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, with reference to site management and future monitoring

Final report to the Esmée Fairbairn Foundation

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Summary

1. The principal element of the suite of projects described in this report is a three-year investigation into the current state of the aquatic flora and invertebrate fauna of coastal grazing marsh ditches in England and Wales. Standard field survey and conservation evaluation methodologies were devised and employed, in order to create baseline information, assess change and investigate the effects of management practices on the biota.

2. As adjuncts to the core project, Buglife instigated, raised funding for and managed the following 'companion' projects:
    - a survey of ditch diatom communities (conducted by Bristol University)
    - a bibliography of ditch surveys in England and Wales
    - repeat sampling of ditches in the Thurne catchment, Norfolk, that were surveyed in the 1970s, 1980s and 1990s
    - a digitised database of previous ditch survey records (for Natural England).

3. The Esmée Fairbairn Foundation funding for the core project was supplemented by a contribution from the Environment Agency. An account of expenditure on the core project is given.

4. In the three years of the core project, 546 ditches were sampled for aquatic plants and 533 for invertebrates. The survey areas in 2007 were the Somerset and Gwent Levels. In 2008, Maltraeth Marsh in Anglesey, the Arun valley marshes and Pevensey Levels in Sussex, Walland Marsh and the North Kent marshes were covered. In 2009, marshes in Essex, Suffolk and Norfolk Broadland were surveyed.

5. A summary of the achievements of the core project is presented here, covering:
    - the extent of field survey for invertebrates and plants
    - the analysis of data obtained during the survey
    - conservation evaluation and ranking of the marshes surveyed
    - an assessment of recent change in the quality of the biota of grazing marsh ditches in the areas surveyed
    - recommendations for ditch management.

6. A digitised database of the 2007-2009 Buglife survey records is held by Buglife. Arrangements have been made to make the data freely available through the National Biodiversity Network.

7. The following are produced as separate Buglife publications for the core project:

    - Drake, M., Stewart, N., Palmer, M. & Kindemba, V. (2010) *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. Volume 2 Appendices.

    - Palmer, M., Drake, M. & Stewart, N. (2010) *A Manual for the Survey and Evaluation of the Aquatic Plant and Invertebrate Assemblages of Grazing Marsh Ditch Systems.*

    - Leaflets on management of ditch systems (In draft in June 2010).

1 Background to the project

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 a number of Biodiversity Action Plan priority species are associated with ditch systems.

Extensive 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, Kent, Essex, Suffolk, Norfolk and Lincolnshire. Many of these coastal grazing marsh systems display a transition from fresh to saline water.

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 are thought to be threatened by agricultural pollution, erratic water supply and rising sea levels. 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.

A project on ditch biodiversity and management is timely because new opportunities for wildlife conservation are arising as a result of the current climate of change in agricultural practice. Some coastal grazing marshes are designated as Protected Areas under the EC Water Framework Directive. It is hoped that information from the Buglife ditch survey project can contribute to the refinement of assessment methods under this Directive and provide advice on how best to manage these fragile wetlands. The information could also prove useful in schemes for recreating coastal grazing marshes 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 NGOs. Much of this survey effort was in the 1980s and 1990s and many of the areas have not been surveyed in detail since then. The statutory conservation agencies' *Common Standards Monitoring* protocol (JNCC website: www. jncc.gov.uk) is used for monitoring the condition of ditch systems in SSSIs and Natura 2000 sites. This is a rapid assessment method, concentrating on aquatic vegetation and only briefly mentioning invertebrate assemblages.

A standard survey method for ditch vegetation has been in operation in the statutory conservation agencies for many years, but a range of methods has been used for sampling invertebrates, making comparison between surveys difficult.

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.

2 The suite of projects

2.1 The core project

The Esmée Fairbairn Foundation funded a three-year project, initiated and managed by Buglife, to:

- carry out targeted survey of the aquatic invertebrate fauna and flora of ditches in a representative sample of grazing marsh sites
- assess the extent of and reasons for any observed change in the biota and, where appropriate, make recommendations for remedial measures
- 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.

