and Fambridge marshes, but particularly high (-5.36) at Brightlingsea.

Species of note
The marshes supported many scarce and rare species, including 24 beetles, four flies, two bugs a snail and the Near Threatened Scarce emerald damselfly *Lestes dryas* . Beetles associated with brackish water were notably among the most frequently found (*Graptodytes bilineatus, Hygrotus parallellogrammus, Rhantus frontalis, Helophorus alternans* and *Enochrus halophilus*). Other species with brackish or coastal affinities were present at lower frequencies and together accounted for most of the list. Brightlingsea had a noticeably short list of species, with few records. As sampling effort was only slightly less here than at the remaining sites, this was a real difference in the representation of uncommon species.

6.3.9 Suffolk Marshes

Site characteristics
Two marshes were surveyed on the Suffolk coast: Shotley Marsh, which was chosen as the most brackish site previously surveyed here, and Sizewell Belts and Minsmere Level, which was chosen for its species-richness. Four of the seven ditches at Shotley and four at Minsmere Level were brackish, but several ditches at Sizewell & Minsmere had particularly low conductivities. There were marked contrasts within the Sizewell & Minsmere site, with Sizewell Belts being entirely on peat and having extensive shelter from bands or blocks of trees and woodland, whereas Minsmere Level (like Shotley) was predominantly on clay and was typical exposed marsh.

Metrics
There were no significant differences between the species metrics for the three sites (treating Sizewell and Minsmere separately) so comparisons with national trends could be made using the combined Suffolk marshes. The eight brackish ditches had significantly lower Species Richness Scores than the fresh ditches but the other metrics showed no differences. The depressing effect of brackishness on species richness was thought to be too small to make much difference when comparing with the national fresh or brackish averages. The mean Species Richness (45), SCS Score (1.35) and Habitat Quality Score (1.11) were no different from the national average for freshwater ditches. Shotley had retained its moderately brackish-water fauna.

Non-native species
Crangonyx pseudogracilis was found in all ditches at Sizewell and Minsmere, and many at Shotley. *Potamopyrgus antipodarum* was found in a few ditches at both sites.

Species of note
The complement of uncommon species at Shotley was small and unremarkable, but both Sizewell Belts and Minsmere Level had a varied and contrasting suite of species. Among the 21 uncommon species (sixteen beetles, four flies and one bug) recorded in Suffolk, two - the Great silver water beetle (*Hydrophilus piceus*) and the soldier-fly *Odontomyia ornate* - are characteristic species of grazing marshes. The record for the water beetle *Graphoderus cinereus* (Vulnerable) was one of the more remarkable for the project, as it is very scarce, with the nearest records being from Catfield Fen

in north Norfolk and Epping Forest in south Essex. Species associated with brackish-water or coastal areas (*Hygrotus parallellogrammus, Rhantus frontalis, Helophorus alternans* and *Enochrus halophilus*) were found at Minsmere Level but not at Sizewell Belts, and this reflected the more varied range of conductivities on Minsmere Level.

6.3.10 Norfolk Marshes

Site characteristics

The choice of marshes in Norfolk was based primarily on areas that had been surveyed well in the past. Buckenham and Cantley (in the Yare valley) and Upton Marshes (in the Bure valley) are nature reserves. Non-SSSI marshes that were surveyed were at Limpenhoe (Yare valley), Oby and South Walsham (Bure valley). At Fleggburgh, in the Bure valley, five ditches inside the SSSI were surveyed and four outside it. Recent repairs to the river walls of the Yare and Bure have removed the salinity gradient across some of the marshes. Three ditches at Limpenhoe and nine scattered across the Bure marshes were brackish.

Metrics

There were no differences in the species metrics between the Yare and Bure marshes, but Species Richness and SCS Score differed between individual marshes. Mean Species Richness in the two catchments (55-56 species) was well above the national average for freshwater marshes and the medians were in the upper quartile. Local differences were low, with scores ranging from 50-51 at Oby and Fleggburgh to 62 at South Walsham and Upton. Mean SCS Scores for the Yare and Bure marshes (1.40 and 1.42 respectively) were slightly above the national level, ranging from high values of 1.45-1.47 at Limpenhoe, South Walsham and Upton to low values of 1.36 at Buckenham and Cantley. Habitat Quality Scores for the two catchments (1.17) were also close to the national average, and did not differ significantly between individual marshes.

Non-native species

Crangonyx pseudogracilis was present in nearly every ditch but was scarcely ever abundant. *Potamopyrgus antipodarum* was patchily distributed, and found in a few ditches at Limpenhoe, Oby and one at South Walsham. These included half of the brackish ditches; it was sometimes abundant.

Species of note

More uncommon species were recorded than on most other freshwater marshes. There were eighteen beetles, five flies, three bugs, one caddisfly, the Norfolk hawker dragonfly (*Aeshna isosceles*) and three snails, including the Little whirlpool ram's-horn snail (*Anisus vorticulus*), which is protected under the Habitats Directive. The most widespread of the uncommon species (*Peltodytes caesus, Hydrophilus piceus, Limnoxenus niger, Noterus crassicornis, Odontomyia ornata* and *O. tigrina*) had a moderate to high fidelity to grazing marshes. The beetle *Noterus crassicornis* reached a particularly high frequency of occurrence in the Norfolk marshes, matched only at Malltraeth Marshes. There were differences in the distribution of some species, for example the beetles *Hydaticus seminiger* and *H. transversalis,* Shining ram's-horn snail (*Segmentina nitida*) and *Anisus vorticulus* were found only in the Bure marshes, although with the exception of *H. seminiger* they had been found in the Yare marshes in previous surveys.

6.4 Validation of the metrics

The trials of the four metrics, both in site evaluation and in the investigation of possible change described in Section 8 of Volume 1, led to the following conclusions. Species Richness and Species Conservation Status Score gave useful measures of faunal quality but Habitat Quality was less useful. This was attributed to the fact that almost all the species regarded as faithful to the grazing marsh habitat are also nationally rare or scarce, so Habitat Quality Score is based largely on scores for a sub-set of the species contributing to SCS. Because only three species contributed to the Naturalness Score, it behaved erratically. A simple account of the non-native species present in a marsh was found to be more useful.

It was therefore decided that the use of Invertebrate Naturalness Score would not be recommended in the final version of *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Drake, Stewart & Palmer. 2010) and that the limitations of the Habitat Quality Score should be pointed out. However, Habitat Quality Scores and Naturalness Scores for individual species are retained in the species tables in the *Manual*, as they provide contextual information. This should be useful for future site comparisons, especially those in the north of Britain or in other habitats such as fens, which may not have the same suite of grazing-marsh specialists.

Table 6.3 Mean and median Species Richness, Species Conservation Status Score and Habitat Quality Score for samples in each of the main areas

Species Richness	Samples	Mean	Median
Anglesey	10	43.3	46.5
Gwent	50	35.5	39.0
Somerset	151	44.9	46.0
Arun	20	42.0	44.5
Pevensey	45	51.3	52.0
Walland	45	45.2	47.0
N. Kent	45	36.9	39.0
Thames	37	35.7	37.0
Crouch	15	33.8	35.0
Colne	11	31.5	30.0
Suffolk	27	44.9	45.0
Yare	30	55.1	56.5
Bure	45	56.0	58.0
All marshes	531	44.1	45.0

Species Conservation Status Score	Samples	Mean	Median
Anglesey	10	1.20	1.20
Gwent	48	1.27	1.27
Somerset	151	1.39	1.39
Arun	20	1.21	1.18
Pevensey	45	1.54	1.56
Walland	45	1.51	1.50
N. Kent	44	1.58	1.56
Thames	37	1.52	1.52
Crouch	14	1.56	1.57
Colne	11	1.31	1.31
Suffolk	27	1.35	1.37
Yare	30	1.40	1.39
Bure	45	1.42	1.44
All marshes	527	1.42	1.41

Habitat Quality Score	Samples	Mean	Median
Anglesey	10	1.08	1.08
Gwent	50	1.12	1.12
Somerset	151	1.16	1.17
Arun	20	1.05	1.05
Pevensey	45	1.16	1.16
Walland	45	1.17	1.18
N. Kent	45	1.24	1.26
Thames	37	1.21	1.22
Crouch	15	1.19	1.17
Colne	11	1.10	1.10
Suffolk	27	1.11	1.11
Yare	30	1.17	1.16
Bure	45	1.17	1.17
All marshes	531	1.16	1.16

6.5 Rare and scarce species

Seventy nationally rare or scarce invertebrates were recorded. Beetles comprised the bulk of the list (47 species), and other orders contributed between 1 and 7 species. Some of these species were particularly widespread, occurring in at least 5% of the 551 samples (Figure 6.5, p. 66).

6.5.1 Species protected by legislation

Eight species have conservation designations other than those of rarity and threat. Seven are included in the most recent UK Biodiversity Action Plan priority list (see www.ukbap.org.uk). Four have been on Schedule 5 of the Wildlife and Countryside Act for many years and two have been included more recently in European legislation. None was widespread in the survey, although several had good populations locally, as judged from the number of records. Table 6.5.1 summarises the records of these species in the Buglife survey.

The Norfolk hawker (*Aeshna isosceles*) was found as a larva only in three ditches at Upton Marshes in Norfolk although adults were seen flying frequently in 2007 and 2008 in the Broads. Its apparent scarcity in pond-net samples probably reflects the method's inadequacy at collecting large, relatively scarce predators.

The Lesser silver water beetle (*Hydrochara caraboides*) was found only in the Brue valley of the Somerset Levels, in the Tadham and Catcott complexes, where all its previous Somerset records originate, although nine records from 50 samples in this valley indicated that its population was probably no smaller than in the recent past.

The Lesser water measurer (*Hydrometra gracilenta*), was long known from only Pevensey Levels and one site in the New Forest although there are more recent records from ditch systems in north Somerset and the Bure valley in Norfolk (NBN Gateway). In the Buglife survey it was particularly frequent in the Pevensey Levels, where it was recorded in 15 of 45 ditches.

The Fen raft spider (*Dolomedes plantarius*) was probably frequent at Pevensey Levels, one of its three known British locations and the one where the largest population has been known for some time. Nine records were made in 45 samples, and this was probably an underestimate of its abundance, since pond-netting is crude method of collecting this shy species.

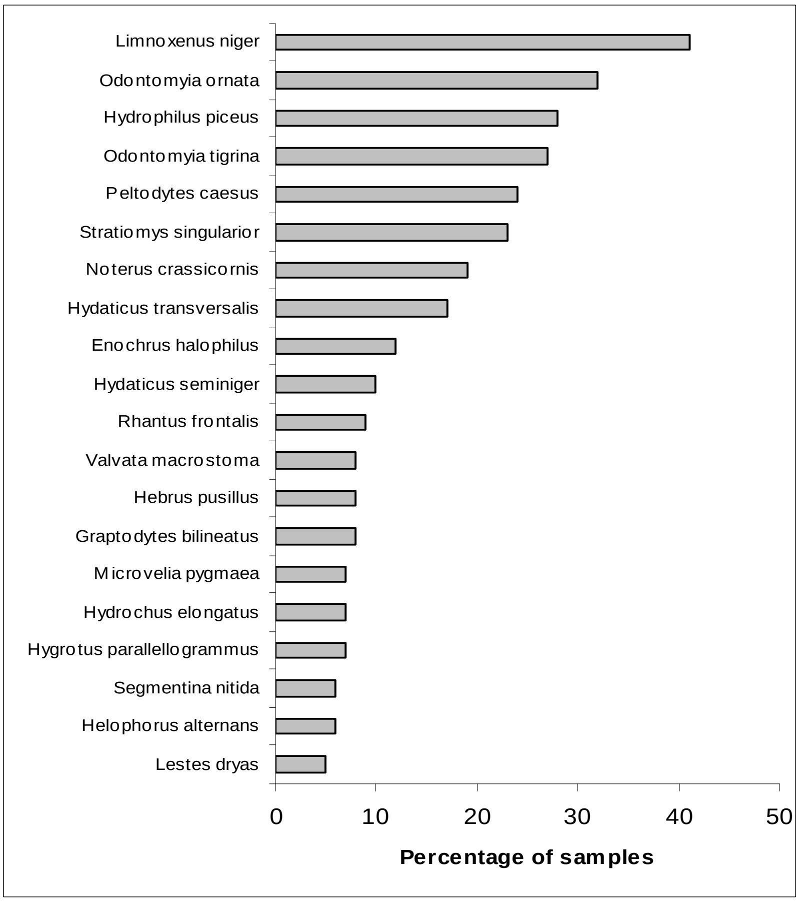
Of the rare snails, the Little whirlpool ram's-horn snail (*Anisus vorticulus*) was found most widely, in four areas, and was clearly locally frequent in the Bure valley (principally Upton Marshes). It had been recorded before at all these sites, and its apparently low occurrence at Pevensey Levels was surprising, given that previous work has shown it to be frequent here (Watson & Ormerod, 2004), although Willing & Killeen (1999) suggested that it was scarce here. The Shining ram's-horn snail (*Segmentina nitida*) and the Large-mouthed valve snail (*Valvata macrostoma*) were both also especially frequent at Pevensey Levels (23 and 33 ditches, respectively, out of 45), and both also had small local populations elsewhere: West Sedgemoor in the Somerset Levels for *V. macrostoma*, where it is well established (Willing, 2004), and at three marshes in the Bure valley in Norfolk for *S. nitida*. An interesting record for *S. nitida* came from Catcott in Somerset, where a tiny population had been known for some time (Hill-Cottingham, 2005) and from a single record from Tadham (Godfrey, 2000). The snail is clearly struggling in this area.

Medicinal leech (*Hirudo medicinalis*) was moderately frequent at its known site at marshes on Walland (Ausden *et al*., 2002); here eight records were made in 45 samples.

Table 6.5.1 Records of species with legal protection

Area	Species	Status	No. of records
Somerset and Avon	Lesser silver water beetle (*Hydrochara caraboides*)	Near Threatened, WCA Schedule 5, BAP	Found only in Somerset, in 9 samples from Tadham and Tealham
	Shining ram's-horn snail (*Segmentina nitida*)	Red List Endangered, BAP	In 1 sample from Catcott
	Large-mouthed valve snail (*Valvata macrostoma*)	Red List Vulnerable, BAP	In 7 samples from West Sedgemoor
River Arun	Little whirlpool ram's-horn snail (*Anisus vorticulus*)	Red List Vulnerable, Hab. Dir. Annexes II and IV, BAP	In 1 sample
Pevensey	Fen raft spider (*Dolomedes plantarius*)	Red List Endangered, WCA Schedule 5, BAP	Found only at Pevensey, in 9 samples
	Lesser water-measurer (*Hydrometra gracilenta*)	Red List Rare, BAP	Found only at Pevensey, in 15 samples
	Little whirlpool ram's-horn snail (*Anisus vorticulus*)	Red List Vulnerable, Hab. Dir. Annexes II and IV, BAP	In 3 samples
	Shining ram's-horn snail (*Segmentina nitida*)	Red List Endangered, BAP	In 23 samples
	Large-mouthed valve snail (*Valvata macrostoma*)	Red List Vulnerable, BAP	In 33 samples
Walland	Medicinal leech (*Hirudo medicinalis*)	Red List Rare, Hab. Dir. Annex V, WCA Schedule 5	Found only at Walland, in 8 samples
Essex	-	-	No records
Suffolk	Large-mouthed valve snail (*Valvata macrostoma*)	Red List Vulnerable, BAP	In 1 sample
River Bure	Norfolk hawker dragonfly (*Aeshna isosceles*)	Red List Endangered, WCA Schedule 5, BAP	In 3 samples from Upton Marsh
	Little whirlpool ram's-horn snail (*Anisus vorticulus*)	Red List Vulnerable, Hab. Dir. Annexes II and IV, BAP	In 10 samples
	Shining ram's-horn snail (*Segmentina nitida*)	Red List Endangered, BAP	In 4 samples from 3 marshes

Figure 6.5 Rare species occurring in at least 5% of samples



6.5.2 Relationship of rare and scarce species with environmental variables

All the rare and scarce species recorded during the survey are listed in Table 6.5.2a, which also shows the geographical area in which they were found.

The records of the 20 rare and scarce species found in at least 5% of samples (Figure 6.5.2) plus the beetle *Agabus conspersus*, which was locally frequent in the Thames marshes, were examined in relation to environmental variables. The numbers of records for these species in fresh and brackish ditches and in each of the wet zone plant groups (see Section 3) are shown in Tables 6.5.2b and 6.5.2c. The occurrence of each species in the botanical groups was compared with the proportions in the entire dataset, using a chi^2 test. In all cases, the distribution of invertebrates differed with high significance from the expected proportions.

Table 6.5.2a Rare and scarce invertebrates grouped by geographic area.

Values are the number of occurrences

Order, Family	Species	SCS	Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Total
	Geographical area		1	2	3	4	5	6	7	8	9	10	11	12	13	
	Number of samples →		10	51	152	20	45	45	45	37	15	11	27	30	45	
Coleoptera																
Dryopidae	*Dryops auriculatus*	4					18									18
	Dryops similaris	3							1	2						3
Dytiscidae	*Agabus conspersus*	3		2					10	3		1	1			17
	Agabus uliginosus	4			12											12
	Dytiscus circumcinctus	3		2	2									3	3	10
	Dytiscus dimidiatus	4		2	4			1							1	8
	Graphoderus cinereus	5											1			1
	Graptodytes bilineatus	3						10	6	13	6	3				38
	Hydaticus seminiger	3			15	2	3	11	4	1			5		7	48
	Hydaticus transversalis	3		13	70								1		3	87
	Hydrovatus clypealis	3						17					1			18
	Hydrovatus cuspidatus	3						1					1			2
	Hygrotus decoratus	3						3							1	4
	Rhantus frontalis	3	1		2			5	13	9	7		6	1	2	46
	Hygrotus parallellogrammus	3					1	4	12	11		1	3	1		33
Gyrinidae	*Gyrinus paykulli*	3						1	4				1	1	2	9
Haliplidae	*Haliplus apicalis*	3							3	5	2					10
	Haliplus mucronatus	3			1											1
	Haliplus variegatus	4						1								1
	Peltodytes caesus	3		8	35	3	6	11	11	9	1	2	9	13	11	119
Helophoridae	*Helophorus alternans*	3							16	9	1		2			28
	Helophorus fulgidicollis	3								1	3					4
	Helophorus nanus	3			5		4			4						13

Order, Family	Species	SCS	Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Total
	Geographical area		1	2	3	4	5	6	7	8	9	10	11	12	13	
	Number of samples →		10	51	152	20	45	45	45	37	15	11	27	30	45	
Heteroceridae	*Heterocerus obsoletus*	3							2		1					3
Hydraenidae	*Aulacochthebius exaratus*	4							2		2					4
	Limnebius aluta	4													1	1
	Limnebius papposus	4			9				1	1						11
	Ochthebius nanus	3			2			4	3	1			2	2	2	16
	Ochthebius viridis	3							5	3	2					10
Hydrochidae	*Hydrochus angustatus*	3								1			2			3
	Hydrochus brevis	4	2													2
	Hydrochus elongatus	4				5	20	4	4	3						36
	Hydrochus ignicollis	4					9	2	5		1					17
Hydrophilidae	*Berosus luridus*	4					1									1
	Chaetarthria	3												1	2	3
	Chaetarthria seminulum	3			1			1								2
	Chaetarthria simillima	3			1											1
	Enochrus bicolor	3							3	5	1			1	2	12
	Enochrus halophilus	3							20	16	12	2	3		7	60
	Enochrus quadripunctatus	3					1	2					1			4
	Helochares obscurus	5													6	6
	Helochares punctatus	3	1													1
	Hydrochara caraboides	5			9											9
	Hydrophilus piceus	4		2	61		3	5	13	10	3		2	17	22	138
	Limnoxenus niger	4			67		23	27	33	17	11	2		7	16	203
	Paracymus scutellaris	3	1													1
Noteridae	*Noterus crassicornis*	3	7					26	1	3				28	31	96
Diptera																
Culicidae	*Ochlerotatus flavescens*	4								2						2
Cylindrotomidae	*Phalacrocera replicata*	3					4	3						1	1	9

Order, Family	Species	SCS	Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Total
	Geographical area		1	2	3	4	5	6	7	8	9	10	11	12	13	
	Number of samples →		10	51	152	20	45	45	45	37	15	11	27	30	45	
Stratiomyidae	*Odontomyia ornata*	4		12	78	2	8	18	3	5	2	1	5	12	13	159
	Odontomyia tigrina	3		7	57	4	4	7	12	10	4	1	7	7	13	133
	Stratiomys potamida	3		1	1											2
	Stratiomys singularior	3			48		1	14	14	12	7	1	4	6	9	116
	Vanoyia tenuicornis	3		4	7			4					6		3	24
Hemiptera																
Corixidae	*Sigara striata*	3						2		1						3
Hebridae	*Hebrus pusillus*	3					6	15	1					7	9	38
Hydrometridae	*Hydrometra gracilenta*	4					15									15
Veliidae	*Microvelia buenoi*	4													1	1
	Microvelia pygmaea	3				1	9	3	6	1		1	5	5	2	33
Odonata																
Aeshnidae	*Aeshna isosceles*	5													3	3
Lestidae	*Lestes dryas*	4							9	12	4					25
Trichoptera																
Hydroptilidae	*Tricholeiochiton fagesii*	3												1		1
Leptoceridae	*Leptocerus lusitanicus*	5							1							1
Araneae																
Pisauridae	*Dolomedes plantarius*	5					9									9
Mollusca																
Planorbidae	*Anisus vorticulus*	5				1	3								10	15
	Gyraulus laevis	3								1		1				2
	Segmentina nitida	5			1		23								4	28
Valvatidae	*Valvata macrostoma*	5			8		33						1			42
Hirudinea																
Hirudinidae	*Hirudo medicinalis*	5						8								8

Table 6.5.2b Distribution of the most frequently recorded nationally scarce or rare species in relation to salinity

Medians with lower and upper quartiles for the salinity index are given for the suite of ditches in which each species was present compared with those in which it was not recorded.

