Broads Annual Water Plant Monitoring Report 2008

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March 2008

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY 4
2 INTRODUCTION 6
2.1 Legislative Framework and Delivery 6
2.2 Restoration 7
2.3 Monitoring 7
3 AIMS AND OBJECTIVES 8
4 METHODOLOGY 8
5 BROADS MACROPHYTE RESULTS. 12
5.1 Thurne Valley 12
5.1.1 Hickling 12
5.1.2 Horsey Mere 13
5.1.3 Martham North 13
5.1.4 Martham South 14
5.1.5 Heigham Sound 15
5.2 Muck Fleet Valley - Trinity Broads 16
5.2.1 Ormesby 16
5.2.2 Rollesby 16
5.2.3 Ormesby Little 17
5.2.4 Filby 18
5.2.5 Lily 18
5.2.6 Little Broad 18
5.3 Ant Valley 19
5.3.1 Barton 19
5.3.2 Alderfen 20
5.3.3 Crome's 20
5.4 Bure Valley 21
5.4.1 Belaugh 21
5.4.2 Bridge 21
5.4.3 Cockshoot 22
5.4.4 Hoveton Great 22
5.4.5 Hoveton Little 23
5.4.6 Mautby Decoy 23
5.4.7 Ranworth 23
5.4.8 Upton Great 24
5.4.9 Upton Little 24
5.4.10 Wroxham 24
5.4.11 Decoy 25
5.4.12 Pound End 25
5.4.13 Hudson's Bay 25
5.5 Yare Valley 26
5.5.1 Rockland 26
5.5.2 Whitlingham Great 26
5.5.3 Whitlingham Little 27
5.5.4 Wheatfen 27
5.5.5 Strumpshaw 27
5.5.6 Buckenham 28
5.5.7 Hassingham Broad 28
5.6 Waveney Valley 30
5.6.1 Barnby 30
5.6.2 Flixton Decoy 30
5.6.3 Lound Lakes 30
5.6.4 Spratt's Water 31
5.6.5 Round Water 31
5.7 Summary of the lakes surveys. 32

6 RIVER SURVEY MACROPHYTE RESULTS 34
6.1 Background 34
6.1.1 River Ant 34
6.1.2 River Bure 35
6.1.3 River Thurne 35
6.1.4 River Waveney 36
6.1.5 River Wensum 36
6.1.6 River Yare 36
6.2 River macrophyte diversity 37
6.3 Summary of River Survey results 37
7 HYDROACOUSTIC PLANT SURVEY. 38
7.1 Introduction 38
7.2 Rollesby Broad Survey 38
7.3 Data Analysis 38
7.4 Results 38
7.5 Conclusions 39
8 GENERAL DISCUSSION 40
9 ACKNOWLEDGEMENTS 43
10 REFERENCES 44
11 APPENDICIES. 45
11.1 Appendix 1. Macrophyte groupings based on form 46
11.2 Appendix 2. Macrophyte abundance trends (1983 – 2008) 47
11.3 Appendix 3a. Latin to Common plant names. 52
11.4 Appendix 3b. Common to Latin plant names. 53

LIST OF FIGURES

Figure 1 Species richness by broad and year. 34
Figure 2 Echogram of transect D (with full echo signal) 41
Figure 3 Echogram of transect D (sediment and plant signal only) 41

LIST OF TABLES

Table 1 Sites surveyed for water plants from 1983 to 2008. 10
Table 2 Sampling dates and transect lengths (metres) (2006-2008). 11
Table 3 River stretches and dates sampled 35
Table 4 The number of species found each year in each river stretch surveyed and the corresponding Simpsons diversity index value (1-D) 38
Table 5 Hydroacoustic survey results from Rollesby Broad July 2008 41
Table 6 Macrophyte scores (diversity) for broads based on abundance and number of species 42
Table 7 Diversity for broads sampled in 2008 based on methodology in the RaBS database 43
Table 8 Trend in abundance of macrophytes over last 5 years. 43

The front cover image of *Potamogeton crsipus,* curled pondweed. Sample pressed and then taken with back-lighting by Tom Barrett.

1 EXECUTIVE SUMMARY

This report presents and discusses the findings from the annual plant surveys carried out for 2007 (40 waterbodies) and 2008 (30 waterbodies). Data from the Broads annual survey is the longest time series and most complete water plant data set for a group of shallow lakes in the UK.

The rivers and broads were sampled using a rake trawl method, with water plant species identified and their abundances scored on a five-point scale. This methodology has been proved to be simple, low-tech and easy to replicate both spatially and temporally and involves partner organisations in the process. The results clearly show changes in water plant species diversity and abundance and it is a rapid way of assessing the ecological status of lakes.

Surveys of river stretches have been incorporated into the annual monitoring programme since 2005. These surveys provide valuable data on the biological response in the river channels to the various on-going Broads-wide nutrient reduction schemes and also gives an indication of necessity for water plant management.

There appears to be a general trend of increased water plant abundance in most of the broads surveyed. At some sites there appears to be a lack of continued stability in the plant communities, with a few key sites suffering drastic loss of overall water plant abundance and disappearance of formerly abundant species.

Key results from the 2007 & 2008 surveys can be summarised as: -

- Hickling and Horsey Mere continue to have a very low number of species present (species richness) and low abundance, with only two species found in Horsey.
- Martham North and South recorded good plant diversity, appearing relatively stable in terms of long term abundance
- The holly leaved naiad (a Biodiversity Action Plan (BAP) species) was found to be present in twelve broads in 2008, including Heigham Sound.
- The Trinity broads in 2008 had good levels of water plant diversity, with Filby improving from two species in 2006 to nine in 2007.
- An encouraging growth of bristly stonewort, greater bladderwort and horned pondweed were found in Little Broad, just nine months after suction dredging was completed in the winter of 2007/08.
- Wroxham showed a surprising increase in species richness in 2008, although abundances continued to be very low. Despite improvement in water quality since the early nineties there has been no significant development of the aquatic plant community.
- The river surveys reveal a generally rich assemblage of marginal and submerged species, with only the Rivers Wensum and Yare containing relatively low numbers (6 and 7 species respectively in 2007).

The greater number of individual waterbodies surveyed between 2006 and 2008 has been due to extra staff resource funded from Defra's additional grant to the Broads Authority to deliver Public Service Agreement (PSA) targets, which aim to bring 95% of SSSI sites in to "favourable" condition by 2010. This expansion of the survey in recent years has led to a greater understanding of the biological resource within the Broads. Such biological indicators are increasingly important, as compliance with the EU Water Framework Directive (WFD) is based on ecological indicators of ecosystem health, which includes assessment of water plant populations. The water plant surveys inform ways in which lake restoration works can be targeted, with the Broads leading the way in lake classification and restoration

nationally. The greater number of broads surveyed is hoped to continue and a rolling programme of visiting new and infrequently surveyed sites is being implemented. The detection of invasive, non-native plant species within the Broads is also important function of the annual survey if the risks posed by these plants are to be effectively managed.

Steady progress is clearly being made through the Lake Restoration Strategy. However much work remains to be done across the Broads to bring degraded broads back to health, in line with national and EU drivers and to increase and subsequently maintain the diversity of those broads lacking in species richness. The annual water plant survey therefore continues to be an important part of targeting and measuring the success of such efforts.

For the first time, data generated by the Broads Authority hydro-acoustic survey equipment is presented. Sonar technology is used to generate quantitative data on submerged water plant abundance and distribution. Plant parameters that are now able to be measured accurately and quickly include plant height from the lake bed, area of bed covered by plants and the volume of plant matter within the water body.

2 INTRODUCTION

Britain's premier lowland wetland system, the Norfolk and Suffolk Broads, contains a high diversity of aquatic plant or macrophyte species; including several national rarities e.g. holly leaved naiad and water solider. The mosaic of habitats that make up the wetland includes; shallow lakes, reed-swamp margins, rivers, carr woodland, fen, reed beds, marshes and marsh dykes, all of which require high quality water in adequate quantity. The major threat to water quality in the Broads has been identified as arising from nutrient inputs. This is exacerbated by sometimes heavy water abstraction from the catchments that can reduce the amount of flushing (Natural England 2006). These issues, in combination with each other, increase the overall nutrient content of water and can lead to eutrophication and have negative ecological consequences. The chemical and physical changes observed in the Broads have been reflected by a shift to low diversity water plant communities. When plant growth in these lakes does increase, it is often only a few vigorous and highly competitive species that become dominant, rather than a range of co-existing species.

The terms richness, abundance and diversity are all used within this report when describing and discussing the findings of the surveys. Each term has a specific meaning relating a broad's plant community. Richness refers to the number of different species found in a given waterbody. High richness means a greater number of different species. Abundance relates to the quantity of plants. It is therefore possible to have a broad completely filled (high abundance) with only one or two species (low richness). Equally a broad referred to as having high species richness and abundance is describing a waterbody which has a large number of different species and each species is found in good numbers. A stable functioning macrophyte community will have good species richness and an even spread of abundance across the species. That is, no single species is dominant. Diversity is a statistical term used when describing a plant community where both richness *and* abundance are taken into account. As species richness and abundance increase, so diversity increases. A community containing only one or two species with high abundances is considered to have a low diversity compared to one that has several different species with similar abundances

Macrophytes i.e. submerged, floating or emergent water plants are an essential part of the ecology of shallow lakes in Broadland. Water bodies with low aquatic macrophyte cover offer little refuge for other aquatic life and tend to contain generalist faunal species that are capable of existing in these simple unstructured habitats. An increase in the diversity of the plant community leads to an increase in the habitats and niches available for aquatic organisms to colonise.

2.1 Legislative Framework and Delivery

The importance of good quality open water habitats is recognized at the national and international level. The European Water Framework Directive (WFD) will assess 'Ecological Status' of water bodies, which will include assessment the condition of water plant communities. Where water bodies are protected under the European Habitats Directive, the recognised ecological features include ones focussed on water plant abundance, diversity and community structure.

To achieve Lakes PSA targets many freshwater SSSI lakes and rivers in the Broads need to have a reduction in the level of nutrient inputs discharged from sewage treatment works and other EA consented point sources. The Office of Water Services' Asset Management Plan (AMP) investment programme and the Environment Agency's Review of Consents are largely delivering this reduction from point sources. Reducing diffuse pollution from the river

catchments, will also aid PSA target delivery. Wider uptake of agri-environment schemes is a potential delivery mechanism for tackling diffuse pollution, as well as the work of the Catchment Sensitive Farming Initiative (CSFI). Alongside these Defra funded officers in the Broads catchment, there are two catchment officers employed in partnership with the Broads Authority in the Trinity Broads and Lound catchments. The CSFI is aimed at improving farm practices and reducing water pollution from agriculture.

Biodiversity Action Plans for habitats and species also recognise the importance of water plant communities and species in lake systems. The BAP process is the UK Government's response to Convention on Biological Diversity signed in 1992, which commits a detailed plan for the protection of these resources from a number of organizations. In addition the Countryside Rights of Way Act (CRoW) outlines the duties of competent authorities, such as the Broads Authority, to enhance and restore the ecological status habitats, which, in the Broads area, includes water plant communities. Several species found in the Broads are also listed in the Joint Nature Conservation Committee (JNCC) Red Data Book. The Red Data Book species are those whose continued existence is threatened.

2.2 Restoration

The restoration process for shallow lakes starts by identifying the cause of the problem e.g. eutrophication (excess nutrients in the water) or increased sediment depth/reduced water depth. Two approaches to lowering the nutrient status of the water body are via catchment controls and/or sediment dredging. Following these restoration processes, the re-establishment of water plants can be further aided by biomanipulation. This is where zooplanktivorous fish are removed to allow populations of zooplankton, such as *Daphnia*, to increase. By feeding on microscopic algal communities, large numbers of zooplankton result in clearer waters and this in turn allows macrophytes to flourish.

Aquatic macrophytes are also key in maintaining clear water conditions, as they provide physical and chemical benefits for the ecology of the shallow lake. These benefits include: sediment stability, providing a refuge for fish and invertebrates and nutrient uptake. Water plants are therefore a key indicator of the ecological health of shallow lakes.

The Broads Authority, in conjunction with Environment Agency, have demonstrated that it is possible to restore lakes by using intensive management (Moss *et al* 1996). Work continues to manage and restore many broads. The Broads Authority recognises the value of partnership, working with organisations and the local community, to achieve restoration aims.

2.3 Monitoring

The Broads Authority, with various researchers and contractors, has carried out surveys of water plants in The Broads every year since 1983. This data has provided a useful tool to assess the significant long-term changes in the submerged macrophyte flora in the Broads throughout the last 26 years. Twenty key sites have been regularly (minimum of 18 years worth of data), if not continually surveyed since 1983, these are Alderfen, Barton, Belaugh, Cockshoot, Crome's, Heigham Sound, Hickling, Horsey, Hoveton Great, the Marthams, Ranworth, Rockland, Upton Great, Wroxham and the five Trinity broads.

During the surveys in 2007-8 monitoring involved partner organisations such as Norfolk Wildlife Trust, RPSB, Natural England, Environment Agency, Ted Ellis Trust and the National Trust in the data collection process.

3 AIMS AND OBJECTIVES

The aim of the Broads annual survey is to monitor water plants within specified broads, along previously defined transects between late July and and early September, using the methodology outlined by Kennison *et al* (1998). Where broads have historically been sampled around a particular date, it is aimed that the survey takes place as near as possible to that date.

The main objectives in the annual programme are to monitor key broads with long-term datasets, those that have had restoration measures put in place or those that are known to be experiencing a change in their macrophyte community. Other broads that are not receiving restoration efforts or are stable and/or are generally without plants, are monitored on a less frequent basis. When resources allow, a rolling program of monitoring sites not previously surveyed is also an ongoing aim.

This report aims to collate the data collected since the last survey report in 2006 and will refer to the long-term data from 1983 to 2008 (Table 1). The report also includes a brief outline of the hydroacoustic survey method and its outputs, as well as an update of the river survey data collected in 2007 and 2008.

4 METHODOLOGY

The rake-trawl method used for the water plant surveys follows that outlined in Kennison *et al* (1998). Relative sampling intensity has been roughly constant between individual broads, with total transect length sampled determined by the area of open water. A ratio of 100 m transect per one hectare of open water has been adopted. Transects are located in fixed positions and were located by a Differential Global Positioning System (DGPS) in the boat.