The two contractors, experienced entomological and botanical consultants, were appointed by Buglife in October 2006. The invertebrate specialist was Dr. Martin Drake, who for many years was employed by English Nature. The botanist was Nick Stewart, who has worked on a large number of contracts for the statutory conservation agencies and Plantlife and is the National Recorder for stoneworts.

An inaugural meeting of the project was held on November 8th 2006, at Natural England's headquarters in Peterborough. This was attended by Buglife staff, the two contractors, potential funders and members of the Steering Group (see *Acknowledgements* for the Steering Group membership.) Subsequent Steering Group meetings were held in November 2007, October 2008 and November 2009.

A suite of ditches in the Somerset Levels was resurveyed in 2008 and 2009 to give an indication of inter-year variation in the ditch biota.

Data from old reports on ditch surveys in the wetlands studied in the current project were digitised, to facilitate comparison of past and present situations.

Outputs from the core project include:

- A digitised dataset of invertebrate, plant and environmental records from grazing marshes in southern England, East Anglia, South Wales and Anglesey, made publicly available through the National Biodiversity Network.
- A manual describing standard methods for surveying and assessing the conservation value of ditch flora and invertebrate fauna.
- A technical report, available as hard copy and on the internet, which contains detailed results, including an evaluation of the marshes visited and a general assessment of change in grazing marsh flora and fauna over the past quarter century.
- Leaflets on grazing marsh ditches, aimed at land and water managers and agricultural advisors.

2.2 Companion projects

In addition to the core project, seven 'companion projects' were initiated or planned, five managed by Buglife. The remaining two required input from Buglife, but were managed by other organisations.

2.2.1 Diatom survey

An overview of water quality in the grazing marshes surveyed and an assessment of its influence on ditch flora and fauna was beyond the scope of this project. It would have involved the collation of the existing scanty data and a programme of water chemistry analysis. Water sampling would have necessitated at least three visits per year to a large number of sites, so the project would have been very expensive. The emphasis therefore shifted to the use of diatoms as biological indicators of water quality in ditches, based on a

method already in operation under the Water Framework Directive using diatoms as a quality element in the assessment of the ecological status of rivers and lakes.

The ditch diatom survey 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.

During the botanical survey, Nick Stewart collected diatom samples from the stems of water plants in 20% of the ditches he surveyed for plants. The material was preserved on microscope slides at the University, the diatom species present were identified and counted and the ecological status of the ditches was deduced. Relationships of diatom assemblages to ditch vegetation and environmental factors (e.g. salinity) were explored.

The results are given in a report (Yallop, *in prep*.), which will be available on Buglife's web site. This project is the first comprehensive programme simultaneously covering 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.

2.2.2 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. This contains over 400 references. 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.

2.2.3 Monitoring in the Thurne catchment, Norfolk Broadland

In 1973, 1981/2 and 1997, Rob Driscoll (Assistant Keeper at the Castle Museum, Norwich from 1985 to 2000) 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 (at 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. Rob also collected detailed information on salinity for the study areas. The survey results had remained unpublished.

A companion project built on this monitoring programme and involved repeat sampling of the ditches in 2009 by Rob Driscoll. 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 will be available on Buglife's web site (Drake & Driscoll, in prep.). The work was funded by the Norfolk Biodiversity Partnership, the Courtyard Farm Trust and Anglian Water.

2.2.4 Digitisation of data from ditch systems in England and Wales

In this project, biological and environmental data from previous grazing marsh surveys in southern and eastern England and Gwent were digitised under a contract to Natural England. The data was useful to the core project and may in future contribute to Conservation Agency work on Common Standards Monitoring and a revision of the SSSI selection guidelines for ditch systems.

2.2.5 Workshop on habitat recreation

A workshop was planned to examine the potential for recreating grazing marsh destroyed by sea level rise. It would have built on information gained during the Buglife ditch survey and involved experts in wildlife conservation, coastal geomorphology and land and water management.

