The Broads Annual Water Plant Monitoring Report 2016

Broads Authority
Yare House
62 – 64 Thorpe Road
Norwich
NR1 1RY

2016

Table Of Contents

Name	Job Title	Project Role	Date
Gavin Devaney	Environment Officer	Author	January 2017
Jonathan Cook	Environment Officer	Author	December 2016
Dan Hoare	Environment & Design Supervisor	Reviewer	19/1/2017

1 Executive Summary

This report presents and discusses the findings from the annual water plant surveys carried out during 2015, which covered 28 waterbodies. 2014 saw a switch from the transect based method that has been used to complete surveys since 1983, to a point based method which has been developed since 2011.

Key Results for 2016 can be summarised as:

- Once again in response to the recent and on-going trend of mild winters and springs, and an hence earlier growing season, the start of the broad's surveys began in early July and continued until the end of August. This is about two weeks earlier than surveys carried out prior to 2014. This slight shift ensures the peak growth of water plants is captured during the survey period.
- This year has seen a shift in dominant species in a few of the regularly surveyed broads. However, it must be noted that water plants can be very variable between years and between broads, hence the value of a long-term monitoring strategy. The underlying cause why a certain plant species outcompetes another in a particular year can be related to a whole host of reasons including; competition for light early in the growth season; water levels; nutrient availability, etc. Those broads which had a change in dominant species were; Decoy Broad, Mautby Decoy, Rockland Broad, and Whitlingham Little Broad.
- Blackfleet Broad was surveyed this year; it has been ten years since it was surveyed last. Blackfleet is located between Horsey Mere and Heigham Sound, adjacent to Meadow dyke. The site is dominated by stonewort species and appears to be a relatively stable site for this type of plant growth in the Upper Thurne.
- The broads which showed a noticeable decrease in abundance scores over the past three years include Cockshoot Broad, Cromes Broad and Upton Little Broad.
    - Cockshoot appeared to have had a 64% decrease in holly-leaved naiad abundance compared to 2015. This could be due to the natural environmental conditions not being ideal here in 2016.
    - Cromes has had a decrease in the abundance of stoneworts over the past three years, over 50% from 2014 to 2015 and then a further decrease in 2016. The increased levels of filamentous algae found in 2015 and 2016 appear to have been at the expense of the vascular plants and stoneworts. Due to this increase in filamentous algae and decrease in the rarer plants, nutrient enrichment may be one possible cause, alongside natural variability in plant species abundances. An investigation into the water quality data is suggested to help determine the significance of external nutrient sources on water plant growth.
    - Upton Little has had a large decrease in the quantity of stoneworts surveyed since 2014. This trend is suggestive of an on-going stabilisation of the plant community following the huge explosion of stoneworts immediately following the mudpumping in 2011.
- Over the past three years broads which showed a noticeable increase in their abundance scores include; Alderfen Broad, Decoy Broad and Little Broad. Alderfen has returned to a condition similar to that from 2014 although without the same quantity of stonewort.

Decoy has an increased number of species recorded and the quantities therein. At Little Broad, stoneworts have returned in moderate numbers although not to the same peak in growth found in 2010 and the years immediately after mud pumping in 2008.

- At Wroxham Broad a species which had not been recorded since 2011 has resurfaced, horned pondweed, *Zannichellia palustris*, and was found at three points within the broad, albeit in small amounts.
- The River Waveney was surveyed this year, the areas selected were Geldeston Dyke and then through Beccles.
- The hydroacoustic survey has shown that the early season surveys conducted in June on Barton and Hickling show similar results in terms of water plant abundance to those conducted in 2015. The additional survey at Hickling in October 2016 did show that the percentage of the bed covered by plants had increased along with their percentage volume within the water column. The good weather and extended growth period in the autumn allowed the plants to keep growing for longer, with clear water conditions observed within the stonewort beds in the west of the Broad

2 Aims & Objectives

The aim of the Broads Annual Survey is to monitor the water plant growth of the broads and waterways within the Broads. The resident water plants are used as an indicator, from which data is produced, which in turn when then using the long term data set, can be used to assess the condition, or health, of the waterbody.

As such our objectives are to use different types of surveys to gain the best information we can while also covering as much of the Broads as possible during the growing season.

Three types of survey included in this report, they are;

- Broads water plant survey. This survey manually assesses the species richness of the water plants within a selected number of the Broads.
- River water plant survey. This survey is similar to the Broads survey but slightly adapted for navigable channels and river stretches within in the Broads.
- Hydro-acoustic survey. This survey uses a form of sonar to assess the density of the water plant growth within the larger waterbodies.