Abundance of each plant species was scored on a five-point scale based on the percentage of the rake covered by plant material. This method was devised to work in turbid lakes where a visual estimate of *in situ* cover and abundance such as Percentage Volume Infested (PVI) or DAFOR cannot be determined. The five-point scale used in the rake survey represents the following percentage rake cover:

1 = 5% or less (this includes very small fragments of plants)
2 = 6-25%
3 = 26-50%
4 = 51-75%
5= 76% or greater

In addition to the standard methodology described by Kennison *et al* (1998), the start and end point of each transect line were recorded by DGPS co-ordinates. DGPS co-ordinates were also taken at points along transects when the rake was retrieved to record plant species and abundance scores before reaching the endpoint. Such stop-points were required where plant growth was dense and the rake clogged quickly, or if a long distance had been trawled, as the rake tines were often clogged by debris that reduced sampling efficiency. The numbers of stops varied according to the total transect length and the plant abundance present along it.

When water clarity was good and abundant plant beds could be viewed from the boat, regular rakes were used to truth visual estimates of rake cover, as it was extremely difficult to use the rake for the whole length of the transect.

The search effort per unit area, expressed as length of transect per hectare of lake waterspace. There is a small amount of variation in this value between broads and between different years within broads. Values between 0.5 and 1.5 have been generated using the formula below, with an average of 1.0. The search effort per unit area has been calculated as:

total transect length (m) / (lake area (ha) x 100)

Within broads that have not been sampled previously, the total transect length sampled is aimed to be as close to 1.0 (using the above formula) as possible, to maintain a consistent search effort. Any variation in search effort does not impact on the final abundance scores of individual macrophyte species, as all results take into account the distance the rake has sampled. A low search effort may however reduce the number of species encountered, particularly the least abundant ones. Use of the DGPS to accurately mark positions whilst towing the sampling rake has enabled the plant results to be corrected for variation in the lengths of transects, as will invariably happen in a small boat.

38, 40 and 30 broads were surveyed in 2006, 2007 and 2008 respectively (see Table 1). The dates surveyed and transect lengths are presented in Table 2.

Table 1. Sites surveyed for water plants from 1983 to 2008.

Broad	No. of Years Sampled	Year 83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Alderfen	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Bargate	2																						■		■		
Barnby	4																						■	■	■	■	
Barton	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Belaugh	18							■	■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■	
Blackfleet	3	■		■																					■		
Bridge	12														■	■	■	■	■	■	■		■	■	■	■	■
Buckenham	5																						■	■	■	■	■
Burntfen	3																■				■				■		
Catfield	1																						■				
Cockshoot	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cromes	25	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■
Decoy	7				■												■						■	■	■	■	■
Filby	21	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	
Flixton Decoy	2																								■	■	
Fritton Lake	1																								■		
Hassingham	5																						■	■	■	■	■
Heigham Sound	18	■	■	■	■	■	■	■	■	■	■	■	■		■	■								■	■	■	■
Hickling	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Hopton 1	1																									■	
Hopton 2	1																									■	
Hopton 3	1																									■	
Hopton 4	1																									■	
Horsey Mere	22	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■
Hoveton Great	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Hoveton Little	13							■						■	■	■	■	■	■	■			■	■	■	■	■
Hudson's Bay	7	■	■	■		■		■							■											■	
Irstead	1																						■				
Lily	21	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	
Little Broad	2																							■			■
Malthouse	6													■	■		■		■	■	■						
Martham North	25	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
Martham South	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■
Mautby Decoy	2																									■	■
MILL	1																									■	
Norton	1																						■				
Ormesby	23	■	■	■	■	■		■	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■	■	■
Ormesby Little	23	■	■	■	■	■		■	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■	■	■
Pound End	14										■			■	■	■	■	■	■	■	■		■	■	■	■	■
Ranworth	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■		■	■	■	■	■
Reedham Water	1																						■				
Rockland	20	■	■	■	■	■	■	■	■	■	■			■			■	■	■			■	■	■	■	■	■
Rollesby	22	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■
Rounds Water	1																										■
Salhouse Great	12				■	■								■	■	■	■	■	■	■			■	■	■		
Salhouse Little	6					■				■				■	■	■	■										
Spratts Water	2																						■				■
Strumpshaw	5																■							■	■	■	■
Upton Great	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Upton Little	3																							■	■	■	
Wheatfen	4																■						■		■	■	
Whitlingham Great	6																					■	■	■	■	■	■
Whitlingham Little	4																							■	■	■	■
Wroxham	26	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	No.sampled	21	20	21	21	22	13	22	20	21	21	15	12	24	26	24	28	20	24	17	21	19	35	33	38	40	30

Table 2 Sampling dates and transect lengths (metres) (2006-2008).

Broad	Date Sampled			Total Transect Length (m)		
	2006	2007	2008	2006	2007	2008
Alderfen	17-Aug	15-Aug	15-Aug	887	866	850
Bargate	30-Aug	-	-	821	-	-
Barnby	?	05-Sep	-	353	-	-
Barton	26-Jul	25-Jul	06-Aug	5410	5458	5234
Belaugh	08-Aug	07-Aug	-	326	332	-
Blackfleet	16-Aug	-	-	337	-	-
Bridge Broad	08-Aug	07-Aug	23-Jul	380	383	430
Buckenham Broad	18-Jul	24-Jul	22-Jul	315	276	331
Burntfen	19-Jul	-	-	545	-	-
Cockshoot Broad	17-Aug	17-Aug	14-Aug	1144	938	1125
Crome's	09-Aug	15-Aug	13-Aug	1029	956	1049
Decoy Broad	24-Aug	09-Aug	29-Jul	1342	1582	1512
Filby	19-Jul	29-Aug	-	3089	2909	-
Flixton Decoy	11-Aug	03-Aug	-	829	903	-
Fritton	18-Jul	-	-	3931	-	-
Hassingham Broad	02-Aug	24-Jul	22-Jul	184	259	232
Heigham Sound	01-Aug	31-Jul	07-Aug	2414	2620	2684
Hickling	03-Aug	01-Aug	07-Aug	8923	8714	8964
Hopton 1	-	04-Sep	-	-	283	-
Hopton 2	-	04-Sep	-	-	741	-
Hopton 3	-	04-Sep	-	-	458	-
Hopton 4	-	04-Sep	-	-	271	-
Horsey Mere	10-Aug	02-Aug	08-Aug	3495	3637	2999
Hoveton Great	09-Aug	08-Aug	30-Jul	3294	3040	3237
Hoveton Little	-	09-Aug	29-Jul	2429	2429	2421
Hudson Bay	-	08-Aug	-	-	322	-
Lily	23-Aug	23-Aug	-	1027	1258	-
Little Broad	-	-	12-Sep	-	-	231
Martham Broad North	27-Jul	26-Jul	28-Jul	852	942	833
Martham Broad South	27-Jul	26-Jul	28-Jul	760	716	752
Mautby Decoy	-	30-Aug	02-Sep	-	455	462
Mill Water	-	04-Sep	-	-	261	-
Ormesby	22-Aug	22-Aug	19-Aug	4447	4916	4641
Ormesby Little	24-Aug	23-Aug	22-Aug	3336	3803	3699
Pound End	09-Aug	09-Aug	29-Jul	492	589	710
Ranworth	15-Aug	13-Aug	12-Aug	4576	4597	4416
Rockland	30-Aug	28-Aug	09-Sep	1609	1631	1518
Rollesby	23-Aug	23-Aug	21-Aug	2401	2430	2391
Round Water	-	-	10-Sep	-	-	33
Salhouse Great	08-Aug	-	-	880	-	-
Spratt's Water	-	-	10-Sep	-		83
Strumpshaw	18-Jul	24-Jul	22-Jul	328	338	447
Upton Great	15-Aug	13-Aug	12-Aug	1024	917	977
Upton Little	15-Aug	13-Aug	-	202	174	-
Wheatfen	29-Aug	28-Aug	-	644	760	-
Whitlingham Great	31-Aug	27-Jul	14-Aug	2825	3111	4884
Whitlingham Little	31-Aug	27-Jul	14-Aug	681	705	689
Wroxham	08-Aug	07-Aug	23-AJul	1856	1786	1913

5 BROADS MACROPHYTE RESULTS.

Each broad that was surveyed in 2007 and 2008 will be reviewed in terms of species richness and abundance. Species recorded in 2006 are listed to enable recent trends in richness to be readily seen. Where data or key events are relevant to the current status of the broad they will be highlighted. The broads are grouped by the river catchment in which they are situated. Some broads are new additions to the surveying programme and as such there is little to report until such time more data is collected.

Appendix 1 classifies the plants into group of similar form/structure. Appendix 3 lists the common and Latin names for all plants found to date during river and broads surveys.

5.1 Thurne Valley

These broads contain the richest population of stoneworts in the UK. Several of which are on the list of high conservation importance plants and have Biodiversity Action Plans attached to them. Stoneworts are recorded in some broads outside of the Thurne catchment but in lower abundances. Species present in the Thurne broads that are included in the Joint Nature Conservation Committee (JNCC) Red Data Book included, three 'Vulnerable' species: Baltic stonewort, Convergent stonewort, Starry stonewort, one 'Rare': Intermediate stonewort (Stewart and Church, 1992). The Thurne broads also provide a stronghold for the rare BAP species holly-leaved naiad, as well as more common vascular plants such as spiked water milfoil and mare's tail.

5.1.1 Hickling

	2006	2007	2008
Common water moss	*		
Curled pondweed	*		
Fennel-leaved pondweed	*	*	*
Holly-leaved naiad	*	*	*
Lesser pondweed	*		
Mare's tail	*	*	
Rough stonewort	*		
Spiked water milfoil	*	*	*
Starry stonewort	*		

Since peaking in the late 1990s/early 2000s, macrophyte diversity in Hickling Broad has been declining. However, the over last four survey years species richness has dramatically decreased from 11 species in 2005 to just three in 2008. Only small fragments of holly-leaved naiad have been found in the last three years of surveying. The effects of salinity are implicated in this declining trend in the Hickling water plant community. Reductions in salinity are widely accepted as the initial water quality factor to improve if water plants are to recover and remain stable.

5.1.2 Horsey Mere

	2006	2007	2008
Fennel-leaved pondweed		*	
Mares tail	*	*	*
Perfoliate pondweed		*	
Spiked water milfoil	*	*	*

There has been a gradual decline in macrophyte species richness and abundance since 2002. The two pondweed species present in 2007 were last seen in 2004 and only occurred at very low abundance. The abundance of spiked water milfoil has remained relatively constant over the last 5 years. Stonewort species were last present in Horsey Mere in 2005, showing a similar decline to that of Hickling Broad.

Martham North and South

For many years, the Martham Broads have been characterised by sustained clear water conditions, resulting from the plentiful supply of good quality freshwater draining from the northeast of the broads. These conditions continue and are reflected in the high diversity of the plant communities found in the most recent surveys.

5.1.3 Martham North

	2006	2007	2008
Starwort sp.			*
Rigid hornwort			*
Hedgehog stonewort			*
Rough stonewort		*	*
Baltic stonewort	*	*	*
Convergent stonewort		*	*
Fragile/Convergent stonewort		*	
Bristly stonewort	*	*	*
Intermediate stonewort	*	*	*
Common stonewort	*	*	
Canadian waterweed			*
Nuttall's waterweed		*	
Enteromorpha			*
Filamentous algae	*	*	*
Common water moss			*
Mare's tail			*
Ivy-leaved duckweed		*	
Spiked water milfoil	*	*	*
Whorled water milfoil			*
Holly-leaved naiad	*	*	*
Pointed stonewort			*
Starry stonewort	*	*	*
Yellow water lily			*
Blunt-leaved pondweed		*	
Fennel-leaved pondweed	*	*	*
Perfoliate pondweed		*	*
Lesser pondweed	*		*
Willow-leaved Pondweed			*
Fan-leaved water crowfoot	*		*
Horned pondweed	*	*	*

Since 1983 Martham North broad has generally had a higher abundance of aquatic plants compared to Martham South. Recent surveys have recorded a dominance of stonewort compared to vascular plants, comprised primarily of Bristly stonewort and Starry stonewort, the latter species classified as a vulnerable Red Data Book species. The 2006 survey showed a slight decrease in overall macrophyte abundance. This decline was most obvious visually during sampling and was characterised by a significant reduction in height of the stonewort beds compared to that observed in previous years. It is these plant volume (or biomass) variations that are poorly detected by the rake method, especially in broads with generally high macrophyte abundance. Species richness in 2008 was very high with six species of both pondweeds and stoneworts. The holly-leaved naiad and the intermediate stonewort were the most abundant species with 19 of the species recording abundances of less than 5%.

5.1.4 Martham South

	2006	2007	2008
Baltic stonewort	*	*	*
Bristly stonewort	*	*	*
Canadian waterweed	*		*
Common stonewort	*		
Common water moss			*
Convergent stonewort	*	*	*
Curled pondweed	*		
Enteromorpha			*
Fan-leaved water crowfoot	*	*	*
Fennel-leaved Pondweed	*	*	*
Filamentous algae	*	*	*
Hedgehog Stonewort	*	*	*
Holly-leaved naiad	*	*	*
Horned pondweed	*	*	*
Intermediate stonewort	*	*	*
Lesser pondweed		*	*
Mare's tail	*	*	*
Perfoliate pondweed			*
Rigid hornwort			*
Rough stonewort	*	*	*
Small pondweed	*		
Spiked water milfoil	*	*	*
Starry stonewort	*	*	*
Starwort sp.	*	*	*
Whorled water milfoil			*
Willow-leaved Pondweed			*
Yellow water lily	*		

From 1983 to 1996 plant richness and abundance was relatively constant. In 1997 and 2000 abundance of all species, apart from filamentous algae increased. The recording of increased species richness in the late 1990s was in part due to improved identification of charophytes to species level, resulting in multiple records for individual stonewort species rather than one record for stoneworts as a group. Surveys show that bristly stonewort, holly-leaved naiad, starry stonewort and mare's tail are abundant across the broad.

