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 2

Appendices

Martin Drake

Nick Stewart

Margaret Palmer

Vicky Kindemba

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Buglife – The Invertebrate Conservation Trust

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Volume 1: summary of contents

APPENDIX 1

Ditch surveys used as information sources

Appendix 1 relates to Sections 2 and 8 of Volume 1
and to Appendix 5, Volume 2, of this report

1 Bibliography of ditch surveys

An extensive list of reports and publications on botanical and invertebrate surveys of ditches is given in: Driscoll, R. J. (2007) *A Bibliography of Ditch surveys in England and Wales: 1878 to 1999.* Buglife – The Invertebrate Conservation Trust, Peterborough. This bibliography is available on Buglife's web site. Further searches by Stewart and Drake have uncovered more accounts of the aquatic flora and fauna of grazing marshes, many of them post-1999. These are given in Tables 1.1 and 1.2 below.

Table 1.1 Surveys of ditch vegetation in Somerset and Avon grazing marsh ditches

Reference	County
Lewis, G. 1981. Somerset Rivers Survey, Tone, Cary, Yeo, North Moor Drain. Report by STNC, WWA Survey of banks and water courses of major drains/rivers on North Moor, King's Sedgemoor, Moorlinch, Wet Moor. Vegetation described in terms of rarity, diversity and dominant species.	Somerset
ADAS, 1987. Somerset Levels and Moors Environmentally Sensitive Area, report on biological monitoring, 1987 for MAFF. Twenty ditch sections surveyed as baseline for ESA monitoring	Somerset
Cadbury, C. 1995. The ditch flora of West Sedgemoor (Somerset) 1984 and 1994. Report for RSPB Partial resurvey (192 ditches) of ditches surveyed by Henderson in 1984, looking at changes.	Somerset
Hughes, M.R.H. 1995. A botanical survey of ditches, North Moor and Southlake Moor, Somerset, 1994. Report for English Nature A repeat of the Wolseley et al. 1984 survey on North Moor and Southlake Moor, looking at 100 ditch sections]	Somerset
Walls, R.M. 1996. Somerset Levels and Moors, botanical survey of rhynes and ditches 1995. Report by Dorset Ecological Consultancy for English Nature. 48 pp + 6 maps Survey of 400 ditch sections on Catcott, Eddington and Chilton Moors, King's Sedgemoor, Tealham and Tadham Moors, West Moor and Wet Moor, including a repeat of those surveyed by Wolesley et al, 1984 survey.	Somerset
Walls, R.M. 1997. Somerset Levels and Moors, survey of rhynes and ditches, Cattcott, Eddington and Chilton and Tealham and Tadham Moors, 1996. Report by Dorset Ecological Consultancy for English Nature.	Somerset
Carter, R.N. 1998. North Moor and Southlake Moors SSSIs, botanical survey of ditches and rhynes 1998. Survey of 100 ditch sections on North Moor and Southlake Moor, matching the ditches surveyed in Hughes 1995 and assessing the changes.	Somerset
Nisbet, A. 2000a. Somerset Levels and Moors, botanical survey of ditches and rhynes. Report for English Nature. 240 ditch sections in the Catcott complex, Tealham and Tadham Moors, King's Sedgemoor, Moorlinch, Langmead and Weston Level. Many of these are repeat surveys from Walls 1996 and some also from Wolseley et al. 1984.	Somerset
Nisbet, A. 2000b. North Somerset Levels and Moors, botanical survey of ditches and rhynes. Report for English Nature. 80 ditch sections in Gordano valley, Tickenham complex, Puxton Moor and Biddle Street. A partial resurvey of ditches surveyed in Pollock et al. 1991.	Somerset & Avon
Pollock, K., Bradford, R. & Christian, S. 1992. A botanical survey of ditches on the Avon Levels and Moors 1991. Report for English Nature. 362 ditch sections in Gordano valley, Tickenham complex, Puxton Moor and Biddle Street (Cadbury Farm).	Somerset & Avon
Prosser, M. & Wallace, H. 1999. Botanical survey of rhynes and ditches in the Somerset Levels and Moors: Wet Moor, Curry and Hay Moors, 1998. Report by Ecological Surveys (Bangor) for English Nature. 141 ditch sections in West Moor, Wet Moor and Curry and Hay Moors. Partial resurvey of ditches in Cox 1994.	Somerset

Ministry of Agriculture, Fisheries and Food, 1991. The Somerset Levels and Moors Environmentally Sensitive Area. Report of monitoring in 1991. Somerset

20 ditch sections outside SSSIs in the ESA area

Hopkins, A., Tallowin, J.R.B., Clements, R.O. & Lewis, G.C. 2001. Somerset Levels and Moors, independent scientific review. Final technical report. Report by IGER for Environment Agency Somerset

Provides a summary and overview of previous surveys for birds, aquatic and terrestrial vegetation and aquatic invertebrates.

Evans, C. 1991. The conservation importance and management of the ditch flora on RSPB reserves. RSPB Conservation Review, 5: 65-71. Somerset

Wolseley, P. 1986. The aquatic macrophyte communities of the ditches and dykes of the Somerset Levels and their relation to management. Proceedings of the European Weed Research Society/Association of Applied Biology 7th Symposium on Aquatic Weeds, 1986, pp. 407-411. Somerset

Further interpretation of surveys covered by Wolseley et al. 1984

Table 1.2 Surveys of aquatic invertebrates in grazing marsh ditches

This list does not include surveys that were purely for single-species or targeted primarily at terrestrial taxa. A summary is given for some surveys in Somerset and Gwent. Many smaller reports have not been seen.

B = aquatic invertebrate survey	H = includes habitat data
S = includes single-species studies	J = includes a classification of aquatic invertebrate fauna
T = includes terrestrial invertebrates.	L = includes biological / ecological assessment

Reference	County	Scope
Acer Environmental. 1995. Celtic *Lakes Business Park. Ecological monitoring* report 1991-'93. Unpublished report. A1032/94/1. Welsh Development Agency.	Gwent	B
AERC. 1998. *Rainham Marsh Ecological Ditch Survey. Applied Environmental Research Centre*. Unpublished report No. 74004 to Havering Riverside.	Essex	B
AMEC Earth & Environmental UK. 2005. [Gwent Europark aquatic invertebrate monitoring – Autumn 2005]	Gwent	B
AMEC Earth & Environmental UK. 2005. *Report on reen water quality, invertebrates and macrophytes, Gwent Europark, August, 2005.* Unpublished AMEC Earth & Environmental UKreport to Burkes Green.	Gwent	B
Argus Ecological Services. 1999. *Gwent Levels Wetland Reserve, Uskmouth: Freshwater invertebrate survey.* Unpublished report. The Environment Practice.	Gwent	B
Armitage, P.D., Szoszkiewicz, K., Blackburn, J.H. & Nesbitt, I. 2003. Ditch communities: a major contributor to floodplain biodiversity. *Aquatic Conservation,* **13**: 165-185.	Dorset	BL
Booth, F. 1992. *Botanical and invertebrate survey*. Unpublished report to Gillingham Borough Council.	Kent	B
Bratton, J.H. 2001. *A comparison of the efficiency of pond net and sieve for catching aquatic beetles and aquatic bugs over the course of a year in a grazing levels ditch in Malltraeth Marsh, Anglesey, Wales. CCW Natural Science Report.* **01/5/1**. Countryside Council for Wales. Comparison of sampling methods for aquatic invertebrates at one ditch sampled for one year.	Anglesey	B
Bristol, Bath and Avon Wildlife Trust. 1997. *Dragonfly Survey 1997 of Tickenham, Nailsea and Kenn Moors and Congresbury Moor (North)*. Unpublished report.	Somerset	B
Carr, R. 1995. *A survey of the aquatic Coleoptera on the North Kent Marshes October 1995.* Unpublished report to English Nature.	Kent	B
Carr, R. 2000. *A survey of the aquatic Coleoptera on High Halstow and Elmley RSPB Reserves*. Unpublished report to RSPB.	Kent	B
Clare, P. 1977. *The fauna of the reens of the Monmouthshire Levels.* Unpublished manuscript.	Gwent	B
Clemons, L. 1982. A survey of the flora and fauna of Murston Marshes. *Transactions of the Kent Field Club*, **9**, 31-64.	Kent	B
Clemons, L. 1984. Some interesting Diptera records from North Kent in 1982. *Entomologist's Record* **96**, 202-206.	Kent	B
Clemons, L. 1995. *English Nature 1995 North Kent Marshes invertebrate surveys.* Unpublished report to English Nature.	Kent	B
Cresswell Associates. 1999. *Ecological appraisal of section 3 of the south eastern coastal strategy pipeline, Caldicot to Nash.* Unpublished report.	Gwent	B
Crossley, R. 1987. *Derwent Ings Survey 1987.* Unpublished report.	Yorkshire	B
Crossley, R. 1991. *Wheldrake Insect Survey 1990*. Unpublished report.	Yorkshire	B
Crossley, R. 1993. *Derwent Ings NNR: Drains and Dykes Invertebrate Survey 1992*. Unpublished report.	Yorkshire	B
Crossley, R. Undated. *Derwent Ings Insect Survey. 1987-1989*. Unpublished report.	Yorkshire	B
Crossley, R. Undated. *Derwent Ings NNR Master List for Invertebrates to the end*	Yorkshire	B

of 1992. Unpublished report.		
Curson, S., Hodge, P. J., Ryland, K. & Willing, M. J. 2002. *Baseline biological survey of the Lower Ouse Valley 2002*. Unpublished report to English Nature, Lewes.	Sussex	B
David Bellamy Associates. 1992. *Cardiff Bay Barrage Mitigation Measures: aquatic invertebrates survey.* Unpublished report. Cardiff Bay Development Corporation.	Gwent	B
David Clements Ecology. 2002. *Capital Business Park: monitoring of aquatic invertebrates in reens.* Unpublished report.	Gwent	B
David Clements Ecology. 2003. *Capital Business Park: monitoring of aquatic invertebrates in reens, 2003.* Unpublished report.	Gwent	B
Dawson, I. & Dawson, D. 2000 *Invertebrates recorded at Shorne Marshes, 3 June 2000.* Unpublished report to RSPB.	Kent	B
Denton, J. 1991. *The water beetles of 'The Dowels' part of the Walland Marsh SSSI, Kent*. Unpublished report to English Nature.	Kent	B
Drake, C.M. 1988. Diptera from the Gwent Levels, South Wales. Entomologist's monthly Magazine, 124, 37-44.	Gwent	BS
Drake, C.M. 1991. A rapid survey of the invertebrates of the Kennet Valley near Hungerford. Unpublished report to Nature Conservancy Council.	Berkshire	B
Drake, C.M. 1991. Ephemeroptera and Plecoptera in freshwater and brackish ditch systems on British grazing marshes. *Entomologist's Gazette* **42**: 45-59.	Gwent	BS
Drake, C.M. 2002. A survey of the aquatic molluscs and beetles of the Yare Valley, 2001. Unpublished report to The Broads authority.	Norfolk	BJ
Drake, C.M. 2003. A survey of the aquatic invertebrates of the Stert Peninsula. Unpublished report to English Nature. Aquatic invertebrate survey of 100 ditches in July and August 2003, in response to proposals for coastal realignment.	Somerset	BHL
Drake, C.M. 2003. A survey of the aquatic molluscs and beetles of the Bure Valley, 2002. Unpublished report to The Broads authority.	Norfolk	BJ
Drake, C.M. 2004. *A survey of Southern Damselfly and other invertebrates at Mottisfont Estate, Hampshire*. Unpublished report to the National Trust.	Hampshire	B
Drake, C.M. 2004. *A survey of the aquatic invertebrates in the ditches on the Gordano Valley NNR*. Unpublished report to English Nature, Taunton. Aquatic invertebrate survey of 60 ditches in August and September 2004; results compared with previous surveys.	Somerset	BHJL
Drake, C.M. 2004. *A survey of the invertebrates of the Nene Washes*. Unpublished report to RSPB, Sandy.	Cambs	B
Drake, C.M. 2004. *A survey of the invertebrates of the Ouse Washes RSPB Reserve*. Unpublished report to RSPB, Sandy.	Cambs	B
Drake, M. 2004. *Fauna survey of Newport Wetlands 2004.* CCW Regional Report. CCW/SEW/04/2. Countryside Council for Wales. Survey of terrestrial and aquatic invertebrates of 16 ditches in May 2004; results compared with previous monitoring.	Gwent	BL
Drake, C.M. 2005. *A survey of the invertebrates of the saltmarsh and freshwater marsh at Keysworth Marsh, Dorset*. Unpublished report to the Environment Agency.	Dorset	B
Drake, C.M. 2005. *A survey of the water beetles of Walland Marsh and Cheyne Court SSSIs, Kent, 2005*. Unpublished report to English Nature, Wye.	Kent	B
Drake, C.M. 2005. *A survey of the water beetles of Westcourt Marshes, part of the South Thames Estuary and Marshes SSSI, Kent, 2005.* Unpublished report to English Nature, Wye.	Kent	B
Drake, C.M. 2005. Survey of the aquatic invertebrates of Kenn Moor south, 2005. Unpublished report to English Nature, Taunton. Aquatic invertebrate survey of six ditches in one small area of Kenn SSSI in August 2005, in response to development pressure.	Somerset	BHL
Drake, C.M. 2006. Gwent Europark aquatic invertebrate monitoring – Spring 2006 draft report. Unpublished report to xxxxxxx	Gwent	B
Drake, C.M. 2007. [*Invertebrate surveillance of ditches on Pawlett Hams, Somerset.*] Unpublished report to xxxx [in prep]	Somerset	BHL

Aquatic invertebrate survey of 6 ditches and 5 ponds in October 2006; mitigation monitoring.		
Lott, D.A. 2007. *ISIS development report: Testing ISIS 2006 projects.* Unpublished report to Natural England, Peterborough.	Somerset, Dorset	B
Edwards, M. & Hodge, P. 1997. *An entomological survey of Tournerbury Farm, Hayling Island.* Unpublished report . 9p.	Hampshire	B
Edwards, M. & Hodge, P. 2000. *An entomological survey of Hacketts Marsh.* Unpublished report to Hampshire County Council. 24p.	Hampshire	B
Environment Agency. No date. [*Pevensey Levels Study - no title provided*]. Unpublished report, Environment Agency, Worthing.	Sussex	B
Environmental Advisory Unit Ltd. 1990. *Aquatic invertebrate survey of the ditches of the Caldicott Levels: October 1990.* Unpublished report. Second Severn Crossing Group.	Gwent	B
Environmental Advisory Unit Ltd. 1990. *Aquatic invertebrate survey of the ditches of the Caldicot Levels: October 1990.* Unpublished report.	Gwent	B
Flint, J. H. 1987. *Insect Survey, Derwent Ings, 1987*. Unpublished report.	Yorkshire	B
Foster, A. P. & Jackson, P. K.. 1999. *Blakeney Freshes, Norfolk.* Unpublished report to National Trust.	Norfolk	B
Foster, A. P. & Lister, J. A. 1994. *Chyngton Farm, East Sussex*. Unpublished report to National Trust.	Sussex	B
Foster, A. P. & Lister, J. A. 1998. *Heigham Holmes, Norfolk*. Unpublished report to National Trust.	Norfolk	B
Foster, A. P. & Lister, J. A. 2002. *Fairlight, East Sussex.* Unpublished report to National Trust.	Sussex	B
Foster, A. P., Jackson, P. K. & Lister, J. A.. 1994. *Frog Firle Farm, East Sussex.* Unpublished report to National Trust.	Sussex	B
Gibbs, D. J. 1985. *The invertebrates of the Kennet Valley (1985). A comparative assessment of sites in the Kennet Valley for their entomological value*. Unpublished report.	Berkshire	B
Gibbs, D. 1991. *Cwm Ivy: Invertebrate survey, 10 July 1991.* Unpublished report. Countryside Council for Wales.	Gwent	B
Gibbs, D. 1991. *Llangennith Moors: Invertebrate survey, 10 July 1991.* Unpublished report. Countryside Council for Wales.	Gwent	B
Gibbs, D. 1991. *Margam Moors: Invertebrate survey, 11 & 22 July 1991.* Unpublished report. Countryside Council for Wales.	Gwent	B
Gibbs, D. J. 1993. *Ouse Washes SSSI: invertebrate survey of ditch system. July and September 1993.* Unpublished report for English Nature	Cambs	B
Gibbs, D. J. 1994. *A survey of the invertebrate fauna of ditches on the Somerset Levels and Moors*. Unpublished report for English Nature, Somerset and Avon Team.	Somerset	BL
Aquatic invertebrate survey of 120 ditches on seven moors in May and June 1994; results compared with previous surveys.		
Gibbs, D. J. 1994. *A survey of the invertebrate fauna of the Somerset Levels*. Unpublished report for English Nature, Taunton.	Somerset	BL
Same as the very similarly titled report of this year.		
Gibbs, D. J. 1994. *Aquatic invertebrate survey: Somerset Levels and Moors. Catcott, Edington and Chilcott Moors, 24 May 1994*. Unpublished report.	Somerset	B
Gibbs, D. 1999. [*Aquatic Invertebrate survey of Weston Fen* or similar title] Unpublished report to Avon Wildlife Trust.	Somerset	B
Godfrey, A. 1992. *Invertebrate survey for the proposed A249(T) re-alignment, Walland Marsh.* Unpublished report to developer.	Kent	B
Godfrey, A. 1992. *Terrestrial invertebrate survey for the A249 Iwade Bypass to Queenborough.* Unpublished report to developer.	Kent	BT
Godfrey, A. 1993. *A249 Iwade to Queenborough road improvement invertebrate survey report.* Unpublished report by Ecosurveys Ltd.	Kent	B
Godfrey, A. 1998. *Aquatic invertebrate survey of the north Somerset Levels*. Unpublished report for English Nature, Somerset and Avon Team.	Somerset	BL
Aquatic invertebrate survey of 28 ditches on Kenn, Puxton and Biddle Street SSSIs in August 1998 to assess interest.		

Godfrey, A. 1999. *Aquatic invertebrate survey of the north Somerset Levels*. Unpublished report for English Nature, Somerset and Avon Team. Aquatic invertebrate survey of 69 ditches on Kenn, Puxton and Biddle Street SSSIs in August 1999; results compared with previous surveys.	Somerset	BL
Godfrey, A. 2000. *Aquatic invertebrate survey of Somerset Levels and Moors 1999*. Unpublished report to English Nature. Aquatic invertebrate survey of 120 ditches on seven moors in July 1999; results compared with previous surveys.	Somerset	BL
Gregory, R. D. 1986. *Freshwater Invertebrate Survey of the Dyke System of The Lower Derwent Valley*. Unpublished report by University of York to Nature Conservancy Council.	Yorkshire	B
Hammond, M. 1998c. *Environmentally Sustainable Management of the Water Resources of The Lower Derwent Valley, III: Ecological Requirements of Key Features B: Invertebrates other than Coleoptera and Odonata, March 1998.* Unpublished report by Entotax Consultants.	Yorkshire	B
Hammond M. 1997. *Environmentally Sustainable Management of the Water Resources of The Lower Derwent Valley II: Invertebrates. December 1997.* Unpublished report.	Yorkshire	B
Hammond, M. 1998. *Environmentally Sustainable Management of the Water Resources of The Lower Derwent Valley, III: Ecological Requirements of Key Features C: Invertebrates Coleoptera and Odonata, March 1998*. Unpublished report by Entotax Consultants.	Yorkshire	B
Hammond, M. 1998. *Lower Derwent Valley Water Beetle Records, 31st August 1998*. Unpublished report to Ryedale District Council.	Yorkshire	B
Hammond, M. 1998. *Water Beetle Records from The Lower Derwent Valley* [North Duffield Ings and Thornton Ings]. Unpublished report.	Yorkshire	B
Hammond, M. 1999. *Water Beetles Recorded from North Duffield Carrs*. Unpublished report to Ryedale District Council.	Yorkshire	B
Hill-Cottingham, P. & Duff, A. 1998. C*atcott Lows invertebrate survey.* Unpublished report to the Somerset Wildlife Trust by the Somerset Invertebrates Group. Survey of terrestrial and aquatic invertebrates in summer 1997 by many recorders to assess interest	Somerset	BT
Hill-Cottingham, P & Smith, T. 1995. *Somerset Levels and Moors, aquatic macroinvertebrate survey*. Unpublished report to Environment Agency. Aquatic invertebrate survey of 46 samples collected by Environment Agency in September 1994 from 13 moors.	Somerset	B
Hill-Cottingham, P & Smith, T. 1996. *Pawlett Hams ditch survey*. Unpublished report to English Nature. 36p. Aquatic invertebrate survey of 21 ditches in October 1996; results compared with some previous surveys.	Somerset	BL
Hill-Cottingham, P & Smith, A. 1997. *A Survey of the Aquatic Macro-invertebrates - Reedbed Development Project Ham Wall.* Report for the RSPB. Aquatic invertebrate survey of developing reed-fen.	Somerset	B
Hill-Cottingham, P. & Smith, A.G. 1997. *Avon Levels and Moors ditch invertebrate survey*. Unpublished report by Somerset Ecology Consultants Ltd.	Somerset	BL
Hill-Cottingham, P & Smith, T. 1998. *Effects of the summer flood on aquatic invertebrates on West Moor, Wet Moor and Currey and Hay Moors: 1997 - 1998.* Unpublished report to English Nature. 75p. Aquatic invertebrate survey of 36 ditches from three moors sampled in October 1997 and again in June 1998 following flooding in August 1997; results compared with some previous surveys.	Somerset	BL
Hill-Cottingham, P & Smith, T. 1998. *Pawlett Hams Ponds: survey of aquatic invertebrates on Bridgewater Bay SSSI*. Unpublished report to English Nature. 42p. Aquatic invertebrate survey of 12 ponds in June 1998; results compared with previous surveys.	Somerset	BL
Hill-Cottingham, P. & Smith, A.G. 2004. *A survey of the ditches on Greylake*	Somerset	B

Reserve. A report for RSPB on the Mollusca, other macroinvertebrates and floating and submerged flora on the ditches of the reserve. Unpublished report to RSPB.

Aquatic invertebrate survey of 32 ditches, in October 2003 and September 2004, concentrating on molluscs and with less detailed information on other groups.

Hodge. P. J. 1987. *Insect records extracted from Pett Levels entomological survey report - May to July 1987*. Unpublished report to Nature Conservancy Council, South East Region — Sussex — B

Hodge. P. J. 1990. *A survey of the aquatic insects of East Guldeford Level*. Unpublished report to Chris Blandford Associates : Blackboys. — Sussex — B

Hodge. P. J. 1990. *A survey of the insects of the Somerset Moors peat production zone with recommendations for their conservation.* Unpublished report to Nature Conservancy Council. — Somerset — BLT

Survey of mainly terrestrial insects (some aquatics) of several areas on the peat, May - Augsut 1989.

Hodge. P. J. 1990. *A survey of the Coleoptera, Diptera and Hemiptera-Heteroptera of the Arun Levels between Arundel and Pulborough.* Unpublished report for Nature Conservancy Council, South East Region. 72p. — Sussex — B

Hodge. P. J. 1991. *The Coleoptera of Arundel Park*. Unpublished report to English Nature. — Sussex — B

Hodge. P. J. 1991. *A survey of insects of the upper Combe Haven valley wetlands.* Unpublished report to Chris Blandford Associates : Blackboys. — Sussex — B

Hodge. P. J. 1992. *A survey of aquatic insects along proposed route of A259 Bexhill to Hastings by-pass for assessment of water quality at proposed outfall sites*. Unpublished report to Chris Blandford Associates : Blackboys. — Sussex — B

Hodge. P. J. 1992. *A survey of insects from the West Hythe wetlands*. Unpublished report to Chris Blandford Associates : Blackboys. — Kent — B

Hodge. P. J. 1992. *A survey of part of the Newhaven Marshes in East Sussex for water beetles and bugs* Unpublished report to Chris Blandford Associates : Blackboys — Sussex — B

Hodge. P. J. 1992. *A survey of the wetland insects of part of the Rye Harbour SSSI.* Unpublished report to Chris Blandford Associates : Blackboys. — Sussex — B

Hodge. P. J. 1992. *A survey of the wetland insects of part of Walland Marsh SSSI and a small area of grazing marsh and shingle beach habitats near Northpoint Beach*. Unpublished report to Chris Blandford Associates : Blackboys — Kent — B

Hodge. P. J. 1992. *A survey of West Brede Level wetland insects*. Unpublished report to Chris Blandford Associates : Blackboys — Sussex — B

Hodge. P. J. 1992. *An aquatic insect survey of drainage outfall sites for proposed road construction at West Hythe and a brief survey of aquatic insects in a section of the Kent Ditch*. Unpublished report to Chris Blandford Associates : Blackboys. — Kent — B

Hodge. P. J. 1992. *An invertebrate survey of Ingrebourne Marshes, south Essex.* Unpublished report. — Essex — B

Hodge. P. J. 1993. *A further survey of aquatic insects at selected sites along the western section of the Hastings by-pass route*. Unpublished report to Chris Blandford Associates : Blackboys. — Sussex — B

Hodge. P. J. 1993. *A survey of aquatic insects at selected sites along the western section of the Hastings by-pass route*. Unpublished report to Chris Blandford Associates : Blackboys — Sussex — B

Hodge. P. J. 1994. *Entomological survey of National Trust land at Chyngton Farm, Seaford*. Unpublished report to National Trust — Sussex — B

Hodge. P. J. 1994. *Entomological survey of National Trust land at Frog Firle Farm, Alfriston.* Unpublished report to National Trust — Sussex — B

Hodge. P. J. 1994. *Insects recorded from Pulborough Brooks R.S.P.B. nature reserve (TQ053164) on 20th July 1994*. Unpublished report to Royal Society for the Protection of Birds. — Sussex — B

Hodge. P. J. 1995. *A survey of insects from Horsham Marsh, north Kent*. — Kent — B

Unpublished report to English Nature, Wye.		
Hodge. P. J. 1995. *A survey of insects from part of Cooling Marshes, north Kent*. Unpublished report to English Nature, Wye.	Kent	B
Hodge. P. J. 1995. *A survey of insects on parts of Walland Marsh relating to the proposed A259 improvement between the Kent Ditch and Brookland.* Unpublished report to Chris Blandford Associates, 1995	Kent	B
Hodge. P. J. 1996. *A survey of the insects of the turf fields at Stodmarsh NNR*. Unpublished report to English Nature, Wye.	Kent	B
Hodge. P. J. 1996. *The Brede valley entomological assessment. A survey of insects within the River Brede flood plain between Westfield and Rye*. Unpublished report to English Nature, Lewes.	Sussex	B
Hodge. P. J. 1999. *A survey of aquatic insects at West Dean Brooks, East Sussex.* Unpublished report to Sussex Downs Conservation Board.	Sussex	B
Hodge. P. J. 1999. *A survey of invertebrates at Montague Farm. Report No. 1. Survey of Hankham Level on 20th August 1999.B145.* Unpublished report to English Nature, Peterborough.	Sussex	B
Hodge. P. J. 1999. *The Pells, Lewes. Survey of Insects. Report No. 1. (Records for 1974 - 1998)*. Unpublished report, Voluntary survey for Pells Amenity Group, Lewes.	Sussex	B
Hodge. P. J. 2000. *The Pells, Lewes. Survey of Insects. Report No. 2. (Records for 1999).* Unpublished report, Voluntary survey for Pells Amenity Group, Lewes.	Sussex	B
Hodge. P. J. 2001. *Ouse estuary - invertebrate survey. A survey of insects of the coastal shingle and wetland habitats likely to be affected by the proposed Newhaven Port access road*. Unpublished report to East Sussex County Council.	Sussex	B
Hodge. P. J. 2002. *Ouse valley survey 2002 Aquatic Coleoptera (water beetles) and Hemiptera-Heteroptera (water bugs)*. Unpublished report to Dolphin Ecological Surveys, Isfield.	Sussex	B
Hodge. P. J. ?in prep. The Arun Valley. *A survey of aquatic insects within the flood plain between Pulborough & Littlehampton*. Unpublished report.	Sussex	B
Hodge. P. J. 2003. *Ouse baseline survey 2003 Aquatic Coleoptera (water beetles) and Hemiptera (water bugs).* Unpublished report to Sussex Wildlife Trust.	Sussex	B
Hodge. P. J. 1987 - 2002. *The insects of the Lewes Railway Land and The Meadowlands. Reports Nos. 1 - 18*. Unpublished report to Railway Land Wildlife Trust, Lewes.	Sussex	B
Hodge. P. J. [?In prep Is this the same as the 1996 report?]. *An assessment of the entomological importance of the Brede Levels, East Sussex based on existing data*. Unpublished report to English Nature.	Sussex	B
Hodge, P. & Edwards, M. no date. *A further survey of insects at Tournerbury Farm, Hayling Island*. Unpublished report . 7p.	Hampshire	B
Honour, K., Lupton, P. & Williams, G. 2001. *Gwent Levels Wetland Reserve: reen flora and fauna surveys 2000.* CCW South Area Report. **CCW/SA/9**. Argus Ecological Services. Survey of aquatic flora and terrestrial and aquatic invertebrates of 20 ditches in May to July 2000; reserve monitoring.	Gwent	BHLT
Howlett, D. 1996. *Mid-Yare mollusc survey, 1996.* Unpublished report to RSPB.	Norfolk	B
Hyder Consulting. 2001. *Gwent Europark - WDC2. Reen flora and invertebrate monitoring 2000*. Unpublished report.	Gwent	B
Hyder Consulting. 2001. *South eastern coastal strategy. Reen flora, invertebrate and water quality monitoring 1999 - 2000*. Unpublished report to Welsh Water.	Gwent	B
Hyder Consulting. 2001. *Gwent Europark - WDC2. Reen flora and invertebrate monitoring 2000.* Unpublished report.	Gwent	B
Hyder Consulting. 2001. *Water quality, flora and invertebrate monitoring 2000-2001.* Unpublished report. [Concerning Gwent Europark.]	Gwent	B
Hyder Consulting Ltd. 2001. *Gwent Europark - WCD2: reen flora and invertebrate monitoring 2000.* Unpublished report. **SH80051/D4/1**. Dwr Cymru.	Gwent	B
Hyder Consulting Ltd. 2001. *Gwent Europark - WCD2: water quality, flora and*	Gwent	B

invertebrate monitoring 2000-2001. Unpublished report. **SH80051/D5/1**. Dwr Cymru.		
Jackson, M. J. & Charter, E. 1978. *Ecological survey of the Yare basin marshlands. Part II. Parts of the mid Yare, lower Brue & Waveney valley. July - Sept 1978.* Unpublished report for Nature Conservancy Council. 140p.	Norfolk	B
Jackson, P.K. & Foster, A.P. 2002. *Horsey Estate, Norfolk.* Unpublished report, National Trust.	Norfolk	B
Jackson, P. K., Foster, A. P. & Lister, J. A.. 1995. *Crutches Farm, East Sussex.* Unpublished report to National Trust.	Sussex	B
Jones, A. & Wistow, R. 1993. *Celtic Lakes Environmental Monitoring Programme Data Report.* Unpublished report. Wallace Evans Ltd. South Area (Cardiff).	Gwent	B
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Willing, M.J. 2001. *Molluscan monitoring of two ditches on Amberley Wildbrooks, 2000.* Unpublished report to Environment Agency, Worthing.	Sussex	B
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2 Data Sources used for comparisons of grazing marsh fauna at different dates

Tables 1.3 to 1.6 give the data sources used in the comparisons of the aquatic fauna of grazing marshes in Somerset, Essex, Suffolk, Norfolk and Gwent at different dates (see Volume 1, Section 8 and Volume 2, Appendix 5).

Table 1.3 Sources, major taxa and number of records in surveys of the Somerset and Avon Moors and Levels at different dates

Source	Moor	Year	number of samples	Coleoptera	Mollusca	Hemiptera	Odonata	Diptera	Hirudinea	Isopoda	Ephemeroptera	Trichoptera	Amphipoda	Araneae	Megaloptera	Decapoda	Plecoptera	Total records
Anderson et al 1991	Gordano	1991	4	47	22		2											71
	Kenn	1991	20	218	170		26											414
Anderson et al 1992	Kenn	1992	4	63	47		14											124
Armitage 1981	Catcott	1981	12	54	80	21	7	3	10	14	6	4						199
	Southlake	1981	6	38	59	14	7		13	7	7				1			146
	Tadham	1981	14	113	106	35	10	1	24	17	8	2						316
	West Sedgemoor	1981	8	62	53	13	7		5	8	4							152
Buglife 2007-2009	Catcott	2007	25	472	256	112	48	57	44	26	30	26	25	3	4			1103
	Kenn	2007	20	375	214	75	34	45	24	20	14	13	21	3	2			840
	Kings Sedgemoor	2007	20	404	224	74	42	48	18	19	22	11	20	8	2			892
		2008	3	61	31	10	5	9	4	3	1	1	3	1				129
		2009	3	57	33	7	5	19	4	3	2	1	3	2				136
	Moorlinch	2007	16	291	173	93	34	43	32	15	23	21	14	1	1			741
		2008	2	38	22	8	2	6	6	2	3	3	1					91
		2009	2	38	23	7	7	8	4	2	3	3	2		1			98
	Non-SSSI-Clay	2007	5	84	50	20	9	13	8	6	6	2	5					203
	Non-SSSI-Peat	2007	5	118	37	11	5	12	4	5	4	1	4		1			202
	Pawlett	2007	15	337	92	77	22	29	25	12	14	6	6					620
	Tadham	2007	21	442	269	97	52	46	38	18	30	16	22	4	2			1036
	West Sedgemoor	2007	24	478	297	123	63	50	42	24	33	23	23	5				1161
		2008	6	108	56	27	16	14	9	5	9	11	5					260

Source	Moor	Year	number of samples	Coleoptera	Mollusca	Hemiptera	Odonata	Diptera	Hirudinea	Isopoda	Ephemeroptera	Trichoptera	Amphipoda	Araneae	Megaloptera	Decapoda	Plecoptera	Total records
		2009	6	110	59	19	7	20	8	5	7	7	5					247
Drake 1989	Kenn	1989	19	368	154	90	43	40	37	19	20	25	15	7				818
Drake 2004	Gordano	2004	60	694	440	394	120	90	31	57	46	5	62	1	23			1963
Drake 2005	Southlake	2004	12	257														257
Drake 2007	Pawlett	2006	9	151	36	57	3	22	16	8	7	2	7		2			311
Drake et al 1984	Catcott	1983	26	492	152	109	47	14	44	20	23	19	2	6				928
	Gordano	1983	9	118	43	38	16	1	8	5	5	7			4			245
	Kenn	1983	2	32	9	7	3	1	4	2	1	3		1	1			64
	Kings Sedgemoor	1983	19	365	92	100	25	16	19	18	12	11		6	2			666
	Moorlinch	1983	9	145	53	47	21	8	9	8	3	3		1				298
	Pawlett	1983	12	242	42	92	9	12	5	2	6		5			4		419
	South Moor	1983	4	59	31	17	7	3	8	3	2	6		2	2			140
	Southlake	1983	17	259	155	76	27	11	49	17	17	25		11	3			650
	Tadham	1983	18	319	117	88	32	7	35	21	22	17	6	4	4		1	673
	West Sedgemoor	1983	27	513	166	97	62	17	43	26	20	29	2	4	2			981
Gibbs 1994	Catcott	1994	20	426	112	43	18	21										620
	Kings Sedgemoor	1994	19	451	145	31	21	14										662
	Southlake	1994	12	204	123	23	21	5										376
	Tadham	1994	18	408	137	40	30	19										634
	West Sedgemoor	1994	20	414	101	69	41	5										630
Gibbs 1999	Gordano	1999	22	374	101	118	37			19		1	21	1				672
Godfrey 1999	Catcott	1999	20	274	119	55	4	10	2	11	8		7	2				492
	Kenn	1999	25	267	206	99	31	21	2	14	7		8	2				657
	Kings Sedgemoor	1999	18	270	162	40	27	26	6	15	6	4	10	5				571
	Tadham	1999	18	206	132	71	11	19		8	5			3	1			456
	West Sedgemoor	1999	20	264	199	72	36	18	17	14	15	6	15	2				658
Godfrey 2000	Southlake	2000	11	139	94	11	9	10	1	9	2	2	4	8				289
Hill-Cottingham & Smith 1995	Catcott	1994	8	61	117	41	8		9	6	3	5	10	2	3			265
	Kings Sedgemoor	1994	4	20	39	22	6	1	10	4	9	5	4	3	3			126
	Moorlinch	1994	3	37	31	11	3	3	7	3			2		1			98
	Southlake	1994	3	25	44	12	6		7	3	3	5	4	3	3			115

Source	Moor	Year	number of samples	Coleoptera	Mollusca	Hemiptera	Odonata	Diptera	Hirudinea	Isopoda	Ephemeroptera	Trichoptera	Amphipoda	Araneae	Megaloptera	Decapoda	Plecoptera	Total records
	Tadham	1994	2	20	30	9	3	3	6	2	2	4	2		2			83
	West Sedgemoor	1994	3	13	24	17	3	1	5	3	2	5	2		1			76
Hill-Cottingham & Smith 1996	Pawlett	1994	21	199	115	65	18	18	14	18	2	3	2	14				468
Hill-Cottingham & Smith 1998	Pawlett	1998	12	104	36	20	18	14	11	13	10	3						229
Palmer 1979	Tadham	1979	3	52	34	38	12		4	6	6	8						160
	West Sedgemoor	1979	5	90	42	44	26		6	8	6	8					2	232
Sheppard 1985	Tadham	1985	13	40		26	13	1							3			83
Southwest Ecological Surveys 2007	Pawlett	2006	3	19	6	14		1	1	1	1		1					44
SW Ecol Surveys 2003	Pawlett	2002	24	442	81	152	21	5	19	14		3	6					743
Grand Total				12841	6093	3198	1262	880	757	588	497	365	356	115	74	4	3	27033
% of records for each taxon				48	23	12	5	3	3	2	2	1	1	0	0	0	0	

Table 1.4 Sources, major taxa and number of records in surveys of the Essex marshes at different dates

Source	Marsh	Year	Number of samples	Coleoptera	Hemiptera	Mollusca	Diptera	Odonata	Amphipoda	Isopoda	Trichoptera	Araneae	Ephemeroptera	Hirudinea	Decapoda	Megaloptera	Mysidacea	Total records
Buglife	Brightlingsea	2009	11	200	21	57	27	8	12	13	15	1	3	2				359
	Fambridge	2009	15	276	64	34	56	35	18	10	13	3	13	6	3			531
	Hadleigh Marsh	2009	7	127	41	14	27	33	8	8	17	1	5	2				283
	Rainham	2009	15	240	58	62	37	24	14	17	7	4	13	10				486
	Vange & Fobbing	2009	15	335	59	47	55	37	18	11	10	6	6	13	2			599
Drake 1988	Brightlingsea	1987	9	98	42	31	7	4	7	5	8	5	5	6	1			219
	Fambridge	1987	10	184	29	14	15	18	12	6	10	3	6		3			300
	Hadleigh Marsh	1987	5	98	23	9	16	10	1	4	15	2	5	4				187
	Rainham	1988	14	150	14	31	13	8	5	11	1		2	2				237
	Vange & Fobbing	1987	15	271	51	35	33	19	11	8	14	6	3	4	2			457
Drake 1990	Rainham	1990	13	190	32	32	10	24	7	18	4	3	1	2				323
Gibbs 1993	Vange & Fobbing	1993	25	174	19	37	6	27	13	6	1	3	8	5	7		1	307
Kirby 1993	Brightlingsea	1987	8	81	39	31	10	3	6	5	6		5		1			187
		1993	16	209	89	34	9	10	5	1			3					360
Leeming 1998	Rainham	1998	79	927	253	223	114	87	65	84	14		7	24	6	1		1805
Leeming 2001	Rainham	2001	18	210	76	55	25	6	14	14			4	4		3		411
Scott Wilson 1996	Rainham	1994	12	102	41	39	3	10	4	13			9	5				226
Grand Total			287	3872	951	785	463	363	220	234	135	37	98	89	25	4	1	7277
% of records for each taxon				53	13	11	6	5	3	3	2	1	1	1	0	0	0	100

Table 1.5 Sources, major taxa and number of records in surveys of the Suffolk and Norfolk marshes at different dates

Area	Source	Marsh	Year	Number of samples	Coleoptera	Mollusca	Hemiptera	Diptera	Odonata	Hirudinea	Isopoda	Amphipoda	Ephemeroptera	Trichoptera	Araneae	Megaloptera	Decapoda	Mysidacea	Total records
Suffolk	Buglife	Shotley	2009	7	137	28	46	24	13	5	8	10	8	9	1		3		292
		Sizewell	2009	20	360	211	134	62	53	38	20	23	21	27	10				959
	Drake 1989	Shotley	1988	6	84	22	37	6	7	14	5	7	8	5	2	1	2		200
		Sizewell	1988	16	197	145	95	20	33	48	18	21	23	31	6	2			639
			1989	9	97	57	23	3	13	22	10	10	9	6					250
	Godfrey 2010	Sizewell	2009	33	209	306	145	116	68	51	33	35	36	43	11				1053
Total					1084	769	480	231	187	178	94	106	105	121	30	3	5		3393
Yare	Buglife	Buckenham	2009	9	212	121	44	23	21	19	14	9	15	13	3	3			497
		Cantley	2009	11	289	127	59	29	46	7	18	11	16	33	8	3			646
		Limpenhoe	2009	10	256	88	87	40	25	9	8	14	9	9	7	1			553
	Drake 2002	Buckenham	2001	22	302	295	31	35				1							664
		Cantley	2001	50	571	505	71	122		1		3							1273
		Limpenhoe	2001	72	915	677	69	60				19			5		2		1747
	Driscoll 1980 BDS B11	Buckenham	1974	21	60	192	67		7	26	15	13	7		2				389
		Cantley	1974	12	23	72	20		3	4	6				2				130
		Limpenhoe	1974	39	66	285	78		32	33	21	17	6	1	11		10		560
	Driscoll 1980 BDS B13	Buckenham	1975	18	3	160	45		6	19	11	5	5	1	6				261
		Cantley	1975	17	4	145	41	2	8	5	6	4	7		3				225
		Limpenhoe	1975	7		44	15			5	4	2			4		2		76
Total					2701	2711	627	311	148	128	103	98	65	57	51	7	14		7021
Bure	Buglife	Fleggburgh	2009	9	214	111	36	19	22	16	14	9	14	12	3	2			472
		Oby	2009	15	335	163	79	47	41	25	26	16	14	20	12				778
		South Walsham	2009	6	170	82	30	20	30	9	11	6	9	6	4	1			378
		Upton	2009	15	440	177	95	51	64	27	16	15	23	41	10	6			965

Area	Source	Marsh	Year	Number of samples	Coleoptera	Mollusca	Hemiptera	Diptera	Odonata	Hirudinea	Isopoda	Amphipoda	Ephemeroptera	Trichoptera	Araneae	Megaloptera	Decapoda	Mysidacea	Total records
	Drake 2003	Fleggburgh	2002	31	268	226	4	1	1			1			8				509
		Oby	2002	23	266	164	4	5				1			5				445
		South Walsham	2002	36	349	344	4	20		4		2			19				742
		Upton	2002	34	321	308	5	11		4		1			14				664
	Driscoll 1976 BDS B2	Fleggburgh	1976	35	62	159	34	5	7	10	26	12	5	6	8				334
		Oby	1976	7	8	38	4		2	6	6	3	1	1	1				70
	Driscoll 1980 BDS B11	Fleggburgh	1974	40	119	281	87		17	29	28	14	4		20	1			600
		Oby	1974	26	51	190	39		14	29	15	4	5		11				358
		South Walsham	1974	23	48	166	21	1	25	18	19	10	3		12	1		3	327
		Upton	1974	35	128	249	70		29	29	30	11	7		14	2			569
	Driscoll 1980 BDS B13	Fleggburgh	1975	19	4	125	29		13	22	14	5	4		11				227
		Oby	1975	11	3	84	19		2	12	6	2			6				134
		Upton	1975	25	8	192	66		26	29	16	13	7		13	1			371
	Killeen & Willing 1997	Upton	1996	1		16													16
Total					2794	3075	626	180	293	269	227	125	96	86	171	14		3	7959
Grand Total					6579	6555	1733	722	628	575	424	329	266	264	252	24	19	3	18373

Table 1.6 Sources, major taxa and number of records in surveys used in comparison of the Gwent Levels

Source	Year	Number of samples	Coleoptera	Mollusca	Hemiptera	Odonata	Hirudinea	Diptera	Isopoda	Ephemeroptera	Trichoptera	Amphipoda	Araneae	Decapoda	Plecoptera	Megaloptera	Total
Buglife	2007	51	889	373	175	71	65	60	50	33	9	49	4	1			1779
Drake 1986	1985	147	2921	1142	880	281	315	229	139	188	170	30	10	6	6		6317
Gibbs 1991	1991	49	448	207	96	57		15									823
Harmer 2007	2007	79	1082	533	198	93	66		75	7	10	71	9			4	2148
Honour *et al* 2000	2000	20	130	62	22	11	5	1	16	7	2	9					265
Total		346	5470	2317	1371	513	451	305	280	235	191	159	23	7	6	4	11332

APPENDIX 2

Classification of plant assemblages

Appendix 2 relates to Volume 1, Section 3 of this report

1 Classification of wet zone vegetation

In 2007, 2008 and 2009, a botanical survey of 586 ditches in grazing marshes in England and Wales was carried out. Species records were analysed using 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 some water-crowfoots (*Ranunculus aquatilis*, *R. peltatus* 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 inundation zone, but excluding the ditch sides above this level and the 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.

Figures 2.1a and 2.1b are dendrograms showing the divisions of the TWINSPAN classification and the end-groups chosen. These dendrograms provide dichotomous keys, enabling samples from other similar surveys to be classified. Tables 2.1 and 2.2 are species constancy tables showing the composition of the end-groups.

2 Classification of floating and submerged vegetation

For the second TWINSPAN analysis, the plant list was reduced to the 48 species that were predominantly found in the ditches as floating or submerged forms. Table 2.3 is a list of the species used in the analysis. Figures 2.2a and 2.2b are the resulting TWINSPAN dendrograms. Tables 2.4 and 2.5 are constancy tables showing the composition of the end-groups.

3 Affinities with the National Vegetation Classification

Affinities of the wet zone classification with the National Vegetation Classification (NVC) aquatic and swamp communities (Rodwell, 1995) are shown in Table 2.6. Only the indicator species for NVC communities that are present at a constancy of over 20% in the wet zone groups are given in this table.

Twelve of the 24 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*), which represents the A20 community, probably occurred, but because of problems with the identification of water crowfoots this cannot be confirmed.

Eleven of the 23 NVC swamp communities are easily recognisable in the wet zone groups. The main indicator species for another ten swamp communities were recorded in the ditches surveyed.

4 References

Hill, M.O. (1979) *TWINSPAN – a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Cornell University, Ithaca, New York.

Rodwell, J.S. ed. (1995) *British Plant Communities Volume 4. Aquatic Communities, Swamps and Tall-herb Fens.* Cambridge University Press, Cambridge.

Figure 2.1 TWINSPAN dendrograms: wet zone (174 species)

Figure 2.1a Main groups

Group 1 (N = 586)

Hyd m-r
L minor | Bol mar

0 -- 1

Group 2 (N = 511)

Phr aus4 | Spa ere
Hyd m-r
L minut

-1 -- 0

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 10 (N = 103)
End Group B
Lemna minor/minuta/gibba

Group 11(N = 376)

Jun eff | Phr aus
L minor2
Pha aru

-1 -- 0

Group 22 (N = 224)

Agr sto3 | L tris3
Gly flu3 | Hyd m-r2
Ele pal | L minor2

-1 -- 0

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

Group 45 (N = 197)
End Group D
Hydrocharis/Glyceria maxima

Group 23 (N =152)

L minor | Str alo
L minuta | Elo can
Gly max
Pot nat

0 -- 1

Group 46 (N = 117)
End Group E
HydrocharisIPhragmites

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

Group 3 (N = 75)
End Group G
Bolboschoenus

Figure 2.1b Sub-groups

Group 1 (N = 586)

Hyd m-r
L minor | Bol mar

0 ---------- 1

Group 2 (N = 511)

Phr aus4 | Spa ere
Hyd m-r
L minut

-1 ---------- 0

Group 3 (N = 75)

Pot pec
Cer sub
Phr aus | Agr sto3
Gly flu
Bol mar3
Rum con

1 ---------- 2

Group 4 (N = 32)
End Group A
Phragmites

Group 5 (N = 479)

L minut3
L gib
L minor2 | L tris2
Hyd m-r2
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
L tris2 | Gly max
Spi pol
Pha aru
Cer dem
Per amp

0 ---------- 1

Group 11(N = 376)

Jun eff
L minor2
Pha aru | Phr aus

-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
Gly flu3
Ele pal | L tris3
Hyd m-r2
L minor2

-1 ---------- 0

Group 23 (N =152)

L minor
L minuta | Str alo
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
Elo nut | *Ber ere2*
Jun sub
Bol mar
Car rip

0 ----------1

Group 46 (N = 117)

Phr aus2
Car rip
L minor2 | Spa ere2
Bol mar
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

Table 2.1 Constancy table: wet zone main groups

End Group	**A**	**B**	**C**	**D**	**E**	**F**	**G**
TWINSPAN group	4	10	44	45	46	47	3
No. of samples	32	103	27	197	117	35	75
Phragmites australis	**V**	III			**IV**	III	II
Filamentous algae	II	II	II	III	**IV**	III	**IV**
Agrostis stolonifera	**IV**	**V**	**V**	**V**	**V**	**V**	**V**
Lemna trisulca	III	II	II	**V**	**V**	**IV**	II
Lemna minor	II	**V**	**IV**	**V**	**IV**		
Lemna minuta		**V**	II	**IV**	**IV**		
Lemna gibba		III					
Oenanthe crocata		II					
Ranunculus sceleratus		II					
Phalaris arundinacea		II	II	III			
Spirodela polyrhiza		III		III			
Ceratophyllum demersum		II		II	II		
Galium palustre		II	**IV**	**IV**	II	II	
Juncus effusus		II	**IV**	**IV**		II	
Juncus inflexus		II	II	II	III	II	
Hydrocharis morsus-ranae		II	II	**IV**	**V**	**V**	
Glyceria maxima		III	II	**IV**		**IV**	
Sparganium erectum		II	**IV**	**V**	**IV**	**V**	
Carex riparia		II		III	II	III	
Berula erecta		II		III	III	III	
Glyceria fluitans		II	**V**	III		II	
Carex otrubae			II				
Myosotis laxa			II				
Callitriche sp.			II				
Schoenoplectus tabernae.			II				
Drepanocladus sp.			II				
Hottonia palustris			II				
Eleocharis palustris			**IV**	II	III	II	
Juncus articulatus			II			II	
Oenanthe fistulosa			III	II	II	III	
Equisetum fluviatile			III	II	II	II	
Alisma plantago-aquatica			III	II	II	II	
Mentha aquatica			II	III	II	III	
Persicaria amphibia				II			
Carex pseudocyperus				II	II		
Rumex hydrolapathum				II	II		
Elodea nuttallii				II	II		
Iris pseudacorus				II		II	
Typha latifolia				II			
Juncus subnodulosus				II		II	
Bolboschoenus maritimus				II	II		**V**
Schoenoplectus tabernaem.					II		
Stratiotes aloides						II	
Potamogeton natans						III	
Elodea canadensis						III	
Rorippa sp.						III	
Myosotis scorpioides						II	
Myriophyllum verticillatum						II	
Sagittaria sagittifolia						II	
Potamogeton pectinatus							III
Juncus gerardii							II
Atriplex prostrata							II
Ranunculus sp. (incl. *baudotii)*							III

Constancy classes: II = >20% to 40%; III = >40% to 60%; IV = >60% to 80%; V = >80%

Table 2.2 Constancy table: wet zone sub-groups

End Group	**A**	**B1**	**B2**	**C**	**D1**	**D2**	**E1**	**E2**	**F**	**G1**	**G2**
TWINSPAN group	4	20	21	44	90	91	92	93	47	6	7
No. of samples	32	34	69	27	85	112	69	48	35	54	21
Phragmites australis	**V**	**IV**	II				**V**	II	III	III	
Filamentous algae	II	II	III	II	III	**IV**	III	**V**	III	**IV**	III
Agrostis stolonifera	**IV**	**IV**	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**
Lemna trisulca	III	III	II	II	**V**	**V**	**V**	**V**	**IV**	II	
Lemna minor	II	**V**	**V**	**IV**	**V**	**V**	**V**	III			
Lemna minuta		**V**	**V**	II	**IV**	**V**	**IV**	**IV**			
Lemna gibba		III	III								
Solanum dulcamara		II									
Ranunculus sceleratus		II	II								
Galium palustre		II	II	**IV**	III	**IV**	III	II	II		
Juncus inflexus		II	II	II	II	II	III	III	II		
Hydrocharis morsus-ranae		II	II	II	**IV**	**IV**	**IV**	**V**	**V**		
Sparganium erectum		II	III	**IV**	**V**	**IV**	**IV**	**V**	**V**		
Carex riparia		II	II		II	III	III		III		
Berula erecta		II	II		II	**IV**	**IV**	II	III		
Glyceria fluitans		II	III	**V**	III	II		II	II		II
Oenanthe crocata			II								
Potamogeton trichoides			II								
Phalaris arundinacea			III	II	III	II					
Spirodela polyrhiza			**IV**		**IV**	II	II				
Ceratophyllum demersum			II			II		II			
Juncus effusus			II	**IV**	III	**IV**			II		
Glyceria maxima			**IV**	II	**IV**	III	II		**IV**		
Persicaria amphibia			II		II	II					
Equisetum fluviatile			II	III	III		II		II		
Iris pseudacorus			II		II	II	II		II		
Myosotis laxa				II							
Callitriche sp.				II							
Hottonia palustris				II	II						
Carex otrubae				II				II			
Schoenoplectus tabern.				II				II			
Juncus articulatus				II	II				II		
Oenanthe fistulosa				III		II	II	II	III		
Alisma plantago-aquatica				III	III	II	II	III	II		
Mentha aquatica				II	II	III	II		III		
Drepanocladus sp.				II						II	
Eleocharis palustris				**IV**	II		II	III	II	II	
Elodea nuttallii					III			II			
Carex pseudocyperus					II	II	II	II			
Rumex hydrolapathum					II	II	II				
Typha latifolia						II		II			
Juncus subnodulosus						II			II		
Bolboschoenus maritimus		II				III		III		**V**	**V**
Callitriche agg.								II			
Ceratophyllum submersum								II		II	
Enteromorpha sp.								II		II	
Potamogeton pectinatus								II		III	
Stratiotes aloides									II		
Potamogeton natans									III		
Elodea canadensis									III		
Rorippa sp.									III		
Myosotis scorpioides									II		
Myriophyllum verticillatum									II		
Sagittaria sagittifolia									II		
Juncus gerardii										II	II
Atriplex prostrata										II	II
Ranunculus sp. (incl. *baudotii*)										II	III
Rumex conglomeratus											II

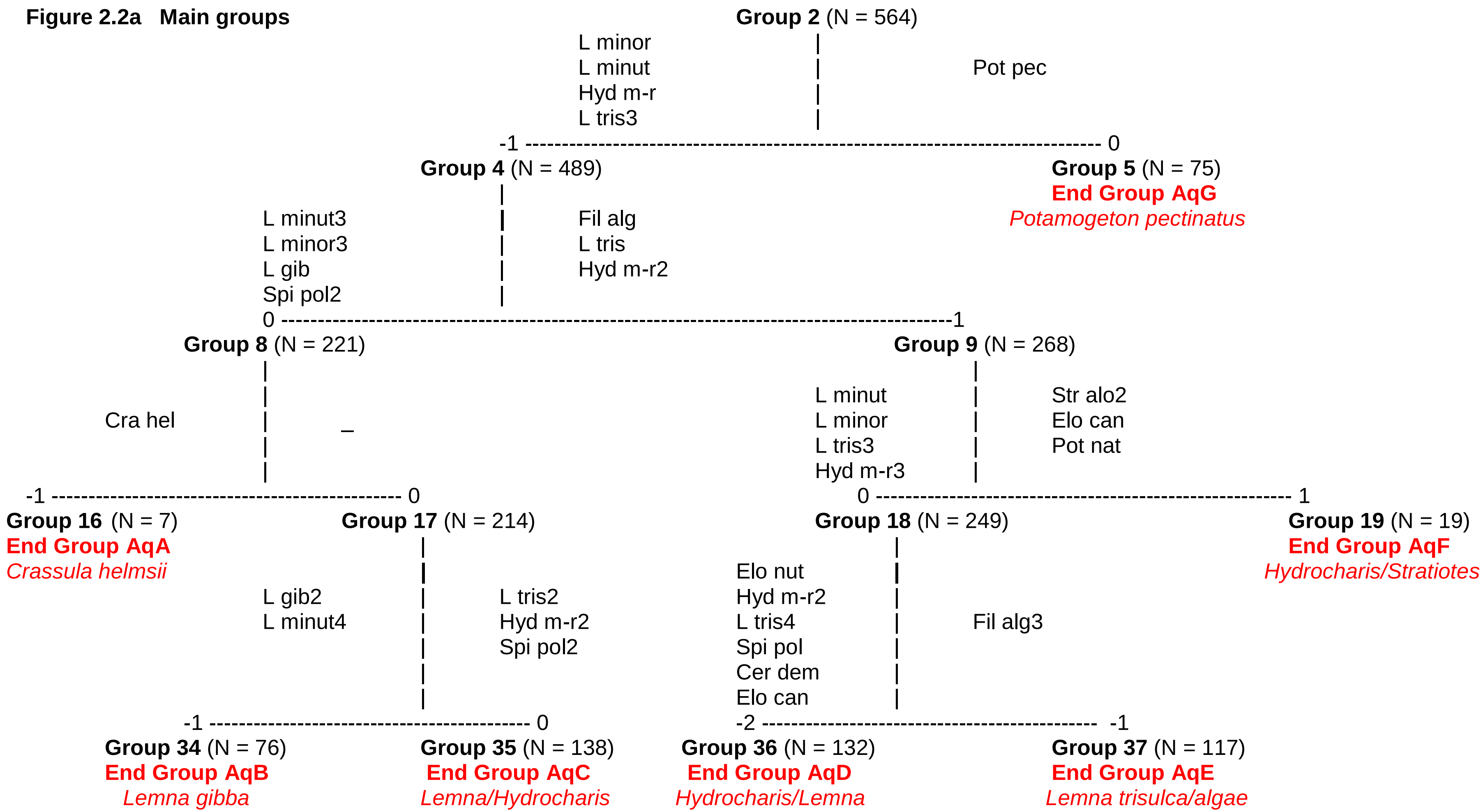
Constancy classes: II = >20% to 40%; III = >40% to 60%; IV = >60% to 80%; V = >80%

Table 2.3 Species included in the analysis of floating and submerged vegetation

Azolla filiculoides	Water fern
Baldellia ranunculoides	Lesser spearwort
Callitriche sp.	Starworts
Chara globularis	Fragile stonewort
Chara hispida	Bristly stonewort
Chara virgata	Delicate stonewort
Chara vulgaris	Common stonewort
Crassula helmsii	Australian swamp-stonecrop
Ceratophyllum demersum	Hornwort
Ceratophyllum submersum	Soft hornwort
Drepanocladus sp.	A moss
Eleogiton fluitans	Floating club-rush
Elodea Canadensis	Canadian waterweed
Elodea nuttallii	Nuttall's waterweed
Enteromorpha species/ Filamentous algae	Gutweed
Hottonia palustris	Water violet
Hydrocharis morsus-ranae	Frogbit
Lemna gibba	Fat duckweed
Lemna minor	Common duckweed
Lemna minuta	Least duckweed
Lemna trisulca	Ivy-leaved duckweed
Lythrum portula	Water purslane
Myriophyllum spicatum	Spiked water-milfoil
Myriophyllum verticillatum	Whorled water-milfoil
Nitella mucronata	Pointed stonewort
Nitella translucens	Translucent stonewort
Nuphar lutea	Yellow water-lily
Nymphaea alba	White water-lily
Pilularia globulifera	Pillwort
Potamogeton acutifolius	Sharp-leaved pondweed
Potamogeton berchtoldii	Small pondweed
Potamogeton crispus	Curled pondweed
Potamogeton lucens	Shining pondweed
Potamogeton natans	Broad-leaved pondweed
Potamogeton obtusifolius	Blunt-leaved pondweed
Potamogeton pectinatus	Fennel-leaved pondweed
Potamogeton pusillus	Lesser pondweed
Potamogeton trichoides	Fan-leaved water-crowfoot
Ranunculus sp.	Water-crowfoots
Riccia fluitans	Floating crystalwort
Sparganium emersum	Unbranched bur-reed
Spirodela polyrhiza	Greater duckweed
Stratiotes aloides	Water-soldier
Utricularia vulgaris/australis	Bladderwort
Wolffia arrhiza	Rootless duckweed
Zannichellia palustris	Horned pondweed

Figure 2.2 TWINSPAN dendrograms: floating and submerged species (48 species)

Figure 2.2a Main groups



Note The first division separated off a single site on the basis of *Nymphaea alba* occurring alone. This is not included in the dendrogram.

Figure 2.2b **Sub-groups**

Group 2 (N = 564)

L minor
L minut
Hyd m-r L tris3 | Pot pec

-1 -- 0

Group 4 (N = 489)

L minut3
L minor3
L gib Spi pol2 | Fil alg
L tris
Hyd m-r2

0 -- 1

Group 8 (N = 221)

Cra hel | _

-1 -- 0

Group 16 (N = 7)
End Group AqA
Crassula helmsii

Group 17 (N = 214)

L gib2
L minut4 | L tris2
Hyd m-r2
Spi pol2

-1 -- 0

Group 34 (N = 76)
End Group AqB
Lemna gibba

Group 35 (N = 138)

_ | Cer dem
Fil alg2
L gib
Elo Nut
Spi pol
Pot tri
Call sp

2 -- 3

Group 70 (N = 90)
End Group AqC1
Lemna trisulca

Group 71 (N = 48)
End Group AqC2
Hydrocharis/Spirodela/
Ceratophyllum demersum

Group 5 (N = 75)
End Group AqG
Potamogeton pectinatus

Group 9 (N = 268)

L minut
L minor
L tris3
Hyd m-r3 | Str alo2
Elo can
Pot nat

0 -- 1

Group 18 (N = 249)

Elo nut
Hyd m-r2
L tris4
Spi pol
Cer dem
Elo can | Fil alg3

-2 -- -1

Group 36 (N = 132)

Cer dem
Fil alg3
Pot pec
Entero
Elo nut3
Utr vul | _

-2 -- -1

Group 72 (N = 29)
End Group AqD1
Hydrocharis/Elodea nuttallii/
Ceratophyllum demersum

Group 73 (N = 103)
End Group AqD2
Hydocharis/
Lemna trisulca

Group 37 (N = 117)
End Group AqE
Lemna trisulca/algae

Group 19 (N = 19)
End Group AqF
Hydrocharis/Stratiotes

Table 2.4 Constancy table for floating and submerged species: main groups

Constancy classes: II = >20% to 40%; III = >40% to 60%; IV = >60% to 80%; V = >80%

Group	**AqA**	**AqB**	**AqC**	**AqD**	**AqE**	**AqF**	**AqG**
TWINSPAN group	16	34	35	36	37	19	5
No. of samples	7	76	138	132	117	19	75
Crassula helmsii	**V**						
Callitriche sp.	II						
Lemna minor	III	**V**	**V**	**IV**	**IV**	II	
Lemna minuta	**IV**	**V**	**V**	**IV**	III		
Lemna gibba		**IV**	II				
Spirodela polyrhiza		II	III	II			
Filamentous algae	II	II	II	III	**V**	**IV**	**IV**
Ceratophyllum demersum			II	II			
Elodea nuttallii			II	III			
Hydrocharis morsus-ranae			**IV**	**V**	III	**IV**	
Lemna trisulca			**V**	**V**	**V**	III	II
Elodea canadensis				II		**IV**	
Stratiotes aloides						**IV**	
Hottonia palustris						III	
Potamogeton natans						III	
Myriophyllum verticillatum						II	
Ranunculus circinatus						II	
Sparganium emersum						II	
Potamogeton pectinatus							III
Drepanocladus sp.							II
Ranunculus sp. (including *baudotii*)							II

Table 2.5 Constancy table for floating and submerged species: sub-groups

Constancy classes: II = >20% to 40%; III = >40% to 60%; IV = >60% to 80%; V = >80%

End Group	**AqA**	**AqB**	**AqC1**	**AqC2**	**AqD1**	**AqD2**	**AqE**	**AqF**	**AqG**
TWINSPAN group	16	34	70	71	72	73	37	19	5
No. of samples	7	76	90	48	29	103	117	19	75
Crassula helmsii	**V**								
Callitriche sp.	II			II	II				
Lemna minor	III	**V**	**V**	**V**	**IV**	**IV**	**IV**	II	
Lemna minuta	**IV**	**V**	**V**	**V**	**IV**	III	III		
Lemna gibba		**IV**		III					
Spirodela polyrhiza		II	III	**IV**	II	III			
Filamentous algae	II	II		**IV**	**V**	III	**V**	**IV**	**IV**
Hydrocharis morsus-ranae			III	**IV**	**IV**	**V**	III	**IV**	
Lemna trisulca			**V**	**IV**	**V**	**V**	**V**	III	II
Ceratophyllum demersum				**IV**	**V**				
Elodea nuttallii				III	**IV**	III			
Potamogeton trichoides				II	II				
Enteromorpha sp.					II				
Utricularia sp.					II				
Myriophyllum verticillatum					II			II	
Potamogeton pectinatus					III				III
Elodea canadensis						II		**IV**	
Stratiotes aloides								**IV**	
Hottonia palustris								III	
Potamogeton natans								III	
Ranunculus circinatus								II	
Sparganium emersum								II	
Drepanocladus sp.									II
Ranunculus sp. (Including *baudotii)*									II

Table 2.6 National Vegetation Communities indicator species present at over 20% constancy in wet zone groups

End group		**A**	**B1**	**B2**	**C**	**D1**	**D2**	**E1**	**E2**	**F**	**G1**	**G2**
No. of samples		32	34	69	27	85	112	69	48	35	54	21
NVC community												
A1	*Lemna gibba*		X	X								
A2	*Lemna minor*	X	X	X	X	X	X	X	X			
A3	*Spirodela polyrhiza-Hydrocharis morsus-ranae*						X	X	X			
A4	*Hydrocharis morsus-ranae-Stratiotes aloides*									X		
A5	*Ceratophyllum demersum*						X					
A6	*Ceratophyllum submersum*								X			
A9	*Potamogeton natans*									X		
A10	*Persicaria amphibia*			X		X	X					
A11	*Potamogeton pectinatus-Myriophyllum spicatum*								X?			
A12	*Potamogeton pectinatus*								X?		X	
A15	*Elodea canadensis*									X		
A16	*Callitriche stagnalis*				X							
A21	*Ranunculus baudottii*										X	X
S4	*Phragmites australis*	X	X	X				X	X	X	X	
S5	*Glyceria maxima*			X	X	X	X	X		X		
S6	*Carex riparia*		X	X	X	X	X	X	X	X		
S10	*Equisetum fluviatile*			X	X	X		X		X		
S12	*Typha latifolia*						X		X			
S14	*Sparganium erectum*		X	X	X	X	X	X	X	X		
S17	*Carex pseudocyperus*					X	X	X	X	X		X
S19	*Eleocharis palustris*				X	X		X	X	X	X	
S20	*Schoenoplectus tab.-montani*				X				X			
S22	*Glyceria fluitans*		X	X	X	X	X					
S23	Other water-margin vegetation		X	X	X	X	X	X	X	X		X
No. of communities		2	7	10	10	10	11	10	12	11	4	3

NVC communities probably present at lower frequency:
A7: *Nymphaea alba*, A8: *Nuphar lutea*, A19: *Ranunculus aquatilis*, A20: *Ranunculus peltatus*
S1: *Carex elata*, S3: *Carex paniculata*, S7: *Carex acutiformis*, S8: *Schoenoplectus lacustris*, S9: *Carex rostrata*, S11: *Carex vesicaria*, S13: *Typha angustifolia*, S15: *Acorus calamus*, S16: *Sagittaria sagittifolia*, S17: *Carex otrubae.*

Note
A12, the *Potamogeton pectinatus* community, was certainly a component of the brackish water assemblage G1. A11, the *Potamogeton pectinatus – Myriophyllum spicatum* community, rather than A12, may have been represented in the more freshwater group E2.