In late 2009, members of the Buglife team participated in a workshop funded by Defra on developing tools to evaluate the consequences for biodiversity of options for coastal zone adaptation to climate change. In the light of this initiative it was decided to delay plans for the Buglife workshop and to co-operate with the Defra funded project. A decision will be made in the future about whether an independent Buglife workshop is needed.

2.2.6 Water Framework Directive compliant monitoring procedures for ditch invertebrates

This study is being undertaken independently by Pond Conservation, in cooperation with Buglife. It is funded by the Environment Agency and aims to develop an invertebrate monitoring procedure for ditch systems that can be used for the Water Framework Directive. Pond Conservation's standard survey method involves laboratory sorting of preserved samples, but Buglife's method relies heavily on live sorting in the field, so there may be considerable differences in the results. Outputs from the two survey procedures will be compared.

Pond Conservation carried out fieldwork in Somerset in 2007, sampling some of the ditches examined by Martin Drake during the Buglife survey. Detailed examination of the material collected is ongoing, but has been held up through lack of funding.

2.2.7 Invertebrate genetic diversity

This is a study of population genetic diversity in selected Biodiversity Action Plan grazing marsh invertebrate species with different dispersal abilities. The aim is to extract mitochondrial DNA from selected beetle and snail species in order to:

- survey geographical patterns of genetic population diversity across their west European ranges
- determine the levels of genetic diversity in isolated populations in the UK
- identify major genetic lineages
- make conservation management recommendations in the light of these findings.

The project is managed by Dr. David Bilton, University of Plymouth, and funded by the Esmée Fairbairn Foundation. Invertebrate samples for this study were collected by Martin Drake during the core project. The project is ongoing.

3 Financial information for the core project

The cost of the core project was covered by a grant of £140,500 from the Esmée Fairbairn Foundation. A summary of the outline budget, put together in 2006 for the project proposal, is as follows:

Preparatory desk study: planning survey, retrieving existing data, liaison with land managers, gaining access permission (work by invertebrate specialist and botanist)	£10,000
Invertebrate specialist: preparation, field survey, laboratory time, data analysis, reporting (200 days @ £250/day)	£50,000
Botanist: preparation, field survey, data analysis, reporting (120 days @ £250/day)	£30,000
Surveyors' expenses	£5,000
Field equipment (conductivity/pH metres, nets)	£500
Project management (Buglife staff time, overheads)	£35,000
Writing and publishing a management booklet	£8,000
Incorporating information in Buglife's website	£2,000
Total	**£140,500**

Late in 2006, the invertebrate specialist (Dr. Martin Drake) and the botanist (Nick Stewart) were contracted to do all the scientific work, including the preparatory desk study, for £57,500 and £37,500 respectively.

In December 2006 the Environment Agency expressed an interest in contributing to the suite of projects and made £15,000 available from central funds, to be spent by March 2007. £5,000 of this was passed to Pond Conservation as a contribution to the companion project on Water Framework Directive compliant monitoring (see Section 2.2.6). The remaining £10,000 was allocated for spending between January and March 2007 (£9,000 on the preliminary desk study by the surveyors and £1,000 for a lap-top computer and other equipment).

The grant from the Environment Agency freed up £10,000 from the Esmée Fairbairn Foundation funds. In consultation with Danyal Sattar, this money was earmarked for the support of a Freshwater Officer post in Buglife. One of the duties of this post is to assist in the management of the ditch survey project, which was originally being administered by Margaret Palmer, in a voluntary capacity as a Trustee. Buglife overheads from the Esmée Fairbairn funding were therefore increased from £35,000 (25% of total project costs) to £45,000 (32% of total project costs) over the whole project.