The numbers of the geographical area numbers refer to Table 6.4.2.a.

	Salinity index		Geographical areas
	present	absent	
Coleoptera			
Agabus conspersus	15 (10 - 16)	4 (0 - 10)	7,8
Enochrus halophilus	10 (6 - 15)	2 (0 - 4)	6-11
Graptodytes bilineatus	5 (4 - 11)	2 (0 - 7)	6-11
Helophorus alternans	7 (4 - 15)	2 (0 - 7)	6-11
Hydaticus seminiger	0 (0 - 2)	0 (0 - 2)	all
Hydaticus transversalis	0 (0 - 0)	0 (0 - 0)	2,3
Hydrochus elongatus	0 (0 - 0)	0 (0 - 5)	4-7
Hydrophilus piceus	0 (0 - 2)	0 (0 - 2)	all
Hygrotus parallellogrammus	11 (7 - 16)	2 (0 - 5)	6-11
Limnoxenus niger	0 (0 - 5)	0 (0 - 0)	all
Noterus crassicornis	0 (0 - 2)	0 (0 - 4)	1,6,12,13
Peltodytes caesus	0 (0 - 2)	0 (0 - 2)	all
Rhantus frontalis	9 (5 - 15)	2 (0 - 5)	6-11
Hemiptera			
Hebrus pusillus	0 (0 - 3)	0 (0 - 2)	5,6,12,13
Microvelia pygmaea	0 (0 - 2)	2 (0 - 5)	5-13
Odonata			
Lestes dryas	10 (4 - 13)	5 (2 - 11)	7-9
Diptera			
Odontomyia ornata	0 (0 - 2)	0 (0 - 2)	all
Odontomyia tigrina	0 (0 - 2)	0 (0 - 2)	all
Stratiomys singularior	1 (0 - 4)	0 (0 - 2)	all
Mollusca			
Segmentina nitida	0 (0 - 0)	0 (0 - 0)	5,13
Valvata macrostoma	0 (0 - 0)	0 (0 - 0)	5

Table 6.5.2c Distribution of the most frequently recorded nationally scarce or rare species in botanical wet zone end groups

	Botanical TWINSPAN Wet Group						
	A	B	C	D	E	F	G
No. of ditches	31	101	26	169	114	35	75
% of whole dataset	6	18	5	31	21	6	14
% occurrence in each group							
Agabus conspersus	0	12	6	0	0	0	82
Enochrus halophilus	5	5	2	3	13	5	67
Graptodytes bilineatus	16	11	5	3	11	0	55
Helophorus alternans	14	4	4	4	11	0	64
Hydaticus seminiger	6	15	2	31	27	8	10
Hydaticus transversalis	0	22	2	69	7	0	0
Hydrochus elongatus	6	3	14	17	42	11	8
Hydrophilus piceus	1	9	3	39	19	15	13
Hygrotus parallellogrammus	3	0	3	3	15	3	73
Limnoxenus niger	3	11	6	27	21	4	27
Noterus crassicornis	4	8	7	17	36	21	6
Peltodytes caesus	2	17	4	27	24	13	14
Rhantus frontalis	7	4	2	7	20	0	61
Hebrus pusillus	3	11	13	11	29	18	16
Microvelia pygmaea	18	9	0	12	45	12	3
Lestes dryas	0	8	0	0	4	0	88
Odontomyia ornata	1	16	1	48	23	4	7
Odontomyia tigrina	0	14	7	41	10	7	21
Stratiomys singularior	1	15	6	33	15	2	29
Segmentina nitida	7	4	21	7	39	21	0
Valvata macrostoma	2	2	14	29	40	12	0

6.5.3 Habitat requirements of halophilic species

Six of the more frequent nationally rare and scarce species were found mainly in the Thames estuary and Essex coast, with a few occurrences as far as Norfolk. These were five beetles (*Enochrus halophilus*, *Graptodytes bilineatus*, *Helophorus alternans, Hygrotus parallellogrammus* and *Rhantus frontalis*) and the Scarce emerald damselfly (*Lestes dryas*). They showed a similar positive response to conductivity. When compared with the whole dataset, this preference for strongly brackish ditches appeared extreme, with the median conductivities being several thousand µScm^{-1} compared to about 800-900µScm^{-1} for ditches without these species. Even when the comparison was made with eastern marshes from Walland to Minsmere the difference was still very pronounced, the conductivity varying between 3780 and 8090µScm^{-1} in occupied ditches compared to less than 2820µScm^{-1} in the remainder.

These five species also shared similar preferences for other features that were probably directly related to the brackish nature of these ditches. Thus, when compared with the entire dataset, the ditches tended to be 'old', not having been cleaned for some time, with more emergent and mat vegetation, more litter, and with more gently sloping underwater profiles. The banks were dominated by short grass, and tall grass was less frequent than in the remaining samples, but there was no consistent association with cattle or sheep grazing, so the short growth on the banks may have simply reflected more stressed condition in dry and brackish eastern marshes. Water depth was marginally shallower and for two species was narrower than 'average' but this also reflected the generally smaller ditches eastern marshes and was probably an irrelevant factor for this suite of species. None of the sites was on peat. Between about a half and three-quarters of the ditches supporting these species were classified as the botanical group G (Sea club-rush (*Bolboschoenus maritimus*) vegetation). Botanical groups D and E (Frogbit (*Hydrocharis morsus-ranae*) vegetation) were consistently under-represented and group F (Frogbit / Water-soldier (*Stratiotes aloides*) vegetation) was absent where these species were recorded.

The comparisons with only eastern marshes from Walland to Minsmere for the five beetles in this group showed some finer distinctions in habitat preference. *Helophorus alternans* was probably at the most extreme end of the brackish-water spectrum and occupied ditches that tended to have less dense vegetation, although other preferences could not be identified. *Enochrus halophilus* preferred 'older' ditches with gently sloping grassy margins although the centre of these ditches (where the beetle probably did not venture) was not necessarily particularly choked. *Graptodytes bilineatus*, in contrast, seemed to occupy ditches with a similar physical structure but at a later successional stage, being much more choked. Apparently 'younger' but nevertheless grassy ditches with more tangled vegetation supported *Rhantus frontalis*, and, moving towards an even earlier stage, *Hygrotus parallellogrammus* was more frequent. Features of ditches with *Agabus conspersus* were compared in just the North Kent and Thames estuary marshes, and the ditches it occupied were most similar to those favoured by *Rhantus frontalis* and *Graptodytes bilineatus*, although were probably rather smaller field ditches. The damselfly *Lestes dryas* was compared between ditches only the North Kent to Crouch, sites since this encompassed the records in the survey, but the conclusions from this more limited range emphasised its preference for small (shallow, narrow), 'old' and moderately choked ditches.

The associated fauna in the occupied ditches was no more species-rich than in ditches where a species was not recorded, and was significantly poorer for *Enochrus halophilus* and *Helophorus alternans*, which is likely to be a direct consequence of brackish ditches being naturally poor in species. The quality of the fauna, indicated by the Species Conservation Status (SCS) and fidelity indices, were both above average. A further indication that half of these species tended to be found in ditches of higher quality was the lower median naturalness index (non-natives).

6.5.4 Habitat requirements of species sometimes associated with mildly brackish water

Three of the more frequent uncommon species showed a weak association with brackish water, indicated by the median conductivity of the ditches in which they occurred being greater than 1000μS^{-1}. They included the beetles *Limnoxenus niger* and *Noterus crassicornis* and the soldierfly *Stratiomys singularior*. Unlike the halophiles described above, these species probably had no common factor determining their occurrence, as their distributions were dissimilar (Table 6.2..5a). It was also clear that they were not united by a preference for slightly more brackish ditches, but probably all tolerated such conditions.

Limnoxenus niger was a widespread species and was particularly frequent in southern marshes. Its apparent absence from the Gwent Levels was probably due to few smaller ditches sampled being sampled here. It showed a weak positive correlation with increasing conductivity and occupied ditches had a median of 1100μScm^{-1} compared to 830μScm^{-1} where it was not recorded. Apart from mat vegetation being marginally denser where it was recorded, no other environmental variable was different between the suite of ditches where it was found and the remaining ditches. It was also marginally over-represented in botanical group G ditches (Sea club-rush) but was otherwise fairly evenly spread across the botanical groups. Species richness, SCS and marsh fidelity scores in ditches with *Limnoxenus niger* were significantly higher than in the remaining ditches.

Noterus crassicornis had a disjunct distribution, being widespread in Norfolk and Walland ditches, scarce in the North Kent and Thames marshes, and surprisingly also frequent in Anglesey. Comparisons between ditches in these areas, excluding the sparsely occupied North Kent and Thames marshes, showed a clear preference for larger and 'younger' ditches which tended to be wider, deeper, with steep-sided underwater profiles, supporting vegetation at an earlier successional stage indicated by greater amounts of submerged aquatics and open water, and low cover of emergents or mats in the channel. This was reflected in these ditches being conspicuously over-represented in the related botanical groups E (Frogbit) and F (Frogbit / Water-soldier) which were found in larger ditches with a rich submerged vegetation. *Noterus crassicornis* was also found in slightly brackish ditches, although this was not an important feature, as indicated by its under-representation in the brackish botanical group G ditches. It did not occur on peat. Species richness, SCS and marsh fidelity indices in ditches with *N. crassicornis* were significantly higher than in the remaining ditches.

The large soldierfly *Stratiomys singularior* was widespread and more frequent in the marshes of Somerset, Kent and Essex than elsewhere, and absent or scarce in Welsh and Sussex marshes. To some extent its distribution resembled that of *Limnoxenus* niger. The occupied ditches tended to be narrower and shallower than those where it was not recorded, and had more tangled vegetation that included greater cover of mat-forming plants. There were indications that it was more frequent where greater effects of cattle were noted (shelf and block formation). Median conductivity was higher in occupied ditches and this was reflected in a clear over-representation in the brackish botanical group G ditches, although it also occurred in all other botanical ditch types. The associated fauna had significantly greater SCS and marsh fidelity scores, but was no more species-rich than in unoccupied ditches.

6.5.5 Habitat requirements of freshwater species

The remaining eleven scarce or rare species that were moderately frequent in the dataset were clearly associated with freshwater.

The tiny skater *Hebrus pusillus* had a disjunct distribution. It was frequent in the Pevensey Levels, Walland and Norfolk marshes where it was found in 13 to 33% of ditches. In these areas, it showed a tendency to occupy ditches that were slightly narrower and shallower, 'older', and with more gently sloping under-water profiles compared to those where it was not recorded, and which had several indications of greater effects due to cattle (grassier margins, more poaching, bare ground and short grass). Several aspects of the vegetation were slightly denser: more submerged aquatics and algae, more mat vegetations and slightly more choked vegetation in the channel. A very similar picture emerged when occupied ditches were compared with the remainder in the whole dataset, which suggested that these weak trends were probably real, and this was further supported by the over-representation of botanical ditch group C ('swampy' or grassy ditches), and under-representation in the deeper group D (Frogbit ditches). The associated fauna had significantly greater SCS and marsh fidelity scores, but species richness was only just significantly greater than in unoccupied ditches.

These marshes are probably the sites of previous records mentioned in the water-bug atlas (Huxley, 2003). This are significant since the populations were reasonable on large marshes so may represent considerable strongholds for a bug otherwise found in poorly defined habitats scattered around the southern British coast.

The other tiny skater, *Microvelia pygmaea*, was present in nearly all marshes from the Arun valley eastwards, but was nowhere frequent. Comparison of ditches with and without the bug in these marshes showed a number of features indicating less impact by cattle (less grazing, poaching, shelf formation, grassy margin and 'tangledness' of vegetation). Ditches supporting the species had steeper banks and underwater profile and slightly greater cover of floating *Lemna* and other floating aquatic plants, but less mat vegetation and more of the channel occupied by emergents. It was not clear what type of ditch this combination represented, but it may have been early to mid-stage ditches with margins less disturbed by grazing animals owing to their steepness, leaving a denser marginal fringe in which the bugs could live quietly. Although emergents were no more frequent than in ditches where the bug was not recorded, it was over-represented in botanical groups A (Common reed *Phragmites*-dominated) and E (Frogbit with Common reed), so there may have been an association with taller marginal vegetation. There was no difference in the species richness or SCS of occupied ditches compared with the remainder, and the marsh fidelity score was significantly lower. These results suggested that the bug was not responding to conditions that would normally result in a 'good' ditch fauna.

The diving beetle *Hydaticus transversalis* was moderately frequent in the Gwent Levels and Somerset moors and levels, and with rare records from Minsmere and the Bure marshes, but was not recorded elsewhere. Comparison of the conditions in just the Gwent and Somerset ditches indicated a slightly confused preference. On the one hand, it was found where effects due to cattle were slightly more pronounced (more grazing, block formation and shorter grass on the bank, and more tangled vegetation and shelf formation at the edge) but it was also associated with marginally less choked conditions and greater cover of submerged plants. Three-quarters of the occupied ditches were on peat, and nearly 70% were in the botanical group D (Frobit ditches), but the apparent preferences for these two variables was probably just related to their greater prevalence in Somerset. Species richness, SCS and marsh fidelity in ditches with *H. transversalis* were significantly higher than in the remaining ditches.

Hydaticus seminiger, in contrast to *H. transversalis*, was more widespread but nowhere especially frequent. Walland Marshes had the greatest proportion of ditches with the beetle. It was not recorded in the Welsh marshes. When compared across all ditches in the dataset, it showed a clear preference for smaller, shallowly profiled ditches at a late successional stage and with more mat vegetation, litter and a choked central channel. Despite this obvious preference, it was distributed remarkably evenly among botanical groups. Species richness and SCS were significantly greater where *H. seminiger* was found, but there was no difference in marsh fidelity score.

Hydrochus elongatus was found sparsely in marshes between the Arun valley and Thames but was frequent in the Pevensey Levels. In these marshes it showed a weak preference for ditches that were probably less intensively grazed, indicated by greater amounts of tall grass and less short grass on the banks, and slightly more mat vegetation and litter, but these effects were unsupported by other variables. The occupied ditches had a lower conductivity than where the beetle was not recorded. Its prevalence in botanical group E (Frogbit with Common reed) ditches may have reflected the preponderance of this ditch type in the south-eastern marshes. The associated fauna was significantly more species-rich but showed no difference in SCS or marsh fidelity score.

The Great silver water beetle (*Hydrophilus piceus*) was widespread and sometimes frequent. It was easily recorded not just as adults but as larvae and egg cocoons, and these immature stages almost doubled the number of records. Nearly all other beetles were not identified as larvae. *Hydrophilus* was particularly frequent in the Somerset and Norfolk marshes. Ditches where the beetle was found showed greater effects due to cattle (more poaching and block formation), greater vegetation complexity (tangledness), considerably greater cover of submerged plants and more mat vegetation, but less cover of emergents. This was the condition of botanically rich ditches at an early to mid stage in the succession. This conclusion was to some extent supported by the low number of occupied ditches falling into botanical groups A and B (Reed-dominated and floating duckweed-dominated, respectively). Species richness, SCS and marsh fidelity scores in ditches with *Hydrophilus* were significantly higher than in the remaining ditches, and it was noteworthy that the median species-richness (50 species) was so high for such a widespread species, suggesting that its presence may indicate some of the best ditches in English grazing marshes.

Peltodytes caesus was another very widespread beetle, absent only from Malltraeth marshes, and showed rather more even distribution than any other of the scarce or rare species. Perhaps because of its wide and even distribution, it showed relatively small preference for particular conditions, although the median values of occupied ditches compared with the remained suggested that it was more prevalent in deeper, more open ditches at an earlier hydroseral stage, with more floating aquatics and less emergent cover and its associated litter. Occupied ditches were distributed fairly evenly across the different botanical types although with slight under-representation of group A (Common reed-dominated) and slightly more group F (Frogbit / Water-soldier) ditches. Species richness, SCS and marsh fidelity scores in ditches with *P. caesus* were significantly higher than in the remaining ditches.

The large soldierfly *Odontomyia ornata* was one of the most widespread of the scarce species, being absent only from Malltraeth marshes. It was particularly frequent in the Somerset Levels and relatively common at Walland and Norfolk marshes. Its wide occurrence led to relatively few clear indications of preferences but it appeared to prefer early to mid-stage ditches, indicated by the low estimated ‘age’, steep underwater profile and low cover of emergents and its associated litter, although with greater cover of mat vegetation, as occurs in mid-stage ditches. Grazing intensity was also slightly greater next to occupied ditches, and conductivity was low. Occupied ditches were under-represented in botanical groups A (Common reed-dominated), C (grassy) and G (brackish); these associations reinforced the suggested preference for more open, early-stage ditches and avoidance of brackish water. Species richness, SCS and marsh fidelity in ditches with *O. ornata* were significantly higher than in the remaining ditches, and, as noted for *Hydrophilus piceus*, the median species-richness (50 species) was high for a widespread species, suggesting that its presence may also indicate some of the best ditches in English grazing marshes.