5.1.5 Heigham Sound

	2006	2007	2008
Curled pondweed	*		*
Holly-leaved naiad			*
Mare's tail	*	*	*
Rigid hornwort			*
Spiked water milfoil	*	*	*
Yellow water lily	*	*	

There has been a decrease in the number of macrophyte species from 10 in 2005 to five in 2008. However, small amounts of the BAP species holly-leaved naiad was present in the south east corner of Heigham Sound in 2008 and the abundance of spiked water milfoil continues to remain high.

5.2 Muck Fleet Valley - Trinity Broads

The Trinity Broads are a series of five lakes draining into the River Bure via the Muck Fleet. Ormesby Broad has the most abundant and diverse population of aquatic plants with stoneworts being present, the lake having benefited from the recent restoration programme. During the last three years of surveying, the plant communities in the Trinity Broads have either remained stable or have increased in both richness and abundance.

5.2.1 Ormesby

	2006	2007	2008
Canadian waterweed	*	*	*
Common duckweed	*		*
Common stonewort			*
Curled pondweed		*	
Enteromorpha	*	*	*
Fennel-leaved pondweed	*	*	*
Filamentous algae	*	*	*
Flat-stalked pondweed	*	*	*
Fragile/Convergent stonewort	*	*	*
Holly-leaved naiad	*		*
Horned pondweed	*	*	*
Ivy-leaved duckweed	*	*	*
Least duckweed		*	
Lesser pondweed	*	*	*
Nuttall's waterweed	*	*	*
Rigid hornwort	*	*	*
Water net		*	*
Yellow water lily	*	*	*

From 1983-87 the macrophyte population was dominated by a low abundance rigid hornwort, water lilies and fine-leaved pondweeds. In the period from 1988-93 filamentous algae and horned pondweed dominated, at a higher abundance than recorded in the period from 1983 to 1987. From 1995 to the present there was an increase in abundance of fine-leaved pondweeds e.g. fennel-leaved pondweed and flat-stalked pondweed, as well as other fined-leaved species such as rigid hornwort. This period of improved macrophyte growth coincided with the biomanipulation work, which started in 1995 and has been ongoing since.

Between 2006 and 2008 the macrophyte community in Ormesby has been very stable. A number of species have been periodically absent from this broad, e.g. curled pondweed and holly-leaved naiad, but this is likely to be a consequence of surveying technique rather than the actual disappearance and reappearance of these species from year to year.

5.2.2 Rollesby

	2006	2007	2008
Canadian waterweed	*	*	*
Common stonewort			*
Enteromorpha	*	*	*
Fan-leaved water crowfoot			*

Fennel-leaved pondweed			*
Filamentous algae	*	*	*
Flat-stalked pondweed	*	*	*
Fragile/Convergent stonewort	*	*	*
Horned pondweed		*	*
Ivy-leaved duckweed		*	*
Lesser pondweed		*	*
Nuttall's waterweed	*	*	*
Rigid hornwort	*	*	*
Starwort sp.		*	
Stonewort sp.	*		
Water net	*	*	*
Yellow water lily		*	*

Although there was a decline in macrophyte abundance between 1997 and 2006, the last two years of surveys have shown a reversal in this trend. There was an increased of seven species between 2006 and 2008, including common stonewort and several pondweeds. Coupled with the increase in species richness the abundance of macrophytes was high in 2008, resulting in a diverse plant community. Fennel-leaved pondweed was the most abundant species in 2008 with the plant visible to the surface over much of the water body.

5.2.3 Ormesby Little

	2006	2007	2008
Blunt-leaved pondweed			
Broad –leaved pondweed		*	
Canadian waterweed	*	*	*
Common duckweed		*	
Common stonewort		*	
Curled pondweed			*
Enteromorpha	*	*	*
Fennel-leaved pondweed	*	*	*
Filamentous algae	*	*	*
Flat-stalked pondweed			*
Fragile/Convergent stonewort	*	*	*
Frogbit		*	
Greater reedmace		*	
Horned pondweed			*
Inflated duckweed		*	
Ivy-leaved duckweed	*		*
Lesser pondweed			*
Nuttall's waterweed		*	*
Rigid hornwort	*	*	*
Sharp-leaved pondweed		*	
Small pondweed		*	
Stonewort species		*	
Water net	*		*
White water lily			*
Yellow water lily	*		*

Similar to Rollesby, Ormesby Little has also shown an increase in species diversity since 2006, with the addition of a number pondweed species. In 2008 clear water areas were present with abundant water plant beds visible from the survey boat.

5.2.4 Filby

	2006	2007
Canadian waterweed		*
Enteromorpha	*	*
Filamentous algae		*
Flat-stalked pondweed		*
Fragile/Convergent stonewort	*	*
Horned pondweed		*
Ivy-leaved duckweed		*
Lesser pondweed		*
Water net		*

Filby has generally been species poor compared to the rest of the Trinity system. However a marked change in richness was observed in 2007, with seven additional species found. Unfortunately, no survey was conducted in 2008.

5.2.5 Lily

	2006	2007
Canadian waterweed	*	*
Common duckweed	*	
Curled pondweed		*
Enteromorpha	*	*
Fennel-leaved pondweed	*	*
Filamentous algae	*	*
Horned pondweed	*	*
Ivy-leaved duckweed	*	*
Least duckweed		*
Lesser pondweed	*	*
Rigid hornwort	*	*
White water lily		*
Yellow water lily	*	*

Since the early 2000s, the species richness has been high, but individual species abundances at the time of sampling have been relatively low, with the exception of Canadian waterweed, which continues to be widespread. No survey was conducted in 2008.

5.2.6 Little Broad

	2005	2008
Bladderwort		*
Bristly stonewort		*
Filamentous algae	*	*
Horned pondweed	*	*

This broad was sampled for the first time in 2005. During winter of 2007/08 restorative suction dredging was carried out to deepen the lake and remove the upper layers of nutrient rich sediment. Approximately nine months later, the broad was surveyed for the second time and found to have clear water and quantities of stonewort and pondweed.

5.3 Ant Valley

In the Ant Valley, Alderfen, Crome's and Barton have been regularly surveyed. These water bodies have been subject to extensive restoration effort over the last 25 years and all have improved water quality and macrophyte populations as a result. Alderfen and Crome's have good populations of rigid hornwort. Aquatic plants are numerous within the clear water areas of Barton Broad, which have been created through zooplanktivorous fish removal behind temporary barriers. The success of these restoration areas has now reached out into the main broad itself, with several macrophyte species being commonly recorded (primarily rigid hornwort and Nuttall's waterweed, particularly along the western side in the shallower margins and along the Neatishead Arm).

5.3.1 Barton

	2006	2007	2008
Arrowhead			*
Bulrush		*	*
Canadian waterweed	*	*	
Common club-rush	*		
Common duckweed		*	*
Common stonewort	*		
Curled pondweed	*	*	*
Fan-leaved water crowfoot		*	
Fennel-leaved pondweed	*	*	*
Filamentous algae	*		*
Greater duckweed		*	*
Hair like pondweed		*	
Horned pondweed		*	
Lesser pondweed		*	
Nuttall's waterweed	*	*	*
Pointed stonewort	*		
Rigid hornwort		*	*
Small pondweed	*		
Stonewort sp.	*		
Stonewort species		*	
Unbranched bur-reed	*	*	*
White water lily	*		
Yellow water lily	*	*	*

Barton Broad historically had a very low abundance and occasional complete absence of recorded aquatic macrophytes. Since 2003 more than 10 macrophyte species have been recorded each summer, with steadily increasing abundance and richness. However, abundances remain relatively low and in 2008 four fewer species were recorded.

Despite continued scrub clearance to ensure a good light climate at the lake margin, the emergent vegetation growth is not yet forming reed-swamp habitat. Erosion and grazing by feral geese are factors contributing to continued reed-swamp loss. Fish curtains may give protection to emergent vegetation, however as reed-swamp extension is slow and governed by many other factors, this has not been conclusively tested.

5.3.2 Alderfen

	2006	2007	2008
Filamentous algae	*		*
Holly-leaved naiad	*	*	*
Rigid hornwort	*	*	*

The abundance of macrophytes in Alderfen appears to be cyclical with years of near absence of plants followed by several years where rigid hornwort, macro-algae and sometimes duckweeds occur. Holly-leaved naiad was recorded for the first time in this broad in 2006 and has remained present.

5.3.3 Crome's

	2006	2007	2008
Canadian waterweed		*	*
Common duckweed	*	*	
Common stonewort	*		
Delicate stonewort	*		*
Enteromorpha	*	*	
Filamentous algae	*	*	*
Fragile/Convergent stonewort	*	*	*
Ivy-leaved duckweed	*		
Nuttall's waterweed			*
Rigid hornwort	*	*	*
Water-soldier		*	
White water lily	*	*	*

Crome's Broad is divided into north and south basins by a reed strip on top of an old peat baulk. The north basin has historically had shallow water depth and very few aquatic macrophytes, whereas the south broad has a greater depth of water as a result of dredging (in 1988) and has had high plant abundance. During the winter of 2004/05 the north basin was mud pumped and a greater water depth achieved. By 2006, the north basin had been colonised by rigid hornwort and filamentous algae. The positive effects of increased water depth from the mud pumping continues and is reflected in the colonization of the north basin by water solider and Nuttall's waterweed. The aquatic plant richness in the whole of Crome's Broad has generally been low, but since 2006 macrophtye diversity has remained stable.

5.4 Bure Valley

The hydrological connection to the River and the position of the Bure Valley broads within the catchment affects both ecological condition and restoration potential of these waterbodies. In recent years Upton and Cockshoot Broads, both isolated from the river, have had the highest populations of aquatic plants present in the Bure Broads. Upton Broad is a stronghold for the rare holly-leaved naiad. Those broads connected to the river, such as Hoveton Little (Blackhorse) and Ranworth, have minimal plant diversity. In contrast to the other online broads of the Bure Valley, Wroxham has shown a dramatic improvement in species richness and abundance.

5.4.1 Belaugh

	2006	2007
Common Duckweed		*
Enteromorpha		*
Filamentous algae	*	*
Nuttall's waterweed	*	*
Rigid hornwort	*	*
Starwort sp.		*
White water lily	*	*
Yellow water lily		*

Prior to 2001, filamentous macro-algae have often completely carpeted the lakebed. Macrophyte survey records date back to 1989, two years after suction dredging, one year after the introduction of yellow & white water lilies, Canadian waterweed and rigid hornwort and the year that grazing bird protection cages were installed to protect the plant beds. In the mid to late nineties a high abundance of rigid hornwort, Canadian waterweed and Nuttall's waterweed was recorded. In the late 1990s and early 2000s, despite the relatively clear water conditions in the upper River Bure, the abundance and diversity of macrophytes remained poor. However, in 2006 clear water conditions were observed and there was a subsequent increase in species diversity in 2007. Rigid hornwort and Nuttall's waterweed were found to be very abundant in 2007. No survey was conducted in 2008.

5.4.2 Bridge

	2006	2007	2008
Branched bur-reed			*
Filamentous algae	*	*	*
Nuttall's waterweed		*	*
Rigid hornwort		*	
Starwort sp.		*	*
Unbranched bur-reed	*	*	*
Yellow water lily	*	*	*

The River Bure flows through Bridge Broad, which in recent years has had good water clarity for much of summer plant growth season. This water clarity is sufficient to allow abundant growth of filamentous algae on the lakebed. Patches of yellow water lily are often recorded, but are prone to being chopped up by propellers in this navigable lake, which is popular mooring location. Over the last few years the submerged strap-like leaves of unbranched bur-reed have been present, reflecting the flow of water through the broad, which this

species prefers. Despite the impact of human activity those species present are relatively abundant.

5.4.3 Cockshoot

	2006	2007	2008
Canadian waterweed	*	*	*
Common duckweed		*	
Common stonewort	*	*	
Enteromorpha	*	*	*
Filamentous algae	*	*	*
Fragile/Convergent stonewort		*	
Frogbit		*	
Holly-leaved naiad	*	*	*
Horned pondweed	*	*	
Ivy-leaved duckweed	*		
Least duckweed		*	
Lesser pondweed	*		
Rigid hornwort	*	*	*
Small pondweed		*	
Water net			*
White water lily	*	*	
Yellow water lily	*	*	

In 2000 and 2003 ten species of submerged rooted aquatic plants (pondweed and stonewort species) were planted into weighted coir pallets. However, the plantings were unsuccessful due to bird grazing or being smothered by filamentous algae. Subsequently 11 species were found in 2005 and 2006, with 2006 being a good year for the holly-leaved naiad. Species richness continued to increase into 2007, but declined to five species in 2008. Holly-leaved naiad remains the dominant species in Cockshoot, with very high abundance covering virtually the entire waterbody in 2008.

5.4.4 Hoveton Great

	2006	2007	2008
Curled pondweed	*	*	*
Enteromorpha		*	
Fennel-leaved pondweed	*	*	*
Filamentous algae		*	*
Horned pondweed	*	*	
Rigid hornwort	*	*	*
Starwort			*
White water lily	*	*	
Yellow water lily	*	*	*

Hoveton Great Broad generally has low macrophyte abundance with remnant patches of water lilies in sheltered bays. The species richness of this broad continues to be stable, at a low level, with only slight changes in species composition over the years. Disused fish

barriers provide increased shelter from the strong wind-induced waves that can disturb the bottom sediments in this broad.

5.4.5 Hoveton Little

	2006	2007	2008
Canadian waterweed			*
Curled pondweed	*	*	*
Fennel-leaved pondweed	*	*	*
Nuttall's waterweed		*	

Hoveton Little Broad has been surveyed sporadically since 1997. During this period both abundance and species richness of macrophytes have been low and remains as such.

5.4.6 Mautby Decoy

	2007	2008
Common duckweed		*
Enteromorpha	*	*
Filamentous algae	*	*
Fragile/Convergent stonewort	*	*
Holly-leaved naiad		*
Horned pondweed	*	
Ivy-leaved duckweed		*
Least duckweed	*	*
Lesser pondweed		*
Rigid hornwort	*	*
Small pondweed	*	

Mautby Decoy was surveyed in 2007 and 2008 prior to and in preparation for suction dredging, which was carried out during the winter of 2008/09. Although the eastern end of the broad was of adequate depth, the western end was no more than 20 cm deep in parts. As a result, the distribution of macrophytes was largely confined to the deeper eastern end. It is hoped that the newly deepened western end will be rapidly re-colonised from the diverse eastern part.