APPENDIX 3

Classification of invertebrate assemblages

Appendix 3 relates to Section 4 of Volume 1 of this report

1 Data analysis: TWINSPAN

1.1 Testing the validity of outputs

For invertebrates, the TWINSPAN program was run using different combinations of data to test whether a) a robust classification could be produced using presence-absence data compared with abundance data on a logarithmic scale, b) similar classifications of samples are produced for all species and for the two major taxonomic groups, beetles and molluscs. All invertebrate samples and all species within the groups concerned were included, as the program is not unduly affected by many zero cells, and the placement of nationally rare species that may also be rare in the dataset was of interest. The cut-levels used to obtain pseudo-species for abundance data were 1, 2 and 3. As the abundance of species was estimated on a logarithmic scale, these cut-levels gave pseudo-species with big differences. All cut-levels were given the same weighting.

Visual comparisons of the classifications produced by TWINSPAN were made by plotting end-groups that were thought to be ecologically recognisable on an ordination of the first two axes of DCA (Detrended Correspondence Analysis). The gradient lengths of the first two DCA axes were about 3.5 so DCA and MDS (Multidimensional Scaling) were appropriate for this large dataset. Down-weighting of rare species was used in the DCA. In MDS, the similarity coefficient used for abundance data was Bray-Curtis and that for presence-absence data was Jaccard. To produce more robust ordinations, one outlying saline sample was removed and only species occurring in ten or more samples were included, reducing the number of species from 335 to 215. MDS was run using PCA (Principal Components Analysis) as the starting position and 10 further runs were done using random starting position, although none improved on the PCA version. Three dimensions were used as the stress was too high using just two.

ANOSIM was used to test the validity of TWINSPAN groups.

A Mantel test was used to compare the TWINSPAN groupings of invertebrates with a plant classification and between major invertebrate groups. Jaccard's similarity coefficient was selected as the simplest available and directly applicable to presence-absence data. It could be argued that Sørensen's coefficient would have been more appropriate as it gives more weight to joint presences, and this may be useful in the present data with a large proportion of zero cells. However, a few tests showed the results to be similar (slightly lower r-values and higher p-values using Sørensen's) but giving the same conclusion. For comparing matrices based on abundance data, Bray-Curtis similarity coefficient was used. The similarity matrices were compared using Spearman's correlation coefficient since this assumes no statistical normality in the similarity coefficients. Permutations were run 9999 times.

The two issues of the ecological reality of sample groups and whether presence-absence data or abundance data gave a superior classification were approached iteratively. An initial selection of groups was made by simple inspection of the TWINSPAN output files. The choice of groups was then modified in the light of ANOSIM analysis and the positioning of samples in ordination space. Rather than give a lengthy account of these processes for all cases that were examined, examples are given to show the thought process, with shorter accounts for the remaining cases.

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.

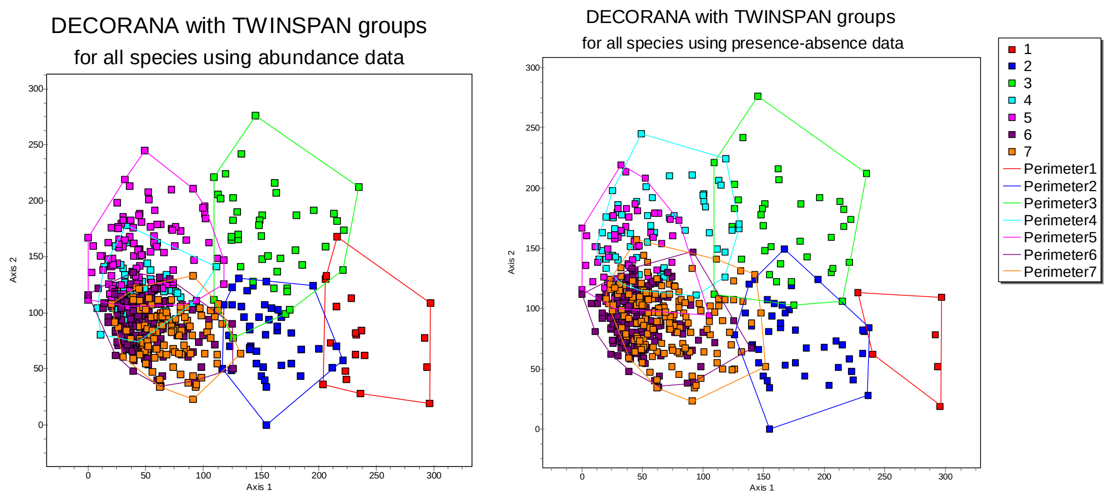
1.2 Position of groups in ordination space: all species of invertebrates

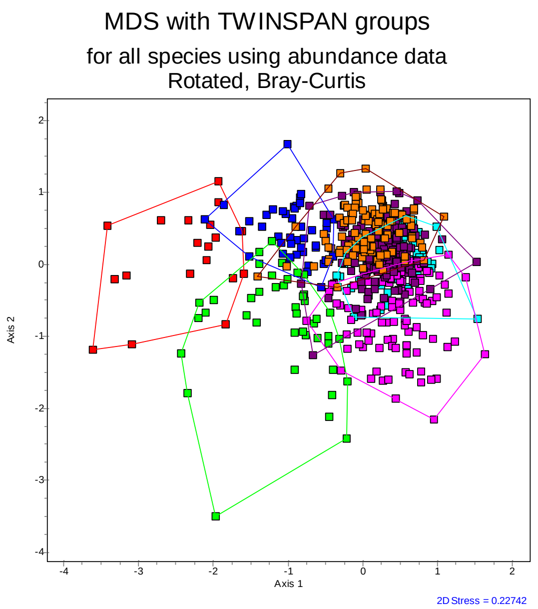
This example, using all the invertebrate taxa, showed the value of examining the separation of samples within TWINSPAN groups. The run used all 551 samples and and all taxa (335 species). No species were removed. Seven groups were initially recognised from the TWINSPAN output using both presence-absence and abundance data and are shown on the first two axes of DCA and MDS ordinations (Figure 3.1). The two ordination methods produced a similar overall pattern but the plots are rotated through 180º. The stress in the MDS plot (3 dimensions) was 0.175, which is regarded as rather high and suggested that the ordination is not a particularly good representation of the relative closeness of related samples (Zuur 2007, quoting the PRIMER manual). However, as the two methods gave similar overall pattern, the MDS plot was considered acceptable.

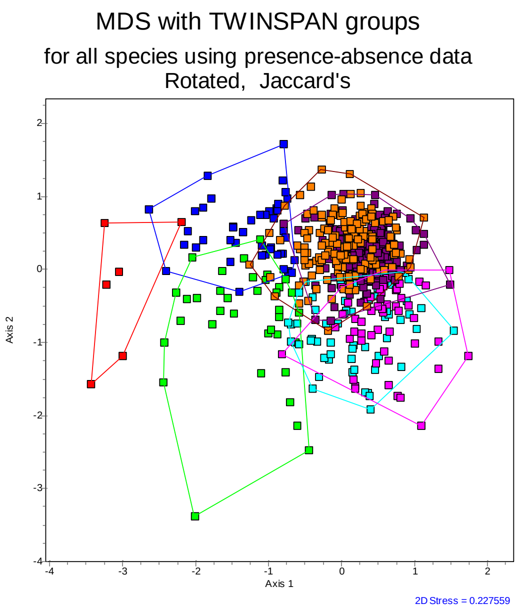
Groups 1, 2 and 3 were from brackish ditches. They were well defined and almost certainly ecologically real groups. The freshwater groups 4, 5, 6 and 7 showed poor separation, although groups 5 and 7 showed very little overlap and were separated along the second axis in both ordinations. Groups 4 and 5 showed conspicuously different behaviour, depending upon whether presence-absence or abundance data are used, and they varied in position and showed different degrees of nestedness in the different ordinations. It seemed likely that any ecological difference between them was small. Further subdivisions of the large groups 5 to 7 showed no separation so were likely to be trivial and due to just a few species. Although different groupings resulted from using presence-absence or abundance data, the ordinations provided no information on which was more robust.

These groups were significantly distinct using ANOSIM. Subdivision of group 6 appeared to be justified by the large R-statistic for the two subdivisions of this group. Although there appears to be no justification from the ordination, the group was split into two while checking the environmental features associated each group.

Figure 3.1 TWINSPAN groups for all species using either abundance or presence-absence data displayed on DCA and MDS ordination plots.







1.3 Using ANOSIM on mollusc data

There were 538 samples containing 43 mollusc taxa and 73.6% zero cells, which represented a fuller dataset than for beetles or all taxa where there were many more empty cells. Eight groups were recognised in the TWINSPAN output using both presence-absence and abundance data, although they were different sets of samples.

The way in which ANOSIM was used to test the validity of TWINSPAN groups is shown here for abundance data. The end-groups included were taken to a level beyond those selected visually in the expectation that there may be real but unrecognised groups at lower levels. Some selectivity was needed since the program would not run when many groups were erected, and 13 were selected ranging in size from 12 to 114 samples.

Table 3.1 shows the R statistic arranged as a matrix of the TWINSPAN end-groups and those initially selected visually. Only two comparisons were deemed non-significant, so the other R values can be used only comparatively to assess the similarity of groups. The following conclusions were drawn:

- Group 3 could be validly split into the small groups (TWINSPAN end-groups 36+37 and 38+39), although this was not done as the ordinations showed samples to be widely spread and the group's perimeter encompassed four other groups, so it was had no discrete identity.
- Groups 4 and 5 were likely to be real (R-values 0.273 - 0.668).
- The visually selected groups 6, 7 and 8 were clearly virtually indistinguishable (all R-values < 0.232, in italics).

When this analysis was done using presence-absence data, only five clearly recognisable groups could be distinguished.

ANOSIM was used to decide whether presence-absence data or abundance data gave a better classification. If group membership was more tightly defined by one of the datasets, then ANOSIM R-values at comparable levels of the TWINSPAN hierarchy would be expected to be consistently higher. No consistency was found with either beetles or molluscs, so this analysis did not suggest that one type of data was better than the other

Table 3.1 ANOSIM results (R statistic) for TWINSPAN groups for molluscs using presence absence data.
The number of TWINSPAN end-groups and their position in the hierarchy of divisions is shown in Figure 3.8.

revised idea		7				6		5		4		3		2,1
'by eye' group		8	7	6		5		4		3				2,1
	TWIN. group	64	65	66	67	68	69	70	71	36	37	38	39	3,5
7	65	*0.108*												
6	66	*0.148*	*0.232*											
	67	*0.105* ^{NS}	*0.205*	*0.079* ^{NS}										
5	68	0.478	0.613	0.620	0.211									
	69	0.700	0.921	0.927	0.753	0.499								
4	70	0.452	0.646	0.567	0.346	0.273	0.477							
	71	0.505	0.609	0.637	0.458	0.396	0.668	0.246						
3	36	0.763	0.954	0.960	0.928	0.504	0.492	0.538	0.503					
	37	0.837	0.967	0.957	0.911	0.725	0.687	0.488	0.371	0.405				
	38	0.937	0.992	0.988	0.963	0.664	0.698	0.721	0.728	0.612	0.362			
	39	0.927	0.989	0.985	0.964	0.816	0.517	0.640	0.691	0.769	0.490	0.521		
2 & 1	3+5	0.954	0.931	0.957	0.633	0.767	0.517	0.739	0.656	0.324	0.429	0.362	0.445	

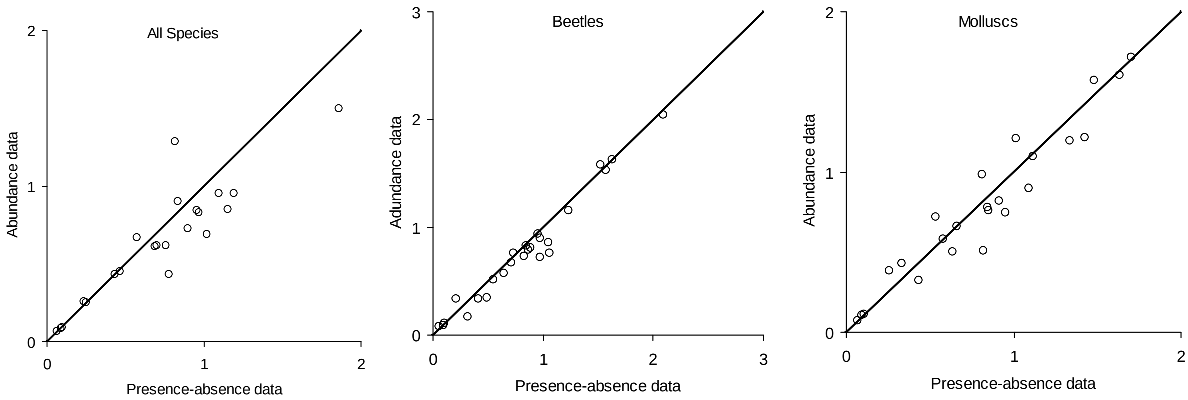
1.4 Use of 'coefficient of variation' to distinguish between abundance and presence-absence data

Simple inspection of the invertebrate data or boxplots of variables provided no indication of whether presence-absence or abundance data gave a more accurate classification. This was further examined by comparing the variation in each non-ordinal environmental variable between the two analyses. The assumption was that the better classification should reflect more tightly defined environmental conditions. As a measure of this variation, a non-parametric equivalent of the coefficient of variation (mean ÷ SD) was used, which was the interquartile range ÷ median of a variable. The average of these was estimated for each variable using the different TWINSPAN groups as the samples, for example, the value for water depth of the nine TWINSPAN groups identified for total species. The average values were plotted against one another. If neither analysis (presence-absence versus abundance data) was better, the variation would be expected to be the same and the points would be scattered roughly equally about the line of equality.

For the classification of all species and beetles, more variables fell below the line of equality, indicating that there was more variation in the analysis using presence-absence data than using abundance data (Figure 3.2). The distinction was less distinct for the mollusc classification but the points still fell slightly in favour of using the abundance data. Although this trend was slight, it suggested that classifications based on abundance data more accurately reflected underlying environmental conditions, and that these should be used as the basis for the classification.

Figure 3.2. Ratio of interquartile range to median for continuous variables in TWINSPAN analysis using presence-absence data or abundance data for all species, beetles and molluscs.

X and Y are the average for this 'coefficient of variation' of all TWINSPAN groups. The line shows equality between the two axes**.**



2 Environmental variables

2.1 Number of variables

The unwieldy set of 60 variables was clearly unworkable for analysis, and was reduced initially by using only the values for the bank that was sampled. Some variables were rarely scored and others (notably land manager) were often unknown, so these were also excluded from analyses. A few missing values in the spring dataset (due to omission, meter failure or inability to take some measurements such as depth of water or silt) were replaced by using summer values or, for water depth, regression of water depth against width for the marsh in question.

Soil type was eventually reduced to peat or mineral, which included sand and alluvium that were identified in spring sampling. This converted a categorical variable into an ordinal one (0 for peat, 1 for mineral). Discrepancies still arose between spring and summer recording of peat in a few sites, and these were resolved by reference to previous survey results or the most likely soil type based on adjacent ditches where there was agreement between the two surveyors.

2.2 Transformation of variables

Measurement fell into three types: continuous, ordinal (0-1), and semi-quantitative. The last type included DAFOR for vegetation cover and arbitrary scales of 0-3 or 0-5 for structural features (e.g. amount of grazing or poaching) and several physical features (e.g. turbidity). These are likely to cause most problems in analysis as they are rather short scales so were subject to greater error in recording and may or may not be linear. Adopting the recommendation by Lepš & Šmilauer (2003) regarding the Braun-Blanquet scale, the similar DAFOR scale was taken to be approximately logarithmic so no transformation was considered valid when attempting to normalise the data. Their alternative recommendation is to convert the scale to the assumed mid-point % that each letter represented, but this was thought likely to result in greater misinterpretation, and would probably need transformation in any case to normalise the distribution.

The spring variables were inspected for outliers using dotplots and boxplots using all 551 samples together and for each of nine geographic areas separately. Frequency histograms were used in conjunction with quantile-quantile (QQ) plots to identify non-normality in the variables and possible improvements that transformation would make. Many variables showed large between-area differences, which often contributed to their overall awkward frequency distribution, making the application of transformations dubious.

Combining some measurements into ranges helped to smooth frequency distribution histograms for some variables. Simplifications of the spring data were:

- water width: '5m' wide included 6 and 7m; '10m' wide included 8 and 9m; '20m' included 25 and 30m. This still left a long 'tail' of a few wide fleets and drains
- freeboard: '20cm' included 10, 15 and 30cm; '50cm' included 40, 60 and 70cm; '100cm' included 80, 90, 110 and 120cm; '150cm' included 130 and 140cm; '200cm' included 180cm.

The only variables that were unambiguously improved by transformation were years since last cleared, conductivity, turbidity and water colour, which were log (or log+1) transformed, and freeboard and slope of bank, which were transformed by their square root. Two percentage measures - shade on the bank and emergents in the channel - were arc-sine transformed, although the distribution of both variables was far from normal so the transformation made no practical improvement. Many variables were not unimodal and some followed no pattern. These were impossible to transform and had to remain as 'difficult' and problematic variables.

Spring variables that were excluded altogether in the invertebrate analysis were:

- fen land-use (14 records in the whole dataset)
- side of bank to which spoil was cleared (insufficient evidence and low number of records)
- presence of a benched profile (insufficient evidence and low number of records)
- ditch manager (inadequate information)

Once the selection of acceptable variables was complete, the relationship between them was visualised using Principal Component Analysis (PCA), which often highlighted repeated patterns between related variables. Only the variable vectors (not the sample positions) are shown. The lengths of the vectors are proportional to the influence of the variable, and the angle between vectors indicates the similarity of the variables. Variables close to the centre of the correlation biplot explain least of the variation, and those farthest out explain most. The label is at the high values for a variable, and, since the mean for all variables is placed at the centre, the low values are on the opposite side (though the convention is not to show this, to avoid confusion).

2.3 Relationship of environmental variables to invertebrate assemblages

2.3.1 Analytical methods

Two methods were used to investigate the relationship of environmental variables with invertebrate assemblages: ordination and a Mantel test. These use radically different methodologies so provided a cross check of the validity of conclusions reached by each method. A classification of the entire dataset (551 samples from many sites in England and Wales) showed that location was often as important as local environmental conditions in determining assemblage composition, so the analysis was done for sites grouped into geographic regions within which the national classification indicated low species turnover between sites.

The two ordination methods available for analysing the relationship with environmental variables are Redundancy Analysis (RDA) and Constrained Canonical Analysis (CCA). RDA is appropriate when species-richness within a site is large compared to between-site differences (alpha diversity is high, beta diversity is low); the relationship between species and environmental variables will be linear. CCA is appropriate when there is a large turnover of species within the dataset (high beta diversity) so that the relationship is unimodal, that is, species' distribution curves form complete bell-shapes as they appear, reach a peak in relation to some environmental variable, then disappear. The gradient length (smallest to greatest value) along the first axes of a Detrended Correspondence Analysis (DECORANA) gives an indication of the species distributions. Values of 4 or more suggest a unimodal distribution and therefore CCA is appropriate; values less than 3 indicate linear distributions and that RDA is appropriate; between 3 and 4, either method is suitable (Hill, 1979; Lepš & Šmilauer, 2003). As the values for individual geographical areas ranged from 1.81 to 3.63, RDA was used. Inspection of the distribution of individual species (coenoclines) was unhelpful since so many species were present on a single plot that it was impossible to discern individual patterns.

The data contained a large proportion of zero cells. This can lead to poor results using RDA so two actions were taken to reduce the number. Firstly, species that were scarce in each dataset were removed by keeping only those present in at least five samples. The reduction in the number of zero cells was modest, for example it dropped from 78% to 65% when 69 species were removed from the total of 161 species in the Gwent dataset. Secondly, the data were treated with a Chord transformation which makes the method less sensitive to double zeroes and the arch effect (Legendre & Gallaher, 2001).

Ordination methods are sensitive to the absolute size of measurements; variables measured on large scales (e.g. conductivity in μS cm^{-1}) can dominate. To reduce the numerical range and bring them into line with most other variables, measurements in centimetres (water and silt depth, freeboard) were converted to decimetres, and the angle of slope of the bank and the underwater profile at the margin were divided by 10. This obviously did not affect their relative values.

RDA was run using the reduced set of variables, using forward selection and a Monte Carlo test of significance of each variable in the model (999 permutations). A Chord transformation was applied to the data illustrated in the ordinations, as recommended by Zuur *et al*. (2007). Occasionally this transformation produced highly skewed and unhelpful ordination plots and in these cases the untransformed (and obviously interpretable) plot was shown.

BVSTEP is a Mantel test with forward selection of variables to find those that give the most significant correlation. The test compares a similarity matrix of environmental variables with that of species by correlating the similarity coefficients. The similarity matrix is made by comparing each sample with every other using a similarity coefficient for the species and then for the environmental variables, resulting in two square matrices of x samples by x samples. These are correlated one against the other. The similarity coefficient used for species was Jaccard's and that used for the environmental variables was Euclidian distance. Jaccard's coefficient applies only to presence-absence data.

2.3.2 Collinearity of variables

As a large number of variables had been collected but only a few were likely to be important, each dataset was inspected for ways to reduce those of little importance. The procedure started with simple exploration using dotplots, pairplots and visual inspection of variables that were rarely recorded. Variance Inflation Factor (VIF) analysis was used to remove remaining strongly correlated variables, but juggling them to attempt to retain those that were likely to directly impact on aquatic invertebrates. For instance, short grass on the bank would be excluded in favour of 'tangledness' if possible. However, some 'useful' variables were often excluded, especially the subjective ones such tangledness and grazing intensity, which were effectively a visual summary of a number of lesser components that were also measured individually. Variables with a VIF above 10 were removed (Zuur *et al*., 2007).

3 Results

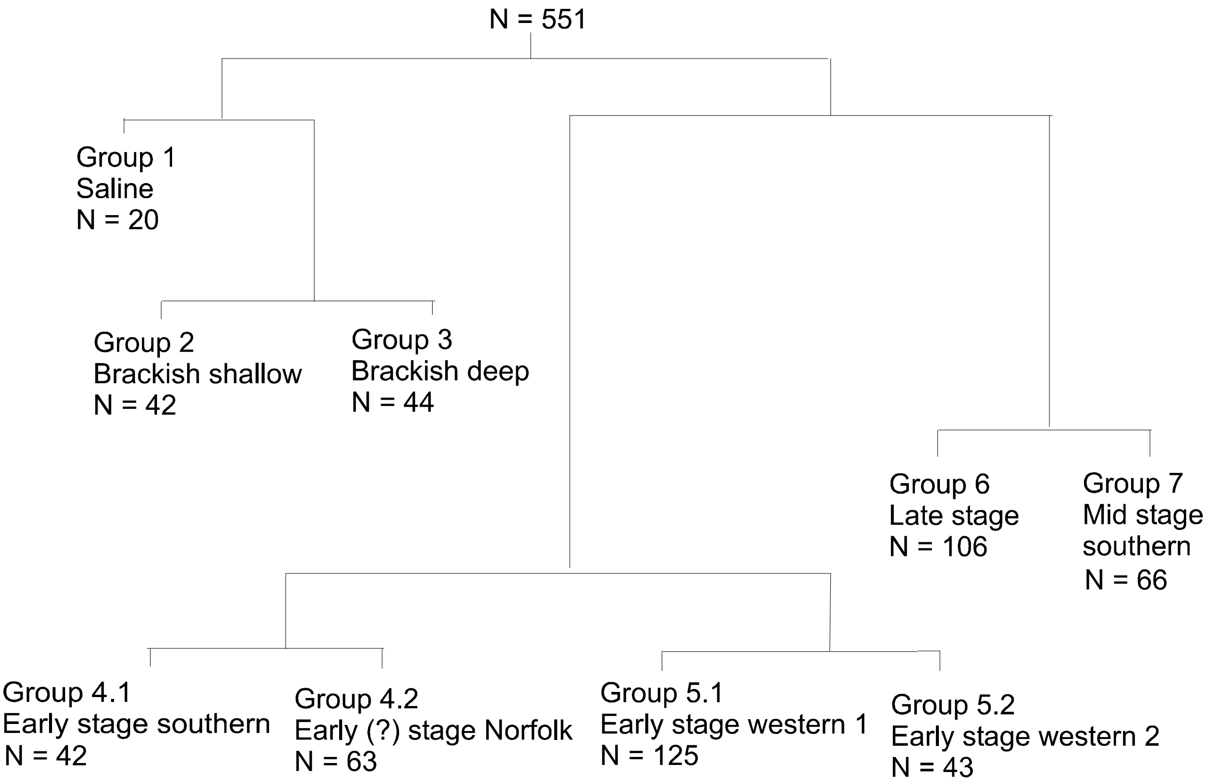
3.1 TWINSPAN groups: all invertebrate species

For the run using all 551 samples and 335 species with three pseudospecies (abundance categories), the principle splits are shown in Figure 3.3. Environmental variables are shown as boxplots in Figure 3.4. Only those that shed light on the groups are shown. Ordinal variables are given as percentages in Table 3.4.

The occurrence of species in each group is conventionally shown as 'constancies' which are the percentage occurrence in a group shown in intervals of 20%. Species are ordered by TWINSPAN, so appear in random taxonomic order. Constancies are shown in Table 3.2, ignoring species with a maximum constancy of 1-20% as this contains a large number of infrequent species. Such tables usually have a pronounced diagonal slant, with species at the top clustering to one side and those at the bottom to the other. If there is no obvious pattern, there is probably poor discrimination between groups.

Salinity, hydroseral stage and geographic location were the main factors associated with major divisions of the classification. Factors related directly to management beyond the crude separation of early and late succession assemblages did not feature in these first divisions. To highlight how important location was in this national classification, the TWINSPAN groups were ordered in Table 3.3 by their grouping in the analysis and by eye to give a diagonal across the table. Location clearly was as important as successional stage, so limited the expectation that the classification would identify factors associated with management. For that purpose, classification would be needed at a local level. Table 3.3 indicates that some marshes could be so grouped without location being an overriding factor. Management-related variables and location did not relate to successive TWINSPAN divisions in a neat way so the description of each group is a confusing mix of local environmental features and geographic location.

Figure 3.3 TWINSPAN groups using all invertebrate species and abundance data



The samples divided initially on the basis of salinity, which was the major environmental factor at a national level. Three brackish groups were distinguished, one being exceptionally saline ditches (group 1), and the others less brackish and separated by water depth or 'age' (groups 2 and 3). The next major division was between 'early' and 'late' stage ditches, which were recognised by a suite of variables that appeared to distinguish more open (early to mid stage) from more choked conditions (mid to late stage). Thus there were higher covers of emergents and proportion of channel with emergents or floating mat, and less open water and submerged vegetation on one side, and the opposite of these characteristics in the other, leading to the first suite of ditches being scored as 'older'. These ditches were not necessarily choked, end-of-succession ditches but perhaps just more densely vegetated across their width.

Further division of the earlier stage ditches was based on geographic position rather than local effects, and there were no other obvious variables that distinguished them (group 4 was eastern, 5 was western). Further division of the early-stage eastern and southern 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 western marshes group 5, further division was correlated to some extent with soil type and water depth in (peat and shallower in group 5.1, clay and deeper in group 5.2). Soil type also correlated with a subdivision of the late stage group 6 but this division was poorly supported by ANOSIM analysis. The late-stage groups 6 and 7 were distinguished partly by water depth and by geographic position (group 6 shallower with greater floating *Lemna* cover and less submerged vegetation) although the distinction was not clear.

The constancy table showed rather little pattern and this reflects poor discrimination, as previously seen in the ordinations (Table 3.2). Species associated with brackish and saline water are highlighted, and these do form a discrete group at the bottom left side of the table.

Descriptions of all the groups identified using the 'national' TWINSPAN analysis are given in Volume 1, Section 5 of this report. These descriptions include information on the main characteristics of the fauna and on the environmental variables showing the most influence on the composition of these assemblages.

Table 3.2 Constancy table for invertebrates in TWINSPAN groups based on all species.
Groups are ordered in their position in the TWINSPAN output. Horizontal lines separate larger species groups identified by TWINPAN. II – 21-40%; III – 41-60%; IV – 61-80%; V – 81-100%. Only those with a constancy >1 in any group are shown. * = Brackish-water species; ** = saline-water species

	TWINSPAN group									
	1	2	3	4	4	5	5	6	6	7
	saline	brackish shallow	brackish deep	early-mid southern	early-mid Norfolk	early-mid western, clay	early-mid western, 'peat'	late shallow	late shallow	mid-late
Hydroporus tessellatus	I	II	I		I	III	III	III	III	I
Dryops luridus		I	II	II	II	III	I	II	I	I
Graptodytes pictus			I	I	II	I	III	I	I	I
Gyrinus marinus		I	I	II	III	I				I
Noterus crassicornis		I	I	III	IV	I		I	I	I
Caenis robusta		I	II	III	IV	IV	III	I	I	I
Theromyzon tessulatum		I	I	II	I	II	II	I	I	I
Lestes sponsa		I		I	II	I	I		I	I
Haliplus sibiricus						I	II	I		I
Hydaticus transversalis		I			I	III	II	II		I
Hydroporus striola					I	II	I	I	I	
Lymnaea stagnalis			I	IV	IV	IV	III	I	I	II
Musculium lacustre			I	I	III	II	IV	II	II	I
Planorbis carinatus				II	III	III	I	I	I	II
Viviparus contectus				I	II	I		I		I
Aeshna grandis					II	I				I
Triaenodes bicolor				I	III	III	I	I	I	II
Ilybius ater			I	I	II	I	I	I	II	I
Rhantus grapii		I	I		II	II	I	III	I	II
Erpobdella octoculata				III	III	V	IV	III	II	III
Glossiphonia complanata		I	I	I	II	I	II	I	II	I
Glossiphonia heteroclita			I	I	I	I	I	I	I	II
Anisus vortex			I	III	V	V	V	IV	III	IV
Bithynia leachii		I		III	IV	IV	II	II	I	IV
Bithynia tentaculata				III	V	V	IV	III	II	V
Hippeutis complanatus		I	I	III	II	III	II	III	II	III
Lymnaea palustris		II	II	IV	V	V	III	IV	IV	V
Planorbarius corneus			I	II	III	IV	II	II	II	IV
Anacaena lutescens	I	I		I	I	IV	II	III	IV	II
Hydroporus pubescens		I	I	I	IV	V	III	IV	III	II

	TWINSPAN group									
	1	2	3	4	4	5	5	6	6	7
Bathyomphalus contortus					II	IV	I	III	I	III
Dryops auriculatus				I						II
Hydraena riparia		I		I	I			I	II	II
Dixella amphibia		I			I	I			II	I
Hydrometra gracilenta				I						II
Erpobdella testacea				II	I	II	I	I	II	III
Acroloxus lacustris				I	III	I		I	I	III
Pisidium		I		III	IV	IV	III	IV	V	V
Segmentina nitida					I			I	I	II
Sphaerium corneum				II	IV	III	II	II	III	IV
Valvata cristata		I	I	II	III	III	II	III	II	IV
Valvata macrostoma				I	I	I		I	I	III
Physa fontinalis			I	III	IV	I	II	I	I	IV
Helophorus aequalis		I	I	I	IV	III	IV	III	IV	I
Crangonyx pseudogracilis		III	II	V	V	V	V	V	V	V
Hesperocorixa moesta			I	II		I	I	I		I
Planorbis planorbis		II	II	V	V	V	IV	IV	III	V
Agabus sturmii		I	I	II	I	I	I	II	II	II
Enochrus coarctatus		I	I	II	II	III	II	IV	II	IV
Ilybius quadriguttatus		I	I	I	I	I	II	II	II	I
Porhydrus lineatus		I	II	II	I	I	II	I	I	I
Cymatia coleoptrata			II	II	I	I				I
Gyraulus crista		II	IV	II	II	III	I	II	I	I
Physella acuta		I	II	I		I	III	I	II	I
Agabus nebulosus		I		I		I	II		I	I
Hydroporus palustris	I	III	II	II	III	III	V	IV	IV	II
Hydrovatus clypealis			I	II						I
Hyphydrus ovatus		I	III	IV	V	III	IV	II	II	IV
Laccobius colon		I	II	III	II	I	I			I
Cloeon dipterum		II	IV	V	V	V	II	I	II	IV
Ilyocoris cimicoides	I	I	IV	IV	IV	V	V	II	I	III
Sigara falleni			I	I	I		II		I	I
Sigara fossarum			I	I	II		I		I	I
Radix balthica		IV	V	V	V	V	V	III	IV	V
Aeshna		I	I	I	I	I	II	I		I
Athripsodes aterrimus			I	II	II	I	I			I
Coelostoma orbiculare		II	I	II	I	I	I	II	I	II
Enochrus testaceus	I	II	III	III	III	IV	IV	IV	II	IV
Hydroporus angustatus		III	II	II	II	III	II	V	IV	III
Anacaena globulus		I	I	I	I	I	II	II	I	I
Hydraena testacea		I	I	I	I	I	I	I	I	II
Hydrochus elongatus		I	I	II	I					II
Hydroporus memnonius		I	I	I	I	I		I	II	
Ochthebius viridis		II	I							
Culiseta annulata		II				I		I	I	
Hesperocorixa sahlbergi		I	I	I	I	I	I	I	II	I
Helobdella stagnalis			I	II	I	I	I	I	II	I
Asellus aquaticus		III	III	IV	V	V	V	V	V	V
Anisus leucostoma		II	I	I		I	I	I	I	
Anacaena bipustulata	I	I	IV	II	II	I	I	I	I	I
Sigara dorsalis	I	I	II	II	I	I	III	I	I	I
Agabus bipustulatus	I	III	I	I	III	III	III	III	III	II
Haliplus ruficollis	I	II	III	III	IV	V	IV	II	II	III
Microvelia reticulata	I	II	IV	V	IV	V	III	III	I	V
Coenagrion	I	II	III	III	IV	V	II	III	II	V
Liopterus haemorrhoidalis	I	II	II	II	I	I	I	III	IV	IV
Asellus meridianus	I	II	III	III	III	I	I	I	III	IV
Gyrinus substriatus	I		I	II	II	I	II	I	I	I
Hydrophilus piceus	I	I	II	I	III	III	I	I		I

	TWINSPAN group									
	1	2	3	4	4	5	5	6	6	7
Peltodytes caesus	I	I	II	II	II	II	II	I	I	I
Odontomyia ornata	I	I	II	II	II	III	II	I	I	I
Oplodontha viridula	III	III	IV	IV	V	V	III	IV	I	IV
Brachytron pratense	I	I	II	I	II	II	I	I	I	II
Dytiscus marginalis	I	I	I	I	II	I	I	I	I	I
Helophorus brevipalpis	II	II	II	II	III	IV	V	IV	III	III
Helophorus minutus	II	III	III	III	V	III	III	II	IV	IV
Hydroporus planus	III	IV	IV	III	V	V	IV	IV	V	IV
Ochthebius dilatatus	I	II		I	III	I	I	II	I	I
Rhantus suturalis	I	II	II	II	IV	I	I	I	I	II
Corixa punctata	I	I	I	II	I	I	I		I	I
Hesperocorixa linnaei	II	II	IV	IV	III	IV	III	I	II	IV
Nepa cinerea	I	I	II	II	III	II	II	II	III	II
Notonecta glauca	II	I	III	IV	V	III	III	I	I	IV
Anacaena limbata	III	V	V	V	IV	V	V	V	IV	V
Haliplus lineatocollis	I	II	III	II	III	II	III	I	I	I
Helochares lividus	I	I	IV	III	II	II	III	I	I	I
Laccobius bipunctatus	I	III	III	III	III	II	III	II	III	IV
Argyroneta aquatica	I	I	III	II	IV	I	I	I	II	IV
Helophorus obscurus	I	II	I	II	II	I	I	I	III	III
Chaoborus crystallinus	I	I	I	I	I	I		I	I	II
Limnephilus marm./flavic.	I	II	III	II	II	II		I	II	V
Cercyon sternalis	I	III	I	I	I	I		I	I	I
Cercyon tristis	I	II	I	I	II	I		I	I	I
Colymbetes fuscus	I	III	I	I	I	I	I	I	I	I
Hygrotus inaequalis	II	IV	V	III	IV	III	IV	III	II	III
Sympetrum	I	IV	III	II	II	II	I	I	I	I
Noterus clavicornis	V	IV	V	V	V	V	V	IV	IV	V
Hydrometra stagnorum	III	II	III	III	II	I	III	II	II	I
Gerris odontogaster	II	II	IV	II	III	II	I	I	I	II
Plea minutissima	II	I	IV	V	II	IV	III	I	I	II
Ischnura elegans	IV	II	V	IV	V	III	IV	I	II	II
Haliplus immaculatus	I		II	II	I	I	I	I		
Stratiomys singularior	II	II	III	II	I	II	I	II	I	I
Anopheles atroparvus	I	I	I		I	I	II	I	I	I
Laccophilus minutus	II	II	IV	III	III	I	II	I	I	I
Aeshnidae	I	I	II	I	III	I		I		I
Limnoxenus niger	IV	III	IV	III	II	III	I	I	I	II
Odontomyia tigrina	I	II	II	I	II	II	I	II	I	I
Gammarus duebeni **	V	II	III	I	I				I	
Gammarus zaddachi **	IV	I	II	I	I		I			
Berosus affinis	III	I	II	I		I	II			I
Gyrinus caspius *	III	I	II	I	I	I	I			I
Palaemonetes varians **	IV	I	I	I			I			
Gerris thoracicus	II	I	I	I	I	I	I	I		I
Notonecta viridis	III	I	I	I	I	I	I			I
Paracorixa concinna	II		I	I						
Sigara lateralis	II	I	I	I	I		I			
Sigara stagnalis *	III	I	I	I				I		
Limnephilus affinis	III	I	I							I
Potamopyrgus antipodarum	III	II	IV	I	I	I	I	I	II	I
Agabus conspersus *	I	II	I					I		
Berosus signaticollis	II	II	I				I			
Enochrus halophilus *	IV	III	II		I				I	I
Graptodytes bilineatus *	I	III	I	I				I	I	I
Helophorus alternans *	II	II	I					I	I	
Hygrotus parallelogrammus *	II	II	I	I	I					I
Rhantus frontalis	II	II	II	I	I	I		I	I	I
Lestes dryas	I	II	I							

	TWINSPAN group									
	1	2	3	4	4	5	5	6	6	7
Dixella attica	I	III	III	I	II	I		I	I	I
Cymbiodyta marginella	IV	V	IV	III	II	I	II	III	IV	IV
Cercyon marinus	I	II	I	I	I	I		I	I	I
Hydrobius fuscipes	III	V	III	III	IV	II	II	III	IV	II
Ochthebius minimus	II	V	II	II	III	I	II	I	IV	II
Hygrotus impressopunctatus	I	II	II	I	III	I	I	I	I	II
Dixella autumnalis	II	III	III	II	III	I	I	I	III	IV

Table 3.3 Geographic distribution of ditches in each TWINSPAN group for all invertebrate species.

TWINSPAN Group		Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Samples
1	Saline	0	0	0	0	0	1	11	3	5	0	0	0	0	20
2	Brackish shallow	0	3	0	0	0	3	11	17	3	3	1	1	0	42
3	Brackish deep	0	0	0	0	0	8	13	10	6	0	4	0	3	44
4.1	Early stage (southern)	0	0	0	1	6	22	3	4	0	1	3	2	0	42
4.2	Early (?) stage (Norfolk)	1	0	0	1	2	0	0	0	0	0	4	24	31	63
5.1	Early stage (western, clay)	1	1	115	0	0	0	0	1	0	0	4	1	1	125
5.2	Early stage (western, ½ peat)	1	28	11	2	0	0	0	1	0	0	0	0	0	43
6	Late stage (scattered)	7	18	43	11	1	3	3	1	1	7	4	1	6	106
(6.1)	(western, partly peat)	0	16	43	0	0	3	0	0	0	0	3	1	2	68
(6.2)	(scattered, clay)	7	2	0	11	1	0	3	1	1	7	1	0	4	38
7	Mid stage (southern)	0	0	2	5	36	8	4	0	0	0	7	1	3	66
	Total samples	10	50	171	20	45	45	45	37	15	11	27	30	45	551
	Possible geographic grouping		---------					———	----				——		

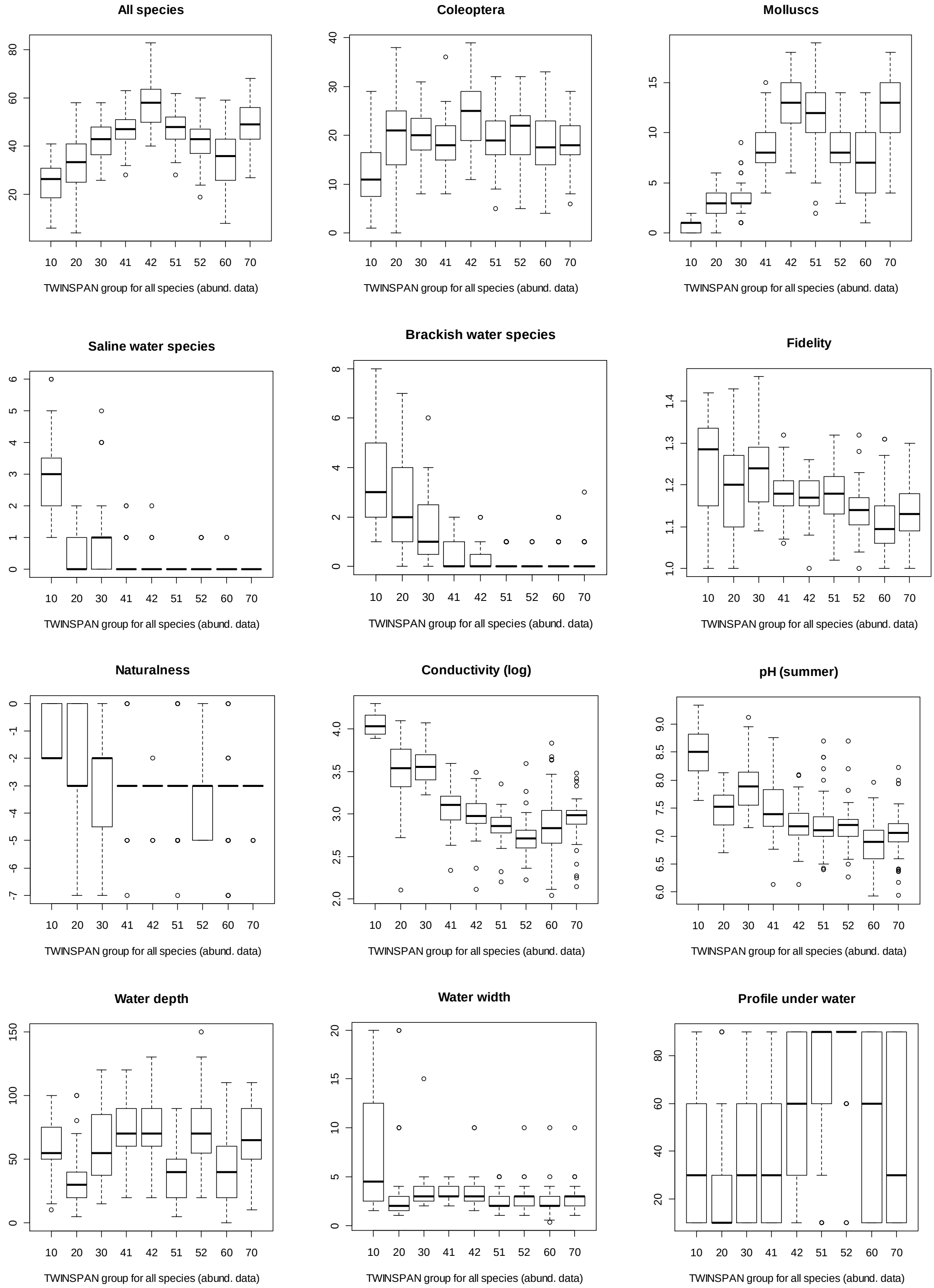
As the previous table but but arranged by eye to obtain a 'diagonal' in the frequency of samples across the table.

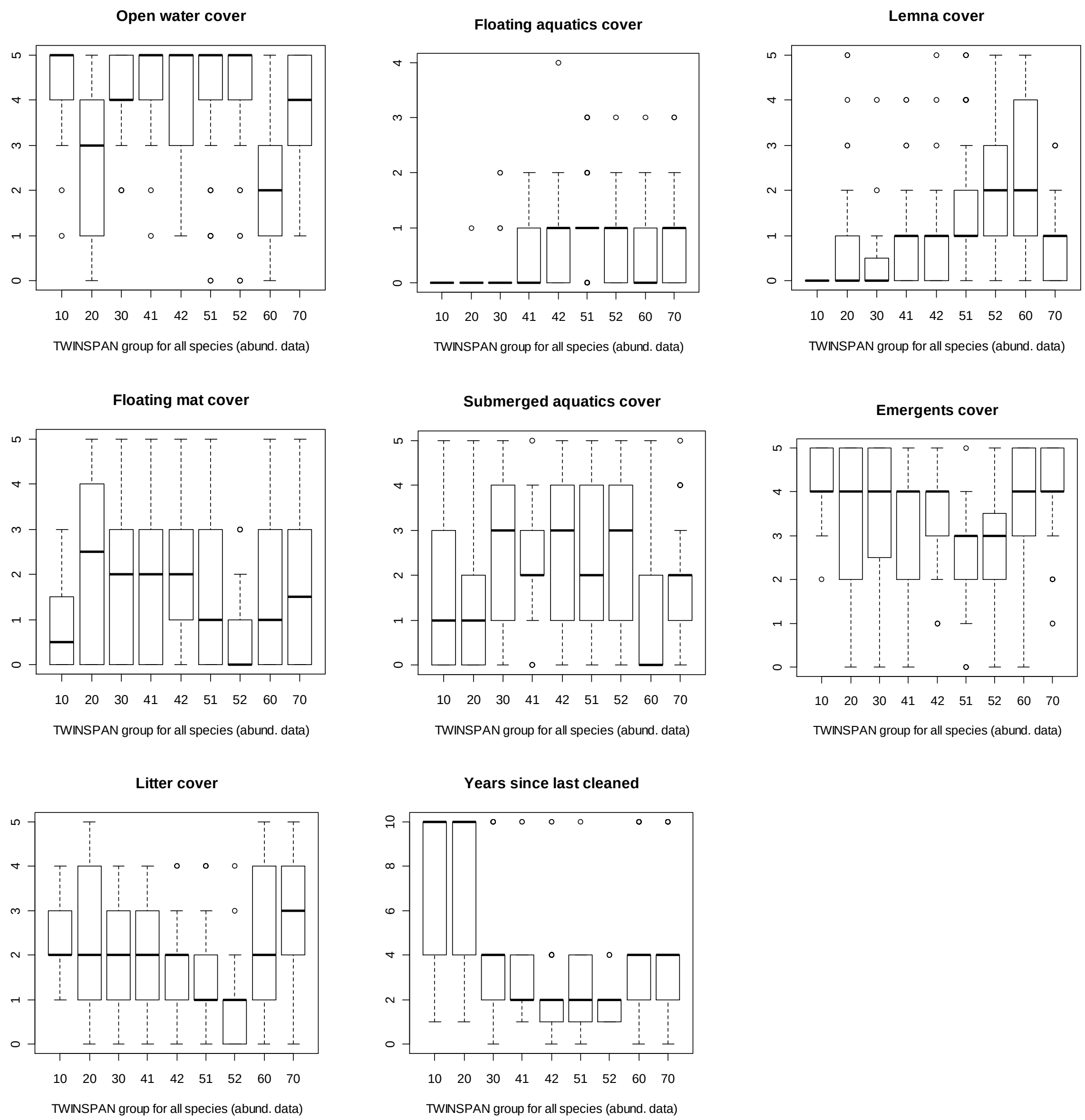
TWINSPAN Group		Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure
4.2	Early (?) stage (Norfolk)	1	0	0	1	2	0	0	0	0	0	4	24	31
2	Brackish shallow	0	3	0	0	0	3	11	17	3	3	1	1	0
3	Brackish deep	0	0	0	0	0	8	13	10	6	0	4	0	3
1	Saline	0	0	0	0	0	1	11	3	5	0	0	0	0
4.1	Early stage (southern)	0	0	0	1	6	22	3	4	0	1	3	2	0
7	Mid stage (southern)	0	0	2	5	36	8	4	0	0	0	7	1	3
5.1	Early stage (western, clay)	1	1	115	0	0	0	1	4	3	0	0	0	0
6.1	Late stage (western, partly peat)	0	16	43	0	0	3	0	0	0	0	3	1	2
5.2	Early stage (western, clay)	1	28	11	2	0	0	0	1	0	0	0	0	0
6.2	Late stage, (scattered, clay)	7	2	0	11	1	0	3	1	1	7	1	0	4
	Total samples	10	50	171	20	45	45	45	37	15	11	27	30	45

Table 3.4 Ordinal environmental variables of TWINSPAN groups for all species, as a percentage of samples in each group. N= number of samples in the group.

Group	N	D_soil (mineral)	L_impr	L_semi	L_unimp	L_arab	L_fen	L_route	L_cattl	L_sheep	L_hay	L_perf	L_temf	L_spoil
1	20	100	15	30	55	0	0	5	45	20	5	5	0	0
2	42	100	7	43	48	0	2	0	67	17	2	10	2	2
3	44	100	14	57	25	2	0	2	77	16	5	0	0	2
4.1	42	95	5	69	19	5	2	2	38	57	0	5	2	19
4.2	63	86	17	67	13	0	2	2	89	2	8	0	0	8
5.1	125	15	14	38	42	0	1	6	83	5	11	1	10	22
5.2	43	93	49	26	7	0	0	19	67	2	12	5	5	12
6.1	68	47	18	35	24	7	1	15	68	4	22	1	4	6
6.2	38	100	13	37	39	0	18	3	82	8	8	3	3	0
7	66	91	9	79	12	0	3	0	59	47	5	2	0	6

Figure 3.4 Number of species in different groups, environmental variables and conservation evaluation metrics for TWINSPAN groups for all invertebrate species.




Open water cover
Floating aquatics cover
Lemna cover
Floating mat cover
Submerged aquatics cover
Emergents cover
Litter cover
Years since last cleaned
10 20 30 41 42 51 52 60 70
TWINSPAN group for all species (abund. data)

3.2 TWINSPAN groups: beetles

3.2.1 The end-groups

TWINSPAN was run using all 113 species from 549 sites where they occurred, excluding one outlying saline site and another that lacked beetles. Inspection of ordinations and ANOSIM analysis suggested that, using abundance data, there were only six ecologically sound groups (Figure 3.5). Both DCA and MDS plots of these six groups showed a clear separation of two brackish groups (red and blue dots in Figure 3.6) and moderate distinction of the pairs 3+4 and 5+6 but with considerable overlap.

ANOSIM of 12 TWINSPAN end-groups in runs with either presence-absence or abundance data showed that nearly all end-groups were significantly different from one another, even when no real ecological separation could be discerned by visual inspection. The R-statistic was smaller when more closely related end-groups were compared, and those separating out at the fifth level of division tended to be rather small (although still significant at p=0.01). R values less than about 0.35 were taken to indicate groups with poor separation but there was no statistically valid reason for the choice of this arbitrary value. This resulted in keeping the originally chosen groups.

As the classification using all species was driven largely by location, the distribution of beetle end-groups was first examined by location. Few groups were thought to be recognisable using ecological knowledge and the ANOSIM analysis. These groups showed a very similar geographic grouping to those for all species (Table 3.5). The constancy table for beetles in TWINSPAN groups is given as Table 3.7 and box plots of environmental variables are shown in Figure 3.7.

The first split was based on salinity. Species showing exceptionally clear separation are listed in Table 3.6. These have been selected from the longer list identified by TWINSPAN and are those showing particular preference for or avoidance of brackish conditions. Those with a preference for brackish conditions are known halophiles. The identification of a suite of predominantly common beetles that avoid brackish conditions appears to be a new insight.

Figure 3.5 TWINSPAN divisions for beetles

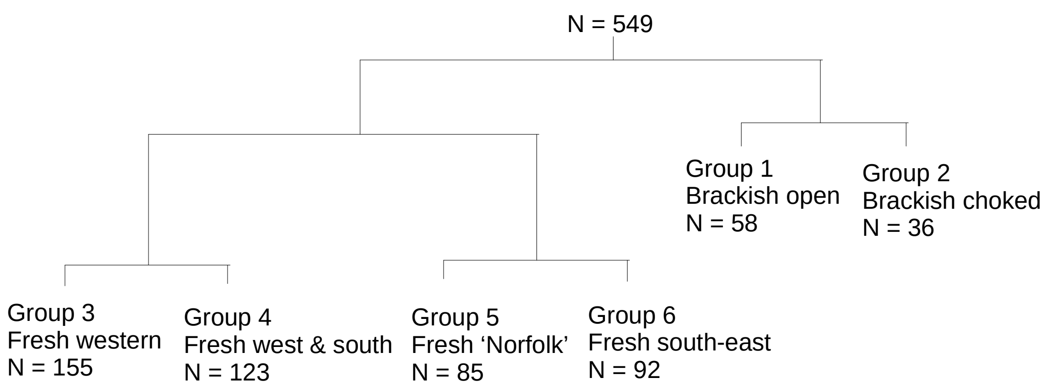


Figure 3.6 DCA and MDS plots for beetles using abundance data and showing TWINSPAN groups

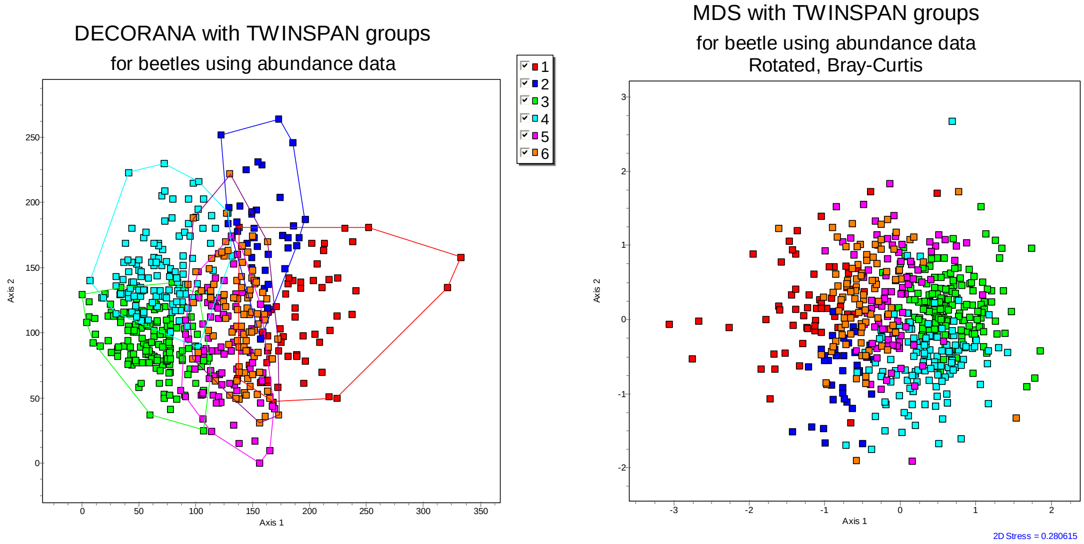


Table 3.5 Geographic distribution of ditches in each TWINSPAN group for beetles

TWINSPAN group		Malltraeth	Gwent Levels	Somerset Levels	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Samples
1	brackish open	0	1	0	0	0	4	21	20	9	0	3	0	0	58
2	brackish choked	0	1	0	0	0	3	6	11	3	9	2	0	1	36
3	fresh western	1	26	111	7	2	0	0	0	0	0	5	0	3	155
4	fresh west and south	9	18	55	12	10	1	3	0	2	2	2	0	9	123
5	fresh 'Norfolk'	0	2	5	0	2	5	0	3	0	0	8	29	31	85
6	fresh south-east	0	1	0	1	31	32	14	3	1	0	7	1	1	92
	Total samples	10	49	171	20	45	45	44	37	15	11	27	30	45	549
	Possible geographic grouping														

Table 3.6 Beetles showing particular preference or avoidance of brackish conditions
Number of occupied ditches in brackets (fresh, brackish); compare with the total for each type.

Species preferring the freshwater group (455 samples)	Species preferring the brackish group (94 samples)
Anacaena lutescens (194, 10)	*Berosus signaticollis* (1, 26)
Dryops luridus (144, 8)	*Enochrus halophilus* (10, 50)
Enochrus coarctatus (222, 1)	*Graptodytes bilineatus* (9, 29)
Helophorus aequalis (211, 8)	*Helophorus alternans* (4, 24)
Hydroporus pubescens (401, 6)	*Hygrotus parallelogrammus* (7, 26)
Hydroporus tessellatus (144, 11)	
Hyphydrus ovatus (264, 10)	
Noterus crassicornis (93, 3)	
Rhantus grapii (127, 0)	

3.2.2 Brackish groups 1 and 2

These split on the basis of group 1 being more saline, having higher pH and being slightly deeper and with more open water than the less brackish, shallower and more choked group 2 ditches. Three-quarters of the more brackish group1 ditches fell into the botanical TWINSPAN group G (brackish *Bolboschoenus*). In contrast, the shallower, well-vegetated group 2 was spread across all but one of the botanical groups, although with a preponderance of them in botanical groups G and A (*Phragmites* dominated).

With the exception of the halophile *Hygrotus parallelogrammus*, the beetles in group 2 appeared to be responding less to salinity and more to the open character, as indicated by the strong preference shown by *Berosus affinis*, *B. signaticollis*, *Gyrinus caspius* and *Laccophilus minutus* (Table 3.7). The more choked group 2 ditches had more of the usual common species of shallow grassy margins (e.g. *Agabus bipustulatus*, *Coelostoma orbiculare*, *Rhantus suturalis* and many more) and none are normally associated with brackish ditches. Group 1 ditches were on average less species-rich than any other TWINSPAN group but the difference was slight.

3.2.3 Freshwater groups

The freshwater samples split mainly on geographic location (Table 3.5). The first split into western + southern sites from Norfolk + south-eastern sites was based mainly on a very small number of beetles with pronounced east-west differences in their occurrence. In western marshes, *Anacaena lutescens*, *Hydaticus transversalis* and *Ilybius quadriguttatus* are moderately frequent but rare or infrequent in the east, and the common *Hydroporus pubescence* and *H. tessellatus* reach greater abundance in the west. Beetles that are absent or scarce in the west but frequent in the east are *Noterus crassicornis*, *Gyrinus marinus* and, to a lesser extent, *Rhantus suturalis*. These served to divide the datasets and made further analysis of the variables unproductive at this level.

3.2.4 Groups 3 and 4

Division of the western and western & southern groups 3 and 4 was based largely on hydroseral stage. Group 3 comprised earlier stage ditches with associated characteristics of less cover of emergents and their litter, floating mat and *Lemna*, and instead having more open water and submerged and floating aquatics, although with only marginally deeper water. However, despite these obviously different environmental characteristics, the two groups were distributed almost identically across the botanical TWINSPAN groups, with about half in group D1 (*Hydrocharis / Spirodela / Glyceria maxima*) and D2 (*Hydrocharis / Juncus effusus*) and about a quarter to a third in group B (*Lemna minor / minuta / gibba*). Soil may also have had an effect as peat underlay two-thirds of group 3 ditches but only about a third of those in group 4.

Beetles showing a strong preference for the earlier stage ditches were *Graptodytes pictus* and *Peltodytes caesus*, and a weaker preference was shown by *Dryops luridus*, *Helochares lividus*, *Hydrophilus piceus*, *Hyphydrus ovatus* and *Limnoxenus niger*. Of those preferring the later stage ditches, only *Hydraena riparia* was markedly more restricted, whereas the others were widespread in other groups and likely to be present in marginal grass at the edge of many types of ditch (*Anacaena globulus*, *Cymbiodyta marginella*, *Hydrobius fuscipes*, *Ilybius ater*, *Liopterus haemorrhoidalis*, *Ochthebius minimus*).

3.2.5 Groups 5 and 6

The 'Norfolk' and south-eastern groups 5 and 6 were divided on the basis of a number of species but only a few showed pronounced separation. Beetles that were particularly strongly skewed towards the 'Norfolk' group were *Cercyon marinus*, *Helophorus aequalis*, *Hydroporus pubescens*, *Ilybius ater* and *Ochthebius dilatatus*, all of which are common and widespread species not known to be more frequent in East Anglian. The south-east group had far greater preponderance of *Hydraena testacea* and *Hydrochus elongatus* which are less common species which may have genuine preferences for the warmer southern counties. However, the split seemed to be one based on tenuous ecological grounds.

Table 3.7 Constancy table for beetles in TWINSPAN groups

Groups are ordered in their position in the TWINSPAN output. Horizontal lines separate larger species groups identified by TWINPAN. II – 21-40%; III – 41-60%; IV – 61-80%; V – 81-100%. * = Brackish-water species.