Odontomyia tigrina was distributed similarly to *O. ornata*, being absent only from Malltraeth Marsh and particularly frequent in the Somerset Levels. However, it occupied a different type of ditch that was older, narrower and shallower, with more complex vegetation, including greater amounts of mat formation. These features indicated late-stage ditches. Although *O. tigrina* showed no response to conductivity, botanical group G (brackish) ditches were over-represented among those that were occupied, although it was absent from group A ditches (Common reed-dominated). There is probably a requirement for late-stage ditches that are not choked to the extent that algae, on which the larvae graze, are reduced by shading. Species richness, SCS and marsh fidelity scores in ditches with *O. tigrina* were significantly higher than in the remaining ditches, although the differences between the medians were rather small.

The Shining ram's-horn snail (*Segmentina nitida*) was very patchily distributed. It was almost common in Pevensey, scarce in Norfolk, where it was recorded only in a few ditches in the Bure valley, and with a single record from one Somerset moor. Comparison of median values for variables of ditches in the Pevensey and Bure marshes indicated a preference for 'older' ditches that were rather more choked in the channel and had more litter. Conductivity was also marginally lower than where the snail was absent. Botanical groups C, E and F (grassy, Frogbit with reed, Frogbit / Water-soldier, respectively) were over-represented, whereas groups B (floating *Lemna*-dominated) was under-represented and group G (brackish) was not represented among occupied ditches. SCS and marsh fidelity scores were significantly higher in occupied ditches compared to those where *S. nitida* was not recorded, but species-richness was similar, although still very high (55 species).

The Large-mouthed valve snail (*Valvata macrostoma*), like *Segmentina nitida*, was very patchily distributed, being common at Pevensey Levels and locally frequent at just one Somerset moor. Comparison of conditions with and without *V. macrostoma* in these two areas perhaps showed a slight preference for a later stage in succession (marginally shallower water, more gentle under-water profile, more tangled vegetation, less open water and more mat vegetation) although these differences were not likely to be significant. Botanical group E ditches (Frogbit) were over-represented. SCS and marsh fidelity scores were significantly higher in occupied ditches compared to those where *V. macrostoma* was not recorded, but species richness was similar, although still high (52 species).

6.5.6 Habitat requirements of less frequent species

Some of the infrequently found species deserve brief comment since the strength of British populations may partly depend on 'good' grazing marshes.

The beetle *Dryops auriculatus* was found only on the Pevensey Levels but here it was frequent, found in 40% of the samples. It is a species of fens and heathland pools, so the clay ditches of Pevensey were an unexpected habitat for it.

The beetle *Agabus uliginosus* was found only at West Sedgemoor on the Somerset Levels where it was recorded in several ditches, including one of those that was sampled in all three years of the project, where its constant presence over this period indicated the permanent nature of this highly localised population. Among the other surveys used in site comparisons, *A. uliginosus* occurred only once, again at West Sedgemoor in 1994 (Gibbs, 1994). Ditches do not fit the characteristic habitat of the beetle which is described as "primarily confined to highly temporary still waters on low ground, sometimes on marshes subject to tidal influence, and in the south-west in association with puddles around springs in otherwise dry terrain" (Foster, 2010). Perhaps the high water levels maintained by the RSPB at West Sedgemoor produce similar habitat at shallowly flooded margins.

The tiny Hydraenidae beetles live at the water margin and were almost certainly under-sampled by pond-netting with a net whose mesh was about the same size as the beetles' lengths. Of the records relevant to ditch systems, the few for the minute *Aulacochthebius exaratus* raised the possibility that this species has moderate dependency on eastern coastal marshes. It was recorded frequently at Pevensey Levels and North Kent marshes by other surveyors, who probably used direct searching or a sieve to supplement pond-netting, Its distribution coincides well with the coastal marshes (NBN Gateway). The distribution of *Ochthebius viridis* , which was found occasionally in the greater Thames estuary marhes, also shows a moderate coincidence with coastal marshes but occurs in other coastal habitats.

Hydrochus ignicollis was quite frequent at Pevensey Levels and scarce in Kentish marshes and at Fambridge, but these records, coupled with the NBN Gateway map, suggest that marshes are important to this species in at least south east England.

Enochrus bicolor is almost confined to brackish water (Foster, 2010), and while grazing marshes are not the only sites with brackish water, they do provide one of the more extensive expanses of suitable habitat. Records during the project were obtained from Kent and Essex marshes, as were all other records from the surveys used in comparisons here, but some more remarkable ones were from Cantley in the Norfolk Yare valley and South Walsham in the Bure marshes. While the Cantley record may represent either a stray of a relict from the recent more saline conditions before the river wall was made impervious to brackish water incursions from the river, the South Walshm records were inexplicable.

6.5.7 Summary

The analysis of habitat requirements for rare and scarce species confirmed previous opinions (e.g. Drake 1991, 2005; Foster, 2010; Huxley, 2003). The results highlighted the broad range of conditions needed to maintain just this small suite of species, ignoring the numerous scarce species that were too infrequent to analyse. Just as the ordination analysis indicated salinity and successional stage to be the key factors influencing assemblage composition, these were recurrent themes in the requirements of the rare and scarce species (see Tables 6.5.2b and 6.5.2c). It seems that invertebrate species have a preference for or intolerance of particular conditions, which are indicated by the associated vegetation type. Many species could be fitted to a matrix of salinity versus successional stage (Table 6.5.7). However, a few of these species may respond primarily to a minor habitat feature unrelated to either of these key trends, as shown by their uncertain positioning within the matrix (indicated by the arrows).

Table 6.5.7 The preferred conditions of the more frequently recorded scarce species.

Salinity	Successional stage		
	Early	Mid	Late
Strongly brackish	*Helophorus alternans* *Hygrotus parallellogrammus*	*Enochrus halophilus* *Rhantus frontalis*	→→→ →→→ *Agabus conspersus* *Graptodytes bilineatus* *Lestes dryas*
Mildly brackish to fresh	*Noterus crassicornis* ←←←	*Limnoxenus niger* *Stratiomys singularior*	→→→ →→→
Completely fresh	*Hydrophilus piceus* *Peltodytes caesus* *Odontomyia ornata* ???←←←	→→→ →→→ →→→ *Microvelia pygmaea* ←←← ?*Hydrochus elongatus* *Hydaticus transversalis* *Odontomyia tigrina* *Valvata macrostoma* ←←←	→→→??? *Hebrus pusillus* *Hydaticus seminiger* →→→ *Segmentina nitida*

Most of these species were found in ditches with significantly higher medians of Species Conservation Status and Habitat Quality Scores compared with ditches from which they were not recorded. Clearly there was an element of circular reasoning, since SCS Score received a boost from the presence of the scarce species, but the differences were nearly all highly significant ($p<0.001$), and most samples included several scarce species. Species Richness differed less often; in the sample of 21 species, ten were significantly richer and two significantly poorer in total species. The overall conclusion was that these more frequent rare and scarce species often indicate a fauna of great conservation interest.

The soldierfly *Odontomyia ornata* (Vulnerable) and the Great silver water beetle (*Hydrophilus piceus*) (Near Threatened) deserve greater attention in the context of grazing marshes. They were among the most widespread and frequent of the scarce species, and both were associated with early to mid stage ditches with particularly high Species Richness. Although median Species Conservation Status and Habitat Quality Scores for ditches supporting these two species were not exceptional compared with those occupied by other arre and scarce species, they may be regarded as flagship species for grazing marshes because they stand out as reliable indicators of particularly 'rich' conditions. Both are also frequent in this habitat but scarce elsewhere, for example, there are almost no records of *O. ornata* from ponds.

A few other species were also both frequent and widespread: the beetles *Hydaticus seminiger*, *Limnoxenus niger*, *Peltodytes caesus* and *Rhantus frontalis*, and the soldierflies *Odontomyia tigrina* and *Stratiomys singularior*. These too appear to find a national stronghold in grazing marshes although they are less dependent upon them than *O. ornata* and *Hydrophilus piceus*. Another suite of species with high occurrence differed in being locally abundant but with a far more limited distribution. Among these were the Large-mouthed valve snail (*Valvata macrostoma*), found mainly at Pevensey Levels, the beetles *Hydaticus transversalis* (south-western marshes), *Enochrus halophilus* (North Kent, Thames Estuary and Essex) and *Hydrochus elongatus* (Pevensey Levels). A case for using the snails *Segmentina nitida* and *Anisus vorticulus* as key indicators for grazing marshes has been made (Watson & Ormerod, 2004) but these are geographically very restricted so have limited leverage at a local level.

Evaluation of invertebrate assemblages and wetlands: key points

- Individual marshes and geographical areas were assessed using metrics for Species Richness, Species Conservation Status (threat and rarity), Habitat Quality (fidelity to grazing narsh) and Naturalness (lack of non-native species).
- The results were compared with the average scores for the whole dataset, using different standards for fresh and brackish systems. Fresh and brackish systems cannot be directly compared using the metrics because different thresholds are appropriate for each of the two habitat types.
- The areas with the highest average species-richness were the predominantly freshwater marshes in the Bure valley, Norfolk and the Pevensey Levels.
- The highest average Species Conservation Status Scores were for the Pevensey Levels, Walland Marsh and the predominantly brackish North Kent, Thames and Crouch areas.
- Average Habitat Quality Scores were highest in the North Kent and Thames areas.
- The three non-native species often present were the crustacean *Crangonyx pseudogracilis* and two snails: *Potamopyrgus antipodarum* and the more recent arrival, *Physella acuta*.
- 70 nationally rare or scarce invertebrates were recorded during the project, 47 of them beetles. Some of these species are closely associated with coastal grazing marshes.
- Nine UK BAP priority invertebrates were recorded, one of which, *Anisus vorticulus*, is protected under European legislation.
- The occurrence of the 21 nationally uncommon species found most frequently in the survey was examined in relation to environmental variables and vegetation groups.
- Many of these species were shown to have particular requirements related to both salinity and vegetation composition and structure (hydroseral stage).

Section 7 Change in vegetation over time

7.1 Setting standards for comparison using repeat surveys in Somerset

Possible change in the quality of ditch vegetation over time in the Somerset and Avon Moors and Levels and in Norfolk Broadland marshes was investigated using two methods. The first was based on comparison of the relative proportions of TWINSPAN end groups at different dates. The second method, used for Norfolk marshes where the raw data were available, involved the application of metrics for Plant Species Richness, Plant Species Conservation Status (PSCS), Habitat Quality and Naturalness (as described in Volume 1, Section 5 of this report and in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of grazing marsh ditch systems* (Palmer, Drake & Stewart, 2010)).

As explained in Section 2.6, an assessment of change in the quality of the vegetation using these metrics must take into account year-to-year variation (for example due to weather and normal ditch cleaning) that would be expected within an area undergoing no obvious change in management. However, some variation in these values often cannot be explained in terms of changes in management or obvious environmental conditions, and this too has to be considered when making comparisons between surveys undertaken many years apart.

To estimate the magnitude of variation in the metrics, the vegetation of twenty ditches in Somerset was sampled in all three years of the Buglife project, during which time there was no intentional change in management regime. This was to establish a 'bar' that must be exceeded before any differences between other surveys could be regarded as real.

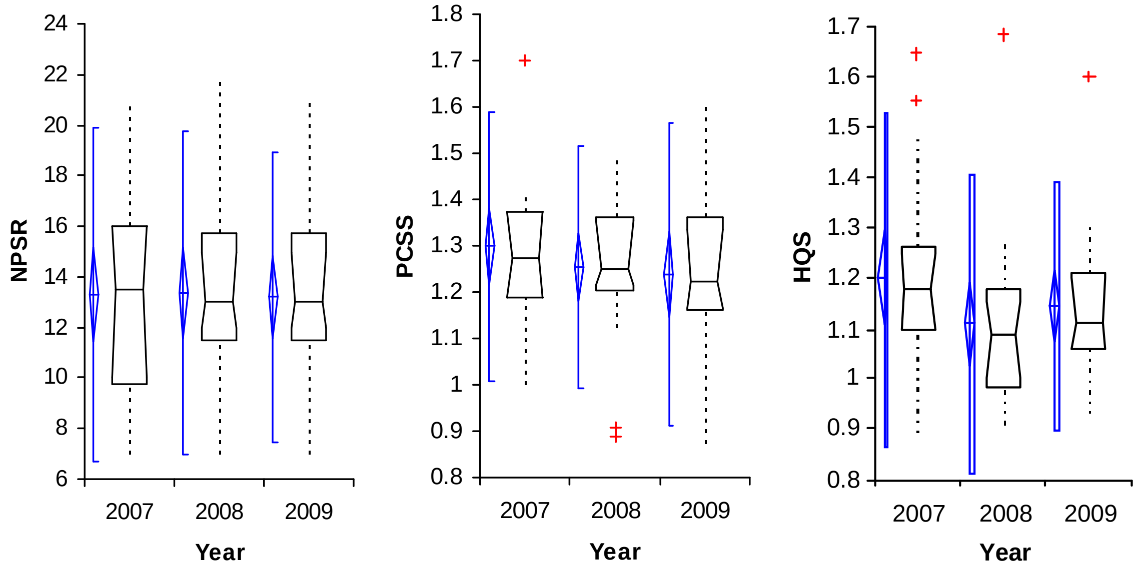
Plant Species Richness, Plant SCS Score, Habitat Quality Score and Naturalness Score were examined for the average and maximum changes over the three years. Details of the statistical methods used to establish the 'bar' are given in Appendix 5, Volume 2 of this report, as the same method was used for vegetation as for the invertebrate fauna.

The results of the analysis are given in Table 7.1 and Figure 7.1. Confidence limits are expressed as a percentage of each mean, to give an indication of the minimum that would represent real change in the properties of the species assemblage. Ditches experiencing no change in management could expect to show variation in means of up to 14% in Plant Species Richness, 8% in Plant Species Conservation Status Score and 8% in Plant Habitat Quality Score. Equivalent values for medians were 26% for Plant Species Richness, 9% for PSCS Score and 8% for Plant Community Naturalness Score. No confidence limits could be estimated for medians with only five samples per marsh. No meaningful levels could be set for Naturalness Score.

Table 7.1 Confidence limits expressed as a percentage of the mean or median of species metrics for 20 ditches in the Somerset Levels sampled over three years

Measure	Year	Plant Species Richness	Plant SCS Score	Plant Habitat Quality Score	Naturalness Score
mean	2007	14.2	6.3	7.9	17.6
	2008	13.6	5.9	7.5	21.5
	2009	12.4	7.5	6.2	29.8
median	2007	25.9	7.8	6.4	-
	2008	15.4	8.1	8.1	-
	2009	15.4	9.1	7.9	-

Figure 7.1 Mean and median values of three species metrics for 20 ditches in the Somerset levels sampled over three years.



If sampling sites are not selected randomly, comparisons between surveys should be undertaken using non-parametric methods. Real differences between surveys are indicated by median values that exceed the minimum likely change due to unexplained variation (i.e. ±26%, for Plant Species Richness, ±9% for Plant Species Conservation Status Score, ±8% for Habitat Quality Score).

Surveyors vary in their sampling efficiency and taxonomic expertise. Therefore, when comparisons are made between survey results, incomplete or obviously suspect datasets should be discarded.

7.2 Comparison of survey results in Norfolk Broadland using metrics

Raw data from a Nature Conservancy Council England Field Unit (EFU) survey of 1988-89 and a subsequent survey in 1997 (Harris *et. al.*, ?1998) for ditches in the Yare and Bure marshes were made available by Natural England. 65 of the ditches surveyed in 2009 were also surveyed on both of the previous occasions (28 in the Yare marshes and 37 in the Bure marshes) but raw data from the 1997 survey were only available for 28 of these.

The four plant metrics were applied to data from the 1988-89 and 2009 samples and the results were compared. They are shown in Table 7.2. As the 1997 survey covered only submerged and floating species, the same comparison could not be made with this dataset. A salinity index was calculated for 1988-89 and 2009, using the salinity tolerance scores for individual plant species, as described in Section 5.2.

The results indicate a fall in Species Richness between 1988-89 and 2009. However, there was a significant increase in Species Conservation Status Score and an increase in Habitat Quality Score, but one falling short of the ‘bar’. Unfortunately, there is doubt about some of the past records of *Oenanthe* species, one of which is the Red List species *O. fistuosa.* If a correction is made for this possible error, the SCS Score for the 1988-89 survey is increased and the difference in mean percentage change compared with 2009 is no longer significant (at 6%).

Median Naturalness Score had decreased, mainly because *Elodea canadensis* was more common and *Lemna minuta* was not recorded in 1988-89 but was widespread in 2009 (see Section 7.3).

There was a marked fall in salinity between 1988-89 and 2009, as indicated by the plant salinity index.

Table 7.2 Results of applying plant metrics to survey data in the Yare and Bure marshes

	Medians for 65 ditches		
	1988/9	**2009**	**% change**
Species Richness	14	13	-7
SCS Score	1.308	1.483	13
Habitat Quality Score	1.679	1.782	6
Naturalness Score	0	-2	-
Plant salinity index	0.49	0.40	-18

A flood prevention scheme for the Yare and Bure valleys has been instigated in recent years. This involves raising and widening the river banks to exclude saline and polluted water from the marshes, and digging new 'soak dykes' parallel to the rivers.

The somewhat contradictory results from the metrics can be explained by postulating that there has been an improvement in water quality in the ditches as a result of the flood defence works, and that this has so far resulted in a definite (but possibly not statistically significant) increase in the occurrence of rare species. The decrease in Species Richness may be due to a decrease in ditch dredging intensity, which has encouraged the growth of tall reedwamp vegetation. This, together with a build-up of silt, may have caused a decline in rooted submerged species (see also Section 7.3). This theory is substantiated by a comparison of the width, freeboard, silt depth and water depth for the 65 ditches in 1988-89 and 2009, as illustrated in Figures 7.2a, 7.2b, 7.2c and 7.2.d. Width was generally greater in 2009 than in 1988-89 because the water levels were higher (i.e. freeboard was less). Nevertheless, water depths were generally slightly less and consequently the smaller freeboards and depths are balanced by a significant increase in silt depths. The associated marked increase in tall emergent cover in these 65 ditches is shown in Figure 7.2e.

