Long-term changes in macrophyte assemblages in UK lakes

Getting the best from historical records

Genevieve Madgwick
Supervisors: Nigel Willby, Carl Sayer

UCL
UNIVERSITY OF STIRLING

Historical records
Why?

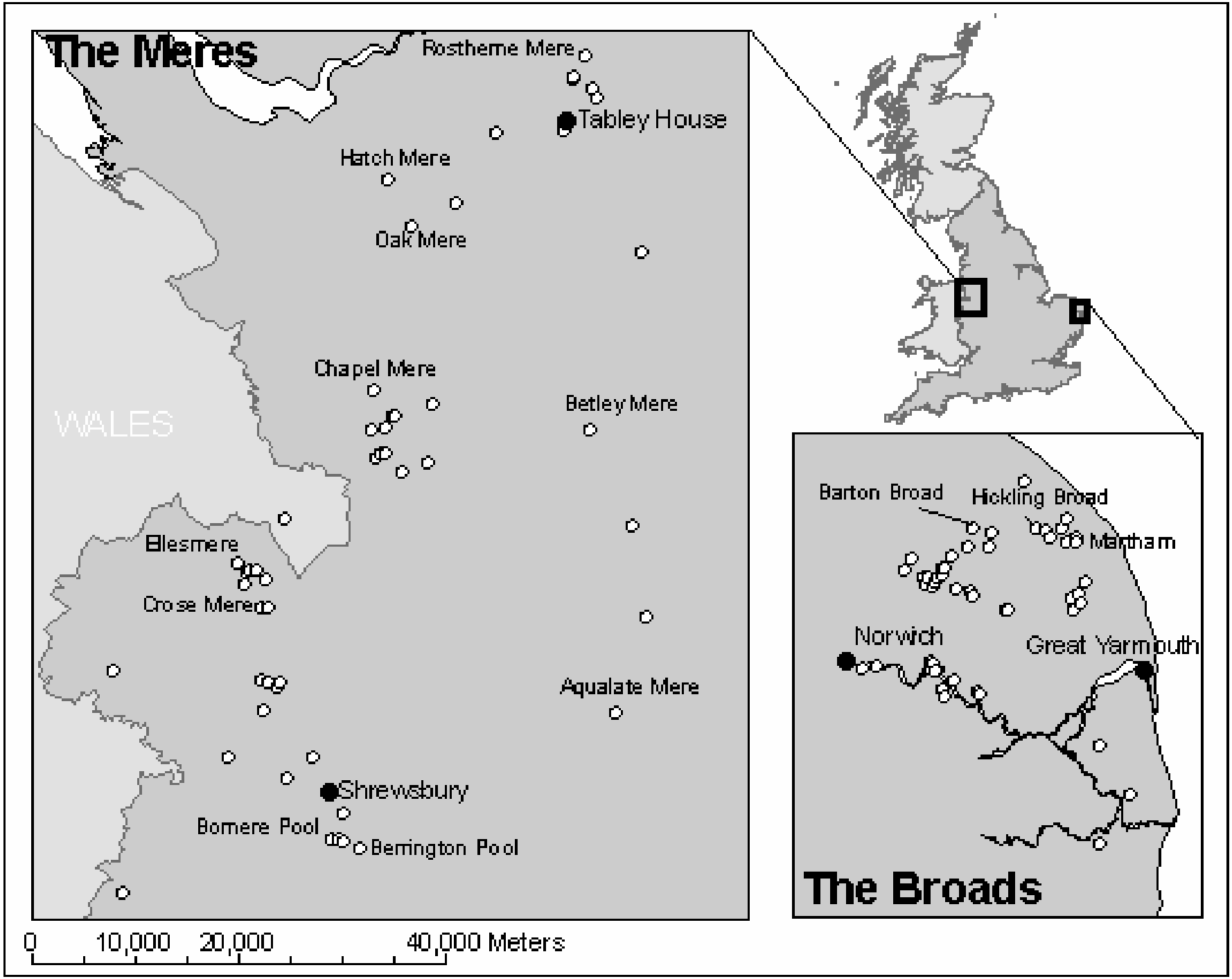
- Scientific understanding
  - Range & variability of community structure prior to modern anthropogenic impacts
  - Variability & trends at individual sites

- Conservation & Management
  - Condition assessments
  - Impacts
  - Remedies

- Legislation
  - Various targets
  - Water Framework Directive:

    "Good ecological status": Ecological status identified using macrophytes must be assessed by measuring the level of deviation from the communities expected under "undisturbed conditions" (European Union, 2000).

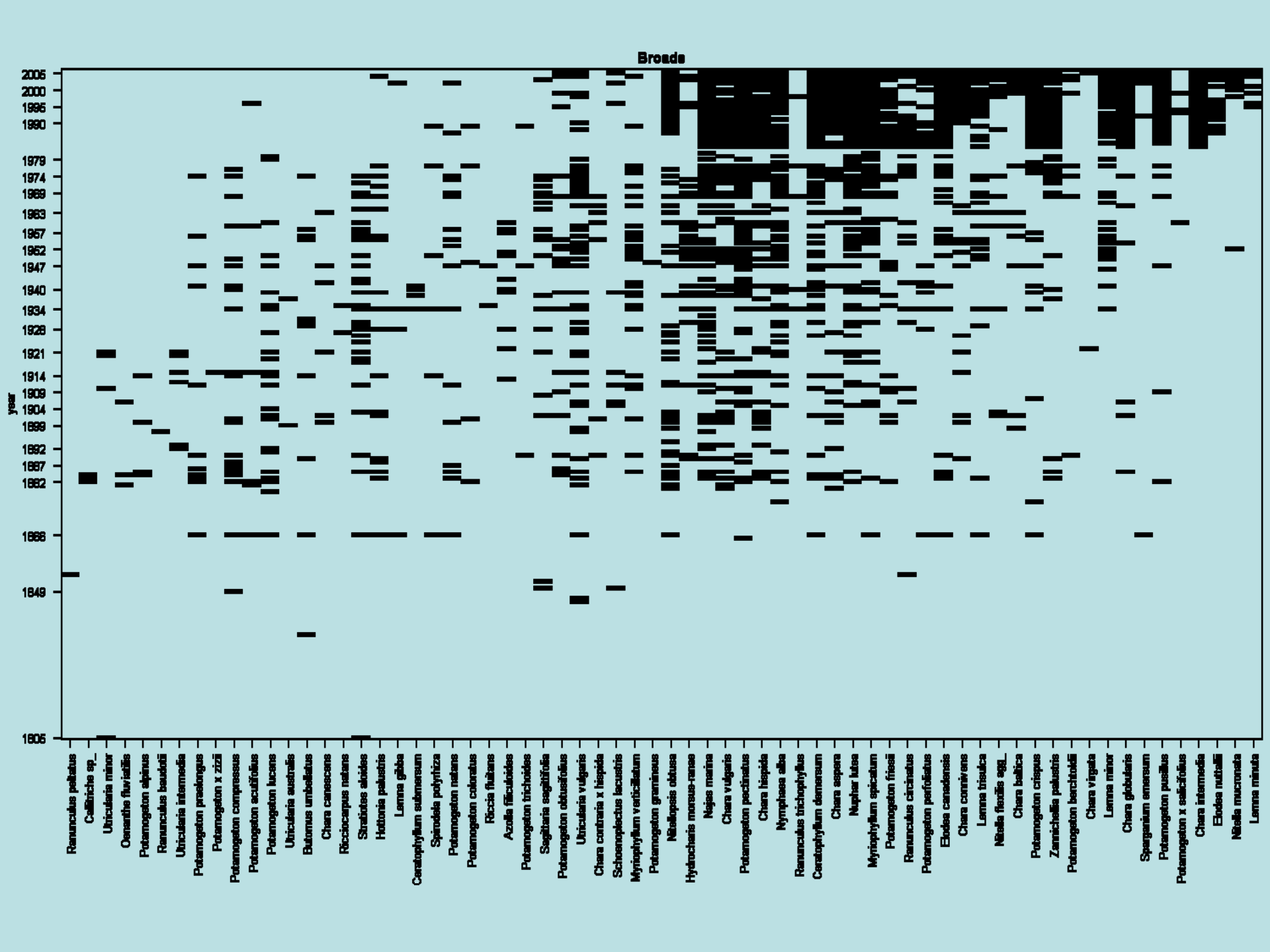
- Particularly useful for highly impacted sights, e.g. lowland lakes


The Meres
Rostherne Mere
Tabley House
Hatch Mere
Oak Mere
Chapel Mere
Betley Mere
WALES
Ellesmere
Crose Mere
Aqualate Mere
Shrewsbury
Bomere Pool
Berrington Pool
0
10,000
20,000
40,000 Meters
Barton Broad
Hickling Broad
Martham
Norwich
Great Yarmouth
The Broads

Historical records
What?