3 Broads Water Plant Survey

3.1 Introduction

The aim of the Broads annual survey in 2016 was to continue to monitor water plant growth within specified broads, but using the point based method across all selected sites. Following the analysis of data recorded in 2011 and 2013 whereby surveys were repeated on the same broads using both the historical transect method and the proposed point based method, Dr. Nigel Wilby, University of Stirling, has been advising the Broads Authority on the requirements of a point based method. A revised scoring mechanism has been implemented, to allow continuation of comparison of long term trends despite changes to the survey methodology used.

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 water plant community. Broads that have not received restoration efforts or are stable and/or 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.

3.2 Survey Methodology

3.2.1 Survey point selection

a. The area of open water of each broad to be surveyed was measured using GIS mapping.

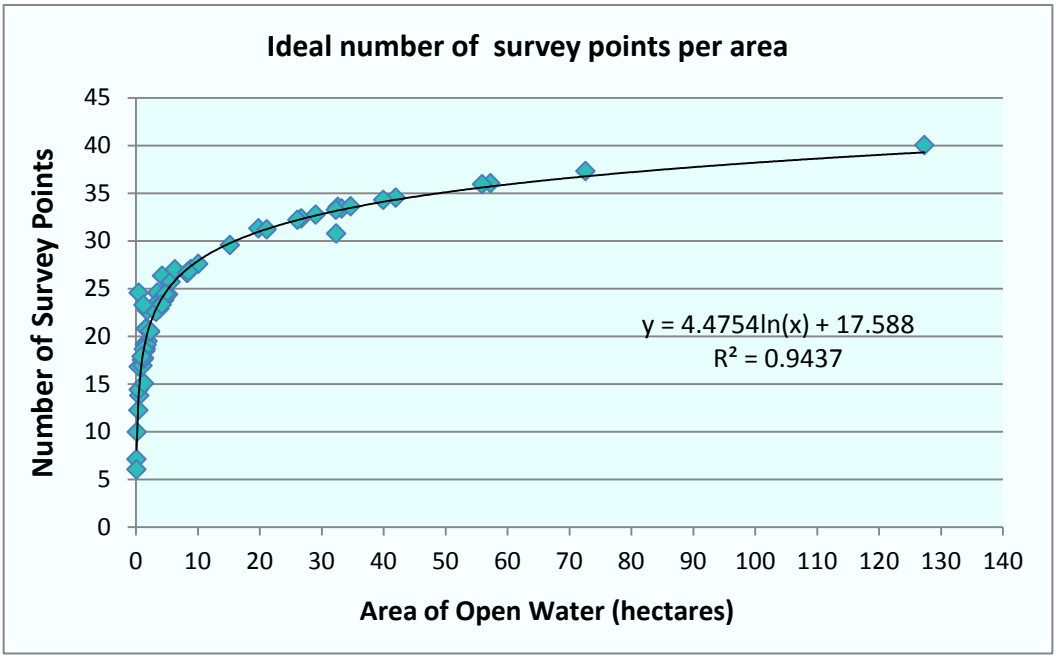


Figure 1. Chart depicting the implementation of survey point in relation to area of open water.

b. The equation y = 4.6242ln(x) + 17.149 was used to calculate the ideal number of survey points, where y = the area of open water in a site. This relationship was generated by Dr Nigel Wilby, based on Broad's species accumulation data. Once this number was calculated, a grid system was applied and a set of points was plotted on to the open water areas of each broad. Points were spaced equidistantly.

c. An aerial photograph of each broad was produced on which each of the numbered survey points was marked. On the reverse was a list of the grid references for each numbered point.

3.2.2 Field method

a. In the field, surveyors used the grid references of each plotted point to identify the point's location. The boat was navigated to each point using a handheld GPS device. Once within 5 m of the plotted grid reference, mud weights were deployed to keep the boat in the correct location.

b. At each point, a 5 m rake throw was completed to the north and to the south. Each sample (either north or south) was recorded separately, for subsequent analysis. Two samples at each point has been previously been found to be a representative number of samples at each point.

c. A double headed survey rake was thrown a distance of 5 m from the boat edge. The rake was left for 10 seconds to sink to the bottom after which the rake was pulled slowly and steadily along the bed of the broad, back towards the boat. For points that were in deeper water, additional rope was thrown to allow the rake to sink and rest on the bed of the lake at a distance of 5m from the edge of the boat.

d. On retrieval of each rake, the plants attached to the rake head were collected in a white survey tray. If necessary, plants were washed to remove excess sediment to aid identification.

e. All the live plant material was identified to species level wherever possible. For example, some particularly difficult groups e.g. any non-fruiting starworts *Callitriche sp*, were only identified to genus level.