Figure 7.2a Comparison of ditch width in 1988-89 and 2009

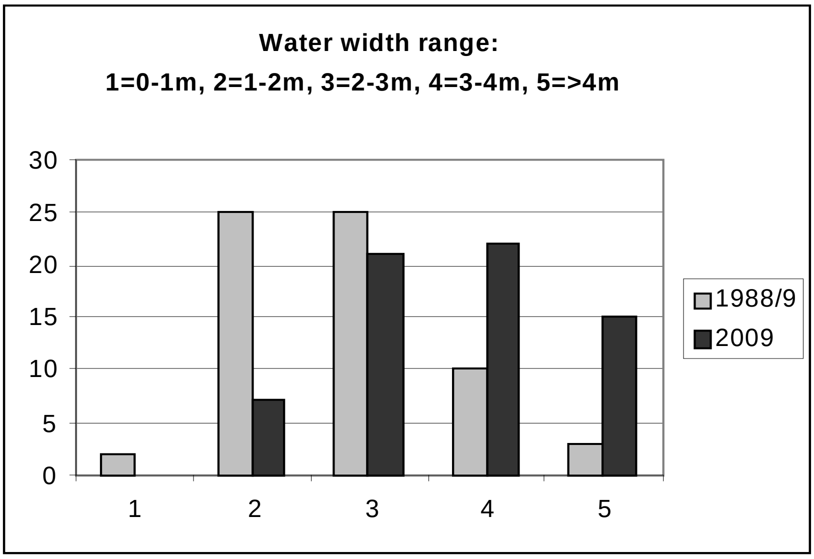


Figure 7.2b Comparison of freeboard in 1988-89 and 2009

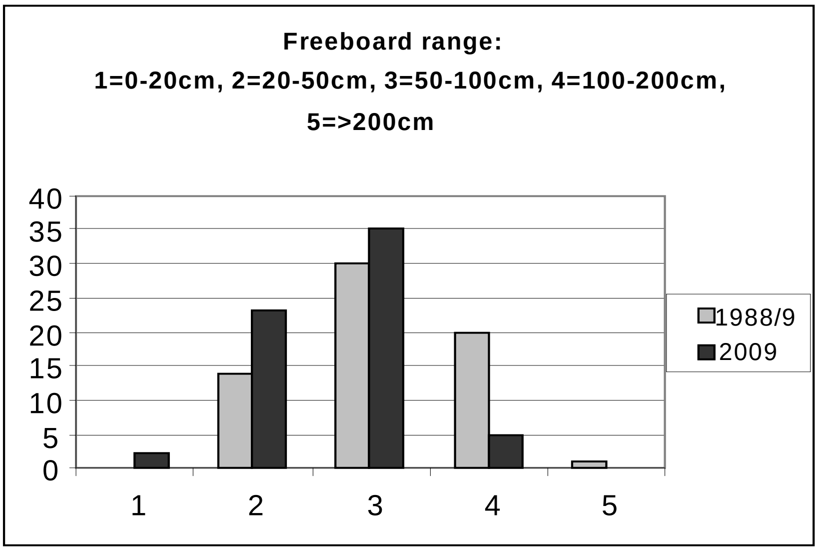


Figure 7.2c Comparison of silt depth in 1988-89 and 2009

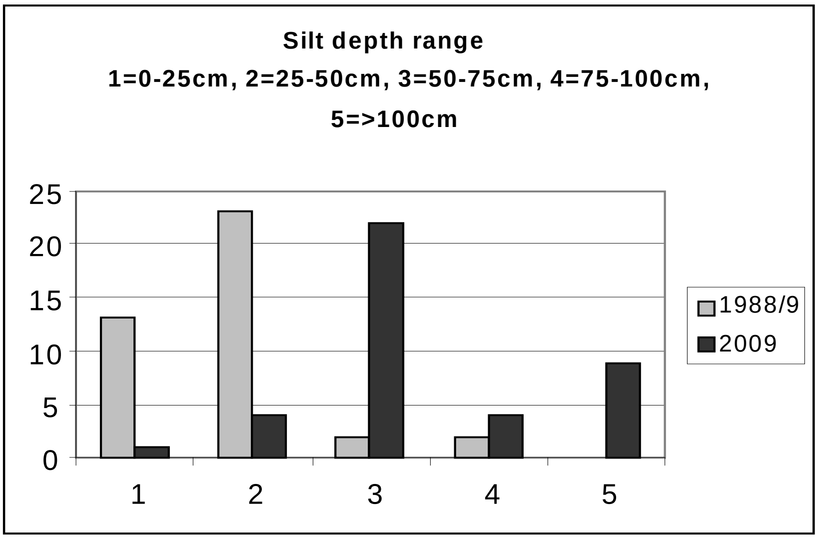


Figure 7.2d Comparison of water depth in 1988-89 and 2009

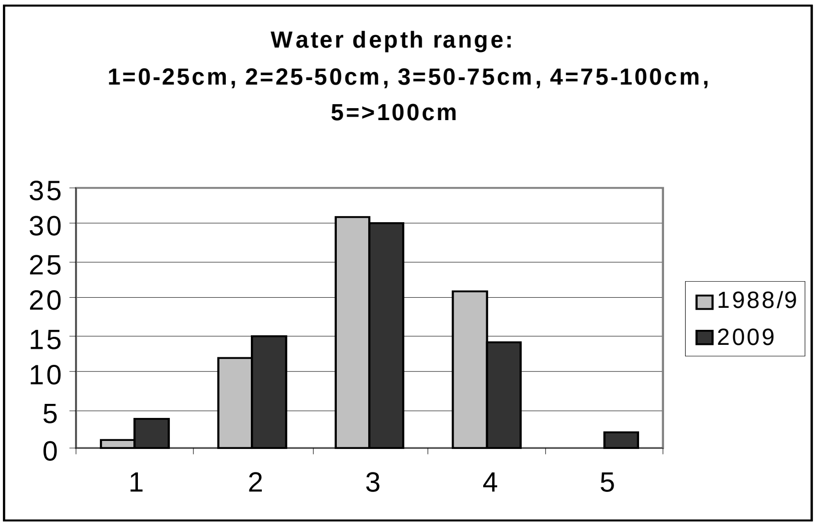
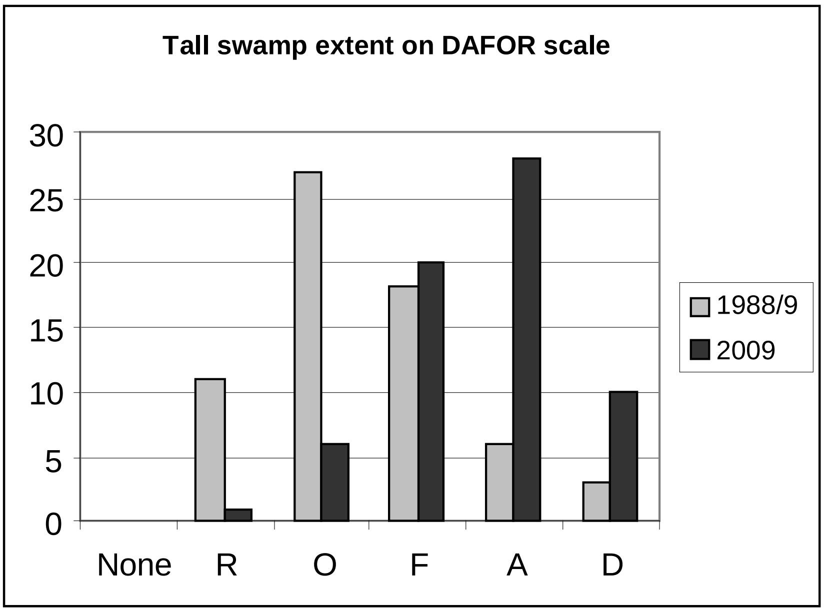
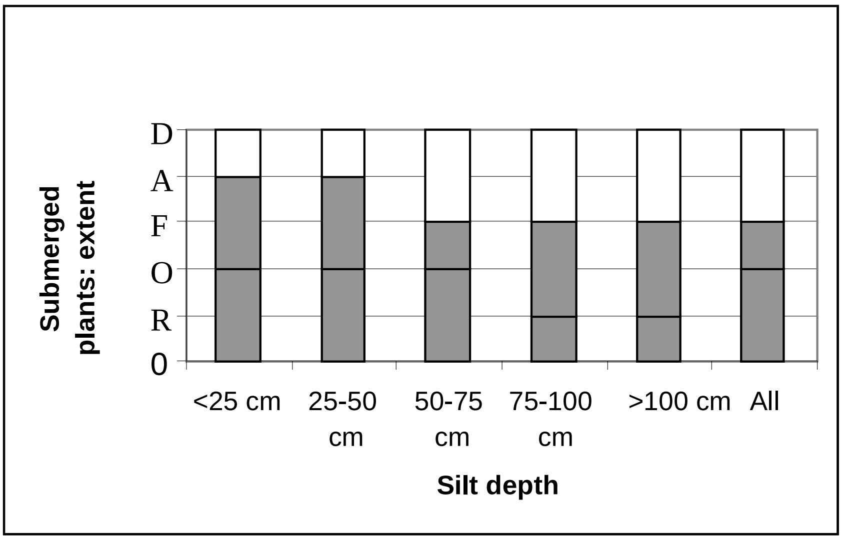


Figure 7.2e Comparison of tall swamp vegetation cover in 1988-89 and 2009



In the opinion of Natural England (Clive doarks, pers. com.) ditch cleaning in Norfolk Broadland marshes has recently been less intensive than previously. There has also been a trend towards weed cutting with a reciprocal bladed cutting bar rather than a hard bucket, which removes the vegetation but not the sediment. Figure 7.2f shows the average DAFOR cover of submerged plants other than *Lemna trisulca* in relation to silt depth, for all the freshwater ditches surveyed during the Buglife project. This supports the premise that a firm substate favours rooted submerged vegetation.

Figure 7.2f Cover of submerged plants (other than *Lemna trisulca*) in relation to silt depth



7.3 Change in individual species in the Yare and Bure valley marshes

Figures 7.3a, 7.3b and 7.3c show changes in the abundance of three key plant taxa, Gutweed (*Enteromorpha*), filamentous algae and Frogbit (*Hydrocharis morsus-ranae*), in 65 ditches in the Yare and Bure valleys, between 1998-89 and 2009. There has been a marked decline in the abundance of both types of algae and an increase in Frogbit. This change is probably a result of a general decline in salinity in the ditches and may also signal an improvement in other aspects of water quality.

Substantial changes in the occurrence of other plant species are shown in Table 7.3. Most of these decreases and increases can be explained by the changes in the management of the marshes postulated in Section 7.2. Floating bur-reed (*Sparganium emersum*), which decreased by over 60%, is tolerant of dredging and can be excluded by tall emergents such as Branched bur-reed (*Sparganium erectum*) (Preston & Croft, 1997). The apparent disappearance of Flat-stalked pondweed (*Potamogeton friesii*) may be explained by competition with tall reedswamp, but this explanation does not hold good for Whorled water-milfoil (*Myriophyllum verticillatum*), which had increased. As might be expected, Frogbit and Water-soldier (*Stratiotes aloides*), which are intolerant of brackish water, increased, whereas Fennel-leaved pondweed (*Potamogeton pectinatus*), which is tolerant of both salinity and pollution, decreased.

Non-native species had increased. *Elodea canadensis* had increased in occurrence by 50% and *Elodea nuttallii* had arrived, although it was present in only a single ditch. The non-native duckweed *Lemna minuta* either had not reached Broadland by 1988-89 or it was not recognised and was recorded as the very similar native Common duckweed (*Lemna minor*).

Figure 7.3a Relative abundance of *Enteromorpha* on two survey dates

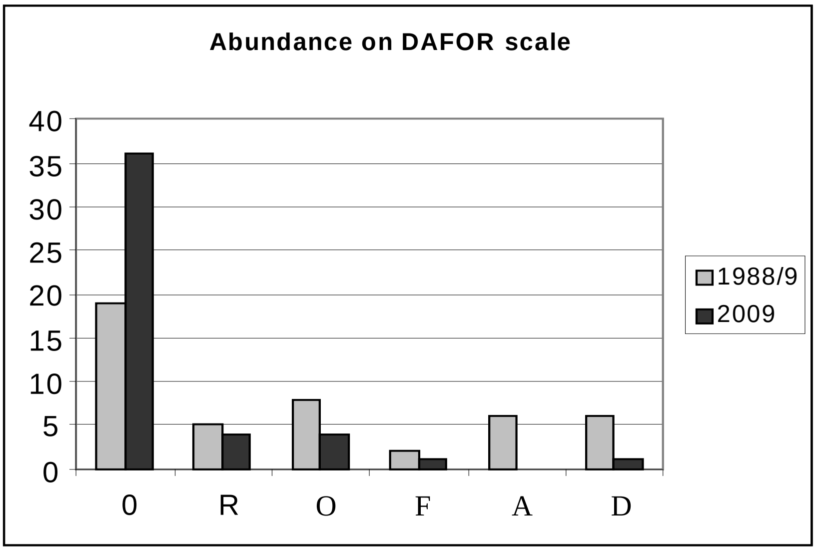


Figure 7.3b Relative abundance of filamentous algae on two survey dates

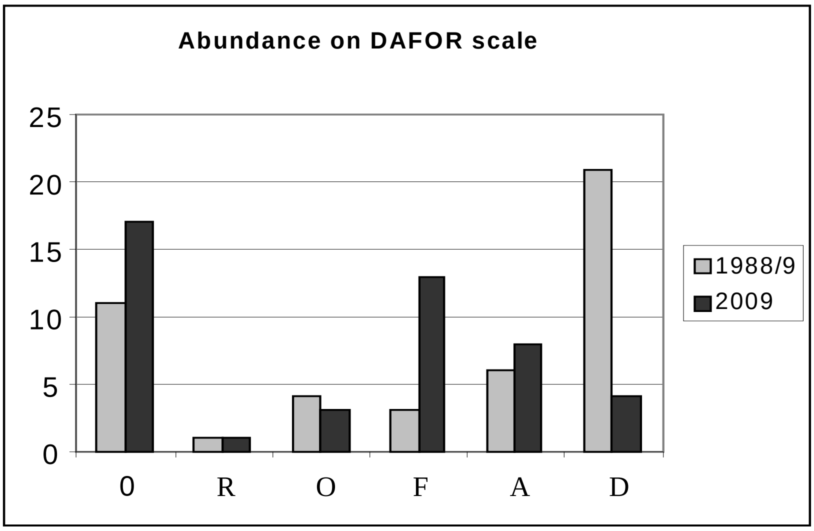


Figure 7.3c Relative abundance of Frogbit on two survey dates

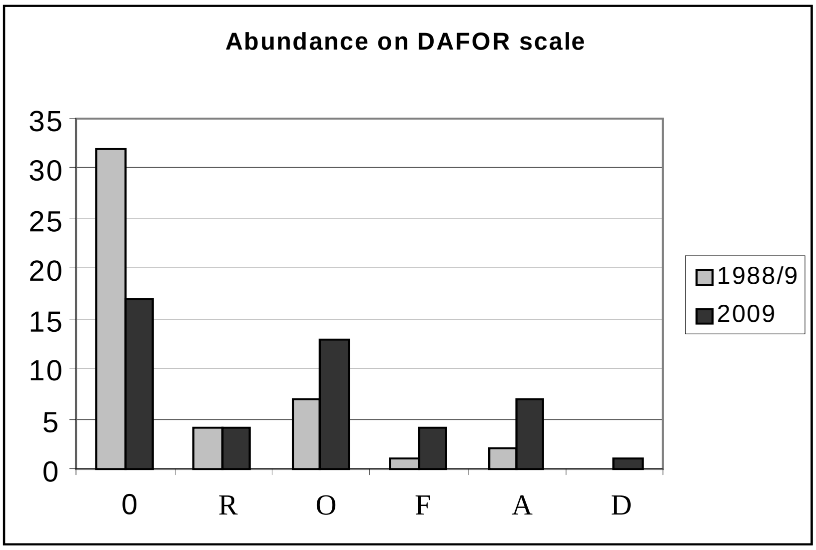


Table 7.3 Changes in some key species between 1988-89 and 2009

Submerged and floating aquatic species	No. of records in 1988-89	No. of records in 2009	% change since 1988-89
Potamogeton friesii	15	0	-100
Enteromorpha sp.	34	13	-62
Sparganium emersum	13	5	-61
Potamogeton pectinatus	13	6	-54
Ceratophyllum demersum	16	10	-37
Hottonia palustris	4	6	50
Myriophyllum verticillatum	7	11	57
Stratiotes aloides	10	16	60
Hydrocharis morsus-ranae	23	45	96
Elodea canadensis	12	18	50
Lemna minuta	0	31	++

7.4 Comparison of survey results in Norfolk Broadland using vegetation classification

7.4.1 The England Field Unit classification

The EFU classification of aquatic (floating and submerged) vegetation in Broadland identified the following ditch types, using data from an extensive survey carried out in 1988-89 (Doarks & Leach, 1990):

- Group A1 – mesotrophic; shallow; peaty; constant species Floating-leaved pondweed (*Potamogeton natans*) and Floating club-rush (*Eleogiton fluitans*)
- Group A2 – mesotrophic; mostly on peat; constant species: Floating-leaved pondweed, Water-violet (*Hottonia palustris*) and Whorled water-milfoil (*Myriophyllum verticillatum*); species-rich
- Group A3 – meso-eutrophic; constant species: Floating-leaved pondweed, Frogbit (*Hydrocharis morsus-ranae*) and Water-soldier (*Stratotes aloides*); A3a is species-rich but A3b is less so.
- Group A4 – large dykes on peat; constant species Rigid hornwort (*Ceratophyllum demersum*)
- Group A5 – eutrophic (A5a) or eutrophic to slightly brackish (A5b); constant species duckweeds (*Lemna*) species and algae; A5a species-rich, A5b species-poor.
- Group A6 – newly dredged or dry out; constant species: starworts (*Callitriche* species); species-poor
- Group A7 – eutrophic to mildly brackish (A7a) or oligohaline to mesohaline (A7b); constant species: filamentous algae and gutweed (*Enteromorpha*) in A7a, Fennel-leaved pondweed (*Potamogeton pectinatus*) and Spiked water-milfoil (*Myriophyllum spicatum*) in A7b; species-poor.

7.4.2 Changes between 1972-74 and 1997

The EFU classification was used retrospectively to classify unpublished data from 294 of the same ditches surveyed by Driscoll in 1972-74 (Doarks, 1990). The aquatic vegetation observed on two occasions fifteen years apart could then be compared. Doarks found that in Broadland as a whole end-groups A2, A3a, A3b and A4, typical of less nutrient-rich conditions, had suffered a net loss of 51%, 52%, 26% and 43% respectively. Conversely, groups A5a, A5b and A6, typical of eutrophic conditions, had increased by 16%, 34% and 25% respectively. The group showing the greatest increase, however, was the eutrophic/brackish group A7a, at 126%. A7b had increased by only 5%. The small A1 group had doubled in size, possibly as a result of its occurrence on acid sulphate soils. Apart from this, the general pattern across Broadland was a gain in eutrophic and brackish assemblages at the cost of the more mesotrophic and highly regarded vegetation groups.

In 1997 the exercise was repeated on new survey data for 2763 ditches (Harris *et al.*, ?1998) and a continued loss of most of the species-rich freshwater communities was apparent. 64% of all dykes supported species-poor degraded or algal-dominated communities. There was no increase in the exclusively brackish community A7b, but there was a 50% increase in algal-dominated dykes of group A7a, apparently because of nutrient enrichment of freshwater dykes. Sub-optimal dyke management was considered to be a contributory factor in this deterioration, as many dykes were in a state of 'neglect'.

7.4.3 Change up to 2009

In 2009, 45 ditches were sampled in the Bure valley marshes and 30 in the Yare valley. Of these, all but ten were matched with ditches sampled in both 1988-89 and 1997. The key provided by Doarks (1990) was used to classify the 65 samples from the 2009 survey according to aquatic EFU end-groups. As the vegetation group for each sample for both of the previous surveys was known, a direct comparison could be made. This contrasted with the situation described in Section 7.4 for Somerset and Avon, where the proportions of end groups in different sized datasets were compared. The results for Norfolk are shown in Figures 7.4.3a, 7.4.3b and 7.4.3c.