5.4.7 Ranworth

	2006	2007	2008
Fennel-leaved pondweed	*	*	*
Nuttall's waterweed		*	*
Rigid hornwort	*	*	*

The plants in Ranworth Broad have nearly always been limited to a few sickly-looking individuals in some of the transects. Holly-leaved naiad has occasionally been found in this broad, although limited to the occasional individual plant. However, it has not been recorded in the last three surveys.

5.4.8 Upton Great

	2006	2007	2008
Convergent stonewort		*	*
Filamentous algae	*		*
Holly-leaved naiad	*	*	*
Horned pondweed	*		
Opposite stonewort	*		*
Yellow water lily	*	*	

Upton Broad has been a stable stronghold for holly-leaved naiad, where it occupies much of the water column and area of the lake. The stonewort population fluctuates throughout the survey period, but is generally restricted to the shallower, marginal areas rather than the deeper, central basin where holly-leaved naiad dominates.

5.4.9 Upton Little

	2006	2007
Fennel-leaved pondweed		*
Filamentous algae		*
Holly-leaved naiad	*	*
Opposite stonewort	*	

This small broad has only been ever been sampled twice. Holly-leaved naiad has been the most abundant species, although with less vigorous growth than in the neighbouring Upton Great. Water depth, particularly on the western side of the broad is very shallow, with bare mud exposed during periods of low rainfall. Macrophytes are limited to the deeper areas, which are no more than 70 cm depth at any point. High rates of epiphytic encrustation cover the growing plants and dense plant beds do not tend to form at this site.

5.4.10 Wroxham

	2006	2007	2008
Fennel-leaved pondweed	*	*	*
Filamentous algae			*
Nuttall's waterweed			*
Pointed stonewort			*
Rigid hornwort			*
Pointed stonewort			*
Yellow water lily			*

Plants that have been recorded since surveying began in 1983 include Canadian waterweed, fennel-leaved pondweed, yellow water lily and the occasional stonewort. Despite improvement in water quality (both lower nutrient and improved water clarity) since the early nineties there has been no development of the aquatic plant community. However, a surprising increase in species richness was found in 2008, although abundances continued to be very low. It is unclear whether this increased species richness is a stable state and continued monitoring is required.

5.4.11 Decoy

	2006	2007	2008
Canadian waterweed		*	
Filamentous algae		*	*
Holly-leaved naiad		*	
Rigid hornwort	*	*	*
Yellow water lily	*	*	*

Prior to 2004 Decoy broad has only been sampled twice before, in 1986 and 1998, and has always had extremely low submerged plant abundance. There are some persistent patches of yellow water lily and rigid hornwort; however the species communities appear unstable. Sparse individual fragments of holly-leaved naiad, rigid hornwort and Canadian waterweed have been found in 2004, 2005 and 2007.

5.4.12 Pound End

	2006	2007	2008
Curled pondweed	*	*	
Fennel-leaved Pondweed		*	*
Filamentous algae		*	*
Holly-leaved naiad	*	*	*
Rigid hornwort			*

Pound End, the western section of Hoveton Little Broad, has received nearly continuous monitoring since 1995. Holly-leaved naiad has been a near permanent feature of the plant community at this site, although the abundance of this, and other species, continues to be low.

5.4.13 Hudson's Bay

	2007
Canadian waterweed	*
Rigid hornwort	*
White water lily	*
Yellow water lily	*

Prior to 2007, Hudson's Bay was last surveyed 1996 and 1989 and therefore no trends in macrophyte communities can be reported. Although species richness in 2007 was low, the abundance of all macrophyte species was moderate.

5.5 Yare Valley

Waterbodies surveyed in the Yare Valley are generally of good condition in terms of their submerged macrophyte populations. Despite high nutrient concentrations, submerged plants are frequent in Rockland and Wheatfen Broads. Whitlingham Great and Little Broads originated from gravel extraction and despite their 'youth' have abundant submerged plant growth and a diverse species assemblage.

5.5.1 Rockland

	2006	2007	2008
Arrowhead			*
Crowfoot sp.		*	
Fennel-leaved pondweed			*
Filamentous algae	*	*	*
Nuttall's waterweed	*		
Rigid hornwort	*	*	*
Starwort sp.	*		
Unbranched bur-reed	*	*	*
Yellow water lily	*	*	*

Submerged macrophyte cover in Rockland is generally low, but with some quite extensive beds of yellow water lily. In 2006 and 2007 rigid hornwort was particularly abundant, but showed a slight decline in 2008. Outside the navigation channel the broad is very shallow in parts. Where the lakebed has a firm substrate it has been observed that macrophytes are recorded in greater abundance. A noticeable feature of the last six years of macrophyte monitoring is the low abundance of filamentous algae, which was common until 2000.

5.5.2 Whitlingham Great

	2006	2007	2008
Amphibious bistort		*	*
Canadian waterweed	*		*
Common stonewort	*	*	*
Enteromorpha	*		
Fan-leaved water crowfoot	*		*
Filamentous algae	*	*	*
Fragile stonewort		*	*
Fragile/Convergent stonewort	*		
Ivy-leaved duckweed	*	*	
Lesser pondweed			*
Nuttall's waterweed	*	*	*
Pointed stonewort			*
Smooth stonewort	*	*	*

There have been five years of macrophyte monitoring at Whitlingham Great. Species richness and abundance have been high in the shallow margins. In the deep central basin, which extends to 6m deep in parts, smooth stonewort is found. In 2006 there were localised areas where sediment-laden water was pumped into the broad from the gravel transport process. This apparently reduced plant growth, but this has now ceased operation.

5.5.3 Whitlingham Little

	2006	2007	2008
Amphibious bistort		*	
Canadian waterweed	*	*	
Common stonewort	*	*	
Common water moss			
Delicate stonewort		*	
Enteromorpha	*		
Fan-leaved water crowfoot	*		*
Filamentous algae	*	*	*
Fragile/Convergent stonewort	*		*
Horned pondweed		*	
Ivy-leaved duckweed	*	*	*
Lesser pondweed		*	
Nuttall's waterweed	*	*	*
Rigid hornwort		*	*
Smooth stonewort	*		
Swamp Stonecrop		*	
White water lily		*	

Whitlingham Little continues to be dominated by Nuttall's waterweed. However, species richness has declined considerably between 2007 and 2008, with the loss of three stonewort and three pondweed species. Changes in possible water quality are being considered as a reason for the decline in species.

5.5.4 Wheatfen

	2006	2007
Arrowhead		*
Common duckweed		*
Filamentous algae	*	*
Frogbit		*
Nuttall's waterweed	*	*
Rigid hornwort	*	*
Starwort sp.	*	*
Unbranched bur-reed	*	*
Yellow water lily	*	*

Prior to 2006/07 the Wheatfen broads and channels had been sampled once in 1998. The most abundant species in the more recent surveys included rigid hornwort and unbranched bur-reed. Since 1998 the abundance of filamentous algae has declined markedly and has remained low; an indication that increased phosphorus removal at Whitlingham wastewater treatment works (WWTW) has been successful in reducing available phosphorus concentrations.

5.5.5 Strumpshaw

	2006	2007	2008
Greater bladderwort	*	*	*
Common duckweed	*		
Common stonewort		*	
Common water moss	*		
Convergent stonewort			*

Fennel-leaved pondweed	*		
Filamentous algae	*	*	*
Fragile/Convergent stonewort	*	*	*
Frogbit		*	
Holly-leaved naiad	*	*	*
Ivy-leaved duckweed	*	*	
Lesser pondweed		*	*
Rigid hornwort	*	*	*
Unbranched bur-reed		*	

Strumpshaw was previously surveyed once in 1998 and the current flora community is similar to that found in 1998. Holly-leaved naiad continues to be very abundant at Strumpshaw. In addition, bladderwort is particularly abundant across the open water; a unique feature amongst the broads surveyed.

5.5.6 Buckenham

	2006	2007	2008
Canadian waterweed	*		
Common duckweed			*
Curled pondweed	*	*	
Enteromorpha	*		
Fennel-leaved pondweed	*		
Filamentous algae	*	*	*
Fragile/Convergent stonewort		*	*
Ivy-leaved duckweed		*	*
Nuttall's waterweed	*		
Rigid hornwort	*	*	*
Whorled water milfoil		*	
Yellow water lily	*		

Buckenham was surveyed for the first time in 2004. Species richness has declined steadily between 2004, when there were nine species, and 2008, with the loss of three pondweed species. Filamentous algae is the overwhelmingly dominant plant and the abundance of all other species is very low. Changes in possible water quality are being considered as a reason for the decline in species and are subject to on-going investigation.

5.5.7 Hassingham Broad

	2006	2007	2008
Bristly stonewort	*	*	*
Common duckweed			*
Curled pondweed	*	*	*
Enteromorpha	*		
Fennel-leaved pondweed	*		
Filamentous algae	*	*	*
Fragile/Convergent stonewort	*	*	*
Ivy-leaved duckweed		*	*
Nuttall's waterweed		*	
Rigid hornwort	*	*	*

Hassingham Broad was also surveyed for the first time in 2004. Water clarity was generally much better in Hassingham compared to Buckenham, resulting in an apparently stable and exceptionally abundant stonewort population. The chara lawn in 2008 covered most of the open water and the water was crystal clear throughout.

5.6 Waveney Valley

There are six broads along the Waveney valley that lay within the Broads Authority executive area. These are Barnby, Spratt's Water, Woolner's Carr, Round Water, Flixton Decoy and Oulton Broad. Surveying and monitoring of these broads has been limited in the past, however restoration programmes are now being developed at some of these sites.

5.6.1 Barnby

	2006	2007
Filamentous algae		*
Rigid hornwort	*	*
Yellow water lily		*

Following mud pumping in winter 2006/07, the previously dominant Rigid Hornwort that was restricted to the deeper southern half of the Broad, had in the 2007 survey extended to all parts of the site. As has been observed previously at freshly mud pumped sites, filamentous algae was also frequent. No survey was conducted in 2008.

5.6.2 Flixton Decoy

	2006	2007
Common duckweed	*	*
Curled pondweed	*	*
Filamentous algae	*	*
Flat-stalked pondweed	*	*
Lesser pondweed		*
Nuttall's waterweed	*	*
Rigid hornwort	*	*
White water lily	*	*
Yellow water lily	*	*

This broad was sampled for the first time in 2006. The water was clear to the bottom and had very abundant growth of Nuttall's waterweed. Although occurring at low abundances, three other species of pondweed were also present. Rigid hornwort and filamentous algae were abundant. No survey was conducted in 2008.

5.6.3 Lound Lakes

2007	Hopton 1	Hopton 2	Hopton 3	Hopton 4	Mill Water
Arrowhead	*				
Australian swamp stonecrop		*	*	*	
Branched bur-reed					*
Canadian waterweed		*	*	*	*
Common water moss			*		
Curled pondweed	*	*	*		
Filamentous algae			*	*	
Intermediate water-starwort		*	*		
Ivy-leaved duckweed			*		
Mare's tail				*	

Nuttall's waterweed			*		
Pondweed sp.		*	*		
Smooth stonewort			*	*	
Starry stonewort	*	*	*	*	
Starwort sp.	*		*		
Unbranched bur-reed	*	*			*
White water lily	*				*
Yellow water lily	*	*	*	*	*

There is only one year of sampling data for the Lound Lakes, including Mill Water. As a group species richness was relatively high with good overall abundances, particularly of key species such as stoneworts and pondweeds. Individually Hopton 3 showed the greatest diversity of the four.

5.6.4 Spratt's Water

	2004	2008
Common duckweed	*	*
Enteromorpha	*	
Filamentous algae	*	
Ivy-leaved duckweed		*
Rigid hornwort	*	*

Water clarity was good and the plant community was dominated by the rigid hornwort in the water column and least duckweed on the surface.

5.6.5 Round Water

	2008
Common duckweed	*
Frogbit	*
Ivy-leaved duckweed	*
Least duckweed	*
Rigid hornwort	*

There is little that can be reported for Round water based on only one year's sampling. The 2008 survey found this small waterbody to be dominated by duckweeds. Beneath the dense mat of duckweed, pink/purple bacteria stained the water when disturbed. A brief visit onto Woolner's Carr was also carried out on the same day, but without establishing clear transect lines. The site was also heavily covered in duckweed.

5.7 Summary of the lakes surveys.

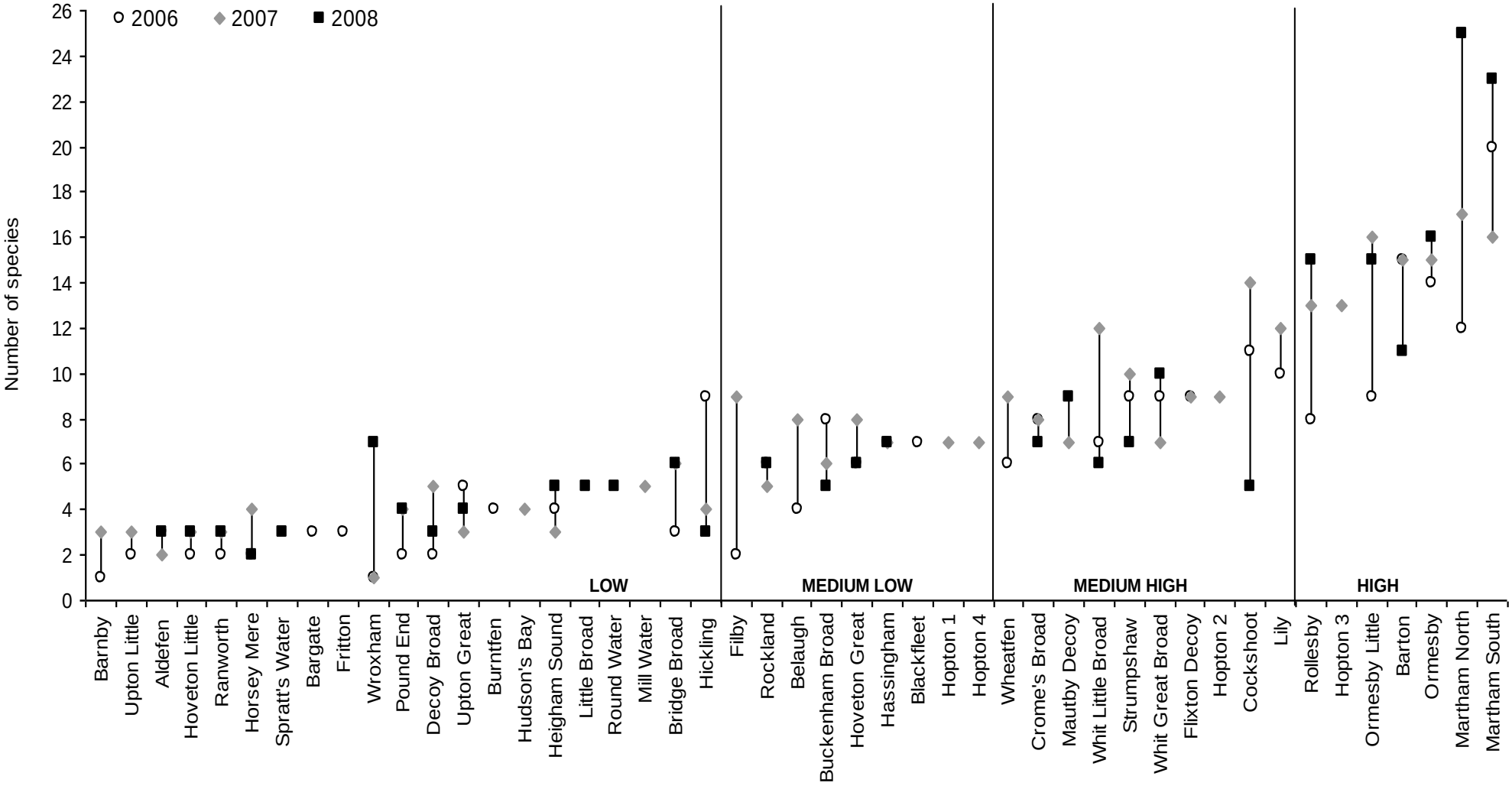
The number of broads sampled has increased from an average of 20 broads per year between 1983 and 2003, to over 30 per year from 2004 onwards, with previously un-surveyed broads now included.