Group	3	4	5	6	1	2
Number of samples	155	123	85	92	58	36
Anacaena lutescens	IV	IV	I	I	I	II
Hydroporus tessellatus	III	III	I	I	I	I
Dryops luridus	III	I	II	II	I	I
Helophorus brevipalpis	IV	IV	III	II	II	I
Hydraena riparia		II	I	I		I
Hydroporus striola	I	II				
Hydaticus transversalis	II	II	I			
Graptodytes pictus	II	I	II	I	I	I
Helophorus aequalis	III	IV	IV	I	I	I
Hydroporus pubescens	V	IV	IV	I	I	I
Ilybius ater	I	II	II	I	I	I
Enochrus coarctatus	III	IV	II	III		I
Rhantus grapii	II	III	II	I		
Gyrinus marinus	I	I	II	II		I
Ochthebius dilatatus	I	II	III	I	I	I
Laccobius colon	I		II	II	I	I
Noterus crassicornis	I	I	IV	II	I	
Gyrinus substriatus	I	I	II	I	I	
Hyphydrus ovatus	IV	II	IV	IV	I	I
Agabus sturmii	I	I	II	II	I	I
Ilybius quadriguttatus	I	II	I	I	I	I
Agabus bipustulatus	III	III	III	II	I	III
Hydroporus palustris	III	III	III	II	I	III
Hydroporus planus	V	V	V	III	IV	V
Hydroporus angustatus	III	IV	II	III	I	IV
Hydrochus elongatus	I	I	I	II	I	I
Helophorus obscurus	I	II	II	II	I	II
Liopterus haemorrhoidalis	I	III	I	IV	I	III
Anacaena limbata	V	V	IV	V	IV	V
Coelostoma orbiculare	I	II	I	II	I	II
Enochrus testaceus	IV	III	III	IV	II	II
Noterus clavicornis	V	IV	V	V	V	IV

Group	3	4	5	6	1	2
Haliplus ruficollis	IV	III	III	III	II	II
Hydrophilus piceus	II	I	III	I	II	I
Helochares lividus	II	I	III	II	II	I
Hygrotus inaequalis	III	III	IV	IV	IV	III
Porhydrus lineatus	I	I	I	II	I	I
Haliplus lineatocollis	II	I	III	I	II	II
Peltodytes caesus	II	I	III	II	I	II
Rhantus suturalis	I	I	IV	II	I	III
Helophorus minutus	II	III	V	III	III	III
Laccobius bipunctatus	II	II	IV	IV	II	III
Anacaena bipustulata	I	I	II	II	II	I
Hygrotus impressopunctatus	I	I	III	II	II	II
Cercyon tristis	I	I	I	I	I	II
Colymbetes fuscus	I	I	I	I	I	II
Hydraena testacea	I	I	I	II	I	II
Cymbiodyta marginella	I	III	II	III	V	V
Cercyon sternalis	I	I	I	I	I	IV
Hydrobius fuscipes	I	III	IV	II	IV	V
Ochthebius minimus	I	II	III	II	III	IV
Laccophilus minutus	I	I	II	II	III	II
Limnoxenus niger	II	I	II	III	IV	III
Cercyon marinus	I	I	II	I	I	I
Berosus affinis	I		I	I	III	
Gyrinus caspius *		I	I	I	II	I
Berosus signaticollis	I				II	I
Enochrus halophilus *	I		I	I	IV	II
Graptodytes bilineatus *		I	I	I	II	II
Helophorus alternans *		I		I	II	II
Hygrotus parall'grammus *			I	I	II	I
Rhantus frontalis		I	I	I	II	II

Figure 3.7 Number of species in different groups, environmental variables of TWINSPAN groups for beetles

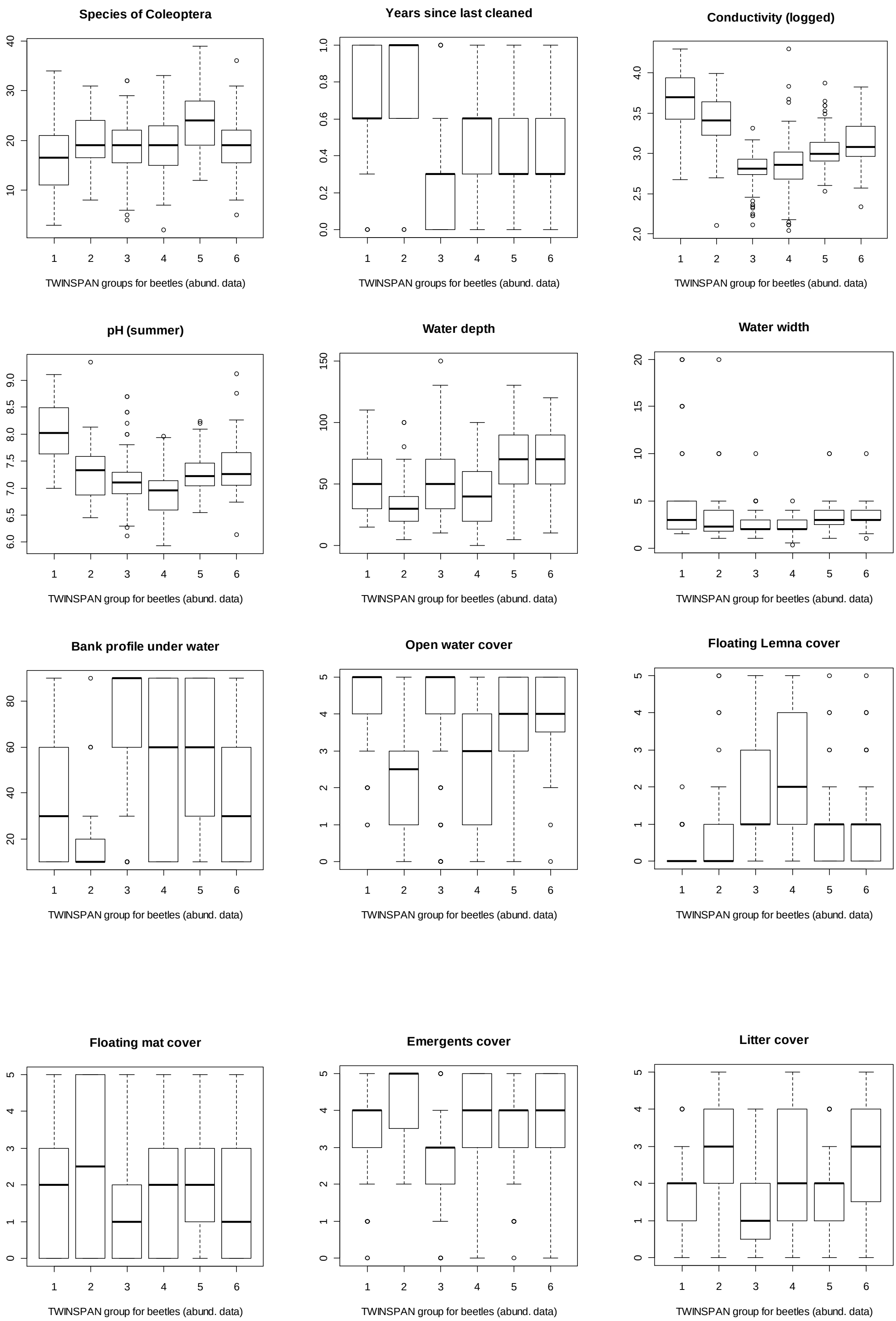


Table 3.8 Ordinal environmental variables of TWINSPAN groups for beetles, as a percentage of samples in each group with the attribute

Group	N	D_soil (clay)	L_impr	L_semi	L_unimp	L_arab	L_fen	L_route	L_cattl	L_sheep	L_hay	L_perf	L_temf	L_spoil
1	58	100	12	47	41	0	0	2	76	12	5	2	0	0
2	36	97	6	31	61	0	3	0	64	11	6	8	0	0
3	155	37	21	39	32	0	1	9	80	6	13	1	10	21
4	123	60	15	45	24	3	8	9	72	10	12	3	2	3
5	85	86	21	59	15	0	1	4	85	6	7	0	0	11
6	92	98	9	71	14	4	1	2	43	52	3	3	1	11

3.3 TWINSPAN groups: molluscs

3.3.1 The end-groups

Seven groups were recognisable using TWINSPAN (Figure 3.8). One extreme outlier with a single species (*Ventrosia ventrosa*) was excluded from the DCA analysis, and 3 dimensional MDS had high stress values but for the purpose of illustrating the similarity of TWINSPAN groups with DCA plots, the error was regarded as acceptable (stress = 0.1595).

Species-poor brackish-water and probably ephemeral or very shallow ditches formed recognisable faunas at one end the ordinations (Figure 3.9). The mass of samples from fresh ditches were less clearly separated on the ordinations, and formed a continuum that TWINSPAN could not distinguish well. There were probably two groups in the centre of the ordinations and another 1-2 at the far end, with small separation between these pairs on the second axis in most cases. (Figure 3.9, DCA only).

To check whether the close cluster of samples at the freshwater end of the ordinations obscured some real separation of the TWINSPAN groups, the brackish and species-poor groups were excluded and ordinations run using just the freshwater samples. This selection removed *Ventrosia ventrosa* and an unidentified snail. When plotted on the first two axes of both DCA and MDS ordinations, there was clearly still a great deal of overlap among most groups but, for both presence-absence and abundance data, five groups were likely to be real ecological entities, if somewhat blurred at times.

The decision whether to use abundance data rather than just presence-absence data was particularly unclear for molluscs. The comparison of variation in the 'coefficient of variation' was not as clear-cut as for all species and beetles. However, the manner in which TWINSPAN separated groups differed markedly between the two datasets: using presence-absence data, groups were picked off almost one at a time with no large divisions, and left a large mass of samples that ANOSIM analysis suggested was fairly uniform. Using abundance data, the sequence of divisions produced more evenly sized groups and, while this in itself did not make it superior to the presence-absence dataset, it was easier to understand and the initial splits were more similar to those using beetles.

Figure 3.8 TWINSPAN divisions for molluscs using abundance data

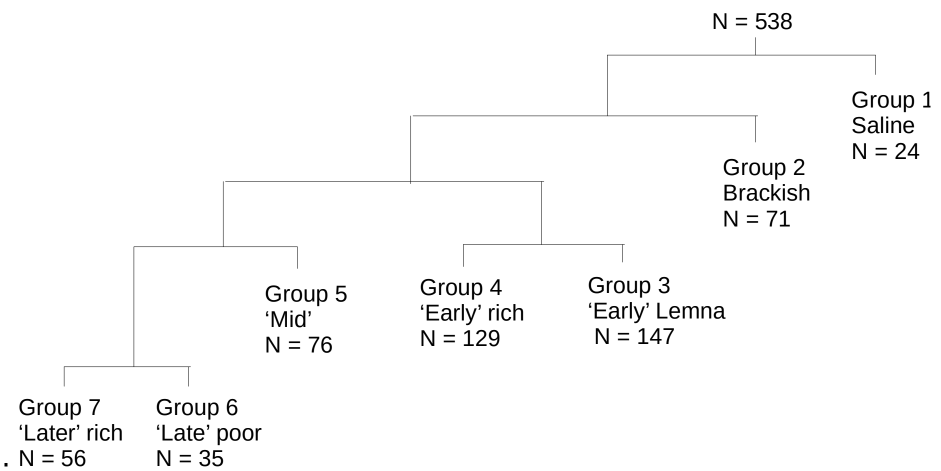
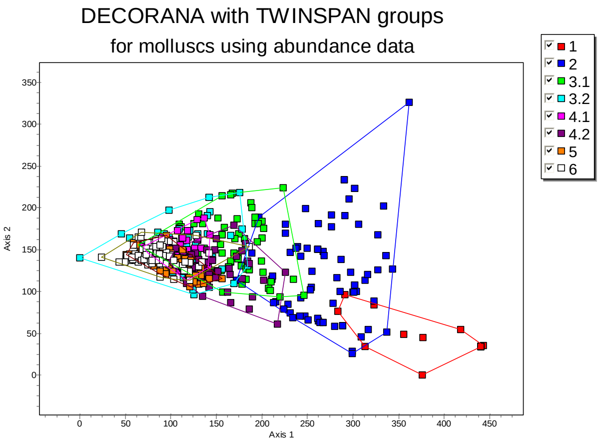
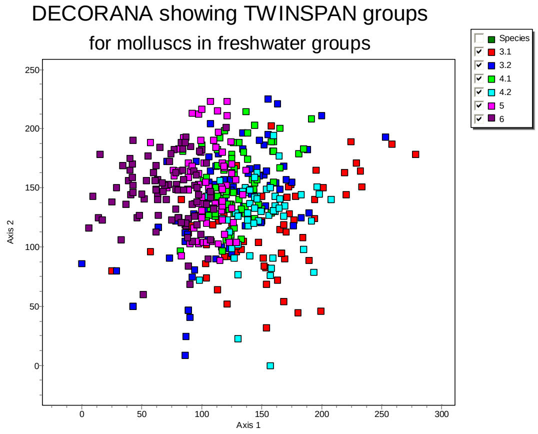


Figure 3.9 DCA plots for molluscs using abundance data and showing all TWINSPAN groups (left) and just freshwater groups (right)





3.3.2 Groups 1 and 2

The first two divisions separate most of the brackish and basic ditches in the dataset. The first group 1 (24 ditches) was markedly more saline and particularly species-poor with usually only one or two species. *Potamopyrgus antipodarum* was the only species showing a preference for it, and could sometimes by particularly abundant. The almost complete absence of other molluscs was more characteristic in some ways, since most of the 13 ditches where no molluscs were recorded were strongly brackish.

The larger less brackish group 2 (71 ditches) was also characterised by a great scarcity of most species and may have been a mix of ditches that dry out and brackish ones. Those that dry out were probably responsible for *Anisus leucostoma* being selected as a preferential species. Other molluscs apparently preferring this group were *Potamopyrgus* at moderate abundance and the tolerant species *Radix balthica* and *Gyraulus crista*. The non-native *Physella acuta* was also a preferential and, although this was a relatively weak candidate, it does suggest wide ecological tolerance.

Freshwater Groups 3 to 7

The bulk of the samples were divided into two large groups of 276 ditches (groups 3+4) and 167 ditches (groups 5+6+7) that were interpreted as representing earlier and later groups in the hydroseral succession.

The 'earlier' grouping (3+4) was characterised only by the preference of the bivalve *Musculium lacustre*, and the 'later' grouping (5+6+7) by often moderately large numbers of *Bithynia leachii*, *Hippeutis complanata*, *Lymnaea 'palustris'*, *Physa fontinalis*, *Sphaerium corneum* and *Valvata cristata*, and by large numbers of *Bithynia tentaculata* and *Pisidium*. The preference shown by *Acroloxus lacustris* may have been real but this limpet is often overlooked during pond-net sampling owing to its habitat of clinging to vegetation. The rare *Valvata macrostoma* was a preferential for the 5+6+7 group.

Environmental features of the 'earlier' group were lower emergent cover and lower proportion of channel with emergents, less litter and often less floating mat, and steeper underwater profiles at the margin; these are features that led to these ditches being rated as cleaned more recently. Soil type may have been partly involved in the distinction as slightly over half these 'early' ditches were on peat, compared to only about a quarter of the 'later' grouping. Land-use may also have been involved, as a larger proportion of the 'early' group was next to improved pasture and a smaller proportion had adjacent sheep grazing, although it is difficult to imagine how the relatively small differences would affect the ditch fauna.

3.3.3 Groups 3 and 4

Group 3 was split from group 4 by the preference for group 3 ditches of the non-native *Physella acuta*, and for group 4 ditches of *Physa fontinalis* and several snails in moderately large numbers: *Bithynia leachii*, *B. tentaculata*, *Lymnaea 'palustris'*, *Planorbis planorbis* and *Anisus vortex*. As *Physella acuta* occurred in a rather small proportion of samples, this distinction is not based mainly on its occurrence, although its prevalence in western marshes was partly responsible for the strong bias towards Somerset and Gwent ditches in group 3.

When compared with group 4 ditches, those in group 3 were characterised mainly by their greater cover of floating *Lemna* and consequent lower cover of submerged plants and lower scores for tangledness. They tended to be less grazed and with poorer shelf development. About a third of group 3 ditches are in the botanical TWINSPAN group B (floating *Lemna* group) but, like group 4 ditches, the remaining ditches are spread across several botanical groups. It is probable that the common snails do not thrive in the less favourable condition found below dense carpets of floating *Lemna*, whereas *Physella acuta* is more tolerant. The constancy table, which ignores differences in abundance, suggested that the differences between the assemblages were small (Table 3.10).

3.3.4 Groups 5 and 6+7

The division of groups 5 and 6+7 was characterised by the great abundance of *Bithynia leachii* and *B. tentaculata* and less pronounced preferences of *Musculium lacustre* and *Gyraulus crista* for group 5. Groups 6+7 were characterised by large numbers, often an abundance, of *Pisidium* and by the rare planorbids *Segmentina nitida* and *Valvata macrostoma*. There was a geographical element to the division, with many Norfolk and some Walland ditches in group 5, and many Pevensey and Arun ditches in group 6+7.

Group 5 may have represented the mid stage rather than later stage in the hydroseral succession as the ditches had markedly higher cover of submerged vegetation, smaller proportions of emergent or mat in the channel and tendency for less emergent cover, and these features are likely to be responsible for the ditches having been scored as more recently cleaned. The ditches were concentrated in the three botanical TWISNPAN groups D, E and F, which are all characterised by *Hydrocharis* in combination with other emergents or submerged plants. Positioning group 5 midway between the early groups 3+4 and the later 6+7 also made ecological sense, and suggested that local factors are at least as influential as geographical location in this national classification.

The pair of groups 6 and 7 was separated as ANOSIM analysis suggested that they were moderately distinct. Group 7 did seem to be a real group characterised by many more species that included moderately large numbers of *Bathyomphalus contortus*, *Bithynia leachii*, *Lymnaea stagnalis*, *Segmentina nitida*, *Valvata macrostoma*, *Planorbis planorbis* and abundance *Valvata cristata*. *Acroloxus lacustris* also showed a preference for this group. Group 6 ditches were rather species-poor and characterised only very weakly by having moderately large numbers of *Planorbarius corneus*. There was a strong geographic element in the division, with many Arun ditches being in the poorer group 6, and Pevensey and Somerset ditches in the richer group 7. The environmental variables that differed between the groups were greater covers of floating mat, submerged vegetation and litter, and smaller freeboards in the richer group 7. Group 6 had some notably low conductivities but these may have been due to recent flooding at the Arun sites. The two groups were otherwise not clearly distinguished.

Table 3.9 Geographic distribution of ditches in each TWINSPAN group for molluscs

TWINSPAN group		Malltraeth	Gwent Levels	Somerset Levels	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Samples
1	Saline	0	0	0	0	0	1	11	5	3	0	2	1	1	24
2	Brackish	1	4	0	0	0	10	15	21	10	4	3	0	3	71
3	‘early’ *Lemna*	8	29	75	3	1	7	2	3	0	7	7	3	2	147
4	‘early’ rich	0	14	62	0	1	10	5	5	0	0	3	16	13	129
5	‘mid’	0	0	14	2	5	12	2	0	0	0	7	10	24	76
6	‘late’ poorer	1	2	5	15	2	3	2	0	0	0	5	0	0	35
7	‘late’ richer	0	0	15	0	36	2	0	1	0	0	0	0	2	56
	Total samples	10	49	171	20	45	45	37	35	13	11	27	30	45	538
	Possible geographic grouping	———	———		———	———	———	----	———	———					

Table 3.10 Constancy table for molluscs in TWINSPAN groups, showing all species

Groups are ordered in their position in the TWINSPAN output. TWINSPAN species groupings are indicated by horizontal lines. I – 1-20%, II – 21-40%, III – 41-60%, IV – 61-80%, V – 81-100%. * = Brackish-water species.

Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	saline	brackish	‘early’ *Lemna*	‘early’ rich	‘mid’	‘late’ poorer	‘late’ richer
Number of samples	24	71	147	129	76	35	56
Bithynia tentaculata	I	I	III	V	V	IV	V
Valvata cristata	I	I	II	II	IV	IV	V
Acroloxus lacustris			I	I	II	I	III
Anisus vorticulus					I	I	I
Radix auricularia							I
Segmentina nitida				I	I		III
Valvata macrostoma			I	I		I	IV
Viviparus contectus			I	I	I	I	
Bathyomphalus contortus			III	II	III	I	IV
Bithynia leachii		I	II	IV	V	I	V
Hippeutis complanatus		I	II	II	III	IV	IV
Planorbarius corneus			II	III	IV	IV	IV
Planorbis carinatus			I	II	III	II	III
Sphaerium corneum		I	II	II	IV	V	V
Gyraulus albus		I	I	I	I	I	I
Musculium lacustre		I	III	III	II	I	I
Pisidium amnicum			I				
Valvata piscinalis			I	I	I	I	I
Anisus vortex		I	IV	V	V	IV	V
Aplexa hypnorum		I	I		I	I	I
Lymnaea stagnalis		I	II	IV	IV	I	III
Pisidium		I	IV	III	IV	V	V
Lymnaea ‘palustris’	I	II	III	V	V	V	V
Physa fontinalis	I	I	I	III	III	II	III
Anisus leucostoma		II	I	I	I		

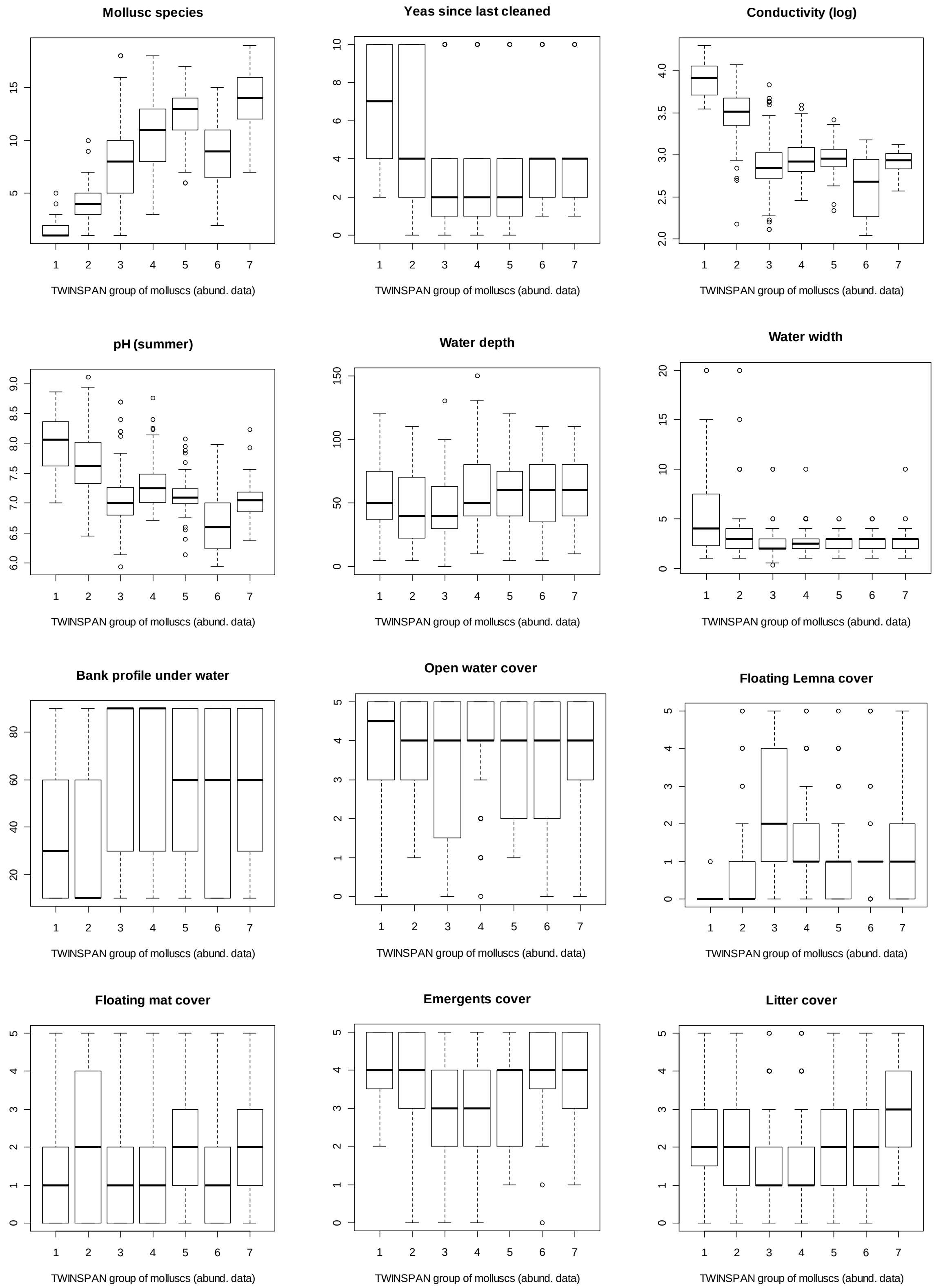
Group	1	2	3	4	5	6	7
Gyraulus laevis		I	I				
Unidentified species[1] *		I					
Radix balthica	I	V	IV	V	V	IV	IV
Planorbis planorbis	I	II	IV	V	V	III	V
Galba truncatula	I	I	I	I			I
Gyraulus crista	I	IV	II	II	II	I	I
Physella acuta	I	II	II	I	I	I	I
Potamopyrgus antipodarum	V	III	I	I	I	I	
Ventrosia ventrosa *	I						

Table 3.11 Ordinal environmental variables of TWINSPAN groups for molluscs, as a percentage of samples in each group with the attribute

Group	N	D_soil (clay)	L_impr	L_semi	L_unimp	L_arab	L_fen	L_route	L_cattl	L_sheep	L_hay	L_perf	L_temf	L_spoil
1	24	100	8	42	50	0	0	4	63	17	0	4	0	0
2	71	100	14	46	34	1	1	3	73	17	3	4	3	3
3	147	58	18	37	29	2	4	11	72	9	10	3	5	15
4	129	57	24	46	23	2	0	5	72	9	16	2	6	16
5	76	75	12	59	22	3	1	4	70	20	4	1	1	9
6	35	69	3	60	31	0	14	3	80	20	0	3	3	6
7	56	73	11	71	16	0	2	2	66	38	13	0	0	4

[1] This specimen has been sent to Dr. Martin Willing for identification. It may be a non-native species.

Figure 3.10 Number of species in different groups, environmental variables of TWINSPAN groups for molluscs



4 Similarity of classifications using different taxa

4.1 Methods

Two approaches were used to investigate the similarity of classifications using all taxa, beetles and molluscs: Mantel tests and simple comparison of the distribution of TWINSPAN groups in different geographic areas.

Mantel tests were used to determine whether beetles and molluscs showed similar patterns of occurrence. The test was run for marshes grouped into nine geographic areas. This acted as an independent test of whether two very different groups of organisms had similar underlying grouping that may have been reflected in the classification.

The test was run for samples in each geographic area using TWINSPAN groups for all species as strata in the permutation test, since this was probably a fair method of grouping similar samples. Many strata within these geographic areas had too few samples for the test to work but in practice there was scarcely any difference between the test run with or without strata, so only the results without strata are presented.

4.2 Results

Six of the nine geographic areas with many samples showed highly significant Mantel r-values ($p<0.001$), which indicated that beetle and mollusc assemblages followed a similar pattern of occurrence (Table 3.12). Areas with relatively few samples (10-27) gave non-significant r-values, and this may have been due to the range of ecological variation being too small for clear differences in assemblages to be detected. The significant results for areas with many samples suggested that grouping for beetles and molluscs may have similar underlying ecological drivers.

Table 3.12 Mantel test comparing beetles and molluscs matrices for different TWINSPAN groupings

Geographic area	Number of samples	Mantel r	p
Malltraeth	10	0.1567	0.1730 NS
Gwent	49	0.3201	0.0113
Somerset	167	0.2831	0.0001
Arun	20	0.0275	0.4461 NS
Pevensey	45	0.2808	0.0010
Walland	45	0.2110	0.0007
Thames and Essex	108	0.2476	0.0001
Suffolk	27	0.0625	0.2573 NS
Norfolk	75	0.2505	0.0007

Tables 3.3, 3.5 and 3.9 (groups by geographic area) showed a strong effect of distribution on all three invertebrate classifications. The bottom line of each table indicates areas that have the closest distribution of groups. There was only small agreement in the three tables, suggesting that beetle and mollusc assemblages behaved differently, and that the amalgam of all taxa may have been a complex artefact. Recurring patterns were the similarity of:

- Gwent and Somerset for beetles and molluscs but surprisingly not with 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 surprisingly not with 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.

4.3 Conclusions

At a national scale, beetle and mollusc assemblages did not appear to follow similar trends, as indicated by the different way in which TWINSPAN divided the samples. For beetles, the divisions tended to be moderately even dichotomies whereas for molluscs small groups tended to be split off one at a time. Similarities at the national scale were the same initial response to salinity and indications that hydrosere may have been important once the confounding factor of geographic location was accounted for. At local scale, the Mantel test showed greater similarity in the grouping of beetles and molluscs, which suggested that they responded to similar underlying ecological factors. One problem in making this comparison was the large difference in overall species-richness and ecologies of the two groups which gave opportunities for beetles to show more variation in their response to habitat variation. Molluscs also appear to be represented far more consistently by the same suite of common species in many types of ditch than are beetles. Therefore, despite the results of the Mantel test, it was felt unlikely that the two groups responded similarly beyond the gross differences caused by salinity and inhospitable conditions of late stage ditches.

5 Key environmental drivers influencing assemblages

5.1 Geographical areas analysed

Classification showed that geographical location had a strong influence on the assemblages of all taxa and on beetles and molluscs taken separately. Apart from the overriding importance of salinity, no environmental variable was consistently more important than geographical location in determining the major divisions of the classification. It was therefore necessary to examine assemblages at a local level to determine which environmental factors had the greatest influence on assemblage structure.

The national classification also 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 North Kent, 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 area alone. 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 as they each had rather few samples.

For four of the areas, the species metrics (species richness, species conservation score, habitat quality score, naturalness) were plotted on the RDA ordination plot after grouping them into quartiles, or actual score for naturalness which showed too little spread of values to get meaningful quartiles. Trends inferred from the environmental variables were related to the characteristics of the samples. For these four areas, a TWINSPAN analysis was run and the end-groups similarly shown on the RDA ordination plot, and the species composition of each group then related to the environmental trends.

5.2 Gwent Levels

The dataset was reduced from 161 to the 92 species present in at least five samples and a total of 50 samples. The gradient length of the first DCA axis was 2.53. The reduced set of variables is given in Table 3.14, which also shows the ten that were significant in the RDA analysis and five that were selected by BVSTEP. Figure 3.11 shows a PCA of these 29 variables to show the strong correlation between many of them. The first two PCA axes explained 38% of the variation in these variables, and the first few axes were highly significant (the scaled eigenvalues were far higher than the ‘broken stick’ test values).

RDA forward selection found ten significant variables (Table 3.14, Figure 3.12). BVSTEP also selected three of these and another two (litter, depth) that were non-significant in RDA. Of these two extra variables, depth was correlated with width, which RDA selected.

The first two axes of the final RDA using only these ten significant variables explained 44.1% of the variation in the invertebrate data (Table 3.13). The first axis followed a trend from wider, more open ditches to their opposite condition. Open water was strongly negatively correlated with the cover of floating Lemna and less so with over of emergents so there was also a possible trend with just Lemna cover, independent of ditch size. Although cover of floating aquatics was selected as a significant variable, the DAFOR values were invariably low and these plants were often absent, so it was thought to be less important than these results suggested. The second RDA axis had a trend following the effects due mainly to cattle – the amount of grazing, tall grass and grassy margins. Presumably the trend with pH along axis 2 was unrelated to the effects due to cattle. Although soil was selected as significant, only four of the 51 ditches were on peat and the analysis over-emphasised its importance.

Table 3.13 Eigenvalues for RDA of Gwent Levels

Axis	Eigenvalue	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.095	31.1	31.1
2	0.040	13.1	44.1

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, F - F-statistic for this increase, p- probability due to chance , column 5 - Eigenvalue using one explanatory variable, column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at p<0.05. * = selected as the four best using BVSTEP.

Table 3.14 Variables used in RDA for Gwent

Variable	Increased in explained variation	F	P	Eigenvalue using one variable	% of all eigenvalues using only one variable	Variable description
S_gmarg*	0.08	3.918	0.001	0.08	11.24	Grassy margin
V_opwat*	0.05	2.638	0.001	0.06	9.01	Open water
V_flaqu	0.04	2.040	0.001	0.06	9.07	Floating aquatics
D_soil	0.04	2.051	0.001	0.05	7.16	Soil type
D_profi	0.03	1.731	0.005	0.04	6.28	Margin profile
D_width	0.03	1.649	0.016	0.04	5.99	Water width
S_graz	0.02	1.395	0.044	0.04	6.18	Grazing
B_talgr	0.02	1.460	0.025	0.04	6.66	Tall grass
D_pH	0.02	1.357	0.049	0.03	4.05	pH (spring)
L_cattl*	0.02	1.409	0.037	0.03	4.27	Cattle-grazed
V_subal	0.02	1.345	0.056	0.04	6.69	Submerged algae
V_mat	0.02	1.325	0.069	0.03	4.72	Floating mat
M_level	0.02	1.121	0.254	0.03	5.05	Level up/down
D_turb	0.02	1.133	0.249	0.03	4.00	Turbidity
S_block	0.02	1.126	0.286	0.03	4.40	Block formation
D_cond2	0.02	1.126	0.273	0.02	3.40	Conductivity
V_litt*	0.02	1.069	0.346	0.03	4.32	Litter
V_subaq	0.02	1.112	0.303	0.06	9.49	Submerged plants
L_impr	0.02	1.116	0.284	0.02	2.76	Improved grass
M_year	0.02	1.064	0.404	0.03	5.12	Last cleared
D_freeb	0.02	0.974	0.534	0.03	3.95	Freeboard
S_shelf	0.02	1.044	0.407	0.05	7.37	Shelf formation
D_depth*	0.02	1.028	0.428	0.05	8.06	Water depth
B_herb	0.01	0.904	0.614	0.03	4.80	Tall herbs
V_emerg	0.02	0.997	0.485	0.03	4.82	Emergent
D_pH_1	0.01	0.932	0.559	0.05	6.79	pH (summer)
D_silt	0.01	0.875	0.636	0.03	4.58	Silt depth
V_lemna	0.01	0.865	0.684	0.04	6.63	Floating Lemna
L_route	0.01	0.696	0.856	0.02	3.36	Road, track

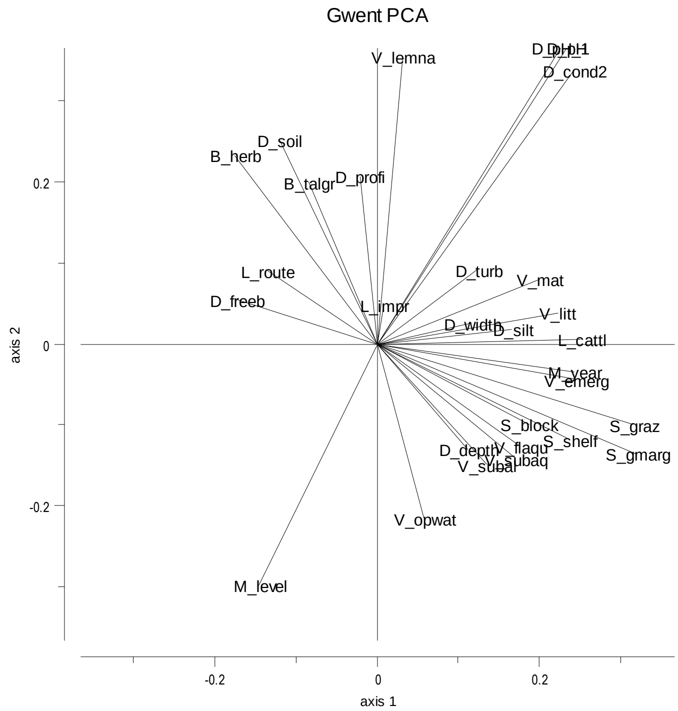


Figure 3.11 PCA of Gwent Levels showing 29 variables with some importance

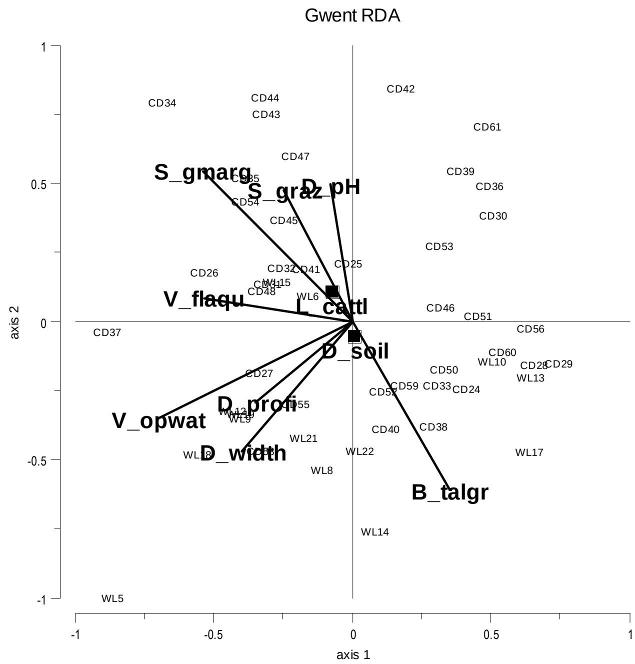


Figure 3.12 RDA ordinations of significant variables for the Gwent Levels

5.3 Somerset and Avon Moors and Levels

The reduced dataset contained 149 species in 171 samples (70.5% zero cells), with the exclusion of 68 species. The length of the gradient of the first DCA axis was 2.10. After VIF analysis and excluding strongly correlated variables in pairplots, 32 variables were used in the following analysis (Table 3.16). A PCA of these variables showed that there was still much correlation between some of them (Figure 3.13). Forward selection of these variables in RDA indicated that nine were non-significant; another two on the borderline of significance ($p \approx 0.05$) were also regarded as unimportant as they did not directly impact on aquatic invertebrates. Four of these were selected as the most important in BVSTEP.

In the final RDA using 20 variables, the first two axes explained 41.3% of the variation in the invertebrate data (Table 3.15). With so many variables regarded as significant, it was difficult to discern much pattern in the ordination. Axis 1 was related to hydroseral stage, shown by open water and wider ditches at the opposite end of this axis to litter (which was strongly correlated with cover of emergents). Chemistry also contributed to the trend on the first axis, with the open or early stage ditches were having higher pH (both spring and summer values) and lower conductivity.

Axis 2 was influenced strongly by soil type (1=clay, 0=peat), as also indicated by silt depth since a high value for 'silt' was invariably recorded on the soft-bottomed peat ditches. Ditches on clay (mainly from Pawlett Hams, Kenn & Nailsea and those selected on clay outside the SSSIs) were clearly associated with the far end of axis 2. The large freeboard associated with clay ditches may be just a function of the ease with which water levels can be raised in peat soils compared to clay or alluvium, perhaps due to peat shrinkage in the last few decades.

The cover of floating *Lemna* (and its obverse of open water and greater submerged vegetation) formed a clear diagonal across the ordination, and this suggested that there may be an effect due to *Lemna* that was independent of hydroseral stage. Variables that had surprisingly little influence on the ordination were water depth, all of the structural features of the water margin (grazing, poaching, tangledness, grassy margin) and most of the aquatic vegetation variables. The absence of emergents and time since last cleaned as important variables was due to their close correlation with litter.

Species Richness, Species Conservation Status (SCS) Score and Habitat Quality (HQ) Score (see Section 6 in Volume 1) were quite evenly spread across the RDA ordination with the exception of the lower left quadrant which had low values, and corresponded to late-stage ditches on clay with much *Lemna* cover (Figure 3.15). It seemed quite probable that *Lemna* cover alone was responsible for depressing the species metrics in this section of the ordination. Low values were also found at the exteme left side, which corresponded to high covers of leaf litter found in shallow late-stage ditches. Consistently high values were found in the top right quadrant that corresponded with the trend to earlier hydroseral stage ditches on peat. Naturalness Scores (see Volume 1, Section 6) were similar in most ditches owing to the widespread occurrence of one species, *Crangonyx pseudogracilis*. Ditches with higher scores (more non-native species) were as likely to be in the 'better' ditches as elsewhere, and these few non-natives avoided the poorer ditches (bottom left) as much as the native species.

TWINSPAN was run using the short species list that included species occurring in at least five samples, abundance data (three cut-levels) and no weighting. Three very clear groups were recognised but the subdivisions of each of these were not distinct in the RDA ordination space (Figure 3.16). The first division was clearly related to hydroseral stage that was identified as the main trend along the first axis. All the beetles preferring the 'older' ditches are typical of shallow densely vegetated ditches (Table 3.17), although also included here was the snail *Bathyomphalus contortus*, which is not usually associated with such conditions. A large proportion of the species preferring the earlier stage or at least more open ditches have a known requirement for more open conditions. Among the more surprising inclusions in the 'newer' group A ditches was the very common snail *Radix balthica*.

In terms of the species preferences, the basis of the division of the large group A earlier stage ditches was far from clear, despite the clear separation on the RDA ordination. Group A1, occupying the lower part of the plot, included a mix of species preferring open conditions (for example the beetles *Haliplus* spp, *Graptodytes pictus*, and *Laccophilus minutus* and the mayfly *Caenis robusta*, and another suite preferring well vegetated shallow margins, for example, the beetles *Helophorus* spp, *Hydroporus palustris* and the water measurer *Hydrometra stagnorum*. A similar mixture of species' preferences was found in the A2 group. Soil type may have played a part since not only was group A1 in the lower part with mineral soils but many of the sites in this group were from clay ditches on Pawlett Hams and the Kenn Moor complex, although soil type in itself would not account for the split in these predominantly common and widespread species. The unclear ecological basis for the split may explain why the RDA ordination produced rather unclear trends apart from that related to hydrological succession.

Table 3.15 Eigenvalues for RDA of Somerset and Avon Moors and Levels

Axis	Eigenvalue	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.060	26.01	26.01
2	0.035	15.29	41.30
	Sum of all canonical eigenvalues: 0.23		

Table 3.16 Variables used in RDA for Somerset and Avon Moors and Levels

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, of a total eigenvalue of 0.23; F - F-statistic for this increase; p- probability due to chance; column 5 - Eigenvalue using one explanatory variable; column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at p<0.05. * = selected as the four best using BVSTEP.

Variable	**Increased in explained variation**	**F**	**p**	**Eigenvalue using one variable**	**% of all eigenvalues using one variable**	**Variable description**
V_opwat*	0.04	6.366	0.001	0.04	12.32	Open water
D_soil*	0.02	4.187	0.001	0.02	7.9	Soil type
V_litt	0.02	3.023	0.001	0.03	8.64	Litter
V_mat	0.02	2.952	0.001	0.02	7.47	Floating mat
L_impr	0.01	2.215	0.001	0.02	7.59	Improved grass
V_flaqu	0.01	2.154	0.001	0.01	4.23	Floating aquatics
L_unimp	0.01	1.833	0.001	0.02	5.66	Unimproved
D_cond2	0.01	1.812	0.001	0.01	3.55	Conductivity
V_subaq	0.01	1.83	0.001	0.02	5.48	Submerged plants
D_width	0.01	1.794	0.001	0.02	5.21	Water width
D_pH_1	0.01	1.644	0.001	0.02	6.61	pH (summer)
D_silt	0.01	1.6	0.001	0.01	5.07	Silt depth
D_freeb*	0.01	1.562	0.001	0.02	6.36	Freeboard
B_shorg	0.01	1.442	0.004	0.01	3.65	Short grass
L_cattl	0.01	1.406	0.007	0.01	3.68	Cattle-grazed
D_turb	0.01	1.401	0.005	0.01	3.7	Turbidity
D_pH*	0.01	1.436	0.004	0.02	5.91	pH (spring)
V_lemna	0.01	1.429	0.008	0.02	8.09	Floating Lemna
V_subal	0.01	1.417	0.007	0.01	3.87	Submerged algae
D_profi	0.01	1.406	0.005	0.02	5.1	Margin profile
L_hay	0.01	1.436	0.004	0.01	2.74	Hay/Silage
B_herb	0.01	1.247	0.049	0.01	2.72	Tall herbs
M_year	0.01	1.232	0.055	0.03	10.61	Last cleared
S_gmarg	0.01	1.1	0.221	0.01	3.4	Grassy margin
S_poach	0.01	1.135	0.173	0.01	3.26	Poaching
D_depth	0.01	0.994	0.485	0.01	4.92	Water depth
S_graz	0.01	0.991	0.501	0.01	3.44	Grazing
V_exmud	0	0.981	0.495	0.01	2.83	Exposed mud
S_tangl	0	0.907	0.738	0.01	5.04	Tangled
B_bare	0	0.887	0.771	0.01	2.49	Bare ground
L_spoil	0	0.823	0.914	0.01	5.09	Spoil on bank
V_emerg	0	0.69	0.989	0.02	5.96	Emergents

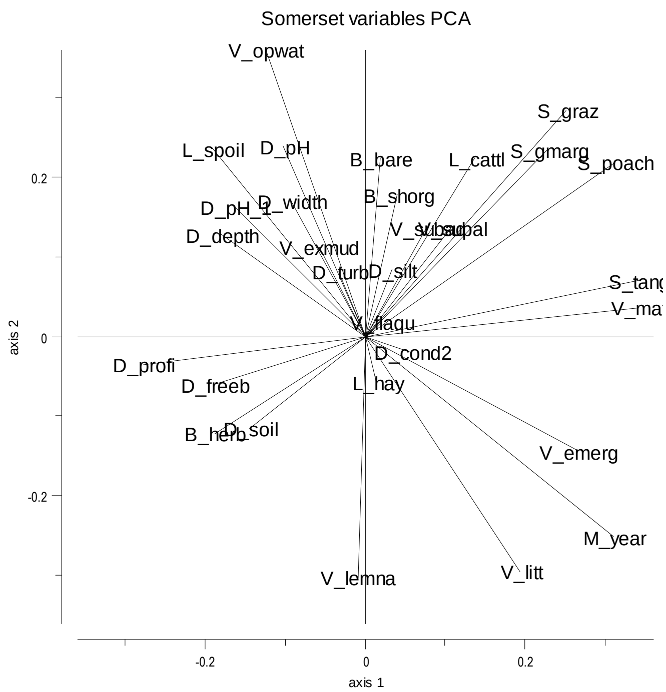


Figure 3.13 PCA of Somerset and Avon Moors and Levels showing 32 variables with some importance

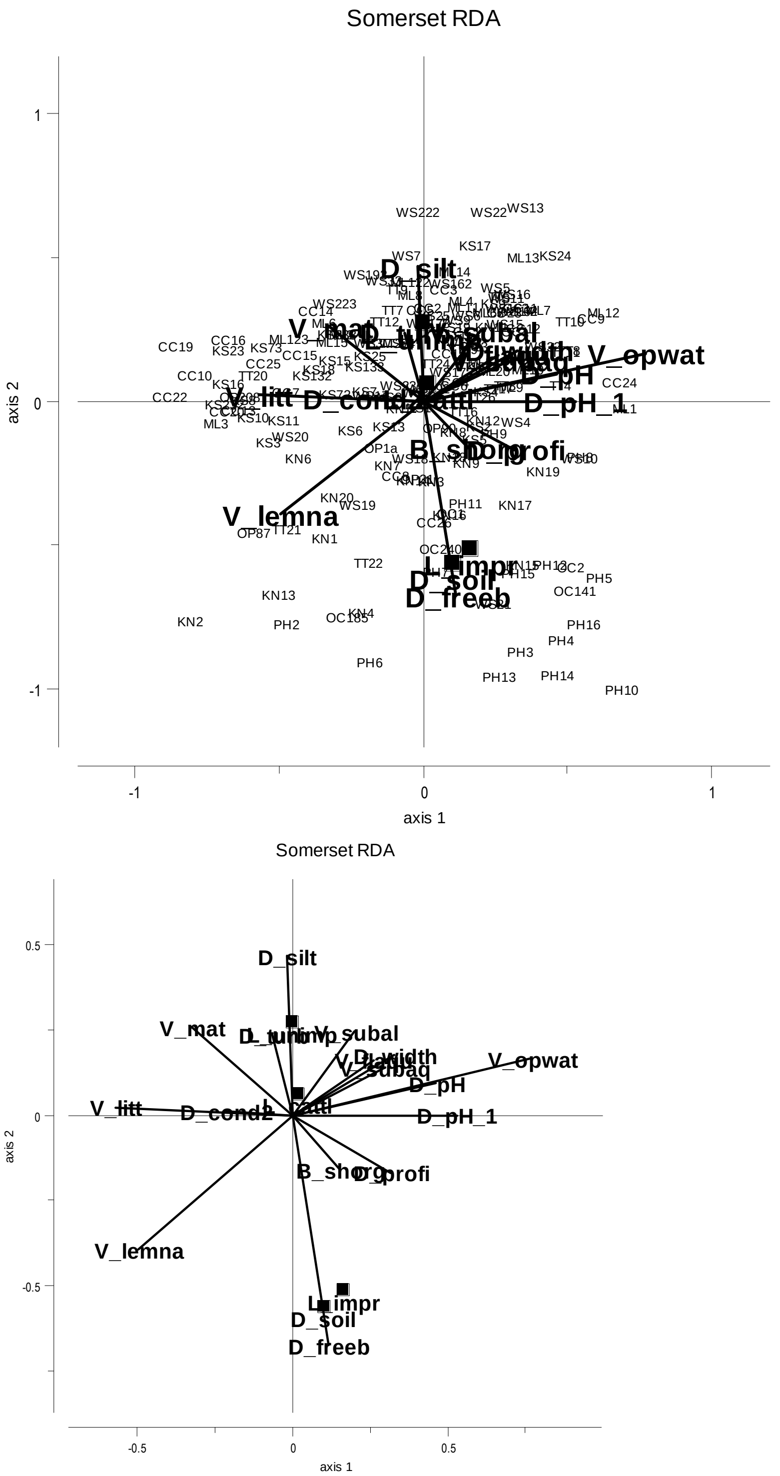


Figure 3.14 RDA ordinations of significant variables for Somerset Moors and Levels

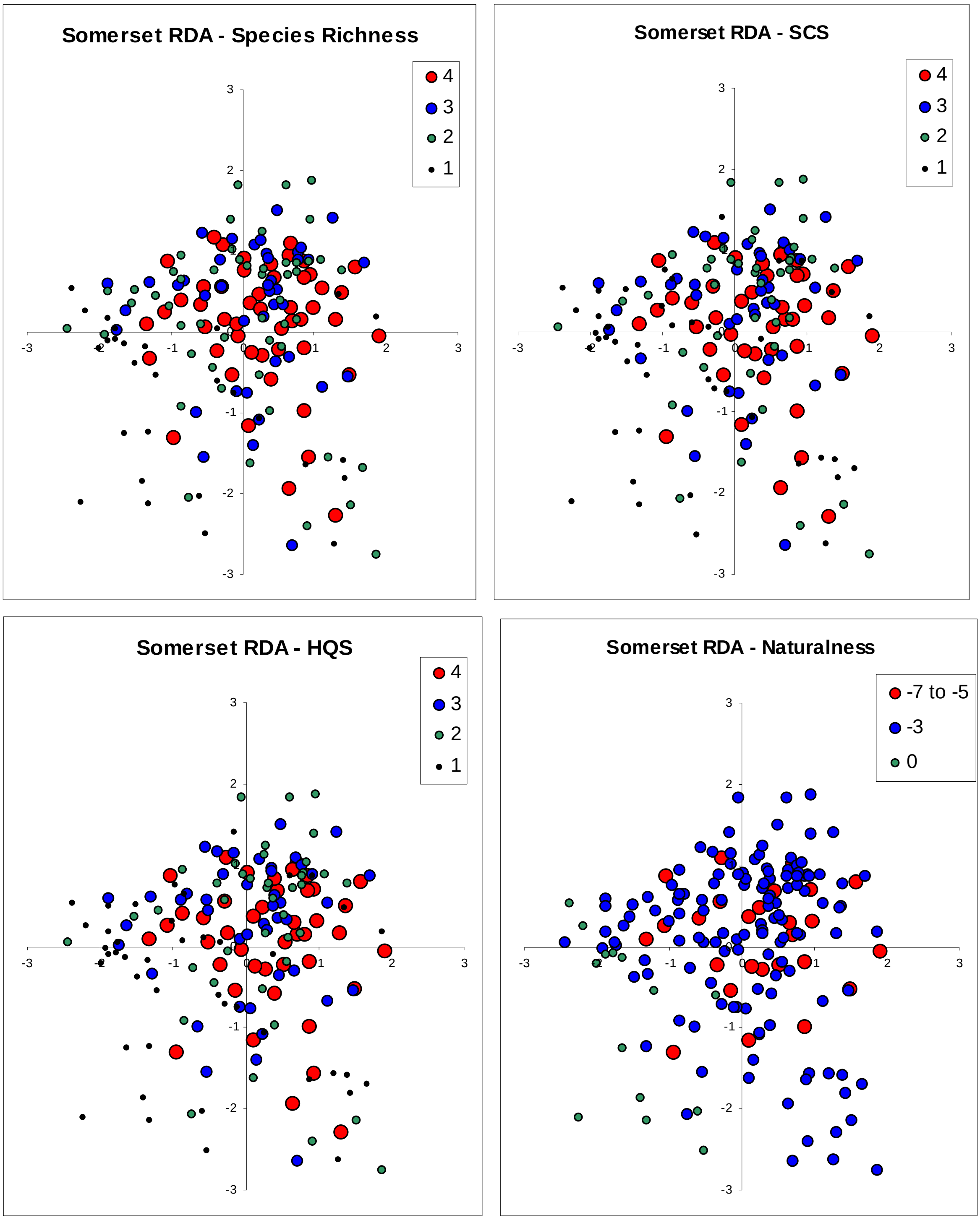


Figure 3.15 Species metrics plotted on the RDA ordination for Somerset and Avon Moors and Levels

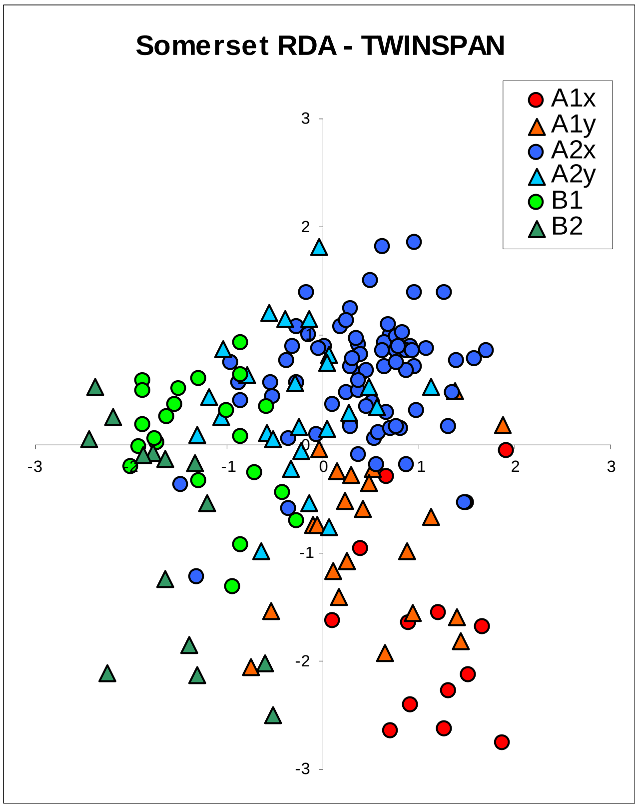


Figure 3.16 TWINSPAN groups plotted on the RDA ordination for Somerset and Avon moors and Levels

Table 3.17 Species preferring either of the groups in the first three TWINSPAN divisons for Somerset ditches (ordered as output by TWINSPAN)

First division of Group A	Abund.	Bias	Group B	Abund.	Bias
Graptodytes pictus	1	(30,3)	*Anacaena globulus*	1	(12,10)
Haliplus lineatocollis	1	(45,3)	*Cercyon tristis*	1	(4,10)
Haliplus ruficollis	1	(110,12)	*Coelostoma orbiculare*	1	(19,14)
Helochares lividus	1	(35,4)	*Cymbiodyta marginellus*	1	(18,21)
Hydrophilus piceus	1	(56,5)	*Hydroporus incognitus*	1	(7,9)
Hyphydrus ovatus	1	(73,3)	*Liopterus haemorrhoidalis*	1	(27,15)
Limnoxenus niger	1	(62,5)	*Rhantus grapii*	1	(40,22)
Peltodytes caesus	1	(35,0)	*Hydroporus angustatus*	2	(4,8)
Odontomyia ornata	1	(71,7)	*Asellus aquaticus*	2	(28,32)
Caenis robusta	1	(90,6)	*Bathyomphalus contortus*	2	(23,14)
Cloeon dipterum	1	(103,1)	*Hippeutis complanatus*	2	(7,9)
Gerris odontogaster	1	(41,1)	*Pisidium*	2	(13,8)
Hesperocorixa linnaei	1	(93,4)	*Asellus aquaticus*	3	(3,13)
Ilyocoris cimicoides	1	(122,6)	*Bathyomphalus contortus*	3	(0,8)
Notonecta glauca	1	(61,4)			
Plea minutissima	1	(80,0)			
Ischnura elegans	1	(56,4)			
Triaenodes bicolor	1	(63,0)			
Gyraulus crista	1	(57,7)			
Lymnaea stagnalis	1	(91,6)			
Musculium lacustre	1	(53,4)			

Planorbis carinatus	1	(59,2)
Radix balthica	1	(122,11)
Theromyzon tessulatum	1	(29,1)
Noterus clavicornis	2	(41,0)
Anisus vortex	2	(40,4)
Radix balthica	2	(29,0)

Second division of Group A

Group A1	**Abund.**	**Bias**	**Group A2**	**Abund.**	**Bias**
Anacaena bipustulata	1	(11,8)	*Anacaena lutescens*	1	(6,85)
Anacaena globulus	1	(11,1)	*Dryops luridus*	1	(10,63)
Graptodytes pictus	1	(24,6)	*Hydrophilus piceus*	1	(7,49)
Gyrinus substriatus	1	(10,11)	*Hydroporus striola*	1	(0,33)
Haliplus flavicollis	1	(8,5)	*Rhantus grapii*	1	(5,35)
Haliplus immaculatus	1	(9,11)	*Limnephilus marmoratus/ flavicornis*	1	(6,44)
Haliplus lineatocollis	1	(26,19)	*Gyraulus albus*	1	(3,21)
Haliplus sibiricus	1	(8,3)	*Physella acuta*	1	(2,21)
Helophorus grandis	1	(8,4)	*Valvata cristata*	1	(6,49)
Hydroporus palustris	1	(30,39)	*Erpobdella testacea*	1	(2,23)
Laccobius bipunctatus	1	(23,23)	*Anacaena lutescens*	2	(1,51)
Laccophilus minutus	1	(12,14)	*Hydroporus pubescens*	2	(4,70)
Ochthebius dilatatus	1	(12,14)	*Microvelia reticulata*	2	(6,32)
Porhydrus lineatus	1	(12,4)	*Crangonyx pseudogracilis*	2	(4,37)
Hydrometra stagnorum	1	(15,12)	*Asellus aquaticus*	2	(4,24)
Physa fontinalis	1	(11,14)	*Lymnaea palustris*	2	(1,21)
Helophorus aequalis	2	(10,7)			
Helophorus brevipalpis	2	(15,9)			
Hydroporus palustris	2	(13,3)			
Caenis robusta	2	(8,5)			

Third division of Group A1

Group A1x	**Abund.**	**Bias**	**Group A1y**	**Abund.**	**Bias**
Agabus nebulosus	1	(3,0)	*Agabus bipustulatus*	1	(2,8)
Berosus affinis	1	(5,0)	*Anacaena lutescens*	1	(1,5)
Graptodytes pictus	1	(14,10)	*Hydaticus transversalis*	1	(3,11)
Gyrinus substriatus	1	(7,3)	*Laccophilus hyalinus*	1	(0,6)
Haliplus immaculatus	1	(5,4)	*Rhantus grapii*	1	(0,5)
Helophorus minutus	1	(5,4)	*Anopheles atroparvus*	1	(1,6)
Helophorus obscurus	1	(4,3)	*Aeshna*	1	(1,5)
Laccobius colon	1	(6,1)	*Sympetrum*	1	(1,7)
Limnoxenus niger	1	(13,7)	*Crangonyx pseudogracilis*	1	(4,23)
Porhydrus lineatus	1	(9,3)	*Bathyomphalus contortus*	1	(0,20)
Gerris odontogaster	1	(6,1)	*Hippeutis complanatus*	1	(3,13)
Ranatra linearis	1	(4,3)	*Lymnaea palustris*	1	(2,19)
Gyraulus crista	1	(8,4)	*Lymnaea stagnalis*	1	(2,15)
Glossiphonia heteroclita	1	(6,2)	*Pisidium*	1	(2,15)
Theromyzon tessulatum	1	(6,3)	*Planorbarius corneus*	1	(1,20)
Graptodytes pictus	2	(4,1)	*Sphaerium corneum*	1	(0,13)
Haliplus ruficollis	2	(5,4)	*Valvata cristata*	1	(1,5)
Hydroporus planus	2	(13,7)	*Valvata piscinalis*	1	(0,7)
Hydroporus tessellatus	2	(3,0)	*Helophorus aequalis*	2	(1,9)
Noterus clavicornis	2	(10,5)	*Coenagrion*	2	(0,5)
Plea minutissima	2	(3,2)	*Bathyomphalus contortus*	2	(0,9)
Bithynia leachii	2	(4,3)	*Lymnaea stagnalis*	2	(0,6)
Bithynia leachii	3	(3,1)	*Planorbis planorbis*	2	(1,11)

Third division of Group A2					
Group A2x	**Abund.**	**Bias**	**Group A2y**	**Abund.**	**Bias**
Hyphydrus ovatus	1	(39,6)	*Agabus sturmii*	1	(7,7)
Gerris odontogaster	1	(32,2)	*Colymbetes fuscus*	1	(3,10)
Notonecta glauca	1	(37,6)	*Cymbiodyta marginellus*	1	(5,9)
Ranatra linearis	1	(15,0)	*Haliplus lineatocollis*	1	(10,9)
Gyraulus albus	1	(19,2)	*Helophorus aequalis*	1	(18,17)
Planorbis carinatus	1	(46,2)	*Helophorus obscurus*	1	(7,8)
Microvelia reticulata	2	(28,4)	*Hydrobius fuscipes*	1	(13,9)
Hydroporus pubescens	3	(17,2)	*Ilybius quadriguttatus*	1	(10,7)
			Liopterus haemorrhoidalis	1	(11,11)
			Ochthebius dilatatus	1	(6,8)
			Ochthebius minimus	1	(3,9)
			Rhantus grapii	1	(15,20)
			Rhantus suturalis	1	(3,7)
			Dixella autumnalis	1	(4,6)
			Aeshna	1	(10,8)
			Brachytron pratense	1	(8,11)
			Acroloxus lacustris	1	(3,6)
			Anacaena limbata	2	(21,15)
			Helophorus aequalis	2	(1,6)
			Coenagrion	2	(10,10)
			Crangonyx pseudogracilis	2	(21,16)
			Asellus aquaticus	2	(10,14)
			Bathyomphalus contortus	2	(6,8)
			Lymnaea palustris	2	(10,11)
			Pisidium	2	(5,6)
			Radix balthica	2	(11,10)

5.4 Pevensey Levels

The full dataset of 168 species in 45 samples, with 69.7% zero cells was reduced to 105 species and 54.4% zero cells by excluding species occurring in fewer than five samples. The length of the gradient of the first DCA axis was 2.13. The reduced set of variables is given in Table 3.19 which shows the seven that were significant in the RDA analysis. Figure 3.17 give a PCA of these 27 variables to show the strong correlation between many of them.

RDA forward selection selected seven significant variables (Table 3.19, Figure 3.18). Three of these were also selected by BVSTEP. The trend along axis 1 was related primarily to the openness of ditches and the amount of leaf litter, which, as can be seen from the PCA plot, was correlated with steep-banked ditches and those thought to be recently cleaned. The second axis showed two trends. One was associated with the effects of cattle on the margin represented in the RDA by the amount of poaching, but correlated with the amount of bare soil and short grass on the bank. The second trend was related to the amount of vegetation, represented in the RDA by mat-forming vegetation which was correlated with tangledness and the cover of submerged and floating aquatic plants. The trend along the diagonal on this plot was with emergent vegetation which was a link between the two principal trends along the two axes; the depth of silt (a measure of time since cleaning) and leaf litter were clearly related to the cover of emergents.

Table 3.18 Eigenvalues for RDA of Pevensey Levels

Axis	Eigenvalue	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.083	31.06	31.06
2	0.054	20.26	51.32

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, of a total eigenvalue of 0.66; F - F-statistic for this increase; p- probability due to chance; column 5 -

Eigenvalue using one explanatory variable; column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at p<0.05. * = selected as the six best using BVSTEP.