Figure 7.4.3a Proportions of EFU vegetation groups for 30 ditches in the Yare valley

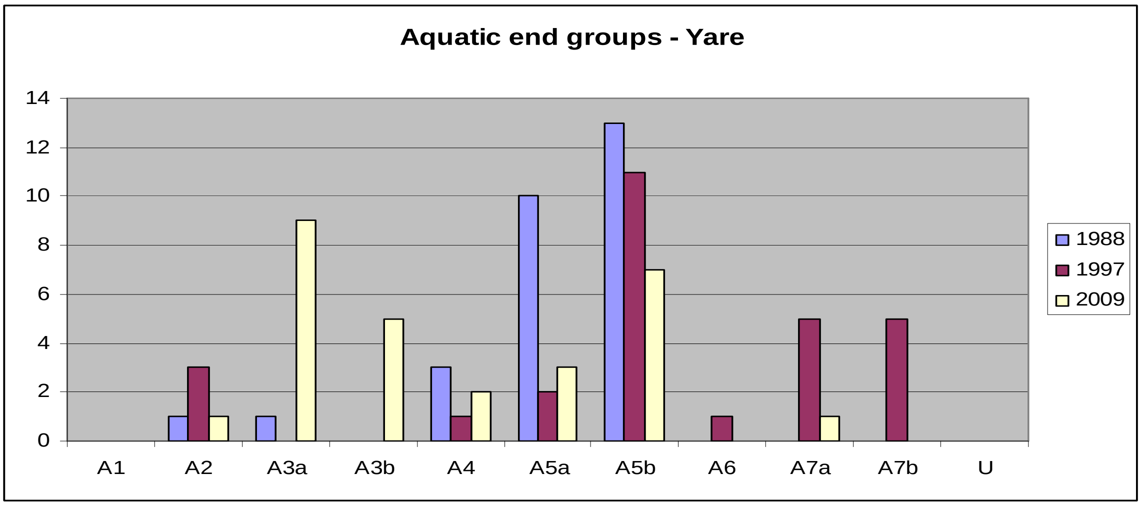


Figure 7.4.3b Proportions of EFU vegetation groups for 45 ditches in the Bure valley

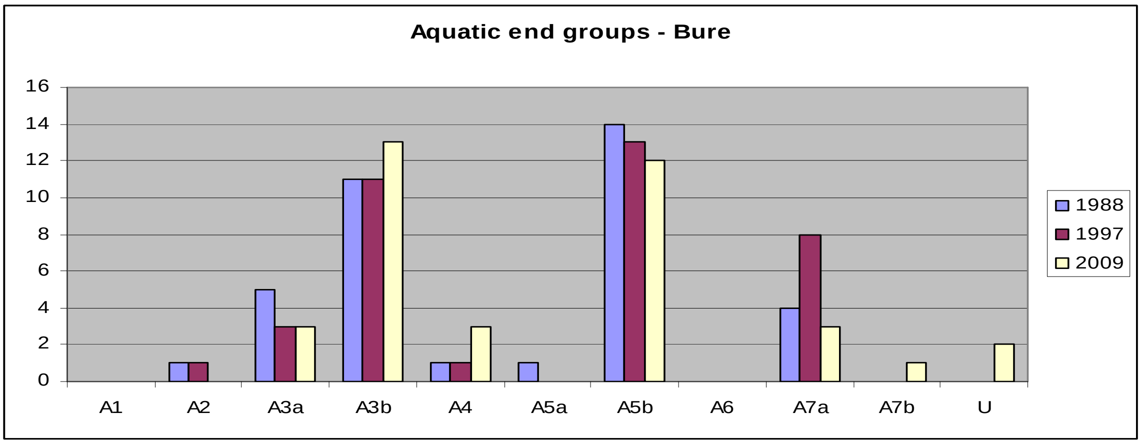
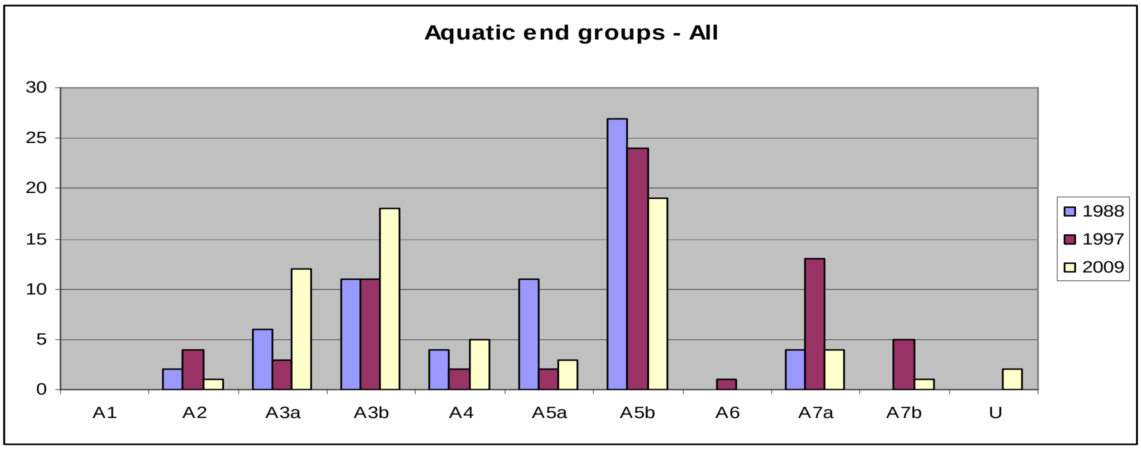


Figure 7.4.3c Proportions of EFU vegetation groups for 65 ditches in the Yare and Bure valleys



For these two valleys in Broadland, the figures indicate a possible slight decrease between 1988-89 and 1997 in the species-poor eutrophic duckweed group A5b, but a marked increase in the algal-dominated group A7a. However, by 2009, the proportion of ditches in the meso-eutrophic Frogbit / Water-soldier groups (A3a and A3b) had increased and the proportions in both the species-poor eutrophic duckweed group (A5b) and the algal-dominated group (A7a) had decreased. This was particularly pronounced in the Yare valley, where the majority of the samples were taken from inside SSSIs. Here, the five saline group A7b ditches identified in 1997 had moved into freshwater groups. These results imply a reversal of the previous trend and an improvement in water quality.

7.5 Summary for Norfolk

A general improvement in the quality of the aquatic flora of the Yare and Bure valley marshes over the last two decades was demonstrated by each of the three assessment methods. The fact that all three methods point to the same conclusion strengthens the argument. There do seem to be a few ‘losers’, such as Flat-leaved pondweed (*Potamogeton friesii*), and an increase in the percentage cover of emergent species, implying that the balance is tipping towards a preponderance of reedswamp vegetation.

The general improvement is heartening, although it is not possible from this limited investigation to extrapolate to the whole of Broadland. These improvements are likely to be linked to improved management with nature conservation in mind, through the mechanisms of the ESA and SSSI system. In particular, the less intensive use of fertiliser or manure on fields within the grazing marsh systems may have resulted in reduced levels of nutrients entering the ditches. Raised water levels may also be a factor, although the benefit of this depends on the source of the water feeding the marsh systems. The flood defence work on the river banks seems to have been of definite benefit to the ditch flora.

7.6 Comparison of survey results in Somerset and Avon using vegetation classification

7.6.1 Method

As described in Section 3, Wolseley *el al.* (1984) produced a TWINSPAN classification of 512 ditch vegetation samples in Somerset, recognising assemblages with the following characteristics:

- Groups 1-3: dominated by algae
- Groups 4-7: dominated by floating vegetation including Fat duckeed (*Lemna gibba*); Frogbit (*Hydrocharis morsus-ranae*) at fairly low constancy; species-poor
- Groups 8, 9a and 9b: open vegetation with Ivy-leaved duckweed (*Lemna trisulca*), Frogbit, Greater duckweed (*Spirodela polyrhiza*) and submerged plants such as Canadian waterweed (*Elodea canadensis*)
- Groups 10 and 11: partially closed vegetation; Ivy-leaved duckweed and Frogbit, with swamp plants prevalent
- Groups 12-14: closed swamp vegetation with Branched bur-reed (*Sparganium erectum*), Common reed (*Phragmites australis*) or Reed sweet-grass (*Glyceria maxima*) dominant.
- Groups 15 and 16: very shallow or dry ditches.

Groups 8 to 11 are species-rich and indicative of less eutrophic conditions than groups 1 to 7.

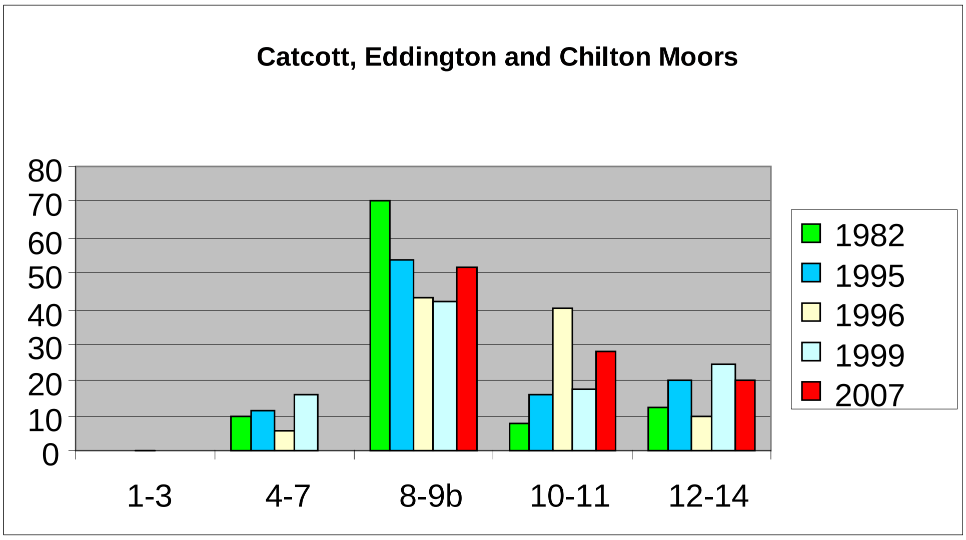
174 vegetation samples collected in 2007 from seven moors in Somerset were classified according to the Wolseley system, using the TWINSPAN key from Wolseley *el al.* (1984). The proportions of the various ditch vegetation groups in the 2007 dataset were compared with the proportions in the initial survey and in subsequent surveys that used the same classification system (Cadbury, 1995; Carter, 1998; Henderson 1985; Hughes, 1995; Nisbet 2000a, 2000b; Pollock *et al.*, 1992; Prosser & Wallace 2000; Walls, 1996, 1997). As the 2007 survey was extensive and had endeavoured to cover a representative sample of ditch types, it was considered that trends could be implied from the comparison. However, very

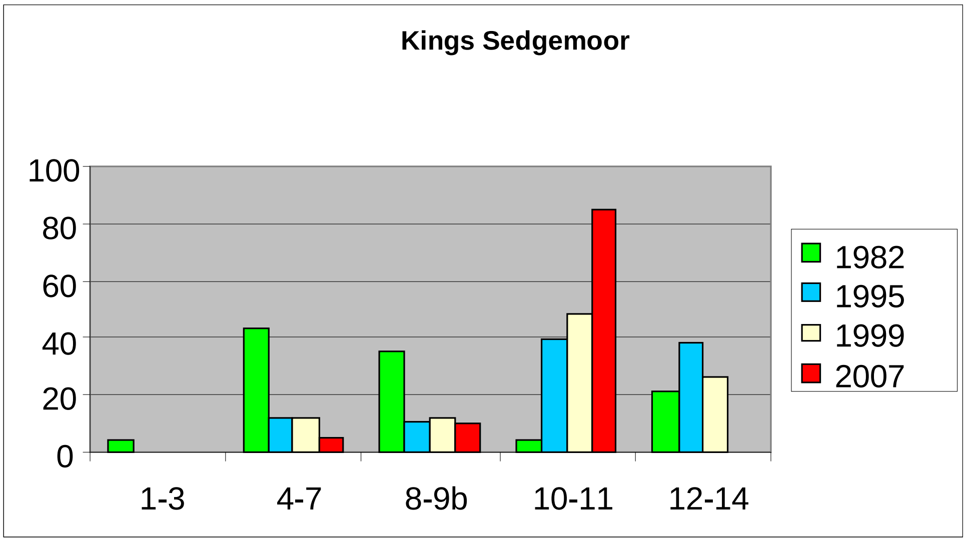
shallow and dry ditches were not sampled in 2007, so no comparisons were made for Groups 15 and 16.

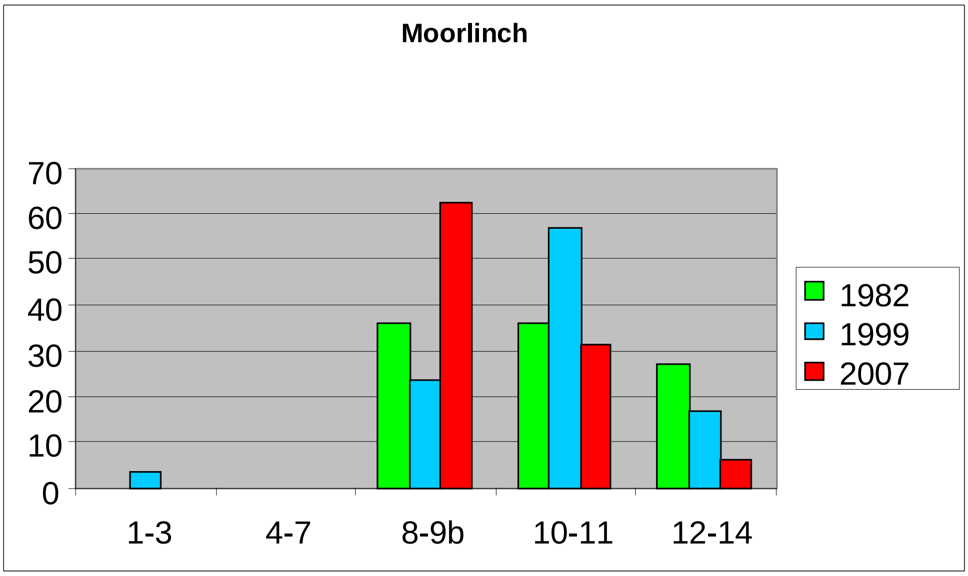
7.6.2 Results of the comparison

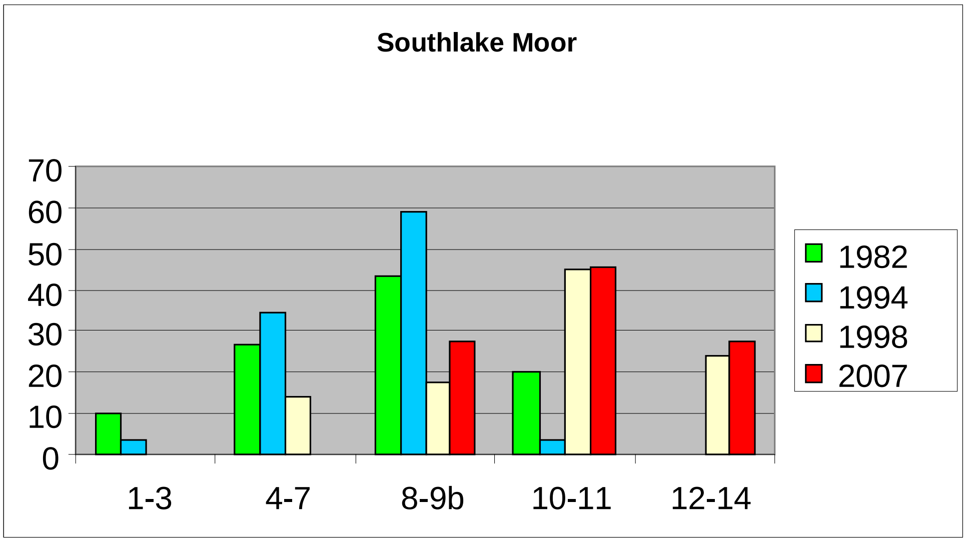
The results of the comparison are shown in Figure 7.6.2.

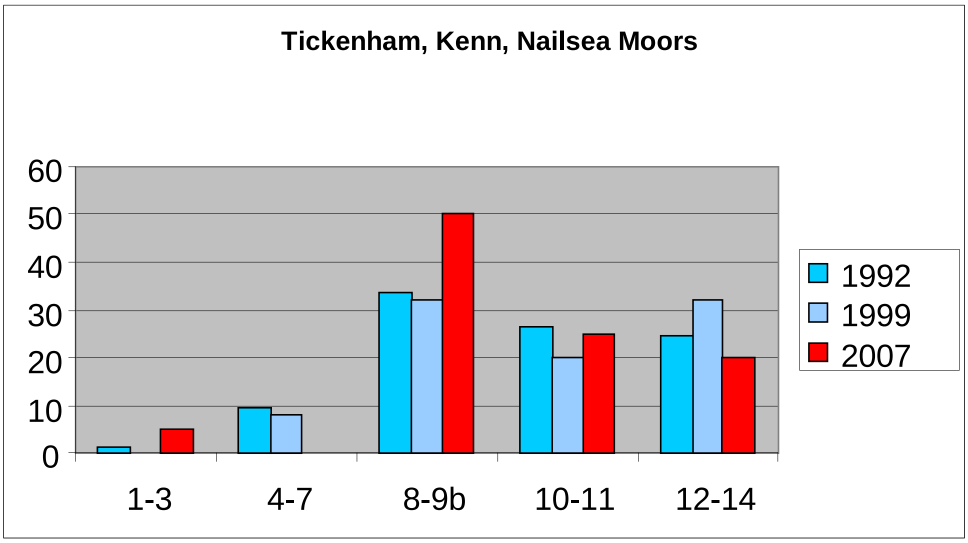
Figure 7.6.2 % of Wolseley end-groups in various surveys

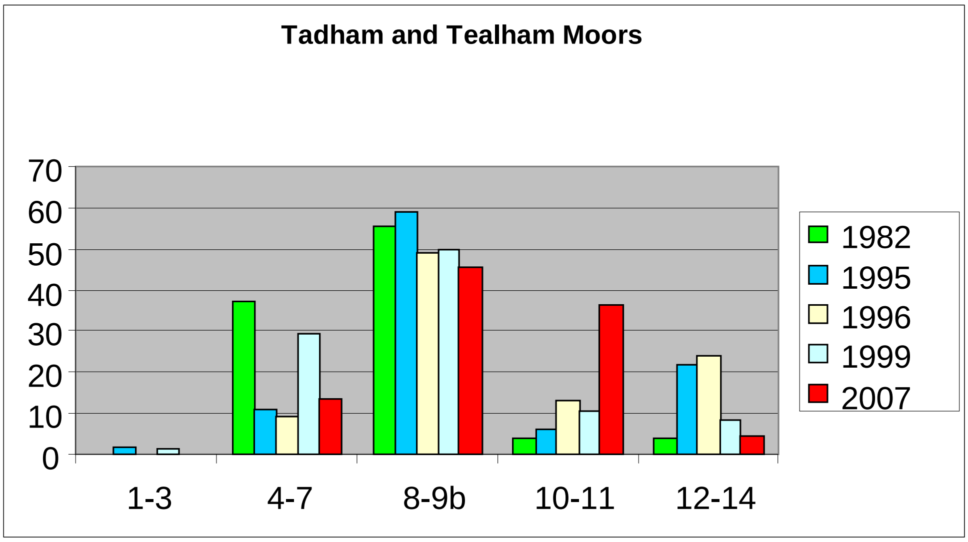


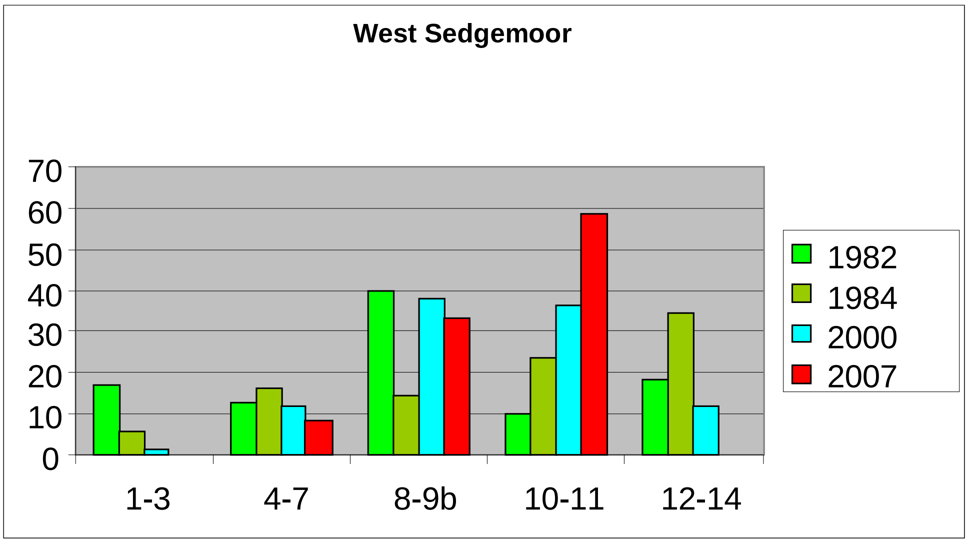



Moorlinch
70
60
50
40
30
20
10
0
1-3
4-7
8-9b
10-11
12-14
1982
1999
2007


Southlake Moor
70
60
50
40
30
20
10
0
1-3
4-7
8-9b
10-11
12-14
1982
1994
1998
2007


Tickenham, Kenn, Nailsea Moors
60
50
40
30
20
10
0
1-3
4-7
8-9b
10-11
12-14
1992
1999
2007





At Catcott, Eddington and Chilton Moors the species-poor groups 1-7 were not represented in 2007, otherwise the proportions of the communities appeared to be not much different from previous surveys.