- Modern surveys by conservation agencies
- Historical sources (notebooks, journal articles, flora, books)
- Herbarium specimens

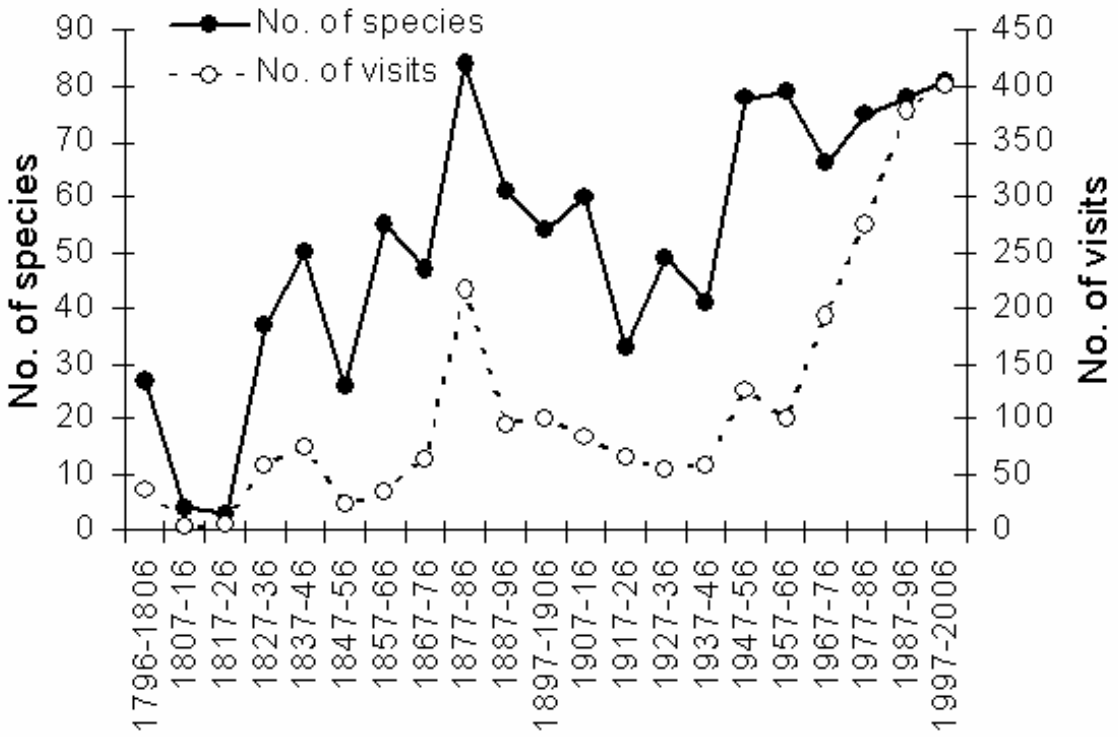
- 140 lakes
- >3000 site visits
- >20000 plant observations
- 1798-present


Broads
year
2005
2000
1995
1990
1979
1974
1969
1963
1957
1952
1947
1940
1934
1928
1921
1914
1909
1904
1899
1892
1887
1882
1866
1849
1805
Ranunculus peltatus
Callitriche sp.
Utricularia minor
Oenanthe fluviatilis
Potamogeton alpinus
Ranunculus baudotii
Utricularia intermedia
Potamogeton praelongus
Potamogeton x zizii
Potamogeton compressus
Potamogeton acutifolius
Potamogeton lucens
Utricularia australis
Butomus umbellatus
Chara canescens
Ricciocarpus natans
Stratiotes aloides
Hottonia palustris
Lemna gibba
Ceratophyllum submersum
Spirodela polyrhiza
Potamogeton natans
Potamogeton coloratus
Riccia fluitans
Azolla filiculoides
Potamogeton trichoides
Sagittaria sagittifolia
Potamogeton obtusifolius
Utricularia vulgaris
Chara contraria x hispida
Schoenoplectus lacustris
Myriophyllum verticillatum
Potamogeton gramineus
Nitellopsis obtusa
Hydrocharis morsus-ranae
Najas marina
Chara vulgaris
Potamogeton pectinatus
Chara hispida
Nymphaea alba
Ranunculus trichophyllus
Ceratophyllum demersum
Chara aspera
Nuphar lutea
Myriophyllum spicatum
Potamogeton friesii
Ranunculus circinatus
Potamogeton perfoliatus
Elodea canadensis
Chara connivens
Lemna trisulca
Nitella flexilis agg.
Chara baltica
Potamogeton crispus
Zannichellia palustris
Potamogeton berchtoldii
Chara virgata
Lemna minor
Chara globularis
Sparganium emersum
Potamogeton pusillus
Potamogeton x salicifolius
Chara intermedia
Elodea nuttallii
Nitella mucronata
Lemna minuta

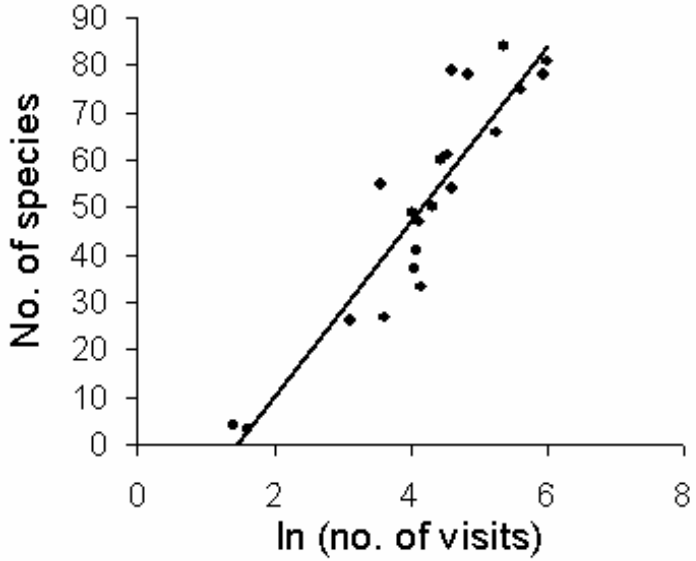
Historical records
The problems

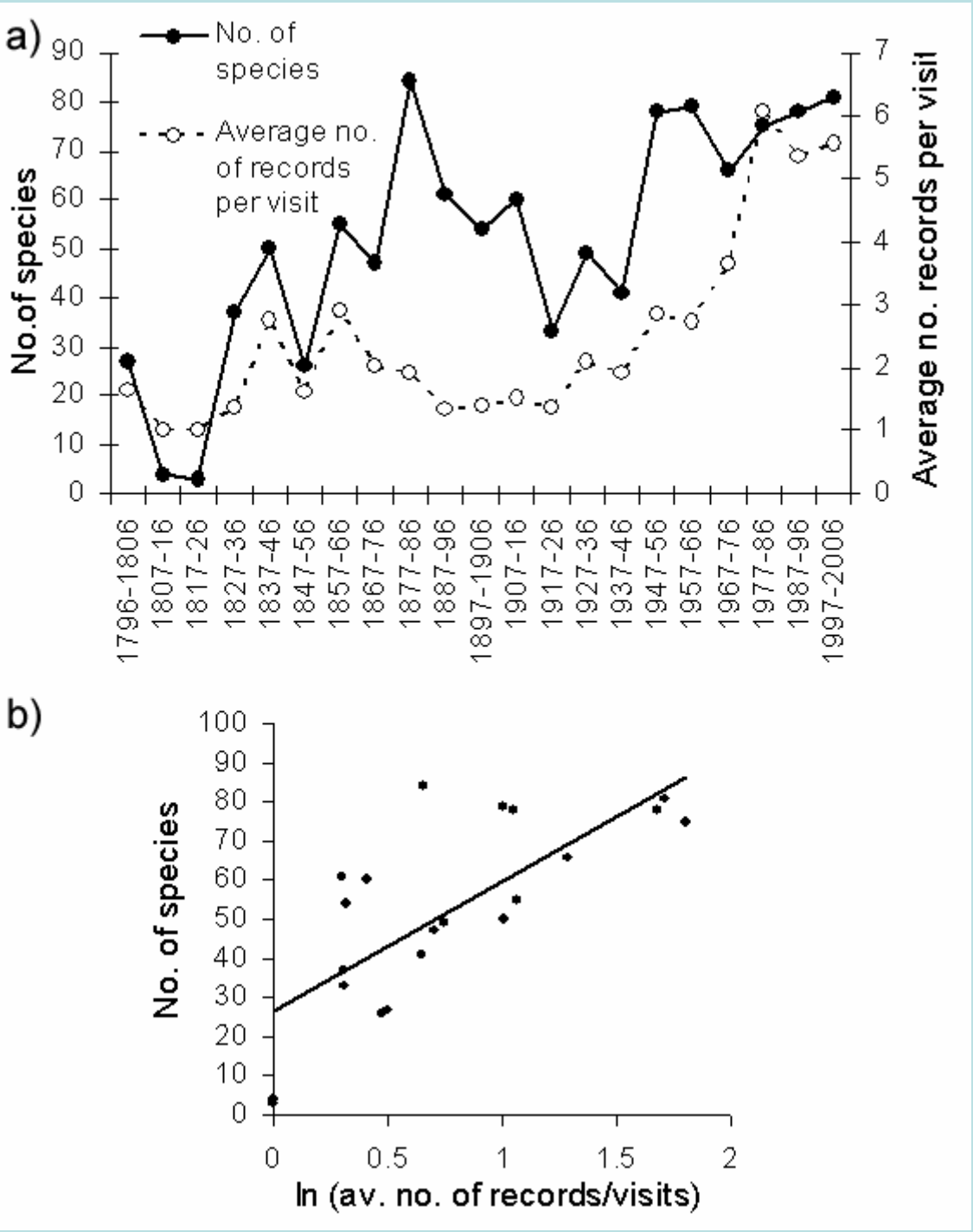
- Recording effort
  - Number of visits
  - Nature of survey