Table 3.19 Variables used in RDA for Pevensey Levels

Variable	Increased in explained variation	F	p	Eigenvalue using one variable	% of all eigenvalues using one variable	Variable description
V_opwat*	0.08	3.532	0.001	0.08	11.46	Open water
V_mat	0.04	2.044	0.001	0.04	6.15	Floating mat
V_emerg*	0.03	1.624	0.004	0.05	7.23	Emergents
D_freeb	0.03	1.504	0.015	0.03	4.71	Freeboard
D_silt	0.03	1.496	0.016	0.03	4.62	Silt depth
S_poach	0.03	1.482	0.009	0.04	6.41	Poaching
V_litt*	0.03	1.355	0.034	0.04	6.5	Litter
L_cattl	0.02	1.17	0.159	0.02	3.66	Cattle-grazed
V_subaq	0.02	1.198	0.162	0.04	5.46	Submerged plants
D_color	0.02	1.185	0.187	0.02	3.41	Water colour
D_turb	0.02	1.195	0.146	0.02	3.68	Turbidity
V_flalg*	0.02	1.157	0.221	0.02	3.37	Floating algae
B_bare	0.02	1.132	0.245	0.02	3.52	Bare ground
D_pH	0.02	1.11	0.28	0.02	3.76	pH (spring)
V_flaqu	0.02	1.091	0.308	0.04	5.66	Floating aquatics
D_pH_1*	0.02	1.035	0.396	0.04	5.9	pH (summer)
V_lemna	0.02	1.007	0.464	0.03	4.28	Floating Lemna
V_exmud*	0.02	1.012	0.456	0.02	3.62	Exposed mud
D_cond2	0.02	0.968	0.51	0.02	2.47	Conductivity
M_year	0.02	0.991	0.473	0.06	9.23	Last cleared
L_sheep	0.02	0.961	0.537	0.02	3.23	Sheep-grazed
B_herb	0.02	0.931	0.563	0.03	4.24	Tall herbs
D_profi	0.02	0.893	0.629	0.03	4.18	Margin profile
S_tangl	0.02	1.05	0.382	0.04	6.45	Tangled
B_shorg	0.02	0.914	0.561	0.02	3.32	Short grass
D_width	0.02	0.8	0.726	0.02	3.61	Water width
D_slope	0.01	0.629	0.87	0.04	5.54	Slope bank

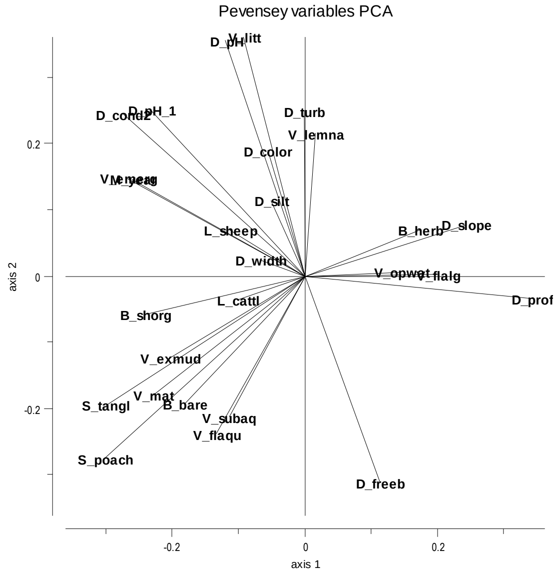


Figure 3.17 PCA for Pevensey Levels showing 27 variables with some importance

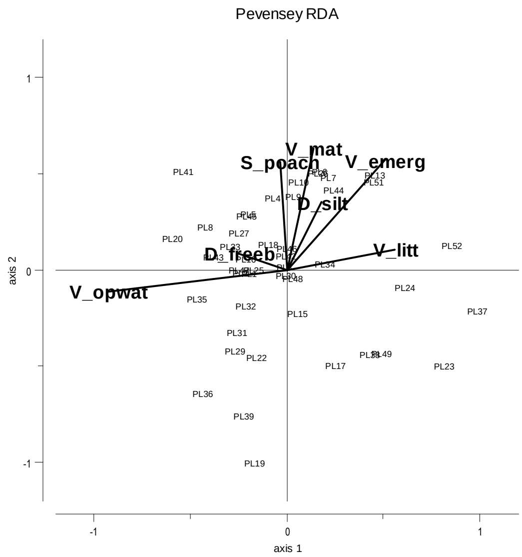


Figure 3.18 RDA ordinations of significant variables for Pevensey Levels

5.5 Walland Marsh

The 179 species recorded was reduced to 111 species (62.6% zero cells) in 45 samples. The gradient length of the first DCA axis was 1.81. The reduced set of variables is given in Table 3.21, which also shows the seven that were significant in the RDA analysis. Figure 3.19 gives a PCA of these 25 variables to show the strong correlation between many of them.

RDA forward selection selected seven significant variables (Table 3.21, Figure 3.20). Three of these were also selected by BVSTEP. The trend along axis 1 was interpreted as relating to hydroseral stage, with litter and water depth acting as surrogates for a suite of closely correlated variables (cover of emergents and time since last cleaned at one end; open water and greater width at the other; Figure 3.19). Tangledness was also greater in what, in this interpretation, were more open or more recently cleaned ditches. Depth of silt and the underwater profile at the margin appeared to be much less important although both followed the trend along axis 1. Although the amount of open water was given low significance in the RDA forward selection, it was one of the more important vegetation variables when considered in isolation (Table 3.21, far right columns) and was selected in BVSTEP among the four best variables explaining variation in the invertebrates.

Water chemistry was clearly important along axis 2, although conductivity and the summer pH values were moderately correlated, so it is likely that salinity was the main factor to which the invertebrates responded.

Species-richness showed no obvious trend with the ordination except for a reduction in ditches interpreted as being late in the succession (Figure 3.21). Species conservation and habitat quality scores were more consistently high on the lower right of the ordination where the trend appeared to be for more tangled, deeper and fresher ditches. Naturalness score was markedly high (more non-natives) only in a few ditches that were probably more brackish than most, and they included some that were rich in species and with high conservation scores. It appeared that old, shallow brackish ditches may have had least interest overall.

TWINSPAN was run using the reduced species dataset with species present in at least 5 samples, abundance data and no weighting. Only the first two divisions, and just three groups, were thought to be real, and they were not particularly well separated on the RDA ordination (Figure 3.22). The first division split late stage and possibly brackish ditches from earlier stage or larger ditches. The suite of species forming Group B were characteristic of shallow ditches, for example the snails *Aplexa hypnorum* and *Anisus leucostoma*, and often those that may dry out or have dense grassy margins, for example, the beetles *Colymbetes fuscus* and *Liopterus haemorrhoidalis*, although few species in this group showed particularly strong affinity to it (Table 3.22). The infrequency of obligate halophiles (e.g. the prawn *Palaemonetes varians* and *Gammarus* spp) was partly due to few being recorded so they were excluded in the reduced species dataset used in this analysis. However, group B ditches did appear to partly follow the RDA trend for brackishness.

The Group A ditches included species with a wide range of ecologies, and its division almost certainly reflected a response to hydroseral succession, and agreed with the trend indicated by the environmental variables. Group A1 ditches had more species known to prefer a clearer water column or open water surface, for example, the beetles *Gyrinus marinus*, *G. substriatus*, *Haliplus* spp. and *Hydrophilus piceus*, the bugs *Corixa punctata*, *Sigara dorsalis* and *Ranatra linearis*, and the mayfly *Caenis robusta*. Group A2 included more species known to prefer more densely vegetated shallow water, for example, the beetles *Agabus sturmii*, *Cymbiodyta marginella*, *Enochrus coarctatus*, *Liopterus haemorrhoidalis* and the leech *Helobdella stagnalis*.

Comparing the position of these groups on the RDA ordination, group A1 was seen to overlap with those with high species conservation scores on the right, which had been interpreted as 'newer' ditches, and A2 was more associated with the 'older' ditches on the left. Group B tended to occupy the region of low species-richness and conservation score but with higher conductivity.

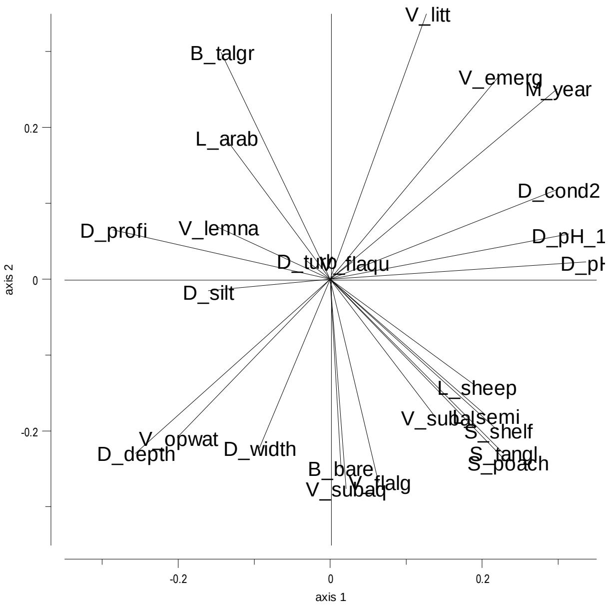


Figure 3.19 PCA for Walland Marsh showing 25 variables with some importance

Table 3.20 Eigenvalues for RDA of Walland Marsh

Axis	Eigenvalue	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.089	13.56	13.56
2	0.074	11.36	24.92

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, of a total eigenvalue of 0.651; F - F-statistic for this increase; p- probability due to chance; column 5 - Eigenvalue using one explanatory variable; column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at $p<0.05$. * = selected as the four best using BVSTEP.

Table 3.21 Variables used in RDA for Walland Marsh

Variable	Increased in explained variation	F	p	Eigenvalue using one variable	% of all eigenvalues using one variable	Variable description
V_litt*	0.07	3.017	0.001	0.07	10.07	Litter
D_cond2*	0.06	2.934	0.001	0.06	9.37	Conductivity
D_depth	0.05	2.52	0.001	0.06	8.62	Water depth
S_tangl	0.04	1.944	0.001	0.05	8.02	Tangled
D_pH_1*	0.03	1.504	0.006	0.05	7.31	pH (summer)
D_silt	0.03	1.344	0.045	0.04	5.39	Silt depth
D_profi	0.03	1.351	0.041	0.03	5.15	Margin profile
L_semi	0.02	1.286	0.069	0.03	4.45	Semi-improved
V_subal	0.02	1.287	0.071	0.03	4.4	Submerged algae
S_shelf	0.02	1.257	0.116	0.03	4.97	Shelf formation
L_sheep	0.02	1.217	0.138	0.02	3.47	Sheep-grazed
L_arab	0.02	1.247	0.127	0.03	4.15	Arable
B_bare	0.02	1.199	0.163	0.04	6.32	Bare ground
V_flaqu	0.02	1.12	0.276	0.03	4.63	Floating aquatics
D_pH	0.02	1.122	0.28	0.02	3.29	pH (spring)
S_poach	0.02	1.066	0.36	0.04	6.21	Poaching
B_talgr	0.02	1.156	0.257	0.05	7.19	Tall grass/reed
M_year	0.02	1.114	0.298	0.04	6.62	Last cleared
V_emerg	0.02	1.076	0.337	0.06	8.75	Emergents
D_width	0.02	1.01	0.458	0.04	6.76	Water width
D_turb	0.02	0.962	0.517	0.02	3.81	Turbidity
V_lemna	0.02	0.933	0.55	0.03	4.5	Floating Lemna
V_flalg	0.01	0.814	0.739	0.03	3.96	Floating algae
V_opwat*	0.02	0.886	0.652	0.05	7.58	Open water
V_subaq	0.01	0.742	0.8	0.03	5	Submerged plants

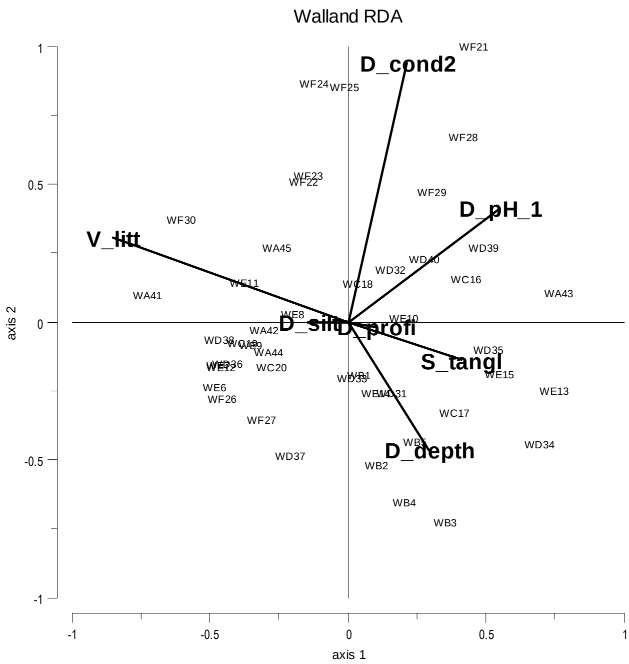


Figure 3.20 RDA ordinations of significant variables for Walland Marsh

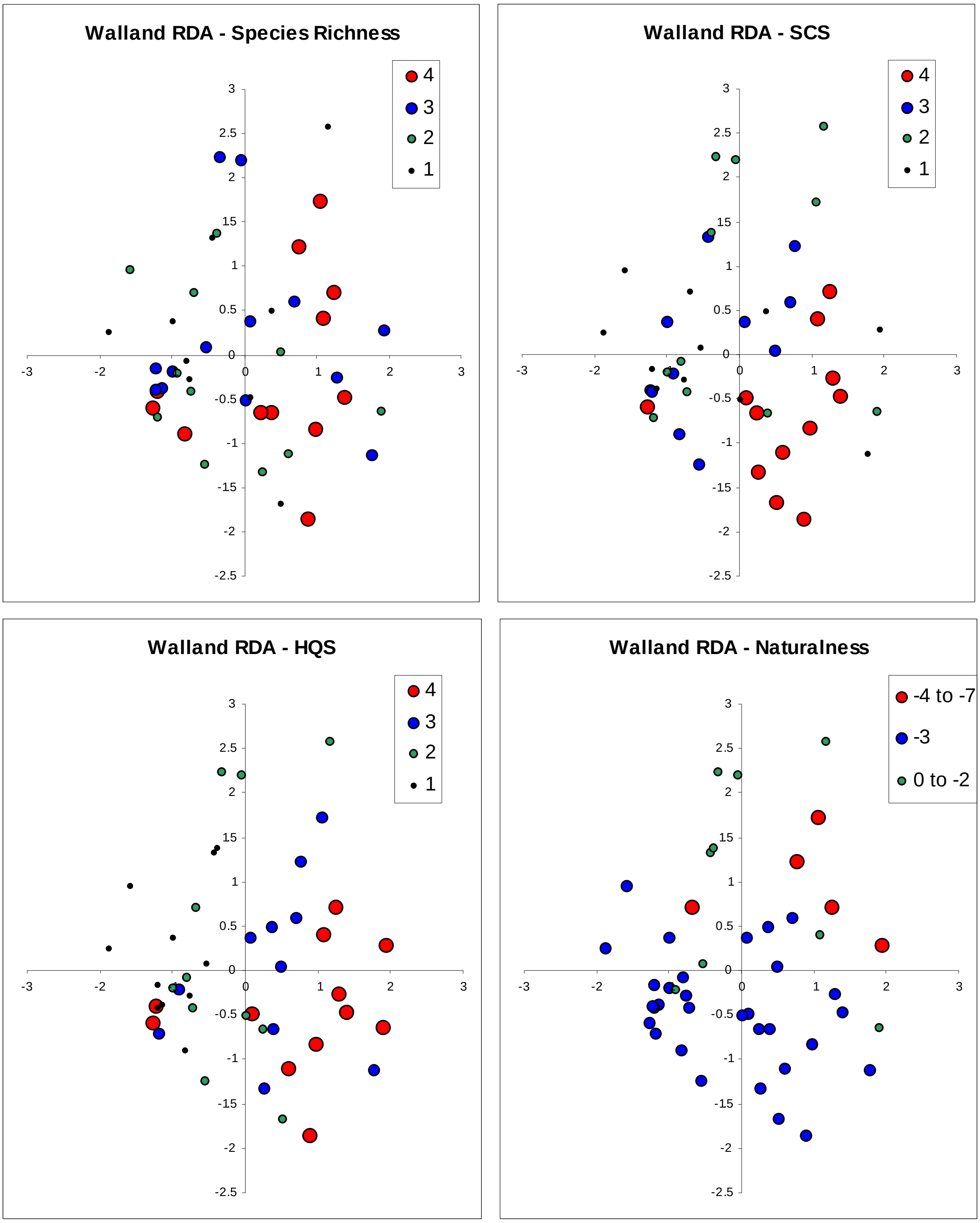


Figure 3.21 RDA ordination showing the species metrics for Walland Marsh

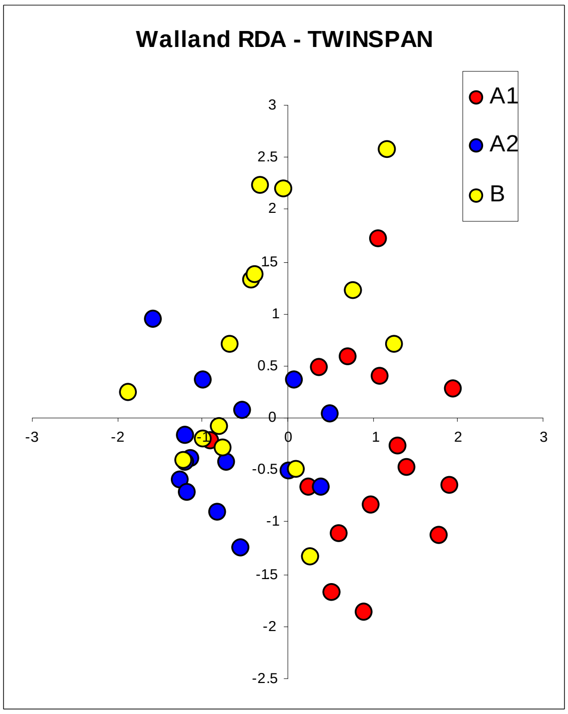


Figure 3.22 RDA ordination showing the TWINSPAN groups for Walland Marsh

Table 3.22. Species preferring either of the groups in the first two TWINSPAN divisons for Walland ditches (ordered as output by TWINSPAN)

First division Species preferring group A	Abundance	Bias	Species preferring group B	Abundance	Bias
Anacaena bipustulata	1	(8,2)	*Anacaena globulus*	1	(2,6)
Enochrus melanocephalus	1	(8,0)	*Cercyon sternalis*	1	(4,6)
Gyrinus marinus	1	(7,0)	*Colymbetes fuscus*	1	(2,4)
Haliplus immaculatus	1	(7,0)	*Graptodytes bilineatus*	1	(4,6)
Helochares lividus	1	(15,2)	*Gyrinus caspius*	1	(4,6)
Hydrovatus clypealis	1	(15,2)	*Hydrobius fuscipes*	1	(13,13)
Laccobius colon	1	(15,0)	*Odontomyia tigrina*	1	(3,4)
Limnebius nitidus	1	(8,0)	*Gerris lateralis*	1	(2,4)
Peltodytes caesus	1	(9,2)	*Argyroneta aquatica*	1	(8,8)
Odontomyia ornata	1	(16,2)	*Anisus leucostoma*	1	(1,4)
Cymatia coleoptrata	1	(11,1)	*Aplexa hypnorum*	1	(1,6)
Hesperocorixa moesta	1	(12,1)	*Potamopyrgus antipodarum*	1	(2,8)
Ilyocoris cimicoides	1	(24,6)	*Liopterus haemorrhoidalis*	2	(2,5)
Sigara dorsalis	1	(7,1)	*Asellus meridianus*	2	(2,6)
Aeshna	1	(7,0)	*Anisus leucostoma*	2	(0,4)
Coenagrion	1	(21,5)	*Gyraulus crista*	2	(4,4)
Anisus vortex	1	(9,1)	*Potamopyrgus antipodarum*	2	(1,4)
Bithynia leachii	1	(22,2)			
Bithynia tentaculata	1	(8,1)			
Hippeutis complanatus	1	(15,3)			
Lymnaea stagnalis	1	(19,2)			
Physa fontinalis	1	(10,2)			
Sphaerium corneum	1	(10,2)			
Valvata cristata	1	(12,3)			
Erpobdella octoculata	1	(12,0)			
Erpobdella testacea	1	(12,3)			
Glossiphonia heteroclita	1	(9,1)			
Helobdella stagnalis	1	(9,0)			
Hydrovatus clypealis	2	(8,1)			
Noterus crassicornis	2	(10,2)			
Cloeon dipterum	2	(17,1)			
Plea minutissima	2	(18,1)			
Anisus vortex	2	(7,0)			
Bithynia leachii	2	(19,1)			
Pisidium	2	(8,2)			
Plea minutissima	3	(10,1)			

Second Division of Group A Species preferring group A1	Abundance	Bias	Species preferring group A2	Abundance	Bias
Anacaena bipustulata	1	(6,2)	*Agabus sturmii*	1	(1,4)
Coelostoma orbiculare	1	(6,3)	*Cymbiodyta marginellus*	1	(4,12)
Enochrus melanocephalus	1	(7,1)	*Enochrus coarctatus*	1	(4,12)
Gyrinus marinus	1	(6,1)	*Haliplus ruficollis*	1	(5,11)
Gyrinus substriatus	1	(5,1)	*Hydaticus seminiger*	1	(1,6)
Haliplus immaculatus	1	(6,1)	*Hydraena testacea*	1	(0,6)
Haliplus lineatocollis	1	(9,3)	*Hydroporus erythrocephalus*	1	(1,4)
Helochares lividus	1	(10,5)	*Liopterus haemorrhoidalis*	1	(4,13)
Helophorus rufipes	1	(4,0)	*Dixella autumnalis*	1	(2,8)
Hydrophilus piceus	1	(5,0)	*Nepa cinerea*	1	(2,5)
Laccobius colon	1	(12,3)	*Limnephilus marmoratus/flavicornis*	1	(1,7)
Ochthebius minimus	1	(6,3)	*Asellus aquaticus*	1	(7,15)
Peltodytes caesus	1	(6,3)	*Pisidium*	1	(3,12)
Oplodontha viridula	1	(13,5)	*Planorbarius corneus*	1	(1,4)
Stratiomys singularior	1	(9,0)	*Sphaerium corneum*	1	(3,7)
Corixa punctata	1	(4,1)	*Valvata cristata*	1	(3,9)
Hebrus pusillus	1	(6,2)	*Glossiphonia heteroclita*	1	(3,6)
Hesperocorixa moesta	1	(8,4)	*Helobdella stagnalis*	1	(3,6)
Ranatra linearis	1	(4,0)	*Anacaena limbata*	2	(2,12)
Sigara dorsalis	1	(6,1)	*Noterus crassicornis*	2	(1,9)
Aeshna	1	(5,2)	*Crangonyx pseudogracilis*	2	(1,13)
Ischnura elegans	1	(10,3)	*Asellus aquaticus*	2	(1,7)
Athripsodes aterrimus	1	(5,0)	*Pisidium*	2	(2,6)
Gammarus zaddachi	1	(4,1)	*Valvata cristata*	2	(1,5)
Hirudo medicinalis	1	(4,1)	*Crangonyx pseudogracilis*	3	(0,4)
Caenis robusta	2	(4,2)	*Bithynia leachii*	3	(2,4)
			Pisidium	3	(0,4)

5.6 North Kent, Thames and Essex marshes

The dataset of 225 species in 108 samples was reduced to 148 species with 77.4% zero cells by excluding species found in less than 5 samples. The gradient length of the first DCA axis was 3.63. The proportion of zero cells and DCA gradient length were higher than in other areas, and this was probably as a result of having amalgamated a larger number of widely distributed marshes from north Kent to the north end of the Essex coast.

RDA forward selection selected 14 significant variables (Table 3.24, Fig 3.23). Only two were selected as the best by BVSTEP, and were among those in the RDA forward selection. The trend along axis 1 was strongly related to conductivity, which was correlated with the summer pH values (D_pH_1). The second axis was clearly related to hydroseral stage, with depth, open water, steep edge profile in opposition to densely vegetatived conditions indicated by the amount of mat-forming vegetation and litter (strongly correlated with emergent vegetation). Tangledness was surprisingly almost unrelated to this trend. The first two axes together explained a large proportion of the variation in the species data (44.3%, Table 3.23).

Species-richness tended to be higher towards the top of the ordination, whereas species conservation and habitat quality scores were greater towards the right (Figure 3.24). This implied that the deeper, perhaps more recently cleaned ditches supported more species than the old, shallow ones but that increasing conductivity led to ditches with greater rarity or specialism. Only old shallow ditches tended to be poorer in all these metrics. The trend with naturalness was more-or-less opposite to that of the conservation and habitat quality scores, and suggested that non-natives were favoured by fresher conditions.

TWINSPAN was run using the dataset with species present in at least 5 samples, abundance data and no weighting. Four groups occupied clearly distinct areas on the RDA ordination (Figure 3.25), and two further divisions are indicated but were unlikely to be ecologically recognisable.

The first division split the strongly brackish ditches from the remainder, as shown by nearly all the species preferring group B (brackish) being either strongly halophilic or with a preference for coastal habitats (Table 3.25). Some of these species, such as the amphipod *Gammarus duebeni* and the beetle *Helophorus alternans*, were also frequent in the 'fresh' group A ditches so the division was probably not entirely based on salinity. These ditches fell to the right of the ordination and thus explained the strong trend with conductivity along the first axis.

The 'freshwater' group A split well into groups separated along the second RDA axis which had a trend explained by hydroseral stage using the environmental variables. Group A1 were mainly species associated with shallow densely vegetated margins, and none of the list would have been expected to be found in any other conditions (Table 3.25). Species in group A2 included many of more open water, such as the, the round-bodied beetles known to prefer open water *Haliplus immaculatus*, *Hyphydrus ovatus*, *Laccophilus colon*, and other beetles *Laccophilus minutus* and *Hydrophilus piceus*, the bugs *Ilyocoris cimicoides*, *Notonecta glauca*, *Plea minutissima* and *Sigara dorsalis*, the water skater *Gerris odontogaster* and the damselflies *Coenagrion* sp and *Ishnura elegans*.

The 'old fresh' group A1 split well on the RDA ordination, and this appeared to be due to the suite of species tolerant of perhaps more stagnant and litter-rich conditions, such as the hoglouse *Asellus aquaticus*, the beetle *Enochrus testaceus* and the mosquito *Culiseta annulata*, in group A1x. The species with a bias towards the other group A1y were a mix with no clear ecological basis, although they included a few with brackish-water tendencies, such as the beetles *Agabus conspersus*, *Enochrus halophilus* and *Ochthebius viridis* and the damselfly *Lestes dryas*. The poorer group A1x coincided on the RDA ordination with the quadrant with low species-richness and species conservation scores, and were the subset of particularly poor ditches.

Table 3.23 Eigenvalues for RDA of North Kent, Thames and Essex marshes

Axis	Eigenvalue	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.064	23.61	23.61
2	0.056	20.71	44.32

Table 3.24 Variables used in RDA for North Kent, Thames and Essex marshes

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, of a total eigenvalue of 0.40; F - F-statistic for this increase; p- probability due to chance; column 5 - Eigenvalue using one explanatory variable; column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at p<0.05. * = selected as the two best using BVSTEP.

Variable	Increased in explained variation	F	p	Eigenvalue using one variable	% of all eigenvalues using one variable	Variable description
D_cond2 *	0.05	6.163	0.001	0.05	13.90	Conductivity
D_depth	0.04	4.631	0.001	0.04	10.24	Water depth
V_litt	0.03	3.051	0.001	0.03	6.81	Litter
D_pH	0.02	2.290	0.001	0.03	8.17	pH (spring)
L_cattl *	0.02	1.996	0.001	0.02	5.69	Cattle-grazed
V_mat	0.02	1.884	0.001	0.03	6.81	Floating mat
D_pH_1	0.01	1.749	0.003	0.03	8.84	pH (summer)
V_opwat	0.01	1.653	0.002	0.04	9.54	Open water
B_bare	0.01	1.594	0.001	0.02	6.12	Bare ground
L_unimp	0.01	1.488	0.008	0.02	4.44	Unimproved
D_width	0.01	1.473	0.012	0.02	4.34	Water width
D_profi	0.01	1.449	0.014	0.01	3.55	Margin profile
D_slope	0.01	1.412	0.021	0.01	2.97	Slope bank
S_tangl	0.01	1.345	0.025	0.02	5.25	Tangled
S_shelf	0.01	1.294	0.065	0.01	2.89	Shelf formation
S_poach	0.01	1.368	0.030	0.02	5.05	Poaching
V_exmud	0.01	1.259	0.081	0.01	3.36	Exposed mud
D_silt	0.01	1.199	0.114	0.02	5.91	Silt depth
B_shorg	0.01	1.179	0.143	0.02	3.90	Short grass
V_flalg	0.01	1.192	0.150	0.01	2.36	Floating algae
L_sheep	0.01	1.194	0.155	0.02	3.91	Sheep-grazed
L_impr	0.01	1.210	0.120	0.01	3.23	Improved grass
D_freeb	0.01	1.022	0.388	0.01	1.98	Freeboard
B_scrub	0.01	0.982	0.498	0.01	2.22	Scrub
B_herb	0.01	0.968	0.545	0.01	3.31	Tall herbs
V_lemna	0.01	0.954	0.565	0.02	4.74	Floating Lemna
V_subaq	0.01	0.915	0.647	0.02	4.20	Submerged plants
M_year	0.01	0.857	0.787	0.03	8.38	Last cleared
V_emerg	0.01	0.710	0.953	0.02	4.02	Emergents

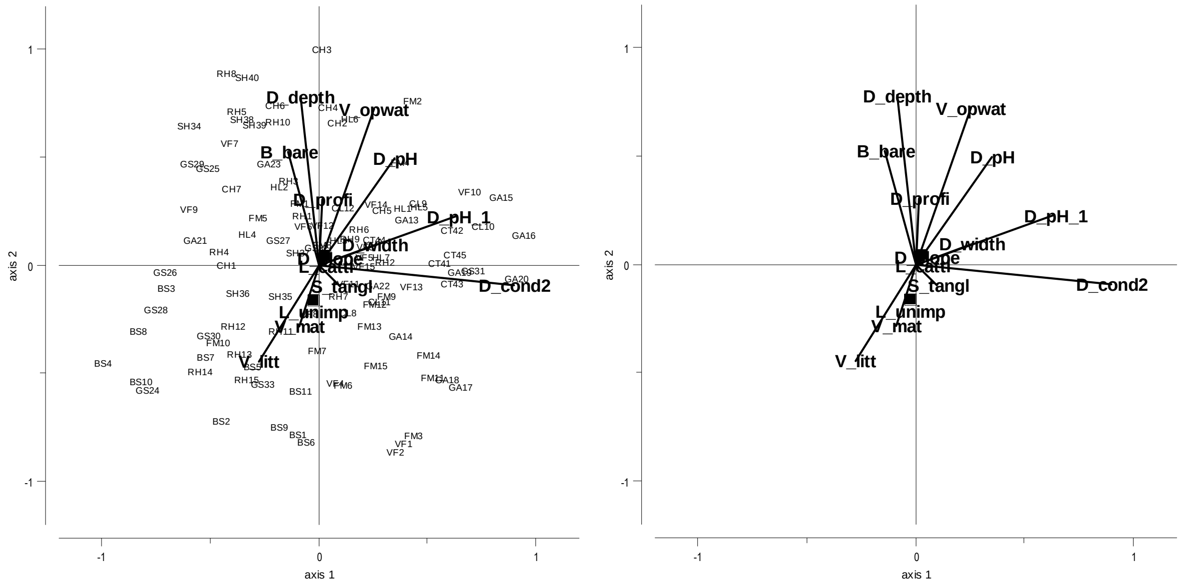


Figure 3.23 RDA ordination of significant variables for North Kent, Thames and Essex marshes

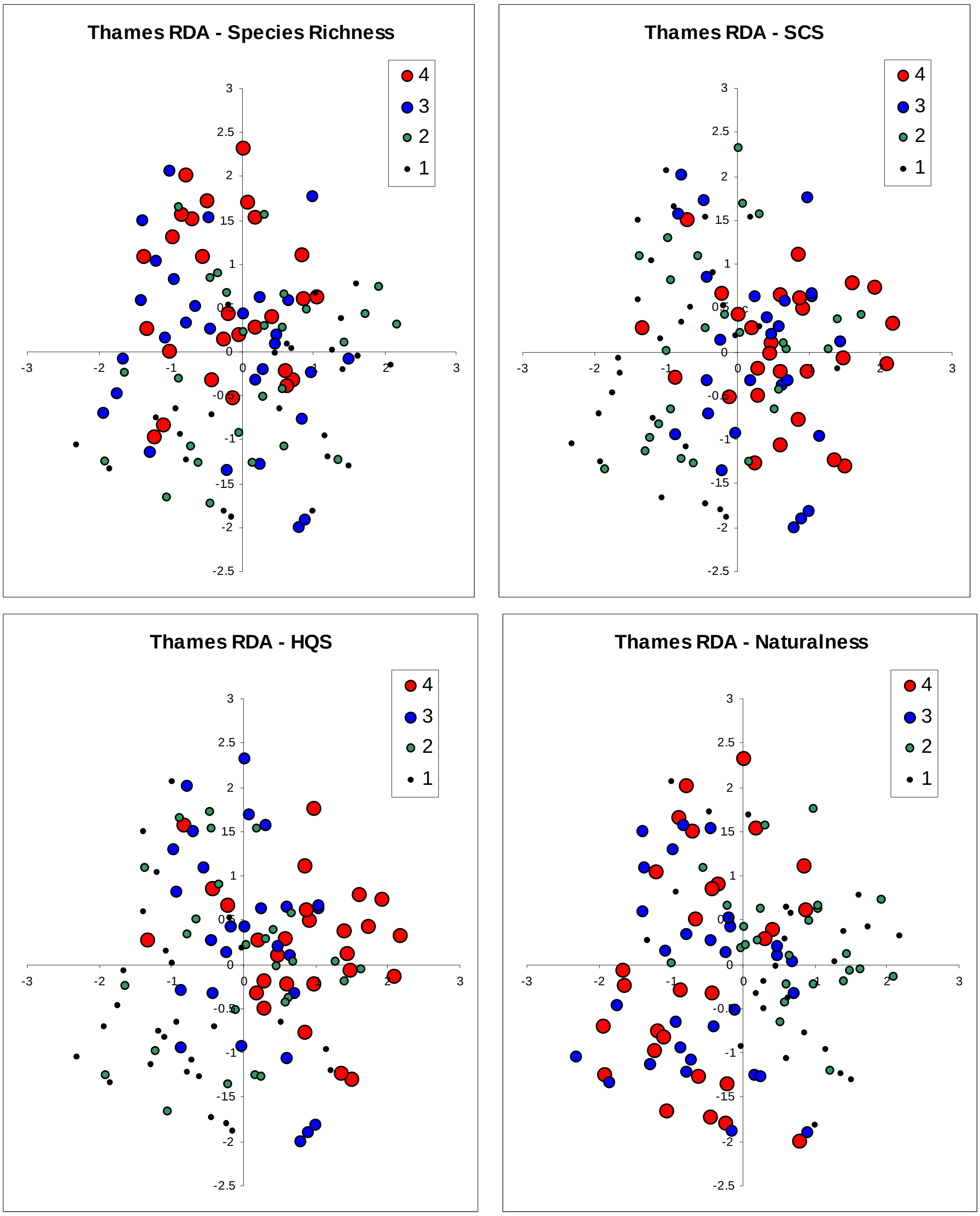


Figure 3.24 Species metrics plotted on the RDA ordination for North Kent, Thames and Essex marshes

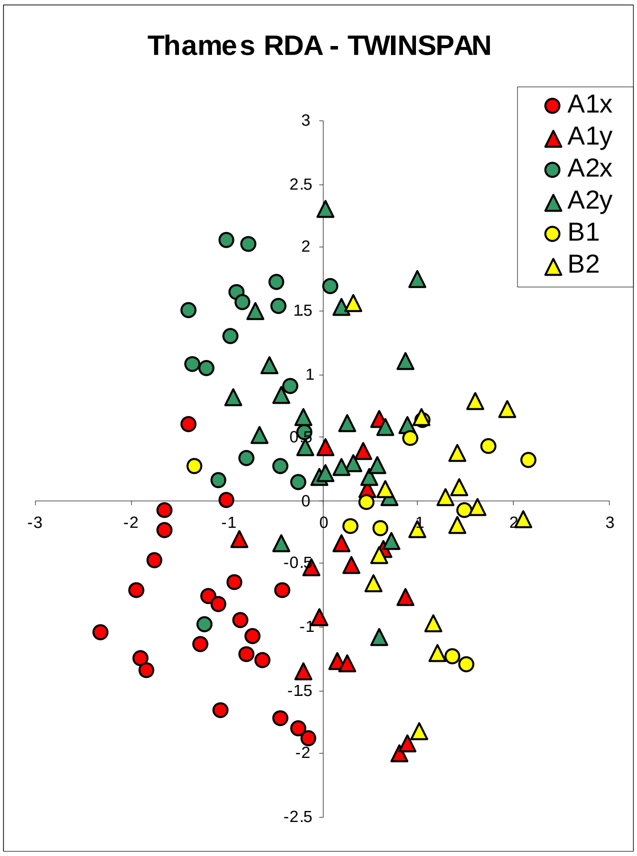


Figure 3.25 TWINSPAN groups plotted on the RDA ordination for North Kent, Thames and Essex marshes

Table 3.25 TWINSPAN divisions of North Kent, Thames and Essex samples, giving the preference for species for one or other side of divisions

First Division **Group A ('fresh')**	**Abund.**	**Bias**	**Group B (brackish)**	**Abund.**	**Bias**
Anacaena bipustulata	1	(31,2)	*Agabus conspersus*	1	(5,9)
Anacaena limbata	1	(76,13)	*Berosus affinis*	1	(15,14)
Cercyon sternalis	1	(28,3)	*Berosus signaticollis*	1	(14,11)
Coelostoma orbiculare	1	(20,0)	*Dytiscus marginalis*	1	(4,6)
Enochrus testaceus	1	(38,1)	*Gyrinus caspius*	1	(9,11)
Graptodytes bilineatus	1	(24,4)	*Helophorus alternans*	1	(15,11)
Haliplus ruficollis	1	(38,3)	*Hygrotus parallelogrammus*	1	(9,15)
Helochares lividus	1	(30,4)	*Rhantus frontalis*	1	(17,12)
Helophorus obscurus	1	(29,3)	*Gerris thoracicus*	1	(6,14)
Hydraena testacea	1	(18,0)	*Notonecta viridis*	1	(4,14)
Hydrophilus piceus	1	(23,3)	*Sigara lateralis*	1	(4,7)
Hydroporus angustatus	1	(30,0)	*Sigara stagnalis*	1	(4,12)
Hydroporus palustris	1	(28,2)	*Limnephilus affinis*	1	(4,13)
Hyphydrus ovatus	1	(27,0)	*Gammarus duebeni*	1	(19,25)
Laccobius bipunctatus	1	(50,4)	*Gammarus zaddachi*	1	(2,16)
Liopterus haemorrhoidalis	1	(30,4)	*Palaemonetes varians*	1	(2,13)
Rhantus suturalis	1	(22,2)	*Agabus conspersus*	2	(1,6)
Dixella attica	1	(43,7)	*Enochrus halophilus*	2	(3,7)

Dixella autumnalis	1	(36,6)	*Sigara stagnalis*	2	(0,8)
Caenis robusta	1	(19,0)	*Gammarus duebeni*	2	(10,24)
Cloeon dipterum	1	(44,2)	*Gammarus zaddachi*	2	(2,10)
Ilyocoris cimicoides	1	(33,4)	*Palaemonetes varians*	2	(1,10)
Microvelia reticulata	1	(34,4)	*Potamopyrgus antipodarum*	2	(10,10)
Sigara dorsalis	1	(25,0)	*Gammarus duebeni*	3	(2,15)
Coenagrion	1	(32,4)	*Gammarus zaddachi*	3	(1,6)
Limnephilus marmoratus/flavicornis	1	(37,4)			
Argyroneta aquatica	1	(26,2)			
Crangonyx pseudogracilis	1	(55,0)			
Asellus aquaticus	1	(55,3)			
Asellus meridianus	1	(33,1)			
Anisus vortex	1	(17,0)			
Gyraulus crista	1	(38,0)			
Lymnaea palustris	1	(23,1)			
Physella acuta	1	(24,0)			
Pisidium	1	(23,0)			
Planorbis planorbis	1	(29,0)			
Radix balthica	1	(64,1)			
Anacaena limbata	2	(61,3)			
Cymbiodyta marginellus	2	(34,3)			
Laccobius bipunctatus	2	(17,0)			
Crangonyx pseudogracilis	2	(32,0)			
Asellus aquaticus	2	(40,0)			
Radix balthica	2	(34,0)			

Second division of A Group A1 ('old')			**Group A2 ('new')**		
Agabus bipustulatus	1	(15,5)	*Anacaena bipustulata*	1	(5,26)
Anacaena lutescens	1	(11,0)	*Berosus affinis*	1	(1,14)
Cercyon sternalis	1	(23,5)	*Haliplus immaculatus*	1	(0,13)
Cercyon tristis	1	(9,3)	*Helochares lividus*	1	(5,25)
Coelostoma orbiculare	1	(14,6)	*Hydrophilus piceus*	1	(6,17)
Colymbetes fuscus	1	(14,1)	*Hyphydrus ovatus*	1	(6,21)
Graptodytes bilineatus	1	(16,8)	*Laccobius colon*	1	(1,9)
Helophorus aequalis	1	(8,3)	*Laccophilus minutus*	1	(8,23)
Helophorus alternans	1	(10,5)	*Limnoxenus niger*	1	(13,29)
Helophorus obscurus	1	(19,10)	*Porhydrus lineatus*	1	(3,9)
Hydroporus angustatus	1	(20,10)	*Caenis robusta*	1	(2,17)
Hydroporus tessellatus	1	(9,2)	*Cloeon dipterum*	1	(8,36)
Hygrotus impressopunctatus	1	(9,4)	*Cymatia coleoptrata*	1	(0,10)
Ilybius quadriguttatus	1	(10,3)	*Gerris odontogaster*	1	(8,24)
Liopterus haemorrhoidalis	1	(22,8)	*Hesperocorixa linnaei*	1	(10,35)
Ochthebius minimus	1	(32,13)	*Ilyocoris cimicoides*	1	(4,29)
Rhantus suturalis	1	(15,7)	*Microvelia reticulata*	1	(6,28)
Pisidium	1	(16,7)	*Notonecta glauca*	1	(3,21)
Cymbiodyta marginellus	2	(27,7)	*Plea minutissima*	1	(5,31)
Hydrobius fuscipes	2	(17,3)	*Sigara dorsalis*	1	(5,20)
Ochthebius minimus	2	(11,0)	*Aeshnidae*	1	(2,16)
Asellus meridianus	2	(11,5)	*Brachytron pratense*	1	(1,13)
Asellus aquaticus	3	(8,0)	*Ischnura elegans*	1	(9,39)
			Athripsodes aterrimus	1	(0,10)
			Oecetis furva	1	(0,11)

			Bithynia tentaculata	1	(3,9)
			Lymnaea stagnalis	1	(1,10)
			Physa fontinalis	1	(2,10)
			Helobdella stagnalis	1	(4,9)
			Hygrotus inaequalis	2	(2,10)
			Noterus clavicornis	2	(6,27)
			Cloeon dipterum	2	(1,14)
			Microvelia reticulata	2	(0,12)
			Plea minutissima	2	(0,13)
			Coenagrion	2	(0,9)
			Ischnura elegans	2	(3,29)
			Radix balthica	3	(3,11)
Third division of A1					
Group A1x			**Group A1y**		
Dytiscus semisulcatus	1	(5,1)	*Agabus bipustulatus*	1	(6,9)
Enochrus testaceus	1	(11,4)	*Agabus conspersus*	1	(0,5)
Ilybius quadriguttatus	1	(8,2)	*Berosus signaticollis*	1	(0,8)
Culiseta annulata	1	(7,0)	*Cercyon marinus*	1	(1,6)
Microvelia pygmaea	1	(6,0)	*Cercyon sternalis*	1	(9,14)
Limnephilus marmoratus/flavicornis	1	(16,2)	*Cercyon tristis*	1	(3,6)
Asellus aquaticus	1	(22,5)	*Colymbetes fuscus*	1	(3,11)
Anisus vortex	1	(10,0)	*Enochrus halophilus*	1	(1,13)
Lymnaea palustris	1	(12,2)	*Haliplus lineatocollis*	1	(2,9)
Pisidium	1	(15,1)	*Helophorus brevipalpis*	1	(4,7)
Potamopyrgus antipodarum	1	(10,1)	*Hydrophilus piceus*	1	(0,6)
Crangonyx pseudogracilis	2	(15,3)	*Hydroporus tessellatus*	1	(3,6)
Asellus aquaticus	2	(19,2)	*Hygrotus impressopunctatus*	1	(1,8)
Anisus vortex	2	(6,0)	*Hygrotus inaequalis*	1	(5,14)
Pisidium	2	(9,0)	*Hygrotus parallelogrammus*	1	(0,6)
Crangonyx pseudogracilis	3	(8,1)	*Laccophilus minutus*	1	(2,6)
Asellus aquaticus	3	(8,0)	*Limnoxenus niger*	1	(1,12)
Pisidium	3	(6,0)	*Ochthebius dilatatus*	1	(1,4)
			Ochthebius viridis	1	(0,4)
			Peltodytes caesus	1	(2,5)
			Rhantus frontalis	1	(1,8)
			Odontomyia tigrina	1	(0,9)
			Oplodontha viridula	1	(4,12)
			Stratiomys singularior	1	(1,9)
			Hesperocorixa linnaei	1	(4,6)
			Hydrometra stagnorum	1	(3,6)
			Ischnura elegans	1	(2,7)
			Lestes dryas	1	(0,9)
			Sympetrum	1	(3,15)
			Cercyon sternalis	2	(0,5)
			Hydrobius fuscipes	2	(4,13)
			Ochthebius minimus	2	(3,8)
			Oplodontha viridula	2	(0,6)
			Sympetrum	2	(0,5)
			Asellus meridianus	2	(4,7)
			Gyraulus crista	2	(1,5)

5.7 Norfolk: Bure and Yare valleys

The dataset was reduced from 207 to 141 species in 75 samples, with 62.6% zero cells when species in fewer than 5 samples were removed. The gradient length of the first DCA axis was 1.97. Variables were reduced to 12 that were significant in an RDA forward selection (Table 3.27). A PCA of these shows the strong correlation between these and excluded variables (Figure 3.26). This figure was plotted using no transformation because Chord and Hellinger transformations produce a strange lop-sided plot.

Twelve variables were significant in RDA forward selection, of which four were also selected by BVSTEP (Table 3.27, Figure 27). The trend along axis 1 was strongly related to hydroseral stage, indicated by the close correlation of year since last cleaned, litter and emergent cover on one side and open water on the other. The size of the ditch also influenced this axis, indicated by water width being very closely correlated with the cover of open water. The second axis was related to conductivity, which was closely correlated with turbidity. These two variables appeared to act in isolation and were almost uncorrelated with the other significant variables.

Species richness showed no trend on the RDA plot but species conservation score was sometimes high in species-poor ditches and in more brackish ditches, indicated by the trend with conductivity (Figure 3.28). No ditches with particularly high species conservation score were associated with the trend towards more open or wider ditches that included some that were species-rich. There was a slight indication that the habitat quality score was generally lower in more choked ditches. Naturalness was greatest (i.e. fewest non-native species) in brackish ditches. This was mostly due to the ubiquitous *Crangonyx pseudogracilis* apparently being intolerant of high conductivity.

TWINSPAN was run using abundance data for the reduced set of species (141 species in at least 5 samples) in 75 ditches. Three clear groups and one outlying single-sample group were recognised, as was made clear when the groups were plotted on the RDA ordination (Figure 3.29). This figure also shows further divisions which probably had no ecological reality. The group names indicate the divisions: A and B were the first division, 1 and 2 were the next level, and x and y were the third level. The first division separated clearly with axis 1 of the RDA ordination, related strongly to hydroseral stage. The second division, although less clear-cut, followed the trend of the second axis and was, at least for outlying sample, related to conductivity.

Species preferring one or other side of the first TWINSPAN division very clearly reflect the known ecologies (Table 3.28). Those preferring the open, wider ditches (group A) include whirligigs (*Gyrinus* spp), the dumpier water beetles known to prefer deeper less choked conditions (*Hydrobia hermanni*, *Hyphydrus ovatus*, *Noterus clavicornis*, *Haliplus flavicollis*, *Peltodytes caesus*), and other beetles that occur often more open conditions (*Laccobius* spp). Other species that spend much time swimming in more open water preferred the open ditches, including the bugs *Corixa punctata*, *Sigara fossarum* and *Plea minutissima*. Abundant *Cloeon* mayflies and *Ishnura* damselflies were also characteristic of the open ditches. Species preferring the more choked conditions included the usual suite of crawling water beetles found in grassy margins (*Anacaena* spp, *Cercyon* spp, *Coelostoma orbiculare*, *Cymbiodyta marginella*, *Ochthebius dilatatus*) and the diving beetles *Hydroporus angustatus* and *Rhantus suturalis*. Also characteristic of densely vegetated margins were the bugs *Hydrometra stagnorum* and *Nepa cinerea*, the soldierflies *Odontomyia tigrina* and *Oplodontha virid*ula and the dragonfly *Sympetrum* sp.

Further division of the large group B was ill-defined and was not interpretable in terms of the species preferences (Table 3.28). With the exception of the brackish-water isopod crustaceans *Gammarus duebeni* and *G. zaddachi* and the brackish-tolerant snail *Potamopyrgus antipodarum* in the smaller group B1, neither group contained suites of species with consistently recognised ecological preferences. The larger group B1 did contain more uncommon species which were almost confined to this group (the beetles *Hydrophilus piceus*, *Peltodytes caesus* and *Rhantus grapii*, and the BAP snail *Anisus vorticulus*). The RDA analysis did not suggest a factor, other than conductivity, that may have helped to explain the separation of these groups, but if conductivity reflected nutrient enrichment as much as salinity, then group B1 with the uncommon species may come from ditches with cleaner water.

Table 3.26 Eigenvalues for RDA of Norfolk marshes

Axis	Eigenvalue (sum of all canonical eigenvalues = 0.29)	Eigenvalue as % of all canonical eigenvalues	Cumulative %
1	0.070	24.05	24.05
2	0.051	17.48	41.53

Column 2: Increase in total sum of eigenvalues (explained variation) after adding new variable, of a total eigenvalue of 0.463; F - F-statistic for this increase; p- probability due to chance; column 5 - Eigenvalue using one explanatory variable; column 6 – Eigenvalue as % of sum all eigenvalues using only one explanatory variable. Variables in bold were significant at p<0.05. * = selected as the five best using BVSTEP.

Table 3.27 Variables used in RDA for Norfolk marshes

Variable	**Increased in explained variation**	**F**	**p**	**Eigenvalue using one variable**	**% of all eigenvalues using one variable**	**Variable description**
V_opwat	0.05	4.062	0.001	0.05	11.39	Open water
D_cond2 *	0.04	3.500	0.001	0.05	9.82	Conductivity
S_poach	0.03	2.138	0.001	0.03	5.82	Poaching
D_width *	0.02	2.000	0.001	0.04	8.54	Water width
V_emerg	0.02	1.810	0.001	0.04	7.67	Emergents
V_bott	0.02	1.762	0.002	0.03	7.27	Open substrate
V_flalg	0.02	1.560	0.006	0.02	4.55	Floating algae
D_pH_1	0.02	1.446	0.010	0.04	8.03	pH (summer)
M_year *	0.02	1.387	0.027	0.04	9.42	Last cleared
V_litt *	0.02	1.410	0.021	0.04	8.26	Litter
L_semi	0.02	1.359	0.039	0.02	4.76	Semi-improved
D_turb	0.01	1.296	0.040	0.02	4.31	Turbidity
V_lemna	0.01	1.285	0.065	0.03	5.58	Floating Lemna
D_profi	0.01	1.283	0.065	0.02	4.56	Margin profile
D_silt	0.01	1.261	0.075	0.02	3.60	Silt depth
S_shelf	0.01	1.183	0.152	0.02	4.51	Shelf formation
V_subaq	0.01	1.170	0.172	0.03	7.26	Submerged plants
B_bare	0.01	1.132	0.216	0.02	3.96	Bare ground
V_flaqu	0.01	1.069	0.353	0.02	3.30	Floating aquatics
D_soil	0.01	1.044	0.375	0.02	4.79	Soil type
D_depth	0.01	1.073	0.326	0.04	7.91	Water depth
B_herb	0.01	1.017	0.427	0.02	4.29	Tall herbs
D_freeb *	0.01	1.021	0.420	0.03	5.46	Freeboard
V_mat	0.01	1.053	0.367	0.03	5.69	Floating mat
B_shorg	0.01	0.983	0.521	0.02	5.21	Short grass
S_tangl	0.01	0.927	0.635	0.03	5.48	Tangled

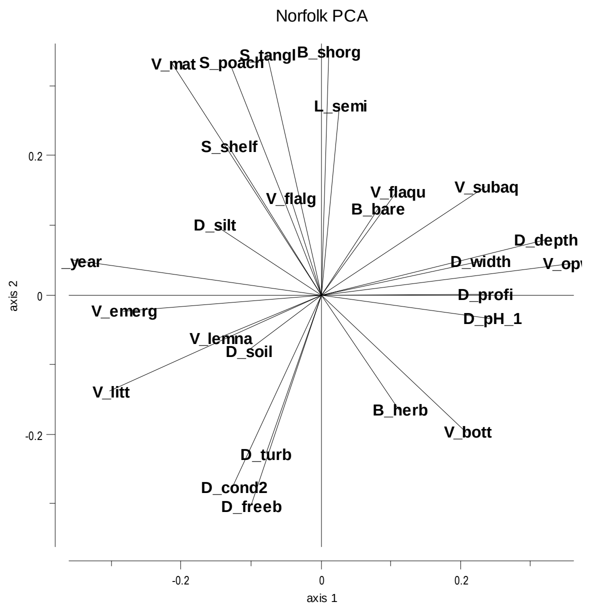


Figure 3.26 PCA for Norfolk marshes showing 26 variables with some importance

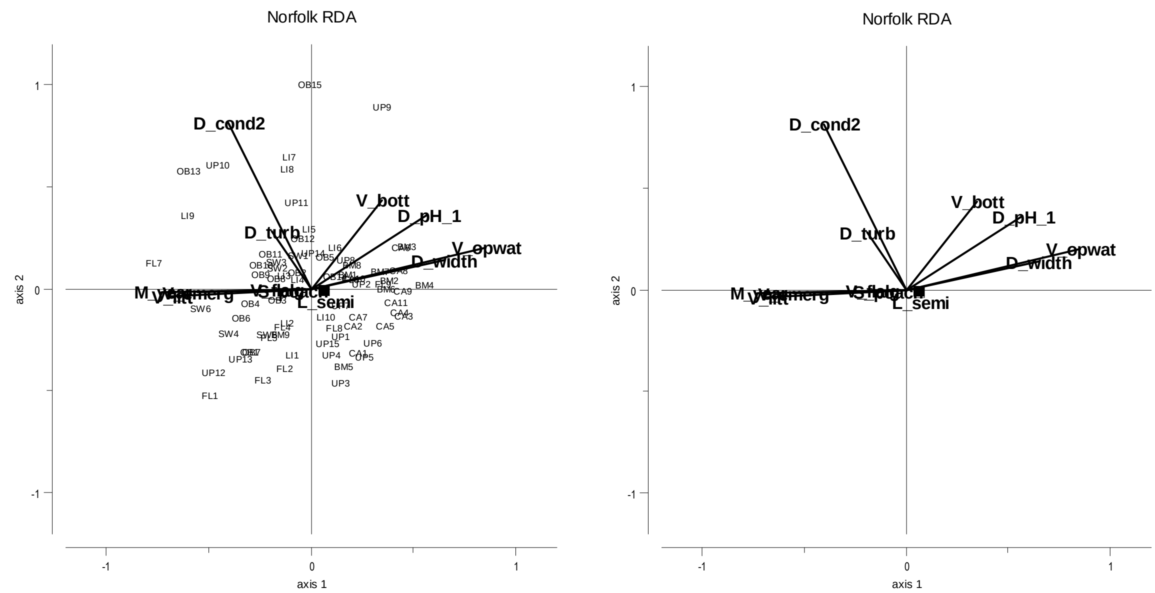


Figure 3.27 RDA ordinations of significant variables for Norfolk marshes

The superimposed labels on the left are M_year, V_litt and V_emerg; those centre left are S_poach and V_flalg.

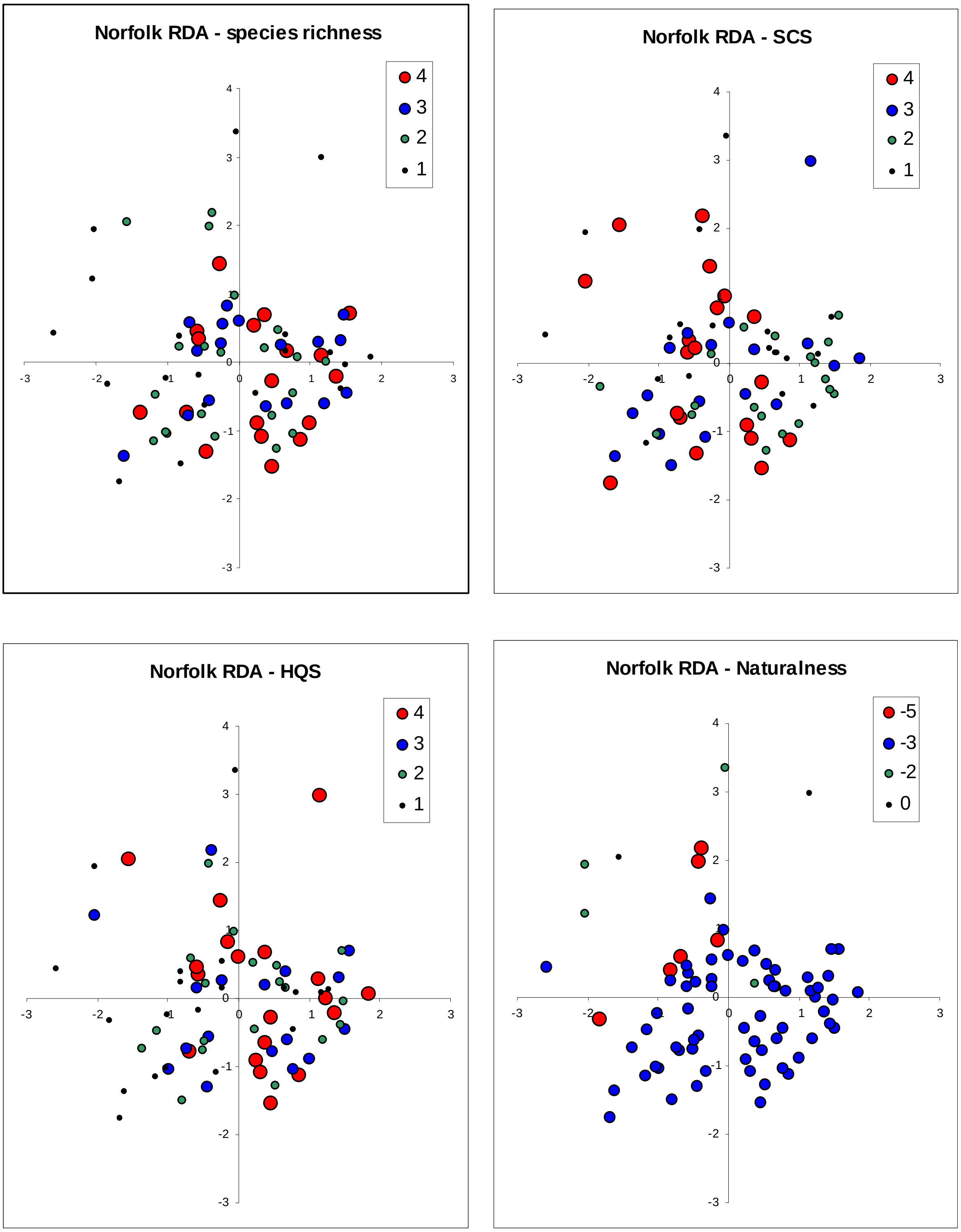


Figure 3.28 Norfolk RDA ordination showing the four quartiles of Species Richness, Species Conservation Status and Habitat Quality Scores and actual scores for Naturalness

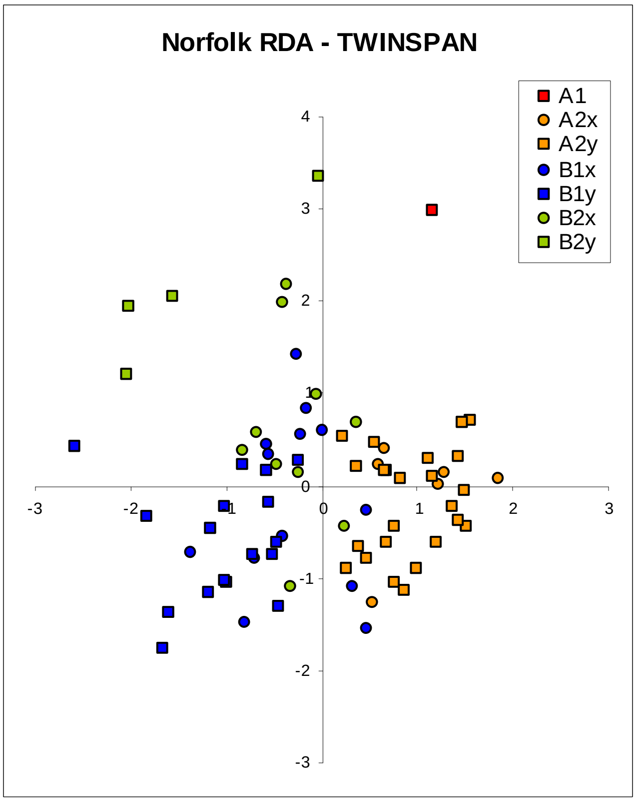


Figure 3.29 Norfolk RDA ordination showing the TWINSPAN groups

Table 3.28 Species preferring either of the groups in the first two TWINSPAN divisions for Norfolk ditches

Abundance is logarithmic and corresponds to TWINSPAN's cut-levels. Bias is the number of samples either side of the division.

First division into A and B					
Species preferring group A	**Abundance**	**Bias**	**Species preferring group B**	**Abundance**	**Bias**
Dytiscus marginalis	1	(9,5)	*Anacaena globulus*	1	(1,14)
Gyrinus marinus	1	(23,6)	*Cercyon marinus*	1	(1,14)
Gyrinus substriatus	1	(15,8)	*Cercyon tristis*	1	(2,16)
Haliplus flavicollis	1	(9,3)	*Coelostoma orbiculare*	1	(1,9)
Helophorus brevipalpis	1	(19,10)	*Cymbiodyta marginella*	1	(3,21)
Helophorus obscurus	1	(10,7)	*Enochrus coarctatus*	1	(2,19)
Hygrobia hermanni	1	(10,0)	*Hydroglyphus geminus*	1	(1,12)
Laccobius colon	1	(20,5)	*Hydroporus angustatus*	1	(2,28)
Laccobius minutus	1	(9,2)	*Ilybius ater*	1	(4,19)
Laccophilus minutus	1	(24,5)	*Limnoxenus niger*	1	(5,18)
Peltodytes caesus	1	(15,9)	*Ochthebius dilatatus*	1	(9,30)
Corixa punctata	1	(9,0)	*Odontomyia tigrina*	1	(5,15)
Plea minutissima	1	(10,1)	*Hebrus pusillus*	1	(2,14)
Sigara fossarum	1	(13,1)	*Hydrometra stagnorum*	1	(8,24)
Aeshnidae sp	1	(22,13)	*Nepa cinerea*	1	(8,27)
Lestes sponsa	1	(11,6)	*Sympetrum sp*	1	(6,19)
Athripsodes aterrimus	1	(11,5)	*Bathyomphalus contortus*	1	(4,21)
Triaenodes bicolor	1	(24,13)	*Hippeutis complanatus*	1	(6,22)
Lymnaea stagnalis	1	(29,19)	*Potamopyrgus antipodarum*	1	(1,9)
Valvata piscinalis	1	(8,2)	*Glossiphonia heteroclita*	1	(2,10)
Theromyzon tessulatum	1	(7,3)	*Haemopis sanguisuga*	1	(2,11)
Gyrinus marinus	2	(11,0)	*Anacaena limbata*	2	(4,30)
Hyphydrus ovatus	2	(15,5)	*Haliplus lineatocollis*	2	(2,11)
Noterus clavicornis	2	(11,5)	*Helophorus aequalis*	2	(3,15)
Cloeon dipterum	2	(21,5)	*Rhantus suturalis*	2	(0,11)
Ischnura elegans	2	(16,8)	*Oplodontha viridula*	2	(3,12)
			Microvelia reticulata	2	(4,13)
			Coenagrion sp	2	(5,18)
			Hippeutis complanatus	2	(1,9)
			Pisidium sp	2	(0,14)
			Potamopyrgus antipodarum	2	(0,9)

Second division of group B					
Species preferring group B1	**Abundance**	**Bias**	**Species preferring group B2**	**Abundance**	**Bias**
Anacaena globulus	1	(13,1)	*Agabus sturmii*	1	(3,5)
Cercyon sternalis	1	(8,0)	*Anacaena bipustulata*	1	(3,5)
Enochrus coarctatus	1	(18,1)	*Cercyon marinus*	1	(7,7)
Helophorus obscurus	1	(7,0)	*Colymbetes fuscus*	1	(2,4)
Hydrophilus piceus	1	(15,2)	*Gyrinus substriatus*	1	(3,5)
Ilybius ater	1	(17,2)	*Laccobius colon*	1	(1,4)
Peltodytes caesus	1	(9,0)	*Laccophilus minutus*	1	(2,3)
Rhantus grapii	1	(16,1)	*Ptychoptera sp*	1	(3,3)
Caenis robusta	1	(17,2)	*Hebrus pusillus*	1	(7,7)
Aeshna grandis	1	(10,0)	*Hydrometra stagnorum*	1	(11,13)
Limnephilus marmoratus/ flavicornis	1	(12,1)	*Microvelia pygmaea*	1	(1,5)
Acroloxus lacustris	1	(15,0)	*Sigara dorsalis*	1	(3,3)
Anisus vorticulus	1	(7,0)	*Gammarus duebeni*	1	(0,5)
Bathyomphalus contortus	1	(18,3)	*Gammarus zaddachi*	1	(0,4)
Gyraulus crista	1	(9,1)	*Potamopyrgus antipodarum*	1	(2,7)
Hippeutis complanatus	1	(22,0)	*Agabus bipustulatus*	2	(2,3)
Lymnaea stagnalis	1	(17,2)	*Haliplus ruficollis*	2	(3,4)
Physa fontinalis	1	(24,2)	*Hydrobius fuscipes*	2	(3,3)
Planorbarius corneus	1	(15,3)	*Hydroporus palustris*	2	(1,4)
Planorbis carinatus	1	(12,0)	*Hygrotus inaequalis*	2	(0,3)
Sphaerium corneum	1	(18,2)	*Noterus clavicornis*	2	(1,4)
Viviparus contectus	1	(7,0)	*Oplodontha viridula*	2	(6,6)
Erpobdella octoculata	1	(21,2)	*Cloeon dipterum*	2	(2,3)
Glossiphonia complanata	1	(9,1)	*Hesperocorixa linnaei*	2	(2,3)
Glossiphonia heteroclita	1	(9,1)	*Microvelia reticulata*	2	(5,8)
Haemopis sanguisuga	1	(10,1)	*Argyroneta aquatica*	2	(2,3)
Helophorus aequalis	2	(13,2)	*Lymnaea palustris*	2	(7,7)
Caenis robusta	2	(7,0)	*Musculium lacustre*	2	(1,7)
Coenagrion sp	2	(16,2)	*Potamopyrgus antipodarum*	2	(2,7)
Ischnura elegans	2	(7,1)			
Crangonyx pseudogracilis	2	(20,4)			
Hippeutis complanatus	2	(9,0)			
Lymnaea stagnalis	2	(9,1)			
Physa fontinalis	2	(16,0)			
Sphaerium corneum	2	(11,0)			

5.8 Key environmental drivers: summary

The analyses started with c. 60 potential 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.

