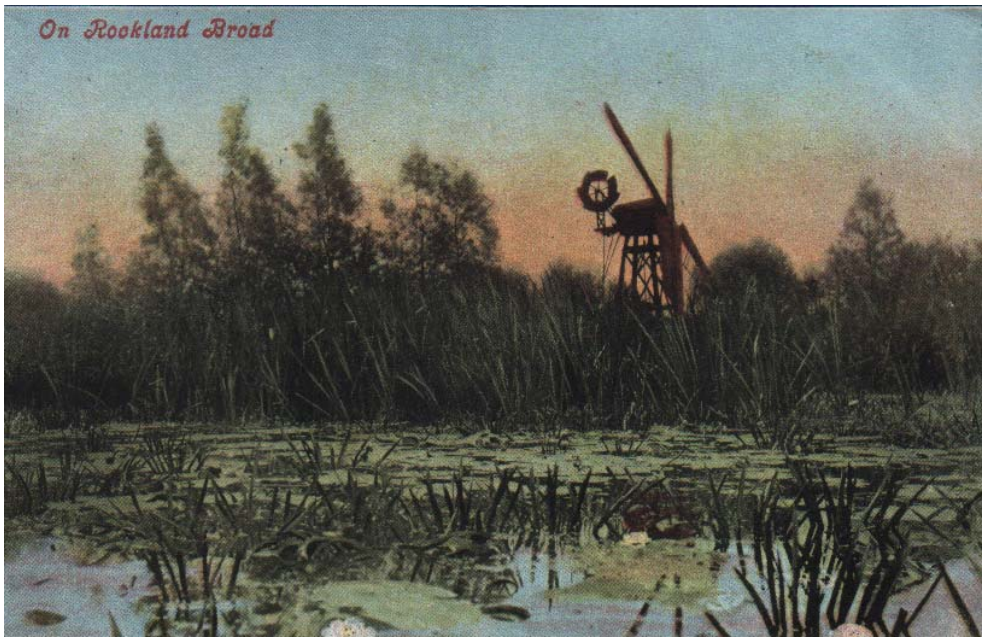
Broads Annual Water Plant Monitoring Report 2006



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The front cover image is an old postcard depicting water soldiers in Rockland Broad.

1 EXECUTIVE SUMMARY

A total of 38 broads and 5 river stretches 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.

Key results from the 2006 survey can be summarised as: -

- Hickling Broad and Horsey Mere had the lowest abundance of stonewort species and the rare holly-leaved naiad since the annual survey began
- Belaugh Broad on the River Bure had clear water and abundant plant growth to the water surface, which has not been observed previously, however, the rest of the broads connected to the River Bure remain in a turbid state with low water plant growth. Wroxham Broad is currently declining in terms of its water plants
- Clear water conditions with abundant plant growth were observed in the isolated broads subject to restoration work at Alderfen, Cromes and Cockshoot
- Barton Broad continues to recover in terms of the number of species present and their abundance across a wider area of the broad.

Surveys of various river stretches have now also been incorporated into the annual routine. This provides valuable data on the biological response to the various on-going Broads-wide nutrient reduction schemes and also to the very different stresses faced by water plants in rivers compared to within the broads themselves.

Data from the Broads annual survey is the longest time series and most complete water plant data set for shallow lakes in the UK. Wider use of this data includes increasing the knowledge of the driving mechanisms behind water plant distributions through our partnerships with university research groups. Students are actively involved with the water plant data through analysis focussing on historical trends and the impacts of nutrients.

The greater number of individual waterbodies surveyed this year has been due to extra staff resource funded from DEFRA's grant 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 measures are set to become increasingly important, as compliance with the EU Water Framework Directive (WFD) will be based on ecological indicators of ecosystem health, which includes assessment of water plant populations. The water plant surveys inform ways in which PSA delivery 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 initiated. The detection of invasive alien plant species within the Broads is also important function of the annual survey if the risks posed by these plants is to be effectively managed.

From the results of the 2006 survey just over 50% of the broads visited had degraded water plant populations. These sites are characterised by a low abundance of water plants, a condition that is not expected within a healthy shallow lake. Some successes in lake restoration have been made, especially in isolated broads, and these are duly congratulated. However much work remains to be done across the Broads to bring degraded broads back to health, in line with national and EU drivers. The annual water plant survey therefore continues to be an important part of targeting and measuring the success of such efforts.

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 rarities. 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. Currently over 60% of SSSI fresh waterbodies in the Broads (> 80% by area) have been evaluated as being in an unfavourable or declining ecological condition. The major threat to water quality in the Broads has been identified as arising from nutrient inputs, which is exacerbated by heavy water abstraction from the catchments, which can reduce the amount of flushing (Natural England 2006). These effects, in combination with each other, increase the overall nutrient content of water, which can then lead to eutrophication and subsequent negative ecological consequences. The chemical and physical changes observed in the Broads have been reflected by a shift to water plant communities with low species diversity. When plant growth in these low diversity lakes does increase, it is often only a few vigorous and competitive species that become numerous, rather than a range of co-existing species.

Water plants i.e., submerged, floating or emergent macrophytes, are an essential part of the ecology of shallow lakes in Broadland. Water bodies with low aquatic macrophyte cover (abundance) offer little refuge for aquatic life and tend to contain generalist faunal species that are capable of existing in these simple unstructured habitats. As macrophyte abundance and diversity increases, so other aquatic communities respond by diversifying, filling additional available niches.

2.1 Legislative Framework and Delivery

The importance of good quality open water habitats is recognised 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 plants. Where waterbodies are protected under the European Habitats Directive, the recognised features include 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. This goal has been given a recent boost in the Broads area, as three DEFRA funded Catchment Sensitive Farming (CSF) officers are working in the Broads catchments over the next two years. Alongside these officers, there are two catchment officers employed in partnership with the Broads Authority in the Trinity Broads and Lound catchments. The CSF initiative is aimed at improving farm practices and reducing water pollution from agriculture. These newly appointed advisers will work on a one to one basis with farmers, as well as leading a series of initiatives including workshops and farm demonstrations to encourage best practice.

Biodiversity Action Plans for habitats and species also recognise the importance of water plant communities and species in lake systems. 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.

2.2 Restoration

The restoration process for shallow lakes follows several stages. It generally starts by identifying the cause of the problem, then, if required, by lowering the nutrient status of the water body via catchment controls or sediment dredging. Biomanipulation (removal of certain fish species to promote clear water) often follows, which aims to aid the re-establishment of water plants. Water plants are key to 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, a shift in fish community from zooplanktivorous dominated (fish that can eat zooplankton) to piscivore dominated (fish that can eat other fish); and nutrient uptake. Water plants are thus a key indicator of the ecological health of shallow lakes.

The Broads Authority, in conjunction with Environment Agency, 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 a number of 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 23 years. The work has been predominantly carried out by Broads Authority Conservation Officers and contracted surveyors. Eighteen key sites have been regularly (minimum of 18 years worth of data), if not consistently surveyed since 1983, these are Alderfen, Barton, Cockshoot, Cromes, Hickling, Horsey, Hoveton Great, the Marthams, Ranworth, Rockland, Upton Great, Wroxham and the five Trinity broads.

During the surveys in 2004-6 monitoring involved partner organisations such as Norfolk Wildlife Trust, Natural England, Environment Agency, Ted Ellis Trust and the National Trust in the data collection process. Staff from these organisations received training in monitoring and macrophyte species identification. This approach worked well and it is expected that it will be repeated in future years.

3 AIMS AND OBJECTIVES

The aim of the Broads annual survey is to monitor water plants within specified broads, along previously defined transects during late July and to 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 objective is to monitor key broads, which have had restoration measures put in place or those that are experiencing a change in their macrophyte community. Other broads, that are not receiving restoration efforts; 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, which collated and analysed data from 1983 - 2003 (Kelly 2004) and will examine the long-term data from 1983 to 2006. This report also includes a brief description of the river survey data collected in 2005 and 2006.

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.

Relative 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.

5 BROADS WATER PLANT SURVEY RESULTS

5.1 All Broads

35, 33 and 38 broads were surveyed in 2004, 2005 and 2006 respectively. The dates surveyed and number of species is presented in Table 1. Table 2 shows the frequency of annual sampling at each broad over the last 23 years.

Table 1 Sampling dates and total transect length per broad (2004-2006)

Broad	Date sampled			Total transect length		
	2004	2005	2006	2004	2005	2006
Alderfen	17-Sep	15-Aug	17-Aug	754	994	887
Bargate	16-Sep	-	30-Aug	458	-	821
Barnby	31-Aug	23-Aug	-	303	359	353
Barton	2-Sep	5-Aug	26-Jul	5582	4779	5410
Belaugh	16-Aug	12-Aug	8-Aug	257	335	326
Blackfleet	-	-	16-Aug	-	-	337
Bridge	16-Aug	12-Aug	8-Aug	239	434	380
Buckenham	28-Jul	21-Jul	18-Jul	244	268	315
Burntfen	-	-	19-Jul	-	-	545
Catfield	1-Sep	-	-	322	-	-
Cockshoot	11-Aug	16-Aug	10-Aug	896	1165	1144
Cromes	21-Sep	23-Aug	17-Aug	952	1163	1029
Decoy	11-Aug	25-Aug	9-Aug	660	1704	1342
Filby	27-Aug	1-Sep	24-Aug	1870	3128	3089
Flixton Decoy	-	-	19-Jul	-	-	829
Fritton	-	-	11-Aug	-	-	3931
Hassingham	28-Jul	21-Jul	18-Jul	339	267	184
Heigham Sound	-	4-Aug	2-Aug	-	2730	2414
Hickling	4-Aug	3-Aug	1-Aug	7935	9325	8923
Horsey	5-Aug	9-Aug	3-Aug	3024	3432	3495
Hoveton Great	10-Aug	19-Aug	10-Aug	2609	2896	3294
Hoveton Little	17-Aug	11-Aug	9-Aug	2127	2243	2429
Irstead Holmes	1-Sep	-	-	113	-	-
Lily	26-Aug	31-Aug	23-Aug	785	1035	1027
Little	-	24-Aug	-	-	390	-
Martham North	8-Sep	2-Aug	27-Jul	895	867	852
Martham South	8-Sep	2-Aug	27-Jul	782	709	760
Norton's	19-Sep	-	-	112	-	-
Ormesby	23-Aug	30-Aug	22-Aug	4745	4648	4447
Ormesby Little	27-Aug	31-Aug	24-Aug	2929	3554	3336
Pound End	17-Aug	11-Aug	9-Aug	425	547	492
Ranworth	6-Sep	17-Aug	15-Aug	3104	4745	4576
Reedham Water	1-Sep	-	-	422	-	-
Rockland	10-Sep	15-Sep	30-Aug	1693	1602	1609
Rollesby	26-Aug	31-Aug	23-Aug	1583	2535	2401
Salhouse Great	17-Aug	11-Aug	8-Aug	545	763	880
Spratt's Water	31-Aug	-	-	62	-	-
Strumpshaw	-	25-Aug	18-Jul	-	475	328
Upton Great	6-Sep	17-Aug	15-Aug	942	1063	1024
Upton Little	-	17-Aug	15-Aug	-	217	202
Wheatfen	10-Sep	-	29-Aug	594	-	644
Whitligham Great	12-Aug	8-Sep	31-Aug	2879	3112	2825
Whitlingham Little	-	8-Sep	31-Aug	-	686	681
Wroxham	16-Aug	12-Aug	8-Aug	1532	1709	1856

Table 2 Sites surveyed for water plants (1983-2006)