A number of smaller adjustments have been made to the budget as the project has progressed:

- Expenses incurred by the contractors in connection with preparation and fieldwork were included in their daily rate. Late in 2007, a decision was made to pay additional expenses for attendance at Steering Group and project management meetings in Peterborough. This added about £1,000 to the expenses budget over the period of the project.
- The cost of maintaining the pages on the website covering the ditch project was less than anticipated. The budget was therefore reduced by £300, to £1,700.
- The budget for producing the management leaflet was reduced from £8,000 to £7,000. Writing the text was undertaken in-house rather than by a contractor, so the leaflet proved to be less costly than initially thought.

In the original timetable, the work was due to be completed by December 2009. By agreement with the Esmée Fairbairn Foundation, the project timetable was extended by six months, to June 2010, to allow adequate time for analysing the huge amount of data accumulated from the 2007-2009 fieldwork and gathered from reports on previous surveys. No additional financial support was sought to cover this extension, as the original number of days worked by the consultants was re-allocated to cover a longer time period. The total management cost of the project remained at £45,000, with £2,000 of this allocated to the first two quarters of 2010.

A summary of total expenditure, excluding the £10,000 from the Environment Agency:

2007	
Invertebrate consultant costs	£15,300
Plant consultant costs	£8,700
Meetings expenses	£374
Project management	£13,000
Web site	£500
Total spend	***£37,874***
2008	
Invertebrate consultant costs	£16,650
Plant consultant costs	£9,636
Meetings expenses	£260
Equipment	£77
Project management	£15,000
Web site	£500
Total spend	***£42,123***
2009	
Invertebrate consultant costs	£14,100
Plant consultant costs	£11,291
Field equipment	£46
Meetings expenses	£252
Project management	£15,000
Total spend	***£40,689***
2010	
Technical report production:	
Invertebrate consultant costs	£6,450
Plant consultant costs	£3,873
Equipment	£13
Management leaflet (writing, printing)	£7,000
Meetings expenses	£126
Project management	£2,000
Web site	£700
Total spend	***£20,162***
Overall total	**£140,848**

In 2007, 2008 and 2009 Buglife received grants of £50,332, £40,334 and £49,834 respectively from the Esmeé Fairbairn Foundation, making a total of £140,500. The figures given above show a small overspend on the whole project of £348.

The quarterly expenditure for the Core Project from 2007 to 2010 is shown inTable 1. Buglife's Annual Report and audited accounts for for 2009 are appended to this report.

Table 1 Core project: budget and expenditure 2007 to 2010

Activity	Element	07 Jan-Mar	07 Apr-Jun	07 Jul-Sept	07 Oct-Dec	08 Jan-Mar	08 Apr-Jun	08 Jul-Sept	08 Oct-Dec	09 Jan-Mar	09 Apr-Jun	09 Jul-Sept	09 Oct-Dec	10 Jan-Mar	10 Apr-Jun	Total
Work by invertebrate specialist	Field survey, laboratory work, data analysis & report writing (including routine expenses)				£15,300	£3,450			£13,200	£2,000			£12,100		£6,450	£52,500
Work by botanist	Field survey, laboratory work, data analysis & report writing (including routine expenses)				£8,700				£9,636				£11,291		£3,873	£33,500
Steering Group meetings	Travel and subsistence				£374				£260				£252		£126	£1,012
Field equipment and postage	Conductivity/pH meters, nets					£77					£46			£13		£136
Project management	Buglife staff time	£2,250	£3,250	£3,750	£3,750	£3,750	£3,750	£3,750	£3,750	£3,750	£3750	£3,750	£3,750	£1,000	£1,000	£45,000
Website	Buglife staff time				£500				£500						£700	£1,700
Ditch management booklet	Buglife staff time for writing; printing costs														£7,000	£7,000
TOTAL		£2,250	£3,250	£3,750	£28,624	£7,277	£3,750	£3,750	£27,346	£5,750	£3,796	£3,750	£27,393	£1,013	£19,149	£140,848

Notes This table excludes an allocation of £10,000 from the Environment Agency, which was spent in 2007 on a desk study and equipment.

4 Survey and evaluation methods

A full account of the marshes surveyed, the species found, the data analysis and the conclusions from the study are given in the technical report on the project (Drake *et al.*, 2010). A brief summary is given here.