f. Any plant specimens where identification in the field was uncertain were collected in plastic bags, labelled using the station number reference and the direction of the throw which is the point. This is then taken for subsequent observation using a high powered microscope, or to be sent for expert identification. Wherever possible, voucher specimens were pressed and dried using standard herbarium techniques.

g. To assign a level of abundance for each species, the total volume of live plant material, was ascribed a value, based on the maximum trapability on the rake. Therefore the maximum possible score would be given to a retrieved rake that couldn't possibly hold any more plant material. To make the scoring simpler in the field, the values ascribed to each species ranged between 1 and 10, with 10 being the maximum trappable. If the maximum plant volume was present on the rake, but split equally between two species for example, then each species would be scored 5. Scores of 0.1 were given to trace and very small amounts of identifiable plant material.

h. The score assigned to each species should take into account the trapability of that particular species on the rake, so that a score of 10 (91 to 100%) represents the maximum amount trappable on the rake. As such, a fine leaved species such as unbranched bur-reed would not be as trappable on the rake as a more structured species such as spiked water milfoil. The scoring for less trappable species then requires a little bit of surveyor experience and judgement to ascribe a suitable score that reflects the likelihood of being retrieved in the rake, and possibly other visual indications as to how much of the species is actually present. The risk being that high abundances of less trappable species are routinely under-scored, compared to more easily retrieved species. Other less trappable water plant families include the duckweeds and water lilies.

Table 1. Species scoring definitions

0.1 = <1%	
1 = 1 to 10%	6 = 51 to 60%
2 = 11 to 20%	7 = 61 to 70%
3 = 21 to 30%	8 = 71 to 80%
4 = 31 to 40%	9 = 81 to 90%
5 = 41 to 50%	10 = 91 to 100%

i. The maximum total of all species abundance scores on an individual rake sample cannot really be more than 100%, plus or minus 10% is an acceptable tolerance to account for the varying trapability of different species.