Broad	Years sampled	Year																							
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Alderfen	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Bargate	2																						■		■
Barnby	3																						■	■	■
Barton	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Belaugh	17							■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■
Blackfleet	3	■		■																					■
Bridge	10														■	■	■	■	■	■	■		■	■	■
Buckenham	3																						■	■	■
Burntfen	3																■					■			■
Catfield	1																						■		
Cockshoot	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cromes	23	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■
Decoy	5				■												■						■	■	■
Filby	20	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■
Flixton Decoy	1																								■
Fritton Lake	1																								■
Hassingham	3																						■	■	■
Heigham Sound	16	■	■	■	■	■	■	■	■	■	■	■	■		■	■								■	■
Hickling	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Horsey Mere	20	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■
Hoveton Great	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Hoveton Little	11							■						■	■	■	■	■	■	■			■	■	■
Hudson's Bay	6	■	■	■		■		■							■										
Irstead	1																						■		
Lily	20	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■
Little	1																							■	
Malthouse	6													■	■		■		■	■	■				
Martham North	23	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■
Martham South	22	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■
Norton	1																						■		
Ormesby	21	■	■	■	■	■		■	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■
Ormesby Little	21	■	■	■	■	■		■	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■
Pound End	12										■	■		■	■	■	■	■	■	■	■		■	■	■
Ranworth	22	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■		■	■	■
Reedham Water	1																						■		
Rockland	18	■	■	■	■	■	■	■	■	■	■			■			■	■	■			■	■	■	■
Rollesby	20	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■	■	■	■	■
Salhouse Great	12				■	■								■	■	■	■	■	■	■			■	■	■
Salhouse Little	6					■				■				■	■	■	■							■	■
Spratts Water	1																						■		
Strumpshaw	3																■								
Upton Great	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Upton Little	2																							■	■
Wheatfen	3																■						■		
Whitlingham Great	4																					■	■	■	■
Whitlingham Little	2																							■	■
Wroxham	24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Total no. sites 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**

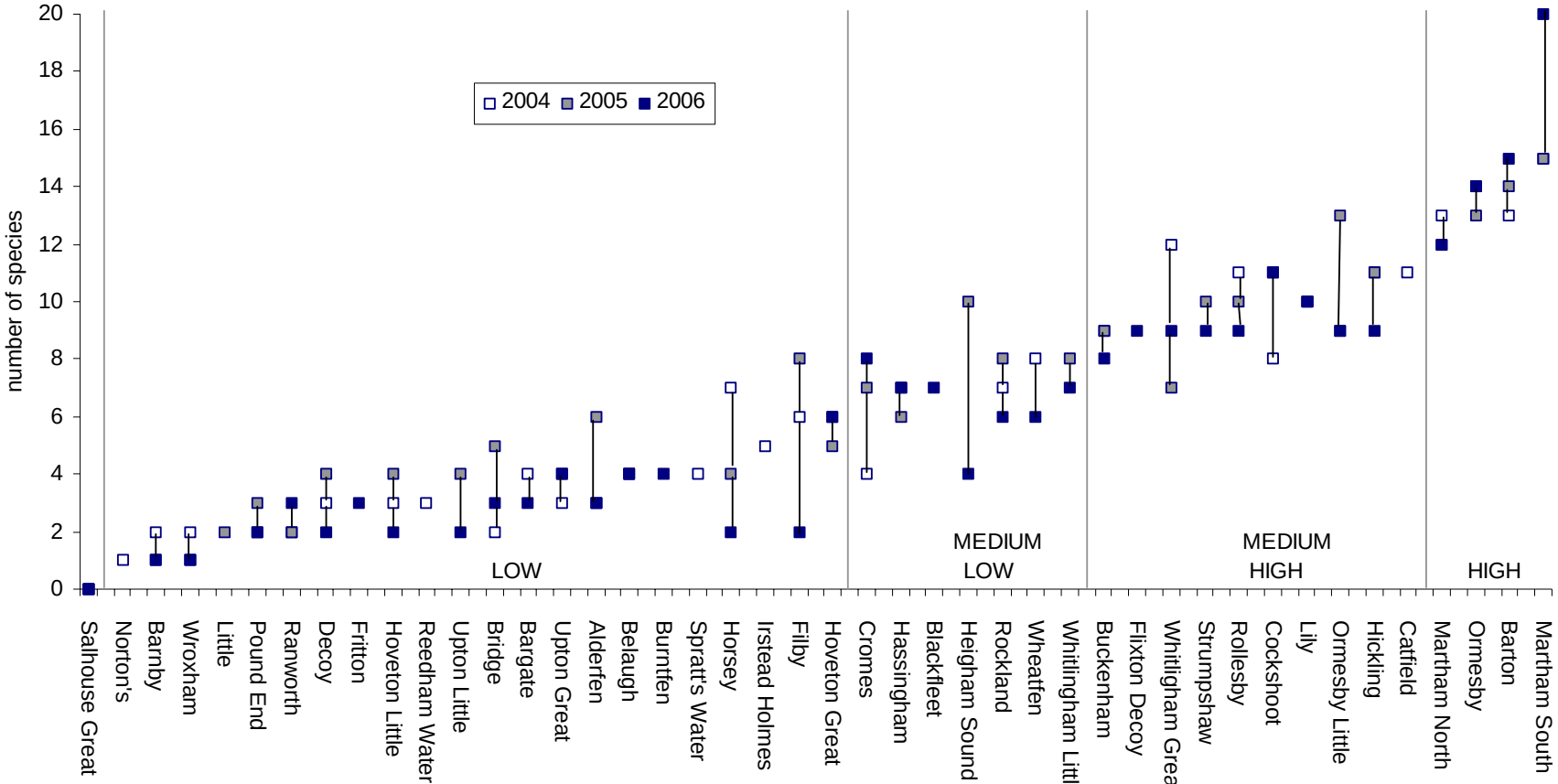

Figure 1 Water plant species diversity recorded at each broad

The number of broads sampled during has increased from an average of 20 broads per year from 1983 – 2003, to over 30 per year from 2004 onwards, with previously un-surveyed broads now included. Sites with the greatest species richness from 2004 to 2006 were Martham South, Barton, Ormesby and Martham North (see Figure 1). The division of high and low species number is based on whether a broad has eight or more species present in any one year. This figure has been derived through previous analysis of the distribution of species data between broads and will be discussed again further when considering the grouping of broads with similar water plant growth. The medium high diversity group of broads includes Hickling, Rollesby, Ormesby Little and Lily. Flixton Decoy was sampled for the first time in 2006 and was found to contain several pondweed species and had clear water.

The presence of several water plant species within a broad is a good indicator that the lake is functioning well in terms of its ecology. Such diversity affords resilience and seasonal stability to a lake, as individual species have their peak in abundance at slightly different times through the growing season, providing a prolonged period of plant cover for other aquatic organisms. The broads with a low number of plant species are however the most numerous group. These broads are often dominated by one or two vigorous species such as rigid hornwort or Nuttall's pondweed, which can rapidly expand, making efficient use of the nutrient resources available. Whilst these broads with low species number may have periods of relative stability and clear water, such conditions generally do not last long. More often than not, the clear water periods are linked to the abundance, or amount of plants, rather than the actual number of species. For instance, during 2006 both Alderfen and Belaugh Broads exhibited very low species number, three and four respectively, but at the time of sampling both broads had clear water to the bottom of the water column. In both sites there was luxuriant plant growth, mainly rigid hornwort, to the water surface. Therefore the analysis of the historical aquatic plant survey data (Figures 1 –20 in the Appendix) will concentrate upon the relative abundances of species, to account for the variation in the amount present, both between years and between sites.

For simplicity water plant species have been split into leaf form categories commonly associated with wetlands in the UK; submerged fine-leaved, broad-leaved, free-floating, algae and mosses, stoneworts and long submerged, emergent or floating ribbon leaved plants (Table 3). Species represented by these groups in the broads were made up of the following 58 species or taxa. The figures in the Appendix are based on these species groups. The abundance values represent the macrophyte percentage cover calculated from the rake scores and the transect length sampled. As macrophyte abundance is scored in a class range, the mid-point of the range is taken, for example where the score was 50-75% of the rake the score used for the graphs was 62.5%. It must be noted that the total score is a result of summing individual plant scores, thus lakes with more species are more likely have higher total scores. In Figures 2-21 in the Appendix, all years where transects were taken have the year labelled along the bottom axis of each graph. Where no survey was conducted, no year is displayed. For simplicity, only the eighteen sites that have the longest data sets (as listed in section 2.3) are displayed, with the addition of Belaugh and Pound End, where restoration work has been carried out.

Table 3 Groups of water plant species

Submerged fine-leaved pondweeds	Free-floating or round floating-leaved	Submerged fine-leaved macrophytes excluding pondweeds)	Stoneworts	Long submerged, emergent, floating ribbon leaves
Small pondweed *Potamogeton berchtoldii* **Flat-stalked pondweed** *Potamogeton friesii* **Blunt-leaved pondweed** *Potamogeton obtusifolius* **Fennel-leaved Pondweed** *Potamogeton pectinatus* **Lesser pondweed** *Potamogeton pusillus* **Hair like pondweed** *Potamogeton trichoides* **Horned pondweed** *Zanichellia palustris*	**Frogbit** *Hydrocharis morsus-ranae* **Least duckweed** *Lemna minor/minuta* **Ivy-leaved duckweed** *Lemna trisulca* **Yellow water lily** *Nuphar lutea* **White water lily** *Nymphaea alba*)	**Starwort** *Callitriche* sp. **Rigid hornwort** *Ceratophyllum demersum* **Floating club-rush** *Eleogiton fluitan*s **Canadian pondweed** *Elodea canadensis* **Nuttall's pondweed** *Elodea nutalli* **Mares tail** *Hippuris vulgaris* **Spiked water milfoil** *Myriophyllum spicatum* **Whorled water milfoil** *Myriophyllum verticillatum* **Holly-leaved naiad** *Najas marina*) **Fan-leaved water crowfoot** *Ranunculus circinatus* **River water crowfoot** *Ranunculus fluitans* **Bladderwort** *Utricularia vulgaris*	**Rough stonewort** *Chara aspera* **Baltic stonewort** *Chara baltica* **Convergent stonewort** *Chara connivens* **Lesser bearded stonewort** *Chara curta* **Fragile stonewort** *Chara globularis* **Opposite stonewort** *Chara contraria* **Bristly stonewort** *Chara hispida* **Intermediate stonewort** *Chara intermedia* **Hedgehog stonewort** *Chara pedunculata* **Delicate stonewort** *Chara virgata* **Common stonewort** *Chara vulgaris* **Pointed stonewort** *Nitella mucronata* **Starry stonewort** *Nitellopsis obtusa* **Smooth stonewort** *Nitella flexilis*	**Sweet flag** *Acorus calamus* **Reed sweet grass** *Glyceria maxima* **Common reed** *Phragmites australis* **Water cress** *Rorippa nasturtium-aquaticum* **Arrowhead** *Saggitaria sagittifolia* **Bulrush** *Schoenoplectus lacustris* **Unbranched bur-reed** *Sparganium emersum* **Lesser reedmace** *Typha angustifolia* **Greater reedmace** *Typha latifollia*
Submerged broad leaved pondweeds	**Macro-algae and mosses**			
Curled pondweed *Potamogeton cripus* **Shining Pondweed** *Potamogeton lucens* **Broad –leaved pondweed** *Potamogeton natans* **Perfoliate pondweed** *Potamogeton perfoliatus*	***Enteromorpha*** **Filamentous algae** **Common water moss** *Fontinalis antipyretica* **Water net** *Hydrodictyon*			

5.2 Thurne Valley

These are the 'jewel in the crown' of the shallow lakes within the Norfolk and Suffolk Broads. All broads, Hickling, Horsey, Marthams and Heigham Sound support both a high diversity of species and a number of rarities. These broads provide a home to the richest population of stoneworts in the UK. A total of 16 species have been recorded in the Broads themselves, five of which are on the list of high conservation importance plants and have Biodiversity Action Plans attached. 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 organisations. Stoneworts are recorded in some broads outside of the Thurne, but in much lower abundance and their presence is often only transitory. Species present in the Thurne broads which were included in the Joint Nature Conservation Committee (JNCC) Red Data Book included, three 'Vulnerable' species: Baltic stonewort, Convergent stonewort, Starry stonewort, one 'Insufficiently known': Lesser-bearded stonewort, one 'Rare': Intermediate stonewort (Stewart and Church, 1992). The Red Data Book species are those whose continued existence is threatened. The Thurne broads also provide a stronghold for the rare holly-leaved naiad (a BAP species) as well as more common vascular plants such as spiked water milfoil and mares tail. This association of plants is unique to the Upper Thurne Broads and not found elsewhere in the broads.