Figure 1 shows the broads ranked according to their *average* species richness for 2006, 2007 & 2008. They were also categorised into low, medium low, medium high and high according to their species richness. The division between high and low species number is based on whether a broad has an average of eight or more species over the period. Sites with the greatest average species richness ('High') over the last three survey years have increased from four broads in 2006 to seven in 2008. Wroxham, Belaugh, Filby, Rollesby, Ormesby Little have all shown large increases in their species richness between 2006 and 2008 with latter three all moving up one classification level.

However within the same time frame Hickling and Cockshoot Broad suffered a significant loss of richness with Hickling being reclassified from 'medium high' in 2006 to 'low' richness in 2008. Declines in species recorded at Cockshoot Broad in the last two years has been due to the vigorous growth of holly-leaved naiad, which has become dominant. Buckenham and Whitlingham Little have also suffered obvious declines in the number of species recorded.

The broads with a low number of plant species remain the most numerous group. These broads are dominated by one or two vigorous species such as rigid hornwort or Nuttall's waterweed. Alderfen, Hickling, Upton Great and Upton Little were very species poor (two to three species recorded). Broads with low species number can have periods of relative stability and clear water, such as at Upton Great which is dominated by holly-leaved naiad. More often than not, the clear water periods are linked to the total plant abundance rather than the actual number of species.

Figure 1. Species richness by broad and year.
The broads are ranked based on their average species richness for 2006, 2007 & 2008 into low, medium low, medium high and high categories. The division of high and low species number is based on whether a broad has an average eight or more species over the period.



6 RIVER SURVEY MACROPHYTE RESULTS

6.1 Background

River macrophytes were previously surveyed in 1992, with the following stretches sampled; Dilham Canal (Honing Lock to Tonnage Bridge); River Waveney (Outney Common to Dunburgh Hill); River Wensum in Norwich (New Mills to Foundry Bridge); and the West Somerton channel (village staithe to first bend) (Kennison 1992). River surveys have again been repeated annually from 2005 to 2008 with slightly different stretches sampled to the 1992 surveys (Table 3). A rake-trawl method was used, similar to that used in the broads and abundances of individual species have been recorded on a similar five-point scale. For the individual river plant lists all the years that have been surveyed are listed e.g. the rivers Yare and Wensum have only been surveyed twice in 2005 and 2008.

Table 3 River stretches and dates sampled

River	Start point	End point	2005	2006	2007	2008
Ant	Honing Lock	Wayford Bridge	13-Sept	31-Aug	8-Sep	-
Bure	Horstead canal	Wroxham Bridge	-	6-Sept	7-Sep	28-Aug
Thurne	West Somerton staithe	Dungeon corner	9-Aug	7-Sept	6-Sep	4-Sep
Waveney	Geldeston Lock	Beccles New Bridge	14-Sept	-	12-Sep	5-Sep
Wensum	New Mills	Foundry Bridge	9-Aug	-	-	8-Sep
Yare	Carrow Bridge	Thorpe Rail Bridge	9-Oct	-	-	5-Sep

Of the river stretches, the Rivers Wensum and Yare contain relatively lower numbers of species (6 and 7 species respectively in 2007). Starworts, waterweeds, pondweeds and milfoils are all well represented with varying levels of abundances. It is a little early to be able to identify any temporal trends in the diversity or abundance of the river channel plant communities, though this analysis will be presented in next year's report.

6.1.1 River Ant

	2005	2006	2007
Amphibious bistort		*	
Arrowhead	*	*	*
Bladderwort		*	
Canadian waterweed	*	*	*
Common duckweed	*	*	*
Enteromorpha		*	
Fan-leaved water crowfoot	*	*	
Filamentous algae	*	*	*
Flowering rush		*	
Frogbit	*	*	*
Ivy-leaved duckweed	*	*	*
Lesser pondweed	*		
Nuttall's waterweed	*	*	*
Rigid hornwort		*	
Starwort sp.	*	*	*
Unbranched bur-reed	*	*	*
Water-soldier	*	*	*
Yellow water lily	*	*	*

6.1.2 River Bure

	2006	2007	2008
Arrowhead	*	*	*
Canadian waterweed			*
Common duckweed	*	*	*
Fan-leaved water crowfoot	*		*
Filamentous algae			*
Flowering rush	*		
Ivy-leaved duckweed	*	*	*
Nuttall's waterweed	*	*	*
Perfoliate pondweed	*	*	*
Pointed stonewort	*	*	*
Starwort sp.	*	*	*
Unbranched bur-reed	*	*	*
White water lily	*		
Yellow water lily	*	*	*

6.1.3 River Thurne

	2005	2006	2007	2008
Arrowhead	*	*	*	*
Canadian waterweed	*	*	*	*
Cladophora		*		
Clustered stonewort	*			
Common stonewort	*	*		*
Common water moss	*	*	*	*
Curled pondweed	*	*		*
Enteromorpha			*	
Fan-leaved water crowfoot	*	*	*	*
Fennel-leaved pondweed	*	*	*	*
Filamentous algae	*		*	*
Fragile stonewort				*
Holly-leaved naiad	*	*	*	*
Ivy-leaved duckweed	*	*	*	*
Mare's tail	*	*	*	*
Opposite stonewort	*			
Perfoliate pondweed	*	*	*	*
Rigid hornwort				*
Spiked water milfoil	*	*	*	*
Starry stonewort	*	*	*	*
Starwort sp.	*	*	*	*
Unbranched bur-reed	*	*	*	*
White water lily	*	*	*	*
Whorled water milfoil	*		*	*
Willow-leaved pondweed	*	*	*	*
Yellow water lily	*	*	*	*

6.1.4 River Waveney

	2005	2007	2008
Amphibious bistort		*	*
Arrowhead	*	*	*
Bulrush	*		
Common duckweed	*	*	*
Common water moss	*	*	*
Filamentous algae			*
Frogbit		*	
Greater duckweed	*		*
Inflated duckweed			*
Nuttall's waterweed	*	*	*
Perfoliate pondweed			*
Pointed stonewort			*
Rigid hornwort	*	*	*
Smooth stonewort	*		
Spiked water milfoil			*
Starwort sp.			*
Unbranched bur-reed	*	*	*
Water Fern	*		
Whorled water milfoil	*	*	*
Yellow water lily	*	*	*

6.1.5 River Wensum

	2005	2008
Arrowhead	*	*
Canadian waterweed	*	
Common duckweed	*	*
Common water moss	*	*
Fennel-leaved pondweed	*	
Nuttall's waterweed		*
Perfoliate pondweed	*	
Starwort sp.	*	
Unbranched bur-reed	*	*
Water fern	*	
Yellow water lily	*	*

6.1.6 River Yare

	2005	2008
Arrowhead	*	*
Common duckweed	*	*
Common water moss	*	
Fennel-leaved pondweed	*	
Nuttall's waterweed	*	*
Pointed stonewort		*
Starwort sp.	*	*
Unbranched bur-reed	*	*
Yellow water lily	*	*

6.2 River macrophyte diversity

The simplest measure of the character of a community that takes into account both abundance and species richness is Simpson's diversity index. The numerical value of this diversity index range is between 0 and 1 with the greater the value, the greater the sample diversity (Begon et al, 1996). Although the Simpson Index is an effective method of comparing the diversity of separate populations, it can be insensitive to subtle changes in abundance or presence of the less abundant species. However, it provides a helpful insight into the make-up of a river's plant community and provides an effective and simple way to compare the rivers surveyed.

The rivers were analysed by year (using Primer v.6, 2005) and the results alongside species richness are in Table 4.

Table 4 The number of species found each year in each river stretch surveyed and the corresponding Simpsons diversity index value (1-D).

	Species Richness				Simpson's Diversity Index				
	2005	2006	2007	2008		2005	2006	2007	2008
Ant	13	17	11		Ant	0.75	0.69	0.74	
Bure		12	9	12	Bure		0.47	0.41	0.51
Thurne	22	19	19	22	Thurne	0.80	0.72	0.74	0.73
Waveney	12		10	16	Waveney	0.69		0.25	0.66
Wensum	10			6	Wensum	0.55			0.52
Yare	8			7	Yare	0.72			0.48

In 2008 the rivers Yare and Wensum had low species richness. However, the river Yare in 2005 was only marginally less diverse than the Ant and Thurne with the Wensum and Waveney being markedly lower. In 2007 the Ant and the Thurne had identical diversity index values even though the Thurne was recorded as having 8 more species. Even with possible poor under-recording in 2008 in the Wensum and Yare surveys their diversity was still comparable to that of the Bure. The river Wensum in 2007 recorded a poor diversity index with low abundances of the species surveyed even though species richness has remained fairly stable.

6.3 Summary of River Survey results

There is insufficient data to assess the stability of the plant communities and identify potential changes in abundance. However, these surveys have provided good characterisation of macrophyte communities in these stretches. The upper River Thurne channel is the most species diverse river stretch sampled. This reflects the good water quality there and also the proximity to the Martham Broads, which themselves have a high number of species present.

7 HYDROACOUSTIC PLANT SURVEY.

Hydroacoustic Survey Results for Water Plants in Rollesby Broad (July 2008)

7.1 Introduction

Hydroacoustics is a general term for the study and application of sound in water. Hydroacoustics, utilising sonar technology, is commonly used for detection, assessment, and monitoring of underwater physical and biological objects. Boat-mounted hydroacoustic equipment can be utilised to detect the depth of a water body (bathymetry), as well as the presence or absence, abundance, distribution and size of underwater plants.

Such survey equipment measures the range to an object and its relative size by producing a pulse of sound and measuring the time it takes for an echo to return from the object and the amplitude of the returned echo. The range is calculated as a function of the speed of sound and the time it takes for the echo to return.

7.2 Rollesby Broad Survey

On 3rd July 2008,the regular transect routes of the Broads Authority Annual Water Plant Survey were followed. This comprised transects A to M, giving a total distance of 2263 m travelled. The area surveyed, using the mean water depth recorded of 1.62 m, equated to 633 m^2. Given the 26.14 ha area of open water in Rollesby, this survey occupied 0.002 % of the total open water area.

The equipment used in this survey included a BioSonics DT-X, single beam (10 º), 420 KHz transducer, with an onboard control unit and operating laptop. All data recorded whilst mobile on the waterbody was georeferenced through connection to an external GPS system. This allowed subsequent quantitative analysis of the data using Sonar5-Pro post-processing software, developed specifically with a vegetation analysis component.

7.3 Data Analysis

Using the Sonar5-Pro software, the sediment surface of each transect file was identified, as well as the quieter return derived from the upper surface of the water plants. Each transect was divided into 10 m sections for ease of analysis and to provide workable units within which to generate values for the bathymetric and water plant parameters recorded. These were water depth (to sediment surface); plant height; area inhabited by plants; total volume of plants; and percent volume inhabited (by plants) or PVI. Only features taller than 5 cm above the inferred sediment surface were recorded as water plants to reduce the likelihood of recording false positive results.

7.4 Results

Figure 2 shows the full signal response detected at the transducer after processing. The black line represents the sediment surface, from which water depth and other calculations were derived. The red line is the upper surface of the water plants. Figure 3 shows this more clearly with noise and return echos removed.