Across the six geographic areas, RDA selected 35 significant variables and BVSTEP selected 14 variables, two of which did not appear in the RDA analysis. To draw common threads from this wide array of variables, they were combined into related groups according to their correlation in pairplots and in the PCA ordinations described above (Table 3.29). This allowed ‘surrogate’ variables to be identified from which recurring trends in the ordinations could be described. Variables selected as significant by RDA were grouped into these classes, and the level of significance given as the p-value of the Monte Carlo tests (Table 3.30). Three variables were not consistently correlated with others so have not been forced into the apparently obvious groupings since these were derived from their degree of correlation and not by *a priori* assumption. A similar grouping was undertaken of the variables selected as the best by BVSTEP (Table 3.31).

Table 3.29 Related variables based on pairplots and PCA plots

Some appear in more than one group.

Grouping	Variables	Variable description	Comments
Land-use grass types	L_semi	Semi-improved	
	L_unimp	Unimproved	mutually exclusive variables
	L_impr	Improved grass	
	L_cattl	Cattle-grazed	
	S_graz	Grazing	
	S_poach	Poaching	
	S_block	Block formation	
	S_shelf	Shelf formation	
	B_shorg	Short grass	
Cattle-related (less often other large herbivores)	B_talgr	Tall grass/reed	
	B_herb	Tall herbs	
Marginal vegetation structure	S_gmarg	Grassy margin	
	S_tangl	Tangled	Often correlated with other cattle-related effects but not directly due to cattle
	S_poach	Poaching	
	S_graz	Grazing	
	V_mat	Floating mat	
Physical structure	D_top	Banktop width	
	D_width	Water width	
	D_depth	Water depth	
	V_opwat	Open water	
Angle of banks	D_slope	Slope bank	
	D_profi	Margin profile	
	D_freeb	Freeboard	
Chemistry	D_cond2	Conductivity	
	D_ph_1	pH (summer)	
	D_turb	Turbidity	
	D_color	Water colour	
Open – closed ditch vegetation	V_opwat	Open water	
	V_lemna	Floating Lemna	
	V_subaq	Submerged plants	
	V_choke	Emergents in channel	
	V_emerg	Emergents	
	V_litt	Litter	
	M_year	Last cleared	
	D_silt	Silt depth	
Open water – open bottom	V_opwat	Open water	due almost purely to the difficulty of observing the ‘openness’ of the sediment
	V_bott	Open substrate	
	D_width	Water width	
Algae	V_flalg	Floating algae	
	V_subal	Submerged algae	
	V_subaq	Submerged plants	

Table 3.30 p-value of F-statistic in RDA forward selection for six geographic areas grouped by related variables

Variable	Gwent	Somerset	Pevensey	Walland	Thames	Norfolk	Variable name	Group
L_impr		0.001					Improved grass	Grass type
L_semi						0.039	Semi-improved	
L_unimp		0.001			0.008		Unimproved	
L_cattl	0.037	0.007			0.001		Cattle-grazed	Cattle effects
B_talgr	0.025						Tall grass/reed	
B_shorg		0.004					Short grass	
B_bare					0.001		Bare ground	
B_herb		0.049					Tall herbs	
S_graz	0.044						Grazing	
S_poach			0.009		0.03	0.001	Poaching	
S_tangl				0.001	0.025		Tangled	Margin vegetation
S_gmarg	0.001						Grassy margin	
V_mat		0.001	0.001		0.001		Floating mat	
D_width	0.016	0.001			0.012	0.001	Water width	Physical structure
D_depth				0.001	0.001		Water depth	
D_freeb		0.001	0.015				Freeboard	
D_slope					0.021		Slope bank	
D_profi	0.005	0.005		0.041	0.014		Margin profile	
D_cond2		0.001		0.001	0.001	0.001	Conductivity	Chemistry
D_pH	0.049	0.004			0.001		pH (spring)	
D_pH_1		0.001		0.006	0.003	0.01	pH (summer)	
D_turb		0.005				0.04	Turbidity	
V_opwat	0.001	0.001	0.001		0.002	0.001	Open water	Open - closed
V_bott						0.002	Open substrate	
V_subaq		0.001					Submerged plants	
V_lemna		0.008					Floating Lemna	
V_emerg			0.004			0.001	Emergents	
V_litt		0.001	0.034	0.001	0.001	0.021	Litter	
M_year						0.027	Last cleared	
D_silt		0.001	0.016	0.045			Silt depth	
V_flalg						0.006	Floating algae	Algae
V_subal		0.007					Submerged algae	
L_hay		0.004					Hay/Silage	Unplaced
D_soil	0.001	0.001					Soil type	
V_flaqu	0.001	0.001					Floating aquatics	

Table 3.31 Variables selected as the best by BVSTEP for six geographic areas grouped by related variables

2 – selected as significant by RDA forward selection, 1 – not selected by RDA

Variable	Gwent	Somerset	Pevensey	Walland	Thames	Norfolk	Variable name	Group
L_cattl	2				2		Cattle-grazed	Cattle effects
S_gmarg	2						Grassy margin	Margin vegetation
D_width						2	Water width	Physical structure
D_depth	1						Water depth	
D_freeb		2				1	Freeboard	
D_cond2				2	2	2	Conductivity	Chemistry
D_pH		2					pH (spring)	
D_pH_1			1	2			pH (summer)	
V_opwat	2	2	2	1			Open water	Open - closed
V_emerg			2				Emergents	
V_litt	1		2	2		2	Litter	
M_year						2	Last cleared	
V_flalg			1				Floating algae	Alga
D_soil		2					Soil type	Unplaced

The following general conclusions were drawn from this analysis:

- The degree of pasture improvement appeared to be unimportant. The selection of hay/silage as an important variable in Somerset was an artefact of the selection procedure; it was likely to have been correlated with another more important variable that had to be excluded during VIF analysis. BVSTEP did not select any land-use categories other than cattle-grazed.

- Factors strongly related to cattle were usually important. The direct effect on aquatic invertebrates was presumably mediated through reduction of marginal shading by tall vegetation and by poaching, and hence the variables of short or tall grass and tall herb appearing as surrogates for trampling and grazing. None of these effects were recognised in the selection by BVSTEP.

- 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. These variables were rarely selected by BVSTEP.

- ‘Chemistry’ was a major factor. This was as expected for conductivity. The significant effects of pH and turbidity were unexpected but as they were often strongly correlated with conductivity they may not have been causal factors. Hence the selection of turbidity in RDA. BVSTEP selected one of these variables at all marshes except Gwent, thus confirming the high significance attached to them in RDA analysis.

- 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, although emergent vegetation was often excluded during VIF analysis as it was strongly correlated with leaf litter. 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 selected. Western marshes had large amounts of floating *Lemna*, which appears in the selection either as open water or

Lemna itself; the infrequency of *Lemna* in eastern marshes explained its non-selection here. BVSTEP also found these variables to have high importance.

- The significance of algae to invertebrates was obscure and it was an unexpected variable that was selected on two areas.
- Soil type (peat or mineral) varied only in Gwent, Somerset and Norfolk but had a realistic impact on the invertebrate assemblages only at the Somerset marshes.

6 References

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APPENDIX 4

Evaluation of invertebrate assemblages and wetlands

Appendix 4 relates to Section 6 of Volume 1 of this report

1 Application of species metrics

The faunal interest of each marsh and each major geographic area was summarised by metrics for the following attributes: Species Richness, Species Conservation Status (SCS: threat and rarity), Habitat Quality and Naturalness. The application of the first two 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

The other two metrics, which were not recommended for use in the final version of the *Manual*, were tested on the dataset, with species scored as follows.

- 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 was 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 was the sum of scores for the non-native species.

Habitat Quality Scores and Naturalness Scores for individual species are included in the *Manual.* In addition, use of a salinity index is described and the salinity tolerance (on the scale 0, 1, 2) of each species is shown. 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; this has no counterpart in parametric statistics.

A Kolmogorov-Smirov test for normality on a sample of 21 marshes indicated that species richness, SCS Score and Habitat Quality Score were usually normally distributed and that there was relatively little skewness in the data (Table 4.1). The use of parametric ANOVA to test differences in mean values was therefore justified in most cases. Naturalness Score and salinity index behaved erratically owing to the few values in each sample (of non-native and brackish-associated species, respectively), leading to considerable skewness, so that mean values, and certainly confidence limits, were unlikely to be particularly meaningful.

In Walland, North Kent and Norfolk, scores for individual marshes were significantly different from one another. These differences are shown in Sections 1.1, 1.2 and 1.3 and Figures 4.1, 4.2 and 4.3. Figure 4.4 (Section 1.4 of this appendix) shows the means and median values for the main areas. Mean and median values for each marsh are in Table 4.2, those for larger areas are in Table 4.3, those for individual marshes after combining all samples into a single list are in Table 4.4, and the values for combined lists of the larger area are in Tables 4.5 and repeated in Figure 4.5. Table 4.6 gives the values for the entire dataset, which can be used as yardsticks against which to judge values for each marsh.

Table 4.1. Statistical behaviour of untransformed metrics for some marshes, giving the significance of the test statistics

SR – Species Richness, SCS – Species Conservation Status Score, HQ – Habitat Quality Score, Nat – Naturalness Score, Bra – Salinity index.
Significance levels: n.s. – not significant, * - p<0.05, ** - p<0.01, *** - p<0.001.

	Kolmogorov-Smirnov					Skewness					Kurtosis				
	SR	SCS	HQ	Nat	Bra	SR	SCS	HQ	Nat	Bra	SR	SCS	HQ	Nat	Bra
Malltraeth	*	ns	ns	*		ns	ns	ns	ns		-	-	-	-	
Wentlooge	*	ns	ns	ns	ns	ns	ns	ns	**	*	-	-	-	-	-
Caldicot	Ns	ns	ns	ns	ns	ns	ns	ns	ns	***	ns	ns	ns	ns	**
Catcott	Ns	ns	ns	ns	ns	ns	ns	ns	***	***	ns	ns	ns	ns	***
Kenn	*	ns	ns	ns	ns	ns	ns	ns	***	**	ns	ns	ns	***	ns
Kings Sedgemoor	Ns	*	ns	***	***	ns	ns	*	***	***	ns	ns	ns	***	***
Moorlinch	Ns	ns	ns	ns	ns	ns	ns	ns	ns	*	-	-	-	-	-
Somerset Non-SSSI-Clay	Ns	ns	ns	***	***	-	-	-	***	***	-	-	-	***	***
Somerset Non-SSSI-Peat	Ns	ns	ns	ns	ns	-	-	-	-	-	-	-	-	-	-
Pawlett	Ns	ns	ns	ns	ns	ns	ns	ns	ns	***	-	-	-	-	-
Tadham	Ns	ns	ns	ns	***	ns	ns	ns	ns	***	ns	ns	ns	ns	***
Amberley	*	ns	ns	***	***	ns	ns	*	***	***	-	-	-	***	***
Pulborough	Ns	ns	ns	***	***	ns	ns	ns	***	***	-	-	-	***	***
Broomhill	Ns	ns	ns	***	ns	-	-	-	***	-	-	-	-	***	-
Cheyne Court	Ns	ns	ns	ns	ns	-	-	-	-	-	-	-	-	-	-
Fairfield	Ns	ns	ns	*	***	ns	ns	ns	**	***	-	-	-	-	***
The Dowels	*	ns	ns	ns	ns	ns	ns	ns	***	ns	***	-	-	-	-
Walland (arable)	Ns	ns	ns	*	ns	-	-	-	-	-	-	-	-	-	-
East Guldeford	Ns	ns	ns	*	ns	ns	ns	ns	ns	*	-	-	-	-	-

1.1 Walland Marsh

The species richness and species conservation score for subsites on Walland Marsh, including the five arable ditches treated as a unit, differed significantly (F=3.07, p=0.0199 and F=4.78, p=0.0017, respectively) but there was no difference in habitat quality scores (Figure 4.1). The arable ditches were noticeably poorer than most SSSI marshes.

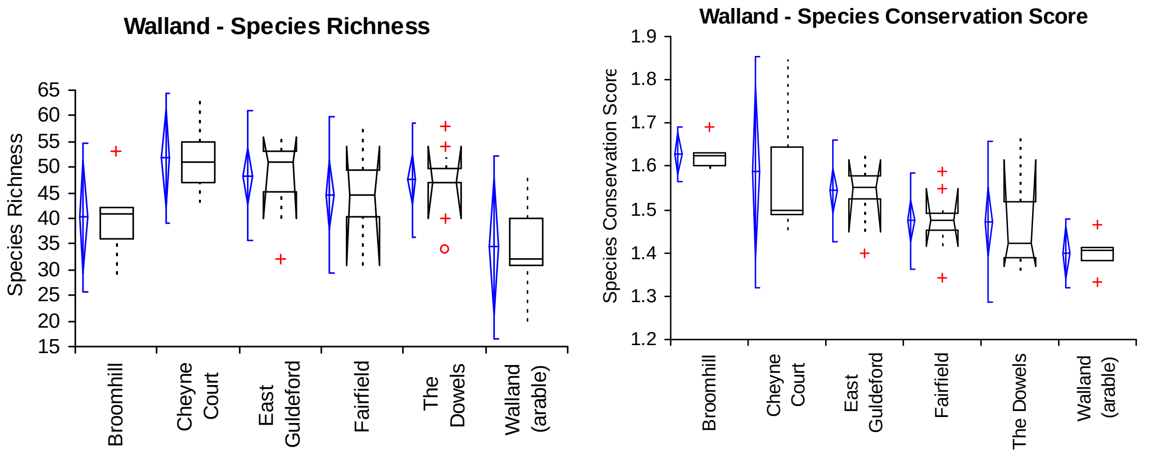


Figure 4.1. Species richness and Species Conservation Status scores for separate marshes at Walland Marsh

1.2 North Kent marshes

All metrics differed significantly between the five blocks of marshes so local variation needed to be taken into consideration when the whole North Kent marshes were compared with other areas. As can be seen in Figure 4.2, these differences were likely to be due to the low species richness at Chetney Marshes, the high SCS and habitat quality scores at Grain & Allhallows marshes and the low values of these metrics at Graveney & Seasalter. The salinity index clearly separated the more freshwater Shorne (0.86) and Graveney & Seasalter (2.1) from the brackish sites (4.42 – 7.55).

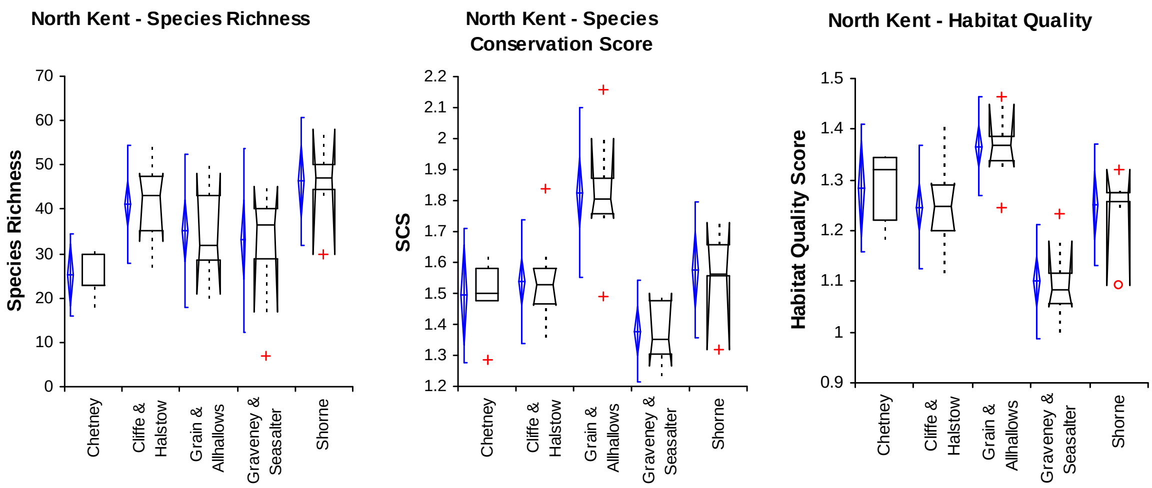
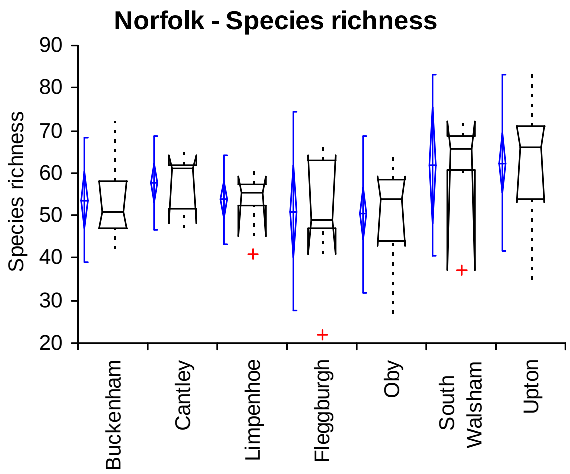


Figure 4.2. Species metrics for individual North Kent marshes

1.3 Norfolk Marshes

There were no differences in the species metrics between the Yare and Bure marshes, but species richness and species conservation score differed between individual marshes (for species richness F=2.34, p=0.041, for conservation score F=2.67, p=0.027, N= 75) (Figure 4.3).



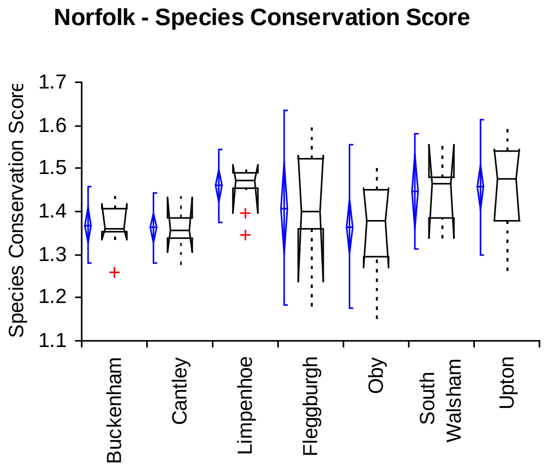


Figure 4.3. Species metrics for individual Norfolk marshes

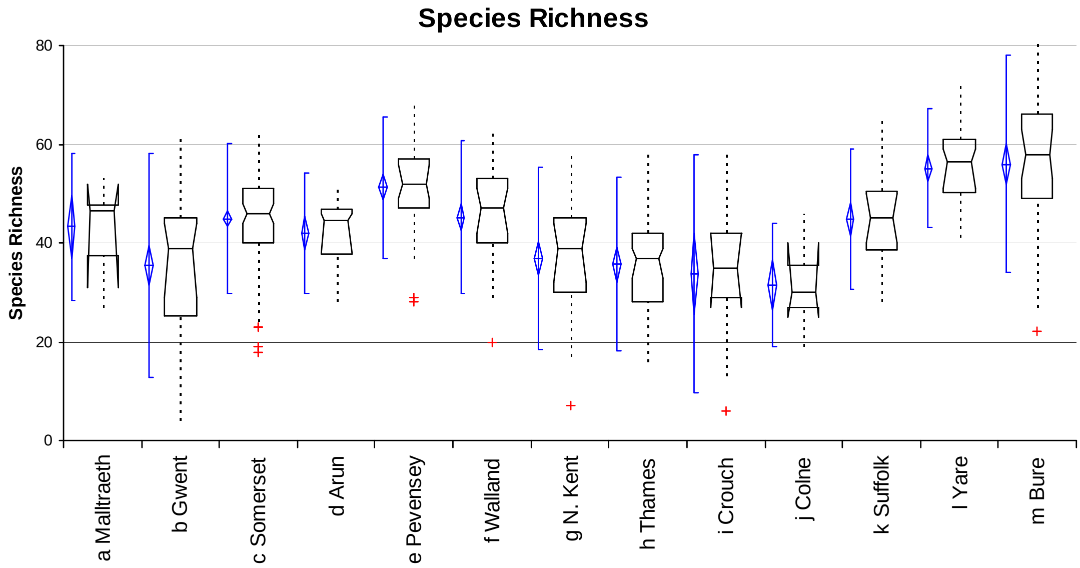
1.4 All areas

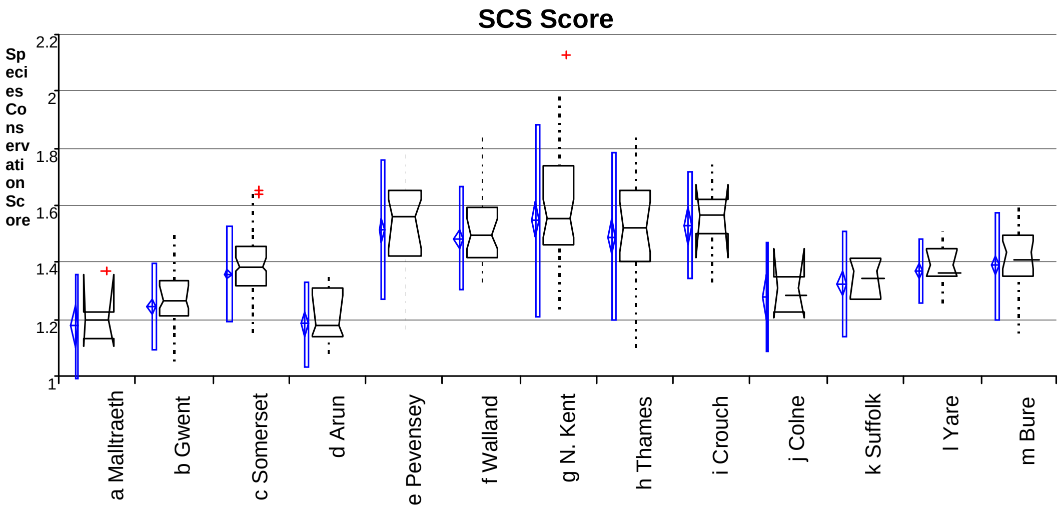
Species richness, Species Conservation Status Score and Habitat Quality Score (mean and median) for each main area are shown in Figure 4.4.

Mean and median values for each marsh are in Table 4.2, those for larger areas are in Table 4.3, those for individual marshes after combining all samples into a single list are in Table 4.4, and the values for combined lists of the larger area are in Tables 4.5.

Figure 4.5 shows the species metrics estimated for the total species list for each main area.

Table 4.6 gives the values for the entire dataset, which can be used as yardsticks against which to judge values for each marsh.





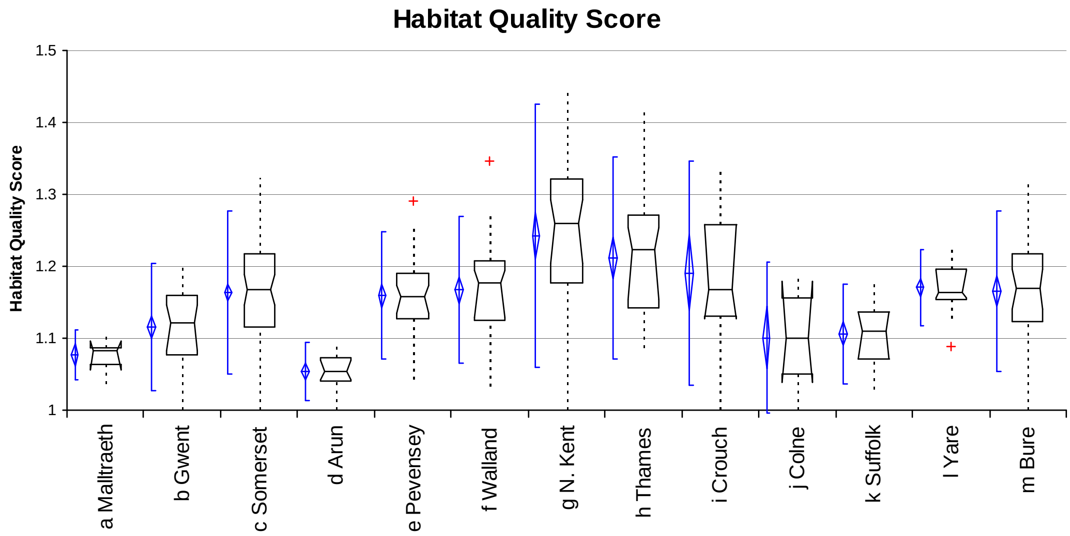


Figure 4.4. Species richness, Species Conservation Status Score and Habitat Quality Score (mean and median) for each main area (data as in Table 4.3)

Table 4.2 Mean and median values for five species metrics at each marsh

Species Richness	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Malltraeth	10	43.3	36.8	49.8	46.5	10.3	31.0	52.0
Wentlooge	14	35.0	28.1	41.9	39.0	7.8	20.0	44.0
Caldicot	36	35.6	30.7	40.6	41.5	20.8	27.0	45.0
Catcott	25	44.1	39.2	49.1	46.0	14.0	40.0	53.0
Kenn	20	42.0	36.5	47.5	44.5	15.8	38.0	49.0
Kings Sedgemoor	20	44.6	41.4	47.8	45.5	10.8	40.0	50.0
Moorlinch	16	46.4	42.7	50.0	47.5	10.3	42.0	53.0
Non-SSSI-Clay	5	40.6	34.2	47.0	38.0	7.0	-	to -
Non-SSSI-Peat	5	40.4	23.1	57.7	43.0	11.0	-	to -
Pawlett	15	41.3	36.0	46.7	43.0	8.5	34.0	46.0
Tadham	21	48.5	45.3	51.7	49.0	9.0	44.0	53.0
West Sedgemoor	24	48.4	46.0	50.8	50.0	7.0	45.0	51.0
Amberley	10	43.9	39.1	48.7	46.0	4.3	37.0	51.0
Pulborough	10	40.1	34.4	45.8	42.0	10.8	30.0	48.0
Pevensey	45	51.3	48.7	53.9	52.0	10.0	49.0	56.0
Broomhill	5	40.2	29.3	51.1	41.0	6.0	-	to -
Cheyne Court	5	51.8	42.2	61.4	51.0	8.0	-	to -
East Guldeford	10	48.3	42.8	53.8	51.0	7.8	40.0	56.0
Fairfield	10	44.6	37.9	51.3	44.5	9.3	31.0	54.0
The Dowels	10	47.5	42.6	52.4	47.0	2.8	40.0	54.0
Walland (arable)	5	34.4	21.0	47.8	32.0	9.0	-	to -
Shorne	7	46.3	38.2	54.4	47.0	5.5	30.0	58.0
Cliffe	12	41.3	36.1	46.4	43.0	12.3	33.0	48.0
Allhallows	11	35.1	28.1	42.1	32.0	14.5	21.0	48.0
Chetney	5	25.2	18.1	32.3	23.0	7.0	-	to -
Graveney	10	33.1	24.1	42.1	36.5	11.0	17.0	45.0
Hadleigh Marsh	7	39.0	30.2	47.8	38.0	16.5	27.0	49.0
Rainham	15	31.3	26.0	36.5	31.0	16.0	22.0	39.0
Vange & Fobbing	15	38.7	32.4	44.9	39.0	7.5	34.0	43.0
Fambridge	15	33.8	25.7	41.9	35.0	13.0	27.0	42.0
Brightlingsea	11	31.5	26.4	36.6	30.0	8.5	25.0	40.0
Shotley	7	40.1	33.4	46.9	37.0	6.5	34.0	55.0
Sizewell	9	46.1	41.3	50.9	46.0	8.0	40.0	54.0
Minsmere	11	46.8	39.9	53.8	45.0	10.5	35.0	57.0
Buckenham	9	53.7	46.9	60.5	51.0	11.0	47.0	58.0
Cantley	11	57.6	53.1	62.2	61.0	10.5	48.0	64.0
Limpenhoe	10	53.7	49.2	58.2	55.5	5.0	45.0	59.0
Fleggburgh	9	51.0	40.1	61.9	49.0	16.0	41.0	64.0
Oby	15	50.4	44.2	56.6	54.0	14.5	43.0	59.0
South Walsham	21	62.2	56.5	67.8	66.0	16.0	55.0	71.0

Table 4.2 continued

Species Conservation Status Score	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Malltraeth	10	1.20	1.13	1.28	1.20	0.09	1.11	1.36
Wentlooge	14	1.29	1.25	1.32	1.30	0.09	1.21	1.35
Caldicot	34	1.27	1.23	1.30	1.26	0.13	1.22	1.32
Catcott	25	1.40	1.34	1.45	1.39	0.17	1.31	1.45
Kenn	20	1.31	1.27	1.36	1.32	0.11	1.26	1.37
Kings Sedgemoor	20	1.44	1.40	1.48	1.45	0.06	1.43	1.47
Moorlinch	16	1.37	1.33	1.42	1.38	0.13	1.31	1.45
Non-SSSI-Clay	5	1.29	1.17	1.42	1.35	0.16	-	to -
Non-SSSI-Peat	5	1.48	1.33	1.62	1.49	0.02	-	to -
Pawlett	15	1.38	1.33	1.43	1.38	0.10	1.33	1.44
Tadham	21	1.39	1.35	1.43	1.40	0.09	1.35	1.44
West Sedgemoor	24	1.41	1.37	1.45	1.40	0.13	1.34	1.47
Amberley	10	1.20	1.14	1.26	1.18	0.13	1.11	1.32
Pulborough	10	1.22	1.15	1.29	1.19	0.09	1.14	1.35
Pevensey	45	1.54	1.50	1.59	1.56	0.24	1.45	1.63
Broomhill	5	1.63	1.58	1.68	1.63	0.03	-	to -
Cheyne Court	5	1.59	1.38	1.79	1.50	0.16	-	to -
East Guldeford	10	1.54	1.49	1.59	1.55	0.05	1.45	1.62
Fairfield	10	1.47	1.43	1.52	1.47	0.04	1.41	1.55
The Dowels	10	1.47	1.39	1.55	1.42	0.13	1.37	1.61
Walland (arable)	5	1.40	1.34	1.46	1.41	0.03	-	to -
Shorne	7	1.58	1.45	1.70	1.56	0.10	1.32	1.73
Cliffe	12	1.54	1.46	1.62	1.53	0.11	1.46	1.58
Allhallows	11	1.82	1.71	1.94	1.81	0.11	1.74	2.00
Chetney	5	1.49	1.33	1.66	1.50	0.10	-	to -
Graveney	9	1.38	1.30	1.45	1.35	0.17	1.27	1.50
Hadleigh Marsh	7	1.53	1.39	1.67	1.53	0.20	1.28	1.71
Rainham	15	1.40	1.33	1.48	1.44	0.17	1.32	1.52
Vange & Fobbing	15	1.63	1.54	1.72	1.72	0.24	1.44	1.74
Fambridge	14	1.56	1.49	1.63	1.57	0.12	1.41	1.68
Brightlingsea	11	1.31	1.23	1.38	1.31	0.12	1.21	1.45
Shotley	7	1.29	1.19	1.40	1.24	0.19	1.18	1.42
Sizewell	9	1.37	1.28	1.45	1.35	0.15	1.28	1.47
Minsmere	11	1.38	1.31	1.45	1.38	0.13	1.26	1.53
Buckenham	9	1.37	1.33	1.41	1.36	0.05	1.33	1.42
Cantley	11	1.36	1.33	1.40	1.36	0.05	1.30	1.43
Limpenhoe	10	1.46	1.42	1.50	1.47	0.04	1.40	1.51
Fleggburgh	9	1.41	1.30	1.51	1.40	0.16	1.24	1.53
Oby	15	1.37	1.30	1.43	1.38	0.16	1.27	1.45
South Walsham	21	1.45	1.41	1.49	1.48	0.16	1.38	1.54

Table 4.2 continued

Habitat Quality Score	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Malltraeth	10	1.08	1.06	1.09	1.08	0.02	1.06	1.10
Wentlooge	14	1.13	1.10	1.15	1.12	0.07	1.08	1.17
Caldicot	36	1.11	1.09	1.13	1.12	0.09	1.08	1.16
Catcott	25	1.14	1.12	1.17	1.15	0.11	1.10	1.17
Kenn	20	1.12	1.09	1.16	1.13	0.09	1.08	1.16
Kings Sedgemoor	20	1.19	1.16	1.21	1.20	0.07	1.18	1.23
Moorlinch	16	1.17	1.13	1.20	1.19	0.10	1.12	1.22
Non-SSSI-Clay	5	1.09	1.03	1.15	1.11	0.07	-	to -
Non-SSSI-Peat	5	1.19	1.12	1.27	1.20	0.08	-	to -
Pawlett	15	1.21	1.18	1.25	1.21	0.07	1.18	1.28
Tadham	21	1.18	1.15	1.21	1.19	0.09	1.14	1.23
West Sedgemoor	24	1.16	1.13	1.18	1.15	0.07	1.13	1.19
Amberley	10	1.06	1.04	1.08	1.07	0.02	1.04	1.08
Pulborough	10	1.05	1.03	1.07	1.04	0.02	1.02	1.09
Pevensey	45	1.16	1.14	1.17	1.16	0.06	1.13	1.17
Broomhill	5	1.20	1.17	1.24	1.21	0.02	-	to -
Cheyne Court	5	1.21	1.10	1.32	1.18	0.08	-	to -
East Guldeford	10	1.17	1.13	1.21	1.19	0.08	1.09	1.22
Fairfield	10	1.13	1.09	1.17	1.13	0.06	1.05	1.20
The Dowels	10	1.18	1.13	1.22	1.18	0.05	1.11	1.24
Walland (arable)	5	1.13	1.07	1.20	1.13	0.02	-	to -
Shorne	7	1.25	1.18	1.31	1.26	0.02	1.09	1.32
Cliffe	12	1.24	1.20	1.29	1.24	0.09	1.19	1.29
Allhallows	11	1.36	1.32	1.39	1.35	0.06	1.32	1.43
Chetney	5	1.28	1.18	1.37	1.30	0.12	-	to -
Graveney	10	1.10	1.05	1.15	1.08	0.06	1.05	1.18
Hadleigh Marsh	7	1.27	1.21	1.33	1.29	0.06	1.16	1.33
Rainham	15	1.14	1.11	1.18	1.14	0.05	1.10	1.15
Vange & Fobbing	15	1.25	1.22	1.29	1.25	0.06	1.21	1.31
Fambridge	15	1.19	1.14	1.24	1.17	0.13	1.13	1.26
Brightlingsea	11	1.10	1.06	1.14	1.10	0.11	1.04	1.18
Shotley	7	1.12	1.07	1.17	1.11	0.07	1.03	1.18
Sizewell	9	1.09	1.07	1.12	1.10	0.04	1.06	1.13
Minsmere	11	1.11	1.08	1.13	1.11	0.08	1.07	1.16
Buckenham	9	1.18	1.15	1.20	1.17	0.06	1.16	1.22
Cantley	11	1.17	1.15	1.19	1.16	0.03	1.15	1.20
Limpenhoe	10	1.16	1.14	1.19	1.16	0.04	1.13	1.20
Fleggburgh	9	1.15	1.11	1.19	1.15	0.07	1.09	1.22
Oby	15	1.14	1.10	1.18	1.15	0.07	1.12	1.19
South Walsham	21	1.19	1.16	1.22	1.21	0.07	1.16	1.24

Table 4.2 continued

Naturalness Score	n	Mean	LCL	UCL	Median	IQR
Malltraeth	10	-4.40	-4.42	-4.38	-3.50	2.00
Wentlooge	14	-4.29	-4.31	-4.26	-5.00	5.00
Caldicot	36	-3.28	-3.29	-3.26	-3.00	3.00
Catcott	25	-3.32	-3.33	-3.31	-3.00	0.00
Kenn	20	-3.20	-3.21	-3.19	-3.00	0.00
Kings Sedgemoor	20	-3.00	-	-	-3.00	0.00
Moorlinch	16	-3.25	-3.27	-3.23	-3.00	3.00
Non-SSSI-Clay	5	-3.00	-	-	-3.00	0.00
Non-SSSI-Peat	5	-2.40	-2.43	-2.37	-3.00	3.00
Pawlett	15	-1.60	-1.63	-1.57	0.00	0.00
Tadham	21	-4.05	-4.06	-4.03	-3.00	0.00
West Sedgemoor	24	-2.96	-2.97	-2.95	-3.00	3.00
Amberley	10	-3.00	-	-	-3.00	0.00
Pulborough	10	-3.00	-	-	-3.00	0.00
Pevensey	45	-3.00	-	-	-3.00	0.00
Broomhill	5	-3.00	-	-	-3.00	0.00
Cheyne Court	5	-2.40	-2.43	-2.37	-3.00	3.00
East Guldeford	10	-2.10	-2.13	-2.07	-0.75	3.00
Fairfield	10	-3.00	-3.03	-2.97	-2.00	0.50
The Dowels	10	-3.20	-3.21	-3.19	-3.00	0.00
Walland (arable)	5	-3.80	-3.83	-3.77	-3.00	0.00
Shorne	7	-4.43	-4.46	-4.40	-3.00	2.00
Cliffe	12	-1.33	-1.37	-1.30	0.00	0.00
Allhallows	11	-1.09	-1.11	-1.07	0.00	2.00
Chetney	5	-0.80	-0.83	-0.77	0.00	0.00
Graveney	10	-3.70	-3.73	-3.67	-3.00	1.00
Hadleigh Marsh	7	-2.86	-2.88	-2.83	-2.00	0.00
Rainham	15	-3.27	-3.29	-3.24	-3.00	3.00
Vange & Fobbing	15	-2.20	-2.22	-2.18	-1.00	3.00
Fambridge	15	-2.40	-2.43	-2.37	-1.00	2.00
Brightlingsea	11	-5.36	-5.40	-5.33	-4.00	2.00
Shotley	7	-2.86	-2.88	-2.83	-2.00	1.00
Sizewell	9	-3.22	-3.24	-3.21	-3.00	0.00
Minsmere	11	-3.36	-3.38	-3.35	-3.00	0.00
Buckenham	9	-3.00	-	-	-3.00	0.00
Cantley	11	-3.00	-	-	-3.00	0.00
Limpenhoe	10	-3.30	-3.32	-3.28	-3.00	1.00
Fleggburgh	9	-3.00	-	-	-3.00	0.00
Oby	15	-3.20	-3.22	-3.18	-3.00	1.00
South Walsham	21	-2.81	-2.82	-2.80	-3.00	3.00

Table 4.2 continued

Salinity index	n	Mean	LCL	UCL	Median	IQR
Malltraeth	10	0.10	0.09	0.11	0.00	1.00
Wentlooge	14	0.64	0.63	0.66	1.00	3.00
Caldicot	36	0.22	0.22	0.23	0.00	2.00
Catcott	25	0.08	0.08	0.08	0.00	1.00
Kenn	20	0.20	0.19	0.21	0.00	1.00
Kings Sedgemoor	20	0.05	0.05	0.05	0.00	1.00
Moorlinch	16	0.25	0.24	0.26	0.25	1.00
Non-SSSI-Clay	5	0.00	-	-	0.00	0.00
Non-SSSI-Peat	5	0.20	0.19	0.21	0.00	1.00
Pawlett	15	0.13	0.13	0.14	0.00	1.00
Tadham	21	0.00	-	-	0.00	0.00
West Sedgemoor	24	0.17	0.16	0.17	0.00	1.00
Amberley	10	0.00	-	-	0.00	0.00
Pulborough	10	0.00	-	-	0.00	0.00
Pevensey	45	0.09	0.09	0.09	0.00	1.00
Broomhill	5	0.60	0.58	0.62	1.00	2.00
Cheyne Court	5	1.80	1.75	1.85	3.00	4.00
East Guldeford	10	1.20	1.17	1.23	1.00	4.00
Fairfield	10	4.20	4.10	4.30	7.50	12.00
The Dowels	10	1.10	1.08	1.12	2.00	2.00
Walland (arable)	5	1.00	0.96	1.04	1.00	4.00
Shorne	7	0.86	0.83	0.88	1.50	3.00
Cliffe	12	4.42	4.37	4.47	6.00	7.00
Allhallows	11	7.55	7.49	7.60	9.00	5.00
Chetney	5	7.40	7.33	7.47	8.00	3.00
Graveney	10	2.10	2.03	2.17	2.75	11.00
Hadleigh Marsh	7	4.14	4.08	4.21	6.00	3.00
Rainham	15	1.53	1.50	1.57	1.50	6.00
Vange & Fobbing	15	4.87	4.79	4.94	8.00	12.00
Fambridge	15	5.00	4.96	5.04	7.50	7.00
Brightlingsea	11	1.00	0.98	1.02	1.50	3.00
Shotley	7	4.71	4.60	4.83	10.00	9.00
Sizewell	9	0.11	0.10	0.12	0.00	1.00
Minsmere	11	1.09	1.07	1.11	1.00	2.00
Buckenham	9	0.00	-	-	0.00	0.00
Cantley	11	0.36	0.35	0.38	0.50	2.00
Limpenhoe	10	1.20	1.16	1.24	2.00	6.00
Fleggburgh	9	0.00	-	-	0.00	0.00
Oby	15	0.73	0.71	0.76	0.50	4.00
South Walsham	21	0.67	0.66	0.68	1.00	3.00

Table 4.3 Mean and median species richness, Species Conservation Status Score and Habitat Quality Score for each main area

Species Richness	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Anglesey	10	43.3	36.8	49.8	46.5	10.3	31.0	52.0
Gwent	50	35.5	31.5	39.4	39.0	19.8	29.0	44.0
Somerset	151	44.9	43.4	46.4	46.0	11.0	44.0	48.0
Arun	20	42.0	38.5	45.5	44.5	9.0	38.0	46.0
Pevensey	45	51.3	48.7	53.9	52.0	10.0	49.0	56.0
Walland	45	45.2	42.4	48.0	47.0	13.0	42.0	51.0
N. Kent	45	36.9	33.6	40.3	39.0	15.0	32.0	44.0
Thames	37	35.7	32.2	39.3	37.0	14.0	33.0	39.0
Crouch	15	33.8	25.7	41.9	35.0	13.0	27.0	42.0
Colne	11	31.5	26.4	36.6	30.0	8.5	25.0	40.0
Suffolk	27	44.9	41.4	48.3	45.0	12.0	40.0	50.0
Yare	30	55.1	52.4	57.9	56.5	10.8	51.0	59.0
Bure	45	56.0	52.0	60.1	58.0	17.0	53.0	63.0
All marshes	531	44.1	43.01	45.11	45.0	16.0	44.0	46.0

Species Conservation Status Score	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Anglesey	10	1.20	1.13	1.28	1.20	0.09	1.11	1.36
Gwent	48	1.27	1.25	1.30	1.27	0.13	1.24	1.32
Somerset	151	1.39	1.37	1.40	1.39	0.14	1.37	1.42
Arun	20	1.21	1.17	1.25	1.18	0.17	1.14	1.29
Pevensey	45	1.54	1.50	1.59	1.56	0.24	1.45	1.63
Walland	45	1.51	1.48	1.54	1.50	0.18	1.45	1.56
N. Kent	44	1.58	1.52	1.64	1.56	0.27	1.49	1.62
Thames	37	1.52	1.46	1.58	1.52	0.26	1.44	1.62
Crouch	14	1.56	1.49	1.63	1.57	0.12	1.41	1.68
Colne	11	1.31	1.23	1.38	1.31	0.12	1.21	1.45
Suffolk	27	1.35	1.31	1.40	1.37	0.15	1.28	1.41
Yare	30	1.40	1.37	1.42	1.39	0.09	1.36	1.44
Bure	45	1.42	1.38	1.45	1.44	0.15	1.38	1.48
All marshes	527	1.42	1.41	1.43	1.41	0.19	1.39	1.42

Habitat Quality Score	n	Mean	95% CI of Mean		Median	IQR	95% CI of Median	
Anglesey	10	1.08	1.06	1.09	1.08	0.02	1.06	1.10
Gwent	50	1.12	1.10	1.13	1.12	0.08	1.08	1.15
Somerset	151	1.16	1.15	1.18	1.17	0.10	1.15	1.19
Arun	20	1.05	1.04	1.07	1.05	0.03	1.04	1.07
Pevensey	45	1.16	1.14	1.17	1.16	0.06	1.13	1.17
Walland	45	1.17	1.15	1.19	1.18	0.08	1.13	1.20
N. Kent	45	1.24	1.21	1.28	1.26	0.14	1.20	1.29
Thames	37	1.21	1.18	1.24	1.22	0.13	1.15	1.25
Crouch	15	1.19	1.14	1.24	1.17	0.13	1.13	1.26
Colne	11	1.10	1.06	1.14	1.10	0.11	1.04	1.18
Suffolk	27	1.11	1.09	1.12	1.11	0.07	1.07	1.14
Yare	30	1.17	1.16	1.18	1.16	0.04	1.16	1.19
Bure	45	1.17	1.15	1.19	1.17	0.09	1.14	1.20
All marshes	531	1.16	1.15	1.17	1.16	0.11	1.15	1.16

Table 4.4 Species metrics estimated for the total species list for each marsh

Area	Marsh	Total Species	SCS Score	HQ Score	Naturalness Score	Salinity index
Anglesey	Malltraeth	116	1.31	1.09	-5	1
Gwent	Gwent Levels	166	1.45	1.14	-7	10
Somerset	Catcott	154	1.56	1.18	-5	1
	Kenn	127	1.48	1.18	-5	1
	Kings Sedgemoor	147	1.51	1.18	-3	1
	Moorlinch	136	1.50	1.19	-5	1
	Non-SSSI-Clay	89	1.42	1.16	-3	0
	Non-SSSI-Peat	95	1.57	1.23	-3	1
	Pawlett	109	1.42	1.25	-7	1
	Tadham	135	1.53	1.19	-7	0
	West Sedgemoor	156	1.53	1.17	-5	1
Arun	Amberley	116	1.35	1.12	-3	0
	Pulborough	111	1.33	1.10	-3	0
Pevensey	Pevensey	174	1.66	1.21	-3	3
Walland	Broomhill	94	1.63	1.19	-3	2
	Cheyne Court	114	1.75	1.23	-3	8
	East Guldeford	130	1.65	1.18	-3	7
	Fairfield	127	1.62	1.17	-7	19
	The Dowels	127	1.63	1.17	-5	6
	Walland (arable)	100	1.52	1.21	-5	5
North Kent	Allhallows	89	1.61	1.28	-2	18
	Chetney	57	1.53	1.25	-2	13
	Cliffe	90	1.64	1.26	-2	14
	Grain	82	1.68	1.28	-2	21
	Graveney	101	1.49	1.19	-7	13
	Halstow	111	1.54	1.21	-5	13
	Seasalter	59	1.36	1.08	-7	0
	Shorne	109	1.68	1.24	-7	3
Thames	Hadleigh Marsh	98	1.63	1.26	-7	12
	Rainham	120	1.58	1.22	-7	11
	Vange & Fobbing	149	1.60	1.22	-7	26
Crouch	Fambridge	137	1.62	1.23	-7	20
Colne	Brightlingsea	95	1.50	1.20	-7	8
Suffolk	Shotley	103	1.45	1.18	-5	16
	Sizewell	150	1.66	1.19	-5	7
Yare	Buckenham	123	1.42	1.17	-3	0
	Cantley	129	1.44	1.19	-3	3
	Limpenhoe	124	1.54	1.18	-5	6
Bure	Fleggburgh	134	1.62	1.21	-3	0
	Oby	133	1.60	1.23	-5	7
	South Walsham	121	1.60	1.21	-5	2
	Upton	164	1.63	1.21	-3	5

Table 4.5 Species metrics estimated for the total species list for each main area

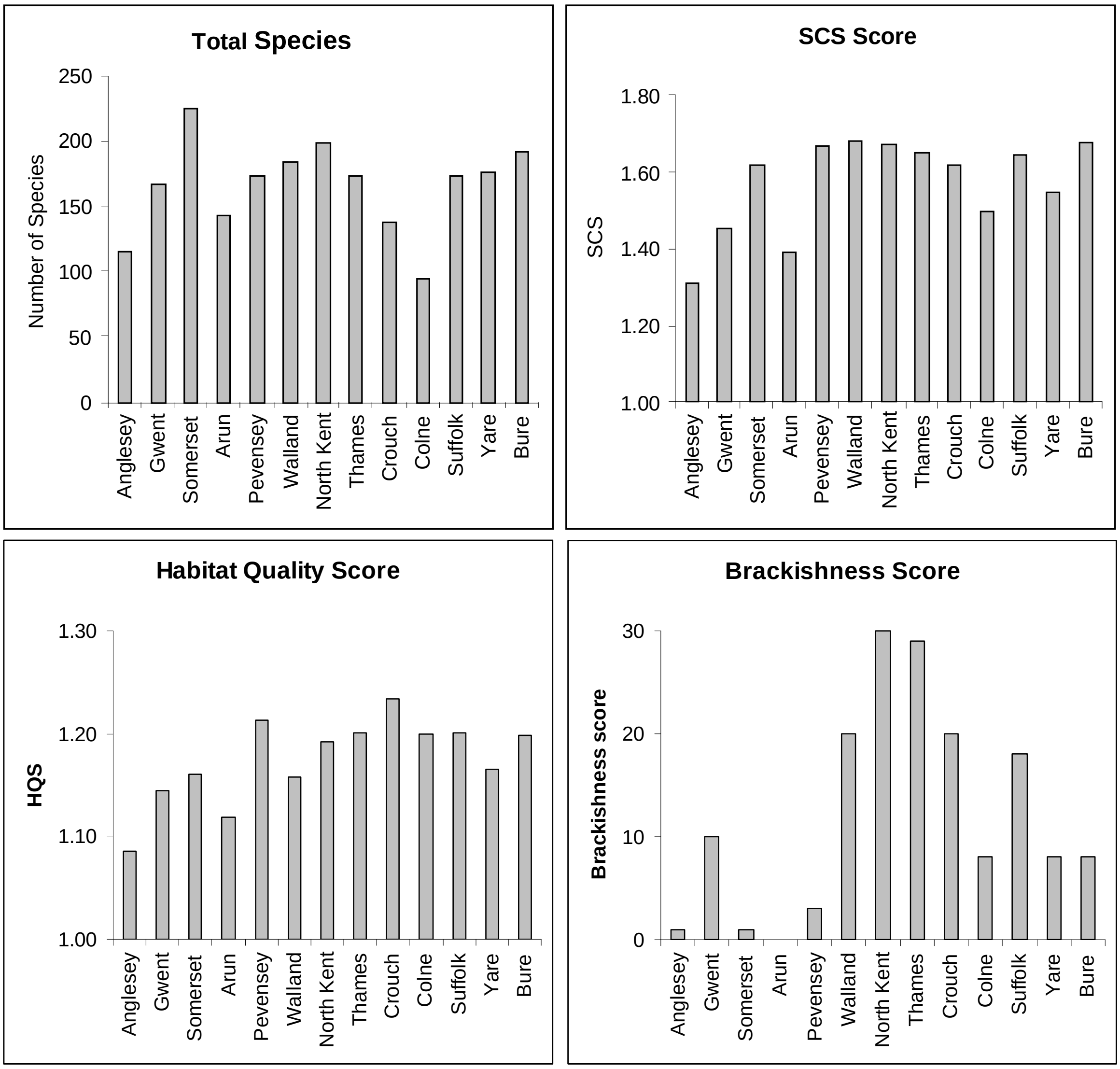
* - excludes 20 higher taxa that duplicate species-level names but not higher taxa that are unique to the dataset; none of these are included in SCS Score or HQ Score calculations.

Area	Total Species	SCS Score	HQ Score	Naturalness Score	Salinity index
Anglesey	116	1.31	1.09	-5	1
Gwent	166	1.45	1.14	-7	10
Somerset	224	1.62	1.16	-7	1
Arun	143	1.39	1.12	-3	0
Pevensey	174	1.66	1.21	-3	3
Walland	183	1.68	1.16	-7	20
North Kent	198	1.67	1.19	-7	30
Thames	174	1.65	1.20	-7	29
Crouch	137	1.62	1.23	-7	20
Colne	95	1.50	1.20	-7	8
Suffolk	174	1.65	1.20	-5	18
Yare	176	1.55	1.16	-5	8
Bure	192	1.67	1.20	-5	8
All marshes	330*	1.87	1.15	-7	36

Table 4.6 Mean and median of species metrics for freshwater and brackish sites, using 2000µS cm^{-1} as the threshold. Medians with lower and upper quartiles

	Number of species			SCS Score	HQ Score	Natural-ness Score	Salinity index
	All taxa	Beetles	Molluscs				
Mean							
Fresh	45.9	19.5	10.2	1.393	1.15	-3.22	0.53
Brackish	37.7	19.1	3.6	1.520	1.21	-2.41	7.50
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)	0 (0)
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)	5 (2-12)

Figure 4.5 Species metrics estimated for the total species list for each main area



2 Salinity

Salinity is known to influence species-richness, so freshwater and brackish water sites should not be directly compared. The behaviour of the species metrics in relation to conductivity is shown in Figure 4.6. Species-richness data fitted a two-order polynomial better than a simple linear regression linear, and showed small declines in richness at low and high conductivities. Although the regression was highly significant, it was a poor predictor as it explained only 15% of the variance in species-richness and the 95% confidence bands (the outer lines on Figure 4.6) are wide. Low species-richness at low conductivities may have been partly an artifact of inadequate sampling in the Gwent Levels during flooding when rainwater was probably responsible for low conductivities, but small values were also recorded at Malltraeth and Arun marshes.

SCS score and habitat quality score both increased with conductivity. As with species richness, the regressions were highly significant but explained only a small percentage of the variance - 23% for SCS score and 17% habitat quality scores (Figure 4.6). Nevertheless, all these metrics differed with conductivity, so fresh and brackish sites need to be evaluated against different national thresholds.

A conductivity of 2000μS cm^{-1} was chosen to separate fresh from brackish samples. Table 4.6 gives mean and median values for the metrics in fresh and brackish sites. However, these average values 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 sites, whereas molluscs showed an unambiguously marked decline in richness above the 2000μS cm^{-1} threshold (Figure 4.7).

Figure 4.8 shows the number of samples from fresh and brackish ditches in each main area of the survey. Samples from marshes west of Kent were from almost entirely fresh ditches, and those from the greater Thames estuary marshes were mainly brackish. A mixture of both types was sampled in the remaining areas.

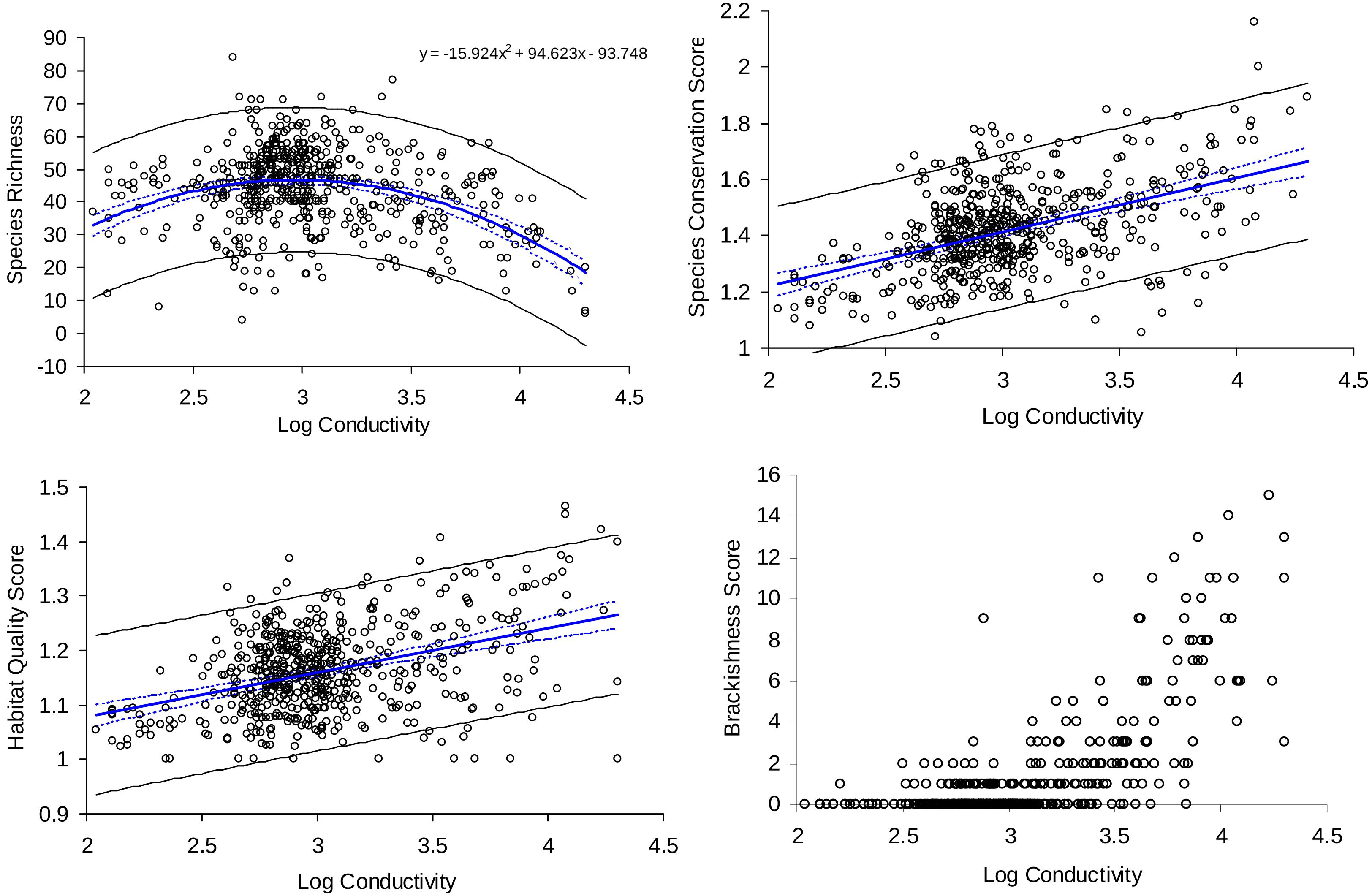


Figure 4.6 Relationship of species metrics with conductivity

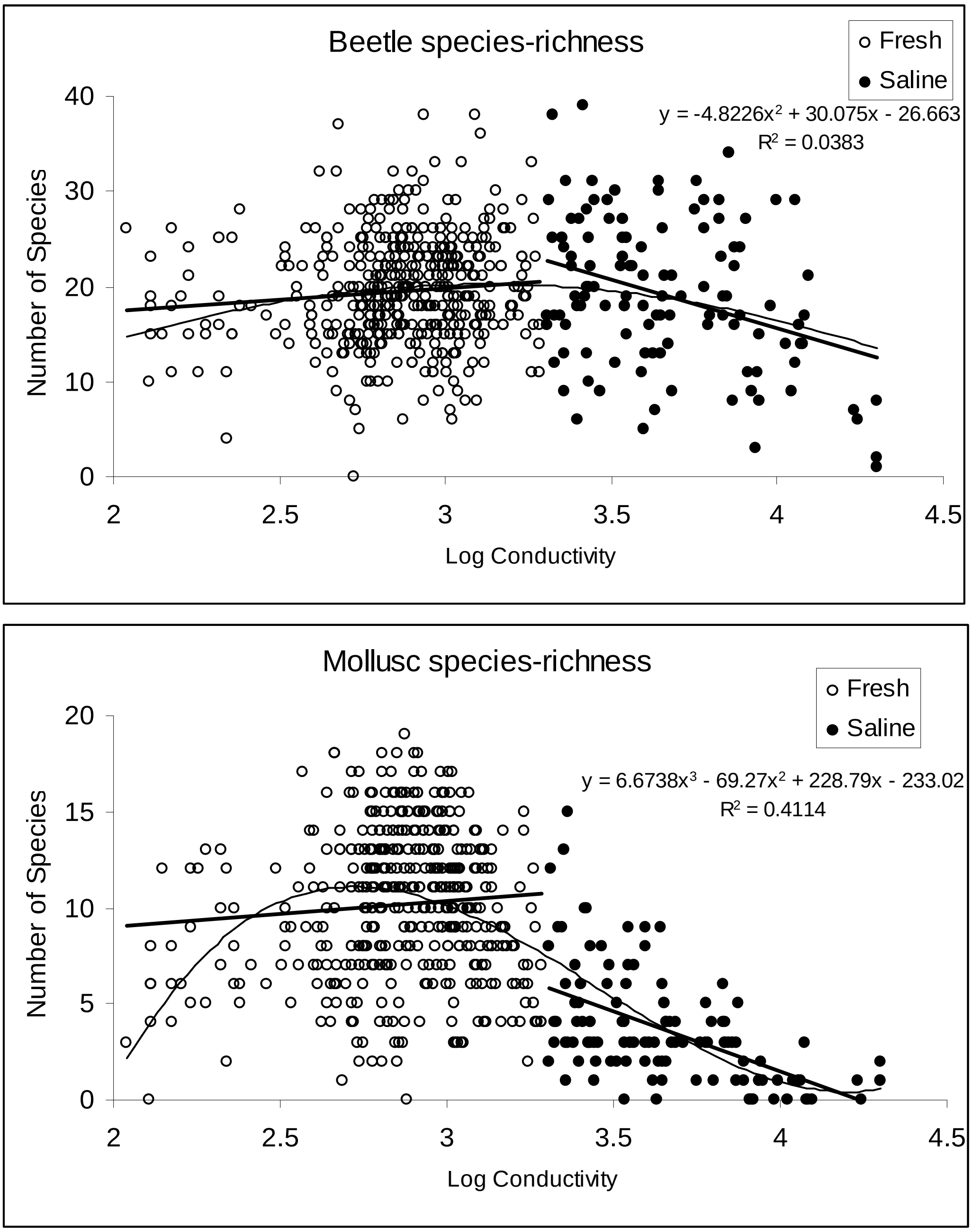


Figure 4.7 Relationship of the species-richness of beetles and molluscs with conductivity

Separate linear curves were fitted to sample either side of 2000µS cm^{-1} (=3.3 on the log scale) and single polynomial fitted to all samples (with the equation and R^2-values shown).

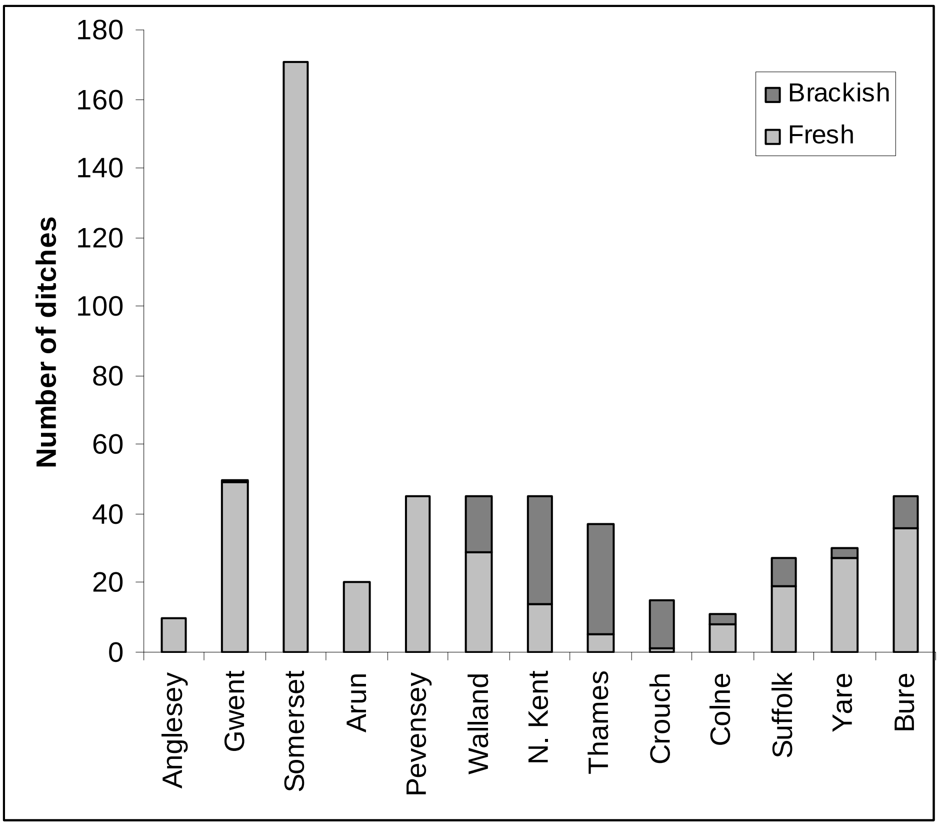


Figure 4.8 Number of fresh or brackish ditches in each main area.