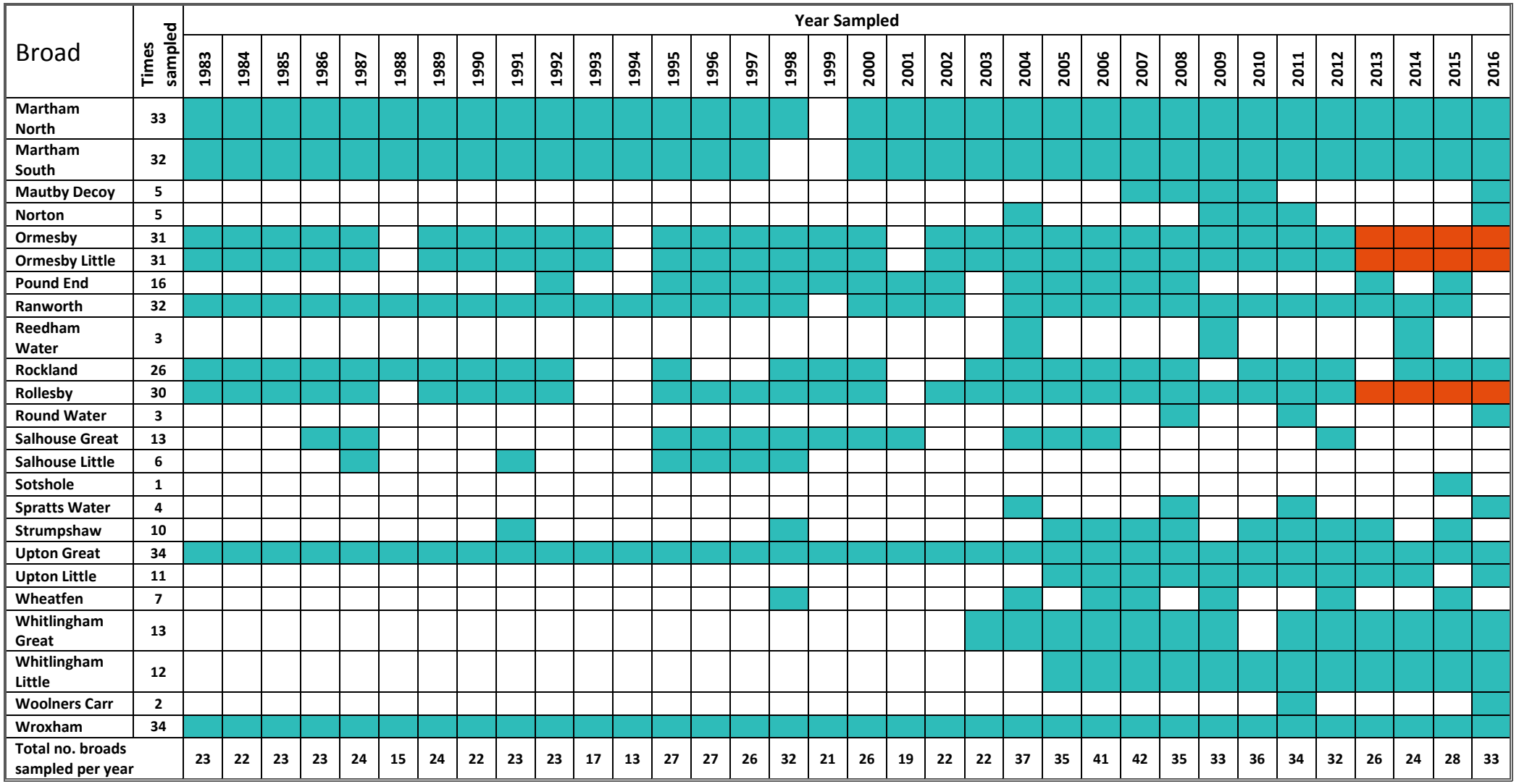
3.2.3 Data processing

a. For each sample, species abundance scores can be totalled, to produce the total abundance score for each sample. Sum of all sample abundance scores produces the site total abundance. Assuming maximum plant abundance on the site, the site abundance score should have a maximum of 10 (± 10%).

b. For data comparison, the results have been calculated to show the species richness (number of species recorded) and the species abundance scores. Species abundance is calculated by summing all the abundance scores for a particular species at each site and dividing by the number of samples, which were surveyed for that site. Within each sites results table, the species abundances have been displayed in descending order so that the most abundant species in 2016 are listed at the top of each site table.

Table 2. Sites surveyed for water plants from 1983 to 2014, sites that the Norfolk Wildlife Trust now survey are in orange

Broad	Times sampled	Year Sampled																																	
		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	2009	2010	2011	2012	2013	2014	2015	2016
Alderfen	34																																		
Bargate	4																																		
Barnby	7																																		
Barton	34																																		
Belaugh	20																																		
Blackfleet	4																																		
Bridge	15																																		
Buckenham	10																																		
Burntfen	7																																		
Calthorpe	7																																		
Catfield	3																																		
Cockshoot	34																																		
Cockshoot Dyke	30																																		
Cromes South	33																																		
Cromes North	31																																		
Decoy	12																																		
Filby	29																																		
Flixton Decoy	3																																		
Fritton Lake	1																																		
Hassingham	10																																		
Heigham Sound	26																																		
Hickling	34																																		
Horsey Mere	30																																		
Hoveton Great	34																																		
Hoveton Little	15																																		
Hudson's Bay	9																																		
Irstead	2																																		
Lily	30																																		
Little	6																																		
Malthouse	7																																		



Broad	Times sampled	Year Sampled																																	
		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	2009	2010	2011	2012	2013	2014	2015	2016
Martham North	33																																		
Martham South	32																																		
Mautby Decoy	5																																		
Norton	5																																		
Ormesby	31																																		
Ormesby Little	31																																		
Pound End	16																																		
Ranworth	32																																		
Reedham Water	3																																		
Rockland	26																																		
Rollesby	30																																		
Round Water	3																																		
Salhouse Great	13																																		
Salhouse Little	6																																		
Sotshole	1																																		
Spratts Water	4																																		
Strumpshaw	10																																		
Upton Great	34																																		
Upton Little	11																																		
Wheatfen	7																																		
Whitlingham Great	13																																		
Whitlingham Little	12																																		
Woolners Carr	2																																		
Wroxham	34																																		
Total no. broads sampled per year		23	22	23	23	24	15	24	22	23	23	17	13	27	27	26	32	21	26	19	22	22	37	35	41	42	35	33	36	34	32	26	24	28	33

Table 3. Survey dates (2009-2016).