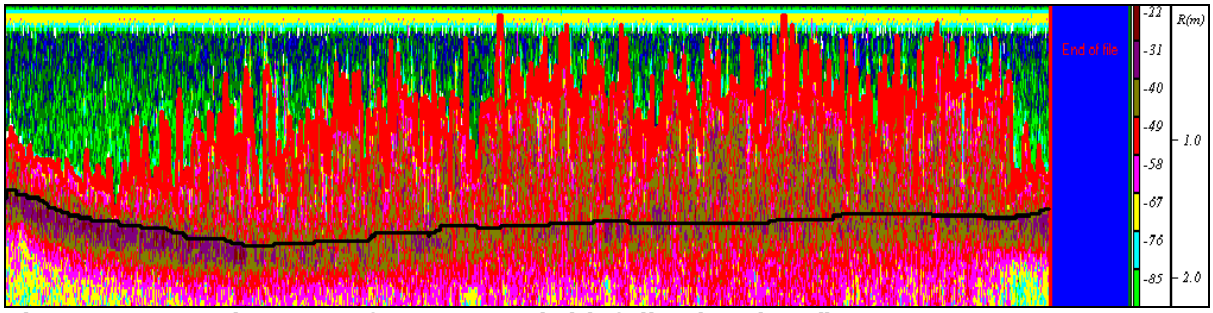


Figure 2 Echogram of transect D (with full echo signal)

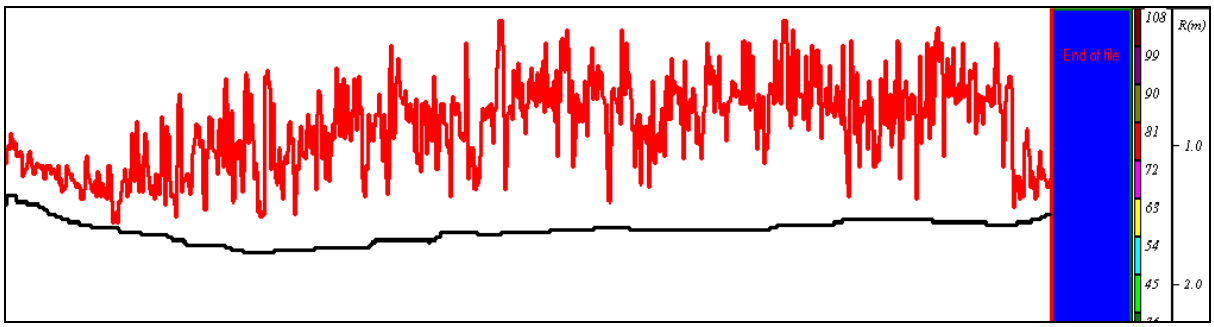


Figure 3 Echogram of transect D (sediment and plant signal only)

Transect D for example had just under 100 % area coverage by water plants. Results for the whole survey are summarised in Table 5.

Table 5 Hydroacoustic survey results from Rollesby Broad July 2008

	Rollesby Broad
Mean water depth (m)	1.62
Min. water depth (m)	0.36
Max. water depth (m)	2.50
Mean plant height (m)	0.75
Max. plant height (m)	1.89
Area inhabited by plants (%)	95.0
Mean Percent Volume Inhabited (PVI) (%)	44.8

7.5 Conclusions

Further work to develop a routine field method to calibrate the hydroacoustic signal response to the actual soft sediment surface is needed. High variability in the composition and density of Broads sediments means site specific calibration is required. Further work to verify the threshold height during post-processing of data (5 cm in this report) is also required to increase accuracy and reproducibility in the water plant signals analysed.

Overall the survey method is very fast and simple to collect data and is therefore cost effective in the longer term. The quantitative data produced is of high quality, well beyond the capability of traditional rake surveys in determining area of bed covered, plant height and PVI. The equipment can collect data even in turbid water when SCUBA surveys would be very difficult and in any waterbody with sufficient water depth (min. 30 cm).

8 GENERAL DISCUSSION

The Broad's annual macrophyte survey is the longest time series and most complete macrophyte data set for a series of shallow lakes in the UK. The methodology used is simple, low tech and easy to replicate both spatially and temporally. The results clearly show changes in plant species richness and abundance and it is a rapid way of assessing the ecological status of lakes. It is important that this data set is maintained through regular monitoring to inform the managers and scientists of ecological health and restoration progress or necessity thereof.

It is planned that the key broads remain surveyed on an annual basis, with a rolling programme of sampling other sites to gain maximum coverage. The survey outputs are used to:

- Inform the impact of restoration efforts
- Continue the long-term change data set
- Monitor macrophyte recovery
- Inform waterspace management plans
- Inform the Water Framework Directive target setting at a National and European level

The Rivers and Broads Strategy (RaBS) database incorporates scores for the status of broads based on their macrophyte populations. These scores combine the abundance and richness of macrophytes. This scoring system classifies the broads into four groups (Table 6). Lakes with high macrophyte abundance (plant cover) and richness score 1 and those with low abundances and low richness score 4. The cut-off value between low and high abundance is based on whether the broad scores greater or less than 0.5 for the sum of all species mean % cover. The cut-off for high and low diversity is arbitrary, but the mid-point of 7.5 is usually greater than the average number of species per broad.

Table 6 Macrophyte scores (diversity) for broads based on abundance and number of species

Score	Total transect score abundance	Number of species
4	Low abundance	< 7.5 species
3	Low abundance	> 7.5 species
2	High abundance	< 7.5 species
1	High abundance	> 7.5 species

In both abundance and species richness scores macro-algae are included and although indicative of a favourable underwater light climate, 100% cover of filamentous algae may not be seen as an ecologically desirable plant population. Examples of lakes that had high scores for filamentous algae are Buckenham and Crome's broads. Table 7 shows the diversity of the broads surveyed in 2008 based on plant abundance and richness.

Table 7 Diversity for broads sampled in 2008.

Low Abundance		High Abundance	
Low Richness	**High Richness**	**Low Richness**	**High Richness**
4	**3**	**2**	**1**
Hickling Hoveton Little Broad Horsey Mere Ranworth Broad		Alderfen Bridge Broad Buckenham Broad Decoy Broad Hassingham Broad Heigham Sound Hoveton Great Broad Little Broad* Pound End Rockland Broad Round Water* Sprat's Water* Strumpshaw Broad Upton Great Broad Whitlingham Little Wroxham Broad	Barton Cockshoot Broad Crome's Broad Martham Broad North Martham Broad South Mautby Decoy* Ormesby Broad Ormesby Little Broad Rollesby Broad Whitlingham Great

*no recent survey to compare any changes to group.

The scoring gives the largest group of broads (53% of those surveyed) as those with high abundance but low species richness (Group 2). Of the sixteen broads in Group 2 four were classed in Group 1 in 2006, with an equal number showing a move up from Groups 3 or 4. Species richness within Group 2 varied widely in 2008, for example Horsey Mere only contained two species mare's tail and spiked water milfoil whereas Cockshoot Broad, Crome's Broad, Hassingham Broad and Strumpshaw Broad all had 7 species.

Group 4 continues to be mainly comprised of the Bure broads. Wroxham Broad stands out within Group 4 having 7 species of plants compared to the more typical 3 or 4 found in the other broads within the group. No broads fell into Group 3 in 2008.

Trends of improvement, stability or decline in macrophyte populations over the last five years within the most regularly surveyed broads are summarised in Table 8.

Table 8 Trend in abundance of macrophytes over last 5 years. Abundances are listed as either stable (S) or Fluctuating (F).

Improving	With abundant macrophytes	Without abundant macrophytes	Declining
Barton Belaugh Crome's Filby Hoveton Great Lilly Martham North Martham South Ormesby Ormesby Little Pound End Rollesby	Cockshoot (S)	Alderfen (S) Horsey (S) Rockland (F) Ranworth (F) Upton (F)	Hickling

Wroxham			
67%[a]	4%[a]	25%[a]	4%[a]

[a] percentage that each group makes of the total number of broads sampled in 2008

It is evident from this report that much more restoration work is required to improve the condition of the shallow lakes in Broadland to a more favourable ecological status. The majority of broads surveyed were classified in the highest two groups for macrophyte diversity. Where lake restoration efforts such as sediment removal and biomanipulation have been undertaken, lake ecological condition has steadily improved. There are also early signs that continued phosphorus reduction from sewage treatment works discharges has benefited macrophytes, especially in the more upstream broads, like Belaugh and Barton. This positive response demonstrates the measurable benefit of lake restoration and management.

Some of the permanent water bodies in Broadland have not been surveyed for macrophytes. It is hoped that future extension of the monitoring programme to all water bodies will enable assessment of the status of the open water in the Broads. This, in turn, will inform the integrated management of the total open water resource in Broadland.

9 ACKNOWLEDGEMENTS

The Broads Authority wishes to thank all those individuals and organisations who assisted during the 2007 and 2008 survey season by providing their time, boats identification or permissions. In no particular order they were: Jane Harris, George Taylor, Mr. & Mrs. R. Starling, Jennifer Johnson, Tim Strudwick, Alasdair Fraser, John Blackburn, Derek Pye, Hoveton Hall estate, Mrs. Cooper, Rick Southwood, Elaine Green, Seaton Rowley, Jo Cullum, Mr. & Mrs J. Nickerson, the many Broads Authority staff and volunteers, Edward Knowles, Tobi Baker, Stephen Prowse, John Buxton, Michael Trafford, David Nobbs, David Griffin, How Hill Trust and staff from the Trinity Broads and Fritton Lake Partnership. The survey would not have been conducted without the assistance from these people and their respective organisations which include: Norfolk Wildlife Trust, Natural England, National Trust, RSPB, Fleggburgh & Billockby Poors Trust, Horsey Estate, F. & A. George Ltd, Whitlingham Charitable Trust, Environment Agency, the Somerleyton Estate, the Ted Ellis Trust, Essex & Suffolk Water and Suffolk Wildlife Trust.

10 REFERENCES

Begon M, Harper JL, Townsend CR (1996) Ecology individuals populations and communities. Blackwell, Oxford.

Boorman, Fuller and Boar (1979) Recent changes in the distribution of reedswamp in

Broadland. Final Report on Project No 605. Institute of Terrestrial Ecology, Colney Research Station Norwich.

Kelly, A. (2003) Broads Annual Macrophyte Monitoring Report 2003. Broads Authority report.

Kennison, G.C.B. (1992) Aquatic macrophyte surveys of the Norfolk Broads 1992. Broads Authority report.

Kennison, G.C.B., Dunsford, D.S. & Schutten, J. (1998) Stable or changing lakes? A classification of aquatic macrophyte assemblages from a eutrophic shallow lake system in the United Kingdom. *Aquatic Conservation : Marine & Freshwater Ecosystems*, 8 669-684.

Dunsford, D. (1995) Aquatic macrophyte surveys of the Norfolk Broads (1995) Broads Authority report.

Harris, J. (2003) Hickling Broad aquatic plant cutting and monitoring programme. Unpublished report to the Broads Authority, Norwich

Harris, J. (2003) SCUBA survey of Barton Broad exclosures 2003. Unpublished report to the Broads Authority, Norwich

Hoare, D. (2002) Upper Thurne Water Quality Monitoring Report**.** Unpublished report to the Environment Agency, Norwich

Moss, B., Madgwick, J. & Phillips. G. (1996) Guide to the restoration of nutrient-enriched shallow lakes. Broads Authority, Environment Agency and EU LIFE programme, Norwich.

Natural England (2006) Condition of SSSI units. Database compiled 01/11/06. http://www.englishnature.org.uk/special/sssi/reportAction.cfm?Report=sdrt13&Category=CF &Reference=1028. Database accessed 27/11/06.

Perrow, M and Tomlinson, M. L., (2003) Extent and status of the designated features in the Trinity Broads (Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation and hard oligo-mesotrophic waters with benthic vegetation of Chara sp). Unpublished report to the Broads Authority, Norwich

PRIMER-E Ltd (2005). Plymouth Routines In Multivariate Ecological Research. Plymouth Marine Laboratory, Plymouth

Schutten, J. (2001) Macrophyte development in the Trinity Broads: a statistical analysis of aquatic macrophyte monitoring data 1997-2000. Unpublished report to the Broads Authority, Norwich

Stewart, N.F. and Church, J.M. (1992) Red Data Book of Britain and Ireland: Stoneworts, The Joint Nature Conservation Committee, Peterborough.

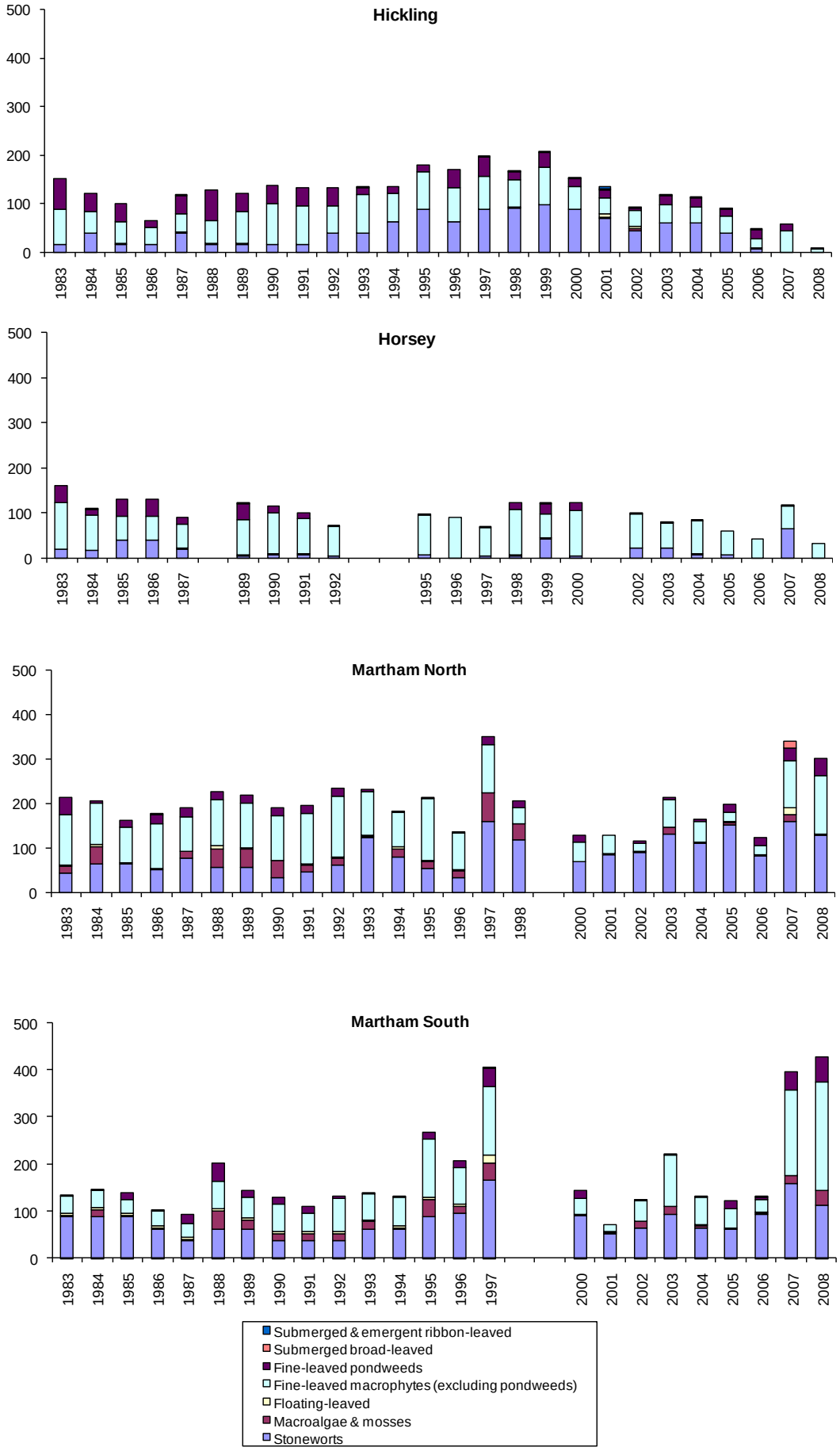
11 APPENDICIES.