a)


No. of species
No. of visits
No. of species
No. of visits
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
400
450
1796-1806
1807-16
1817-26
1827-36
1837-46
1847-56
1857-66
1867-76
1877-86
1887-96
1897-1906
1907-16
1917-26
1927-36
1937-46
1947-56
1957-66
1967-76
1977-86
1987-96
1997-2006

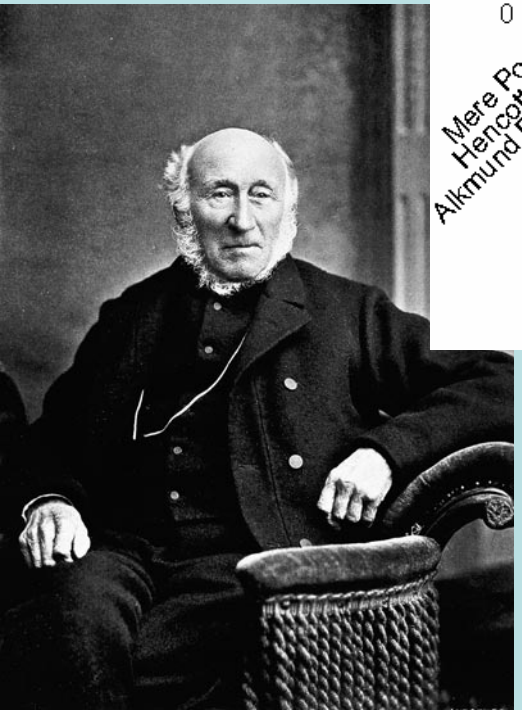
b)

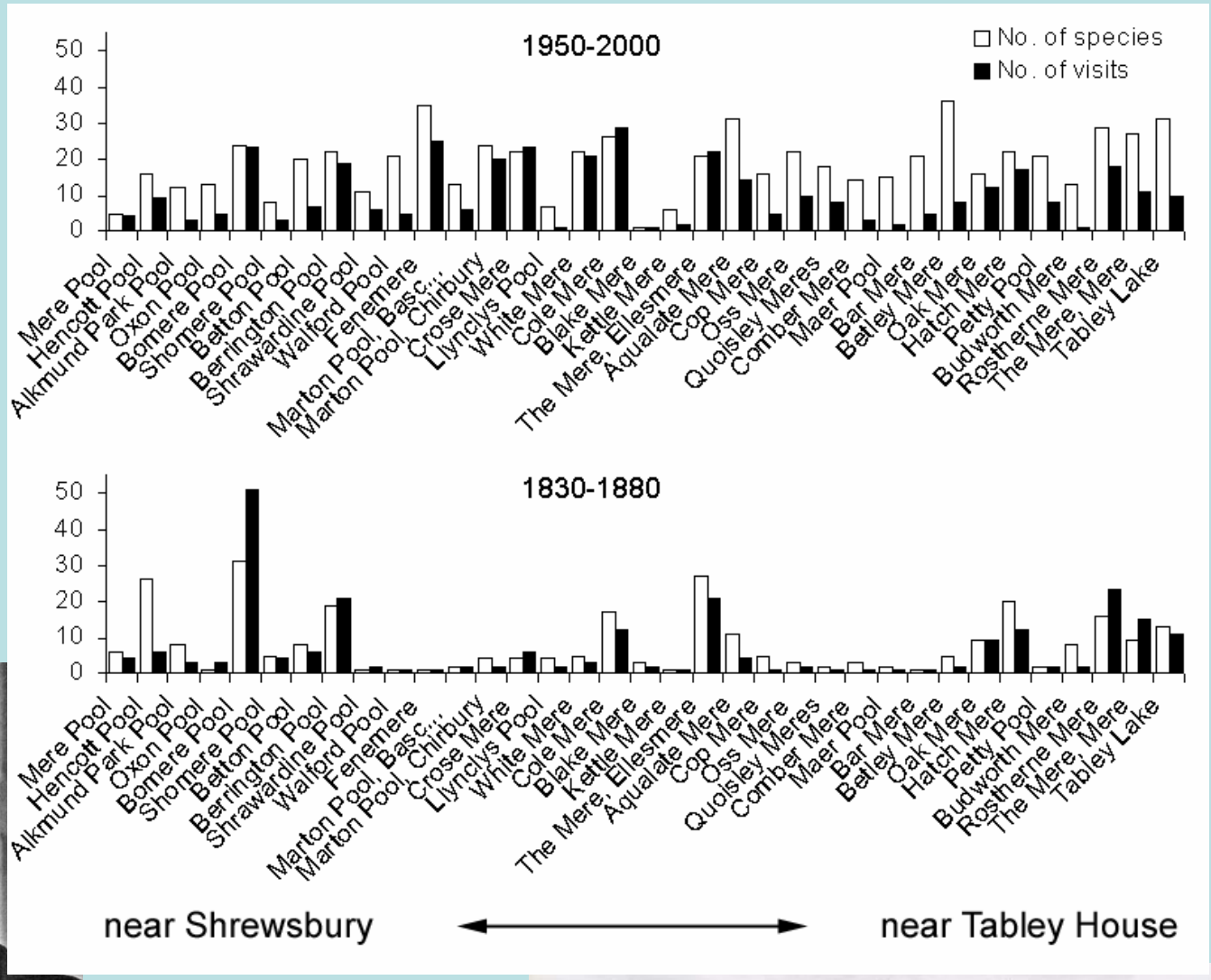

No. of species
ln (no. of visits)
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8


a)
No. of species
Average no. of records per visit
No.of species
Average no. records per visil
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5
6
7
1796-1806
1807-16
1817-26
1827-36
1837-46
1847-56
1857-66
1867-76
1877-86
1887-96
1897-1906
1907-16
1917-26
1927-36
1937-46
1947-56
1957-66
1967-76
1977-86
1987-96
1997-2006
b)
No. of species
ln (av. no. of records/visits)
0
10
20
30
40
50
60
70
80
90
100
0
0.5
1
1.5
2

Historical records
The problems

- Recording effort
  - Number of visits
  - Nature of survey
- Record distribution
  - Tendency for the distribution of plants to reflect the distribution of botanists (Rich and Woodruff, 1992)