4.1 Sites surveyed

Survey coverage in the three field seasons is shown below. Most of these marshes are SSSIs and many are nature reserves run by organisations such as the RSPB, County Wildlfe Trusts and local authorities.

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, 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	Essex	15	15
N. Thames: Hadleigh	Essex	7	7
Crouch estuary: Fambridge	Essex	15	15
Colne estuary: Brightlingsea	Essex	11	11
Orwell estuary: Shotley	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**

Ditches were sampled for invertebrates in spring and the same ditches (plus a few extra) were surveyed for plants in summer and early autumn. A total of 546 ditches was examined.

4.2 Field survey methods

A standard field survey methodology was incorporated in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches* (Palmer, Drake & Stewart, 2010), which was produced as part of the core project. This method was followed in the three years of the fieldwork. In 2007, the invertebrate specialist found that sampling eight ditches per day was very strenuous. A reduced target of sampling seven ditches per day was therefore introduced for 2008 and 2009, but even this reduced workload took on average 10 hours per day in the field for the invertebrate specialist.

Environmental variables recorded for each ditch included:

- ditch features (dimensions, profile, depth, substrate)
- water characteristics (pH, electrical conductivity, colour, turbidity, depth)
- vegetation cover (submerged, floating, emergent, bank)
- adjacent land use and its management (grazed grassland, arable etc.)
- details of the ditch management regime (where available).

At about every fifth ditch, the botanist collected a diatom sample from the stems of aquatic plants, for diatom analysis by Bristol University (see Section 2.2.1).

In addition, ten ditches in Somerset that had been sampled in 2007 were resampled in 2008 and 2009 for invertebrates, and twenty ditches were resurveyed for plants. Repeat sampling was carried out to give an indication of the amount of year-to-year variation that may be expected as a result of influences such as the weather and the normal ditch cleaning cycle. The aim was to establish a threshold that must be exceeded before any differences between surveys at different dates could be regarded as real.

4.3 Data analysis

A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of ditches (Palmer, Drake & Stewart, 2010) gives a method for assessing the conservation value of the aquatic flora and fauna of ditch systems. It uses metrics for plant and invertebrate assemblages, based on scores for richness (number of species), rarity (number and status of rare species), habitat quality (water quality) and naturalness (i.e. presence or absence of non-native species).

All the data collected in 2007-09 were digitised and classifications of the flora and fauna were produced. The environmental features influencing the composition of the plant and animal assemblages were identified.

Data from previous surveys were digitised. The average metrics for richness, rarity, habitat quality and naturalness were calculated for matched datasets from surveys that were many years apart. Using the confidence limits set by the repeat sampling exercise in Somerset, information from past invertebrate and plant surveys was compared with the results obtained in 2007-09. These results were used to indicate whether there had been any significant deterioration or improvement in the flora and fauna of the marshes in the period between the surveys.

For ditch vegetation in Norfolk and Somerset, it was also possible to compare the relative proportions at different dates of plant assemblages typical of good and poor water quality.

5 Summary of results

5.1 Species recorded

A total of 326 target aquatic invertebrate species and 174 plant species were recorded from ditches in the marshes surveyed. The most numerous invertebrate group was the water beetles, of which 153 species were recorded.

Seventy of the invertebrate species and eleven of the plant species are nationally rare or scarce. These are defined as follows:

- Species protected under the EC Habitats Directive
- Species protected under the Wildlife and Countryside Act 1981
- British Red List species (nationally threatened)
- Near Threatened species (near to qualifying for Red List)
- Nationally Scarce species (occur in 100 or fewer 10x10 km squares in Britain)
- UK Biodiversity Action Plan (BAP) priority species.