5.2.1 Hickling

Species list 2004: Rough stonewort, Baltic stonewort, Convergent stonewort, Intermediate stonewort, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Curled pondweed, Fennel-leaved pondweed, Lesser pondweed

Species list 2005: Rigid hornwort, Rough stonewort, Baltic stonewort, Convergent stonewort, Intermediate stonewort, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Curled pondweed, Fennel-leaved pondweed

Species list 2006: Rough stonewort, Common water moss, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Curled pondweed, Fennel-leaved pondweed, Lesser pondweed

From when monitoring began in 1983 (Figure 2) the submerged macrophytes in Hickling Broad consisted of a community dominated by a few common vascular plant species and lower abundances of the rare Holly-leaved naiad and stonewort species. In the early nineties the submerged fine-leaved macrophytes (Table 3) dominated by Spiked water milfoil and stoneworts began to increase in abundance. By the mid-nineties the Spiked water milfoil had reached peak abundance and stonewort species were becoming more important.

Evidence from the SCUBA survey (Harris, 2003) commissioned by the Broads Authority from 1994 onwards, showed this transition from vascular plants to stoneworts more clearly than the present survey method, as the SCUBA survey accounted for volume of the water column occupied.

During the late-nineties peak stonewort abundance was recorded in 1998 and 1999, with *Intermediate stonewort* dominating this group. This was combined with clear water conditions (Appropriate Assessment Team Report, 1999). In addition, submerged fine-leaved macrophytes became less important compared to the mid-nineties and with the reversion to the turbid water state in 2000 all macrophytes declined apart from the filamentous algae, which increased slightly.

The 2003 transect data showed a slightly higher abundance of stoneworts and fine-leaved macrophytes; this is supported by a full SCUBA survey of Hickling Broad (Harris, 2003). This brief recovery of stonewort abundance did not last, as within the 2006 transect data only sparse Rough stonewort was present, with complete loss of Intermediate stonewort and Baltic stonewort. Only one small fragment of holly-leaved naiad was found, but pondweeds and Mare's tail were still present. The loss of the dense lawns of Intermediate stonewort from the whole of Hickling Broad has meant that turbid water conditions were present during 2006 and reduced abundance, or loss, of all other macrophyte species.

The margin of Hickling broad is reed-swamp with some areas of emergent vegetation forming reed-swamp and some areas of hover (floating reed). Bird grazing, from mainly feral greylag geese, is one of the factors that have contributed to loss of reed in some areas of the Broad. Protective fences have been installed in two areas of the lake and are proving effective at preventing grazing.

5.2.2 Horsey

Species list 2004: Baltic stonewort, Intermediate stonewort, Filamentous algae, Mare's tail, Spiked water milfoil, Fennel-leaved pondweed, Perfoliate pondweed

Species list 2005: Baltic stonewort, Convergent stonewort, Mare's tail, Spiked water milfoil

Species list 2006: Mare's tail, Spiked water milfoil

There has been a gradual decline in macrophyte species diversity and abundance since 2002. The abundance of Spiked water milfoil has remained relatively constant over the last 3 years, but the number of other macrophyte species present in Horsey has declined. The 2006 survey showed an absence of stonewort species, which was a pattern also observed in Hickling Broad.

5.3 Martham North and South

The Martham Broads have been characterised by sustained clear water conditions. This clear water relies on a plentiful supply of good quality water draining from the northeast of the broads. This was demonstrated in 2000 when water quality in the Martham Broads rapidly deteriorated as a result of the failure of Somerton South IDB drainage pump. This led to a lack of flushing allowing phosphorus concentration to increase in the water, as well as a higher than normal algal concentration (Hoare, 2002). During 2002 and 2003, when the pump was working again, the Martham Broads had the most species-rich beds of abundant submerged macrophytes within the broads system, providing a food supply and a undisturbed refuge for winter and summer wildfowl. In the more recent period, 2004 – 2006, Martham South has consistently been the most species diverse site, with Martham North also of similar quality.

5.3.1 Martham North

Species list 2004: Baltic stonewort, Convergent stonewort, Bristly stonewort, Intermediate stonewort, Canadian pondweed, filamentous algae, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Fennel-leaved pondweed, Lesser pondweed, Horned pondweed

Species list 2005: Baltic stonewort, Bristly stonewort, Intermediate stonewort, filamentous algae, Common water moss, Mare's tail, Ivy-leaved Duckweed, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Fennel-leaved pondweed, Lesser pondweed

Species list 2006: Baltic stonewort, Bristly stonewort, Intermediate stonewort, Common stonewort, filamentous algae, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Fennel-leaved pondweed, Lesser pondweed, Fan-leaved water crowfoot, Horned pondweed

The macrophyte species assemblage in Martham North has been dominated by up to seven species of stonewort and Holly-leaved naiad since the survey began in 1983 (Figure 4). 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.

5.3.2 Martham South

Species list 2004: Starwort, Rough stonewort, Baltic stonewort, Convergent stonewort, Bristly stonewort, Intermediate stonewort, Hedgehog stonewort, Enteromorpha, filamentous algae, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Yellow water lily, Fennel-leaved pondweed

Species list 2005: Starwort, Rough stonewort, Convergent stonewort, Bristly stonewort, Intermediate stonewort, Hedgehog stonewort, filamentous algae, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Fennel-leaved pondweed, Lesser pondweed, Fan-leaved water crowfoot, Horned pondweed

Species list 2006: Callictriche sp., Rough stonewort, Baltic stonewort, Convergent stonewort, Bristly stonewort, Intermediate stonewort, Hedgehog stonewort, Common stonewort, Canadian pondweed, filamentous algae, Mare's tail, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Yellow water lily, Curled pondweed, Fennel-leaved pondweed, Small pondweed, Fan-leaved water crowfoot, Horned pondweed

In Martham South stoneworts have been recorded since 1983 (Figure 5), with nine species recorded since 2000. From 1983 to 1996 plant assemblage and abundance was relatively constant. In 1997 and 2000 abundance of all species, apart from filamentous algae increased. This increase 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. Unfortunately no survey was carried out at Martham South in 1998 or 1999. Recent surveys have shown that Bristly stonewort has remained

dominant, with Holly-leaved naiad and Starry stonewort also featuring regularly across the broad.

The margins of the Martham Broads consist of reed-swamp. A number of factors have caused the loss of reed-swamp in some areas of the Broads. Protective fences have been installed to prevent loss of reed-swamp by grazing feral geese and to safeguard reed islands that separate and screen the river from the lakes.

5.3.3 Heigham Sound

Species list 2005: Callictriche sp., Rigid hornwort, Canadian pondweed, Mare's tail, Spiked water milfoil, Starry stonewort, Yellow water lily, Curled pondweed, Fennel-leaved pondweed, Fan-leaved water crowfoot

Species list 2006: Mare's tail, Spiked water milfoil, Yellow water lily, and Curled pondweed

This waterbody was most recently surveyed in 2005 and 2006 after a seven-year hiatus that followed previously uninterrupted sampling between 1983 and 1997. This gap was caused by the greater effort required to sample the neighbouring Hickling Broad during the charophyte-dominated period between 1997 and 2003. During 2005 ten macrophyte species were found in Heigham Sound, with Mare's tail and Spiked water milfoil dominant. However in 2006 only four macrophyte species were found, still with a relatively unchanged abundance of mare's tail and milfoil, but without the other species, including Starry stonewort that was found in 2005.

5.3.4 Blackfleet

Species list 2006: Baltic stonewort, Fragile/Convergent stonewort, Bristly stonewort, Intermediate stonewort, Common stonewort, Holly-leaved naiad, and Fennel-leaved pondweed

This broad has been sampled very infrequently, with the most recent visit being in 2006 and prior to that 1985 was the last sampling occasion. Jane Harris visited the site some time in the mid 1990s and confirmed the presence of clear water and stonewort beds at that time. In 2006 dense lawns of Bristly stonewort formed the dominant component of the macrophyte community, interspersed with strong growth of Intermediate stonewort. The water was clear to the bottom sediment throughout the broad and the marginal vegetation was in apparently good health. The expansion of marginal vegetation was so much so, that one of the original transects, transect E, which extended into a sheltered bay (last sampled in 1985) was overgrown and inaccessible.

5.4 Muck Fleet Valley - Trinity Broads

The Trinity Broads are a series of five lakes draining into the River Bure via the Muck Fleet. The Trinities are sampled using this transect survey as well as a more detailed point-abundance plant survey method (Schutten, 2001). 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. The submerged plants in the lakes downstream of Ormesby (Ormesby Little, Rollesby, Lily, Filby and Little broad) have poorer water quality and macrophyte populations.

5.4.1 Ormesby

Species list 2004: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, Enteromorpha, Filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Holly-leaved naiad, Curled pondweed, Flat-stalked pondweed, Fennel-leaved pondweed, Lesser pondweed, Horned pondweed

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, Enteromorpha, Filamentous algae, Common Duckweed, Least Duckweed, Ivy-leaved Duckweed, Yellow water lily, Flat-stalked pondweed, Fennel-leaved pondweed, Lesser pondweed

Species list 2006: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, Enteromorpha, Filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Holly-leaved naiad, Yellow water lily, Flat-stalked pondweed, Fennel-leaved pondweed, Lesser pondweed, Horned pondweed

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. There is no data for 1994. Then 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 Rigid hornwort and Canadian pondweed. This period of improved macrophyte growth coincided with the biomanipulation work, which started in 1995 and has been ongoing since. The stonewort taxa Fragile/Convergent stonewort that has subsequently been observed in the rest of the Trinities has been regularly recorded in Ormesby since 1995. The rake survey was not completed in 2001, although the macrophyte population was recorded to have been the best recorded since biomanipulation. In 2002 macrophyte abundance declined, similar to levels recorded in the 1988 to 1993 period. Then in 2003 the population recovered with abundant plant beds, but again appeared to decline in 2006.

A large bulk of the pondweed growth, especially lesser pondweed had died off by the date of the 2006 survey (22 August). This date was no later then in previous years (Table 3.1), but every rake sample had a large amount of what appeared to be heavily decayed lesser pondweed. This made scoring the amount of material difficult and results for 2006 are therefore rather conservative. A comparison with the more detailed point sampling methodology, which is conducted twice a year in late spring and mid summer, will reveal greater information on the longer-term pattern of macrophyte abundances in the Trinity Broads.

Ormesby Broad has two finger-like bays or arms, north and east, which usually have different macrophyte abundance. Generally the eastern arm has a higher abundance of macrophytes compared to the rest of the basin.

The emergent margin has a good belt of reed-swamp and includes some Bulrush, which has been lost from most of the broads as the species that was associated with open reed-swamp communities.