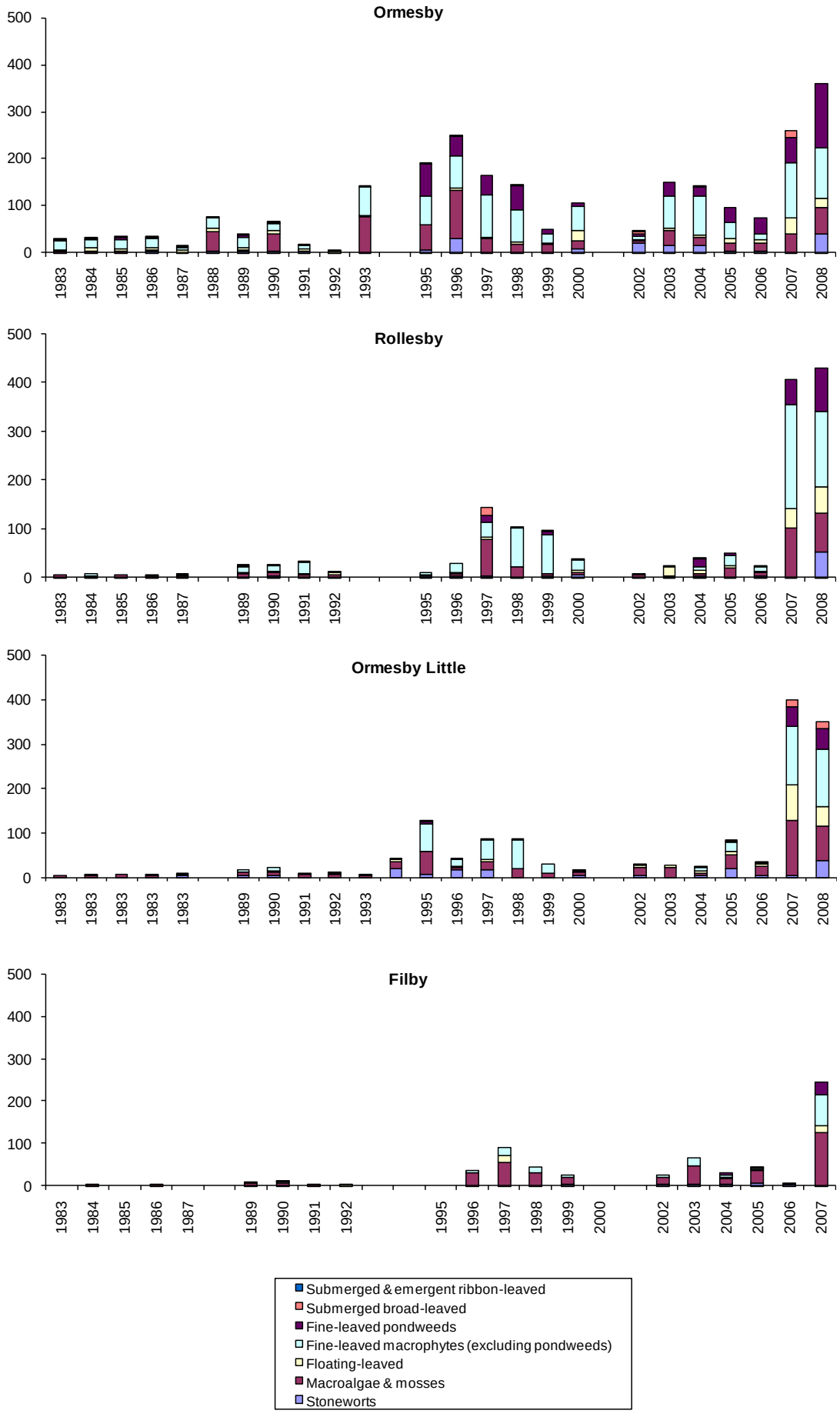
Appendix 1. Macrophyte groupings based on physical form.
Appendix 2. Long term macrophyte abundance trends (1983 – 2008)
Appendix 3a & b. Plant common and Latin names.

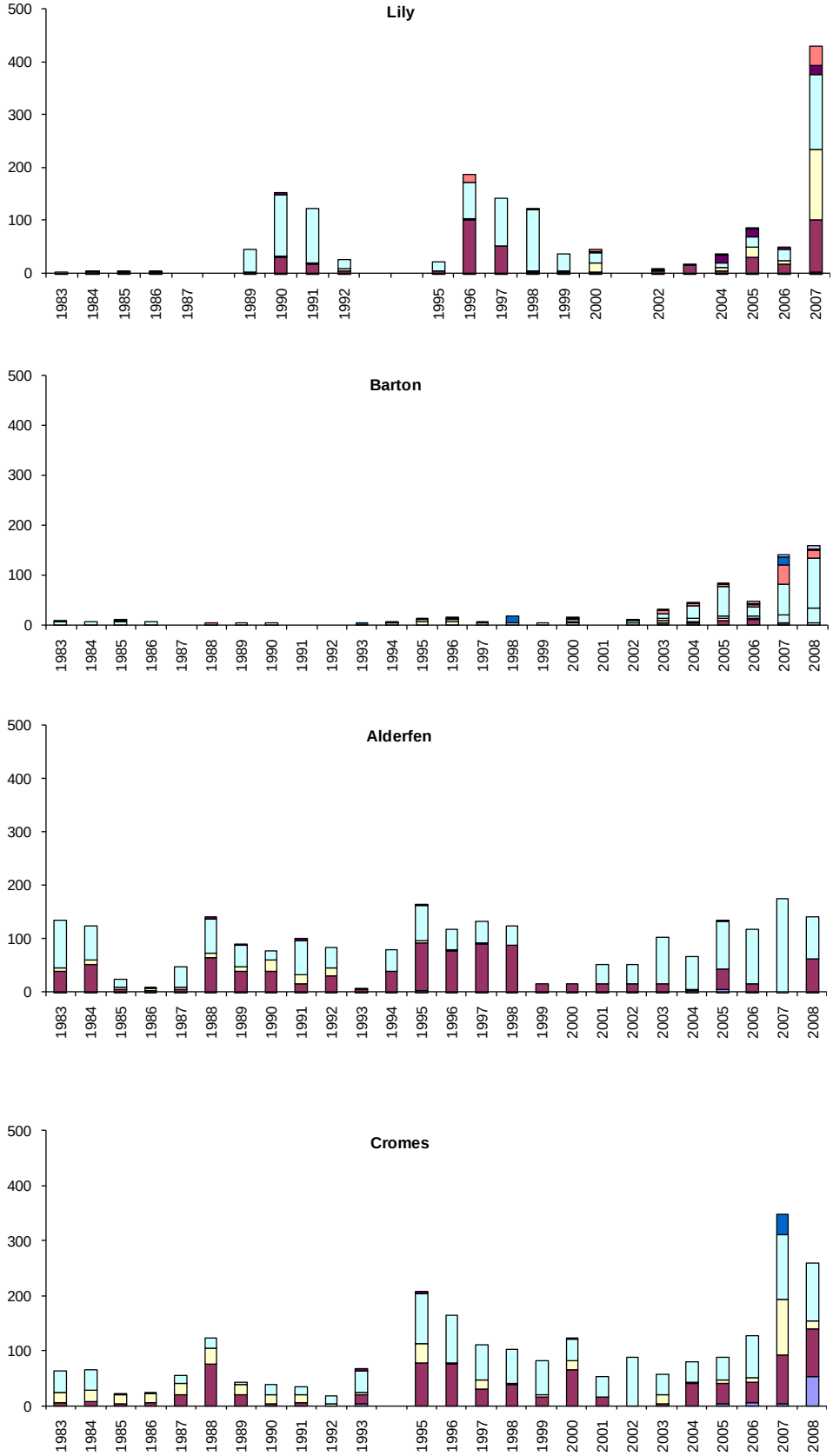
11.1 Appendix 1. Macrophyte groupings based on form

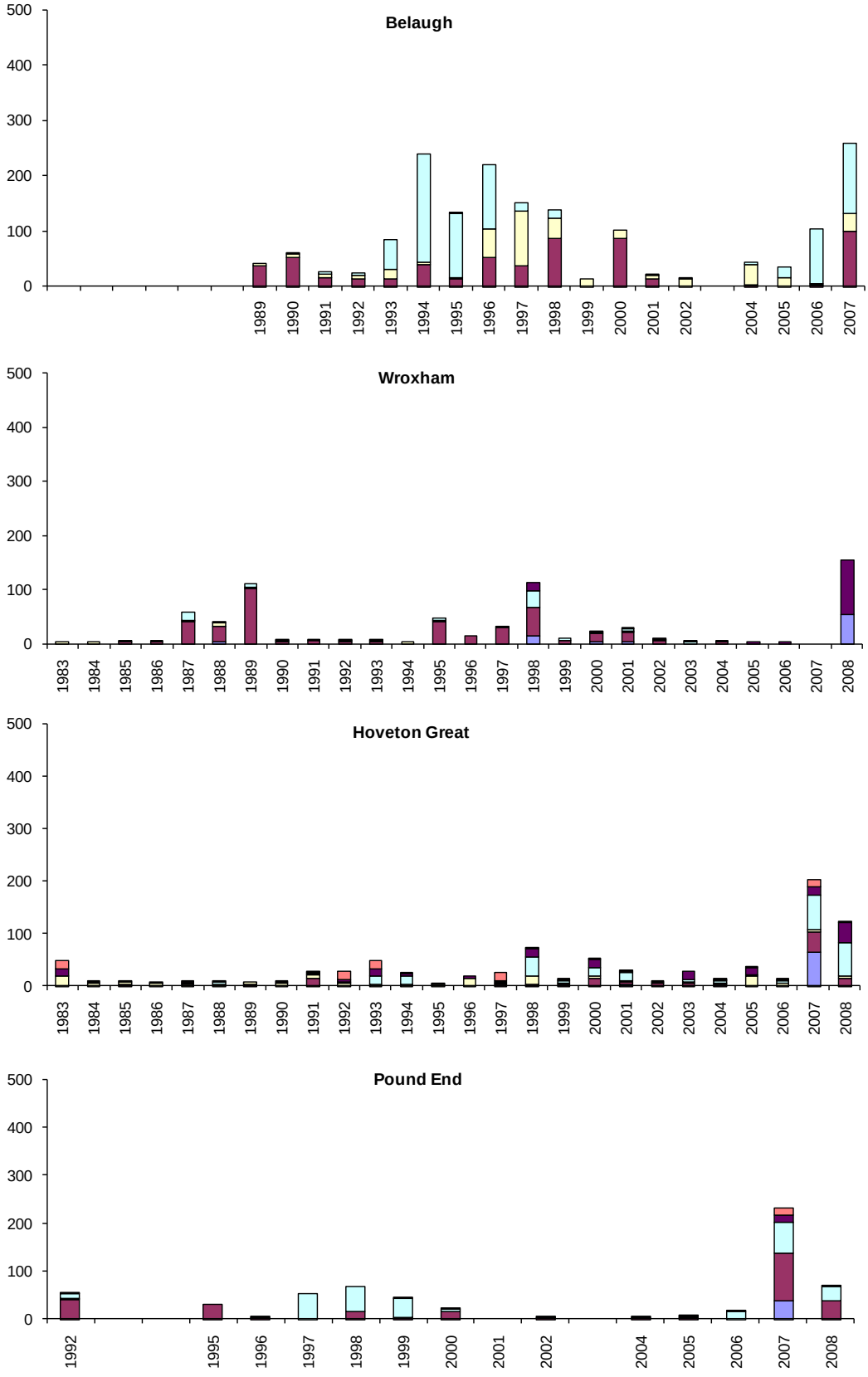
Submerged fine-leaved pondweeds	**Free-floating or round floating-leaved**	**Submerged fine-leaved macrophytes (excluding pondweeds)**	**Stoneworts**	**Long submerged, emergent, floating ribbon leaves**
Blunt-leaved pondweed Fennel-leaved pondweed Flat-stalked pondweed Hair like pondweed Horned pondweed Lesser pondweed Sharp-leaved pondweed Small pondweed	Amphibious bistort Common duckweed Frogbit Greater duckweed Inflated duckweed Ivy-leaved duckweed Least duckweed White water lily Yellow water lily	Greater bladderwort Canadian waterweed Crowfoot sp. Fan-leaved water crowfoot Floating club-rush Holly-leaved naiad Mare's tail Nuttall's waterweed Rigid hornwort Spiked water milfoil Starwort sp. Australian swamp stonecrop Whorled water milfoil	Baltic stonewort Bristly stonewort Common stonewort Convergent stonewort Delicate stonewort Fragile stonewort Hedgehog stonewort Intermediate stonewort Lesser bearded stonewort Opposite stonewort Pointed stonewort Rough stonewort Smooth stonewort Starry stonewort Translucent stonewort	Arrowhead Branched bur-reed Bulrush Common reed Greater reedmace Lesser reedmace Reed sweet grass Sweet flag Unbranched bur-reed Water cress Water-soldier
Submerged broad-leaved pondweeds	**Macro-algae and mosses**			
Broad –leaved pondweed Curled pondweed Perfoliate pondweed Shining Pondweed Willow-leaved pondweed	*Enteromorpha* Common water moss Filamentous algae Stringy moss Water net			