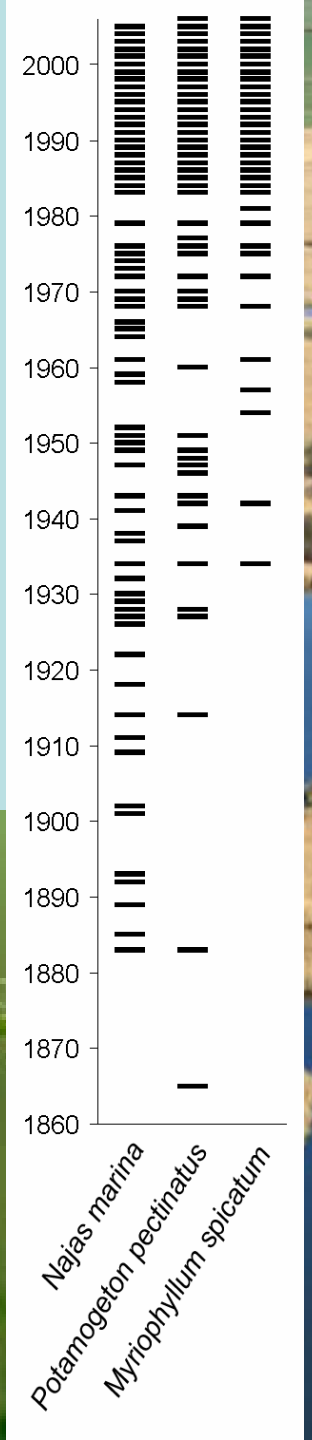

1950-2000
No. of species
No. of visits
50
40
30
20
10
0
Mere Pool
Hencott Pool
Alkmund Park Pool
Oxon Pool
Bomere Pool
Shomere Pool
Betton Pool
Berrington Pool
Shrawardine Pool
Walford Pool
Fenemere
Marton Pool, Basc...
Marton Pool, Chirbury
Crose Mere
Llynclys Pool
White Mere
Cole Mere
Blake Mere
Kettle Mere
The Mere, Ellesmere
Aqualate Mere
Cop Mere
Oss Mere
Quoisley Meres
Comber Mere
Maer Pool
Bar Mere
Betley Mere
Oak Mere
Hatch Mere
Petty Pool
Budworth Mere
Rostherne Mere
The Mere, Mere
Tabley Lake
1830-1880
50
40
30
20
10
0
Mere Pool
Hencott Pool
Alkmund Park Pool
Oxon Pool
Bomere Pool
Shomere Pool
Betton Pool
Berrington Pool
Shrawardine Pool
Walford Pool
Fenemere
Marton Pool, Basc...
Marton Pool, Chirbury
Crose Mere
Llynclys Pool
White Mere
Cole Mere
Blake Mere
Kettle Mere
The Mere, Ellesmere
Aqualate Mere
Cop Mere
Oss Mere
Quoisley Meres
Comber Mere
Maer Pool
Bar Mere
Betley Mere
Oak Mere
Hatch Mere
Petty Pool
Budworth Mere
Rostherne Mere
The Mere, Mere
Tabley Lake
near Shrewsbury
near Tabley House

Historical records
The problems

- Recording effort
  - Number of visits
  - Nature of survey
- Record distribution
  - Tendency for the distribution of plants to reflect the distribution of botanists (Rich and Woodruff, 1992)
- Selective recording of species
  - Species vs. habitat focus
  - Species bias
  - Flora format

e.g. Najas marina

- discovered 1883 in Hickling Broad (Bennett 1884)
- collectors' hotspot (Bennett 1909)
- P.pectinatus & M.spicatum described as dominant and abundant (Pallis 1911)



Historical records Analysis

- Qualitative
- Complement with other data, e.g. macrofossils
- Compensate for bias (e.g. no. of records as percentage of total no. of records per period, randomisation procedures)
- Replicate historical survey
- Indices of change

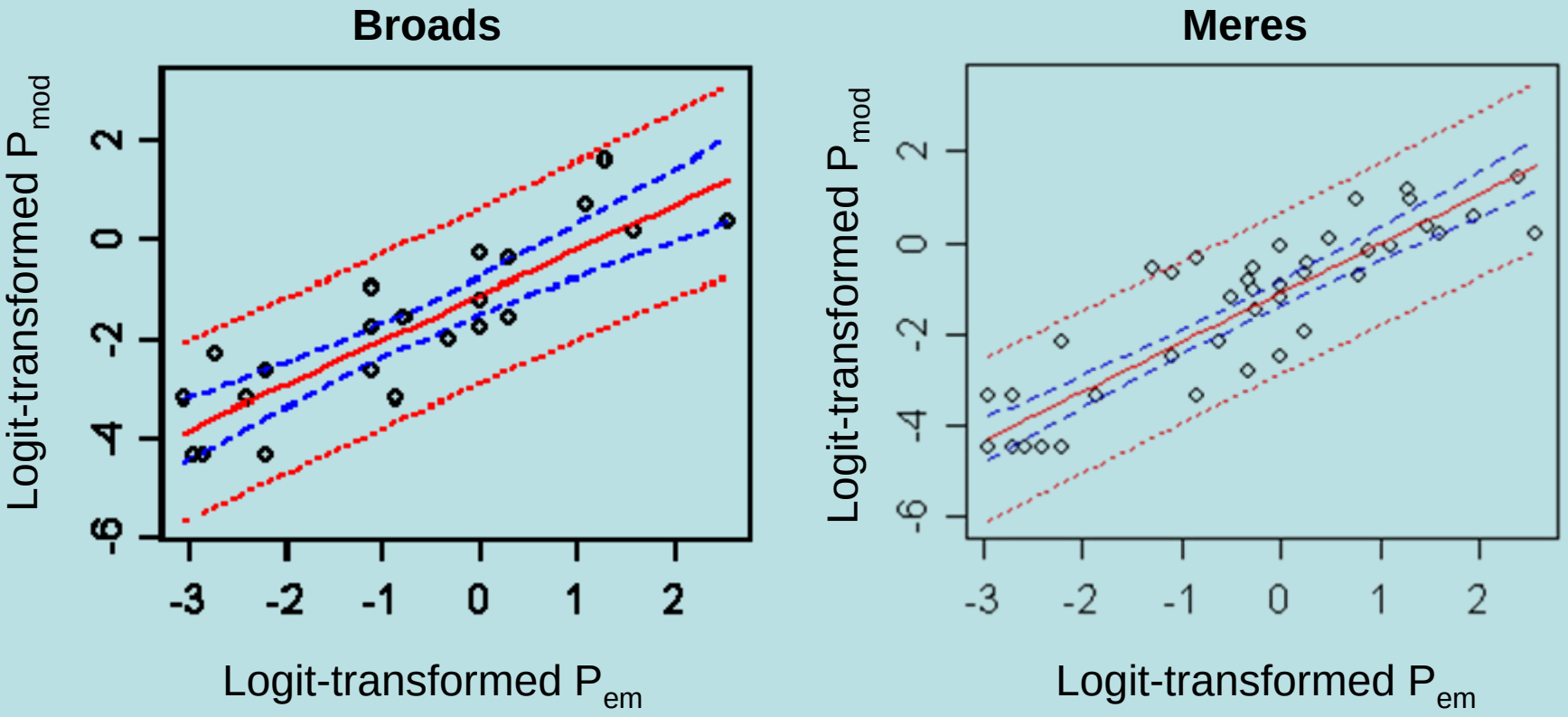
The Change Index

			Early period			Late period		
Dataset	Year span	Total no. records	No. lakes	No. species	Total no. records	No. lakes	No. species	Total no. records
Broads	1805-2006	7714	24	55	1424	37	50	2957
Meres	1798-2006	9838	38	88	2536	44	71	6593

The Change Index

- P_{em} = proportion of early period lakes still being occupied by the same species in the late period
- P_{mod} = proportion of modern sites occupied by that species

The Change Index



($p<0.0001$ for both broads and meres)

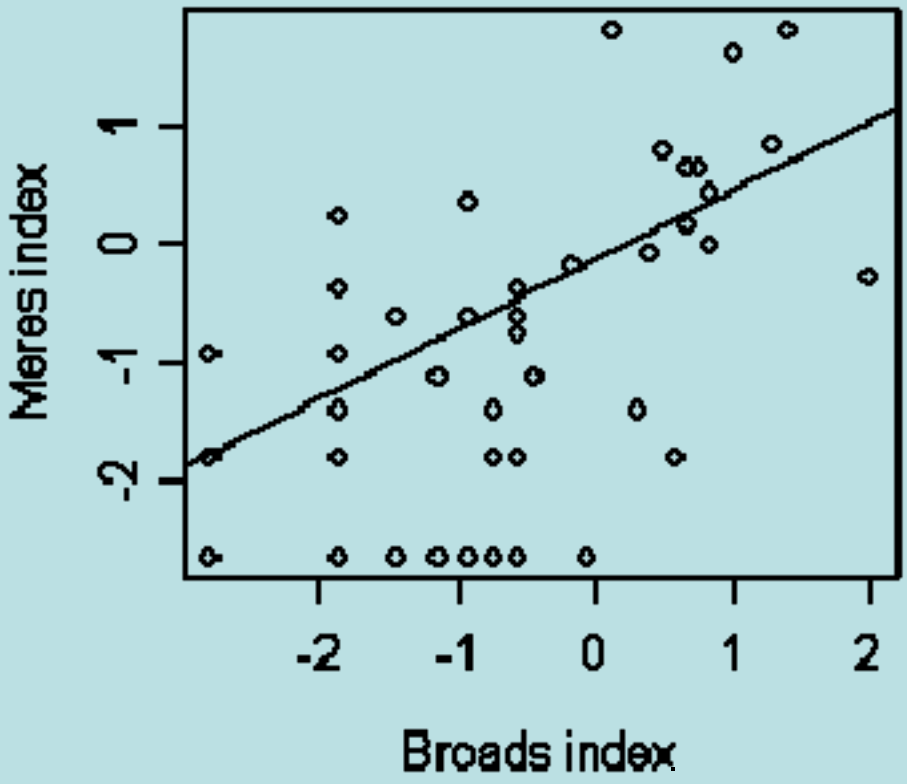
The Change Index

- Low index score = species characterised by decline and restricted modern distribution
- High index score = species with large modern distributions and either high levels of persistence or a genuine increase in distribution since the early period