3 Nationally rare and scarce species

3.1 Relationship with environmental variables

Seventy nationally rare or scarce invertebrates were recorded (Table 4.8). Beetles comprised the bulk of the list (47 species), and other orders contributed between 1 and 7 species. Several of these species were particularly widespread, occurring in at least 5% of the 551 samples (Figure 4.9).

The 20 species found in at least 5% of samples were examined in relation to environmental variables. The analysis used the entire dataset (551 samples) for widespread species. Many scarce species were geographically restricted, so including ditches well outside their apparent natural range added considerable noise to the comparisons. The analysis of twelve more restricted species and the beetle *Agabus conspersus*, which was locally frequent in the Thames marshes, was restricted to marshes in geographic areas in which they were found, although excluding marshes with rare outliers. All the marshes in the Thames estuary and Essex coast were included for the suite of species associated with brackish water.

Initial inspection of pairplots suggested a few likely correlations between the species (using the crude logarithmic abundance categories) and variables. Medians of each variable were compared between the suite of sample containing the species and those where it was not recorded. These data are not presented here but are summarised in the text. Differences in medians were not tested so the stated preferences indicate only possible trends. Differences in medians of the species metrics (Species Richness, SCS Score, Habitat Quality Score) were tested using a Mann-Whitney U-test (Tables 4.9 and 4.10). The occurrence of a species in botanical wet zone TWINSPAN groups was tested using a chi^2 test comparing the proportions in the entire dataset, even for geographically restricted species, since the botanical classification was a ‘national’ one. In all cases, the distribution of invertebrates differed with high significance from the expected proportions (Table 4.11). This result indicated that every species may have a preference for or intolerance of particular conditions indicated by the associated vegetaton type.

It is stressed that taking variables one at a time is crude form of analysis and can only suggest trends in preferred conditions. More detailed analysis is needed using generalised linear or additive modeling to obtain more robust relationships between the species and environmental conditions. A commentary on the findings for individual species is given in Volume 1, Section 6 of this report.

Just as the ordination analysis indicated salinity and successional stage to be the key factors influencing assemblage composition on many marshes, these too were recurrent themes in the requirements of the scarce species. Many could be fitted to a matrix of salinity versus successional stage (Table 4.7). A few of these species may respond primarily to a minor habitat feature unrelated to either of these key trends, as indicated by their uncertain positioning within the matrix.

Table 4.7 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*	→→→???
		←←←	*Hebrus pusillus*
		?*Hydrochus elongatus*	
		Hydaticus transversalis	
			Hydaticus seminiger
		Odontomyia tigrina	→→→
		Valvata macrostoma	
		←←←	*Segmentina nitida*

Figure 4.9 Species occurring in at least 5% of samples

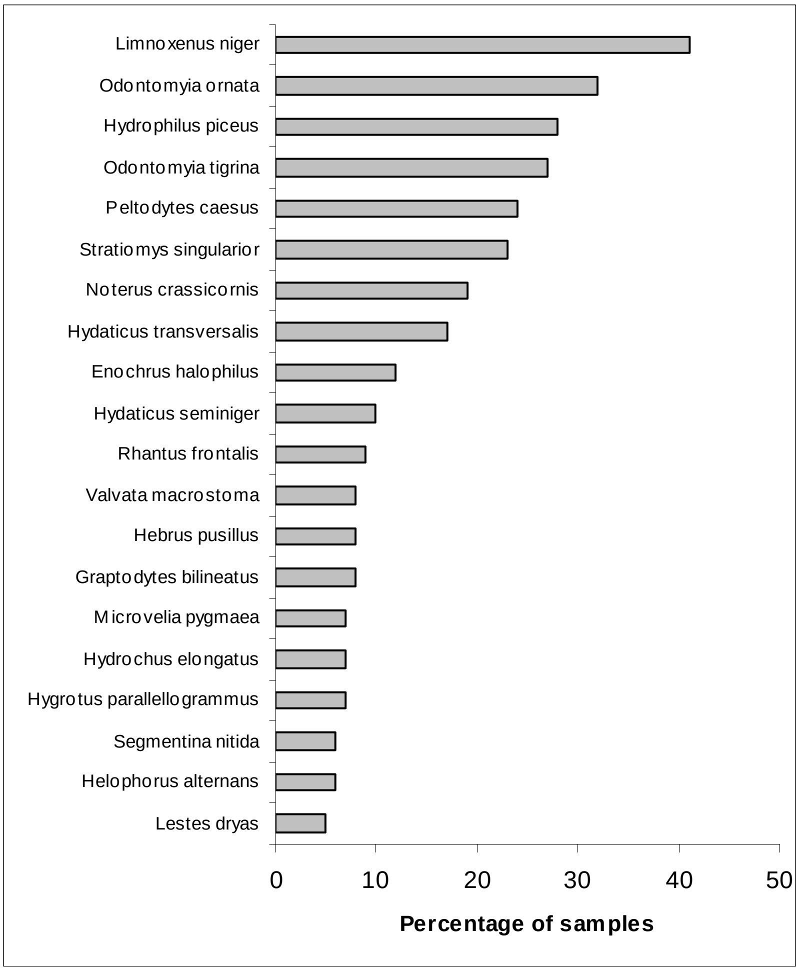


Table 4.8 Rare and scarce invertebrates grouped by geographic area

Values are the number of occurrences. Numbers below each geographic area cross-refer to Tables 4.9 and 4.10.

Order, Family	Species	SCS	Malltraeth	Gwent	Somerset	Arun	Pevensey	Walland	North Kent	Thames	Crouch	Colne	Suffolk	Yare	Bure	Total
			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
			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
			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						1		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 4.9 Species metrics for 21 nationally scarce or rare species that were frequent in the survey

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

	Species richness		SQI		Fidelity		Geog. areas
	present	absent	present	absent	present	absent	
Agabus conspersus	40 (30 - 42)	36 (28 - 43)	1.79 (1.73 - 1.85)	1.50 (1.39 - 1.59)	1.36 (1.32 - 1.38)	1.23 (1.14 - 1.28)	7,8
Enochrus halophilus	35 (29 - 42)	41 (33 - 48)	1.63 (1.53 - 1.74)	1.44 (1.35 - 1.53)	1.27 (1.21 - 1.33)	1.14 (1.10 - 1.20)	6-11
Graptodytes bilineatus	41 (32 - 48)	40 (30 - 47)	1.57 (1.50 - 1.68)	1.47 (1.35 - 1.59)	1.20 (1.13 - 1.25)	1.17 (1.10 - 1.26)	6-11
Hebrus pusillus	54 (48 - 60)	51 (44 - 57)	1.54 (1.50 - 1.61)	1.44 (1.36 - 1.54)	1.20 (1.16 - 1.23)	1.16 (1.13 - 1.20)	5,6,12,13
Helophorus alternans	34 (25 - 42)	40 (33 - 47)	1.54 (1.46 - 1.74)	1.49 (1.36 - 1.59)	1.27 (1.14 - 1.34)	1.17 (1.11 - 1.24)	6-11
Hydaticus seminiger	50 (44 - 56)	44 (36 - 51)	1.50 (1.42 - 1.60)	1.41 (1.32 - 1.51)	1.16 (1.11 - 1.23)	1.16 (1.10 - 1.21)	all
Hydaticus transversalis	46 (41 - 52)	43 (31 - 49)	1.41 (1.34 - 1.47)	1.35 (1.37 - 1.43)	1.19 (1.15 - 1.23)	1.13 (1.11 - 1.18)	2,3
Hydrochus elongatus	51 (48 - 56)	43 (34 - 49)	1.56 (1.45 - 1.65)	1.49 (1.36 - 1.60)	1.18 (1.10 - 1.21)	1.17 (1.10 - 1.23)	4-7
Hydrophilus piceus	50 (44 - 56)	43 (34 - 49)	1.46 (1.40 - 1.55)	1.39 (1.29 - 1.5)0	1.22 (1.17 - 1.25)	1.14 (1.09 - 1.19)	all
Hygrotus parallellogrammus	40 (30 - 46)	40 (31 - 47)	1.64 (1.53 - 1.80)	1.47 (1.35 - 1.57)	1.31 (1.20 - 1.35)	1.16 (1.10 - 1.23)	6-11
Lestes dryas	40 (32 - 46)	35 (27 - 43)	1.68 (1.61 - 1.75)	1.50 (1.38 - 1.58)	1.26 (1.24 - 1.32)	1.20 (1.12 - 1.29)	7-9
Limnoxenus niger	47 (40 - 54)	43 (35 - 50)	1.51 (1.43 - 1.62)	1.36 (1.27 - 1.44)	1.22 (1.18 - 1.26)	1.13 (1.08 - 1.17)	all
Microvelia pygmaea	47 (39 - 52)	45 (35 - 55)	1.45 (1.35 - 1.50)	1.48 (1.37 - 1.59)	1.11 (1.07 - 1.16)	1.18 (1.13 - 1.23)	5-13
Noterus crassicornis	53 (46 - 59)	47 (34 - 52)	1.45 (1.38 - 1.53)	1.40 (1.34 - 1.48)	1.18 (1.15 - 1.21)	1.13 (1.08 - 1.18)	1,6,12,13
Odontomyia ornata	50 (43 - 54)	43 (34 - 49)	1.46 (1.39 - 1.54)	1.39 (1.29 - 1.50)	1.20 (1.16 - 1.23)	1.14 (1.09 - 1.20)	all
Odontomyia tigrina	46 (41 - 53)	44 (35 - 51)	1.47 (1.39 -	1.40 (1.31 -	1.19 (1.14 -	1.15 (1.10 -	all

			1.60)	1.50)	1.24)	1.20)	
Peltodytes caesus	49 (44 - 56)	43 (35 - 50)	1.44 (1.37 - 1.56)	1.40 (1.31 - 1.50)	1.21 (1.16 - 1.25)	1.14 (1.09 - 1.20)	all
Rhantus frontalis	40 (32 - 45)	39 (31 - 47)	1.62 (1.48 - 1.76)	1.46 (1.35 - 1.57)	1.25 (1.15 - 1.32)	1.17 (1.10 - 1.23)	6-11
Segmentina nitida	55 (50 - 59)	52 (46 - 62)	1.63 (1.55 - 1.68)	1.42 (1.35 - 1.51)	1.19 (1.14 - 1.21)	1.15 (1.12 - 1.20)	5,13
Stratiomys singularior	46 (40 - 53)	44 (36 - 51)	1.53 (1.43 - 1.64)	1.39 (1.30 - 1.48)	1.21 (1.17 - 1.26)	1.14 (1.09 - 1.20)	all
Valvata macrostoma	52 (49 - 57)	50 (45 - 55)	1.60 (1.53 - 1.67)	1.42 (1.38 - 1.54)	1.17 (1.14 - 1.21)	1.12 (1.09 - 1.14)	5

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

Table 4.10 Mann-Whitney U-test of medians of metrics in ditches with and without each scarce species

Geographic areas where the species was likely to be absent or was very scarce in the survey were excluded (compare with Table 4.8). Non-significant p-values are italicised.

Species	Species richness		SCS Score		Habitat Quality Score		Geographic areas
	U	p	U	p	U	p	
Agabus conspersus	462	0.8688	819	0.0001	799	0.0001	7,8
Enochrus halophilus	2529	0.0086	5501	0.0001	5570	0.0001	6-11
Graptodytes bilineatus	2846	*0.6037*	3669	0.0003	2976	*0.3298*	6-11
Hebrus pusillus	2872.5	0.0486	3563.5	0.0001	3116.5	0.0034	5,6,12,13
Helophorus alternans	1558	0.0245	2683	0.0198	2985	0.0007	6-11
Hydaticus seminiger	13500	0.0021	13642	0.0010	10678	*0.9607*	3-13
Hydaticus transversalis	7355	0.0004	7253	0.0004	8111	0.0001	2, 3
Hygrotus parallellogrammus	2178	*0.6168*	3627	0.0001	3735	0.0001	6-11
Hydrochus elongatus	3126	0.0001	2426	*0.0588*	1922	*0.6908*	4-7
Hydrophilus piceus	40506	0.0001	37121	0.0001	44385	0.0001	all
Lestes dryas	1093	*0.1112*	1414	0.0001	1279	0.0018	7-9
Limnoxenus niger	42896	0.0001	56967	0.0001	61722	0.0001	all
Microvelia pygmaea	4428	*0.7627*	3536	*0.1178*	2225	0.0001	5-13
Noterus crassicornis	2422	0.0006	2154	0.0378	2345	0.0023	1,6,12,13
Odontomyia ornata	42705	0.0001	39871	0.0001	43433	0.0001	all
Odontomyia tigrina	32274	0.0051	35713	0.0001	35921	0.0001	all
Peltodytes caesus	35542	0.0001	31015	0.0003	37465	0.0001	all
Rhantus frontalis	2749	*0.8606*	4130	0.0001	3805	0.0005	6-11
Segmentina nitida	929	*0.4892*	1523	0.0001	1106	0.0245	5, 13
Stratiomys singularior	28180	*0.0527*	38435	0.0001	38471	0.0001	all
Valvata macrostoma	237	*0.3162*	309	0.0044	318	0.0022	5

Table 4.11 Occurrence in botanical wet zone groups of 21 nationally scarce or rare species that were frequent in the survey

Species	Botanical TWINSPAN Group						
	A	B	C	D	E	F	G
Number in whole dataset	31	101	26	169	114	35	75
% in whole dataset	6	18	5	31	21	6	14
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
Hebrus pusillus	3	11	13	11	29	18	16
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
Lestes dryas	0	8	0	0	4	0	88
Limnoxenus niger	3	11	6	27	21	4	27
Microvelia pygmaea	18	9	0	12	45	12	3
Noterus crassicornis	4	8	7	17	36	21	6
Odontomyia ornata	1	16	1	48	23	4	7
Odontomyia tigrina	0	14	7	41	10	7	21
Peltodytes caesus	2	17	4	27	24	13	14
Rhantus frontalis	7	4	2	7	20	0	61
Segmentina nitida	7	4	21	7	39	21	0
Stratiomys singularior	1	15	6	33	15	2	29
Valvata macrostoma	2	2	14	29	40	12	0

3.2 Records for individual marshes

Lists of nationally rare and scarce species recorded in individual marshes are given in the following tables. Scores for Species Conservation Status and Habitat Quality (marsh fidelity) are shown.

Malltraeth Marshes

Family	Species	SCS	HQ	Total
Dytiscidae	*Rhantus frontalis*	3	1	1
Hydrochidae	*Hydrochus brevis*	4	1	2
Hydrophilidae	*Helochares punctatus*	3	1	1
	Paracymus scutellaris	3	1	1
Noteridae	*Noterus crassicornis*	3	2	7

Gwent Levels

Family	Species	SCS	HQ	Total
Dytiscidae	*Agabus conspersus*	3	2	2
	Dytiscus circumcinctus	3	1	2
	Dytiscus dimidiatus	4	1	2
	Hydaticus transversalis	3	3	13
Haliplidae	*Peltodytes caesus*	3	3	8
Hydrophilidae	*Hydrophilus piceus*	4	3	2
Stratiomyidae	*Odontomyia ornate*	4	3	12
	Odontomyia tigrina	3	2	7

	Stratiomys potamida	3	1	1
	Vanoyia tenuicornis	3	1	4

Somerset and Avon Levels and Moors

Order, Family	Species	SCS	HQ	Catcott	Kenn	Kings Sedgemoor	Moorlinch	Non-SSSI-Clay	Non-SSSI-Peat	Pawlett	Tadham	West Sedgemoor	Total
Coleoptera													
Dytiscidae	*Agabus uliginosus*	4	1									12	12
	Dytiscus circumcinctus	3	1	1								1	2
	Dytiscus dimidiatus	4	1	1	1	1						1	4
	Hydaticus seminiger	3	1	4		6	1		1		3		15
	Hydaticus transversalis	3	3	10	12	13	4	1	1	2	9	18	70
	Rhantus frontalis	3	1	1					1				2
Haliplidae	*Haliplus mucronatus*	3	1				1						1
	Peltodytes caesus	3	3	6	3	4	7			3	6	6	35
Helophoridae	*Helophorus nanus*	3	2	2					1			2	5
Hydraenidae	*Limnebius papposus*	4	1	2		1						6	9
	Ochthebius nanus	3	1				2						2
Hydrophilidae	*Chaetarthria simillima*	3	1			2							2
	Hydrochara caraboides	5	2	5					1		3		9
	Hydrophilus piceus	4	3	4	1	9	12	1	3	2	13	16	61
	Limnoxenus niger	4	3	7		14	7		1	13	11	14	67
Diptera													
Stratiomyidae	*Odontomyia ornate*	4	3	9	7	8	12	1	2	8	13	18	78
	Odontomyia tigrina	3	2	10	8	9	4	1	4	3	7	11	57
	Stratiomys potamida	3	1								1		1
	Stratiomys singularior	3	2	7	3	9	10	2	1	5	4	7	48
	Vanoyia tenuicornis	3	1	2		3		1			1		7
Mollusca													
Planorbidae	*Segmentina nitida*	5	3	1									1
Valvatidae	*Valvata macrostoma*	5	3									8	8

Arun Valley

Order, Family	Species	SCS	HQ	Amberley	Pulborough	Total
Coleoptera						
Dytiscidae	*Hydaticus seminiger*	3	1	2		2
Haliplidae	*Peltodytes caesus*	3	3	2	1	3
Hydrochidae	*Hydrochus elongatus*	4	1	1	4	5
Diptera						
Stratiomyidae	*Odontomyia ornata*	4	3		2	2
	Odontomyia tigrina	3	2	1	3	4
Hemiptera						
Veliidae	*Microvelia pygmaea*	3	1	1		1
Mollusca						
Planorbidae	*Anisus vorticulus*	5	3	1		1

Pevensey Levels

Order, Family	Species	SCS	HQ	Total
Coleoptera				
Dryopidae	*Dryops auriculatus*	4	1	18
Dytiscidae	*Hydaticus seminiger*	3	1	3
	Hygrotus parallellogrammus	3	2	1
Haliplidae	*Peltodytes caesus*	3	3	6
Helophoridae	*Helophorus nanus*	3	2	4
Hydrochidae	*Hydrochus elongatus*	4	1	20
	Hydrochus ignicollis	4	1	9
Hydrophilidae	*Berosus luridus*	4	1	1
	Enochrus quadripunctatus	3	1	1
	Hydrophilus piceus	4	3	3
	Limnoxenus niger	4	3	23
Diptera				
Cylindrotomidae	*Phalacrocera replicata*	3	1	4
Stratiomyidae	*Odontomyia ornata*	4	3	8
	Odontomyia tigrina	3	2	4
	Stratiomys singularior	3	2	1
Hemiptera				
Hebridae	*Hebrus pusillus*	3	1	6
Hydrometridae	*Hydrometra gracilenta*	4	2	15
Veliidae	*Microvelia pygmaea*	3	1	9
Araneae				
Pisauridae	*Dolomedes plantarius*	5	3	9
Mollusca				
Planorbidae	*Anisus vorticulus*	5	3	3
	Segmentina nitida	5	3	23
Valvatidae	*Valvata macrostoma*	5	3	33

Walland Marsh

Order, Family	Species	SCS	HQ	Broomhill	Cheyne Court	East Guldeford	Fairfield	The Dowels	Arable	Total
Coleoptera										
Dytiscidae	*Dytiscus dimidiatus*	4	1					1		1
	Graptodytes bilineatus	3	1	2	1	3	3		1	10
	Hydaticus seminiger	3	1		2	3	3	3		11
	Hydrovatus clypealis	3	1		2	8	1	6		17
	Hydrovatus cuspidatus	3	1				1			1
	Hygrotus decoratus	3	1		2	1				3
	Hygrotus parallellogrammus	3	2		1		1	2		4
	Rhantus frontalis	3	1		1		3	1		5
Gyrinidae	*Gyrinus paykulli*	3	1		1					1
Haliplidae	*Haliplus variegatus*	4	1		1					1
	Peltodytes caesus	3	3	2	3	2	2	2		11
Hydraenidae	*Ochthebius nanus*	3	1		1	1		2		4
Hydrochidae	*Hydrochus elongatus*	4	1	1	1	2				4
	Hydrochus ignicollis	4	1			1			1	2
Hydrophilidae	*Chaetarthria seminulum*	3	1			1				1
	Enochrus quadripunctatus	3	1	1				1		2

	Hydrophilus piceus	4	3	1	1	2		1		5
	Limnoxenus niger	4	3	5	3	5	6	7	1	27
Noteridae	*Noterus crassicornis*	3	2	4	3	8	3	7	1	26
Diptera										
Cylindrotomidae	*Phalacrocera replicata*	3	1	1		2				3
Stratiomyidae	*Odontomyia ornata*	4	3	1	2	6	4	4	1	18
	Odontomyia tigrina	3	2	2	1	1	1	2		7
	Stratiomys singularior	3	2	5	2	3	2	1	1	14
	Vanoyia tenuicornis	3	1			3	1			4
Hemiptera										
Corixidae	*Sigara striata*	3	1				1	1		2
Hebridae	*Hebrus pusillus*	3	1	5	2	2	4	2		15
Veliidae	*Microvelia pygmaea*	3	1				1	1	1	3
Hirudinea										
Hirudinidae	*Hirudo medicinalis*	5	1	1	1	2	3	1		8

North Kent Marshes

Order, Family	Species	SCS	HQ	Chetney	Grain & Allhallows	Cliffe & Halstow	Graveney & Seasalter	Shorne	Total
Coleoptera									
Dryopidae	*Dryops similaris*	3	1			1			1
Dytiscidae	*Agabus conspersus*	3	2		8	2			10
	Graptodytes bilineatus	3	1	1	1	3	1		6
	Hydaticus seminiger	3	1				3	1	4
	Hygrotus parallellogrammus	3	2	1	9	2			12
	Rhantus frontalis	3	1		7	5		1	13
Gyrinidae	*Gyrinus paykulli*	3	1			2	2		4
Haliplidae	*Haliplus apicalis*	3	1	1	2				3
	Peltodytes caesus	3	3		4	3	1	3	11
Helophoridae	*Helophorus alternans*	3	2	4	6	6			16
Heteroceridae	*Heterocerus obsoletus*	3	1		1	1			2
Hydraenidae	*Aulacochthebius exaratus*	4	2			2			2
	Limnebius papposus	4	1			1			1
	Ochthebius nanus	3	1					3	3
	Ochthebius viridis	3	2		4	1			5
Hydrochidae	*Hydrochus elongatus*	4	1					4	4
	Hydrochus ignicollis	4	1			3		2	5
Hydrophilidae	*Enochrus bicolor*	3	2		1	1	1		3
	Enochrus halophilus	3	2	2	10	6		2	20
	Hydrophilus piceus	4	3	1	3	1	2	6	13
	Limnoxenus niger	4	3	4	11	11	1	6	33
Noteridae	*Noterus crassicornis*	3	2		1				1
Diptera									
Stratiomyidae	*Odontomyia ornata*	4	3				1	2	3
	Odontomyia tigrina	3	2		8	3		1	12
	Stratiomys singularior	3	2		10	2		2	14
Hemiptera									
Hebridae	*Hebrus pusillus*	3	1				1		1
Veliidae	*Microvelia pygmaea*	3	1			2	4		6
Odonata									

Lestidae	*Lestes dryas*	4	2	7	2	9
Trichoptera						
Leptoceridae	**Leptocerus lusitanicus**	5	1		1	1

Thames and Essex Marshes

Order, Family	Species	SCS	HQ	Hadleigh	Rainham	Vange & Fobbing	Fambridge	Brightlingsea	Total
Coleoptera									
Dryopidae	*Dryops similaris*	3	1	1	1				2
Dytiscidae	*Agabus conspersus*	3	2	1	1	1		1	4
	Graptodytes bilineatus	3	1	3	3	7	6	3	22
	Hydaticus seminiger	3	1			1			1
	Hygrotus parallellogrammus	3	2	4	3	4		1	12
	Rhantus frontalis	3	1	1	3	5	7		16
Haliplidae	*Haliplus apicalis*	3	1	2	1	2	2		7
	Peltodytes caesus	3	3	1	3	5	1	2	12
Helophoridae	*Helophorus alternans*	3	2		6	3	1		10
	Helophorus fulgidicollis	3	1			1	3		4
	Helophorus nanus	3	2		4				4
Heteroceridae	*Heterocerus obsoletus*	3	1				1		1
Hydraenidae	*Aulacochthebius exaratus*	4	2				2		2
	Limnebius papposus	4	1		1				1
	Ochthebius nanus	3	1	1					1
	Ochthebius viridis	3	2		1	2	2		5
Hydrochidae	*Hydrochus angustatus*	3	1		1				1
	Hydrochus elongatus	4	1	1		2			3
	Hydrochus ignicollis	4	1				1		1
Hydrophilidae	*Enochrus bicolor*	3	2		2	3	1		6
	Enochrus halophilus	3	2	4	3	9	12	2	30
	Hydrophilus piceus	4	3	2	1	7	3		13
	Limnoxenus niger	4	3	5		12	11	2	30
Noteridae	*Noterus crassicornis*	3	2		3				3
Diptera									
Culicidae	*Ochlerotatus flavescens*	4	1			2			2
Stratiomyidae	*Odontomyia ornata*	4	3	3		2	2	1	8
	Odontomyia tigrina	3	2	4		6	4	1	15
	Stratiomys singularior	3	2	2	2	8	7	1	20
Hemiptera									
Corixidae	*Sigara striata*	3	1		1				1
Veliidae	*Microvelia pygmaea*	3	1		1			1	2
Odonata									
Lestidae	*Lestes dryas*	4	2	4		8	4		16
Mollusca									
Planorbidae	*Gyraulus laevis*	3	1	1				1	2

Suffolk Marshes

Order, Family	Species	SCS	HQ	Shotley	Sizewell	Minsmere	Total
Coleoptera							
Dytiscidae	*Agabus conspersus*	3	2	1			1
	Graphoderus cinereus	5	1		1		1
	Hydaticus seminiger	3	1		1	4	5
	Hydaticus transversalis	3	3		1		1
	Hydrovatus clypealis	3	1		1		1
	Hydrovatus cuspidatus	3	1	1			1
	Hygrotus parallellogrammus	3	2			3	3
	Rhantus frontalis	3	1			6	6
Gyrinidae	*Gyrinus paykulli*	3	1			1	1
Haliplidae	*Peltodytes caesus*	3	3	2	4	3	9
Helophoridae	**Helophorus alternans**	3	2	2			2
Hydraenidae	*Ochthebius nanus*	3	1		1	1	2
Hydrochidae	*Hydrochus angustatus*	3	1		1	1	2
Hydrophilidae	*Enochrus halophilus*	3	2			3	3
	Enochrus quadripunctatus	3	1			1	1
	Hydrophilus piceus	4	3			2	2
Diptera							
Stratiomyidae	*Odontomyia ornata*	4	3		2	3	5
	Odontomyia tigrina	3	2	1	3	3	7
	Stratiomys singularior	3	2	1	2	1	4
	Vanoyia tenuicornis	3	1	1	4	1	6
Hemiptera							
Veliidae	*Microvelia pygmaea*	3	1	1	2	2	5

Norfolk Marshes

Order, Family	Species	SCS	HQ	Buckenham	Cantley	Limpenhoe	Fleggburgh	Oby	S. Walsham	Upton	Total
Coleoptera											
Dytiscidae	*Dytiscus circumcinctus*	3	1		3					3	6
	Dytiscus dimidiatus	4	1					1			1
	Hydaticus seminiger	3	1				2	2	2	1	7
	Hydaticus transversalis	3	3				1	1		1	3
	Hygrotus decoratus	3	1						1		1
	Hygrotus parallellogrammus	3	2		1						1
	Rhantus frontalis	3	1			1	1			1	3
Gyrinidae	*Gyrinus paykulli*	3	1	1				1		1	3
Haliplidae	*Peltodytes caesus*	3	3	6	7		1	1	1	8	24
Hydraenidae	*Limnebius aluta*	4	1						1		1
	Ochthebius nanus	3	1			2				2	4
Hydrophilidae	*Chaetarthria*	3	1			1	2				3
	Enochrus bicolor	3	2		1				2		3
	Enochrus halophilus	3	2					1	2	4	7
	Helochares obscurus	5	1				2	2	1	1	6
	Hydrophilus piceus	4	3	6	9	2	3	4	4	11	39
	Limnoxenus niger	4	3			7	2	5		9	23
Noteridae	*Noterus crassicornis*	3	2	8	10	10	8	11	5	7	59
Diptera											
Cylindrotomidae	*Phalacrocera replicata*	3	1			1				1	2
Stratiomyidae	*Odontomyia ornata*	4	3	3	1	8	1	4	2	6	25
	Odontomyia tigrina	3	2	2	2	3		8	1	4	20
	Stratiomys singularior	3	2	1	2	3	1	2	3	3	15
	Vanoyia tenuicornis	3	1					2		1	3
Hemiptera											
Hebridae	*Hebrus pusillus*	3	1			7	2	1		6	16
Veliidae	*Microvelia buenoi*	4	1				1				1
	Microvelia pygmaea	3	1			5		1		1	7
Odonata											
Aeshnidae	*Aeshna isosceles*	5	3							3	3
Trichoptera											
Hydroptilidae	*Tricholeiochiton fagesii*	3	1			1					1
Mollusca											
Planorbidae	*Anisus vorticulus*	5	3				2		1	7	10
	Segmentina nitida	5	3				2	1	1		4

APPENDIX 5

Change in the invertebrate fauna over time

Appendix 5 relates to Volume 1, Section 8 of this report

1 Repeat survey in Somerset

1.1 Rationale and analytical methods

One of the main aims of the Buglife project was to establish whether there had been any change in the fauna and flora of ditches over the last three or four decades. The main method used was comparison of the number of species found and metrics for Species Conservation Status (SCS), Habitat Quality (in terms of species fidelity to the grazing marsh habitat) and Naturalness (presence / absence of non-native species). This method is described in detail in *A manual for the survey and evaluation of the aquatic plant and invertebrate assemblages of grazing marsh ditch systems* (Palmer, Drake & Stewart 2010) and in Volume 1 Section 8 of this report.

Some variation in these values often cannot be explained in terms of changes in management or obvious environmental conditions, and this has to be taken into account when making comparisons between surveys undertaken many years apart. To estimate the magnitude of this unexplained variation, ten ditches were sampled in all three years of the project and Species Richness, SCS Score, Habitat Quality Score and Naturalness Score were examined for the average and maximum changes. The aim was 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. Two ditches were cleaned out during the period and this was taken to be part of the normal management cycle.

The data for Species Richness, SCS Score and Habitat Quality Score were normally distributed as indicated by a Kolgaromarov-Smirnov test, so could be analysed using parametric as well as non-parametric methods. Naturalness was not normally distributed and the 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.

One-way ANOVAR was done on each variable against year with tests between pairs of years. The Analyse-it add-in to Excel provided 95% confidence limits of medians using the equation given in Snedecor & Cochran (1967).

1.2 Results

There were no significant differences between mean values of species richness, SCS score or marsh fidelity score between years or across the period (the respective F and p values were 0.08, 0.924; 0.80, 0.460; 1.36, 0.274; with 29 df; Figure 5.1). This indicated that conditions in the ditches had been fairly stable over the three years.

A significant difference between means is indicated by a mean value lying outside the 95%CL. Confidence limits were 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 (Table 5.1). These values were small and indicated that ditches experiencing no change in management could expect to show variation of up to 11% in Species Richness, 7% in Species Conservation Status (SCS) Score and 5% in Habitat Quality Score.

As samples in many surveys were not selected randomly, comparisons between surveys must be undertaken using non-parametric methods. The measure of variation used here is the 95%CL of the median expressed as a percentage of the median. The upper and lower confidence limits are not necessarily symmetrically arranged about the median, so, since the purpose was to find the largest variation, the wider of the two confidence limits is given here (Table 5.1). The limits may be up to 22% of the median for Species Richness, 11% for SCS Score and 8% for Habitat Quality Score.

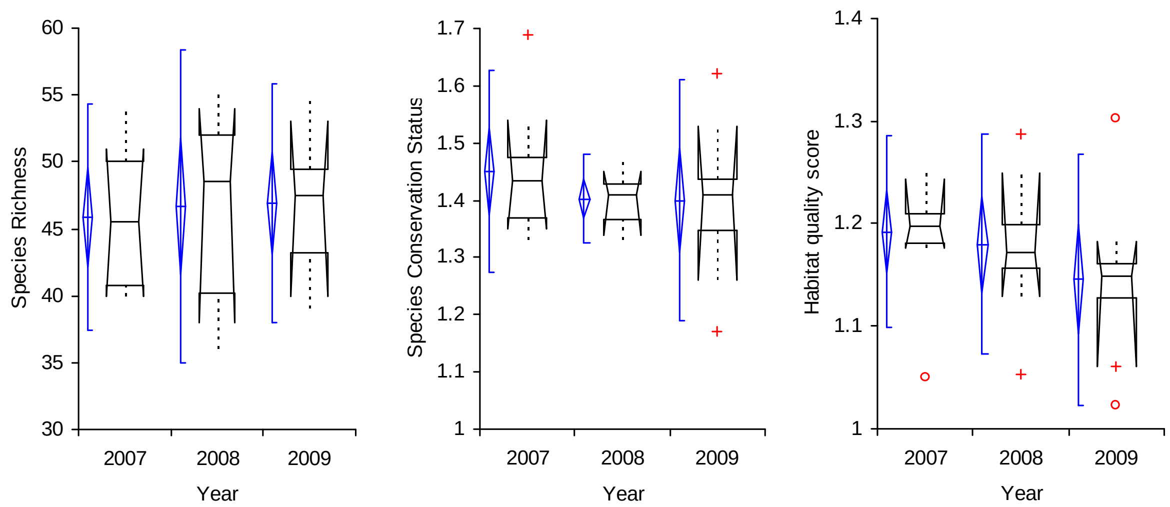
Table 5.1 Confidence limits expressed as a percentage of the mean or median of species metrics for ten ditches in the Somerset Levels sampled in three years

95% confidence limits as percentage of the mean value (Mean) and interquartile range as percentage of the median (Median).

Measure	Year	Species richness	SCS Score	Habitat Quality Score
Mean	2007	8.0	5.3	3.4
	2008	10.9	2.4	4.0
	2009	8.2	6.5	4.6
Median	2007	12.1	7.3	3.8
	2008	21.6	5.0	6.7
	2009	15.8	10.6	7.6

Figure 5.1 Mean and median values of species metrics for ten ditches in the Somerset Levels sampled in three years

Mean with 95% confidence limits are the middle and tips of the diamonds. Median and upper and lower quartiles are the boxes, with outliers as crosses and circles.



An indication of the turnover of species was the numbers occurring in one, in any two or in all three years in each ditch. This was expressed as a percentage of all species recorded in each ditch, and the mean estimated for each year class. Species were separated into nationally commoner and rarer ones to see whether rarer species had a higher turnover compared to commoner ones. Commoner species were taken here to be those with species conservation status scores of 0-2 (non-natives, common or local), and the rarer ones had higher statuses of 3-5 (nationally scarce and threatened species).

About one third of all species were found in all three years compared to slightly fewer in any two years and slightly more in only one year (Figure 5.2, left histogram). This indicated considerable turnover of species with only a small core that were found repeatedly. The maximum turnover for an individual ditch was as much as 45% of the species occurring only once, that is, almost half the species recorded in a ditch are unlikely to be found in a single repeat survey. In the most stable ditch 43% of the species (again, nearly half) were found in all three years. These figures suggested either that surveys missed a large number of species or that species did fluctuate considerably. It is likely that both factors contributed.

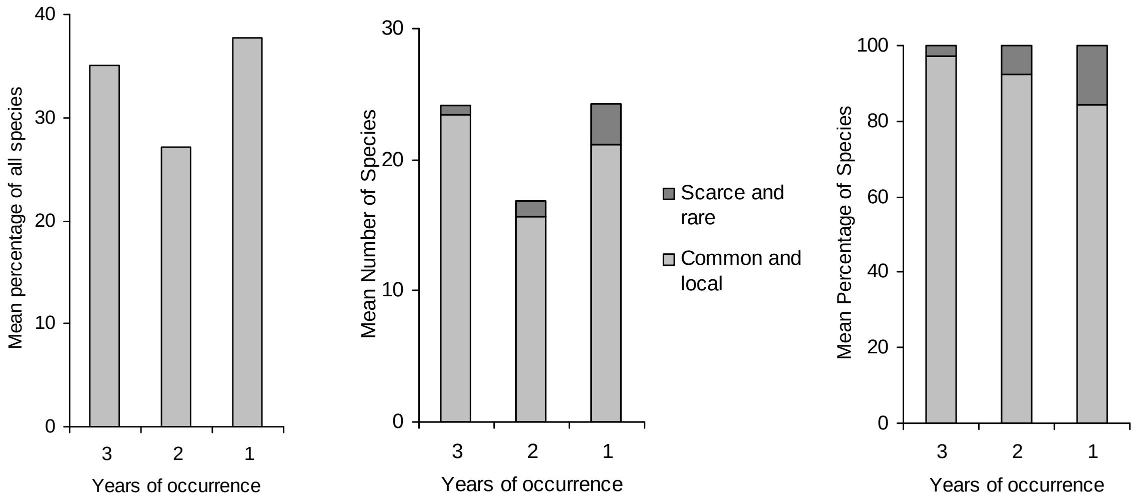
Commoner species were more likely to be found in all three years, and rare ones were more likely to occur in just one year, as indicated by commoner species making up a larger proportion of the species found in all three years (Figure 5.2, middle and right histograms). Several times as many rare species were found only once compared to three times (compare the top sections of the histograms in Figure 5.2) so rare species had a much smaller chance of being refound than did common species. This result was partly expected since nationally rare species were also rarer in the samples.

In conclusion, 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 uncommon species should not be expected to be re-found in up to about half the surveys. 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 taxonomic expertise. Therefore, when comparisons are made between survey results, less complete or obviously suspect datasets should be discarded. Great care should be taken in interpreting change if sampling methodology differs between workers.

Figure 5.2 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.



2 Comparison of surveys in the Somerset and Avon wetlands

2.1 Methods

Data from many surveys covering the same set of marshes investigated in 2007-2009 were digitised and converted to a single list of records. The data were made comparable between surveys by using the same taxon and site name as used in the Buglife survey, and allocating Species Conservation Status (SCS) Score, Habitat Quality Score, Naturalness Score and a score for salinity tolerance to each record. Non-target taxa and sites that were not to be compared with the Buglife surveys were eliminated from the list. Table 1.1 in Appendix 1 of this volume shows the surveys investigated.

Records of target taxa were separated into those that were unlikely to have been found by pond-netting, for instance, records of adult dragonflies, or the taxonomic level was too vague to be sure of the identity, for instance females of the beetle in the *Haliplus ruficollis* group (which cannot be reliably identified), beetle larvae identified to genus or mosquito larvae identified to subfamily. These records were excluded from the analysis.

A few species or taxa were identified to slightly different levels in different surveys, for example, Odonata were often identified to species level but using unreliable characters. Some of these sources of error were eliminated by combining taxa, for example, where more than one species of *Coenagrion* or *Sympetrum* was identified in a survey, all species were treated at genus level, even though some identifications may have been correct. Correcting all such possible duplication was not complete, notably the common beetle *Anacaena limbata* was found to consist of two equally common species in the 1990s, but the loss of information in the more thorough recent surveys in these cases did not warrant amalgamating species. A tiny increase through time may therefore be attributed to this cause, but it would be swamped by variation in richness due to other causes.

As many records as possible were retained by scrutinising each survey rather than applying a blanket removal of certain taxa. For instance, where it was obvious that one taxon was only ever taken to the same higher level, it was retained, but if it duplicated a species-level identification in the same survey, it was flagged as unwanted. Inevitably, some inconsistency arose but this affected only the species count since these non-species taxa scored zero for SCS, Habitat Quality, Naturalness and salinity index (brackishness).

The final list included c. 25,000 records from the 2007-2009 Buglife surveys and c. 60,390 records from other surveys, making a total of c. 85,390. Excluded records were c. 1,520 inconsistently named aquatic target taxa, 16,760 from sites not being compared with the Buglife dataset, and c. 11,580 of non-target taxa; all these currently exist as lists on the Buglife dataset.

Surveys for each area were tabulated to show the coverage and number of records for major groups. Groups that were not covered consistently could be identified and eliminated from the comparisons. For example, in one important survey in Somerset, only beetles, bugs, dragonflies, flies and molluscs were identified, so comparison of most Somerset marshes had to be restricted to these groups.

All the samples were from freshwater ditches. For each sample, scores for Species Richness, SCS and Habitat Quality were calculated, and the medians and interquartile ranges estimated for a whole marsh. Kruskal-Wallis tests were used to compare median values of several surveys for each site. Changes in the proportions of single species were tested using a chi-squared test. Box-plots were produced using Analyse-it in Excel, and these show the upper and lower 95% confidence limits of the median rather than the interquartile range.

The major groups were ordered by the total number of records. Beetles, bugs, dragonflies, flies (usually only soldierflies) and molluscs were covered consistently in nearly all surveys, with rare exceptions for bugs and flies. As the remaining taxonomic groups were covered unevenly, it was decided to omit them from the analysis. Together they accounted for 91% of all records in these surveys and omitting them reduced the species total from 326 to 272. However, the 54 omitted species were either common or local, including only one (the mayfly *Caenis robusta*) that was regarded as characteristic of grazing marshes, and just a few *Gammarus* were associated with brackish conditions. The non-native amphipod *Crangonyx pseudogracilis* was omitted, as crustaceans were not included by Gibbs (1994), which was a key survey, so the naturalness index (score for non-natives) was not included in the analysis. The loss of information in the metrics was considered to be acceptable.

2.2 Results of applying the metrics to individual sites
2.2.1 Differences between surveyors

Box-plots of medians and means are given in Figure 5.3. All relevant surveys for each moor were included in Kruskal-Wallis tests of the medians. The medians differed significantly for species richness on all moors and for SCS score on all but Gordano (Table 5.3). The medians for habitat quality differed significantly on five of the nine moors (not on Gordano, Kenn, Moorlinch and Pawlett).

The box-plots in Figure 5.3 and the number of records of major taxa (Table 1.1 of Appendix 1) suggested that the reason for the large numbers of significant differences may be due to different approaches used in the surveys. The following comments on some surveys may explain why these results cannot be taken at face value.

Armitage *et al*. (1981) produced consistently very low species richness (Catcott, Southlake, Tadham, West Sedgemoor) and inspection of the raw data showed that beetles were under-represented compared to molluscs, which suggested that sampling concentrated on the submerged vegetation in the centre of channels where beetles are scarce but molluscs are abundant. The paucity of beetles was reflected in low SCS and habitat quality scores, to which beetles make a large contribution.

Hill-Cottingham & Smith (1995) was based on a few samples from many moors sampled by the Environment Agency. As with Armitage *et al*., (1981), beetles appeared to have been under-sampled compared with molluscs, and this is almost certainly not due to the preference of these authors, since their Pawlett Hams surveys of ditches (1996) and ponds (1998) show the more usual ratio of beetles to molluscs with beetles well out-numbering molluscs.

Palmer *et al*. (1979) at West Sedgemoor and Tadham and Sheppard (1985) at Tadham did not appear to be obviously biased to any group but many common species were not found, which suggested under-sampling by comparison with later surveys. It seems unlikely that such low values obtained within a few years of the survey by Drake *et al*. (1984) were due to a rapid change in faunal quality.

Godfrey (1999, 2000) produced consistently lower median species richness values than those of Gibbs (1994) and Drake *et al*. (1984) or the present Buglife survey (2007), but these values were usually higher than in most other surveys. The consistent dip in species richness between the 1994 and 2007 surveys is more likely to be due to sampling method than an ecological reality. This conclusion is supported by the similar SCS Scores obtained by all survey by Drake and Gibbs, which collectively were usually greater than those obtained in other surveys. As SCS Score is an average per species, there appears to have been no consistent bias by Godfrey but perhaps just a shorter sampling time (hence fewer species but an adequate representation to give similar SCS values).

Surveys by Drake *et al*. (1984), Buglife (2007) and Gibbs (1994, 1999) gave similar species richness medians falling above those of nearly all other surveys. The Buglife survey nearly always had the greatest Species Richness and SCS Score but not the Habitat Quality Score. These were probably the most directly comparable surveys.

Once these between-surveyors effects are appreciated, the results can be inspected for changes that may be due to environmental effects. Kruskall-Wallis tests for differences between median was used as the first indication of real differences, and these tests were repeated after removing some of the poorer surveys. The other indication of real differences between surveys are values that exceed the minimum likely change due to unexplained variation, as identified in Section 1, which showed that medians need to exceed ±22%, for Species Richness, ±11% for SCS Score, and ±8% for Habitat Quality Score.

2.2.2 Results for individual wetlands

Catcott, Chilton and Eddington Moors
There appeared to have been little consistent change in Species Richness since 1983 apart from the large value in 2007, and the fluctuations may have been due to surveyor rather than changes in the

environment. There was a slow and fairly steady increase in SCS Score, which was significant even when only the four more thorough surveys were considered (Kruskall-Wallis statistic = 9.54, p = 0.0229). Habitat Quality Score appeared to fluctuate but when the two poorer surveys were removed there was no significant difference between the median obtained in the remaining surveys.

Gordano Moor
This was not surveyed in the Buglife project but data were available from a survey by Drake undertaken a few years before the Buglife work, using a similar sampling protocol. When the small survey (4 ditches) by Anderson *et al*. (1991) was removed, none of the metrics were significantly different between surveys.

Kenn, Nailsea and Tickenham Moors
The tiny sample of two ditches sampled by Drake *et al*. 1984 was excluded, and four ditches sampled by Anderson *et al.* in 1992 were added to their 1991 sample of 20 ditches. The large dip in Species Richness in 1991 and 1999 was thought to be almost entirely due to sampling protocol. A change in quality was not reflected in SCS or Habitat Quality Scores, the difference in medians of SCS Score being significant, but not those of Habitat Quality Score.

Kings Sedgemoor
Of the five surveys available, that by Hill-Cottingham & Smith (1995) with only four ditches sampled by the Environment Agency could be can safely ignored. Differences between medians of Species Richness and scores for SCS and Habitat Quality were all significantly different, but without the Hill-Cottingham & Smith survey the significance of the differences was reduced or, for Habitat Quality Score, removed. These results appear to suggest a slight and steady improvement over the years, although probably falling within the band of uncertainty due to unexplained variation.

Moorlinch
This moor received rather little survey, and one of the surveys (Hill-Cottingham & Smith, 1995) consisted of only three samples. When only the 1983 and 2007 surveys were compared, there was significantly greater Species Richness and SCS Score, but no difference in Habitat Quality Score. The difference in medians for Species Richness (31 versus 40.5) and for SCS Score (1.29 versus 1.43) may also exceed that due to unexplained variance. It seems likely that there has been a genuine improvement in the quality of the fauna at Moorlinch between 1983 and 2007.

Pawlett Hams
Seven surveys have been undertaken at Pawlett Hams although one was just ponds (Hill-Cottingham & Smith, 1998) and another investigated only three ditches (Southwest Ecological Services, 2007) which were excluded from the analysis. The survey by Southwest Ecological Services in 2002 consisted of May and August sampling in the same year, and these were treated as separate surveys here. The survey of ditches by Hill-Cottingham & Smith (1996) resulted in notably lower median Species Richness than other surveys but there were no clear grounds for excluding it as the methodology seemed as robust as used by other surveyors. Removing this sample made no difference to the significance of the differences of the medians, so it alone was not responsible for a possible U-shaped trend in Species Richness and SCS Scores. However, a simpler explanation was that had been no change, as suggested by the non-significant Kruskall-Wallis statistic for all metrics in the three surveys in which the surveyor was Drake (1983, 2006, 2007).

Southlake Moor
The site was not included in the main Buglife project but had been surveyed in 2004 as part of the Buglife pilot project (Drake, 2005). In that survey, samples were taken using the method later adopted in the main project and using the method of Gibbs, but only the first of these was analysed here. The methodology used by Armitage *et al.* (1981) appeared to be different from most other surveyors so the low values for all metrics were not regarded as real. Metrics for the remaining four more thorough surveys behaved more erratically than on most moors. Species Richness and SCS Score showed indications of a gradual increase over time were it not for the very low Species Richness values by Godfrey (2000) and for SCS Score by Gibbs (1994). Medians for Species Richness and SCS Score remained highly significantly different when Armitage *et al.* was removed, although differences in Habitat Quality Scores changed from significant to not significant. The difference between the highest value and next highest for Species Richness (40.5 and 32) exceeded the minimum expected due to unexplained variation, but this was not true for SCS Score (1.44 and

1.38), although the gradual trend for increasing SCS Score was more convincing than for Species Richness. It was concluded that there was weak evidence for a gradual increase in the quality of the fauna at Southlake.

Tadham & Tealham Moors
Of eight surveys that had taken place here, three were excluded: Sheppard (1985) did not cover molluscs, Palmer *et al*. 1979 investigated only three ditches, and Hill-Cottingham & Smith investigated two ditches. There were markedly more outliers in the surveys by Armitage *et al.* and Drake *et al.* in the early 1980s; the low values in Drake *et al*. came from recently deep-dug ditches that were almost devoid of vegetation, and there was no justification for their removal. The low values in Armitage *et al.* were from small field ditches that were probably poorly sampled for beetles (the dominant group in such ditches) which were consistently under-sampled in this survey. However, removing this poorer survey did not change the significant difference between medians for Species Richness and SCS Score, although Habitat Quality Score changed to being non-significantly different. The pattern of relatively low values for Species Richness but not for SCS Score in Godfrey surveys compared with those of Gibbs and Drake was the same as found at Kings Sedgemoor and Southlake, and suggested that this pattern was a survey-related artefact. The difference between highest to next highest values for Species Richness (43 and 34.5) was greater than the minimum due to unexplained variation, and suggested that this may be a real increase between 1994 and 2007. As at Southlake, SCS Scores showed no such large change between the higher values and a steady increase over time. The evidence suggested that there had been a small increase in the quality of the fauna since the 1980s.

West Sedgemoor
Of seven surveys that had taken place here, that by Hill-Cottingham & Smith (1995) was excluded as it was based on only three ditches. Those by Palmer (1979) and Armitage *et al.* (1981) showed indications of inadequate sampling. Differences in the medians of all metrics were significant regardless of whether these poorer surveys were included, and the pattern for Species Richness and SCS Score for surveys by Godfrey, Gibbs and Drake were the same as found in several other moors. Differences between values for the two highest medians were just below the minimum expected due to unexplained variation for both Species Richness (42.5 and 33) and SCS Score (1.41 and 1.33). Habitat Quality Score showed no obvious trend, even though there were differences between the medians. These results indicated a possible but unsubstantiated increase in Species Richness and SCS Score over time.

Changes in the metrics for these wetlands are summarised in Table 5.5.

Table 5.3 Kruskal-Wallis tests of medians of species richness, species conservation status score and habitat quality score for all relevant surveys at each moor

Kruskall-Wallis statistic significant at p<0.05 are in bold.

	Species richness		SCS		HQ	
	KW	p	KW	p	KW	p
Catcott	**43.73**	<0.0001	**18.74**	0.0022	**24.57**	0.0002
Gordano	**8.20**	0.0420	6.17	0.1036	2.71	0.4384
Kenn	**32.77**	<0.0001	**13.57**	0.0035	2.65	0.4489
Kings Sedgemoor	**20.03**	0.0005	**18.55**	0.0010	**11.51**	0.0214
Moorlinch	**12.35**	0.0021	**10.38**	0.0056	4.19	0.1232
Pawlett	**35.62**	<0.0001	**18.58**	0.0023	10.01	0.0749
Southlake	**29.38**	<0.0001	**22.84**	0.0001	**10.33**	0.0351
Tadham	**46.22**	<0.0001	**15.14**	0.0044	**13.71**	0.0083
West Sedgemoor	**50.46**	<0.0001	**36.93**	<0.0001	**18.96**	0.0020

Table 5.4 Kruskal-Wallis tests as above but with poorer surveys removed as detailed in text

	Species richness		SCS		HQ	
	KW	p	KW	p	KW	p
Catcott	**21.44**	<0.0001	**9.54**	0.0229	0.59	0.8990
Gordano	1.26	0.5335	2.67	0.2633	1.79	0.4090
Kenn	none excluded					
Kings Sedgemoor	**14.10**	0.0028	**11.60**	0.0089	0.96	0.8097
Moorlinch	**11.20**	0.0008	**8.67**	0.0032	2.34	0.1262
Pawlett	**11.62**	0.0204	**15.43**	0.0039	5.13	0.2741
Southlake	**21.50**	<0.0001	**20.56**	0.0001	4.14	0.2463
Tadham	**29.54**	<0.0001	**10.19**	0.0170	5.97	0.1132
West Sedgemoor	**32.43**	<0.0001	**28.66**	<0.0001	**11.16**	0.0109

Table 5.5 Summary of changes in species metrics at Somerset Moors

- = no change
↑ = significant increase in the score ('bar' exceeded)
"↑" = possible increase in the score (but 'bar' not exceeded)

	Species Richness	Species Conservation Status Score	Habitat Quality (Marsh Fidelity) score
Catcott, Chilton & Eddington	-	↑	-
Gordano	-	-	-
Kenn, Nailsea & Tickenham	-	↑	-
Kings Sedgemoor	"↑"	"↑"	-
Moorlinch	↑	↑	-
Pawlett Hams	-	-	-
Southlake Moor	"↑"	"↑"	-
Tadham & Tealham	↑	"↑"	-
West Sedgemoor	"↑"	"↑"	-

2.3 Changes in individual species

2.3.1 Proportions on each moor

A drawback to the method used to analyse proportions on each moor was that the small numbers associated with infrequent species led to a greater likelihood of a significant result. The results were therefore restricted to the more frequent species, which were the twelve nationally scarce and rare species (with conservation status scores of 3 to 4) found in at least 2% of 686 samples included in this analysis, and common species found in at least 15% of samples. Most species on most moors showed no indication of a change in frequency (Table 5.6). A meaningful trend was indicated by a significant change being found at several moors.

The only scarce species to show several significant changes (three in each case) were the large soldierfly *Stratiomys singularior* and the diving beetle *Hydaticus seminiger.* The change in the soldierfly may have been due to random changes in a relatively sparsely distributed species but later analysis of the trend through time supported the reality of the present result. *Hydaticus seminiger* appeared to be recent arrival in Somerset. Of the 16 records, the first was from Gordano in 2004, 14 were from the 2007 Buglife survey at the Catcott complex, Kings Sedgemoor, Tadham & Tealham and Queens Sedgemoor (east of Tadham), and the most recent from Moorlinch in 2009 (not included in the chi-squared analysis). It is unlikely that this moderately large and distinctive beetle had been overlooked in a well surveyed area.

The most widespread of the common and local species were essentially unchanged in their occurrence in the county's marshes. The occasional indications of change were sporadic and confined to one or rarely two marshes, so did not constitute a trend across the marshes. Pawlett Hams often stood out but this was due to species intolerant of brackish water being scarce here.

Few of the less widespread species showed any real changes in frequency. The beetle *Hydroporus erythrocephalus* was moderately common the 1983 survey by Drake *et al.* (1984) and Gibbs (1994) but was otherwise scarce, notably in the period after 1994. The large bug *Corixa punctata* appeared to show unstable occurrence but this may have been due to the timing of surveys, since adults are more common later in the year outside the period of some surveys. No other species appeared to have undergone a consistent change in frequency in the marshes.

2.3.2 Correlation with year

Correlation of year with the proportion of occupied ditches indicated significant changes in the frequency of several species in groups that were included in most surveys (Table 5.7, Figures 5.4 to 5.7). Those whose taxonomic group was not included in most surveys (e.g. leeches) or variously treated (e.g. many dragonflies) were omitted, as was the beetle *Anacaena lutescens*, which was recognised as British only in the 1990s. No corrections were made of doubtful identifications. The main weakness lay in the surveys by Hill-Cottingham & Smith (1996), who recorded the rare saltmarsh soldierfly *Stratiomys longicornis* which was probably *S. singularior*, and the beetles *Paracymus scutellaris* (probably *Anacaena globulus*) and *Enochrus halophilus* (probably *E. ochropterus*); they also recorded almost no hydraenids or *Helophilus minutus*. Most of these were among species showing significant change, but including Hill-Cottingham & Smith's results did not appear to make much difference to the overall trends.

2.3.3 Species increasing in frequency

Two snails appear to have increased (Figure 5.4). *Bithynia leachii* was considerably more frequent in the 2000s than in the 1980s, and this was unlikely to be due to confusion with *B. tentaculata*. Kerney (1999) suggested that it was undergoing declines locally, so an upturn after the publication of his mollusc atlas does not contravene his statement. The small snail *Hippeutis complanata* also appeared to have increased but this was more likely to be the result of greater experience by Drake at finding it, thus accounting for the low frequency in the 1980s compared to high frequencies later.

Increases unlikely to be artefacts were those of two large bugs that are unmistakable even when small immatures, the saucer bug *Ilyocoris cimicoides* and the water stick insect *Ranatra linearis*. Driscoll (per comm.) reported *R. linearis* changing from extreme rarity to moderate frequency between the 1970s and 2000s in Norfolk marshes. Huxley (2003) reported that *I. cimicoides* appeared to be extending its range northwards, so it too may be experiencing more favourable conditions generally, even in southern England where it has been regarded as common for some time.

The large soldierfly *Stratiomys singularior* may also have increased in frequency since the 1990s. All records for *Stratiomys* sp have been interpreted here as being this species. The change from scarcity in the extensive 1983 survey to moderate frequency later strongly suggested an increase, and the result was supported by the chi-squared analysis of proportions within marshes. *Odontomyia ornata* also showed a significant correlation with time but the graph is less convincing than that for *S. singularior*, particularly as nearly all the points above zero in Figure 5.4 were made by surveyors with a particular interest in Diptera. Removing zero values, all made by non-dipterists, produced a non-significant correlation, whereas removing zero points for *S. singularior* resulted in no change to the significance of the correlation (i.e. even dipterists failed to record *S. singularior* in earlier surveys).

Six beetles appeared to have increased in frequency. These increases were almost certainly real since misidentification is unlikely for four of them. *Enochrus coarctatus*, which could be overlooked as a large *Anacaena limbata*, also seemed to show a convincing increase (Figure 5.4); three of the four later zero points are from Pawlett Hams where the species did appear to be particularly scarce. Identifying the very common *Helophorus minutus* is slow work since it must be dissected, but there is no reason to suppose it was overlooked or wrongly identified in early surveys since it is the 'default' determination of the lazy identifier for small *Helophorus* once the more obvious *H. brevipalpis* is eliminated. Apparent increases in three other small species may not be real as they were likely to have been under-recorded – the tiny margin-dwelling beetles *Ochthebius minimus* and *O. dilatatus* and the tiny water skater bug *Microvelia reticulata*. The apparent increase in emperor dragonfly *Anax imperator* is almost certainly an identification issue since it was recorded more frequently in late summer surveys, when large larvae were obvious, than those in spring, so the data were not equivalent across years.

2.3.4 Species declining

There were fewer significant decreases than increases, and all were thought to be real since the possibility of misidentification or inadequate sampling in later years is far less of as issue than for the earliest surveys (Figure 5.5). 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 in the moors to occupying a small proportion of ditches. The diving beetle *Suphrodytes dorsalis* was never particularly frequent in the Somerset Moors but, like *H. erythrocephalus*, was almost absent by the time of the Buglife survey. *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.

Some species with significant negative correlations with time occurred at low frequencies so the reality of a decline may be in doubt. The mud snail *Aplexa hypnorum*, which is occasionally found in late-stage ditches, showed apparent decline until the last year of the Buglife survey but the sudden upturn here was an artefact of the small sample size (10 ditches); if this is ignored, the decline appeared pronounced. The beetle *Haliplus heydeni* was scarce in the two earliest surveys (1979, 1983) but was not recorded thereafter. In the same two surveys, *Haliplus fluviatilis* was moderately frequent (in 15-35% of samples) but afterwards had fluctuated at low levels, although did not disappear altogether.

A few species did not show a significant correlation between time and their frequency but deserve some discussion (Figure 5.6). Hill-Cottingham (2006) suggested that the hoglouse *Asellus meridianus* was becoming progressively rarer in the Somerset Moors. There is weak evidence to support this suggestion although it is still present. The large red damselfly *Pyrrhosoma nymphula* appeared to have become much less consistently frequent than in the 1980s. The two 'spikes' (Gordano in 2004 and Southlake in 2005) were from late summer surveys so its near absence from many other 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 beetle *Hydroporus memnonius* seems to have been more frequent in a few surveys between 1989 and 1999 than before or since, although whether this is related to surveyor s unclear (two by Gibbs, one by Drake).

The small diving beetle *Porhydrus lineatus* was suggested to be declining, based on analysis of national data (Garth Foster, pers. comm.). In the Somerset dataset, the correlation was not significant (although close to $p = 0.05$) but there were markedly more zero or near zero occurrences in later surveys compared with moderately high frequencies in most surveys before 1995. There was an effect of location or soil type, since the frequencies greater than 0.3 from 1989 onwards were from clay moors in the north (Kenn complex) or the coastal Pawlett Hams where the beetle probably showed no change in status (Figure 5.6). However, a steady and large drop occurred through the large and widespread surveys from 1983, 1994, 1999 to 2007. There appeared to be evidence to support the contention that *P. lineatus* was in overall decline but has better populations on the clay moors and levels.

2.3.5 Non-native species

The snail *Potamopyrgus antipodarum* was a fairly scarce animal in the Somerset Moors but had a more persistent population at the coastal Pawlett Hams where mildly brackish conditions suite this snail (the two highest points in Figure 5.7).

The snail *Physella acuta* is a recent colonist to Somerset marshes. The first records in the marshes investigated by Buglife was 1994 at the Catcott complex and Tadham & Tealham in the Brue valley, followed by a considerable expansion to both north Somerset (Kenn, Nailsea & Tickenham) and the most southerly marsh, West Sedgemoor (Table 5.8, Figure 5.7). The population at Tadham was the largest and most consistently recorded, and suggests that it may have been close to the origin of the present colonisation episode. The snail was found in the Gwent Levels in 1984 so the colonisation of Somerset presumably post-dates that.

The North American amphipod crustacean *Crangonyx pseudogracilis* (first recorded in Britain in the London area in the 1930s (Gledhill *et al*. 1993)) appears to be a recent colonist to the Somerset moors. It was almost unrecorded in the large 1983 survey but became increasingly frequent thereafter so that it was one of the commonest animals by 2004. The correlation of frequency with time was significant. NBN Gateway data also showed Somerset's late colonisation.

2.4 Summary for Somerset

There was no indication of a decline in overall quality on any Somerset moor and, on most moors, a moderate to high possibility that either species richness or SCS Score (or both) had increased over the last c. 30 years (Table 5.8). 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. Equivocal results were obtained for several of these and other species using the crude method necessitated by the disparate survey data. Of those that had declined, the greatest concern was for the relatively common beetles *Agabus sturmii*, *Hydroporus erythrocephalus*, *Laccophilus minutus*, *Suphrodytes dorsalis* and *Porhydrus lineatus*. One nationally uncommon species, *Stratiomys singularior*, was apparently increasing in frequency, as were the local species *Bithynia leachii*, *Hippeutis complanata*, *Ranatra linearis* and *Enochrus coarctatus* and a few common species.

Two non-native species, *Physella acuta* and *Crangonyx pseudogracilis*, had increased in frequency n the last 30 years. The snail was unlikely to have much impact, but the amphipod was ubiquitous and may have an impact on the native fauna. However, any effect was presumably small since the overall quality and species richness of the fauna had not declined in the period of its occupancy.