5.4.2 Rollesby

Species list 2004: Fragile/Convergent stonewort, Canadian pondweed, Enteromorpha, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Curled pondweed, Flat-stalked pondweed, Lesser pondweed, Horned pondweed

Species list 2005: Rigid hornwort, Canadian pondweed, Enteromorpha, filamentous algae, Ivy-leaved Duckweed, Yellow water lily, Flat-stalked pondweed, Lesser pondweed, Fan-leaved water crowfoot, Horned pondweed

Species list 2006: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, Enteromorpha, filamentous algae, Water net, Common Duckweed, Flat-stalked pondweed

Since the peak in macrophyte abundance in 1997 there has been a decline and a shift from rooted species, such as Canadian pondweed and hornwort rigid hornwort to macro-algae. Currently diversity is relatively high, but the growth of individual species appears to be held back from reaching its potential.

There remains emergent reed-swamp vegetation despite declines from the mid-century. Scrub clearance is ongoing to ensure there are no further losses caused by shading.

5.4.3 Ormesby Little

Species list 2004: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, filamentous algae, Common water moss, Ivy-leaved Duckweed, Yellow water lily, Lesser pondweed, Horned pondweed

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Delicate stonewort Canadian pondweed, Enteromorpha, filamentous algae, Common water moss, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Lesser pondweed, Common club-rush, Horned pondweed

Species list 2006: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Enteromorpha, filamentous algae, Water net, Ivy-leaved Duckweed, Yellow water lily, Fennel-leaved pondweed

Since 1995 there has been sparse macrophyte growth in Ormesby Little, comparable with the abundances observed in Rollesby Broad. However, we know from additional macrophyte monitoring that macrophyte biomass is higher in the early summer season compared to the late summer in all the Trinity Broads (Perrow, 2003). Recent August transect surveys have been characterised by low macrophyte abundance and dominance of the macro-algae *Enteromorpha*, filamentous algae and Water net. In the last few years however total macrophyte species diversity has increased, with Ormesby Little in the medium high diversity group of broads (Figure 1).

There remains emergent reed-swamp vegetation despite declines from the mid-century. Scrub clearance is ongoing to ensure there are no further losses caused by shading.

5.4.4 Filby

Species list 2004: Fragile/Convergent stonewort, Canadian pondweed, filamentous algae, Common Duckweed, Fennel-leaved pondweed, Lesser pondweed, Horned pondweed

Species list 2005: Fragile/Convergent stonewort, Common stonewort, Canadian pondweed, *Enteromorpha*, filamentous algae, Common Duckweed, Lesser pondweed, Horned pondweed

Species list 2006: Fragile/Convergent stonewort, *Enteromorpha*

Since 1996 the abundance and diversity of aquatic macrophytes recorded in Filby has been the lowest recorded in the Trinity's, with macro-algae dominating and occasional presence of rooted vascular macrophytes such as Horned pondweed and Canadian pondweed. There were no plants recorded in 2000 and in 2001 the lake was not surveyed. In the last five years the undifferentiated taxa Fragile/Convergent stonewort has been found regularly, although not in great abundance. To separate these two species the reproductive stages (oospores) need to be present and so far, no individuals have been found with these diagnostic features attached. There remains emergent reed-swamp vegetation despite declines from the mid-century. Scrub clearance is ongoing to ensure there are no further losses caused by shading.

5.4.5 Lily

Species list 2004: Rigid hornwort, Canadian pondweed, *Enteromorpha*, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Curled pondweed, Lesser pondweed, Horned pondweed

Species list 2005: Rigid hornwort, Canadian pondweed, *Enteromorpha*, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, White water lily, Curled pondweed, Lesser pondweed, Horned pondweed

Species list 2006: Rigid hornwort, Canadian pondweed, *Enteromorpha*, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Fennel-leaved pondweed, Lesser pondweed, Horned pondweed

Lily or Lady Broad has been surveyed since 1983 and from 1996 to 2000 the aquatic flora has been made up of fine-leaved submerged plants including pondweeds with Rigid hornwort and Canadian pondweed. Macrophyte abundance has ranged from low to medium cover over the sample period. In 2002 and 2003 plant cover was extremely low with only an occasional record of Rigid hornwort and macro-algae. Over the last three years diversity has been high, but individual species abundances at the time of sampling have been relatively low. As for the other Trinity Broads macrophyte biomass is higher in the early summer (Perrow, 2003).

There remains emergent reed-swamp vegetation despite declines from the mid-century. Scrub clearance is ongoing to ensure there are no further losses caused by shading.

5.4.6 Little Broad

Species list 2005: filamentous algae, Horned pondweed

2005 has been the only year that this broad was sampled. Filamentous algae covered most of the bottom of this very shallow waterbody.

5.5 Ant Valley

In the Ant Valley, Alderfen, Cromes 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 Cromes 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 pondweed, particularly along the western side in the shallower margins and along the Neatishead Arm.

Other SSSI waterbodies in the Ant valley that were surveyed for the first time in 2003 included Catfield Broad, Irstead Holmes and Reedham Water. These have not been revisited since and the 2003 species lists are given.

5.5.1 Barton

Species list 2004: Starwort, Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Curled pondweed, Blunt-leaved pondweed, Fennel-leaved pondweed, Fan-leaved water crowfoot

Species list 2005: Starwort, Rigid hornwort, Fragile/Convergent stonewort, Common stonewort, Canadian pondweed, *Enteromorpha*, filamentous algae, Holly-leaved naiad, Yellow water lily, White water lily, Curled pondweed, Blunt-leaved pondweed, Fennel-leaved pondweed, Perfoliate pondweed, Pointed stonewort

Species list 2006: Rigid hornwort, Delicate stonewort, Common stonewort, Canadian pondweed, Nuttall's pondweed, filamentous algae, Yellow water lily, White water lily, Small pondweed, Curled pondweed, Fennel-leaved pondweed, Common club-rush, Unbranched bur-reed, Pointed stonewort

Barton Broad historically had a very low abundance and occasional complete absence of recorded aquatic macrophytes. Up to the mid-nineties occasional Yellow water lily, Rigid hornwort and macro-algae were recorded (Figure 11). Since the mid-nineties Rigid hornwort and Curled pondweed, have been more regularly recorded. Since 2003 more than 10 macrophyte species have been recorded each summer, with steadily increasing abundance and diversity. 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.

5.5.2 Alderfen

Species list 2004: Rigid hornwort, Fragile/Convergent stonewort, filamentous algae,

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Bristly stonewort, filamentous algae, Lesser pondweed, Horned pondweed

Species list 2006: Rigid hornwort, filamentous algae, Holly-leaved naiad

Rigid hornwort continues to be the major component of the aquatic plant community along with some filamentous algae (Figure 12). The abundance of Rigid hornwort rarely achieves complete cover unlike the high abundance found in Cromes Broad. 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. In 2006 the rare Holly-leaved naiad was found in vigorous patches throughout the broad. This was the first year that it has been recorded at this site during the Broads Authority's annual aquatic plant survey. Sedges and reed vegetation make up the littoral margin; much of the marginal scrub is managed on a routine basis. However there is little emergent reed-swamp vegetation.

5.5.3 Cromes

Species list 2004: Rigid hornwort, *Enteromorpha*, filamentous algae, Common Duckweed

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, *Enteromorpha*, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, White water lily

Species list 2006: Rigid hornwort, Fragile/Convergent stonewort, Delicate stonewort, Enteromorpha, filamentous algae, Common Duckweed, Ivy-leaved Duckweed, White water lily

Cromes Broad is divided into to 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. As found by the 2006 survey, the north basin has already been colonised by abundant Rigid hornwort and filamentous algae growth, which is encouraging in terms of restoration. The aquatic plant diversity in Cromes broad has generally been low, but a maximum of 8 species were found in 2006. Since 1993 (Figure 13) the lake has had a high biomass of hornwort Rigid hornwort, which has been co-dominant with macro-algae (filamentous and *Enteromorpha*). The abundance of macro-algae has declined in recent years (apart from in the north basin) and Rigid hornwort can be seen at the water surface. This improvement in the aquatic community probably resulted from effective isolation from the River Ant in 1992 by repair to the sluice.

5.5.4 Catfield Broad

Species list 2006: Rigid hornwort, Canadian pondweed, filamentous algae, Frogbit, Common Duckweed, Least Duckweed, Ivy-leaved Duckweed, Blunt-leaved pondweed, Bladderwort, Whorled water milfoil, Water violet

5.5.5 Irstead Holmes

Species list 2006: Rigid hornwort, *Enteromorpha,* filamentous algae, Frogbit, Bladderwort

The aquatic plant community found at Catfield Broad and Irstead Holmes was reflective of the more dyke type of habitat present, as opposed to extensive open water like in other larger waterbodies. The particularly dyke associated species found were Frogbit, Whorled water milfoil and Water violet.

5.5.6 Reedham Water

Species list 2006: Rigid hornwort, *Enteromorpha,* filamentous algae

5.6 Bure Valley

The location of the Bure Valley broads in relation to their hydrological connection to the River and their relative position within the valley appears to affect both ecological condition and restoration potential. In recent years Upton and Cockshoot Broads, isolated from the river, have the highest populations of aquatic plants present in the Bure Broads. Upton Broad is a stronghold for the rare holly-leaved naiad. The other Bure Broads connected to the river, such as Wroxham, Hoveton Little (Blackhorse) and Ranworth have very little submerged plant growth and in several summers there has been a complete absence, especially within Salhouse and Malthouse.

5.6.1 Belaugh

Species list 2004: Rigid hornwort, Canadian pondweed, filamentous algae, White water lily

Species list 2005: Rigid hornwort, Nuttall's pondweed, Yellow water lily, White water lily

Species list 2006: Rigid hornwort, Nuttall's pondweed, filamentous algae, White water lily

Rigid hornwort, White water lily and Canadian and Nuttall's pondweed, with occasional Yellow water lily make up the aquatic flora of Belaugh broad (Figure 14). 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 introduction of Yellow & White water lilies, Canadian pondweed 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 pondweed and Nuttall's pondweed was recorded, occurring both inside and outside the bird exclosures. 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 in early August with abundant Rigid hornwort and Nuttall's pondweed nearly reaching the water surface. Diversity of species remained low, but the amount of plant growth clearly had a significant effect upon water clarity.

The littoral margin is dominated by unmanaged alder scrub, reducing the light climate for growth of emergent plant species which may be a factor explaining their low abundance around Belaugh broad.

5.6.2 Bridge

Species List 2004: Filamentous algae, Yellow water lily

Species List 2005: Nuttall's pondweed, filamentous algae, Yellow water lily, Pointed stonewort

Species List 2006: Filamentous algae, Yellow water lily, Unbranched bur-reed

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, which occasionally has Pointed stonewort entwined within the carpet of filamentous algae. 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.

5.6.3 Burntfen

Species List 2006: filamentous algae, Common water moss, Yellow water lily, Curled pondweed

Burntfen Broad, located to the north of the river is isolated from tidal influence and has deep, unconsolidated and probably nutrient rich sediment as a result of agricultural catchment inputs. A large proportion of the lake is covered by Yellow water lily. The owner regularly removes a proportion of the lilies to retain open water. Emergent reed-swamp vegetation was restricted to a few patches where light and/or substrate were favorable. Scrub formed much of the littoral vegetation.

5.6.4 Cockshoot

Species List 2004: Rigid hornwort, Canadian pondweed*, Enteromorpha*, filamentous algae, Common Duckweed, Holly-leaved naiad, White water lily, Horned pondweed

Species List 2005: Sweet flag, Rigid hornwort, Canadian pondweed, *Enteromorpha*, filamentous algae, Least Duckweed, Ivy-leaved Duckweed, Holly-leaved naiad, White water lily, Lesser pondweed, Horned pondweed

Species List 2006: Rigid hornwort, Common stonewort, Canadian pondweed, *Enteromorpha*, filamentous algae, Ivy-leaved Duckweed, Holly-leaved naiad, Yellow water lily, White water lily, Lesser pondweed, Horned pondweed

Despite mud pumping and isolation from the River Bure in 1982 the aquatic plant population showed little sign of immediate recovery, thus many aquatic plants were introduced in 1984/5 (Figure 18). Many of these introduced plants were grazed by birds or failed to establish as a result of factors such as foraging bream or turbid water conditions. Until the early nineties the plant population remained at fairly low abundance with Rigid hornwort and water lilies recorded. Selective fish removal (biomanipulation) throughout the 1990's resulted in clear water conditions for most of the 1990's. However clear water reverted to turbid water when fish entered the broad via channels that opened around the dams isolating Cockshoot from the River Bure. Plant growth reached a peak in 1994 with abundance of fine-leaved pondweeds and other fine-leaved submerged plants.