Broad	Survey Date							
	2009	2010	2011	2012	2013	2014	2015	2016
Alderfen	19-Aug	03-Aug	09-Aug	14-Aug	14-Aug	14-Aug	30-Jul	26-Jul
Bargate	-	-	-	31-Aug	-	03-Sep	-	-
Barnby	14-Aug	-	-	19-Jul	-	-	04-Aug	-
Barton	12-Aug	21-Jul	04-Aug	06-Aug	09-Aug	07-Aug	07-Aug	17-Aug
Belaugh	-	05-Aug	11-Aug	-	-	-	-	-
Blackfleet	-	-	-	-	-	-	-	31-Aug
Bridge Broad	-	-	-	03-Aug	-	-	14-Aug	-
Buckenham Broad	-	30-Jul	20-Jul	-	26-Jul	-	28-Jul	-
Burntfen	-	12-Aug	01-Sep	-	20-Aug	-	-	18-Aug
Calthorpe	-	03-Sep	17-Aug	11-Sep	-	02-Sep	-	-
+Cockshoot Broad	03-Sep	01-Sep	18-Aug	29-Aug	05-Sep	27-Aug	20-Aug	04-Aug
Catfield	03-Sep	-	-	-	-	-	21-Aug	-
Crome's	19-Aug	03-Aug	08-Aug	14-Aug	08-Aug	06-Aug	29-Jul & 07-Aug	27-Jul
Decoy Broad	05-Aug	-	-	-	23-Aug	01-Sep	-	24-Aug
Flixton Decoy	-	06-Aug	-	-	-	-	-	-
Hassingham Broad	28-Aug	30-Jul	20-Jul	-	26-Jul	-	24-Jul	-
Heigham Sound	07-Aug	23-Aug	29-Jul	26-Jul	02-Aug	22-Jul	14-Jul	12-Jul
Hickling	13-Aug	23-Jul	05-Aug	25-Jul	31-Jul	23-Jul	15-Jul	13-Jul
Horsey Mere	07-Aug	28-Jul	29-Jul	31-Jul	30-Jul	24-Jul	16-Jul	14-Jul
Hoveton Great	06-Aug	05-Aug	03-Aug	06-Sep	13-Aug	12-Aug	05-Aug	02-Aug
Hoveton Little	-	-	-	-	15-Aug	13-Aug	-	-
Hudsons Bay	-	-	-	06-Sep	-	-	06-Aug	-
Irstead Holmes	04-Aug	-	-	-	-	-	-	-
Little Broad	09-Sep	02-Sep	-	-	20-Aug	-	-	11-Aug
Malthouse	-	17-Aug	-	-	-	-	-	-
Martham Broad North	30-Jul	29-Jul	25-Jul	24-Jul	25-Jul	29-Jul	21-Jul	21-Jul
Martham Broad South	30-Jul	29-Jul	26-Jul	24-Jul	24-Jul	30-Jul	22-Jul	19-Jul
Mautby Decoy	09-Sep	02-Sep	-	-	-	-	-	07-Jul
Mill Water	-	-	-	-	-	-	-	-
Nortons	29-Jul	05-Aug	11-Aug	-	-	-	-	03-Aug
Pound End	-	-	-	-	23-Aug	-	06-Aug	-
Ranworth	21-Aug	31-Aug	16-Aug	02-Aug	28-Aug	02-Sep	31-Jul	-
Rockland	-	30-Aug	25-Aug	30-Aug	-	28-Aug	11-Aug	16-Aug
Reedham	04-Aug	-	-	-	-	31-Jul	-	-
Round Water	-	-	23-Aug	-	-	-	-	23-Aug
Salhouse Great	-	-	-	08-Aug	-	-	-	-
Salhouse Little	-	-	-	08-Aug	-	-	-	-
Sotshole	-	-	-	-	-	-	04-Aug	-
Spratt's Water	-	-	23-Aug	-	-	-	-	23-Aug
Strumpshaw	-	30-Jul	20-Jul	27-Jul	01-Aug	-	13-Aug	-
Upton Great	18-Aug	13-Aug	10-Aug	22-Aug	21-Aug	19-Aug	18-Aug	09-Aug
Upton Little	18-Aug	13-Aug	-	22-Aug	22-Aug	20-Aug	-	09-Aug
Wheatfen	-	-	-	30-Aug	-	-	12-Aug	-
Whitlingham Great	28-Aug	-	19-Jul	18-Jul	17-Jul	17-Jul	08-Jul	05-Jul
Whitlingham Little	28-Aug	30-Aug	19-Jul	18-Jul	17-Jul	17-Jul	08-Jul	06-Jul
Woolners Carr	-	-	23-Aug	-	-	-	-	23-Aug
Wroxham	04-Aug	04-Aug	21-Jul	03-Aug	06-Aug	05-Aug	23-Jul	17-Aug

3.3 Results.

Each broad that was surveyed in 2016 is reviewed in terms of species richness (the number of species recorded) and abundance (the amounts of each species recorded) according to the point survey and scoring method (outlined in Section 3). Some analysis of recent trends of plant abundance has been made. Given the three year run of comparable data, the significance of observed trends is limited, but a general impression can be made.

The results tables also illustrate how many points each species was recorded at, giving an indication of the frequency of occurrence.