There were rather few open water ditches at Kings Sedgemoor in 1995 and 2007, compared to 1982. However, by 2007 there had apparently been a marked increase in the proportion of ditches with partially closed swamp vegetation (groups 10 and 11) but there were no completely closed ditches (groups 12-14) in the sample. This result implies that overgrown ditches had been restored.

At Moorlinch, where the species-poor groups 1 to 7 were not represented in any of the surveys, there was an apparent increase in 2007 in open water ditches (groups 8, 9a and 9b) at the expense of ditches with more closed vegetation (groups 10 to 14).

In 1998 and 2007, reedswamp (as indicated by groups 12-14) and mixed vegetation (groups 10 and 11) at Southlake Moor appeared to show an increase at the expense of the open water groups. Results implied a loss of species-poor groups (4-7) in 2007 and an increase in the more species-rich open water types (groups 8-9b). This result indicates an overall improvement in habitat quality. It is supported by the results of Natural England's Common

Standards Monitoring because, unlike other SSSI wetlands in Somerset, the condition of Southlake Moor was considered to be favourable (see www.naturalengland.org.uk).

At Tickenham, Kenn and Nailsea SSSI in Avon, there appeared to be a slight increase in the proportion of open water ditch types since the 1990s and a slight reduction in the eutrophic groups 1-7.

Species-poor groups 1 to 7 showed a decrease at Tadham and Tealham Moors, especially when compared with the original Wolseley survey. The proportion of ditches with open vegetation (groups 8 to 9b) appeared to remain stable over the years, but partially closed vegetation increased.

At West Sedgemoor the main trend seemed to be for fewer ditches with closed swamp vegetation and more with a mixture of open water and swamp vegetation (groups 10 and 11).

These results are not produced from direct comparisons of individual ditches because the surveys varied in their coverage. However, the overall impression is that in Somerset and Avon SSSIs there has been a trend since the 1980s away from species-poor eutrophic ditch types (groups 1-7) to ditches with more species-rich vegetation, either the open water types (groups 8-9b) or the types containing a mixture of swamp and open water vegetation (groups 10-11).

Change in vegetation over time: key points

- The magnitude of variation that can be expected in data from repeat sampling of ditches under a stable management routine was estimated by comparing results from the same 20 ditches in Somerset, sampled for their plants in all three years of the project.
- The annual variation in three metrics applied to the results indicated that comparisons between surveys need to show differences in median values that exceed 26% for Plant Species Richness, 9% for Plant SCS Score and 8% for Plant Habitat Quality Score.
- Results of previous surveys of ditch vegetation in Norfolk Broadland and Somerset were compared with results from 2009 and 2007.
- In Norfolk, data were compared in three ways: by using metrics for Species Richness, Species Conservation Status, Habitat Quality and Naturalness, by examining the occurrence of individual key species, and by comparing the relative proportions of various ditch vegetation types. All three methods indicated similar trends.
- In Norfolk, species-poor vegetation associated with eutrophic and brackish water had decreased and the distinctive Water-soldier / Frogbit vegetation, typical of meso-eutrophic conditions, had become more prevalent.
- These changes are likely to be linked with less intense fertilisation of fields and local decline in salinity as a result of flood defence works.
- There are indications that water levels are now maintained at a higher level.
- Deeper silt and an increase in swamp vegetation are likely to be linked to less intensive ditch management in Broadland.
- The comparison for Somerset was based on change since 1982 in the relative proportions of ditch vegetation types.
- Some improvement in the quality of the vegetation was apparent in Somerset, because plant assemblages typical of good water quality had increased at the expense of those indicative of more eutrophic conditions.

Section 8 Change in the invertebrate fauna over time

8.1 Setting standards for comparison using repeat surveys

The main method used to evaluate invertebrate assemblages was comparison of metrics for Species Richness, Species Conservation Status (SCS), Habitat Quality (based on species fidelity to the grazing marsh habitat) and Naturalness (based on the impact of non-native species), as discussed in Section. For a full explanation of the scoring system see *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of grazing marsh ditch systems* (Palmer, Drake & Stewart 2010). As explained in Section 2.6, ten ditches in Somerset were sampled for invertebrates in each of the three years of the survey, in order to establish the extent of variation in the metrics, and to use this as a 'bar' that must be exceeded before any differences in results between surveys can be regarded as real.

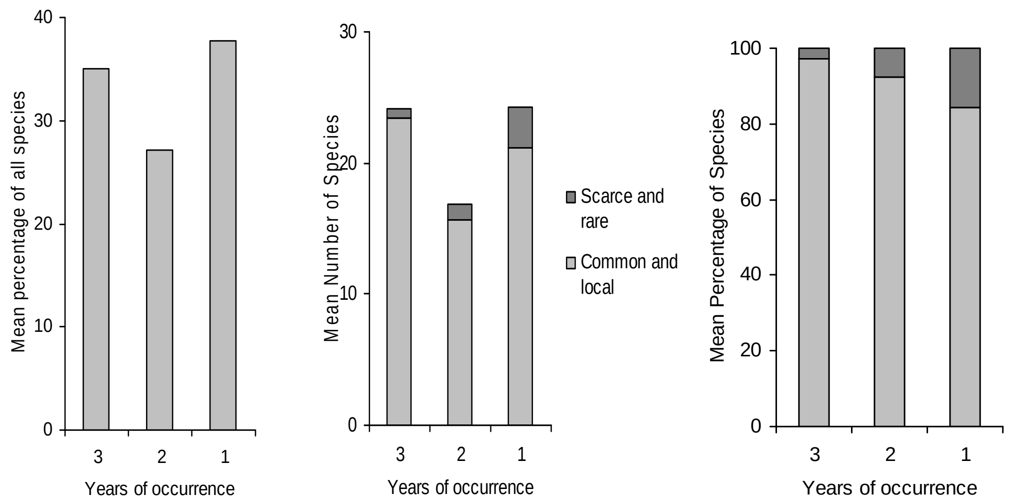
Species Richness, SCS Score and Habitat Quality Score were examined for the average and maximum changes. Naturalness values were nearly all the same due to the nearly ubiquitous occurrence of the non-native amphipod *Crangonyx pseudogracilis*, so this metric was not considered further.

Details of the statistical methods used to establish the 'bar' and a full discussion of the results are given in Appendix 5, Volume 2 of this report. There were no significant differences between mean values of Species Richness, SCS Score or Habitat Quality Score between years or across the period. This indicated that conditions in the ditches had been fairly stable over the three years, despite the fact that two ditches were cleaned out during the period as part of the normal management cycle.

About one third of all species were found in all three years and almost half the species recorded in a ditch are unlikely to be found in a single repeat survey. Only a small core was found repeatedly. This suggests either that surveys miss a large number of species or that species fluctuate considerably. It is likely that both factors contribute. Commoner species were more likely to be found in all three years, and rare ones were more likely to occur in just one year (Figure 8.1). This result was partly expected since nationally rare species were also rarer in the samples.

Figure 8.1 Numbers of species occurring in one, two or three years in ten ditches on the Somerset Levels

Mean percentage of all species (left), mean number of commoner and rarer species per ditch (centre) and the same data expressed as the mean percentage.



The analysis of results from the repeat survey in Somerset indicate that the ‘confidence bar’ is high: comparisons between surveys need to show differences in mean and median values that exceed 11% or 22%, respectively, for Species Richness, 7% or 11% for SCS Score, and 5% or 8% for Habitat Quality Score. Nationally rare and scarce species should not be expected to be re-found in up to about half the surveys. As samples in many surveys were not selected randomly, comparisons between surveys must be undertaken using non-parametric methods. Real differences between surveys are indicated by median values that exceed the minimum likely change due to unexplained variation (i.e. ±22%, for Species Richness, ±11% for SCS Score, and ±8% for Habitat Quality Score). These minima are likely to be conservative. SCS Score is likely to be a more reliable measure of change than Species Richness.

Surveyors vary in their sampling efficiency and in their taxonomic expertise. Therefore, when comparisons are made between survey results, less complete or obviously suspect datasets should be discarded. Great care should be taken when dealing with data obtained through different sampling methods. The assessments of change undertaken in this report rely heavily on previous surveys undertaken by Drake in Somerset, Essex, Suffolk, Norfolk and Gwent. In these cases, observer bias can be discounted, as the sampling method has remained the same over many years.

8.2 Comparison of survey results: Somerset and Avon

8.2.1 Comparison of marshes over time using the species metrics

Data from many surveys (going back to 1979) and covering many of the marshes investigated in 2007-2009 were digitised and converted to lists of records of target aquatic taxa. The final lists included c. 25,000 records from the 2007-2009 surveys and c. 60,390 records from others, making a total of c. 85,390 records. Gordano Moor was not surveyed in the Buglife project but data were available from a survey by Drake in 2004. The old surveys used in these comparisons are listed in Volume 2, Appendix 1.

Metrics for Species Richness, SCS, Habitat Quality and Naturalness were calculated for past and 2007 data to investigate possible increase or decrease in the conservation value of the marshes, using the threshold of variation of 22% in median Species Richness, 11% in SCS Score and 8% in Habitat Quality Score. Examination of conductivity measurements and the salinity tolerance of species showed that all the ditches contained fresh water.

For the nine marshes, metrics were applied to data from past surveys and from the 2007 survey. There was no evidence to show deterioration in the fauna of any of the marshes, but there were significant differences between medians for Species Richness and/or SCS Score for some marshes at different dates:

- Catcott, Chilton and Eddington: a significant increase in SCS Score since 1983
- Gordano: no significant differences were found
- Kenn, Nailsea and Tickenham: SCS Score had increased significantly
- Kings Sedgemoor: a slight and steady improvement over the years, although this fell within the band of uncertainty due to unexplained variation
- Moorlinch: Species Richness and SCS increased significantly between 1983 and 2007
- Pawlett Hams: no change could be detected
- Southlake: weak evidence for a gradual increase in SCS Score, but falling short of the ‘bar’
- Tadham and Tealham: a real increase in Species Richness between 1994 and 2007 but only weak evidence for an increase in SCS Scores since the 1980s.
- West Sedgemoor: a possible but unsubstantiated increase in Species Richness and SCS Score over time.

8.2.2 Changes in individual species abundance and distribution

Changes in the proportions of single species were tested using a chi-squared test. Most were essentially unchanged in their occurrence but some changes were demonstrated.

Examples of decline
Two nationally very common water-surface dwellers have declined: the skater *Gerris lacustris* and the whirligig *Gyrinus substriatus*. This may reflect increases in floating duckweeds. Three diving beetles, *Agabus sturmii*, *Hydroporus erythrocephalus* and *Laccophilus minutus*, have all declined from common to occupying a small proportion of ditches. *Agabus sturmii* and *L. minutus* have different habitat preferences, the former being typical of grassy margins and the latter of more open conditions, so their decline may not have a common underlying cause. The decline of common and widespread species is unexplained and of concern, especially in the light of the slow national decline documented for common moths and butterflies (Fox *et al*., 2006a, b).

There was weak evidence that the hoglouse *Asellus meridianus* was becoming rarer in the Somerset Moors. The Large red damselfly (*Pyrrhosoma nymphula*) appeared to have become much less frequent than in the 1980s, but its near absence from many surveys since 1995 may be due to increasingly early emergence as springs have become warmer, leading to its conspicuous larvae being missed by aquatic sampling after mid April. The small diving beetle *Porhydrus lineatus* appeared to be in overall decline but had better populations on the clay moors and levels than on peat.

Examples of increase
The snail *Bithynia leachii* was considerably more frequent in the 2000s than in the 1980s. The large soldierfly *Stratiomys singularior* may also have increased in frequency since the 1990s. Two unmistakable large bugs, the Saucer bug (*Ilyocoris cimicoides*) and the Water stick insect (*Ranatra linearis*), appear to have increased in Somerset and are also reported to be on the increase in Norfolk (Driscoll, pers. com.). These species have southerly distributions in Britain and it has been suggested (Huxley, 3002) that *Ilyochoris cimicoides* is extending its range northwards. This may be a response to climate change. The distinctive beetle *Hydaticus seminiger* appears to be a recent arrival in Somerset, with the first record from Gordano in 2004 and 14 from the 2007 Buglife survey.

Two non-native species, the snail *Physella acuta* and the North American isopod crustacean *Crangonyx pseudogracilis*, had increased in frequency in the last thirty years. *Potamopyrgus antipodarum* was fairly scarce in the Somerset Moors but had a more persistent population at the coastal Pawlett Hams, where mildly brackish conditions suite this snail. *Physella acuta* was unlikely as yet to have had much impact, but the amphipod was ubiquitous and may have had some impact on the native fauna.

8.2.3 Summary for Somerset and Avon

There was no indication of a decline in overall quality on any Somerset moor and, on most there was a moderate to high possibility that either species richness or SCS Score (or both) had increased over the last three decades. There appeared to be no change at Pawlett Hams or Gordano Moor. This positive result probably reflects the input of conservation effort on these SSSIs since their notification in the early 1980s. Most species showed no change in abundance over time but 18 appeared to have increased in frequency and 9 appeared to have declined.

The species that showed a significant increase or decrease are listed in Table 8.2.3.

Table 8.2.3 Species that have increased and decreased in Somerset and Avon

Increase	National status	Decrease	National status
Snails			
Bithynia leachii	Local	*Aplexa hypnorum*	Local
Hippeutis complanatus	Local		
Physella acuta	Non-native		
Beetles			
Agabus bipustulatus	Common	*Agabus sturmii*	Common
Colymbetes fuscus	Common	*Gyrinus substriatus*	Common
Enochrus coarctatus	Local	*Haliplus fluviatilis*	Common
Helophorus minutus	Common	*Haliplus heydeni*	Local
Hydaticus seminiger	Nationally Scarce	*Hydroporus erythrocephalus*	Common
Noterus clavicornis	Common	*Laccophilus minutus*	Common
Ochthebius dilatatus	Local	*Suphrodytes dorsalis*	Local
Ochthebius minimus	Common		
Bugs			
Ilyocoris cimicoides	Common	*Gerris lacustris*	Common
Microvelia reticulata	Common		
Ranatra linearis	Local		
Flies			
Odontomyia ornata	Red List Vulnerable		
Stratiomys singularior	Nationally Scarce		
Dragonflies			
Anax imperator	Common		
Crustaceans			
Crangonyx pseudogracilis	Non-native		

8.3 Comparison of survey results: Essex

8.3.1 Comparison of marshes over time using the species metrics

Eight surveys have been undertaken in the Essex marshes that were re-surveyed in 2009 (Volume 2, Appendix 1 Table 1.2). Altogether, 287 ditches in Essex were used in comparisons. For each sample, scores for Species Richness, Species Conservation Status, Habitat Quality and Naturalness were calculated, and the medians and interquartile ranges estimated for a whole marsh.

Inner Thames Marshes
The Inner Thames Marshes SSSI consists of two parts, Aveley and Wennington Marshes and Rainham Marsh. The Inner Thames Marshes SSSI was selected for survey in the Buglife project because it differed from many Essex marshes in supporting fewer brackish-water species and having a fairly high species-richness. It had also been well surveyed at approximately decade intervals.

Comparison of previous and 2009 survey data for Aveley and Wennington Marshes showed that Species Richness had increased by more than the 22% change that may be due to unexplained variation. SCS and Habitat Quality Scores remained stable, but there were significant increases in the representation of non-native and brackish-water species.

The fauna of Rainham Marsh itself showed no change in Species Richness or in scores for Habitat Quality or Naturalness over two decades, but SCS Score increased significantly. There was no indication of a change in salinity.

Vange and Fobbing Marshes
Vange and Fobbing Marshes were selected for re-survey because they were rated as one of the most important Essex wetlands for aquatic invertebrates (Drake, 1988).

There was no change in the faunal quality at Vange Marsh apart from an increase in the representation of brackish-water species. When conductivities were compared with Fobbing Marsh, Vange was seen to have significantly higher values (median of 7785μS cm^{-1} compared with 3370 μS cm^{-1}.

At Fobbing Marsh there was essentially no difference in metrics for 1987 and 2009 (both surveys by Drake), and an intermediate dip was attributed to a different surveyor, who found remarkably few species.

Hadleigh Marsh
Hadleigh Marsh was selected because its fauna was highly rated in 1987 and for the presumed absence of poor water entering from inland, since the site backs onto a chalk hillside.

There was no difference change in the species metrics for 1987 and 2009 except for Naturalness Score, which indicated greater numbers of non-native species.

Fambridge
There was a single early survey in 1987 of this rather poor quality fauna on intensively farmed land. While there had been no change in Species Richness, the scores for SCS and Habitat Quality had increased. The change for SCS Score was just greater than the 11% hange in median that may be due to unexplained variation, and the change in Habitat Quality Score was just less than the 8% threshold. Naturalness Score had also changed significantly and indicated an increase in the representation of non-native species. There was no change in the brackish component although one borrowdyke was not only particularly saline but had one of the lowest species counts in the entire Buglife survey.

Brightlingsea
Brightlingsea NNR, in the Colne Estuary, was selected for re-survey as it was found to be a rather indifferent marsh for invertebrates in 1987. the results of four surveys were compared. There was no change in any species metric except that for Naturalness, which indicated a significant increase in the representation of non-native species in the last survey in 1993.

8.3.2 Changes in individual species abundance and distribution

Analysis was restricted to correlation of the frequency of each species through time, regardless of the marsh from which they were found. More detailed analysis was not possible with the small number of surveys.

Of the species present in at least 10% of the 287 samples, three native species showed a significant correlation with year: the water skater *Gerris odontogaster*, the diving beetle *Hydroporus angustatus* and the nationally scarce diving beetle *Rhantus frontalis*. The skater is associated with moderately open ditches (although with plenty of cover) whereas the beetles are associated with dense marginal vegetation such as grasses, so they are unlikely to be responding to the same environmental change. The leech *Helobdella stagnalis* also showed a significant increase through time but was not particularly frequent so the correlation may be suspect. No species showed a significant decrease in frequency.