Records of the invertebrate species of highest conservation importance were as follows:

Area	Species	Status	No. of records
Somerset and Avon	Lesser silver water beetle (*Hydrochara caraboides*)	Red List Near Threatened, WCA Schedule 5, BAP	Found only in Somerset, in 9 samples
	Shining ram's-horn snail (*Segmentina nitida*)	Red List Endangered, BAP	In 1 sample
	Large-mouthed valve snail (*Valvata macrostoma*)	Red List Vulnerable, BAP	In 7 samples
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	Little whirlpool ram's-horn snail (*Anisus vorticulus*	Red List Vulnerable, Hab. Dir. Annexes II and IV, BAP	In 1 sample
	Large-mouthed valve snail (*Valvata macrostoma*)	Red List Vulnerable, BAP	In 1 sample
Norfolk: 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

Records of the plant species of most conservation concern were these:

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

The most widespread of the rare plants is Frogbit, which occurred in over half the ditches sampled. Tubular water-dropwort (a BAP species) was recorded in a quarter of the ditches. Grazing marshes are the British stronghold for these two species and for Sharp-leaved pondweed (*Potamogeton acutifolius*) and Water soldier (*Stratiotes aloides*).

Three non-native invertebrate species were recorded frequently: the small crustaceans *Crangonyx pseudogracilis* and two snails *Potamopyrgus antipodarum* and *Physella acuta*, the latter being a recent immigrant to Britain. The impact of these species on the native fauna is unknown. A claw from a Chinese mitten crab was found in the Inner Thames Marshes, but it may have come from a crab that had been caught elsewhere and dropped there by a predator.

Nine non-native plant species were recorded. Some of these, such as Australian swamp stonecrop (*Crassula helmsii*), Nuttall's waterweed (*Elodea* nuttalli)i and Least duckweed (*Lemna minuta*), were dominant in places and obviously out-competing the native flora.

5.2 Environmental influences

One of the special characteristics of coastal grazing marshes is the range of salinity encountered. The presence of both fresh and brackish water, and the transition between the two extremes, is an important element leading to biodiversity. This balance is threatened by rising sea levels. Ditch plants that are associated with saline conditions are Sea club-rush (*Bolboschoenus maritimus*), Brackish water-crowfoot (*Ranunculus baudotii*) and Tasselweed (*Ruppia maritima*). Other species, such as Common reed (*Phragmites australis*) and Fennel-leaved pondweed (*Potamogeton pectinatus*), are tolerant of a wide range of saline and fresh water. Salt-tolerant invertebrates include crustaceans such as prawns, and certain water beetles, flies, water-boatmen and snails.

Classifications of the plant and invertebrate assemblages recorded during the survey showed that salinity has an over-riding influence on the type of communities that are present in the marshes. Most of the brackish marshes lie in the east of the country.

Other somewhat less important environmental features that influence the composition of the plant and invertebrate communities are geographical location, ditch dimensions, water depth, vegetation structure (the proportion of open water to swamp vegetation and the prevalence of algae and floating duckweeds), soil type and cattle grazing.

5.3 Evaluation and ranking of the areas surveyed

The results of applying the evaluation metrics to the invertebrates showed that the areas with the highest average species richness were the predominantly freshwater marshes in Norfolk and Pevensey Levels; the highest average rarity scores were for Pevensey Levels, Walland Marsh, the North Kent Marshes and wetlands beside the Thames and Crouch estuaries; and the highest habitat fidelity scores were the brackish marshes in the North Kent and Thames areas. It was obvious that the brackish-water fauna was species-poor but that these assemblages contained many rare species and had high fidelity to the grazing marsh habitat.

For plants, marshes in Norfolk had the highest mean species richness. The Pevensey Levels was also outstanding for its rarity 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. Ditches in Anglesey scored highest for water quality, as judged by the plant assemblage they supported.

5.4 Recent change in the quality of ditch biota

Comparison of conservation value metrics for past surveys and the 2007-2009 survey indicated that no marshes had deteriorated recently, and that there were signs that the general quality of the invertebrate fauna had improved, at least in Norfolk, Somerset and Fambridge Marsh, which has recently been managed as a nature reserve by Essex Wildlife Trust. The results of the comparisons for the invertebrate fauna are shown in the following table.