Appendix 1 lists the common and Latin names for all plants found to date during broads surveys.

3.3.1 Thurne Valley

The broads which are located in the Thurne valley contain one of the most diverse populations of stoneworts in the UK.

These bodies of water are a haven for vulnerable and rare species which are stated in the Joint Nature Conservation Committee (JNCC) Red Data Book, they include; three 'Vulnerable' species: baltic stonewort, convergent stonewort and starry stonewort, and one 'rare' species: intermediate stonewort (Stewart and Church, 1992). They are 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.

a. Blackfleet

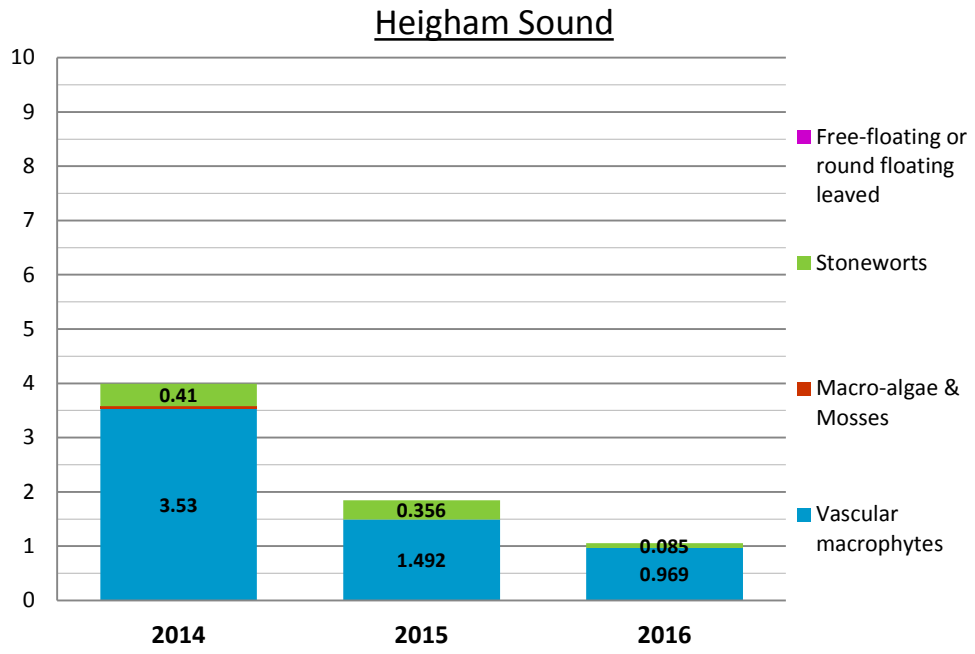
Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Bristly stonewort	*Chara hispida*	7.188	15
Translucent stonewort	*Nitella translucens*	0.063	1
Total number of species recorded		**2**	**Total samples taken 16**

This broad is located off Meadow dyke between Horsey Mere and Heigham Sound, it was last surveyed in 2006. It is a collection of connected and partially connected pools with some encroaching reedbed. They are a nice sheltered group of ponds, dominated by the rare Bristly stonewort. Fennel-leaved pondweed was also seen but not picked up in the survey.

b. Heigham Sound

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Mare's tail	*Hippuris vulgaris*	0.461	17
Spiked water milfoil	*Myriophyllum spicatum*	0.340	35
Curled pondweed	*Potamogeton crisipus*	0.085	16
Intermediate stonewort	*Chara intermedia*	0.081	2
Rigid hornwort	*Ceratophyllum demersum*	0.073	27
Smooth stonewort	*Nitella flexilis*	0.018	2
Holly-leaved naiad	*Najas marina*	0.005	3
Nuttall's waterweed	*Elodea nuttallii*	0.003	2
Bristly stonewort	*Chara hispida*	0.002	1
Stonewort (Chara) species	*Chara sp.*	0.002	1
Whorled water milfoil	*Myriophyllum verticillatum*	0.002	1
Total number of species recorded		**11**	**Total samples taken 62**