In 2000 and 2003, 10 species of submerged rooted aquatic plants (pondweed and stonewort species) planted into weighted coir pallets were introduced to the lake in an attempt to provide a firm substrate for plants to grow from and to increase plant diversity. The plantings were however unsuccessful due to either bird grazing or being smothered by filamentous algae. In 2003 species richness was the highest recorded in Cockshoot with 12 species of aquatic plant including macro-algae. Subsequently 11 species were found in 2005 and 2006. 2006 was also a very good year for the holly-leaved naiad *Holly-leaved naiad* in Cockshoot Broad. At the date of sampling (10th August) holly-leaved naiad was the most dominant species, having followed a period of dominance by fine-leaved pondweeds (Lesser pondweed) during the late spring and early summer. This broad is now showing signs of having more seasonal variation in the submerged plant species present, which has had the effect of extending the period of plant cover which may therefore increase the longer-term stability of this broad.

There are a few small areas of reed-swamp growth, notably in Cockshoot dyke. Scrub has been managed along the dyke and parts of the broad, allowing light to reach the littoral margin. In an attempt to reintroduce emergent plants the extremely shallow undredged west margin of the main lake was planted in early 2003 with Bulrush and Lesser reedmace. This experiment also failed due to a very dry summer in 2003.

5.6.5 Hoveton Great

Species List 2004: Rigid hornwort, *Enteromorpha*, Yellow water lily, Curled pondweed, Fennel-leaved pondweed, Horned pondweed

Species List 2005: Rigid hornwort, Yellow water lily, White water lily, Curled pondweed, Fennel-leaved pondweed

Species List 2006: Rigid hornwort, Yellow water lily, White water lily, Curled pondweed, Fennel-leaved pondweed, Horned pondweed

Hoveton Great Broad generally has low macrophyte abundance (Figure 16) with remnant patches of yellow and white water lilies in sheltered bays. The lake has several bays that have been enclosed by fish-proof curtains to allow temporary biomanipulation. During the periods when the curtains have formed an effective barrier to fish, clear water and macro-algal growth has resulted, although the abundance of rooted macrophytes has been low. These barriers are no longer maintained to exclude fish and currently mainly provide increased shelter from the strong wind-induced waves that can disturb the bottom sediments in this broad.

The emergent vegetation in Hoveton Great Broad is limited to the hover margin, which appears solid, as it has regressed dramatically since the mid-century. The margin has recently been cleared of scrub and it is hoped that over time reed-swamp habitat will reform.

5.6.6 Hoveton Little

Species List 2006: Curled pondweed, Fennel-leaved pondweed

Hoveton Little Broad has only been surveyed using the transect methodology sporadically since 1997. During this period both abundance and diversity of macrophytes have been low. The emergent vegetation in Hoveton Little Broad is limited to the margin and does not extend into the water to form reed-swamp communities, which once formed almost 5ha area in 1946 (Boorman, Fuller and Boar, 1979).

5.6.7 Ranworth

Species list 2004: Rigid hornwort, Fennel-leaved pondweed

Species list 2005: Holly-leaved naiad, Fennel-leaved pondweed

Species list 2006: Rigid hornwort, Fennel-leaved pondweed

As a result of poor water quality and soft nutrient-enriched sediments, Ranworth Broad has had low abundance and diversity of plants recorded since surveying began in 1983 (Figure 19). Almost continuous monitoring has taken place at Ranworth, with only two years missed. Fennel-leaved pondweed, Curled pondweed and Rigid hornwort have been the most frequent plant species detected, but abundance has nearly always been limited to a few rather sickly looking individuals in a few of the transects. Since 1995 Holly-leaved naiad has also been found as sporadic individual plants. 1998 had the greatest amount of plant growth recorded, when abundance of Rigid hornwort was particularly high, having steadily built up during the previous two years. This was however not a long-term increase. There are a few patches of Yellow water lily that appear to be surviving within the physical wave shelter provided by an old bird protection carousal.

Much of the littoral margin is managed by cutting back invading scrub, however there is little reed-swamp vegetation around the edges of the open water.

5.6.8 Upton Great

Species list 2004: Opposite stonewort, Holly-leaved naiad, Horned pondweed

Species list 2005: Opposite stonewort, Holly-leaved naiad, White water lily, Fennel-leaved pondweed

Species list 2006: Opposite stonewort, filamentous algae, Holly-leaved naiad, Yellow water lily, Horned pondweed

Upton Broad has been a stronghold for Holly-leaved naiad where it occupies much of the water column and area of the lake. The population of Holly-leaved naiad has been relatively stable. During the 1980's macro-algae (mainly filamentous) was generally more prolific (Figure 20). 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.

There are patches of reed-swamp around the margin of the lake.

5.6.9 Upton Little

Species list 2005: Opposite stonewort, filamentous algae, Holly-leaved naiad, Fennel-leaved pondweed

Species list 2006: Opposite stonewort, Holly-leaved naiad

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. This means macrophytes are limited to the deeper areas, which are no more than 80 cm depth at any point.

5.6.10 Wroxham

Species list 2004: filamentous algae, Fennel-leaved pondweed

Species list 2005: Fennel-leaved pondweed

Species list 2006: Fennel-leaved pondweed

Very few submerged macrophytes have been recorded in Wroxham Broad (Figure 15), which has had the luxury of being sampled every year since 1983. The dominant group of plants are macro-algae (filamentous algae), which were present at moderate levels in the late 1980's and 1990's. Other plants that have been recorded include Canadian pondweed, Fennel-leaved pondweed, Yellow water lily and the occasional stonewort record. Despite improvement in water quality (both lower nutrient and improved water clarity) since the early eighties there has been no development of the aquatic plant community.

Much of the reed-swamp margin has been lost since the mid 20th century. The island that separates the River Bure from the lake has been repaired in several places to ensure that it remains intact.

5.6.11 Decoy

Species list 2004: Rigid hornwort, Holly-leaved naiad, Yellow water lily

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Holly-leaved naiad, Yellow water lily

Species list 2006: 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 sparse individual fragments of Holly-leaved naiad have been found. In 2006 blue-green algae were abundant in the water column.

5.6.12 Pound End

Species list 2004: Rigid hornwort, filamentous algae

Species list 2005: filamentous algae, Curled pondweed, Fennel-leaved pondweed

Species list 2006: Holly-leaved naiad, Curled pondweed

Pound End, the enclosed section of Hoveton Little Broad, has received nearly continuous monitoring since 1995 (Figure 17). An estimate of relative species abundance was generated in 1992, but was not based on the permanent transects. Holly-leaved naiad has been a near permanent feature of the plant community at this site, being particularly abundant in the late 1990s. There have also been frequent records of small amounts of Rigid hornwort and filamentous algae.

5.6.13 Norton's

Species list 2004: filamentous algae

This small broad was found to only contain dense mats of filamentous algae when it was sampled for the first time in 2004.

5.6.14 Other waterbodies in the Bure valley

Other broads that have been surveyed in the past, but not at least in the last three years are Hudson's Bay and Salhouse Little. There are also two permanent waterbodies that have not been surveyed to date, these being Snape's Water and Sotshole Broad.

5.7 Yare Valley

Waterbodies surveyed in the Yare valley are generally of good condition in terms of their submerged macrophyte populations. Hassingham and Buckenham Broads have good populations of stoneworts and a good diversity of vascular macrophytes. Despite high nutrient concentrations submerged plants remain in Rockland and Wheatfen Broads. Whitlingham Great and Little Broads, despite their 'youth' have abundant submerged plant growth and a diverse species assemblage. Other locations sampled over the last three years have included Bargate and Stumpshaw broads. The Brundall basins and Surlingham channels have not been surveyed.

5.7.1 Rockland

Species list 2004: Starwort, Rigid hornwort, Nuttall's pondweed, Filamentous algae, Yellow water lily, Unbranched bur-reed, Horned pondweed

Species list 2005: Starwort, Rigid hornwort, Nuttall's pondweed, Filamentous algae, Smooth stonewort, Yellow water lily, Unbranched bur-reed, Horned pondweed

Species list 2006: Starwort, Rigid hornwort, Nuttall's pondweed, Filamentous algae, Yellow water lily, Unbranched bur-reed

Submerged macrophyte cover in Rockland is generally low (Figure 21) with occasional patches of Nuttall's pondweed and some quite extensive beds of Yellow water lily. In 2006 Rigid hornwort was particularly abundant. Outside the navigation channel the broad is very shallow in parts. Where the lakebed has a firm substrate it was observed that macrophytes were recorded in greater abundance. Where the margin was shallow submerged plants were grazed by water birds. Rockland Broad is the site within the Yare valley that has been surveyed for the longest, with six years not sampled from 1983 to 2006. A noticeable feature of the last four years macrophyte monitoring in Rockland is the current low abundance of filamentous algae that was up until 2000 rather common.

The rake transects did not cross the beds of emergent sweet flag (*Sweet flag*) therefore these were not recorded in the survey. Records suggest that the emergent vegetation has declined as in many other lakes in Broadland.

5.7.2 Whitlingham Great

Species list 2004: Water plantain, Rigid hornwort, Common stonewort, Canadian pondweed, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Ivy-leaved Duckweed, Smooth stonewort, Amphibious bistort, Lesser pondweed, Fan-leaved water crowfoot, Lesser Reedmace

Species list 2005: Water plantain, Common stonewort, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Smooth stonewort, Persicaria amphibia, Small pondweed, Lesser pondweed

Species list 2006: Fragile/Convergent stonewort, Common stonewort, Nuttall's pondweed, Canadian pondweed, *Enteromorpha*, filamentous algae, Ivy-leaved Duckweed, Smooth stonewort, Fan-leaved water crowfoot

The Whitlingham Broads originated from gravel extraction and are recent in origin. So far there have been four years of macrophyte monitoring at Whitlingham Great. The bed of Whitlingham Great has been progressively colonised by Nuttall's pondweed. However, species diversity and abundance has high within the shallow margins. In areas of firm

substrate around the shallow margins where *Elodea* was absent, patches of low growing Common stonewort have been recorded. In the deep central basin, which extends to 6m deep in parts, Smooth stonewort, which is common throughout Britain, has been found. In 2006 there was with clear water throughout the broad, except in localised areas where sediment-laden water was pumped in the broad from the gravel transport process still in operation.

Marginal plant growth was diverse and well established. Growth of amphibious bistort was particularly abundant. Where plantings of emergent vegetation had been made these were extending into the shallow margin to form valuable reed-swamp habitat.

5.7.3 Whitlingham Little

Species list 2005: Water plantain, Rigid hornwort, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Ivy-leaved duckweed, Lesser pondweed, Fan-leaved water crowfoot, Amphibious bistort, Horned pondweed

Species list 2006: Rigid hornwort, Common stonewort, Canadian pondweed, Nuttall's pondweed, filamentous algae, Ivy-leaved duckweed, Greater Reedmace

Whitlingham Little has, in the two surveys performed so far, been dominated by Rigid hornwort and Nuttall's pondweed. At the time of sampling in 2006 there was bloom of the blue-green algae *Aphanizomenon* sp. Around the sandy margin of the eastern shore, dense growth of the invasive alien plant Australian swamp stonecrop was noted.