Four non-native species were recorded in the Essex surveys. The Chinese mitten crab was found in the Inner Thames Marshes as a claw, which may represent a resident population or have been dropped by birds feeding on the adjacent estuary. The long-resident snail *Potamopyrgus antipodarum* was widespread and showed no change in frequency over time. Another snail, *Physella acuta*, showed a significant correlation with year and appeared to be a fairly new and now widespread addition to the Essex marshes. The date of colonisation of these marshes postdates 1990. The amphipod *Crangonyx pseudogracilis* was widespread in Essex but showed no significant increase over the last two decades. It has probably been in the marshes since well before the mid 1980s, unlike the situation in the Somerset Levels where colonisation appeared to have been recent.

8.3.3 Possible reasons for change in Essex

Despite considerable changes in management at some Essex marshes, there were few changes in the characteristics of the fauna. No significant declines were identified.

Inner Thames Marshes
Aveley and Wennington Marshes are contiguous and were managed as sheep pasture while owned by the MOD, but lately have been cattle-grazed after being bought by the RSPB and subsumed into its Rainham reserve. Water levels have been raised and made constant by the RSPB, in contrast to conditions under MOD management when the water remained shallow and sometimes partially dried out. Rainham Marsh itself is separated from Aveley and Wennington and has, since surveys began, been neglected rank grassland. Havering Borough Council manages it as a nature reserve and has recently managed some of the ditches and dug new ones, but several have remained untouched and probably unmanaged for at least 20 years.

The fauna of Rainham Marsh had remained fairly stable, although SCS Score had increased. It appeared that the recent improvements in ditch management had not yet made much impact on the fauna.

The rise in Species Richness at Aveley and Wennington was presumably a direct response to a marked changed in water management, but there was no concurrent change in SCS Score or Habitat Quality here. There were significant increases in the representation of non-native and brackish-water species. These results suggest that the new management with high water levels has led to a richer fauna, but with the unexpected result of more brackish-water species that would not have been expected with more flushing with (presumably) freshwater from the feeder stream. It is possible that raised water levels have led to a more diverse range of habitats that may have encouraged colonisation by widespread species initially, but that there has not yet been sufficient time for noticeable colonisation by rare ones.

Vange and Fobbing Marshes
Since the early surveys, Vange Marsh has been bought and managed by the RSPB and Essex Wildlife Trust, whose recent management included raising water levels, flooding pastures and probably ditch clearance. The raised water levels had not resulted in a change in species metrics. This may be due to an increase in salinity, because brackish water has been used to raise levels.

Fobbing Marsh is in private ownership and has remained completely unchanged since 1988. It is grazed by cattle. The pasture is unimproved (or barely improved), the ditches are cleaned out on long cycles and many dry out in late summer. It is the only Essex marsh surveyed in the Buglife project that remained in private ownership and managed in an old-fashioned traditional manner. The stability in the fauna of Fobbing Marsh is not surprising because the management of the site had not changed for twenty years.

Hadleigh Marsh
Management had probably not changed much here, since the site had been a Local Nature Reserve for 21 years. It was grazed by cattle and sheep. One marked change was invasion by Australian swamp stonecrop *Crassula helmsii* which occurred in one sampled ditch (see also Section 3). There was no change in the metrics apart from an increase in the number of non-native invertebrate species.

Fambridge Marsh
Fambridge wetlands are in disparate ownership and management. The site was chosen to represent what in 1987 was rather poor quality fauna on intensively farmed land. The change in ownership of a large portion of the land to the Essex Wildlife Trust (it is now their Blue House Farm reserve) and of another portion to Marsh Farm Country Park, managed by Essex County Council, has resulted in considerable changes in management practice. Just one ditch remained in private ownership.

While there had been no change in Species Richness at Fambridge, the scores for Species Conservation Status and Habitat Quality increased and it may be assumed that the change was real and a result of more sympathetic management. This includes raising water levels, digging new ditches with gentle profiles and lowering the intensity of cattle and sheep grazing. The change in faunal quality may have taken place over the relatively short time since the Essex Wildlife Trust instigated the new regime.

Brightlingsea Marsh
Brightlingsea Marsh has been managed as an NNR for the period covered by the surveys compared here. There was no change in any species metric except that for Naturalness, which indicated a significant increase in the representation of non-native species in the survey in 1993. The result suggests that consistent management had at least maintained a fauna with consistent characteristics, even though it was not especially notable.

8.4 Comparison of survey results: Norfolk and Suffolk

8.4.1 Previous surveys

Despite their size, the marshes of Norfolk have received little invertebrate survey effort. Only two workers have undertaken widespread work: Driscoll put in considerable effort in the mid 1970s and Drake (2002 and 2003) surveyed many areas. However, despite the widespread coverage of these surveys, the taxonomic groups investigated were not covered with equal effort. For instance Driscoll identified rather few beetles and the recording of dragonflies often included adults. Drake was contracted in 2001 and 2002 to survey the beetles and molluscs of the Yare and Bure valleys, and other groups are represented by casual records that were not systematically recorded. Driscoll used a methodology that differed markedly from the Buglife method. Only molluscs were recorded with similar effort by both surveyors. Direct comparison of these surveys therefore tells more about the method than the assemblages.

The Suffolk marshes have been given even less attention than those in Norfolk, but the same wide range of taxonomic groups was covered by two surveyors. Shotley Marsh and Minsmere Level were surveyed in 1988 and 2009, whereas Sizewell belts was surveyed twice at almost the same time (1988 and 1989, and by two surveyors in 2009).

The four species metrics (for species richness, SCS, habitat quality (marsh-fidelity) and naturalness) were calculated for past and present surveys for all taxa at Suffolk sites, and for molluscs alone at Norfolk sites.

8.4.2 Norfolk marshes

Yare valley
Ot the three marshes along the north bank of the River Yare that were surveyed, Buckenham and Cantley Marshes are contiguous and are managed by the RSPB. Limpenhoe is the next block of marsh downstream from Cantley, separated by about 1.5km of slightly higher land, and is in private ownership. Thus, although they are hydrologically separate, these marshes would be expected to share similar faunal characteristics. In recent years the river banks have been raised and widened to prevent the incursion of saline and polluted water into the adjacent marshes.

Owing to the uneven coverage of major taxa, only molluscs could safely be compared. It is assumed that surveyor differences were small for molluscs. There was a clear and significant increase in Species Richness between the 1970s and 2000s, supported by the ranking of the three marshes in both decades, with Buckenham being the richest in species and Limpenhoe the poorest.

SCS Score for molluscs at the Yare marshes showed no differences through time at Buckenham and Cantley, but a highly significantly greater value at Limpenhoe in the 1970s. This was entirely due to a highly localised population of *Segmentina nitida* outside the ditches sampled at Limpenhoe in 2009. Habitat Quality Score showed no differences between surveys.

The salinity index showed no differences between surveys because there were no strictly brackish-water molluscs but some changes were inferred from the occurrence of the non-native *Potamopyrgus antipodarum*. This snail is often abundant in mildly brackish water but is usually scarce in still freshwater, although curiously also found abundantly in streams. At Buckenham Marsh and Cantley it was found in a small proportion (12-21%) of ditches in the 1970s, but none were found later at Buckenham nor in 2009 at Cantley, suggesting that it had died out at these sites. This may be a response to recent maintenance work to reduce intrusion of brackish river-water. It was still found in one ditch at Limpenhoe in 2009, and this was a marked reduction from its frequency in earlier surveys (39% in 1974, 72% in 2001). Significantly different Naturalness Scores were attributed entirely to whether *Potamopyrgus antipodarum* was found, as this was the only non-native species in the Yare surveys.

Bure valley
The marshes surveyed form a continuous block that spans the River Bure, but are hydrologically separate. Most of Upton marsh is managed by the Norfolk Wildlife Trust, which has instigated improvements to one half of the marsh that was previously arable or improved grassland. Fleggburgh marsh is an SSSI. The remaining sites are working farmland. At South Walsham there has been reclamation from arable land to pasture in the last decade. A similar flood defence scheme to that on the Yare has been under way for some years.

Species Richness of molluscs followed a similar pattern through the years at all four marshes, with low values in the 1970s, often rising slightly in 2002 and then usually markedly higher in 2009. The large difference between the earliest and latest surveys mirrored that seen in the Yare marshes. While in those marshes the differences could be ascribed to changes in water quality management, it seems unlikely that the pattern would be repeated so consistently in the Bure marshes too. The possibility of more intensive sampling effort in 2009 than in other years casts doubt on the reality of the apparent increase in Species Richness.

SCS Score failed as a useful measure of rarity owing to the spasmodic occurrence of the threatened snails *Segmentina nitida* and *Anisus vorticulus*. A similar problem arose with Habitat Quality Score, since only these two species contributed to it. *S. nitida* and *A. vorticulus* were the only molluscs of real conservation concern in the marshes (ignoring rare pea-shell cockles *Pisidium* species). Fleggburgh supported low but historically consistent populations of both species, but neither species was recorded in the 1970s at the other sites where one or other have been found since. Upton Marsh appeared to host a strong population of *A. vorticulus*, and South Walsham may have been preferred by *S. nitida*.

The only non-native mollusc was *Potamopyrgus antipodarum*, which was therefore the sole contributor to the Naturalness Score. The actual number of records showed a strong decrease in frequency since the 1970s at Fleggburgh and Upton, where it was once widespread, but it appeared to be maintaining its population at Oby. It appeared never to have been frequent at South Walsham.

The numbers of records of these three snail species over the years in Norfolk are given in Table 8.4.2.

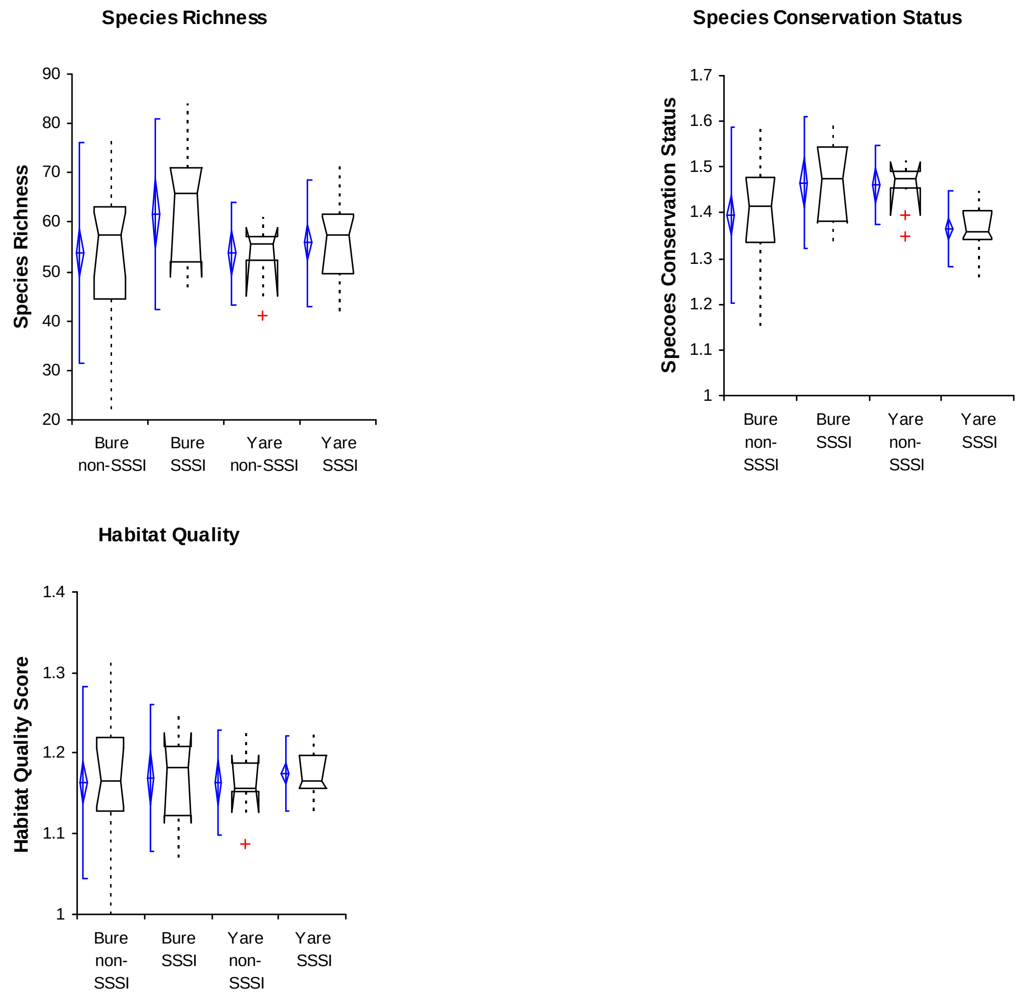
Table 8.4.2 Number of records of two threatened and one non-native mollusc in the Bure marshes

Marsh	Year	Number of samples	*Anisus vorticulus*	*Segmentina nitida*	*Potamopyrgus antipodarum*
Fleggburgh	1974	40	2	3	27
	1975	19	2	1	0
	1976	35	0	0	0
	2002	31	1	5	2
	2009	9	2	2	0
Oby	1974	26	0	0	8
	1975	11	0	0	0
	1976	7	0	0	0
	2002	23	0	1	3
	2009	15	0	1	6
South Walsham	1974	23	0	0	0
	2002	36	1	7	1
	2009	6	1	1	1
Upton	1974	35	0	0	16
	1975	25	0	0	6
	2002	34	7	1	1
	2009	15	7	0	2

Ditches inside and outside SSSIs

Of the 75 ditches sampled in Norfolk, 33 were within SSSIs and 42 were not. One-way ANOVA of the species metrics for all taxa showed that there was no significant difference between the fauna inside and outside SSSIs, with the exception of SCS Score, which was significantly, although only slightly, higher in Limpenhoe (not an SSSI) compared with Cantley and Buckenham, (both SSSIs), with the other marshes surveyed in the Yare valley. Figure 8.4.2 illustrates this. Values for the different metrics within the SSSIs were not consistently higher or lower than those outside. All the ditches sampled were within the ESA and a few that were outside SSSIs had ELS or HLS agreements (see www.naturalengland.org.uk) so their management probably did not differ greatly from that of ditches within the SSSIs.

Figure 8.4.2 Species metrics for ditches within and outside SSSIs in Norfolk.



8.4.3 Suffolk marshes

Shotley Marsh, Suffolk

This marsh selected for re-survey as it was one of the most brackish of those surveyed in 1988 along the Suffolk coast, although the fauna was not outstanding in any other way. It is a small site bordering the coast, and has few ditches, but these were well managed at that time. The site was still in private ownership in 2009, and appeared superficially unchanged.

None of the species metrics had changed significantly in 21 years, and this was probably in reasonable agreement with the constant management the marsh had undergone.

Sizewell Belts, Suffolk

Sizewell Belts is a peat area with blocks of open, sunlit ditches delineated by tree-lined ditches, shelter belts or strips of woodland, and is quite unlike most grazing marsh. The Suffolk Wildlife Trust manages Sizewell Belts. This marsh was among the most species-rich surveyed in 1988, although it did not have an exceptional complement of uncommon species

Two early surveys (by Drake in 1988 and 1989) showed that the fauna of ditches inside the SSSI was of a higher quality than outside it. SCS Score in 2009 showed no change once the 1989 sample of non-SSSI ditches was discounted. Since that time, the Suffolk Wildlife Trust has managed the site to a higher standard than in 1989, so it is likely that the quality over a wider area of the site has been brought up to a similar standard.

Minsmere Level, Suffolk
Minsmere Level is 'conventional' exposed grazing marsh, managed by the RSPB. Like Sizewell Belts, Minsmere Level was species-rich in 1988 but not notable for uncommon species.

The two surveys of Minsmere Level ditches (1988 and 2009) showed no change in species metrics other than SCS Score, which had increased. However, the increase was smaller than the 11% change that may have been due to unexplained variation alone, and this suggests that there may have been no real increase in the representation of nationally uncommon species.

8.4.4 Summary for Suffolk and Norfolk

The comparisons over time were inconclusive for both counties owing to the uncertainties associated with survey methodology. A conclusion of no change appeared to be the safest interpretation for the Suffolk sites, and was likely to be true for Shotley and Minsmere Level, which had undergone no great changes in management. Parts of Sizewell Belts may have improved and been brought to a similar condition to ditches within the SSSI, but more detailed inspection of the data would be needed to confirm this.

Comparison of Norfolk sites between the early 1970s surveys and two in the 2000s was severely hampered by being restricted to molluscs, which was the only group to have been consistently sampled. A possible increase in the quality of the mollusc fauna was inferred for the Yare marshes but such a conclusion was difficult to uphold for the Bure marshes. With more understanding of changes in the marshes since the 1970s, it may be possible to re-interpret the results more satisfactorily. Nevertheless, sampling methodology was still likely to have a big impact on the metrics, especially with such small numbers of species.

8.5 Comparison of survey results: Gwent

8.5.1 Application of the species metrics

There were some apparent changes over time in the metrics, but observer bias appeared to be the over-riding factor in explaining this. There was no significant difference in Species Richness, SCS or Habitat Quality Scores between surveys at different times, but Naturalness Score declined (i.e. there was greater representation of non-native species) at Caldicot by comparison with earlier surveys. However, this metric remained at its historically low value at Wentlooge.

8.5.2 Change in individual species

The occurrence of six nationally uncommon species has remained more-or-less unchanged since 1984: the beetles *Hydrophilus piceus*, *Peltodytes caesus*, *Hydaticus transversalis, Agabus conspersus* and the soldierflies *Odontomyia ornata* and *O. tigrina.* These species rarely occur outside ditch systems. However, one other beetle characteristic of grazing marshes, *Limnoxenus niger*, was not found, and the latest record in the Countryside Councils for Wales' Invertebrate Site Register is 1992. The large diving beetle *Dytiscus circumcinctus* appeared to be a new record for the marshes in 2007.

8.6. Summary of changes

Table 8.6 shows significant changes identified for all the wetlands investigated. No decline was detectable in any of the marshes and the metrics indicated improvement in some of them.