The Change Index

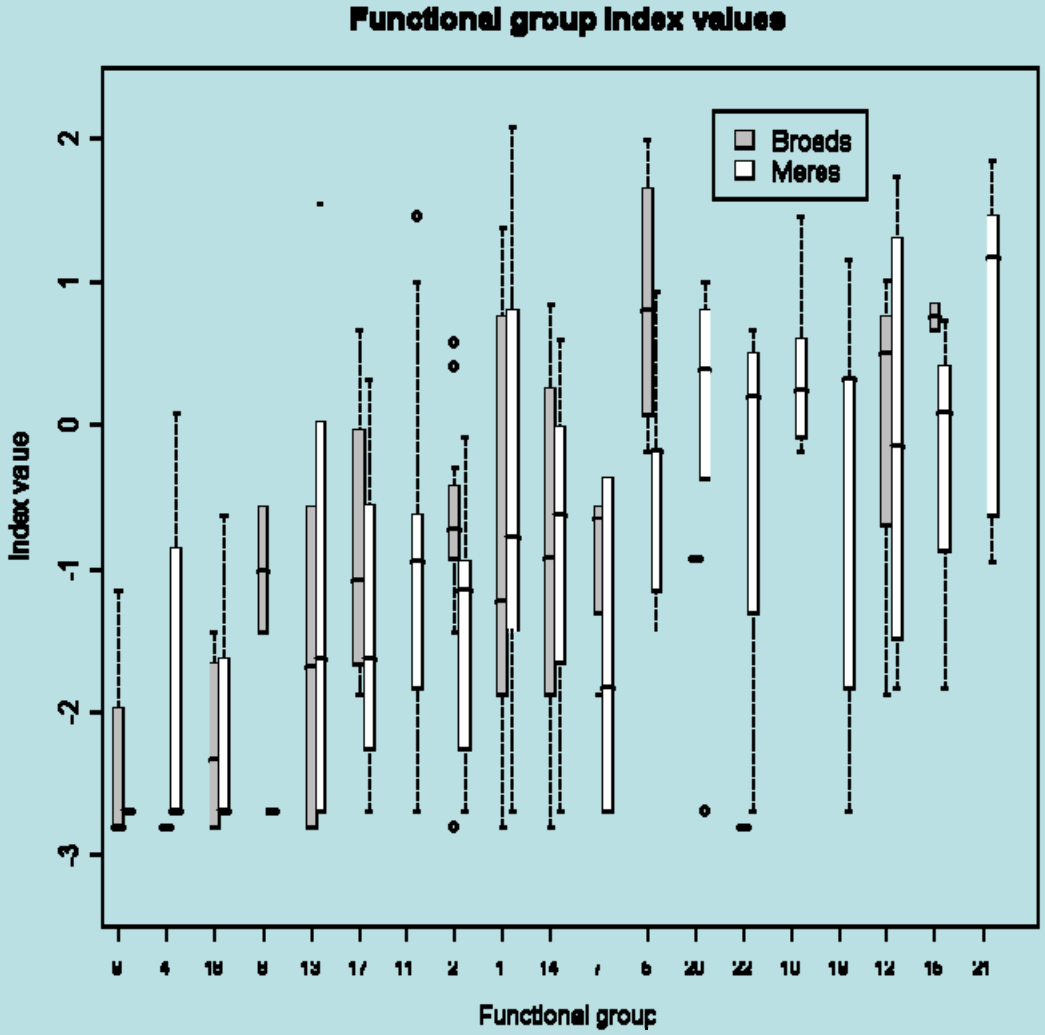
- Low index score species: Potamogeton coloratus, Potamogeton praelongus, Utricularia minor
- High index score species: Elodea canadensis, Lemna minor, Lemna trisulca, Nuphar lutea, Nymphaea alba, Potamogeton crispus, Potamogeton pusillus, Zannichellia palustris

The Change Index



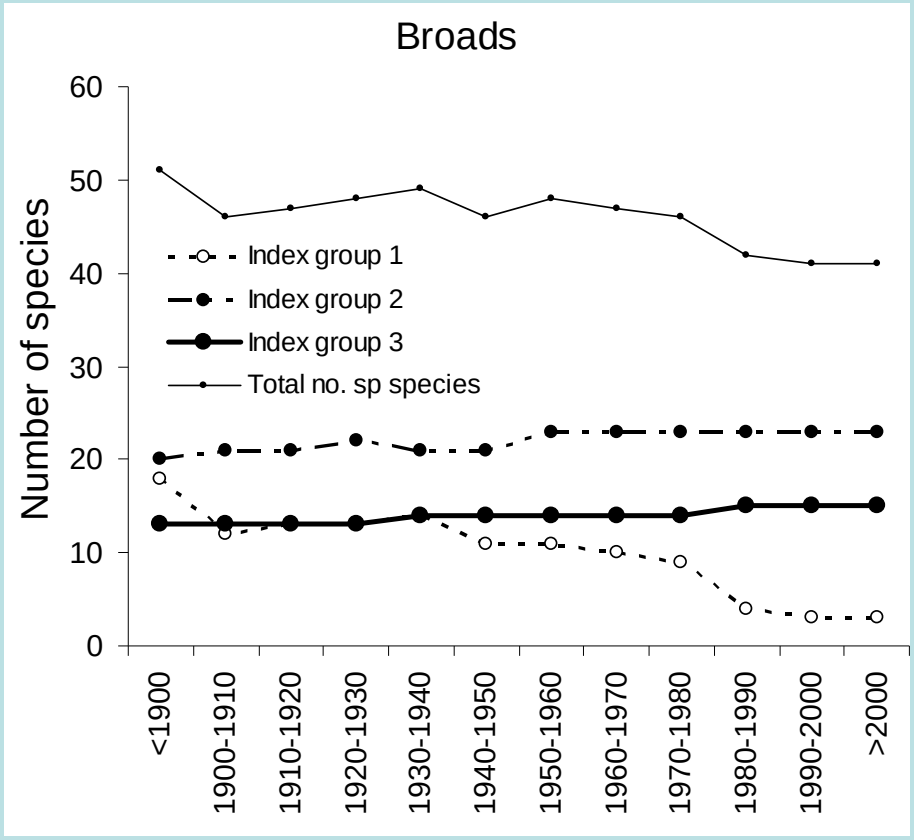
(Pearson's r = 0.656, n = 42, p = 0.0001)