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 Score	Species Rarity 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	-	-
Norfolk (molluscs only)		
Yare valley	↑	-
Bure valley	-	↑
Suffolk		
Shotley	-	-
Sizewell	-	-
Minsmere	-	**
Gwent		
Caldicot	-	-
Wentlooge	-	-

Botanical data from a survey in Norfolk Broadland marshes carried out in 1988-89 were made available to Buglife by Natural England. Application of the evaluation system to data from this survey and the 2009 Buglife survey showed an increase in plant species rarity and habitat quality scores, but these fell a little short of the thresholds set to confirm real change. However, the proportion of ditches in species-rich vegetation assemblages typical of good water quality had increased and the proportion in the species-poor duckweed-dominated and the algal-dominated groups decreased. Some rare species, such as Water-soldier (*Stratiotes aloides*) had also increased in occurrence. These results imply an improvement in water quality brought about by recent flood alleviation measures aimed at preventing saline and polluted river water entering the marshes.

A similar result was obtained when the frequency of vegetation communities in Somerset ditches was compared, using Buglife's data from 2007 and a survey carried out in 1982. Again the species-poor duckweed-dominated communities had decreased and the more species-rich communities, indicative of cleaner water, had increased.

These results for plants and invertebrates imply a reversal of previous reported trends and suggest that current management of protected sites for wildlife conservation is bearing fruit. This optimistic picture is tempered by a decrease in some rare species and a general increase in non-native species.

5.5 Recommendations for ditch management

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

Water quality should be as good as possible. Low levels of manure or fertiliser application to the fields within the marsh system is important, and external sources of water should be as free of pollution as possible.

Water levels should be kept high in summer and at least moderately high in winter, so that ditches do not dry out.

Salinity gradients on marshes where there is a long history of mild salinity should be maintained, as should the whole hydroseral range (i.e. all stages in vegetation succession). This is because the various species assemblages and rare species are dependent on different combinations of these two features.

Because ditch vegetation matures at different rates depending on local conditions, managers should be encouraged to take account of the range of vegetation present and decide on the frequency of ditch cleaning that will maximise diversity. Vegetation types that are undesirable are those dominated by algae, dense carpets of floating duckweeds or invasive non-native species.

A wide range of hydroseral stages can be maintained in individual ditches 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, allowing 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.

Leaving ditches unfenced to allow cattle access to ditch margins may be in conflict with recommended management for birds and water voles.

Occasional de-silting rather than frequent de-weeding favours submerged aqualtic plants such as stoneworts that need a firm substrate. 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.

If new ditches are dug they should be given a variety of profiles, from saucer-shaped to deeper, more conventional profiles, but with shallow slopes under water at the edges

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.

6 General conclusions

1. Grazing marshes are extremely biodiverse and are a British stronghold for a number of threatened plant and invertebrate species.

2. Several non-native aquatic plant species are well established in grazing marsh ditches, generally to the detriment of native species. A few non-native invertebrate species are also well established, but their impact is unknown.

3. For both plants and invertebrates, salinity is the over-riding factor determining the composition of species assemblages. Brackish water assemblages are restricted geographically and reach their best expression in marshes in north Kent and Essex. The brackish water invertebrate fauna, although species-poor, contains a large number of rare species and species with a high fidelity to coastal grazing marshes.

4. Secondary influences on invertebrate assemblages are geographic location and local environmental factors that relate especially to the relative amounts of open water and marginal vegetation, and therefore to the ditch cleaning regime.

5. There is evidence of recent general improvement in the quality of the flora and fauna of English grazing marshes that are managed for the benefit of wildlife.

6. Recommendations for optimum management of ditches for aquatic plants and invertebrates are made in the light of the findings of this project. The most important features to maintain are salinity gradient, diversity of vegetation types and good water quality.

7. Grazing marshes in different parts of the country are not equivalent or interchangeable. Loss of marshes due to rising sea level, managed retreat or development should be made good at a local level.

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Photographs by Nick Stewart

Frogbit and stonewort