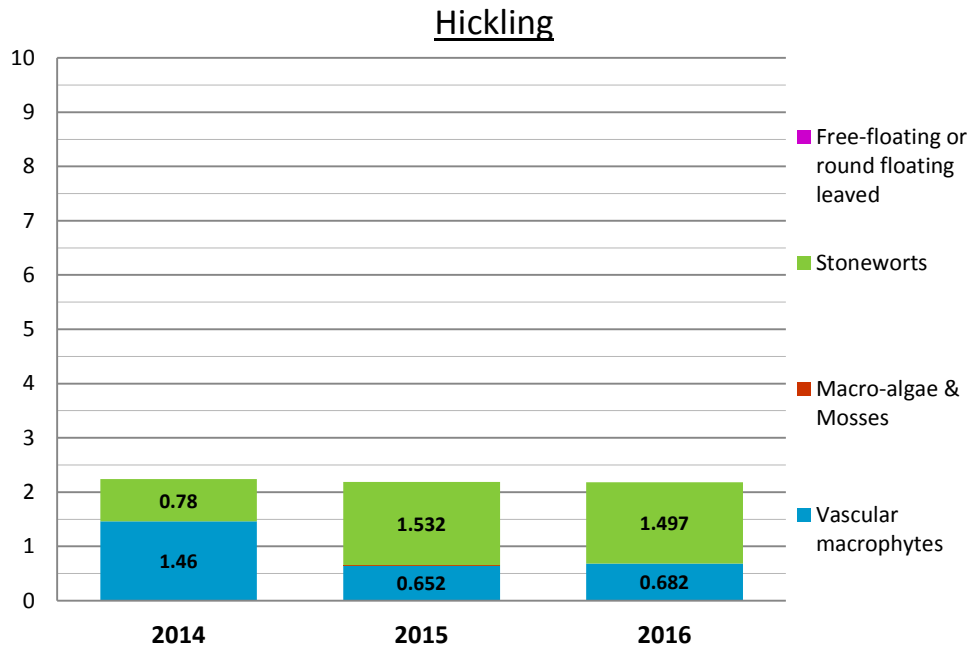
There has been a slight decrease in abundance this year, particularly intermediate stonewort and rigid hornwort. Conversely on the upside there has been the addition of bristly stonewort this year. Beds of mare's tail were seen in the more sheltered areas outside of the marked channel and there was some reed encroachment at the entrance to Duck Broad.



c. Hickling

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Intermediate stonewort	*Chara intermedia*	0.663	28
Baltic stonewort	*Chara baltica*	0.491	17
Spiked water milfoil	*Myriophyllum spicatum*	0.464	53
Holly-leaved naiad	*Najas marina*	0.199	17
Hedgehog stonewort	*Chara pedunculata*	0.128	2
Fragile/convergent stonewort	*Chara globularis/connivens*	0.079	8
Bristly stonewort	*Chara hispida*	0.079	5
Rough stonewort	*Chara aspera*	0.055	6
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.018	5
Convergent stonewort	*Chara connivens*	0.001	1
Stonewort (Chara) species	*Chara sp.*	0.001	1
Curled pondweed	*Potamogeton crispus*	0.001	1
Total number of species recorded		**12**	**Total samples taken 78**

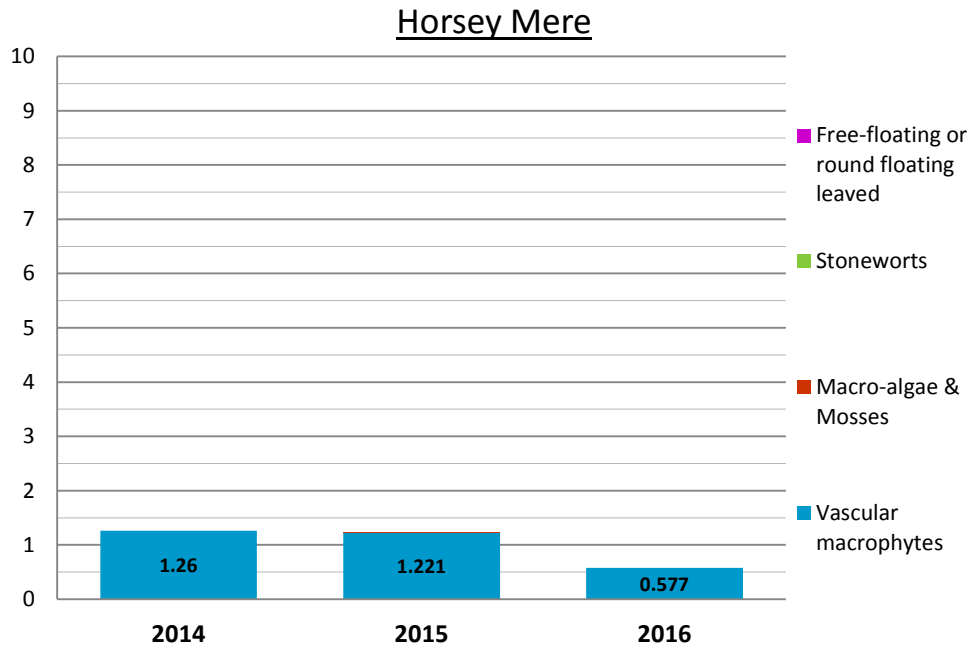
Hickling has had a similar total abundance score to last year, as seen below in the graph, indeed even the groupings look similar, however the composition of the species has changed and the number of species recorded has decreased. Two of the more common species were not recorded this year rigid hornwort and mare's tail. The southern section of the marked channel noticeably lacked plant growth along with the basin in front of the Pleasure boat inn dyke, this is understandable as a considerable amount of dredging has taken place here.