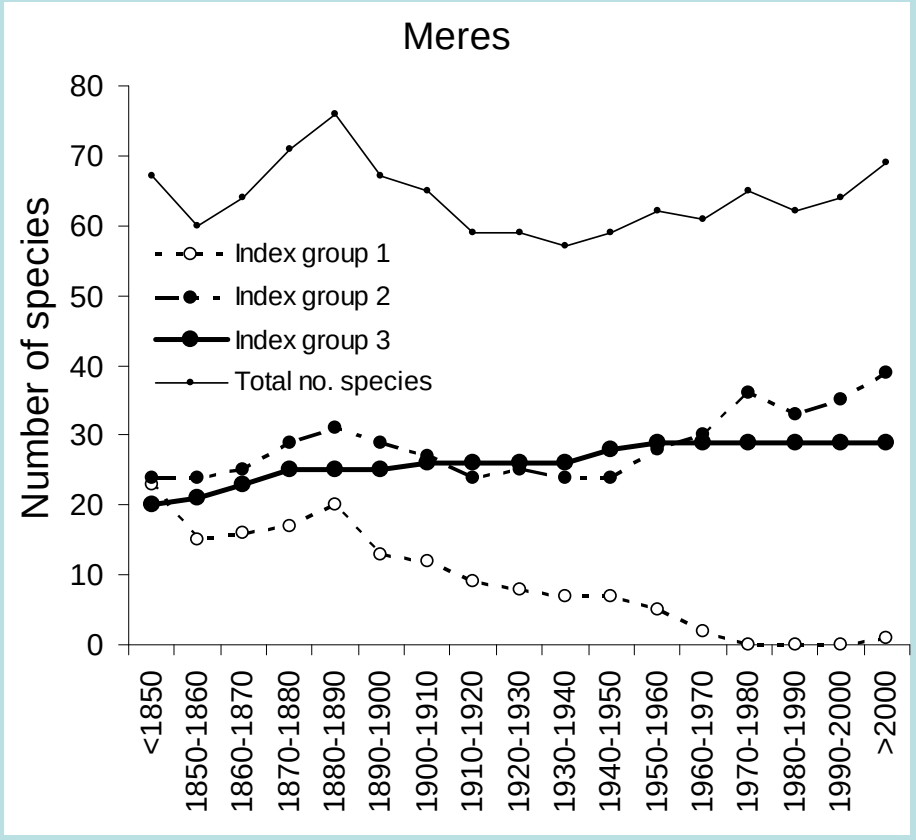
The Change Index

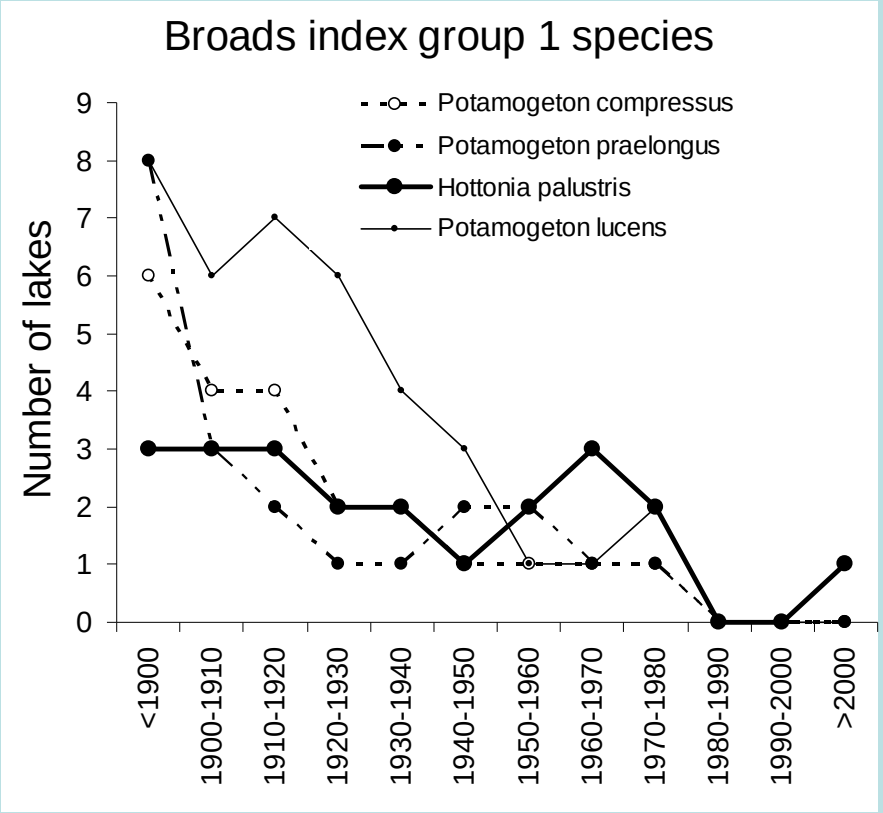


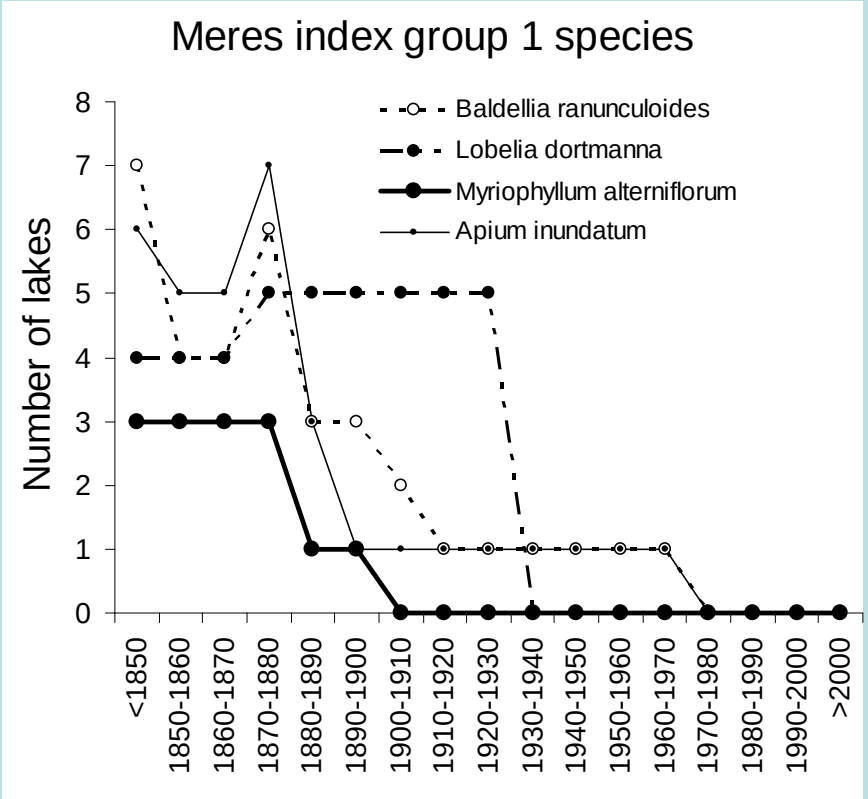
(ANOVA p=0.007 and p=0.006 for Broads and Meres)