5.7.4 Wheatfen

Species list 2004: Starwort, Nuttall's pondweed, filamentous algae, Yellow water lily, Pointed stonewort, Lesser pondweed, Unbranched bur-reed, Horned pondweed

Species list 2006: Starwort, Rigid hornwort, Nuttall's pondweed, filamentous algae, Yellow water lily, Unbranched bur-reed

Prior to these years the channels and open water of the Wheatfen waterway has 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, an indication that increased phosphorus removal at Whitlingham wastewater treatment works (WWTW) has been successful in reducing available phosphorus concentrations. The previously recorded *Nitella* s was not found in the 2006 survey.

5.7.5 Bargate

Species list 2004: Nuttall's pondweed, filamentous algae, Yellow water lily, Unbranched bur-reed

Species list 2006: Rigid hornwort, Yellow water lily, Unbranched bur-reed

This site has only been sampled in these two years. All species were present in low abundance.

5.7.6 Strumpshaw

Species list 2005: Rigid hornwort, filamentous algae, Common water moss, Mare's tail, Common Duckweed, Ivy-leaved Duckweed, Holly-leaved naiad, Fennel-leaved pondweed, Unbranched bur-reed, Bladderwort

Species list 2006: Fragile/Convergent stonewort, Rigid hornwort, filamentous algae, Common water moss, Common Duckweed, Ivy-leaved Duckweed, Holly-leaved naiad, Fennel-leaved pondweed, Bladderwort

Strumpshaw was previously surveyed once in 1998 and had then a similar flora. Bladderwort is particularly common at this site, a unique feature amongst the broads surveyed.

5.7.7 Buckenham

Species list 2004: Rigid hornwort, Fragile/Convergent stonewort, Canadian pondweed, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Yellow water lily, Curled pondweed, Fennel-leaved pondweed

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Yellow water lily, Curled pondweed, Fennel-leaved pondweed

Species list 2006: Rigid hornwort, Canadian pondweed, Nuttall's pondweed, *Enteromorpha*, filamentous algae, Yellow water lily, Curled pondweed, Fennel-leaved pondweed

These three years are the whole dataset for Buckenham. During this short time, it has been noted that Rigid hornwort and filamentous algae are the most abundant species, with low abundances of the rest. Species diversity is good and has potential to improve further.

5.7.8 Hassingham Broad

Species list 2004: Rigid hornwort, Fragile/Convergent stonewort, Bristly stonewort, *Enteromorpha*, filamentous algae, Common Duckweed, Ivy-leaved Duckweed

Species list 2005: Rigid hornwort, Fragile/Convergent stonewort, Bristly stonewort, *Enteromorpha*, filamentous algae, Common Duckweed

Species list 2006: Rigid hornwort, Fragile/Convergent stonewort, Bristly stonewort, *Enteromorpha*, filamentous algae, Curled pondweed, Fennel-leaved pondweed

As with the neighbouring Buckenham Broad, the last three years represent the entire dataset collected with the rake-trawl method from this broad. Water clarity is generally much better in Hassingham, a fact reflected by the presence of stoneworts. In 2006 Fragile/Convergent stonewort was relatively abundant compared to the previous years. Rigid hornwort has consistently been the most dominant species, but the other species appear to be able to grow amongst it quite well.

5.8 Waveney Valley

There are six broads along the Waveney valley and which lay within the Broads Authority executive area, these are; Barnby, Spratt's Water, Woolner's Carr, Round Water, Flixton Decoy and Oulton Broad. Fritton Lake is outside of the executive area, but has been surveyed in 2006 for the first time as part of the Broads Authority contribution to the Fritton Lake Partnership between the Authority, Northumbrian Water (locally known as Essex & Suffolk Water, the Environment Agency and the Somerleyton Estate. Transect surveys have so far only been performed on Barnby, Flixton Decoy, Fritton and Spratt's Water and all of these have been done in the last three years. This is mainly due to the main lake restoration projects being focused in the more numerous and more frequently visited northern rivers. Monitoring programmes are developing around restoration projects at these sites to inform progress.

5.8.1 Barnby

Species list 2004: Rigid hornwort, filamentous algae

Species list 2005: Rigid hornwort

Species list 2006: Rigid hornwort

The northern half of this broad is very shallow (<0.4 m) and all of the Rigid hornwort is situated in the deeper southern half were mud-pumping was conducted over 15 years ago. The remainder of Barnby will be mud-pumped in early 2007 to achieve greater average water depth, remove nutrient rich sediment and to encourage further macrophyte growth.

5.8.2 Flixton Decoy

Species list 2006: Rigid hornwort, Nuttall's pondweed, filamentous algae, Common Duckweed, Yellow water lily, White water lily, Small pondweed, Curled pondweed, Flat-stalked pondweed

This broad was sampled for the first time in 2006. The water was clear to the bottom and had abundant growth of (in decreasing order of abundance); Nuttall's pondweed; Rigid hornwort; and a range of other pondweed species; to the water surface.

5.8.3 Fritton Lake

Species list 2006: *Enteromorpha,* Common water moss, White water lily

This lake had almost no macrophyte growth at all. The patches of water lily may have been introduced cultivars, as they had rather small flowers compared to others seen during the 2006 survey and were located in a sheltered bay with cabins overlooking the water. The *Enteromorpha* and Common water moss records were of single fragments.

5.8.4 Spratt's Water

Species list 2004: Rigid hornwort, *Enteromorpha,* filamentous algae, Common Duckweed

This small waterbody was dominated in 2004 by Rigid hornwort and filamentous algae.

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 (staithe to first bend) (Kennison 1992). River surveys have again been repeated in 2005 and 2006; with slightly different stretches sampled to the 1992 surveys (Table 4). 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. Table 4 details where and when which river reaches have been sampled.

Table 4 River stretches and dates sampled

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

6.1.1 River Ant

Species list 2005: Starwort, Canadian pondweed, Nuttall's pondweed, filamentous algae, Frogbit, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Lesser pondweed, Fan-leaved water crowfoot, Arrowhead, Unbranched bur-reed, Water soldier

Species list 2006: Starwort, Canadian pondweed, Nuttall's pondweed, filamentous algae, Frogbit, Common Duckweed, Ivy-leaved Duckweed, Yellow water lily, Fan-leaved water crowfoot, Arrowhead, Unbranched bur-reed, Water soldier, Amphibious bistort, Bladderwort, Rigid hornwort, *Enteromorpha*, Flowering rush

6.1.2 River Bure

Species list 2006: Starwort, Nuttall's pondweed, Common Duckweed, Ivy-leaved Duckweed, Arrowhead, Unbranched bur-reed, Yellow water lily, White water lily, Perfoliate pondweed, Fan-leaved water crowfoot, Pointed stonewort, Flowering rush

6.1.3 River Thurne

Species list 2005: Starwort, Opposite stonewort, Common stonewort, Canadian pondweed, filamentous algae, Common water moss, Mare's tail, Ivy-leaved Duckweed, Spiked water milfoil, Whorled water milfoil, Holly-leaved naiad, Starry stonewort, Yellow water lily, White water lily, Curled pondweed, Fennel-leaved pondweed, Perfoliate pondweed, Pondweed hybrid (x salicifolius), Fan-leaved water crowfoot, Arrowhead, Unbranched bur-reed, Clustered stonewort

Species list 2006: Starwort, Common stonewort, Canadian pondweed, filamentous algae, Common water moss, Mare's tail, Ivy-leaved Duckweed, Spiked water milfoil, Holly-leaved naiad, Starry stonewort, Yellow water lily, White water lily, Curled pondweed, Fennel-leaved pondweed, Perfoliate pondweed, Pondweed hybrid (x salicifolius), Fan-leaved water crowfoot, Arrowhead, Unbranched bur-reed

6.1.4 River Waveney

Species list 2005: Starwort, Rigid hornwort, Nuttall's pondweed, Common water moss, Common Duckweed, Whorled water milfoil, Smooth stonewort, Yellow water lily, Arrowhead, Bulrush, Unbranched bur-reed, Greater duckweed

6.1.5 River Wensum

Species list 2005: Water fern, Starwort, Canadian pondweed, Common water moss, Common Duckweed, Yellow water lily, Fennel-leaved pondweed, Perfoliate pondweed, Arrowhead, Unbranched bur-reed

6.1.6 River Yare

Species list 2005: Starwort, Nuttall's pondweed, Common water moss, Common Duckweed, Yellow water lily, Fennel-leaved pondweed, Arrowhead, Unbranched bur-reed

6.2 Discussion

There is insufficient data to draw conclusions regarding long-term changes, but a good characterisation of each river stretches macrophyte community has been gained from the methodology. 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. The abundance data has not been presented here as the data is awaiting entry into a new database.

7 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 diversity 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.

84% of the area of open water bodies (excluding Breydon water) has been sampled in this way at least once, though a much lesser proportion than this is sampled in any one year. 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

Trends of improvement, stability or decline in macrophyte populations over the last five years within the most regularly surveyed broads are summarised in Table 5.

Table 5 Trend in abundance and condition of macrophytes over last 5 years

Improving	**Fluctuating/stable with abundant macrophytes**	**Fluctuating/stable without abundant macrophytes**	**Declining**
Barton Cromes Alderfen Belaugh	Ormesby Lily Upton Cockshoot Martham North Martham South	Bridge Hoveton Great Salhouse Pound end Hoveton Little Ranworth Malthouse Rollesby Ormesby Little Filby Rockland	Hickling Horsey Wroxham
17 %[a]	29 %	42 %	12 %

[a] percentage that each group makes of the total number of broads sampled in 2006

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 diversity of macrophytes (Table 5).

Table 6 Macrophyte scores 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

This scoring system classifies the broads into four groups (Table 6). Lakes with high macrophyte abundance (plant cover) and diversity score 1 and those with low cover and low diversity 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. In both cover and species 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 Bridge and Cockshoot.

Table 7 Scores for broads sampled in 2006 based on methodology in the RaBS database

LOW ABUNDANCE		HIGH ABUNDANCE	
LOW DIVERSITY	**HIGH DIVERSITY**	**LOW DIVERSITY**	**HIGH DIVERSITY**
4	**3**	**2**	**1**
Bridge	Rollesby	Whitlingham Little	Cromes
Wroxham	Ormesby Little	Wheatfen	Cockshoot
Burntfen	Lily	Hassingham	Whitlingham Great
Salhouse Great	Hickling	Belaugh	Strumpshaw
Hoveton Great	Barton	Upton Little	Buckenham
Decoy		Upton Great	Flixton Decoy
Hoveton Little		Alderfen	Ormesby
Pound End		Heigham Sound	Martham North
Ranworth		Blackfleet	Martham South
Rockland			
Bargate			
Fritton Lake			
Barnby			
Filby			
Horsey			

The scoring gives the largest group of broads as those with the poorest category for macrophytes, with low abundance and low diversity (Group 4). Most of these lakes are phytoplankton dominated, stable and show fluctuating patterns of macrophyte growth rather than an overall trend of improvement. Group 4 is mainly comprised of the Bure broads. Group 3 lakes have more species recorded and have generally improved from category 4 to 3 in recent years. Hickling has moved into this group from Group 1 five years ago. Group 2 lakes have higher abundance but low diversity compared to category 1 lakes, which make up 24% of the lakes surveyed. All Group 1 and 2 lakes are macrophyte dominated or have shown improvements in their macrophyte population in recent years. This simple classification of Broadland lakes forms a layer within the Rivers and Broads Strategy GIS database, which collates data on the current and potential of lakes to satisfy a variety of uses.

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 poorest category for macrophyte growth

and have been in that condition since recording began in 1983. 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.

Many 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.