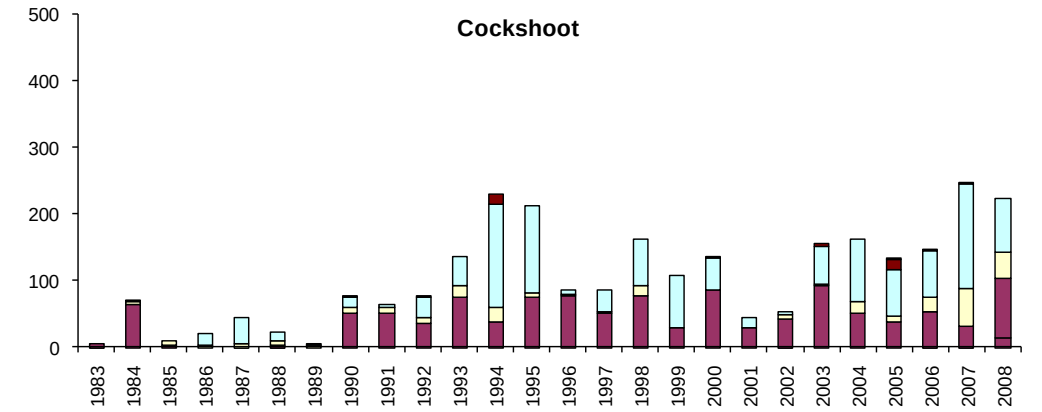
11.2 Appendix 2. Macrophyte abundance trends (1983 – 2008)

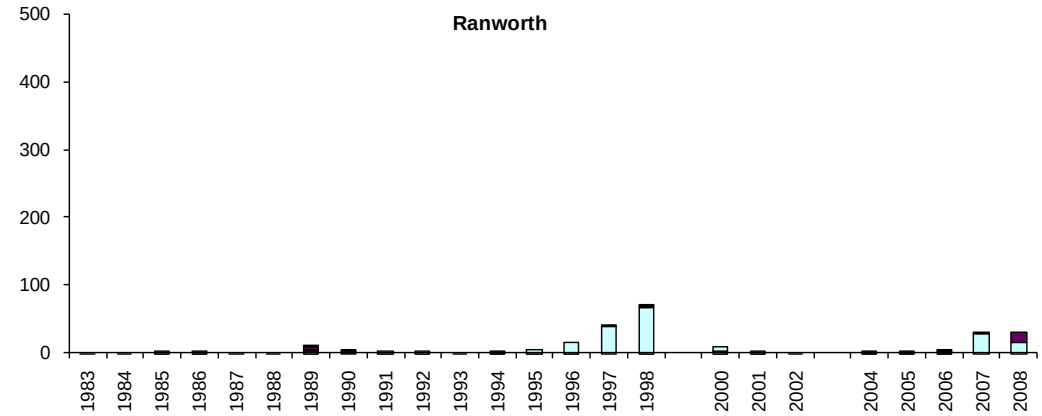


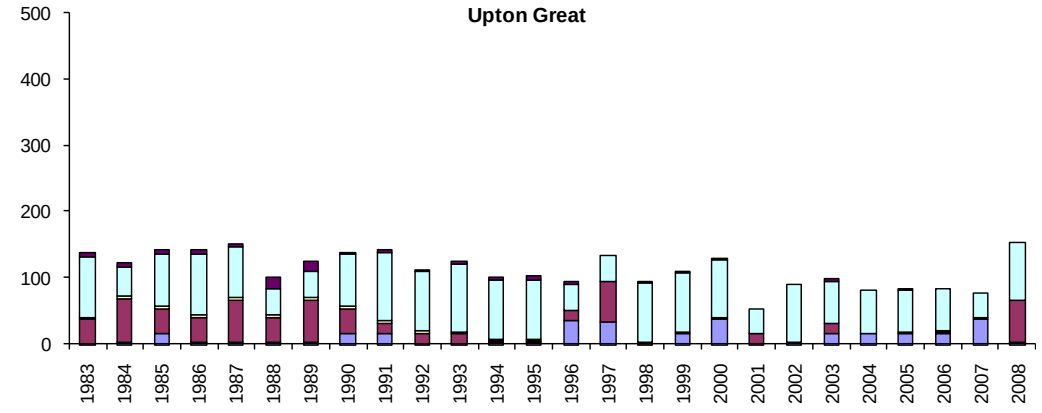

Ormesby
Rollesby
Ormesby Little
Filby
500
400
300
200
100
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1995
1996
1997
1998
1999
2000
2002
2003
2004
2005
2006
2007
2008
Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
Fine-leaved macrophytes (excluding pondweeds)
Floating-leaved
Macroalgae & mosses
Stoneworts

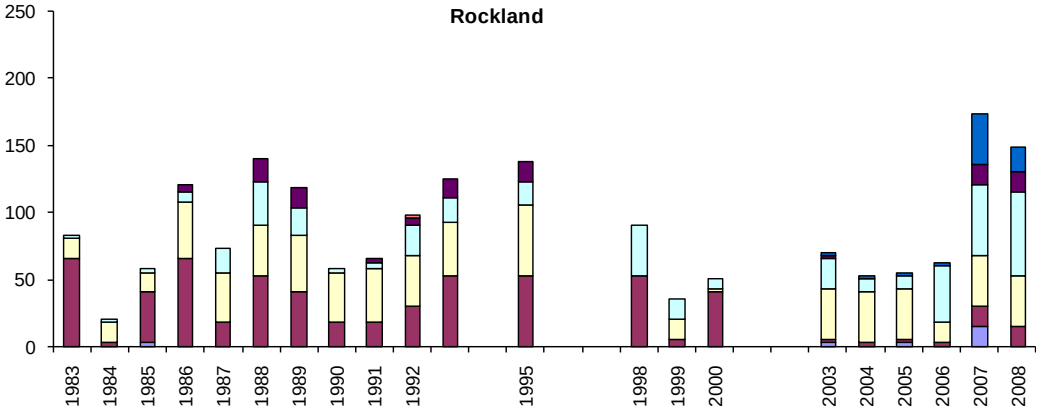

Lily
Barton
Alderfen
Cromes
0
100
200
300
400
500
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
Fine-leaved macrophytes (excluding pondweeds)
Floating-leaved
Macroalgae & mosses
Stoneworts

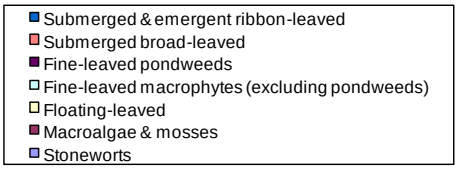

Belaugh
Wroxham
Hoveton Great
Pound End
Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
Fine-leaved macrophytes (excluding pondweeds)
Floating-leaved
Macroalgae & mosses
Stoneworts


Cockshoot
500
400
300
200
100
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008


Ranworth
500
400
300
200
100
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 2000 2001 2002 2004 2005 2006 2007 2008


Upton Great
500
400
300
200
100
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008


Rockland
250
200
150
100
50
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1995 1998 1999 2000 2003 2004 2005 2006 2007 2008


Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
Fine-leaved macrophytes (excluding pondweeds)
Floating-leaved
Macroalgae & mosses
Stoneworts

11.3 Appendix 3a. Latin to Common plant names.

Latin	Common
Acorus calamus	Sweet flag
Alisma plantago-aquatica	Common water-plantain
Chara aculeolata	Hedgehog stonewort
Callitriche stagnalis	Intermediate water-starwort
Callitriche sp	Starwort sp.
Ceratophyllum demersum	Rigid hornwort
Chara pedunculata	Hedgehog stonewort
Chara aspera	Rough stonewort
Chara baltica	Baltic stonewort
Chara connivens	Convergent stonewort
Chara contraria	Opposite stonewort
Chara curta	Lesser bearded stonewort
Chara globularis/connivens	Fragile/convergent stonewort
Chara globularis	Fragile stonewort
Chara hispida	Bristly stonewort
Chara intermedia	Intermediate stonewort
Chara sp.	Stonewort *(Chara)* species
Chara virgata	Delicate stonewort
Chara vulgaris	Common stonewort
Crassula helmsii	Swamp stonecrop
Elodea canadensis	Canadian waterweed
Eleogiton fluitans	Floating club-rush
Elodea nutalli	Nuttall's waterweed
Enteromorpha	*Enteromorpha*
Filamentous algae	Filamentous algae
Fontinalis antipyretica	Common water moss
Glyceria maxima	Reed sweet grass
Hippuris vulgaris	Mare's tail
Hydrocharis morsus-ranae	Frogbit
Hydrodictyon	Water net
Lemna gibba	Inflated duckweed
Lemna minor	Common duckweed
Lemna minuta	Least duckweed
Lemna trisulca	Ivy-leaved duckweed
Leptodictyum riparium	Stringy moss
Myriophyllum spicatum	Spiked water milfoil
Myriophyllum verticillatum	Whorled water milfoil
Najas marina	Holly-leaved naiad
Nitella flexilis	Smooth stonewort
Nitella mucronata	Pointed stonewort
Nitellopsis obtusa	Starry stonewort
Nitella translucens	Translucent stonewort
Nitella sp.	Stonewort *(Nitella)* species
Nuphar lutea	Yellow water lily
Nymphaea alba	White water lily
Persicaria amphibia	Amphibious bistort
Potamogeton acutifolius	Sharp-leaved pondweed
Potamogeton berchtoldii	Small pondweed
Potamogeton crsipus	Curled pondweed
Potamogeton friesii	Flat-stalked pondweed
Potamogeton lucens	Shining pondweed
Potamogeton natans	Broad –leaved pondweed
Potamogeton obtusifolius	Blunt-leaved pondweed
Potamogeton pectinatus	Fennel-leaved pondweed
Potamogeton perfoliatus	Perfoliate pondweed
Potamogeton pusillus	Lesser pondweed
Potamogeton x salicifolius	Willow-leaved pondweed
Potamogeton sp.	Pondweed sp.
Potamogeton trichoides	Hair like pondweed
Phragmites australis	Common reed
Ranunculus circinatus	Fan-leaved water crowfoot
Ranunculus fluitans	River water crowfoot
Ranunculus sp.	Crowfoot sp.
Rorippa nasturtium-aquaticum	Water cress
Saggitaria sagittifolia	Arrowhead
Schoenoplectus lacustris	Bulrush
Sparganium emersum	Unbranched bur-reed
Sparganium erectum	Branched bur-reed
Spirodela polyrhiza	Greater duckweed
Stratiotes aloides	Water-soldier
Typha angustifolia	Lesser reedmace
Typha latifollia	Greater reedmace
Utricularia vulgaris	Bladderwort
Veronica catenata	Pink water speedwell
Zanichellia palustris	Horned pondweed

11.4 Appendix 3b. Common to Latin plant names.

Common	*Latin*
Amphibious bistort	*Persicaria amphibia*
Arrowhead	*Saggitaria sagittifolia*
Baltic stonewort	*Chara baltica*
Bladderwort	*Utricularia vulgaris*
Blunt-leaved pondweed	*Potamogeton obtusifolius*
Branched bur-reed	*Sparganium erectum*
Bristly stonewort	*Chara hispida*
Broad –leaved pondweed	*Potamogeton natans*
Bulrush	*Schoenoplectus lacustris*
Canadian waterweed	*Elodea canadensis*
Common duckweed	*Lemna minor*
Common reed	*Phragmites australis*
Common stonewort	*Chara vulgaris*
Common water moss	*Fontinalis antipyretica*
Common water-plantain	*Alisma plantago-aquatica*
Convergent stonewort	*Chara connivens*
Crowfoot sp.	*Ranunculus sp.*
Curled pondweed	*Potamogeton crispus*
Delicate stonewort	*Chara virgata*
Enteromorpha	*Enteromorpha*
Fan-leaved water crowfoot	*Ranunculus circinatus*
Fennel-leaved pondweed	*Potamogeton pectinatus*
Filamentous algae	*Filamentous algae*
Flat-stalked pondweed	*Potamogeton friesii*
Floating club-rush	*Eleogiton fluitans*
Fragile stonewort	*Chara globularis*
Fragile/convergent stonewort	*Chara globularis/connivens*
Frogbit	*Hydrocharis morsus-ranae*
Greater duckweed	*Spirodela polyrhiza*
Greater reedmace	*Typha latifollia*
Hair like pondweed	*Potamogeton trichoides*
Hedgehog stonewort	*Chara aculeolata/pedunculata*
Holly-leaved naiad	*Najas marina*
Horned pondweed	*Zanichellia palustris*
Inflated duckweed	*Lemna gibba*
Intermediate stonewort	*Chara intermedia*
Intermediate water-starwort	*Callitriche stagnalis*
Ivy-leaved duckweed	*Lemna trisulca*
Least duckweed	*Lemna minuta*
Lesser bearded stonewort	*Chara curta*
Lesser pondweed	*Potamogeton pusillus*
Lesser reedmace	*Typha angustifolia*
Mare's tail	*Hippuris vulgaris*
Nuttall's waterweed	*Elodea nutalli*
Opposite stonewort	*Chara contraria*
Perfoliate pondweed	*Potamogeton perfoliatus*
Pink water speedwell	*Veronica catenata*
Pointed stonewort	*Nitella mucronata*
Pondweed sp.	*Potamogeton sp.*
Reed sweet grass	*Glyceria maxima*

Common	*Latin*
Rigid hornwort	*Ceratophyllum demersum*
River water crowfoot	*Ranunculus fluitans*
Rough stonewort	*Chara aspera*
Sharp-leaved pondweed	*Potamogeton acutifolius*
Shining pondweed	*Potamogeton lucens*
Small pondweed	*Potamogeton berchtoldii*
Smooth stonewort	*Nitella flexilis*
Spiked water milfoil	*Myriophyllum spicatum*
Starry stonewort	*Nitellopsis obtusa*
Starwort sp.	*Callitriche sp*
Stonewort *(Chara)* species	*Chara sp.*
Stonewort *(Nitella)* species	*Nitella sp.*
Stringy moss	*Leptodictyum riparium*
Swamp stonecrop	*Crassula helmsii*
Sweet flag	*Acorus calamus*
Translucent stonewort	*Nitella translucens*
Unbranched bur-reed	*Sparganium emersum*
Water cress	*Rorippa nasturtium-aquaticum*
Water net	*Hydrodictyon*
Water-soldier	*Stratiotes aloides*
White water lily	*Nymphaea alba*
Whorled water milfoil	*Myriophyllum verticillatum*
Willow-leaved pondweed	*Potamogeton x salicifolius*
Yellow water lily	*Nuphar lutea*