Table 8.6. Summary of changes in species metrics for invertebrates in the wetlands investigated

- \- = no change detected or possible increase in the score but threshold not exceeded
- ↑ = significant increase in the score (threshold for change exceeded)
- ** = amount of change detected was very close to exceeding the threshold

	Species Richness	Species Conservation Status Score	Habitat Quality (Marsh Fidelity) score
Somerset and Avon			
Catcott, Chilton & Eddington	-	↑	-
Gordano	-	-	-
Kenn, Nailsea & Tickenham	-	↑	-
Kings Sedgemoor	-	-	-
Moorlinch	↑	↑	-
Pawlett Hams	-	-	-
Southlake Moor	-	-	-
Tadham & Tealham	↑	-	-
West Sedgemoor	-	-	-
Essex			
Rainham	-	↑	-
Aveley & Wennington	↑	-	-
Vange	-	-	-
Fobbing	-	-	-
Hadleigh	-	-	-
Fambridge	-	↑	-
Brightlingsea	-	-	-
Suffolk			
Shotley	-	-	-
Sizewell	-	-	-
Minsmere	-	**	-
Norfolk (molluscs only)			
Yare valley	↑	-	-
Bure valley	-	↑	-
Gwent			
Caldicot	-	-	-
Wentlooge	-	-	-

Change in the invertebrate fauna over time: key points

- The magnitude of variation that can be expected in data from repeat sampling of ditches under a stable management routine was estimated by comparing results from the same ten ditches in Somerset, sampled in all three years of the project.
- Only about a third of the species were found in all three years; almost half the species recorded were unlikely to be found in a single repeat survey.
- The annual variation in three metrics applied to the results indicated that comparisons between surveys need to show differences in median values that exceed 22% for Species Richness, 11% for SCS Score and 8% for Habitat Quality Score.
- The metrics were applied to data from previous surveys in Somerset, Essex, Norfolk and Suffolk marshes and the Gwent Levels, and compared with results using data from the 2007-2009 survey.
- In Somerset there was no indication of a decline in quality and on most moors either Species Richness or SCS Score or both appeared to have increased. This probably reflects the input of conservation effort on these SSSIs since the early 1980s.
- In Essex marshes few changes were obvious except at Fambridge, where the scores for SCS and Habitat Quality increased. The change was likely to be a result of more sympathetic management.
- The results for the Suffolk marshes and the Gwent Levels were inconclusive.
- Comparison of Norfolk sites was hampered by being restricted to molluscs, the only group to have been consistently sampled. A possible increase in the quality of the mollusc fauna was inferred for the Yare marshes.
- Increases and decreases in some native species were evident (e.g. Saucer bug (*Ilyocoris cimicoides*) and Water stick insect (*Ranatra linearis*) have increased in Somerset and the beetle *Hydaticus seminiger* has arrived).
- Some increase in non-native species was evident (e.g. the snail *Physella acuta* is more frequent in Somerset and it has recently spread to Essex).

Section 9 Conclusions and recommendations

9.1 The aims of the project

The four major aims of the Buglife grazing marsh ditch project were to:

- carry out targeted survey of the aquatic invertebrate fauna and flora of ditches in a representative sample of grazing marsh sites, to establish a baseline for the future
- assess the extent of and reasons for any observed change in the biota
- obtain information on ditch management, water quality and surrounding land use in the sites surveyed
- define optimum management and produce management guidelines for ditches.

9.1.1 Survey

Survey coverage was heavily biased towards marshes that are managed with nature conservation as the main aim. Ten geographical areas in Wales and southern England were covered in the three years of fieldwork. Limited time and resources meant that other marshes in north Norfolk, Lincolnshire and Humberside, and fen systems farther inland in Cambridgeshire could not be covered. Nevertheless, coverage was far wider than any previous ditch survey and there was the added advantage that surveys for flora and fauna were closely coordinated.

It was necessary before fieldwork started to define a standard methodology. This was accomplished by producing *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010), which describes field survey methods and gives check lists of target species.

Over the three field seasons of the project 533 ditches were sampled for invertebrates and the same ones (plus 13 extra) were sampled for plants. 326 target invertebrate species were recorded and 174 plant species were found within the wet zone of the ditches. This produced a very large dataset. For invertebrates, about 25,000 species records were made over the three years, all tied to records of environmental variables.

In order to make sense of this mass of data, classifications were produced for both vegetation and invertebrates, and the environmental variables associated with the assemblages were identified (see Volume 1, Sections 3 and 4; Volume 2, Appendices 2 and 3). This gave a clear picture of the types of flora and fauna present in grazing marsh ditches, their distribution and the influences that had moulded them.

All this effort fully satisfied the first aim of the project. Standard methods were defined and a comprehensive baseline was laid down. Arrangements are being made to pass the data to the National Biodiversity Network so that all the records will be freely available for others to use in the future.

9.1.2 Assessment of change

Assessing change by comparing the results of past and present surveys was a difficult task, especially for invertebrates, for which past survey methods have been ill defined and the products of fieldwork uneven in quality. Information (especially raw data) available from previous surveys was limited, so change was assessed in a sample of areas rather than being comprehensive.

A scoring system for assessing the quality of the fauna and flora of ditches was devised for the project (see *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010)). This was applied to digitised data from past surveys in a range of sites (see Sections 7 and 8 and Volume 2, Appendix 4). In addition, the relative abundance of rare species found in the various surveys was examined. For the vegetation, previous regional classification systems were applied to data from the Buglife survey and the proportion of ditches in the various vegetation types at different dates was used as a measure of change.

For invertebrates, no recent deterioration was detected. The general picture that emerged was for modest improvement in species richness and/or in the proportion of rare species present. Surprising increases in some native species were evident, for instance in the very distinctive Saucer bug (*Ilyocoris cimicoides*) and Water stick insect (*Ranatra linearis*). Conversely, some invertebrate species showed declines, among them some relatively common water beetles in Somerset. It is hoped that this does not signal the start of a general deterioration in the aquatic beetle fauna.

There was a shift in Broadland from vegetation typical of over-enriched and saline water towards that of cleaner and less brackish conditions. These results imply an improvement in water quality and a reversal of the previous trend up to the 1990s of continued loss of species-rich freshwater communities. Three approaches to estimating change were applied to the data and they all indicated a general improvement in the ditch flora. In Somerset, different kinds of changes had occurred on the various wetlands, but generally, species-poor vegetation types had decreased and species-rich ones had increased.

To summarize, methods of assessing change were devised and tested, and their application suggested that there has recently been a general improvement in the quality of the flora and fauna of grazing marshes, at least within SSSIs. This optimistic view is tempered by the unexplained decline in abundance of some species, notably a suite of beetles in Somerset.

9.1.3 Ditch management and environmental influences

Environmental features were recorded at each of the sampling sites but, except in the case of RSPB reserves, detailed information on ditch management proved very difficult to obtain. Ditches were generally said to be "cleaned out when they needed it", which probably meant that management did not follow a regular cycle, but was governed by the rate of hydroseral succession. Most of the marshes in the survey lay within protected sites, so they were managed with wildlife conservation to the fore. A number of standard practices were followed. These included improving water quality by reducing fertiliser applications, maintaining a high water table, regularly clearing vegetation and silt from choked ditches and in some cases digging new ditches with gently sloping profiles. In Broadland, flood defence work along the Yare and the Bure has reduced the influx of saline water to the marshes.

Samples were taken from 57 ditches that lay outside SSSIs, only five of which (in Walland Marsh) were in arable land. Thirty three of the non-SSSI ditches were in Norfolk and ten in Somerset. In Norfolk, the quality of the mollusc fauna inside and outside SSSIs was similar. This was not surprising because all the samples were from land within the ESA, so management everywhere would probably have been sympathetic to wildlife. However, the five ditches in arable land at Walland Marsh were noticeably poorer in species and supported fewer rare species than most SSSI marshes, and in Somerset the non-SSSI ditches tended to be less rich in species than those within SSSIs. The fauna of some SSSIs, for instance that of the Essex Wildlife Trust's reserve at Fambridge, has improved following the instigation of conservation management.

Searches produced very little existing information on water quality in ditches, and the cost of obtaining new water chemistry data was prohibitive. Diatom assemblages were therefore used as surrogates to indicate the ecological status and water quality of the ditches. At the time of writing this report, work on the diatom samples was still proceeding, but preliminary analysis indicated good matches between ecological status, as predicted by the diatom species, and vegetation type.

The available information on ditch management was limited, but data analysis did suggest that current management practices for nature conservation are generally meeting with success. However, this conclusion is in contrast with Natural England's latest results from protected site monitoring (see www.naturalengland.org.uk). In Somerset, overall condition of most of the grazing marsh SSSIs fell into the 'Unfavourable Recovering' or 'Unfavourable / No change' classes (only Southlake Moor passed with flying colours). The reasons given were usually poor water quality, but in some cases inappropriate ditch management or water levels.

Leaflets giving advice on ditch management are being produced by Buglife, to meet the fourth aim of the project.

9.2 Classification of ditch flora and fauna

Salinity was shown to have an over-riding influence on the composition of both plant and invertebrate assemblages. Brackish ditches occurred predominantly in the North Kent and Essex marshes, but with a few surprisingly far inland, as at Fairfield in Walland Marsh.

Ditch vegetation is typically an intimate mixture of marginal swamp species and abundant free-floating plants. Rooted submerged species are relatively scarce because they are vulnerable to dredging and shaded by floating and marginal plants. There was a clear distinction in the vegetation classification between ditches at an advanced stage in the hydrosere, with swamp plants such as Common reed or Reed sweet-grass dominating, and open vegetation of more recently cleaned ditches. There were two distinct open freshwater assemblages: vegetation dominated by duckweed species that blanketed the water surface and more species-rich vegetation typified by Frogbit on the surface and Ivy-leaved duckweed suspended beneath it. Ditches of the floating duckweed type were predominant in the western marshes of Gwent and Somerset. A distinctive vegetation type centred on Norfolk Broadland and containing Water-soldier was also recognised.

The principle environmental variables influencing ditch vegetation types were salinity, water quality, ditch management, water levels and grazing intensity. The brackish flora is distinctive, but poor in species. Poor water quality often results in high cover of floating duckweed and filamentous algae, although in Somerset and Gwent, high cover of duckweed usually supresses algal growth so that high algal cover is often associated with rather less eutrophic conditions and better developed submerged macrophytes. Newly cleaned ditches often have well developed submerged vegetation, intermediate stages tend to have more prominent floating species mixed with some swamp vegetation, and late stages have swamp predominating. Shallow ditches that occasionally or frequently dry out tend to have high covers of low-growing wetland species. Grazing usually has a beneficial effect in increasing the diversity of wetland species and creating openings in marginal tall swamp that are suitable for low swamp species.

The invertebrate classification was strongly influenced by an east-west bias in the national distribution of many species, so it was not possible to derive a classification of aquatic invertebrates that is robust for the entire spectrum of ditch types at a ‘national’ scale. The environmental variables having the most influence on invertebrate community composition were salinity, vegetation structure (principally hydroseral stage), ditch dimensions, water depth and grazing by cattle. Differences related to vegetation cover are obviously also related to the management cycle. Overgrown ditches, despite their poverty of species, can therefore contribute to the overall richness of a marsh

The invertebrate fauna of brackish ditches has a far more discrete identity than that of freshwater ditches. This salt-tolerant fauna contains fewer species, especially of molluscs, but a greater proportion of species with a high fidelity to coastal grazing marshes.

9.3 Evaluation of ditch flora and fauna

Grazing marshes are very rich in species and in rarities. Ten Red List or Near Threatened aquatic plant species were recorded during the survey, five of which are on the UK BAP priority list. Grazing marshes are the British stronghold for Frogbit and Tubular water-dropwort, both rated as Vulnerable, Sharp-leaved pondweed (*Potamogeton acutifolius*), which is Critically Endangered and Water soldier (*Stratiotes aloides*), which is Near Threatened.

Seventy nationally rare or scarce invertebrates were recorded during the project, 47 of them water beetles. These species include nine UK BAP priority invertebrates, one of which, the Little whirlpool ram’s-horn snail (*Anisus vorticulus*), is protected under European legislation. Many of these rare species were shown to have particular requirements related to both salinity and successional stage. The red listed soldierfly *Odontomyia ornata* and the Great silver water beetle (*Hydrophilus piceus*) were among the most widespread and frequent of the nationally rare species, and could be regarded as 'flagship' species for grazing marsh.

The invasive non-native plants Nuttall's waterweed (*Elodea nuttallii*) and Least duckweed (*Lemna minuta*) were widespread and abundant. Australian swamp stonecrop (*Crassula helmsii*) was dominant in some ditches in Essex. These three species are undoubtedly competing successfully with the native vegetation. The three non-native invertebrate species recorded were the crustacean *Crangonyx pseudogracilis* and two snails: *Potamopyrgus antipodarum* and *Physella acuta.* The latter is a recent arrival in Britain that has now spread to Essex. The impact of these three species on the native fauna and flora is unknown.

The areas with the highest mean score for invertebrate Species Richness were the Bure marshes and the Pevensey Levels. For plants, marshes in the Yare and Bure valleys had the highest mean score for Species Richness. The highest Species Conservation Status Scores for invertebrates were for the Pevensey Levels, Walland Marsh and the brackish North Kent and Essex sites. The Pevensey Levels was also outstanding for its plant SCS Score, but brackish areas scored badly for this metric. This illustrates the fact that ditches that are poor for vegetation may be of great interest for their invertebrate fauna.

The sets of metrics for plants and invertebrates behaved differently when applied to samples from freshwater and brackish ditches. Mean Species Richness and Naturalness Scores for both taxonomic groups were lower for brackish ditches than for freshwater ones. For plants, both mean SCS and Habitat Quality Scores were lower in brackish ditches than freshwater ones, whereas for invertebrates both these scores were higher in brackish than in freshwater ditches. This is due to the fact that brackish water supports a considerable number of rare invertebrates, many of which are 'faithful' to the grazing marsh habitat, but this is not true for plants. Also Habitat Quality Score is based on different criteria for plants and invertebrates.

9.4 Ditch management recommendations

The following recommendations are made for the management of grazing marsh ditch systems for their aquatic flora and fauna, using the experience gained from the project.

Pollution of the water source should be reduced wherever possible. Low levels of manure or fertiliser application on the fields within the marsh system is of particular importance as this limits direct nutrient inputs into the ditches during the growing season. Nutrient enrichment of water sources outside the marsh system can be more difficult to address. Raising water levels within the system can help to isolate ditches from polluted arterial ditches, but this is only of benefit if the source is low in pollutants.

Distinct invertebrate assemblages and individual rare species are dependent on different combinations of salinity and hydroseral stage, so it is important to maximise the range of these two features. Salinity gradients on marshes where there is a long history of stable, mildly brackish conditions should be maintained. However, intermittent incursion of highly saine water, as has happened in the Norfolk Broadland, is physiologically taxing for animals and plants and leads to low biodiversity, so is not desirable.

Because ditch vegetation matures at different rates depending on local conditions, the ditch cleaning cycle should be tailored to individual marshes. Managers should be encouraged to decide for themselves on the best regime for encouraging a balance of hydroseral stages, with plenty of open water but also some dense reedswamp. A range of hydroseral stages in individual ditches can be maintained by:

- cleaning alternate sections or just one bank of a ditch, so that floating mats of swamp vegetation or the fringe of emergent plants is retained
- leaving ditches unfenced to allow cattle to soften the margins and graze them, so that a fringe of dense low vegetation is encouraged

- constructing cattle drinking bays with a shallow slope along steep-sided ditches, to enable emergent and mat-forming aquatic plants to provide small refuges for invertebrates along otherwise sparsely vegetated margins
- raising water levels and keeping them high so that the sloping upper bank becomes submerged, giving more shallow water.

Vegetation types that are the least valuable for biodiversity are those dominated by algae, dense carpets of floating duckweeds or invasive non-native species. Shallow-rooted plants, such as pondweeds (*Potamogeton* species), stoneworts and Water-soldier (which floats in the summer but sinks to the bottom and roots in the autumn) need open water and a fairly firm substrate, but are vulnerable to frequent dredging, so a fine balance is needed to maintain their populations. There may therefore be disadvantages in the little-but-often management approach that is sometimes favoured, whereby ditches tend to be de-weeded rather than de-silted. This may, for example, be the reason for the decrease in *Potamogeton friesii* observed in Norfolk (see section 7.3) although this needs further investigation. Deeper cleaning will often expose the firm substrates preferred by some species, but it should be undertaken less often than de-weeding.

Allowing ditches to become swamp-dominated between clean-outs is likely to favour plants that reproduce from seed over those that reproduce from shorter-lived propagules, such as *Elodea* species. The sloping underwater sides of ditches tend to accumulate less silt than the bottom, and steeper sides tend to be scoured more in the ditch cleaning process, which can also favour the species that prefer firmer substrates.

Very advanced hydroseral stages, such as reed-choked ditches, have low diversity for aquatic species (the target of this study), but are important for wetland plants and for invertebrates such as ground beetles, rove beetles and flies typical of more fen-like conditions. Ditches that dry out in late summer can support a rich invertebrate fauna earlier in the season, but their number on a marsh should be limited and balanced by deep ditches, which are needed as reservoirs.

If new ditches are dug they should have a range of profiles, from saucer-shaped to deeper, more conventional shapes, but with shallow slopes under water at the edges. in order to benefit the invertebrate fauna. There is, however, no evidence that having a shallow underwater bench at the edges of the ditch has any benefits for the diversity of aquatic vegetation. Indeed, in some cases where there is no grazing and the bench is not disturbed in the dredging process this has resulted in a thick, species-poor fringe of tall emergents. On the other hand, a gradual slope above the water level is often beneficial for non-aquatic wetland species.

The advice to leave ditches unfenced and allow cattle access to ditch margins may be in conflict with recommended management for birds and water voles, but is generally of benefit for both invertebrates and plants.

9.5 Possible future work

More analysis is needed to determine how environmental variables affect the metrics that were used to evaluate marshes and indicate change. This should give a direct link between variables inferred as representing good practice and the condition of invertebrate and plant assemblages, so adding credence to management guidelines.

Silt depth and its effect on vegetation has been discussed in Sections 7.3 and 9.4 of this report, but some of the observations have been subjective and need to be explored further, as this has a direct relevance to ditch management.

When the analysis of the diatom samples is complete, the relationships between plant and invertebrate communities, diatom assesmblages and environmental variables can be investigated.

This survey has concentrated on grazing marshes within sites protected by SSSI status and/or with some form of management for nature conservation. A comparison is needed with areas that are not protected, particularly where there is more intense agricultural management.

As part of this project, a large body of historical data has been digitised and is now available for analysis. In this report we have analysed some of the botanical data from two areas, the Norfolk Broads and the Somerset/Avon Levels, but time did not permit similar analyses in other areas. It would be useful to assess whether similar patterns can be discerned in the vegetation elsewhere.

This survey has developed and built on several techniques for analysing ditch systems for their biodiversity and for estimating change. Many ditch systems have not been surveyed in detail since the 1990s and, as this report has shown, a number of changes have occurred in the interim. Survey and assessment of change is needed in areas that the Buglife survey did not cover. Further comprehensive rounds of survey at ten-yearly intervals are recommended, in order to monitor future change.

Obtaining management histories for marshes has proved to be very difficult in this project. A detailed study of the effects of management on a few sites where there is good documentation could yield very useful information. West Sedgemoor in Somerset might be a suitable study site because here the RSPB holds full records going back a number of years, and various techniques, including desilting, deweeding and cleaning one side of the ditch at a time, have been tried out.

Following previous surveys, a number of botanical ditch classifications have been developed for individual ditch systems or regions. There is a need to bring these together into a national classification. An initial step has been taken in this report but there are still gaps. The existence of a large body of digitised data from this and other surveys means that the development of a more comprehensive ditch vegetation classification is now feasible.

9.6 Key messages

Coastal grazing marshes ditches support a very rich and special flora and invertebrate fauna and are the national stronghold for a number of rare and threatened species. They are threatened by climate change.

Brackish ditches are restricted geographically and are an important and distinctive element of the grazing marsh habitat, especially in the east of England. In order to maintain maximum diversity of flora and fauna, the complete spectrum of stable brackish and freshwater ditches represented in a marsh or a geographical area should be retained.

Invertebrate and plant assemblages of ditches are strongly interrelated. In order to maximise the biological potential of a marsh, all stages in the hydrosere should be represented.

Comparison of information from past surveys with data gathered in the Buglife survey suggests that current management for nature conservation appears to be benefiting the flora and invertebrate fauna of ditch systems.

Because the influence of geographical location is so important for invertebrates, marshes in different parts of the country are not equivalent or interchangeable. Invertebrate assemblages separated by more than about one or two counties are likely to be as different from one another as ditches at different stages of the hydroseral cycle. Loss of marshes due to rising sea level, managed retreat or development should therefore be made good at a local level.

Section 10 References

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