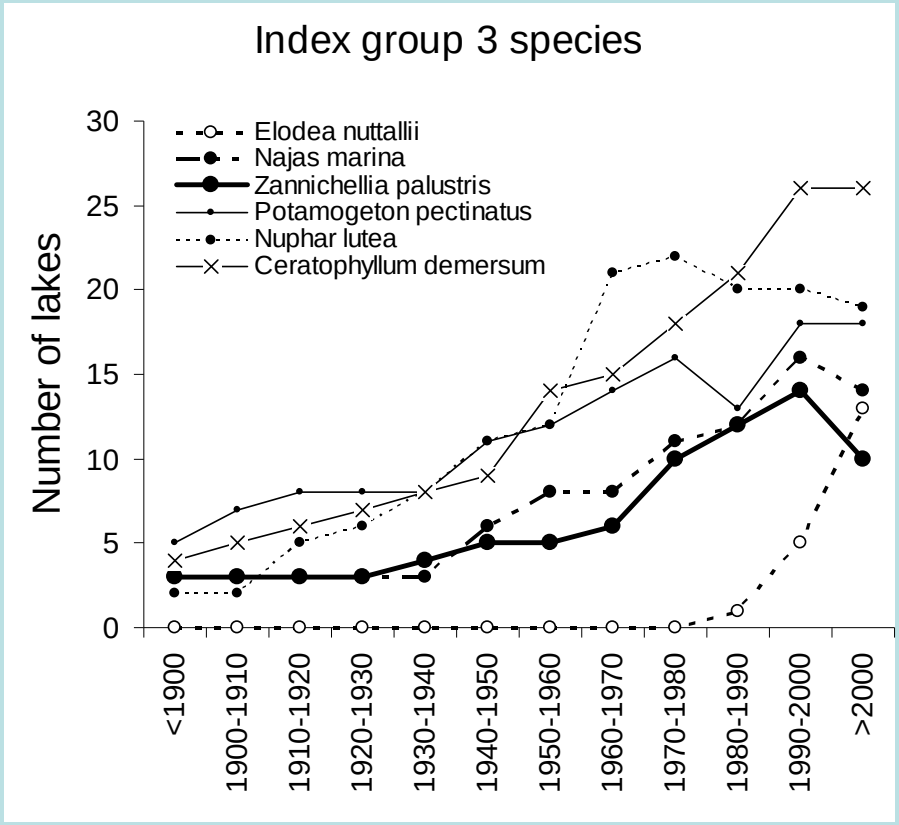
Application

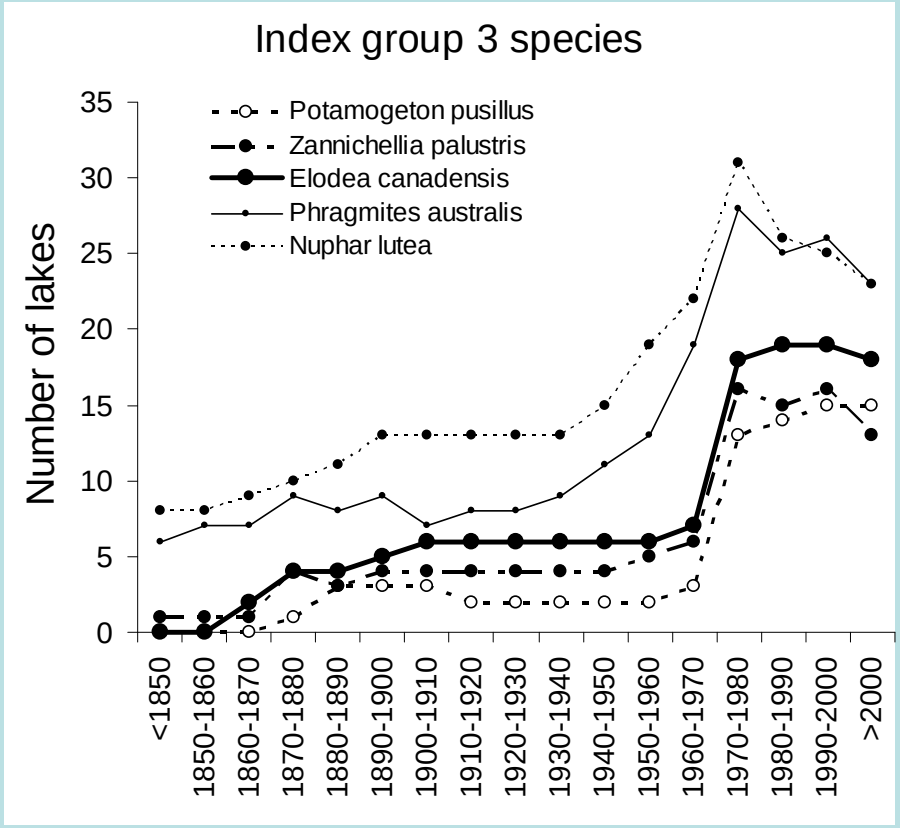





Broads index group 1 species
Number of lakes
0
1
2
3
4
5
6
7
8
9
Potamogeton compressus
Potamogeton praelongus
Hottonia palustris
Potamogeton lucens
<1900
1900-1910
1910-1920
1920-1930
1930-1940
1940-1950
1950-1960
1960-1970
1970-1980
1980-1990
1990-2000
>2000


Meres index group 1 species
Number of lakes
0
1
2
3
4
5
6
7
8
Baldellia ranunculoides
Lobelia dortmanna
Myriophyllum alterniflorum
Apium inundatum
<1850
1850-1860
1860-1870
1870-1880
1880-1890
1890-1900
1900-1910
1910-1920
1920-1930
1930-1940
1940-1950
1950-1960
1960-1970
1970-1980
1980-1990
1990-2000
>2000


Index group 3 species
Number of lakes
Elodea nuttallii
Najas marina
Zannichellia palustris
Potamogeton pectinatus
Nuphar lutea
Ceratophyllum demersum
0
5
10
15
20
25
30
<1900
1900-1910
1910-1920
1920-1930
1930-1940
1940-1950
1950-1960
1960-1970
1970-1980
1980-1990
1990-2000
>2000


Index group 3 species
Number of lakes
Potamogeton pusillus
Zannichellia palustris
Elodea canadensis
Phragmites australis
Nuphar lutea
0
5
10
15
20
25
30
35
<1850
1850-1860
1860-1870
1870-1880
1880-1890
1890-1900
1900-1910
1910-1920
1920-1930
1930-1940
1940-1950
1950-1960
1960-1970
1970-1980
1980-1990
1990-2000
>2000

The Change Index

- Pros:
  - classifies species based on level of their change in lake occupancy
  - allows index allocation to species where historical data is missing
  - can utilise a variety of historical sources and yet still ascertain which species have declined and identify periods of more rapid decline
  - more sensitive than index based on hectads, where losses within one site within a hectad may be obscured by persistence at other sites in hectad

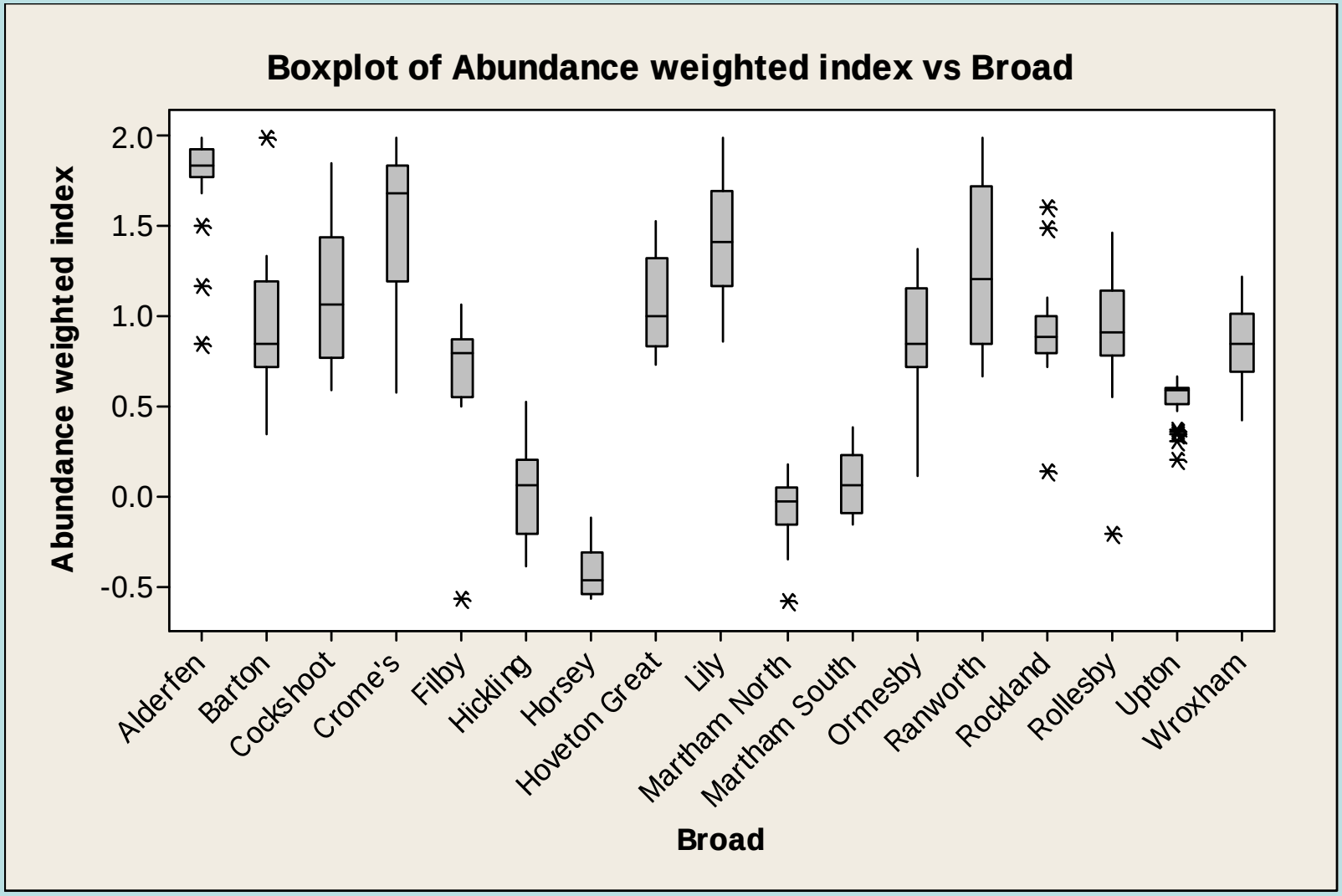
The Change Index

- Cons:
  - can only provide information on species decline
  - takes no account of abundance within lakes

How to identify reference conditions?