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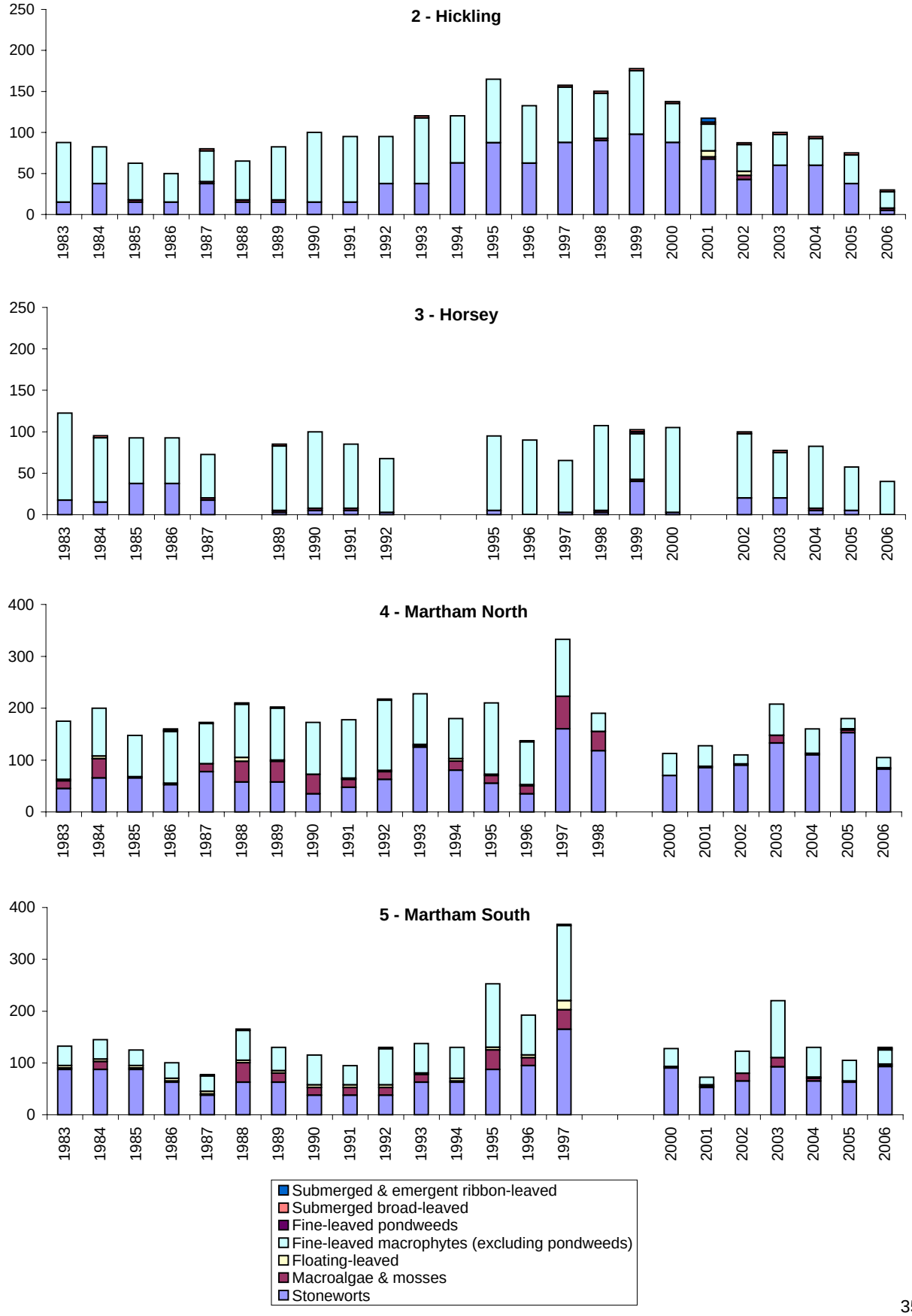
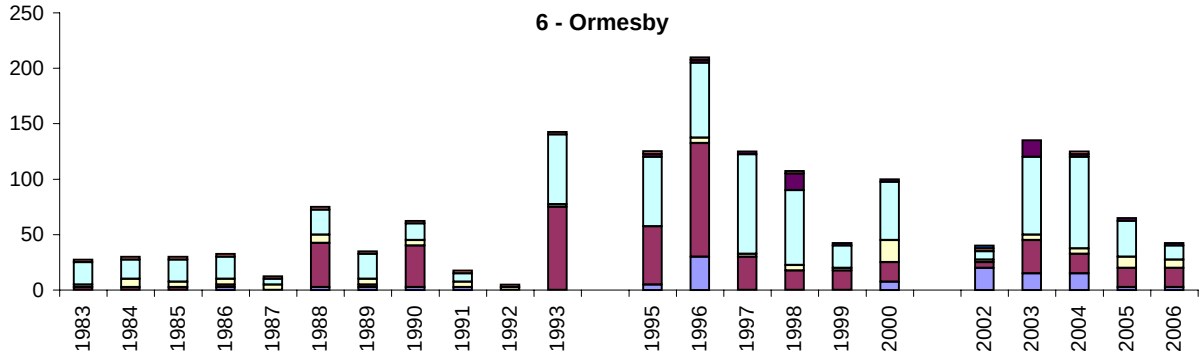
Appendix – Long-term macrophyte abundance trends

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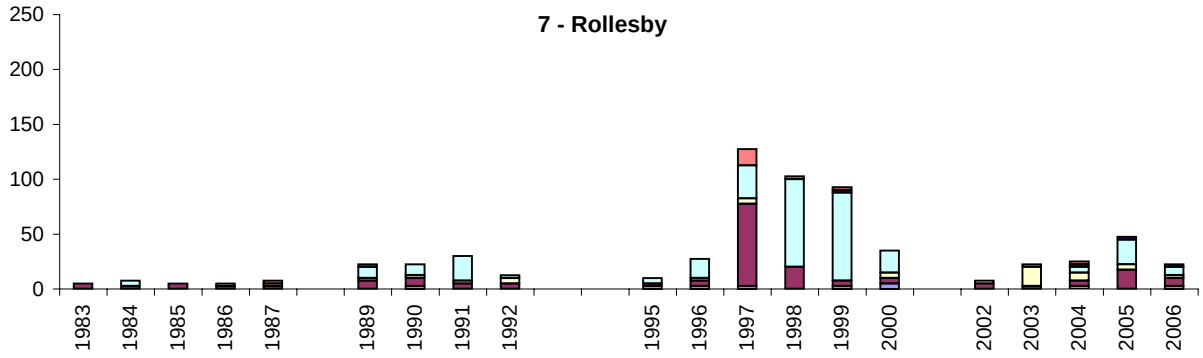
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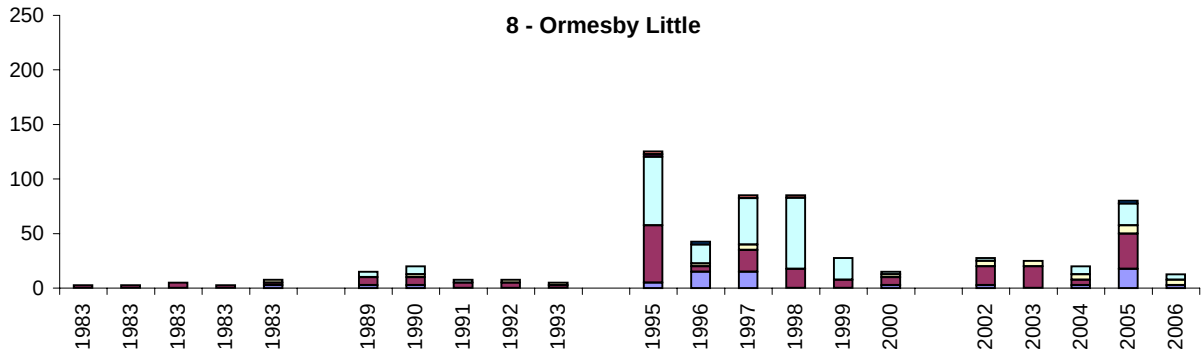
8 - Ormesby Little
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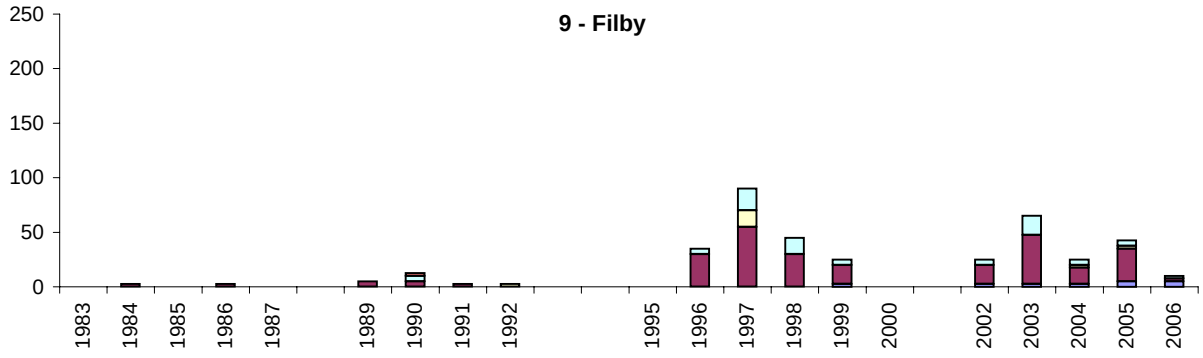
9 - Filby
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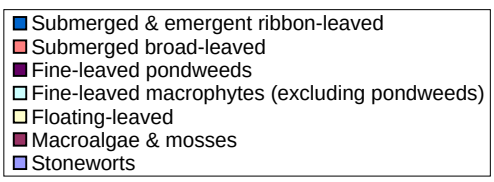
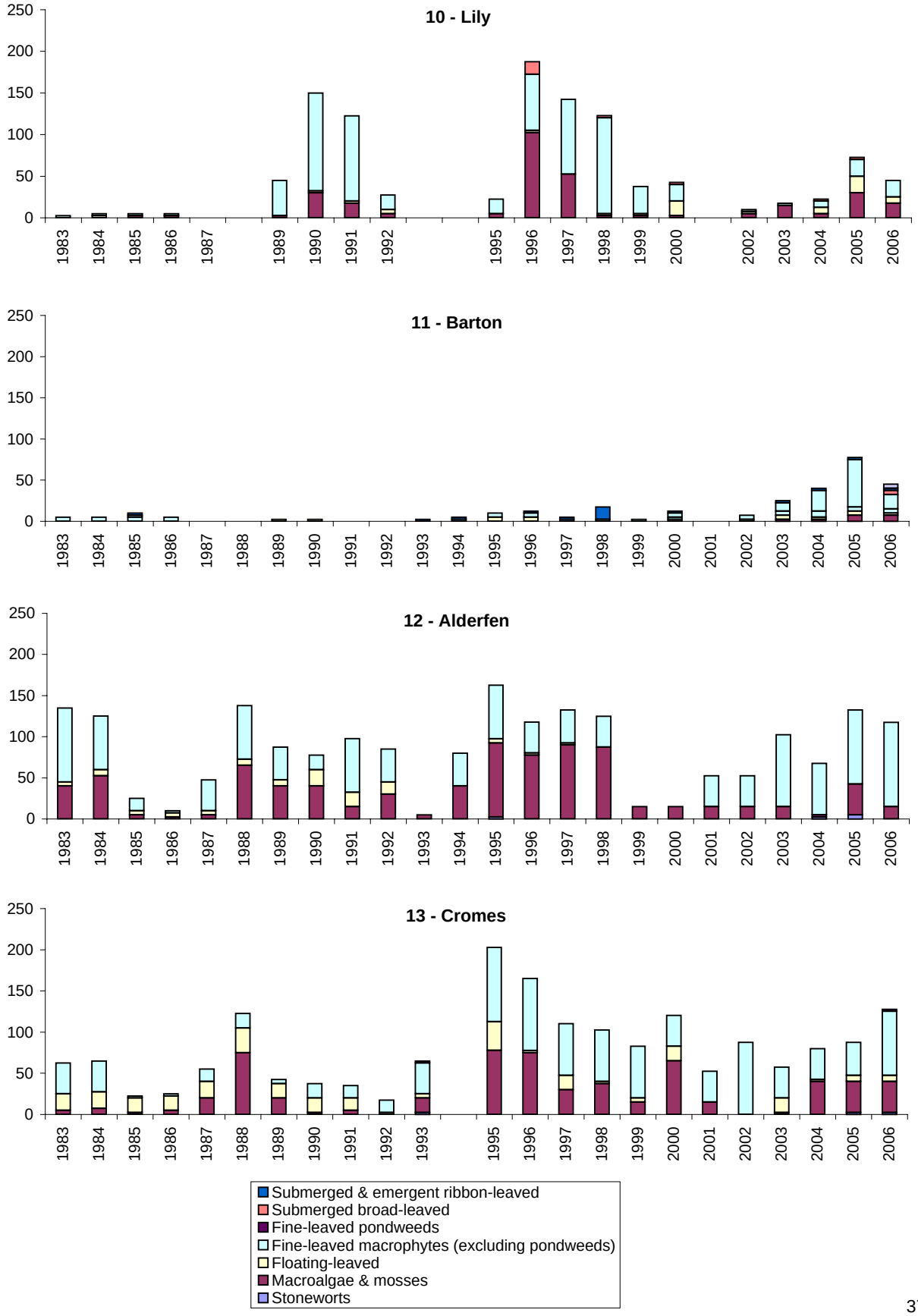

Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
Fine-leaved macrophytes (excluding pondweeds)
Floating-leaved
Macroalgae & mosses
Stoneworts


10 - Lily
11 - Barton
12 - Alderfen
13 - Cromes
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Submerged & emergent ribbon-leaved
Submerged broad-leaved
Fine-leaved pondweeds
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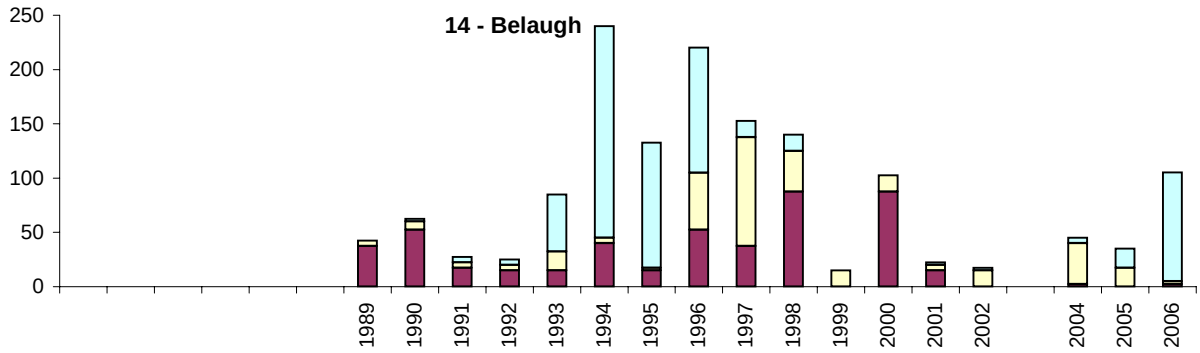
Floating-leaved
Macroalgae & mosses
Stoneworts


14 - Belaugh
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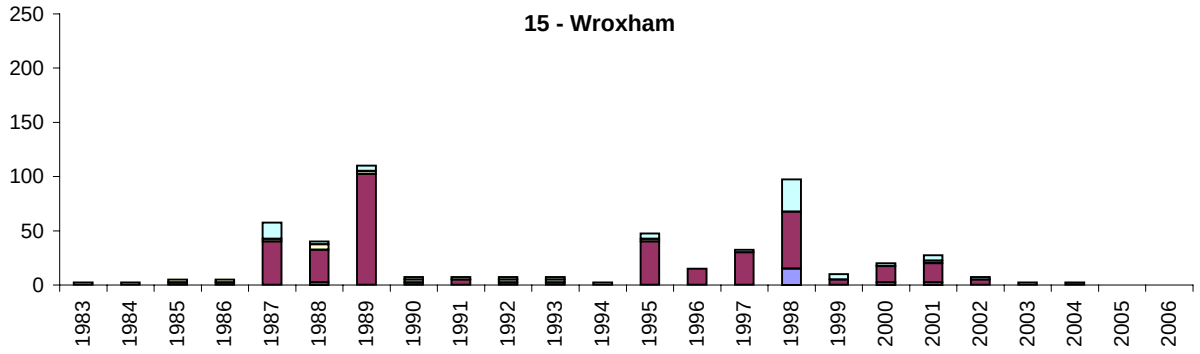
15 - Wroxham
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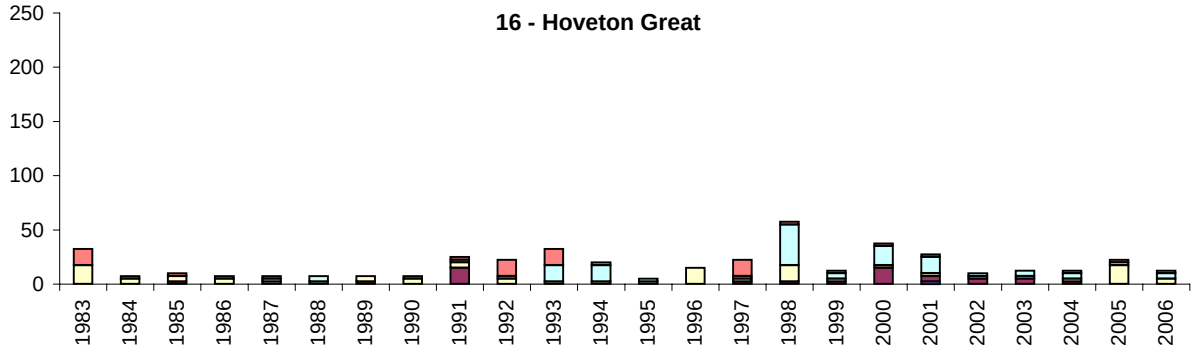
16 - Hoveton Great
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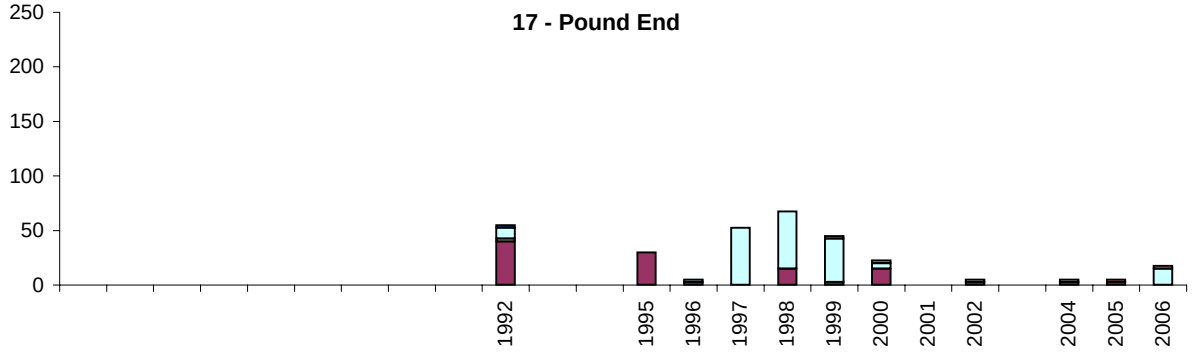
17 - Pound End
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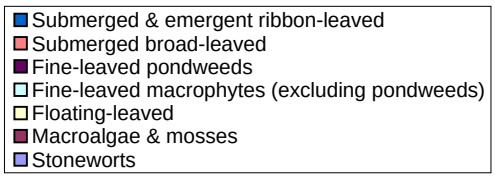
Submerged & emergent ribbon-leaved
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Fine-leaved pondweeds
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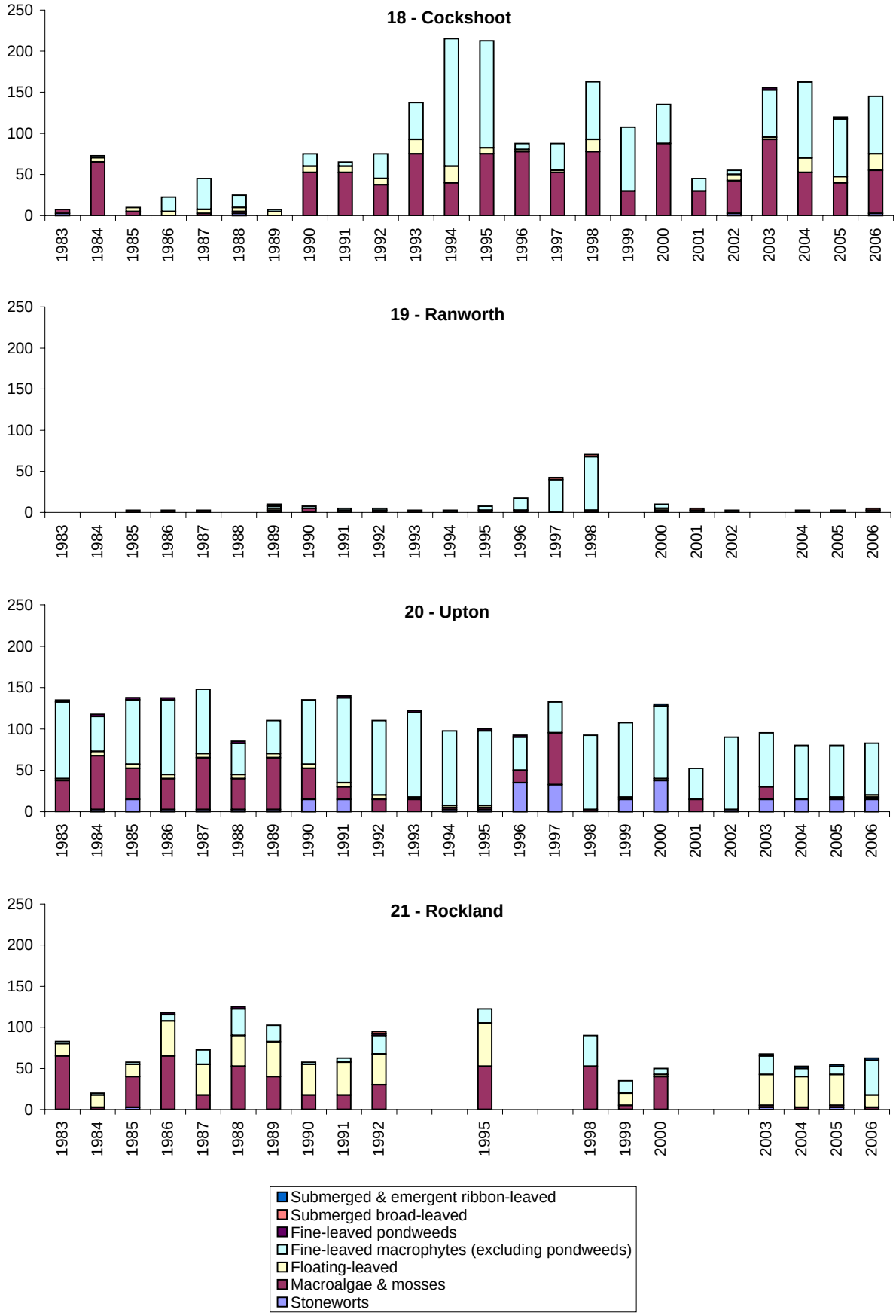
Floating-leaved
Macroalgae & mosses
Stoneworts


18 - Cockshoot
19 - Ranworth
20 - Upton
21 - Rockland
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