Table 5.6 Probability of significance of chi-squared for the proportion of uncommon species differing between surveys for species in more than 2% of all samples from detailed surveys in the Somerset Levels. If p is >0.05 (not bold), then there is no reason to suppose that the frequency of a species has changed between surveys

Species	SCS		Catcott	Gordano	Kenn	Kings Sedgemoor	Moorlinch	Pawlett	Southlake	Tadham	West Sedgemoor	Percentage of all samples with the species
		totals	99	91	84	75	25	93	52	76	91	686
Odontomyia ornata	4	212	0.932	0.422	0.850	0.878	0.888	0.741	0.799	0.905	0.851	30.9
Hydaticus transversalis	3	173	0.929	0.533	0.595	0.905	0.719	**0.000**	0.722	0.803	0.903	25.2
Peltodytes caesus	3	136	0.748	0.713	0.785	0.808	0.804	0.791	0.719	0.780	0.654	19.8
Limnoxenus niger	4	129	0.859			0.887	0.816	0.720	0.150	0.893	0.211	18.8
Hydrophilus piceus	4	121	0.485	0.418	0.068	0.785	0.862	0.123	0.529	0.898	0.767	17.6
Odontomyia tigrina	3	104	0.818	0.779	0.694	0.831	0.619	**0.001**	0.203	0.688	**0.012**	15.2
Stratiomys singularior	3	64	0.712	0.418	**0.000**	0.126	0.809	**0.031**	**0.000**	0.460	0.120	9.3
Limnebius papposus	4	47	0.256			0.131		**0.009**	0.232	**0.000**	0.500	6.9
Hydrochus angustatus	3	16	**0.000**	**0.044**							0.188	2.3
Hydrochara caraboides	5	15	0.101							0.462		2.2
Hydaticus seminiger	3	14	**0.004**	0.175		**0.032**				**0.003**		2.0

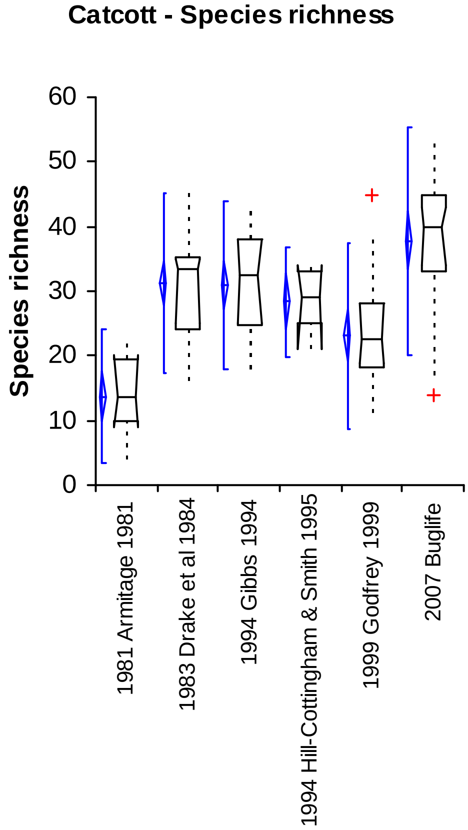
Table 5.7 Significant (at $p<0.05$) Pearson's correlation coefficients for year with the proportion of samples in each survey for each species

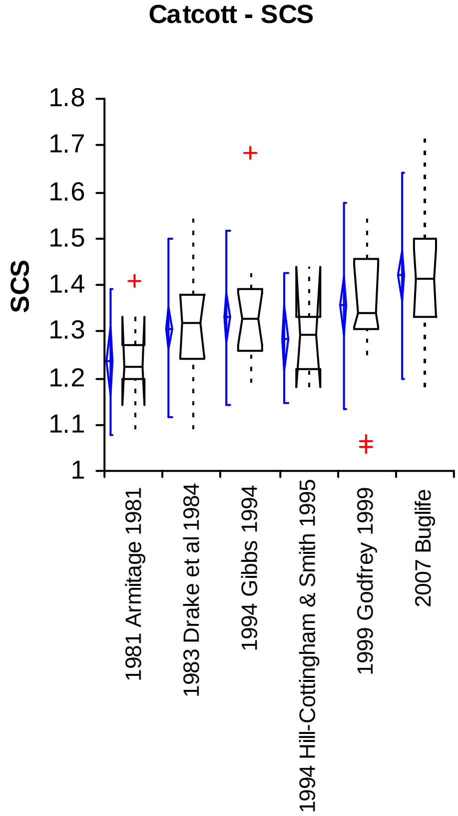
Increasing		**Decreasing**	
Hippeutis complanatus	0.699	*Hydroporus erythrocephalus*	-0.809
Stratiomys singularior	0.654	*Laccophilus minutus*	-0.710
Crangonyx pseudogracilis	0.637	*Aplexa hypnorum*	-0.642
Bithynia leachii	0.621	*Suphrodytes dorsalis*	-0.566
Ilyocoris cimicoides	0.585	*Gyrinus substriatus*	-0.562
Helophorus minutus	0.559	*Gerris lacustris*	-0.549
Ranatra linearis	0.554	*Haliplus fluviatilis*	-0.526
Anax imperator	0.543	*Agabus sturmii*	-0.501
Colymbetes fuscus	0.540	*Haliplus heydeni*	-0.485
Agabus bipustulatus	0.526		
Ochthebius dilatatus	0.513		
Odontomyia ornata	0.512		
Microvelia reticulata	0.512		
Enochrus coarctatus	0.493		
Ochthebius minimus	0.490		
Noterus clavicornis	0.479		

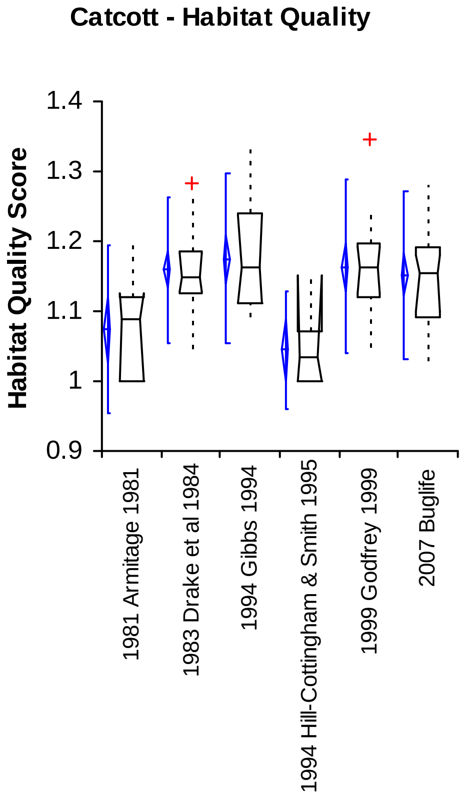
Table 5.8 Occurrence of the non-native *Physella acuta* in Somerset

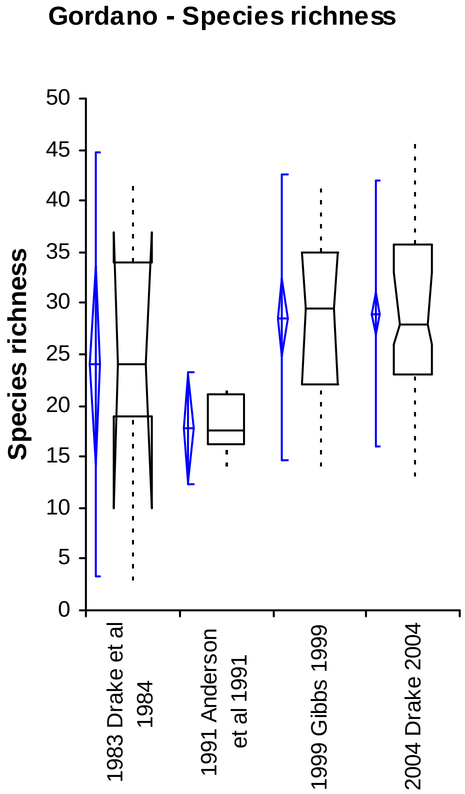
Survey	Year	Marsh	Number of ditches
Hill-Cottingham & Smith 1995	1994	Catcott	2
		Tadham	1
	1996	Pawlett	1
Godfrey 1999	1999	Kenn	2
		Tadham	1
Buglife	2007	Catcott	4
		Kenn	2
		Moorlinch	5
		Pawlett	1
		Tadham	10
		West Sedgemoor	1
	2009	West Sedgemoor	1
	Total		31

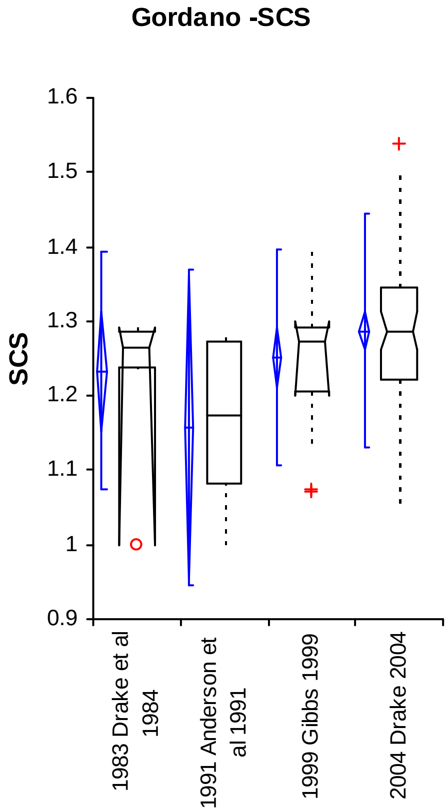
Figure 5.3 Species metrics for Catcott Moor, Somerset Levels

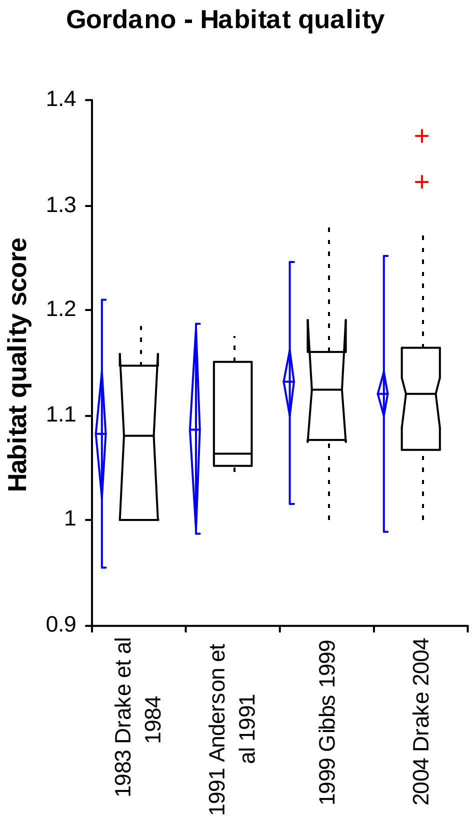


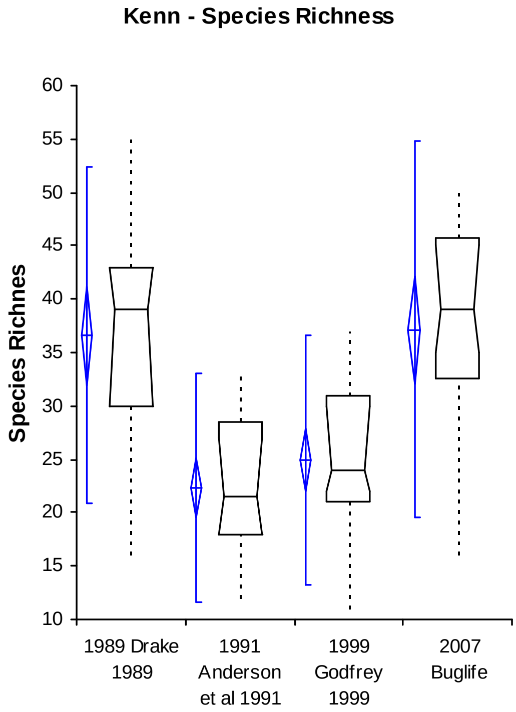


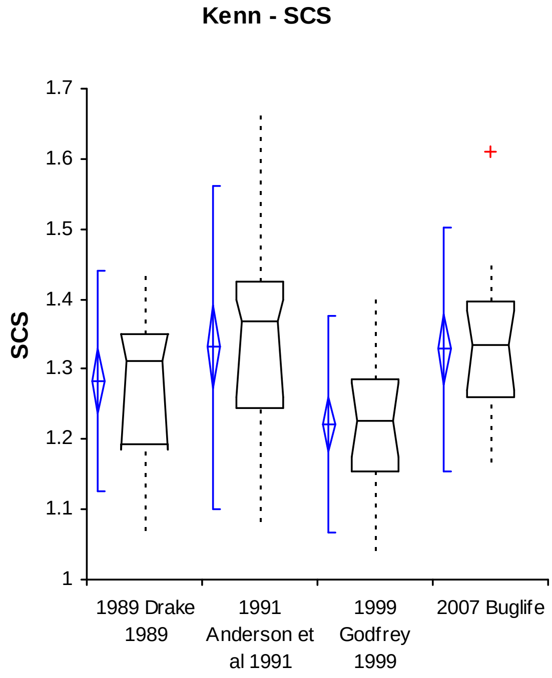


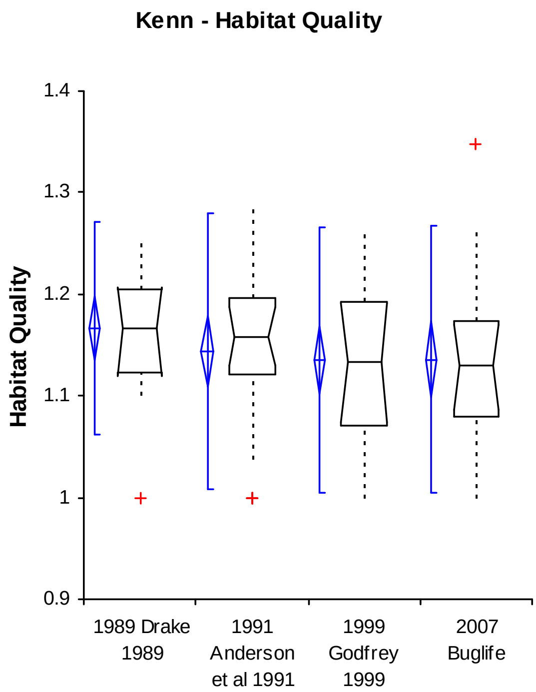

Gordano - Species richness
Species richness
0
5
10
15
20
25
30
35
40
45
50
1983 Drake et al 1984
1991 Anderson et al 1991
1999 Gibbs 1999
2004 Drake 2004


Gordano -SCS
SCS
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1983 Drake et al 1984
1991 Anderson et al 1991
1999 Gibbs 1999
2004 Drake 2004


Gordano - Habitat quality
Habitat quality score
0.9
1
1.1
1.2
1.3
1.4
1983 Drake et al 1984
1991 Anderson et al 1991
1999 Gibbs 1999
2004 Drake 2004


Kenn - Species Richness
Species Richnes
60
55
50
45
40
35
30
25
20
15
10
1989 Drake 1989
1991 Anderson et al 1991
1999 Godfrey 1999
2007 Buglife


Kenn - SCS
SCS
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1989 Drake 1989
1991 Anderson et al 1991
1999 Godfrey 1999
2007 Buglife


Kenn - Habitat Quality
Habitat Quality
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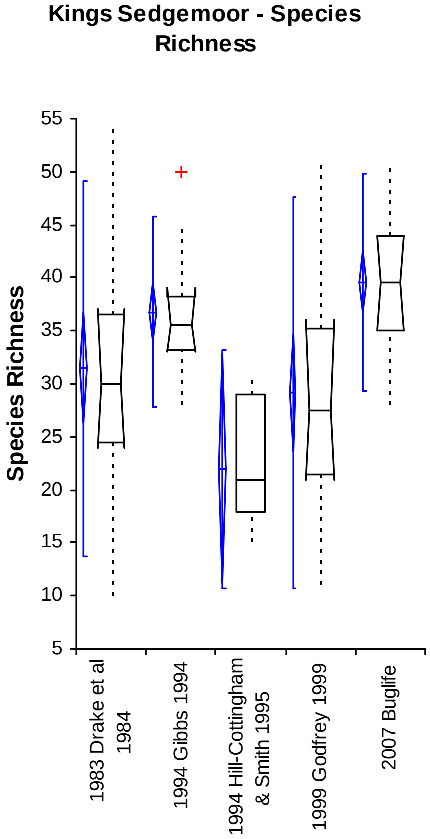
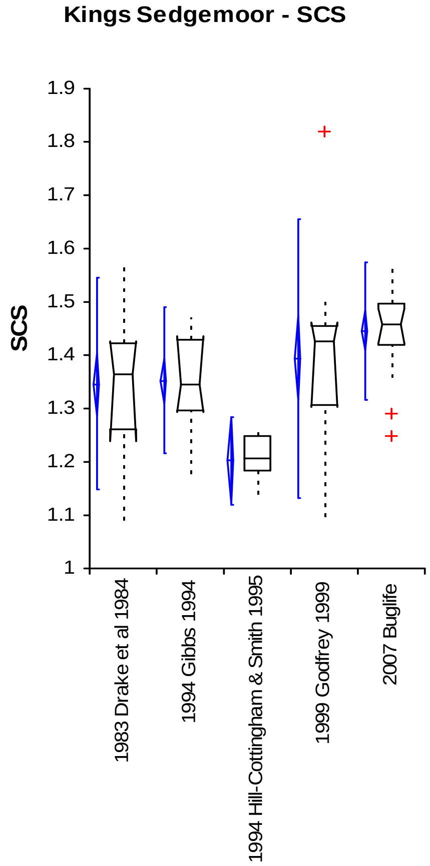
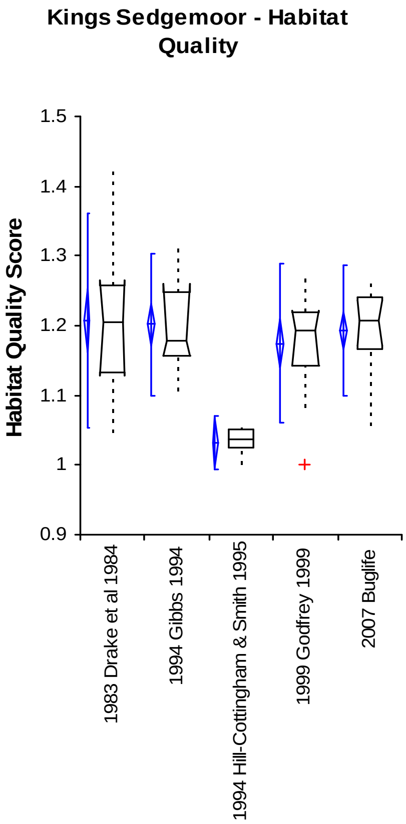
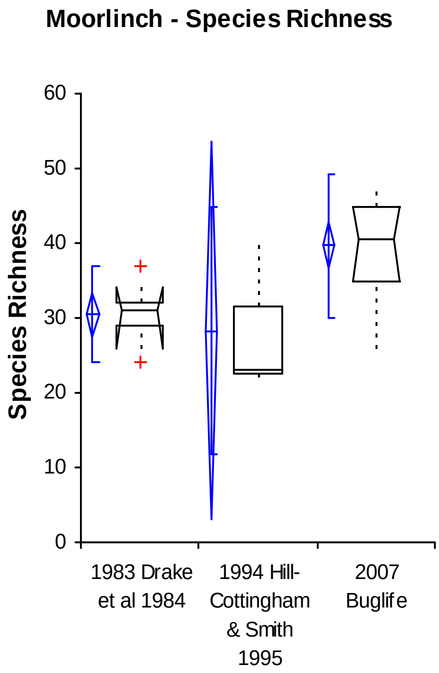
1.3
1.2
1.1
1
0.9
1989 Drake 1989
1991 Anderson et al 1991
1999 Godfrey 1999
2007 Buglife

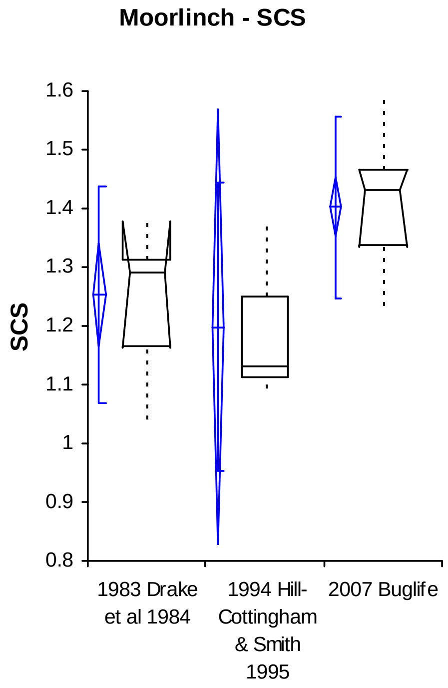

Kings Sedgemoor - Species Richness
Species Richness
55
50
45
40
35
30
25
20
15
10
5
1983 Drake et al 1984
1994 Gibbs 1994
1994 Hill-Cottingham & Smith 1995
1999 Godfrey 1999
2007 Buglife


Kings Sedgemoor - SCS
SCS
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1983 Drake et al 1984
1994 Gibbs 1994
1994 Hill-Cottingham & Smith 1995
1999 Godfrey 1999
2007 Buglife

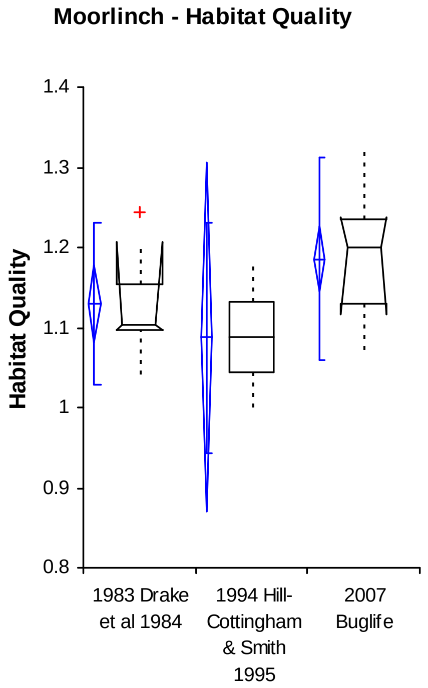

Kings Sedgemoor - Habitat Quality
Habitat Quality Score
1.5
1.4
1.3
1.2
1.1
1
0.9
1983 Drake et al 1984
1994 Gibbs 1994
1994 Hill-Cottingham & Smith 1995
1999 Godfrey 1999
2007 Buglife



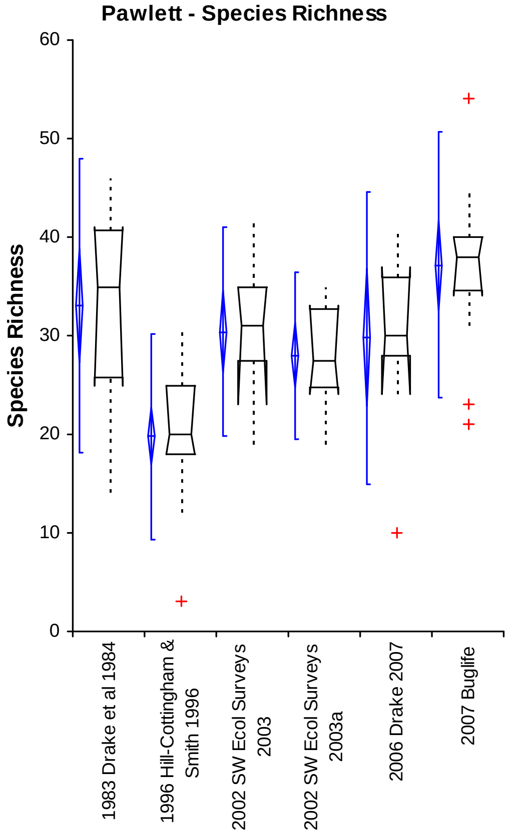
Moorlinch - Species Richness
Species Richness
60
50
40
30
20
10
0
1983 Drake et al 1984
1994 Hill-Cottingham & Smith 1995
2007 Buglife



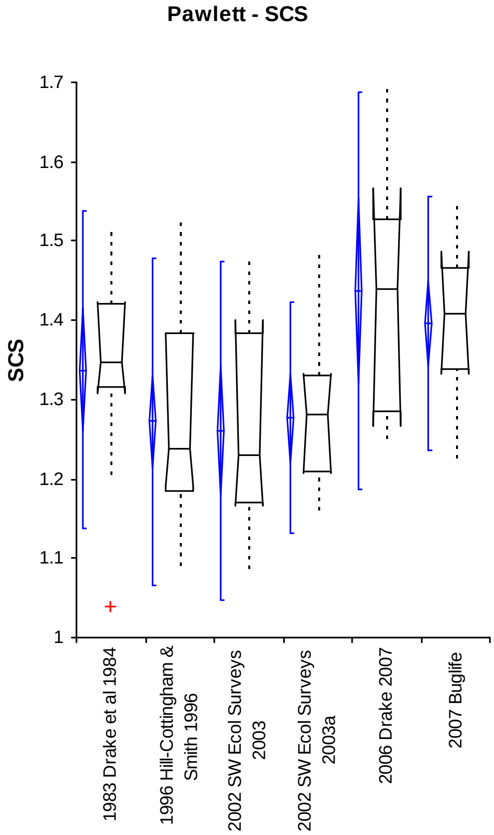
Moorlinch - SCS
SCS
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
1983 Drake et al 1984
1994 Hill-Cottingham & Smith 1995
2007 Buglife



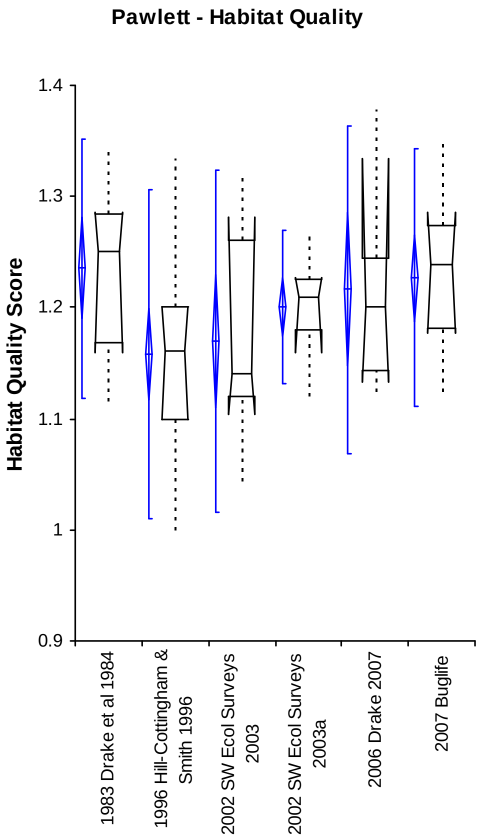
Moorlinch - Habitat Quality
Habitat Quality
1.4
1.3
1.2
1.1
1
0.9
0.8
1983 Drake et al 1984
1994 Hill-Cottingham & Smith 1995
2007 Buglife



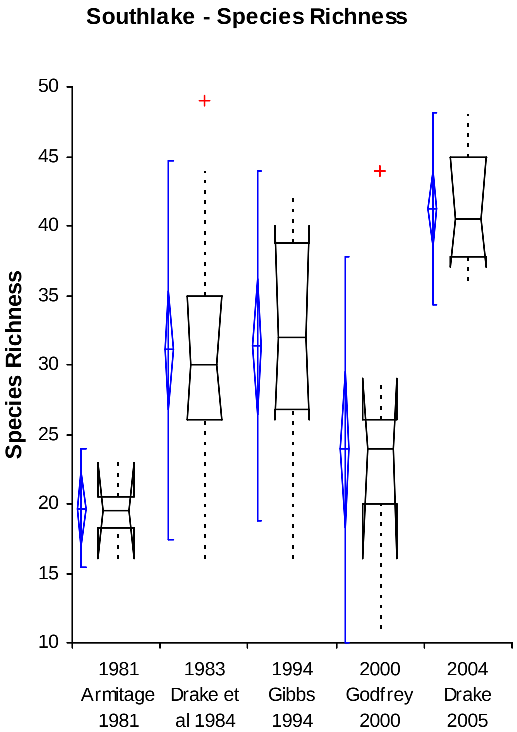
Pawlett - Species Richness
Species Richness
60
50
40
30
20
10
0
1983 Drake et al 1984
1996 Hill-Cottingham & Smith 1996
2002 SW Ecol Surveys 2003
2002 SW Ecol Surveys 2003a
2006 Drake 2007
2007 Buglife

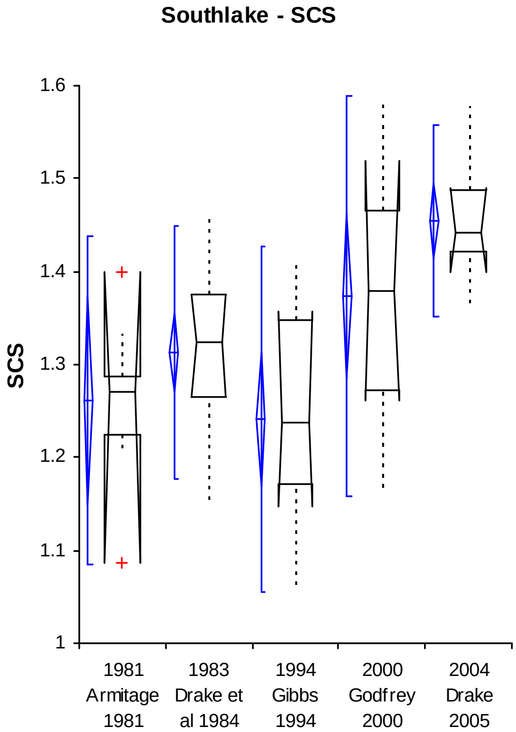


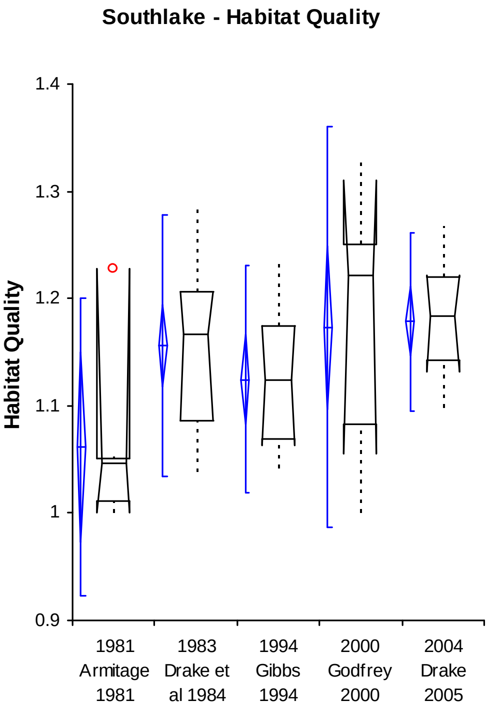
Pawlett - SCS
SCS
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1983 Drake et al 1984
1996 Hill-Cottingham & Smith 1996
2002 SW Ecol Surveys 2003
2002 SW Ecol Surveys 2003a
2006 Drake 2007
2007 Buglife

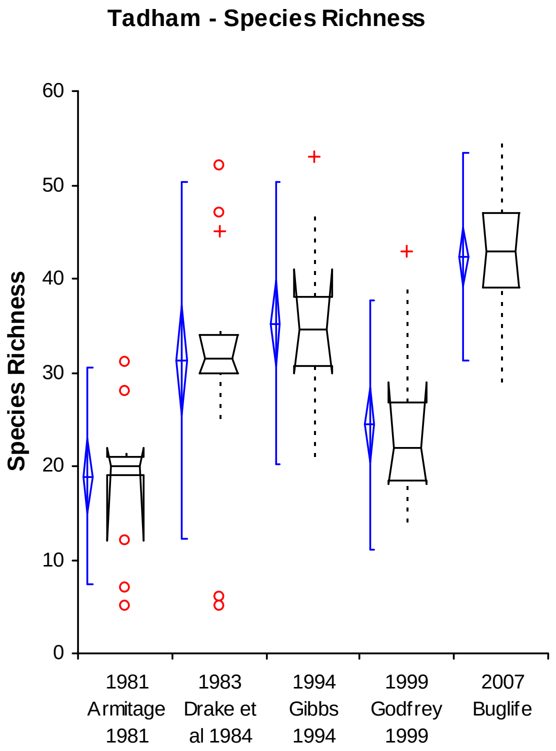


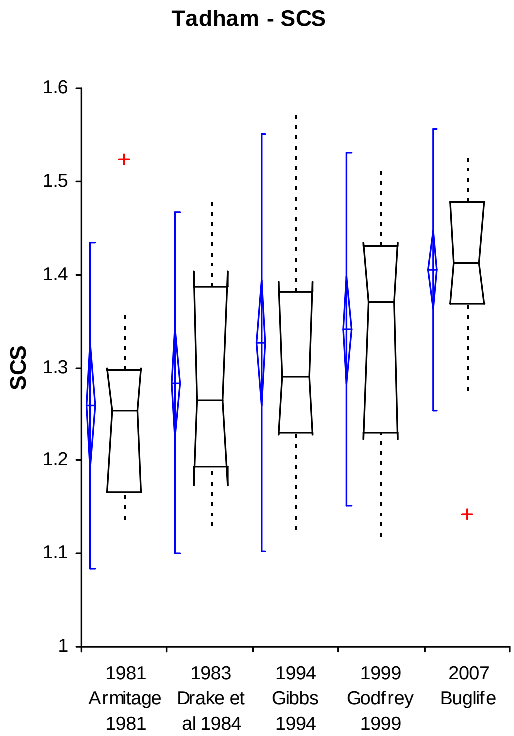
Pawlett - Habitat Quality
Habitat Quality Score
1.4
1.3
1.2
1.1
1
0.9
1983 Drake et al 1984
1996 Hill-Cottingham & Smith 1996
2002 SW Ecol Surveys 2003
2002 SW Ecol Surveys 2003a
2006 Drake 2007
2007 Buglife

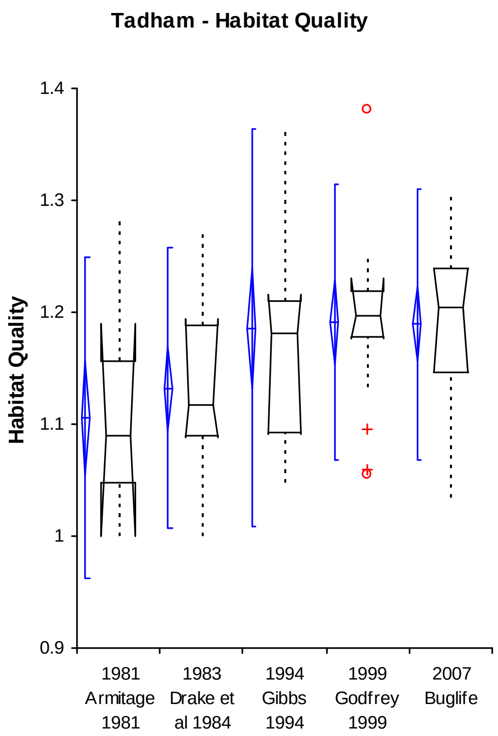

Southlake - Species Richness
Species Richness
50
45
40
35
30
25
20
15
10
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
2000 Godfrey 2000
2004 Drake 2005

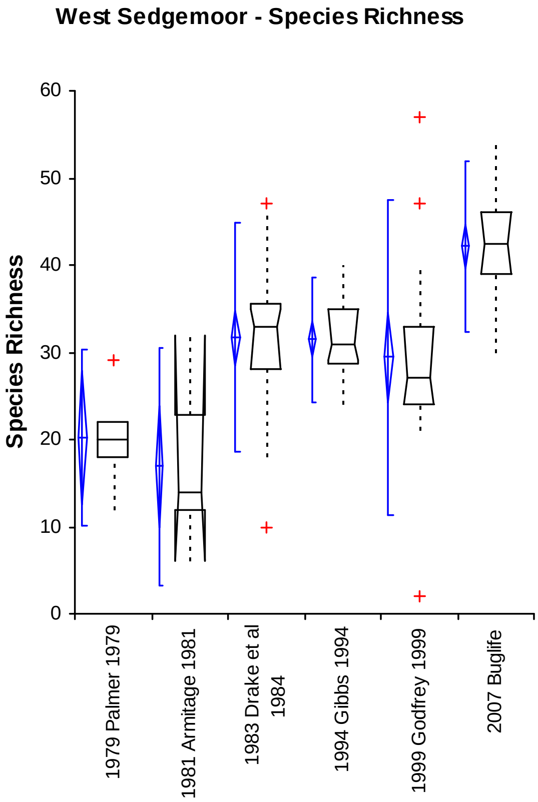

Southlake - SCS
SCS
1.6
1.5
1.4
1.3
1.2
1.1
1
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
2000 Godfrey 2000
2004 Drake 2005

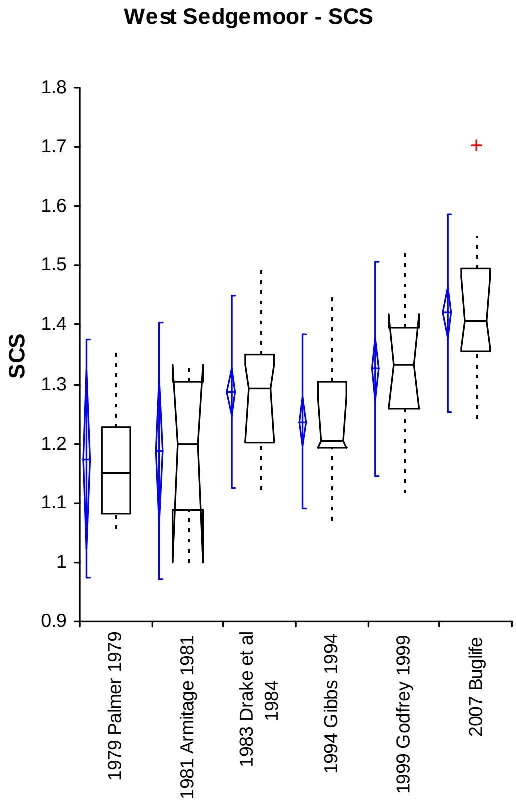

Southlake - Habitat Quality
Habitat Quality
1.4
1.3
1.2
1.1
1
0.9
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
2000 Godfrey 2000
2004 Drake 2005


Tadham - Species Richness
Species Richness
0
10
20
30
40
50
60
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife


Tadham - SCS
SCS
1
1.1
1.2
1.3
1.4
1.5
1.6
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife


Tadham - Habitat Quality
Habitat Quality
0.9
1
1.1
1.2
1.3
1.4
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife


West Sedgemoor - Species Richness
Species Richness
60
50
40
30
20
10
0
1979 Palmer 1979
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife


West Sedgemoor - SCS
SCS
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
1979 Palmer 1979
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife

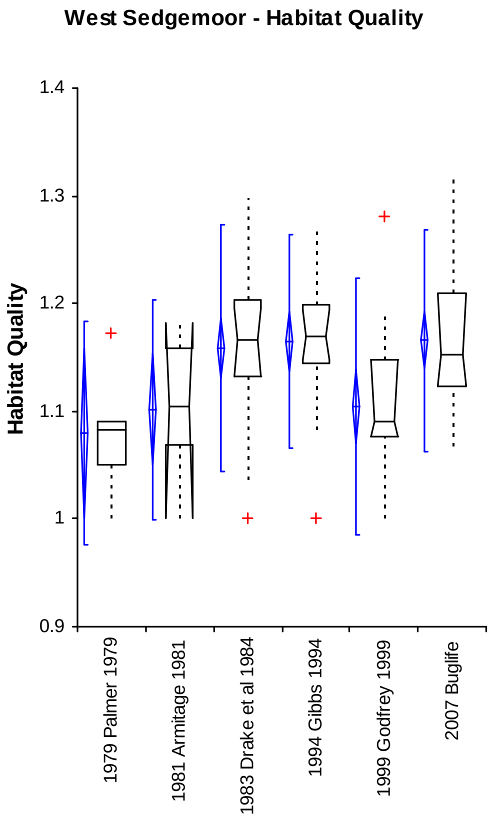
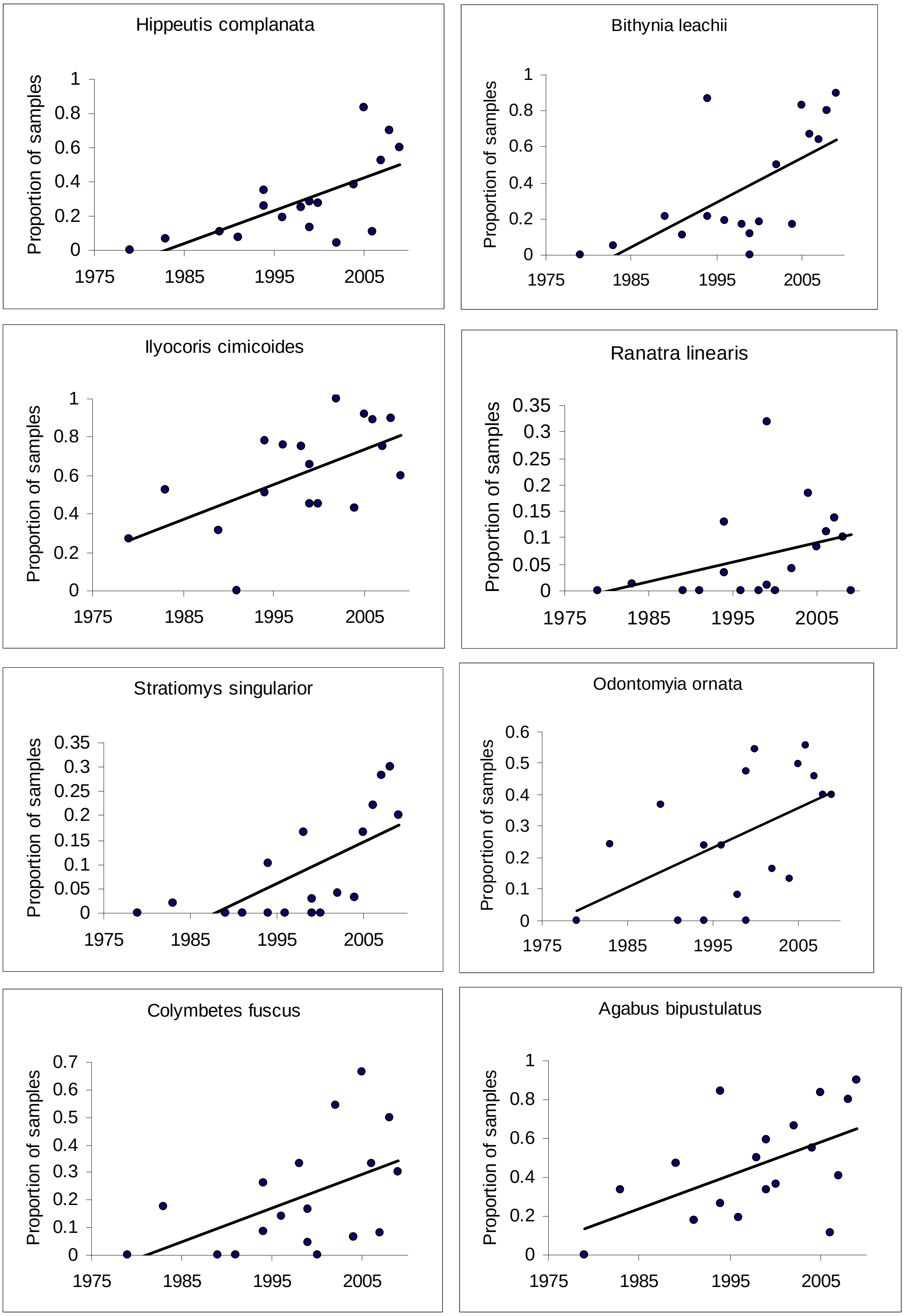

West Sedgemoor - Habitat Quality
Habitat Quality
1.4
1.3
1.2
1.1
1
0.9
1979 Palmer 1979
1981 Armitage 1981
1983 Drake et al 1984
1994 Gibbs 1994
1999 Godfrey 1999
2007 Buglife

Figure 5.4 Species that appear to have increased in the Somerset Moors



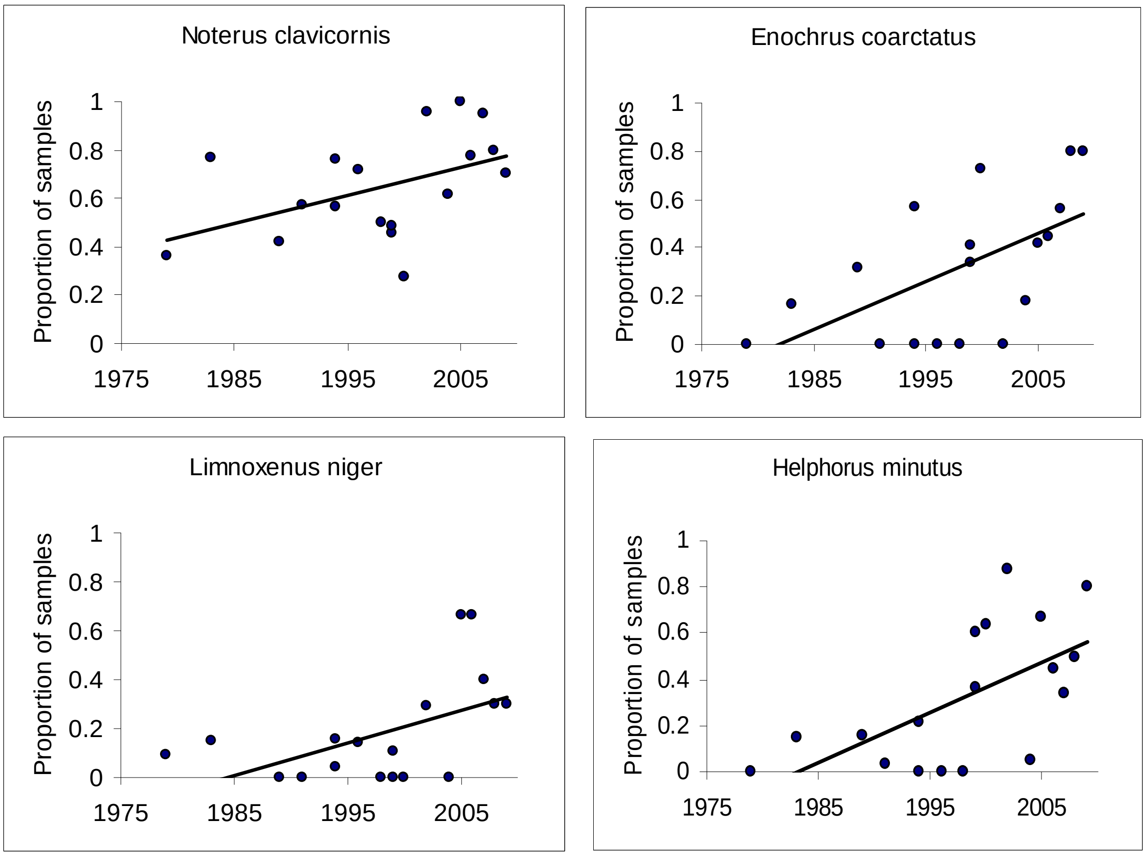

Noterus clavicornis
Enochrus coarctatus
Limnoxenus niger
Helphorus minutus
Proportion of samples
0
0.2
0.4
0.6
0.8
1
1975
1985
1995
2005

Figure 5.5 Species that appear to have undergone a decline in the Somerset Moors

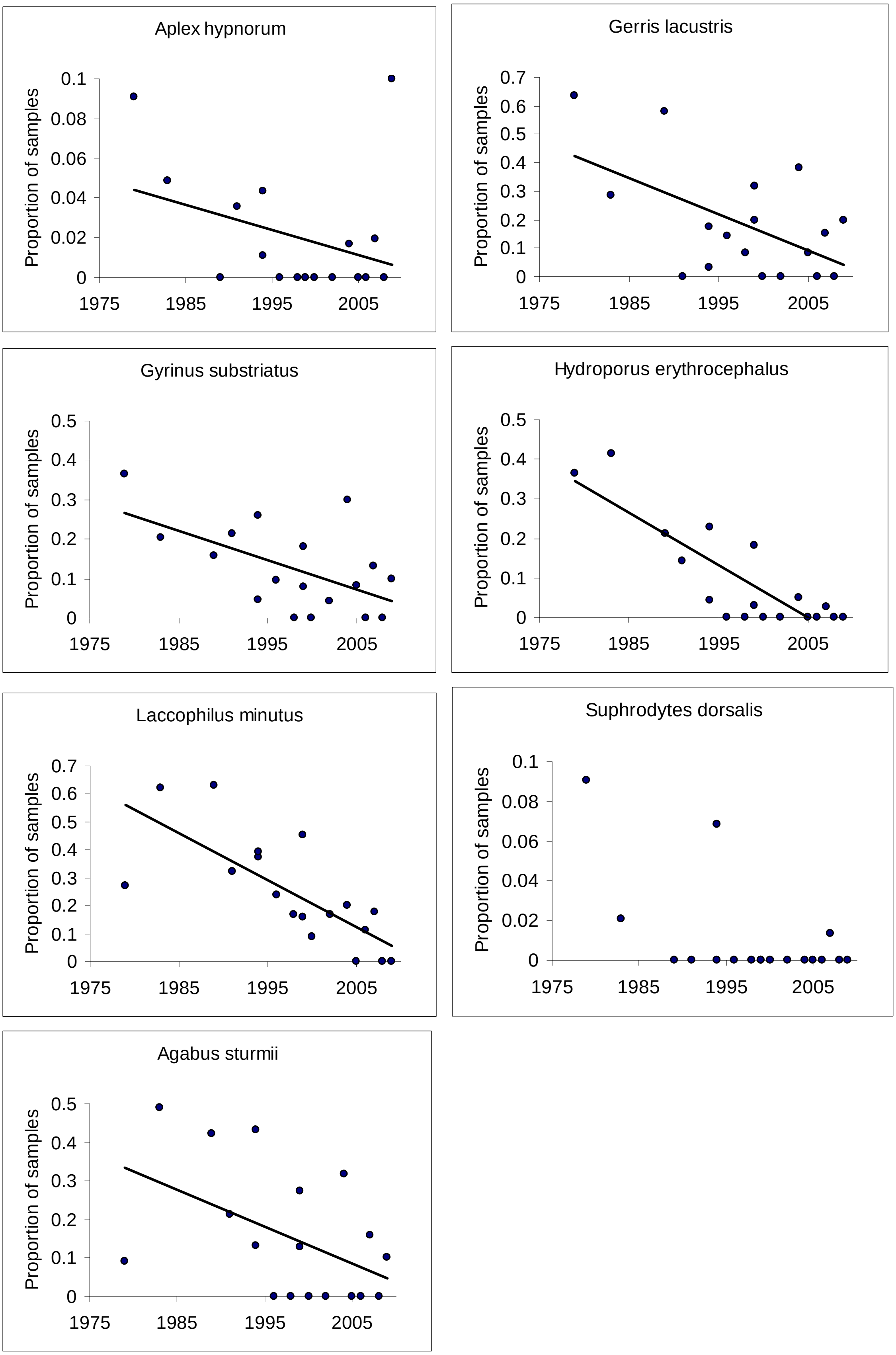


Figure 5.6 Species whose frequency may be changing in the Somerset moors

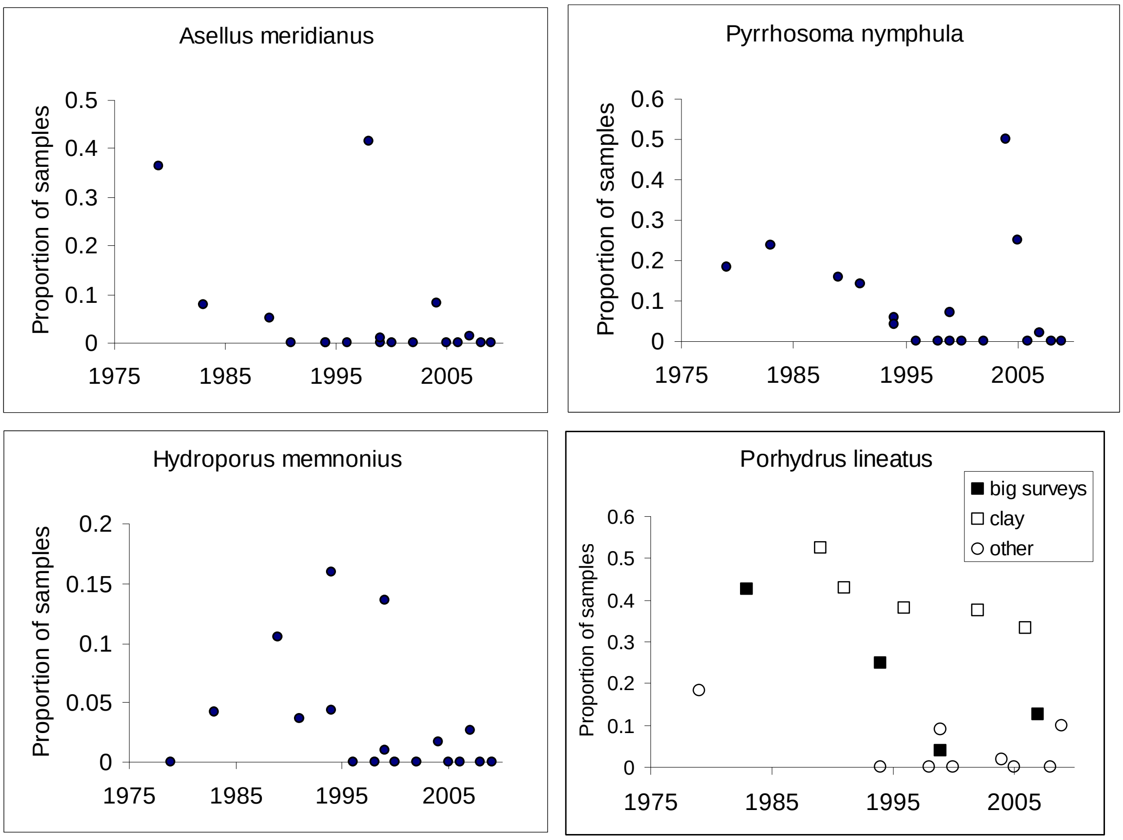
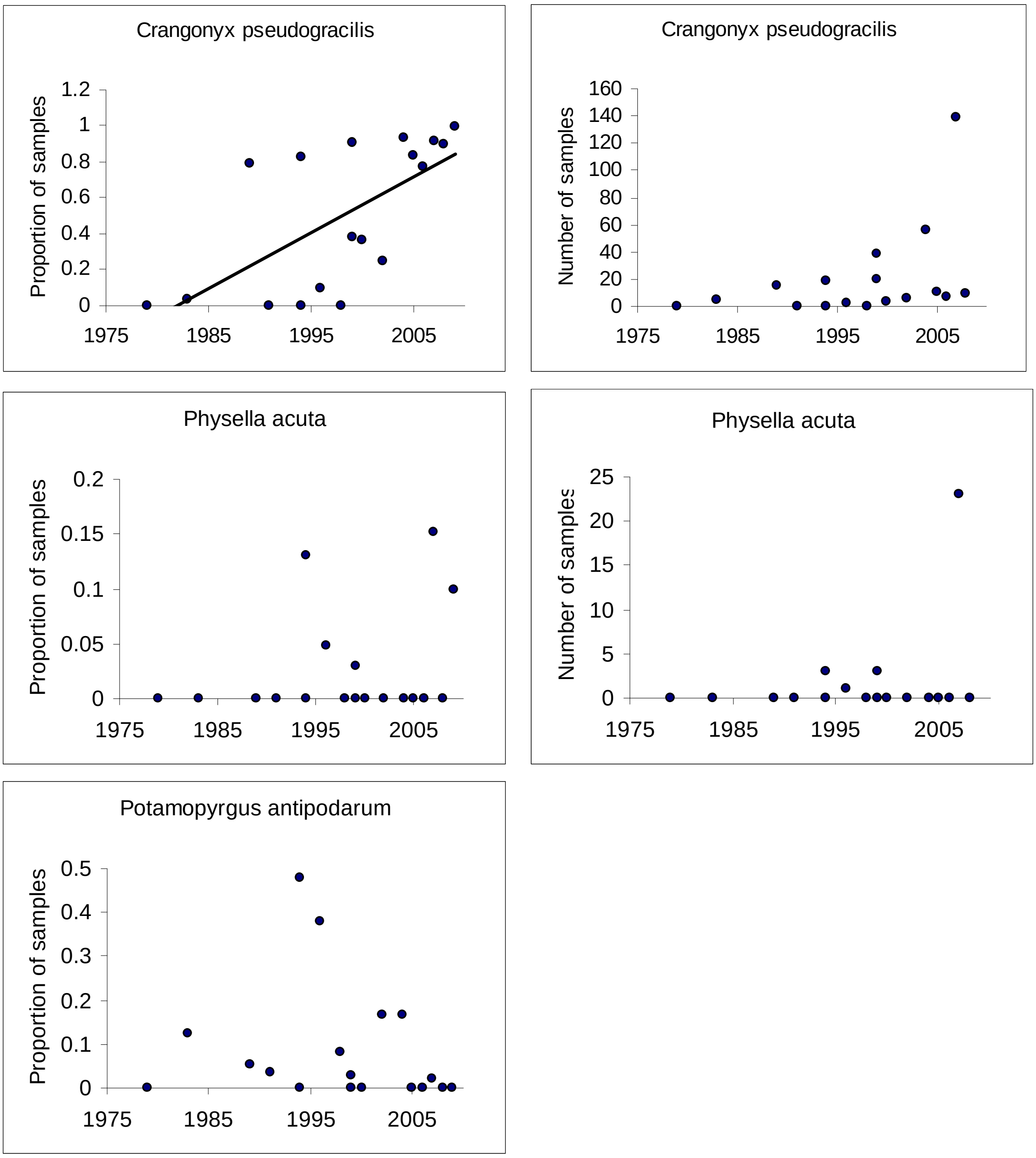


Figure 5.7 Change in frequency of non-native species in the Somerset Moors. Proportion (left) and number of records (right)



3 Comparison of surveys in Essex

3.1 Surveys compared

Eight surveys have been undertaken in Essex marshes that were re-surveyed in 2007-9. These are listed in Table 1.2, Appendix 1 of this volume. With a few minor exceptions, all major taxa were identified in all the surveys, and none was excluded from the analysis. Altogether, 287 ditches were used in comparisons of metrics for Species Richness, Species Conservation Status (SCS), Habitat Quality and Naturalness (Table 5.9).

3.2 Results of applying the metrics to data from individual sites

3.2.1 Rainham Marshes (Aveley & Wennington, Rainham)

Comparisons of species metrics for the surveys by Drake, Leeming and Scott Wilson Resource Consultants were complicated by differences that were almost certainly due to surveyor and sampling approach. Leeming sampled a large number of ditches, including those with exceptionally poor faunas, and this may account for lower median values, although not for the smaller maximum richnesses compared with those found in the Buglife survey. Scott Wilson Resource Consultants sampled only ditches close to the railway line which may not have been representative of the whole marsh.

Aveley and Wennington appeared to have become more species rich, whichever earlier surveys are used for the comparison (including those by Drake) and the change between latest and largest value for Species Richness exceeded the next largest by more than the 22% change that may be due to unexplained variation, so the result did seem to be real (Figure 5.8). SCS Score remained stable, with the exception of a low median value by Scott Wilson Resource Consultants that was responsible for the significant Kruskal-Wallis statistic. Habitat Quality Score also remained constant, but there were significant increases in the representation of non-native and brackish-water species.

By comparison, the fauna of Rainham Marsh itself had remained more stable over the two decades, showing no change in Species Richness, or in scores for Habitat Quality or Naturalness. There was no indication of a change in salinity. The only apparent significant increase was for SCS score, although individual ditches sampled in 1998 exceeded the best scores in 2009 and also exceeded the change that may be due to unexplained variation.

3.2.2 Vange and Fobbing Marshes

These marshes were selected for re-survey because they were rated as one of the most important Essex marshes for its aquatic invertebrates (Drake, 1988) and Fobbing Marsh had been well surveyed in 1993. Comparisons between years were limited.

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 considerably higher values (median of 7785µS cm^{-1} compared with 3370 µS cm^{-1}, which was significant: Mann-Whitney U-statistic = 48, $p=0.012$).

For Fobbing Marsh, Kruskal-Wallis tests of medians of all metrics except brackish-water species were significant for the three surveys but this was due to the lower values in the intermediate survey. There was essentially no difference between 1987 and 2009 values (both surveyed by Drake), and the intermediate dip was attributed to the different surveyor, who found remarkably few species.

3.2.3 Hadleigh Marsh

The only survey other than those of 1987 and 2009 was one of a few ponds, and this was not included in the comparison. There was no change in the species metrics except for naturalness score which indicated greater numbers of non-native species.

3.2.4 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 significantly. The change for SCS Score was just greater than the 11% change in median that may be due to unexplained variation, and the change in Habitat Quality Score was just less than the 8% threshold. However, given the closeness of these values, it may be assumed that the change was as likely to be a real response to more sympathetic management rather than to unexplained variation. 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 (the extreme outlier in Figure 5.8).

3.2.5 Brightlingsea NNR

There was no change in any species metric here except that for Naturalness which indicated a significant increase in the representation of non-native species since the last survey in 1993.

3.3 Changes in individual species

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* and the diving beetles *Hydroporus angustatus* and the nationally scarce *Rhantus frontalis* (Figure 5.9). 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 although the beetles *Helophorus brevipalpis* and *Hydroporus pubescens* were less frequent in the Buglife survey than in several earlier ones. They are both very common nationally and showed no decline elsewhere.

Four non-native species were recorded in the Essex surveys. The Chinese mitten crab was found in the Inner Thames Marshes only 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* showed no significant increase over the years but was clearly more widespread now than in some early surveys. 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. The increases in *P. acuta* and perhaps in *C. pseudogracilis* were likely to be the reason for significant rise in the median for the Naturalness Score in most marshes.

3.4 Summary for Essex

Despite considerable changes in management at some Essex marshes, there were few changes in the summary characteristics of the fauna (Table 5.10). Species Richness rose only at RSPB's new Rainham reserve (the old marshes Aveley and Wennington), and this is presumably a direct response to a marked changed in water management. There was no concurrent change in the overall rarity here, and it is possible that raised water levels have led to a more diverse range of habitats, which may have encouraged colonisation by widespread species initially, but has not had time to for noticeable colonisation by rare ones. SCS Score did rise at Rainham, and this was inexplicable since the site had undergone little change apart from recent ditch management. The rise in SCS Score at Fambridge may, however, be attributed to a considerable increase in the treatment of ditches, which principally included raising water levels, digging new ditches with gentle profiles and lowering the intensity of cattle and sheep grazing. At this site, Habitat Quality Score also increased, and this supported the conclusion that there was a real beneficial response to better management at Blue

House Farm. Vange Marsh was also under markedly different management but the raised water levels had not resulted in a change in species metrics. This may be due to an increase in the salinity of the water used to raise levels, although greater salinity may also have been expected to encourage some uncommon coastal specialists.

Few species were either increasing or decreasing in frequency but they did include that nationally scarce diving beetle *Rhantus frontalis*. The non-native snail *Physella acuta* appeared to be a recent colonist that was rapidly spreading. The amphipod *Crangonyx pseudogracilis* was of less concern in Essex because although it was widespread it did not appear to have changed in frequency over the two decades.

Table 5.9 Kruskal-Wallis tests of medians of Species Richness, Species Conservation Status Score and Habitat Quality Score for Essex marshes.

Kruskall-Wallis statistic significant at p<0.05 are in bold.