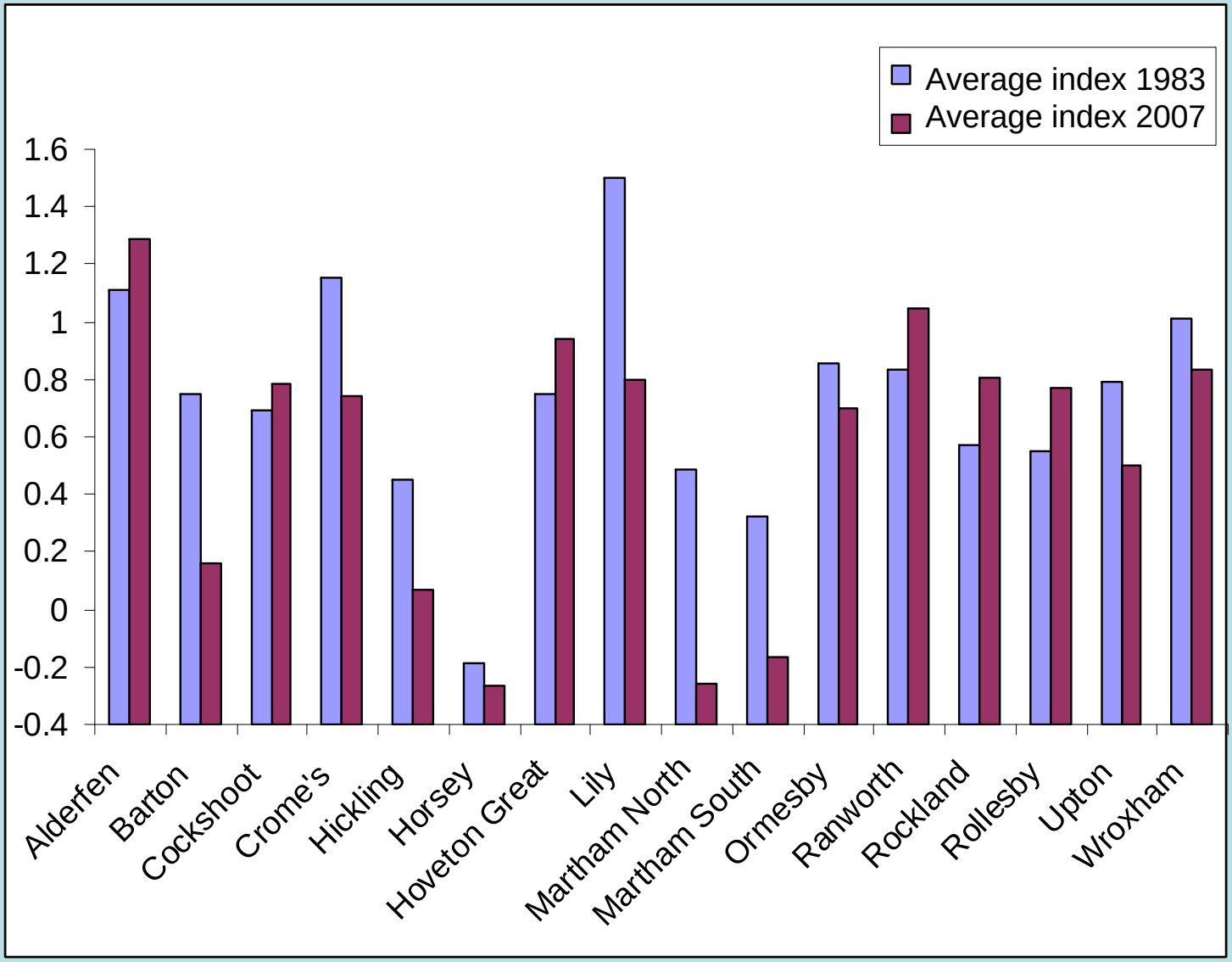
- Based on present assemblages
  - Link environmental variables with aquatic vegetation (JNCC lakes classification)
  - LEAFPACS
- Modelling based on land use records
  - (Moss, Johnes & Phillips, 1996)
- Paleolimnology
  - Diatoms (Bennion, Fluin & Simpson, 2004)
  - Macrofossils (Ayres et al, in press)
- Historical data!

Further application

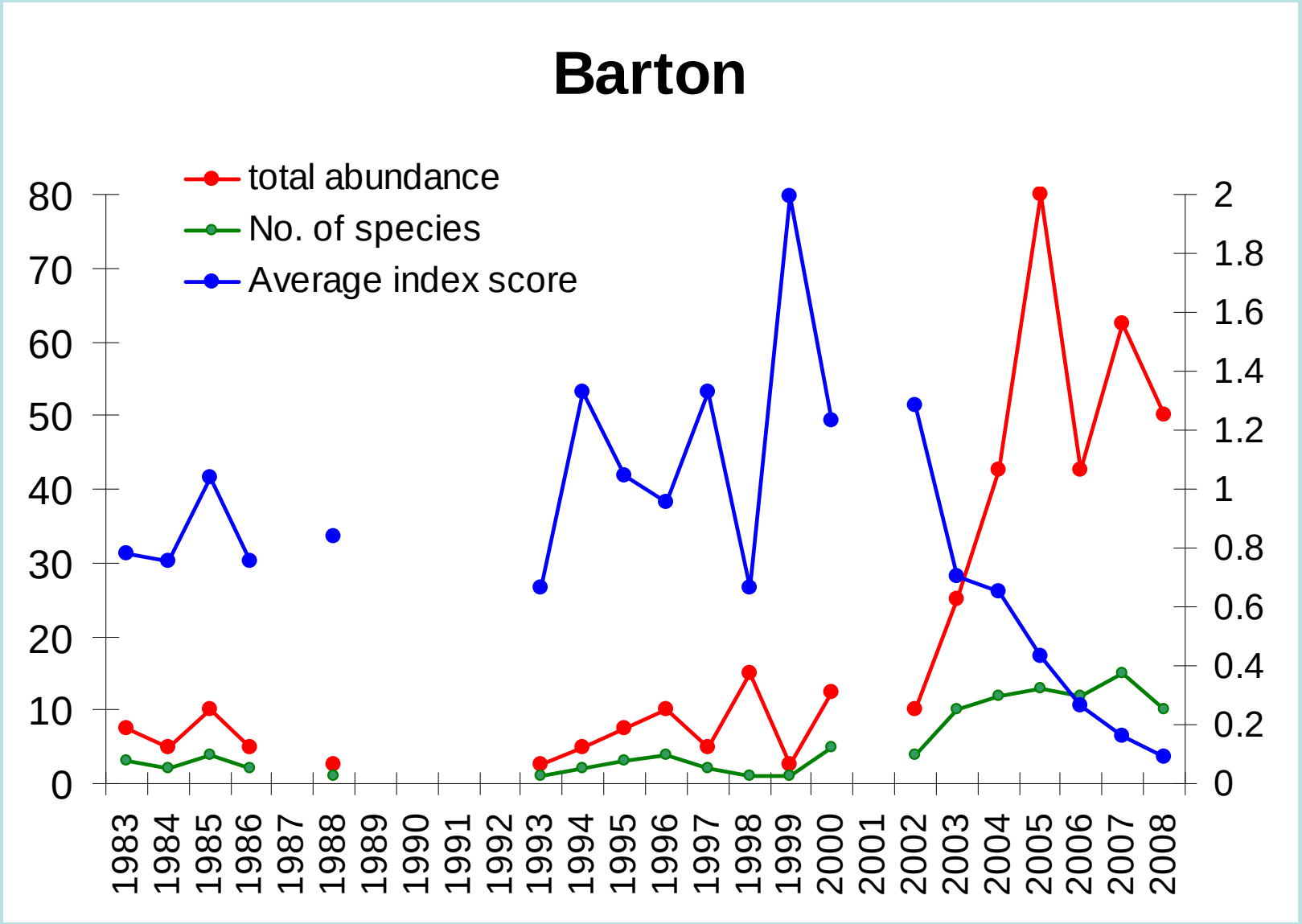


Abundance weighted Index scores for each lake over the entire period (1983-2008)

Further application



Further application



Further work

- Comparing to other methods, e.g. macrofossil evidence
- Combine richness, abundance and change index into overall index of ecological integrity

Acknowledgements

Funders:

Broads Authority
The Broads - a member of the National Park family

ENGLISH NATURE

ENVIRONMENT AGENCY

…and, in no particular order:
Michael Jackson, Dan Hoare
Andrea Kelly, Jo Pitt, Stewart Clarke, Iwan Jones, John Birks, Richard Telford, Alex Lockton and people at the ECRC, NHM & Norwich Castle Museum

Water-lilies at Barton Broad, Norfolk.