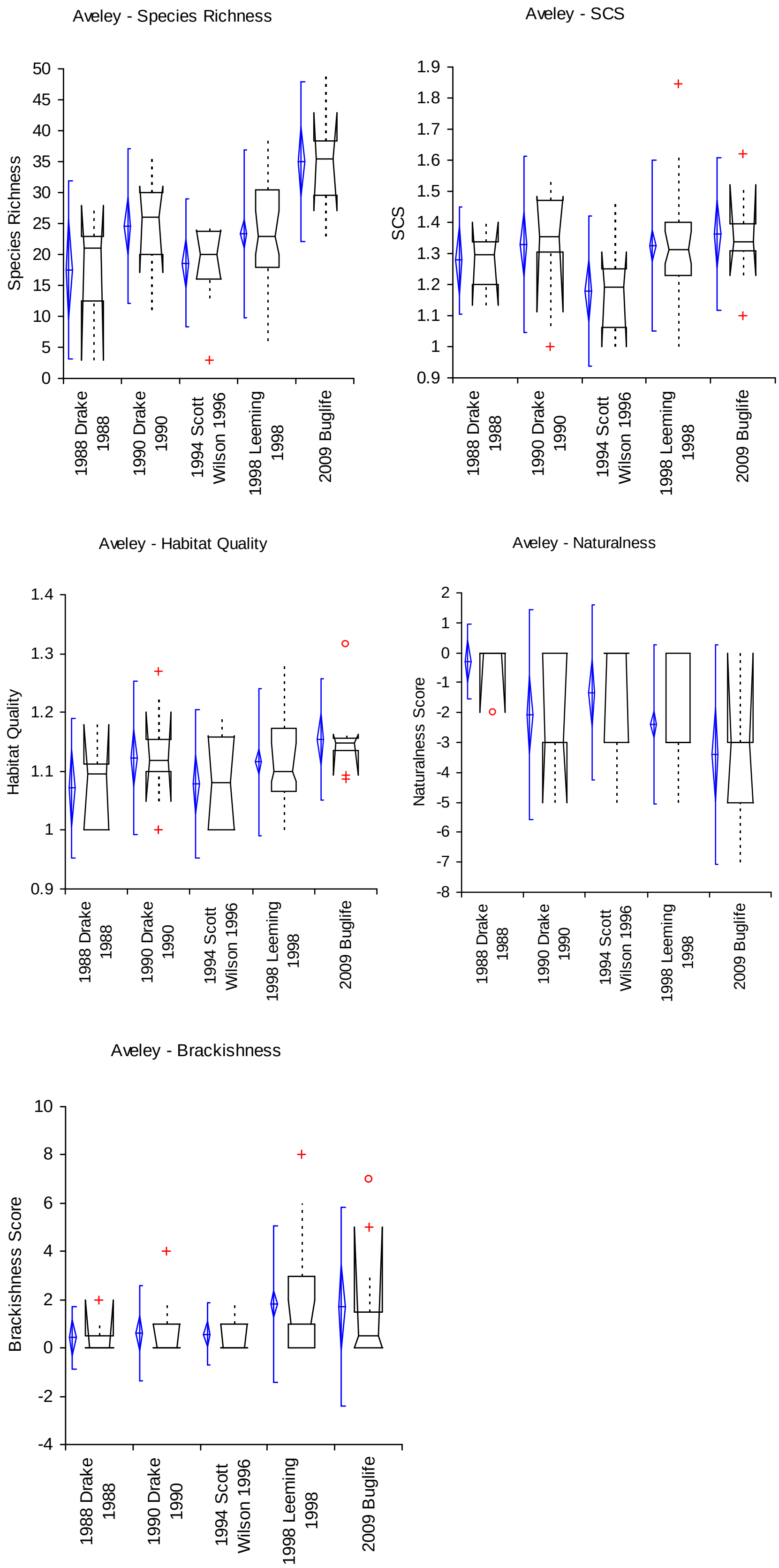
	Species richness		SCS		Habitat Quality		Naturalness		Salinity	
	KW	p	KW	p	KW	p	KW	p	KW	p
Rainham	**18.57**	0.002	**15.44**	0.009	**12.79**	0.025	**19.96**	0.001	**13.46**	0.019
Rainham proper	2.95	0.400	**10.19**	0.017	5.96	0.114	4.27	0.233	3.82	0.281
Rainham - Aveley & Wennington	**19.87**	0.001	**9.64**	0.047	6.40	0.171	**15.02**	0.005	**9.88**	0.043
Vange & Fobbing	**29.27**	0.000	**12.53**	0.002	**24.21**	0.000	**15.57**	0.000	2.27	0.322
Vange	1.41	0.234	1.64	0.201	2.70	0.100	0.22	0.637	**4.03**	0.045
Fobbing	**25.88**	0.000	**6.85**	0.033	**16.68**	0.000	**24.33**	0.000	3.22	0.199
Hadleigh	0.03	0.871	0.11	0.745	0.53	0.465	**7.08**	0.008	0.97	0.324
Fambridge	0.65	0.420	**4.20**	0.040	**4.56**	0.033	**5.67**	0.017	0.20	0.654
Brightlingsea	6.23	0.101	3.34	0.342	0.50	0.919	**19.92**	0.000	2.01	0.570

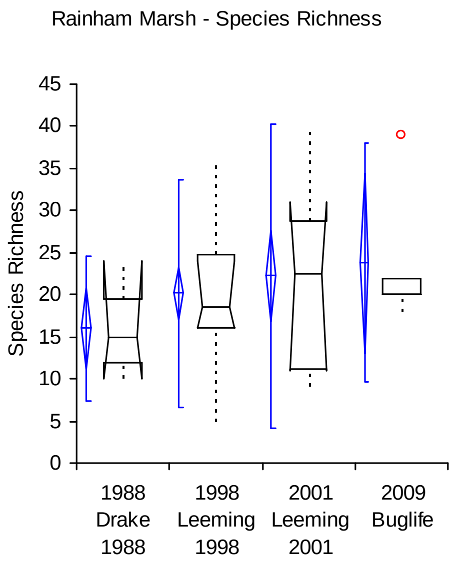
Table 5.10 Summary of changes in species metrics at Essex marshes

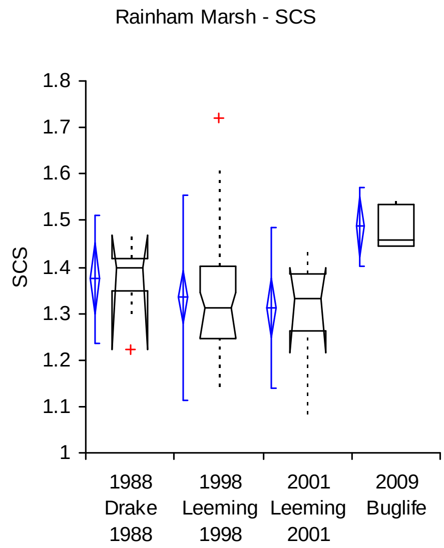
- = no change
↑ = significant increase in the score ('bar' exceeded)
"↑" = possible increase in the score (but 'bar' not exceeded)

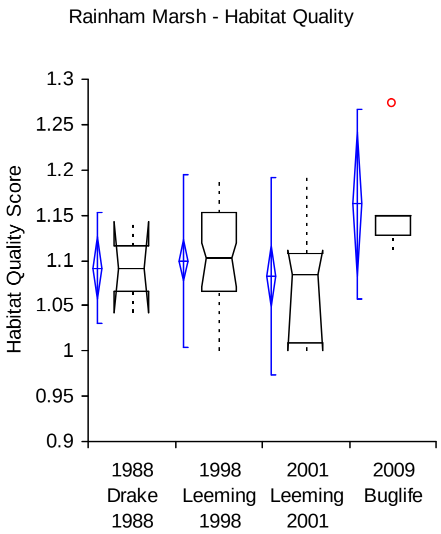
	Species Richness	Species Conservation Status Score	Habitat Quality (Marsh Fidelity) Score
Rainham proper	-	↑	-
Rainham - Aveley & Wennington	↑	-	-
Vange	-	-	-
Fobbing	-	-	-
Hadleigh	-	-	-
Fambridge	-	↑	"↑"
Brightlingsea	-	-	-

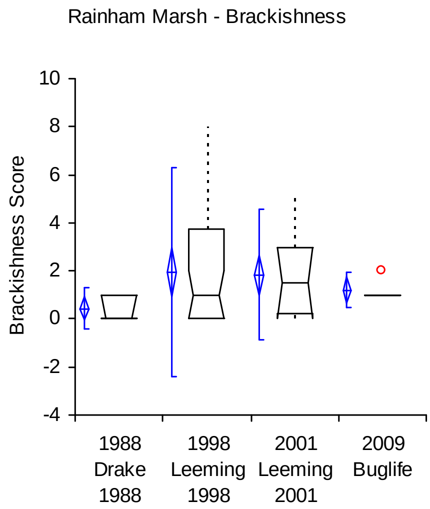
Figure 5.8 Species metrics for Essex marshes, giving mean and median with 95% confidence limits.



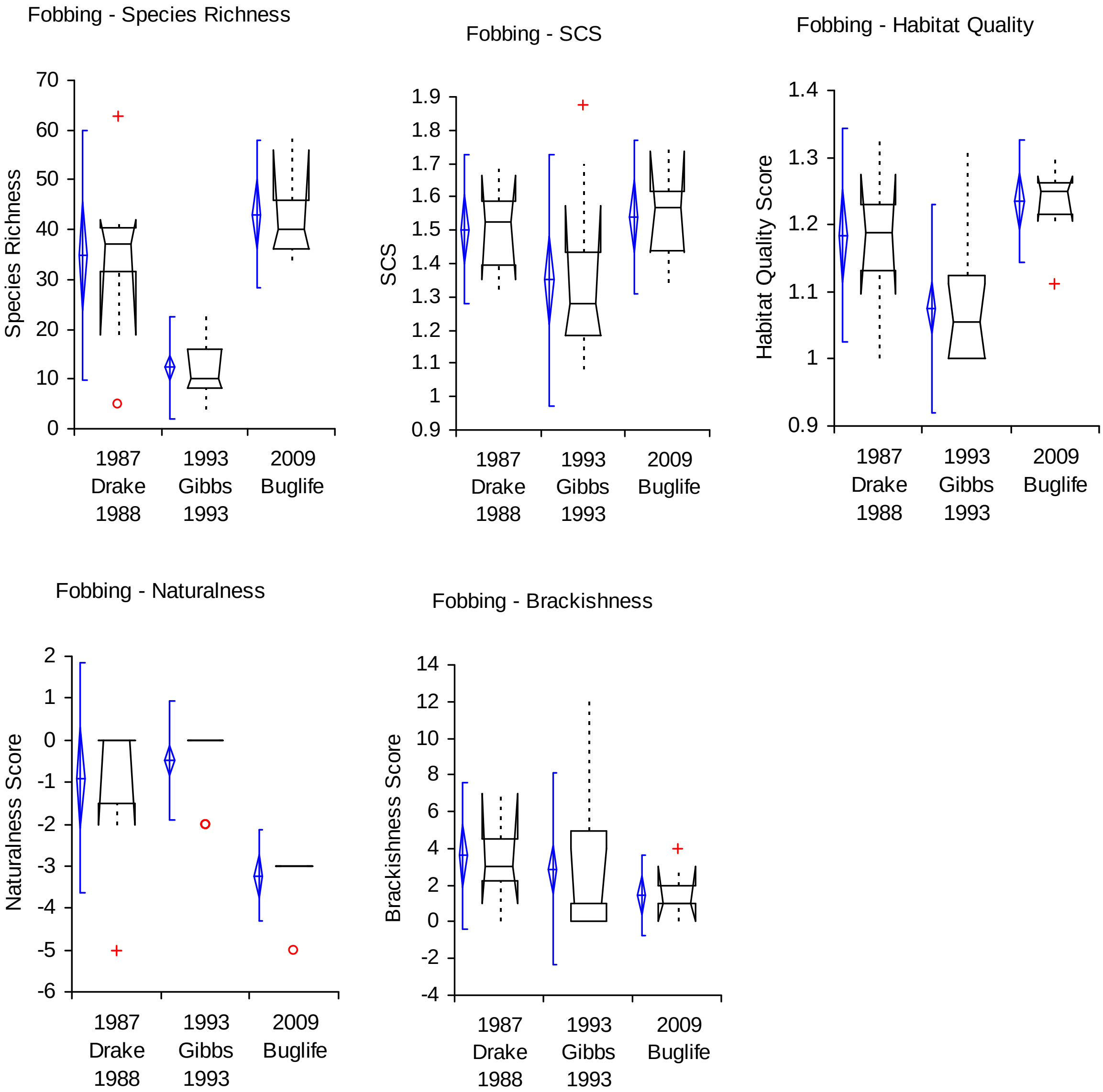


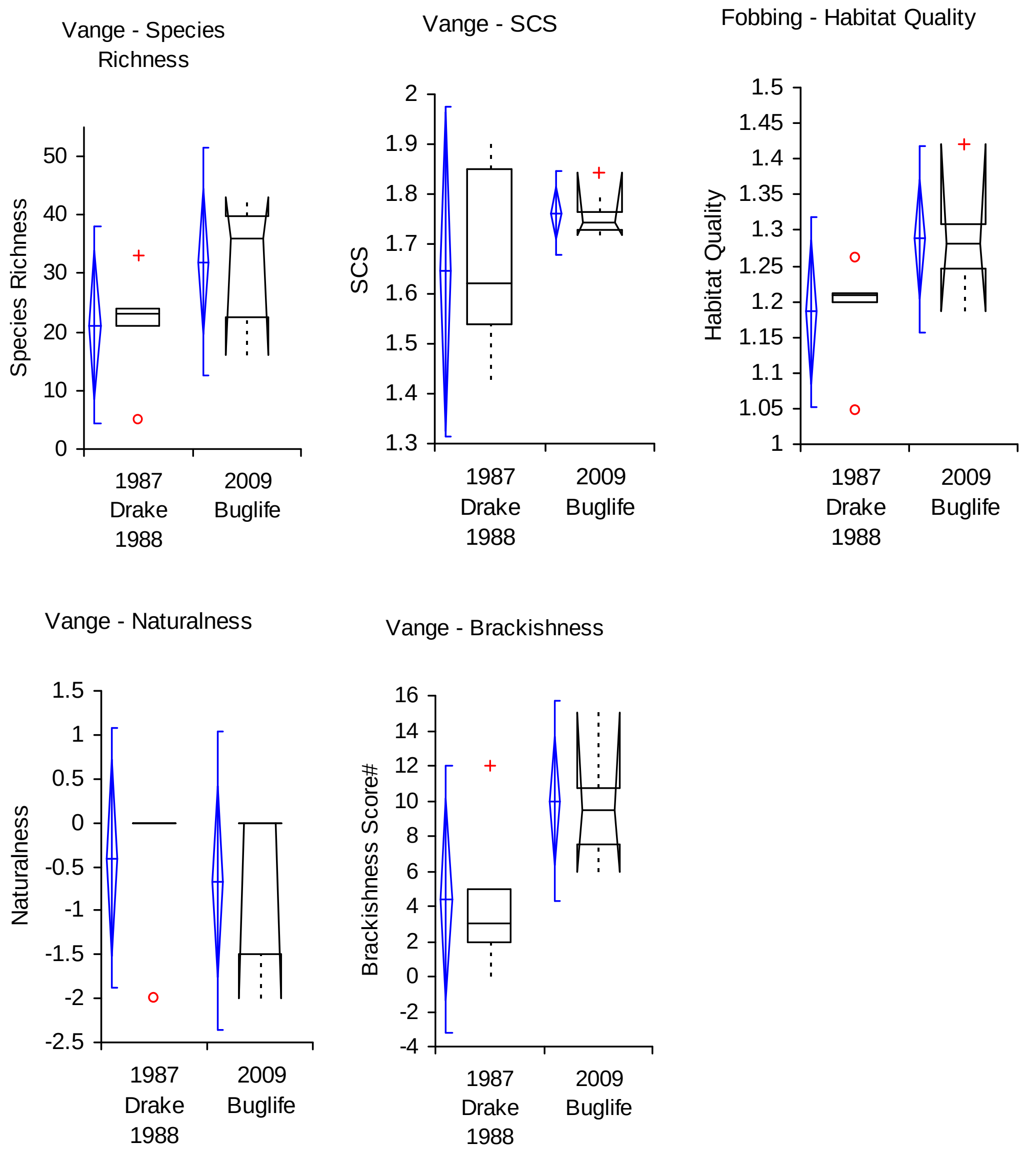


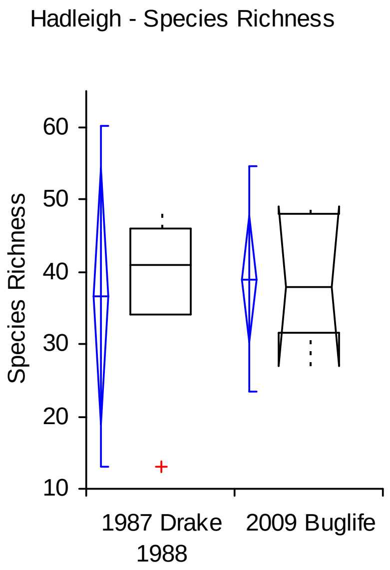


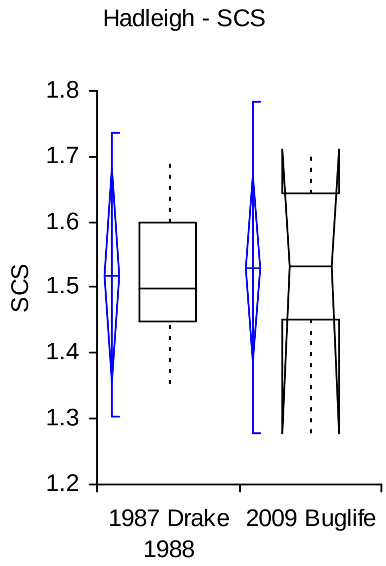


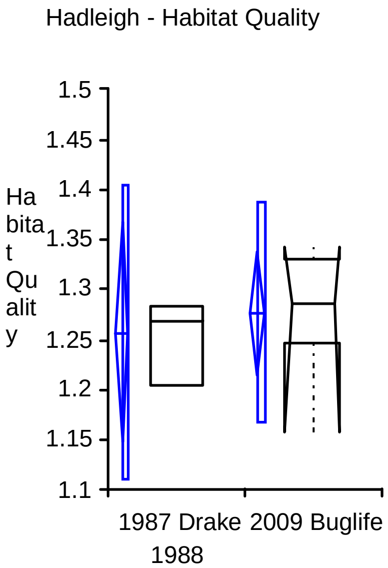
No computation for naturalness

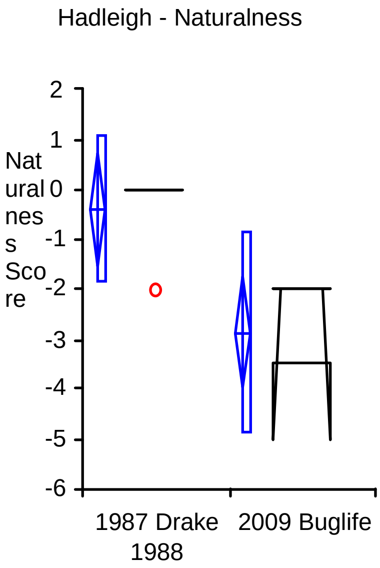

Fobbing - Species Richness
Species Richness
70
60
50
40
30
20
10
0
1987 Drake 1988
1993 Gibbs 1993
2009 Buglife
Fobbing - SCS
SCS
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
1987 Drake 1988
1993 Gibbs 1993
2009 Buglife
Fobbing - Habitat Quality
Habitat Quality Score
1.4
1.3
1.2
1.1
1
0.9
1987 Drake 1988
1993 Gibbs 1993
2009 Buglife
Fobbing - Naturalness
Naturalness Score
2
1
0
-1
-2
-3
-4
-5
-6
1987 Drake 1988
1993 Gibbs 1993
2009 Buglife
Fobbing - Brackishness
Brackishness Score
14
12
10
8
6
4
2
0
-2
-4
1987 Drake 1988
1993 Gibbs 1993
2009 Buglife

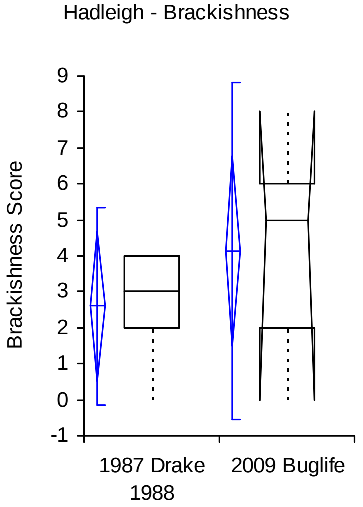

Vange - Species Richness
Species Richness
50
40
30
20
10
0
1987 Drake 1988
2009 Buglife
Vange - SCS
SCS
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1987 Drake 1988
2009 Buglife
Fobbing - Habitat Quality
Habitat Quality
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
1987 Drake 1988
2009 Buglife
Vange - Naturalness
Naturalness
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1987 Drake 1988
2009 Buglife
Vange - Brackishness
Brackishness Score#
16
14
12
10
8
6
4
2
0
-2
-4
1987 Drake 1988
2009 Buglife

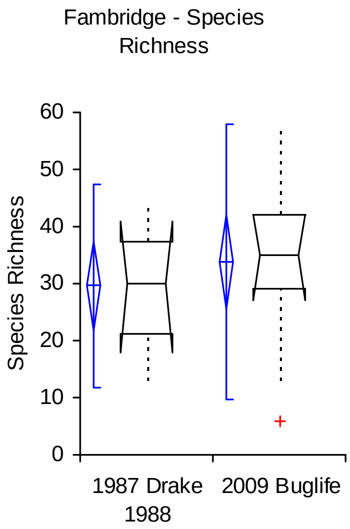

Hadleigh - Species Richness
Species Richness
60
50
40
30
20
10
1987 Drake 1988
2009 Buglife

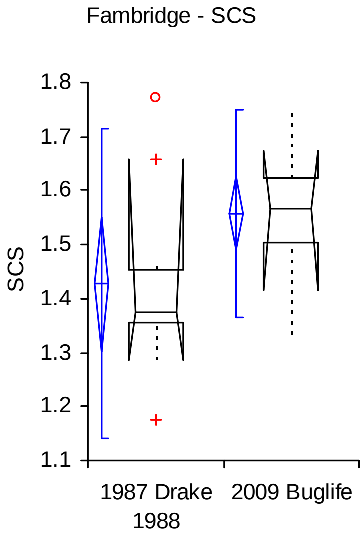

Hadleigh - SCS
SCS
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1987 Drake 1988
2009 Buglife

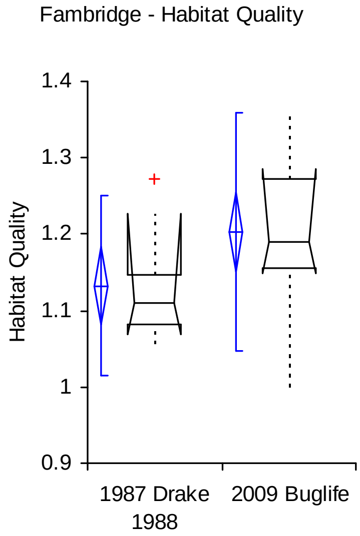

Hadleigh - Habitat Quality
Habitat Quality
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1987 Drake 1988
2009 Buglife

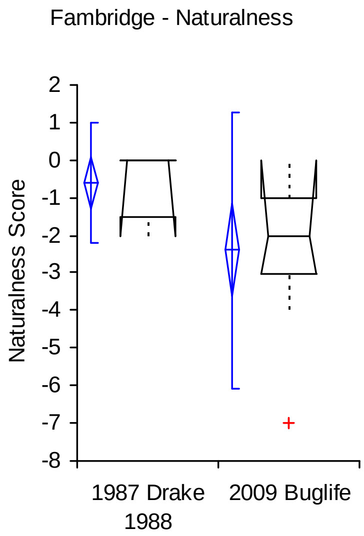

Hadleigh - Naturalness
Naturalness Score
2
1
0
-1
-2
-3
-4
-5
-6
1987 Drake 1988
2009 Buglife

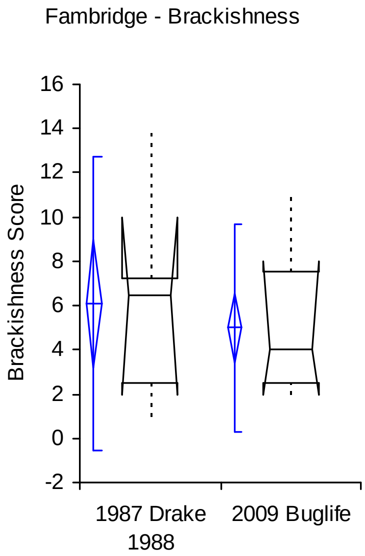

Hadleigh - Brackishness
Brackishness Score
9
8
7
6
5
4
3
2
1
0
-1
1987 Drake 1988
2009 Buglife


Fambridge - Species Richness
Species Richness
0
10
20
30
40
50
60
1987 Drake 1988
2009 Buglife

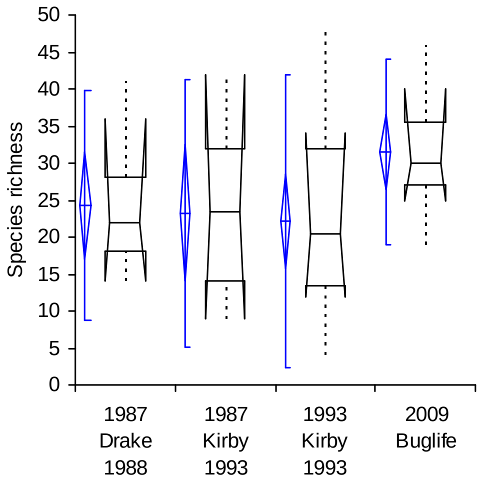

Fambridge - SCS
SCS
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1987 Drake 1988
2009 Buglife


Fambridge - Habitat Quality
Habitat Quality
0.9
1
1.1
1.2
1.3
1.4
1987 Drake 1988
2009 Buglife

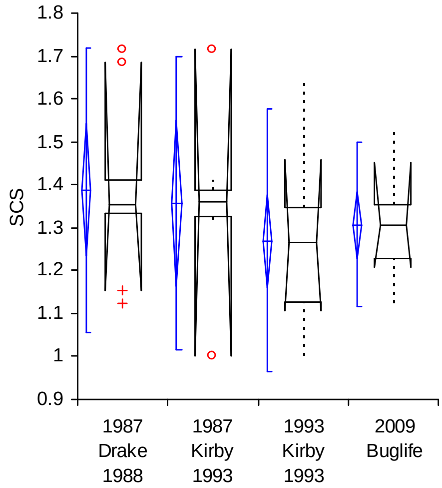

Fambridge - Naturalness
Naturalness Score
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
1987 Drake 1988
2009 Buglife


Fambridge - Brackishness
Brackishness Score
-2
0
2
4
6
8
10
12
14
16
1987 Drake 1988
2009 Buglife

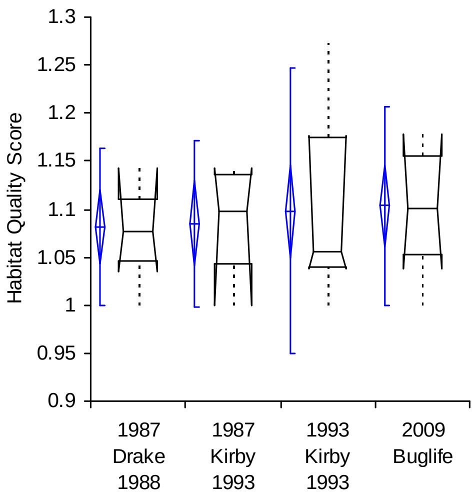
Brightlingsea - Species richness



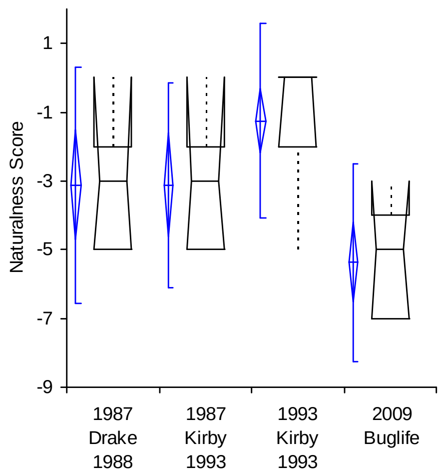
Brightlingsea -SCS



Brightlingsea - Habitat Quality



Brightlingsea - Naturalness



Brightlingsea - Brackishness

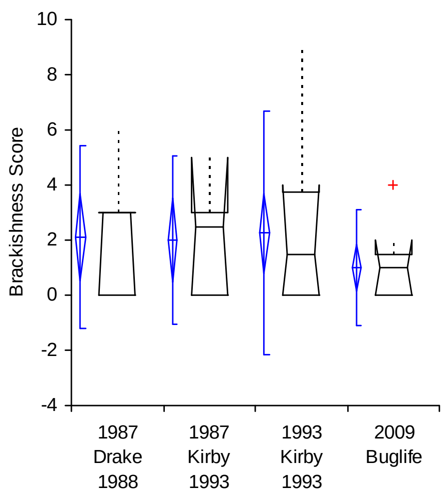
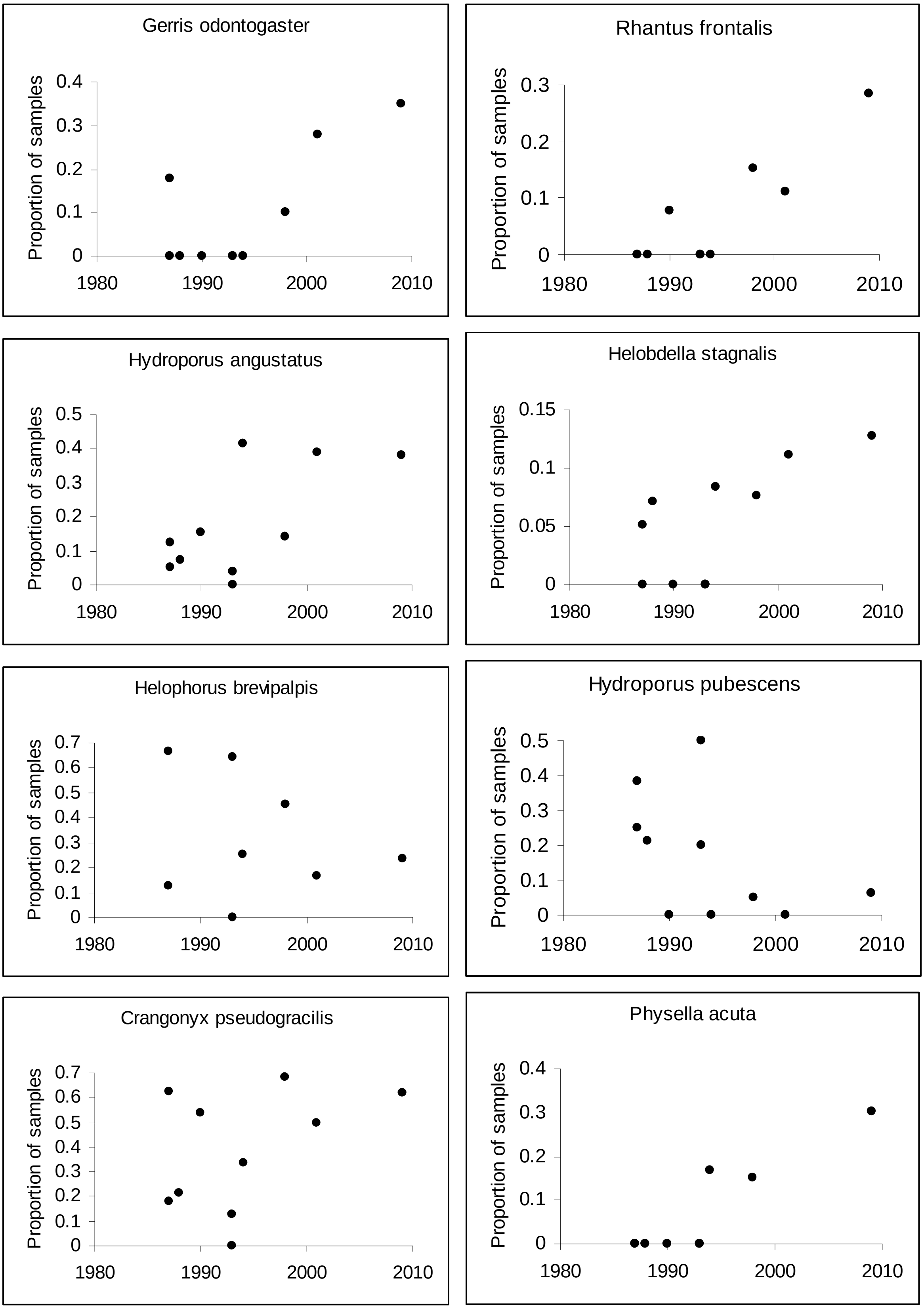


Figure 5.9 Species showing possible changes in frequency in Essex marshes



4 Comparison of surveys in Norfolk and Suffolk

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 (1976, 1980) put considerable effort in the early years and Drake (2002, 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, as indicated by the smaller number of beetle records, and there was uncertainty over the recording of dragonflies that often included adults. Drake was contracted to identify only beetles and molluscs, and other groups are represented by casual records that were not systematically recorded (other than soldierflies which were identified later). He also used a methodology that differed markedly from the Buglife method and was not thought to be as thorough. Only molluscs were recorded with similar effort by both surveyors. Direct comparison of these surveys will therefore show more about the method than the assemblages.

Suffolk marshes have been given even less attention than those in Norfolk but the same wide range of taxonomic groups were covered by two surveyors. Two sites are included here. Table 1.3 in Appendix 1 of this volume shows the surveys investigated in Norfolk and Suffolk.

For the Norfolk sites the metrics for Species Richness, Species Conservation Status (SCS), Habitat Quality (marsh fidelity) and Naturalness are presented for molluscs and beetles separately. The threshold for inclusion of molluscs and beetles in SCS Score was reduced from 10 to 5 species.

4.2 Results of applying the metrics to sites in Norfolk

4.2.1 Yare Valley

Three hydrologically separate marshes along the north bank of the River Yare were compared. Buckenham and Cantley marshes are contiguous, Limpenhoe is downstream from Cantley, separated by about 1.5km of slightly higher land.

Owing to the uneven coverage of major taxa, only molluscs could be safely compared (Figure 5.10). If it is assumed that surveyor differences were small for molluscs (a reasonable assumption in this case), there was a clear and significant increase in species richness between the 1970s and 2000s. Possible support for genuine increase being more important than between-surveyor differences comes from the clear 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. 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.

4.2.2 Bure marshes

The marshes surveyed form a continuous block that spans the River Bure, but are hydrologically separate.

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 (Figure

5.11). The Kruskall-Wallis test for differences between medians was significant and could be attributed largely to the high 2009 values. 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. A crude check on thoroughness was made using the minimum and maximum values recorded in each survey. The minima tended to be similar over the surveys and not invariably higher in 2009 but the maxima were invariably greater by three species in 2009 than in any other survey (Figure 5.12). This did suggest more intensive sampling effort in 2009 than in other years, and casts doubt on the reality of the apparent increase in richness in recent years.

SCS Score failed as a useful measure of average rarity owing to the spasmodic occurrence of the threatened species *Segmentina nitida* and *Anisus vorticulus* (Table 5.12). All the wide confidence limits and outliers in Figure 5.11 were associated with the presence of these species. It is not possible to read any more into these scores. A similar problem arose with Habitat Quality Score since only these species contributed to it. *Segmentina nitida* and *A. vorticulus* were the only aquatic molluscs of real conservation concern in the marshes (ignoring rare *Pisidium*), and the number of records over the years is shown since the SCS Score does not give useful information (Figure 5.11). 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 were 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 its 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.

4.3 Results of applying the metrics to sites in Suffolk

For Suffolk sites the species metrics are presented for all taxa combined.

4.3.1 Shotley

This marsh was 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. None of the species metrics had changed significantly in 21 years (Figure 5.13).

4.3.2 Sizewell and Minsmere

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. Minsmere Level is conventional exposed grazing marsh. These marshes were among the most species-rich areas surveyed in 1988, although they did not have an exceptional complement of uncommon species. The sites are contiguous but are treated separately here because of their strongly contrasting character. Minsmere Level was surveyed once in 1988 and once again in 2009, whereas Sizewell belts was surveyed twice at almost the same time (1988 and 1989, and by two surveyors in 2009).

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.

The results for Sizewell Belts highlighted the problems in making comparisons over time as there were greater differences between chronological adjacent surveys than those c. 20 years apart. At the time of the early surveys, differences between the two 1980s surveys (by Drake) were attributed to the better condition of ditches sampled inside the SSSI (1988) than outside (1989). The significantly different Species Richness by two surveyors in the same 2009 season is attributed to sampling effort since the median Species Conservation Status Scores were the same (SCS Score in theory removes the effect of sampling effort), but a significant difference in Habitat Quality Score was not easy to explain. So, depending on which set of samples are compared, the conservation interest of the fauna at Sizewell can be made to increase, decrease or stay the same. The most important of the metrics in this instance is SCS Score, and this showed no change over time when the 1989 sample of non-SSSI ditches was discounted.

4.4 Summary for Norfolk and Suffolk

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 into 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, even though the reasons given for the decision appeared to be in conflict. 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.

Table 5.11 Kruskal-Wallis tests of medians of Species Richness, Species Conservation Status Score, Habitat Quality Score and Naturalness Score for surveys of all taxa at Suffolk sites and molluscs at Norfolk sites

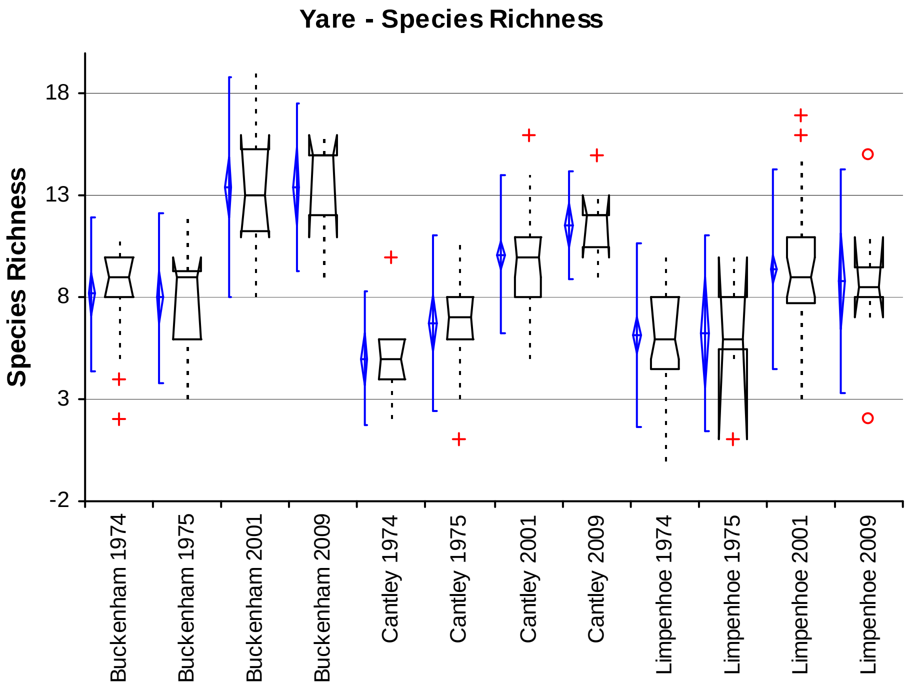
Kruskall-Wallis statistic significant at p<0.05 are in bold.

	Richness		SCS		Habitat quality		Naturalness	
	KW	p	KW	p	KW	p	KW	p
All Taxa								
Shotley	2.26	0.1331	0.51	0.4751	1.31	0.2518	2.93	0.0868
Sizewell	**32.21**	<0.0001	**15.15**	0.0017	**14.47**	0.0023	1.99	0.5752
Molluscs								
Buckenham	**35.63**	<0.0001	5.32	0.1496	˜□	**-**	**8.11**	0.0437
Cantley	**41.17**	<0.0001	6.51	0.0894	4.29	0.2314	**14.75**	0.0020
Limpenhoe	**27.15**	<0.0001	**17.26**	0.0006	5.42	0.1436	2.36	0.5014
Fleggburgh	**27.98**	<0.0001	**12.43**	0.0144	8.52	0.0742	7.79	0.0998
Oby	**16.93**	0.0020	**21.00**	0.0003	2.52	0.6403	**14.85**	0.0050
Upton/South Walsham	**43.72**	<0.0001	**53.31**	<0.0001	**29.03**	<0.0001	0.08	0.9941

Table 5.12 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

Figure 5.10 Species Richness and Species Conservation Status Score for molluscs in the Yare marshes



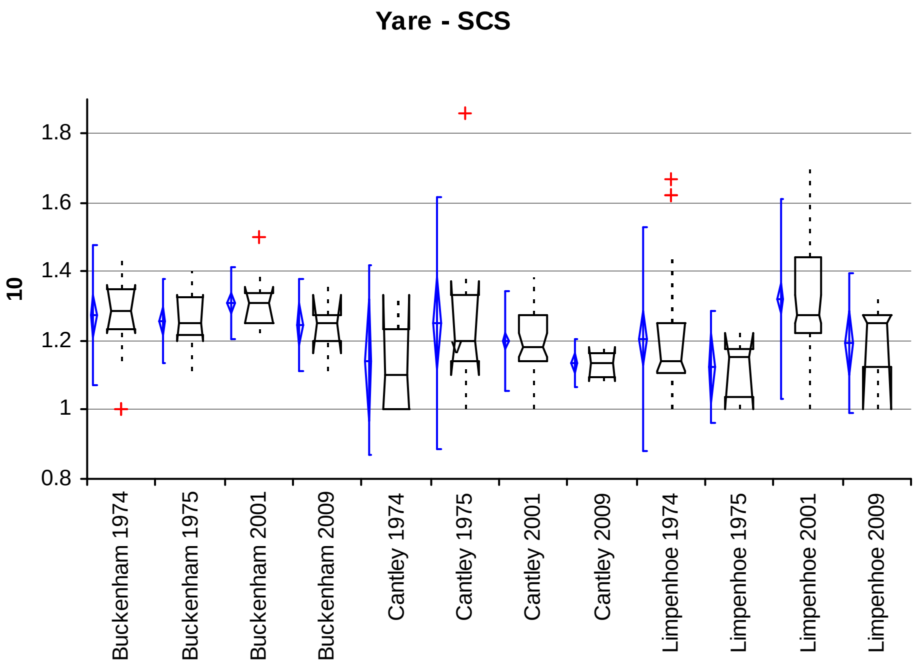
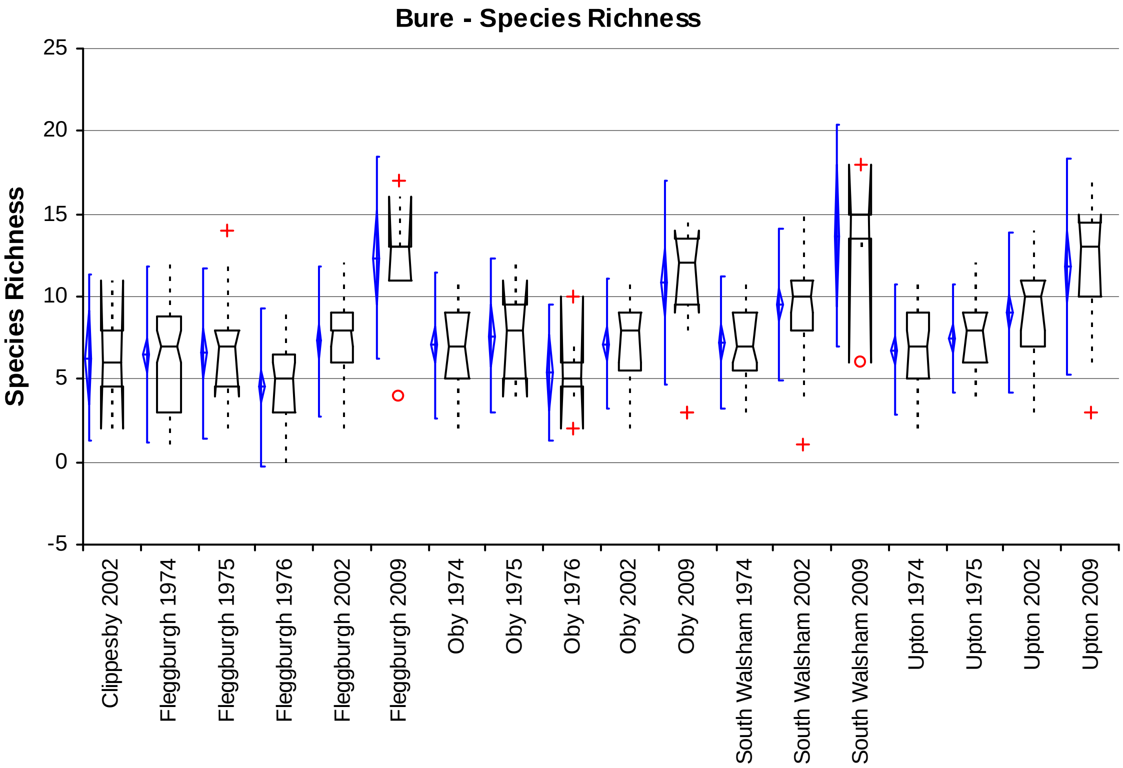


Figure 5.11 Species Richness and Species Conservation Status Score for molluscs in the Bure marshes



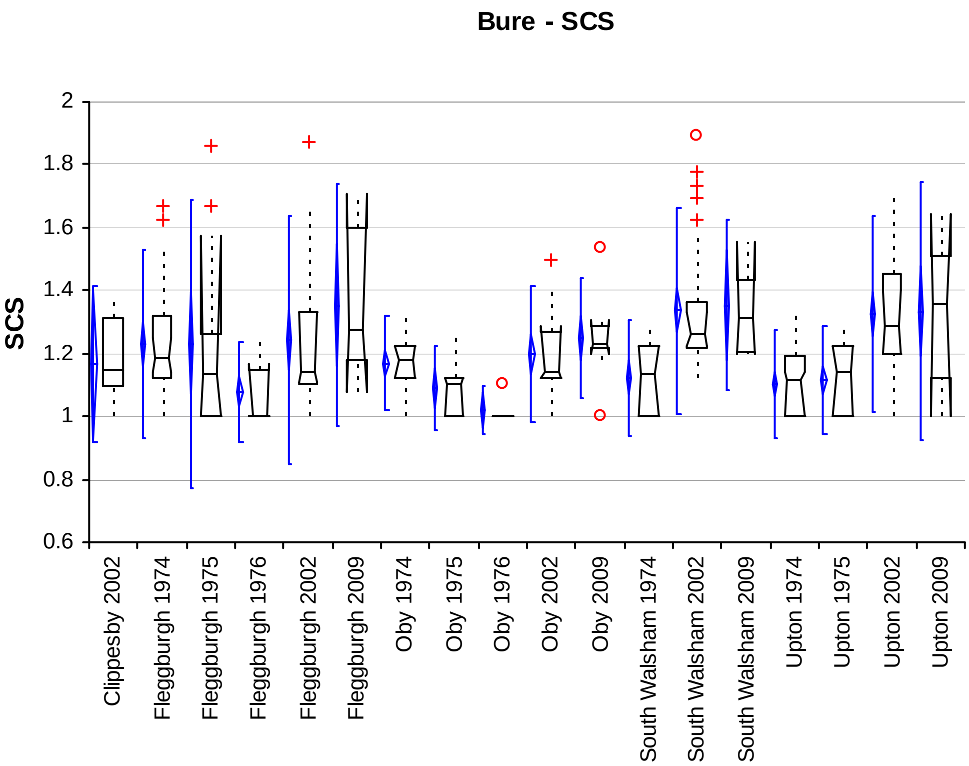


Figure 5.12 Maximum and minimum number of records of molluscs in Bure marshes

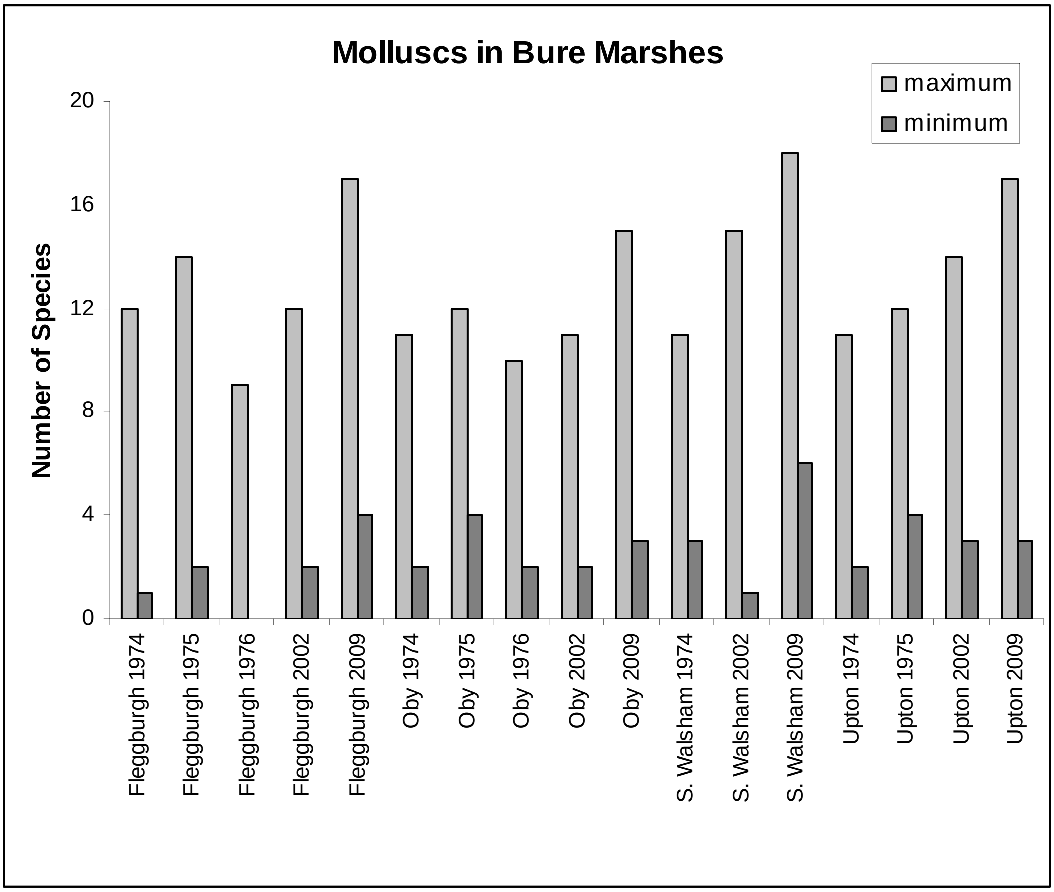


Figure 5.13 Species Richness, SCS Score, Habitat Quality Score and salinity index for Shotley Marsh, Suffolk

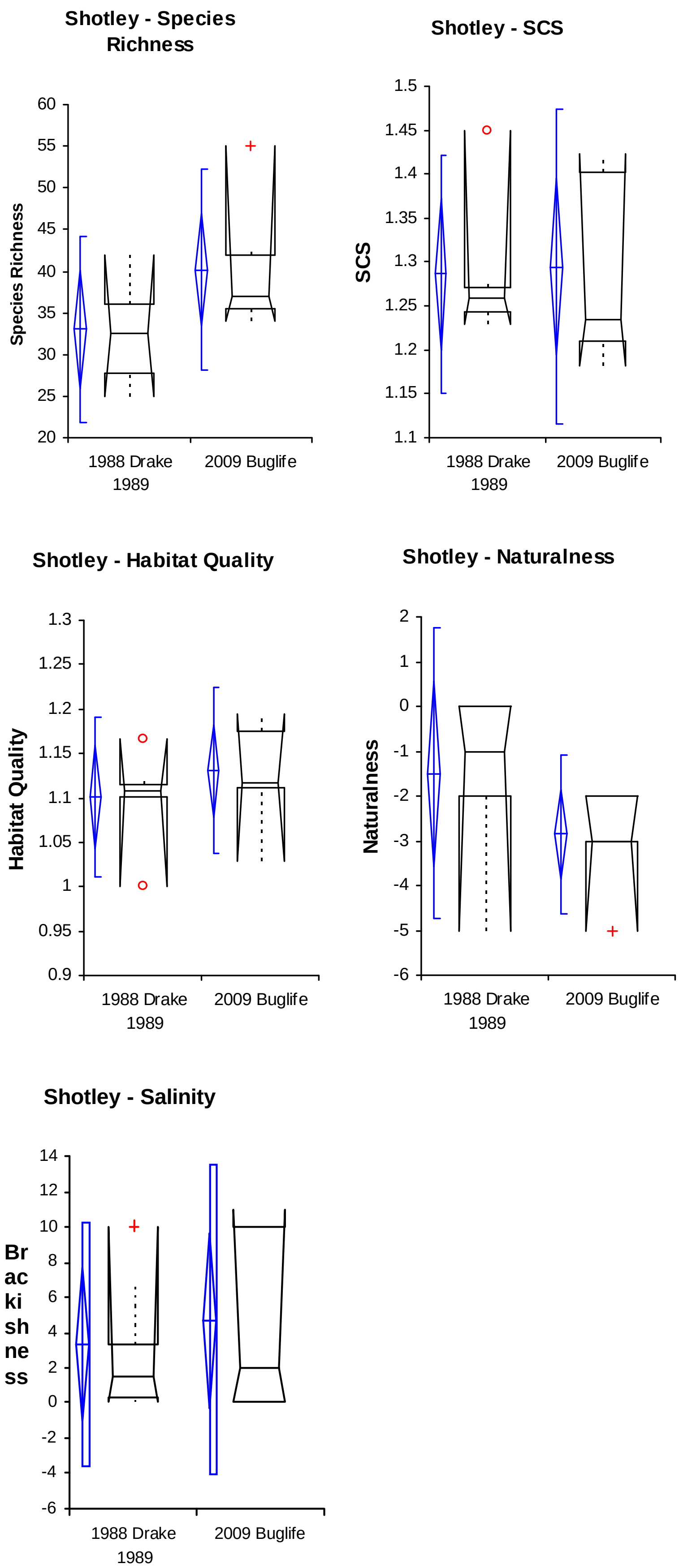
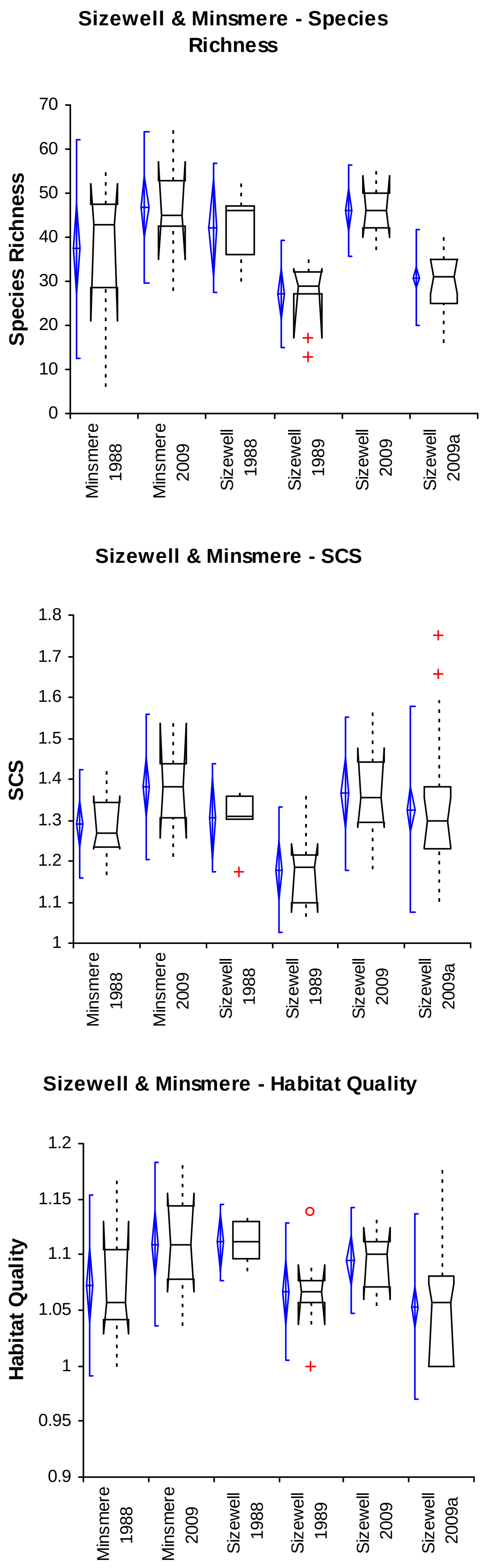


Figure 5.14 Species Richness, SCS Scores and Habitat Quality Scores for Sizewell Belts and Minsere Level, Suffolk



5 Comparison of surveys in Gwent

5.1 Previous surveys

Many surveys have taken place on the Gwent levels, nearly all in response to development pressures. Only a few covered a moderate area of the Levels and also a number of major taxa. The earliest extensive survey by Clare (1979) does not include full data so has been omitted. Gibbs (1991) undertook a key survey and his restricted range of taxonomic groups has meant that the comparisons have had to be restricted to beetles, molluscs, bugs, soldierflies and dragonflies. Flies were not covered by Harmer in 2007 but the omission will make a relatively small difference to the analysis. Soldierflies were retained since they include two scarce species of considerable importance in grazing marshes. The final dataset used had 221 taxa (nearly all species) and c. 9870 records, which was 87% of all records for the 259 target taxa in all the surveys.

5.2 Results of applying the metrics in Gwent

The Gwent Levels consists of two main marshes, Wentlooge and Caldicot, separated by the estuary of the River Usk. Although there are separate SSSIs within each marsh, they were not treated separately as the number of sample per SSSI was sometimes small.

Surveyor appeared to be the over-riding factor in explaining the apparent differences over time in all the metrics (Figure 5.15). These remained unchanged (not significantly different) between the surveys undertaken by Drake in 1984 and 2007 on both marshes, but both were considerably greater than recorded by Gibbs in the intervening 1991 survey. Harmer’s 2007 survey of St Brides Wentlooge included many reed-choked field ditches that were infrequent in the Buglife project, so lower richness would be expected, but there was no significant difference in Species Richness Score between these two concurrent surveys. The significantly lower SCS Score in Harmer’s survey was in part due to the omission of soldierflies, which included several higher-scoring species. Naturalness appeared to have declined (greater representation of non-native species) at Caldicot by comparison with earlier surveys, but remained at its historically low value at Wentlooge.

5.3 Change in individual species

The occurrence of six nationally uncommon species in these few surveys 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* (Table 5.14). These are species characteristic of grazing marshes and most of them are rarely occur outside ditch systems. Two species characteristic of grazing marshes were not found in later surveys. The beetle *Limnoxenus n*iger was recorded only in the 1985 survey, and the latest record in the Countryside Councils for Wales’ Invertebrate Site Register was 1992. The soldierfly *Stratiomys singularior* was last recorded in the 1991 survey, although a putative *S. potamida* was found in a coastal ditch in the Buglife survey and, despite it appearing to be *S. potamida*, was more likely to have been *S. singularior* in this situation (Magor Marsh in Gwent holds a population of *S. potamida*). A likely reason for not finding *S. singularior* was the low representation of small field ditches in later surveys by Gibbs and Buglife, but this explanation was unlikely to apply to *L. niger* which may have undergone a genuine decline in the Gwent Levels.

A number of other species recorded only in the 1985 survey were scarce then so their non-appearance in all smaller later surveys may be due to inadequate sampling effort.

Only three species appeared for the first time in this small set of surveys in 2007. The soldierfly *Vanoyia tenuicornis* was recorded in 2007 as larvae, but the larval stage had not been described until 2001 so this species was likely to have been previously overlooked as a species of *Oxycera*. The large diving beetle *Dytiscus dimidiatus* had been recorded in the late 1990s (CCW Invertebrate Site Register) but *D. circumcinctus* appeared to be a new record for the marshes.

On balance, it appeared likely that, with the exception of *Limnoxenus niger* and *Stratiomys singularior*, the species that are particularly characteristic of grazing marshes had not undergone a noticeable change in frequency but it may be of some concern that there were more 'losses' than gains of infrequently recorded species. The small size of the surveys compared here tempers this conclusion, although it is supported for some species by data from CCW's Invertebrate Site Register.

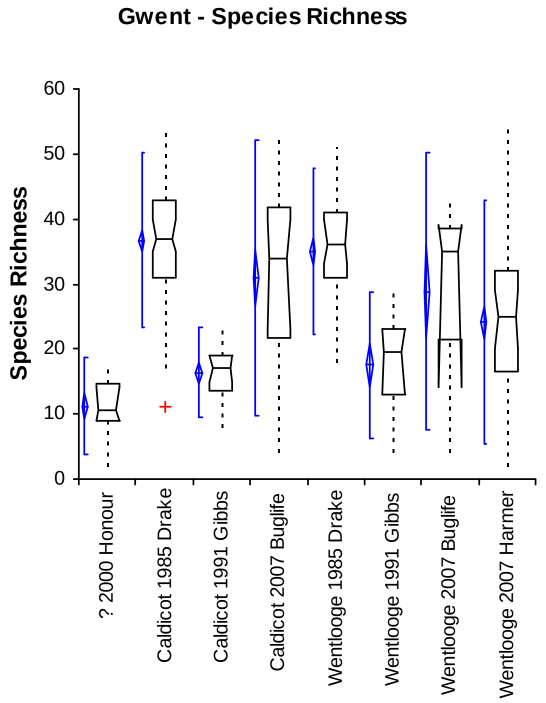
Table 5.13 Kruskal-Wallis tests of medians of Species Richness, Species Conservation Score and Habitat Quality Score for the two main marshes of the Gwent Levels

	Species richness		SCS		Habitat Quality		Naturalness	
	KW	p	KW	p	KW	p	KW	p
Caldicot	61.76	<0.0001	18.99	<0.0001	14.60	0.0007	7.86	0.0196
Wentlooge	46.86	<0.0001	15.83	0.0012	8.21	0.0418	16.50	0.0009

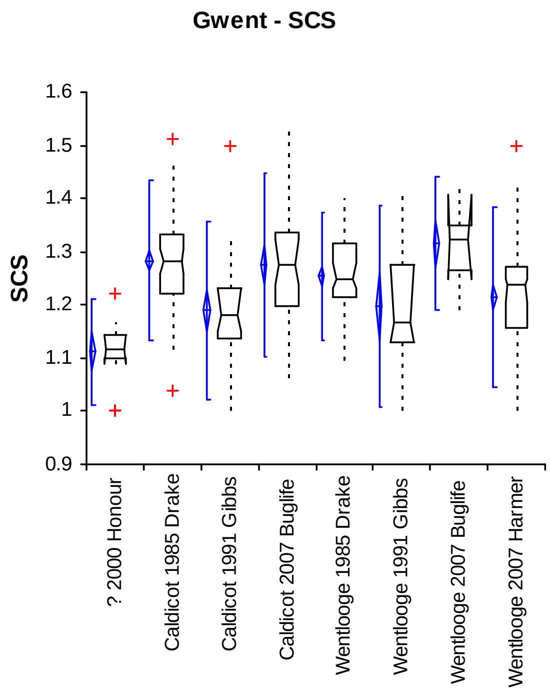
Table 5.14 Number of records of uncommon species recorded at the Gwent Levels in a few large surveys

SCS = species conservation score. * *Chaetarthria seminulum* has recently been found to consist of two species.

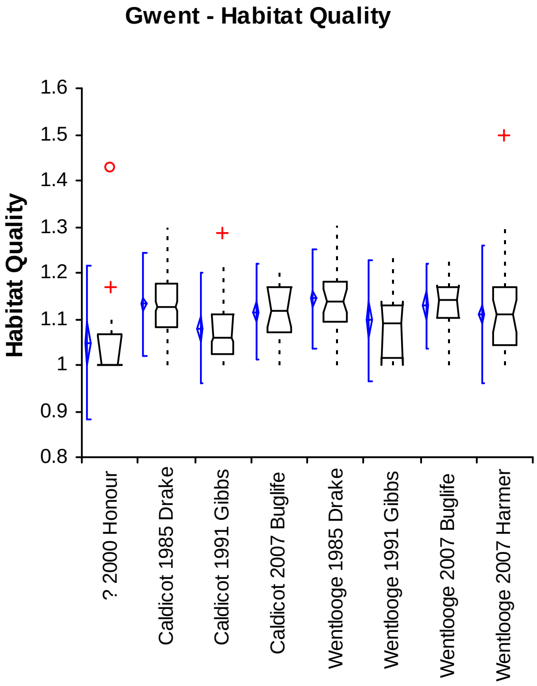
Species	**SCS**	**Caldicot**			**Wentlooge**			
		1985 Drake 1986	1991 Gibbs 1991	2007 Buglife	1985 Drake 1986	1991 Gibbs 1991	2007 Buglife	2007 Harmer 2007
Number of samples		93	31	36	54	18	15	79
Coleoptera								
Agabus conspersus	3	1	1	1	1		1	
Dytiscus circumcinctus	3			1			1	
Dytiscus dimidiatus	4			2				
Hydaticus transversalis	3	6		7	18	1	6	33
Hygrotus parallellogrammus	3	1			1			
Oulimnius troglodytes	3	1						
Haliplus mucronatus	3	1						
Peltodytes caesus	3	9		2	8	2	6	9
Hydrochus angustatus	3	1						
*Chaetarthria seminulum**	3	1						
Enochrus quadripunctatus	3	1						
Hydrophilus piceus	4	7		1	1	1	1	3
Limnoxenus niger	4	4						
Diptera								
Odontomyia ornata	4	40	1	10	17	2	2	
Odontomyia tigrina	3	17	2	6	7		1	
Stratiomys potamida	3			1				
Stratiomys singularior	3	9	1		2			
Vanoyia tenuicornis	3			3			1	



Gwent - Species Richness
Species Richness
60
50
40
30
20
10
0
? 2000 Honour
Caldicot 1985 Drake
Caldicot 1991 Gibbs
Caldicot 2007 Buglife
Wentlooge 1985 Drake
Wentlooge 1991 Gibbs
Wentlooge 2007 Buglife
Wentlooge 2007 Harmer



Gwent - SCS
SCS
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
? 2000 Honour
Caldicot 1985 Drake
Caldicot 1991 Gibbs
Caldicot 2007 Buglife
Wentlooge 1985 Drake
Wentlooge 1991 Gibbs
Wentlooge 2007 Buglife
Wentlooge 2007 Harmer



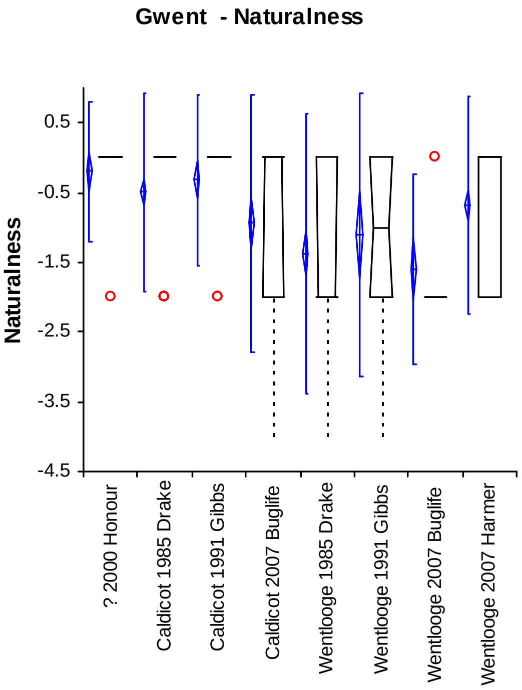


Figure 5.15 Species Richness, SCS, Habitat Quality and Naturalness Scores for Gwent Levels

6 References

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