d. Horsey Mere

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Mare's tail	*Hippuris vulgaris*	0.459	16
Spiked water milfoil	*Myriophyllum spicatum*	0.111	36
Rigid hornwort	*Ceratophyllum demersum*	0.003	2
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.002	1
Perfoliate pondweed	*Potamogeton perfoliatus*	0.002	1
Total number of species recorded		**5**	**Total samples taken 66**

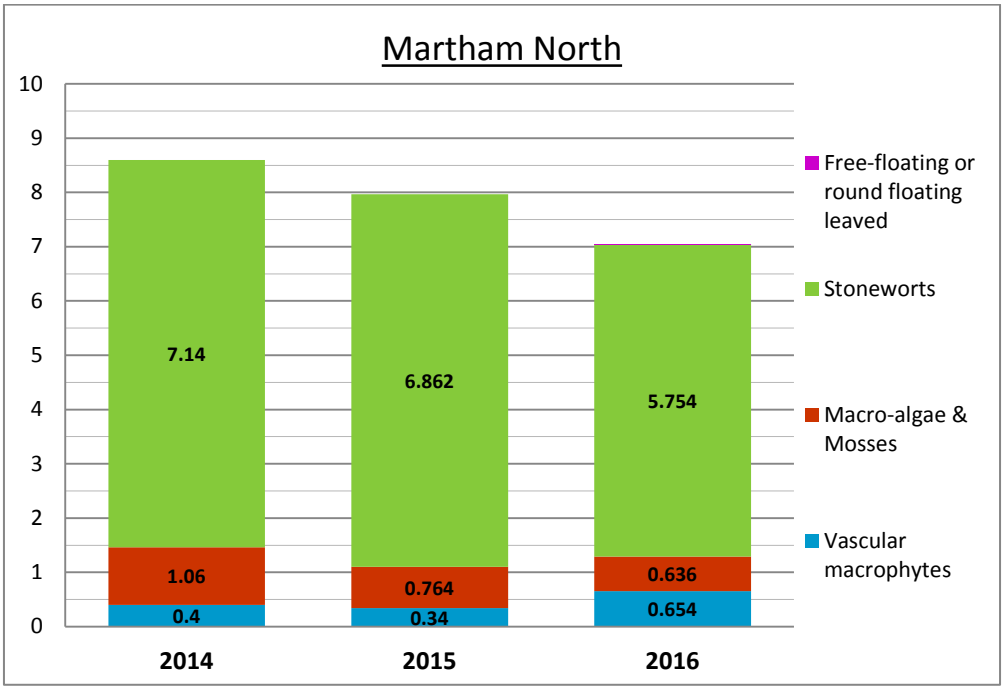
This year has seen a slight decrease in the quantity of mare's tail recorded on the survey. A new record was found this year perfoliate pondweed (*Potamogeton perfoliatus*), located in the southern bay close to Meadow Dyke.



e. Martham North

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Bristly stonewort	*Chara hispida*	5.586	40
Filamentous algae	*Zygnematales*	0.636	14
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.442	7
Holly-leaved naiad	*Najas marina*	0.190	13
Intermediate stonewort	*Chara intermedia*	0.104	7
Smooth stonewort	*Nitella flexilis*	0.040	1
Lesser pondweed	*Potamogeton pusillus*	0.022	2
Fragile/convergent stonewort	*Chara globularis/connivens*	0.020	1
Opposite stonewort	*Chara contraria*	0.002	1
Stonewort (Chara) species	*Chara sp.*	0.002	1
Ivy-leaved duckweed	*Lemna trisulca*	0.002	1
Total number of species recorded		**11**	**Total samples taken 50**

This year there is an increase in the number of species found within Martham North, however there has also been a slight decrease in the abundance score. Horned pondweed which was plentiful last year was absent in 2016, conversely intermediate stonewort has resurfaced after an absence last year. Mare's tail was observed at a few locations within the broad but not acquired in the survey. In the south east corner of the broad beds of smooth stonewort were seen below the boat. Beds of mares's tail and water lily (white and yellow) along with islets of reed denote a separation of this broad from the river, alas the three former species were not picked up during the survey.

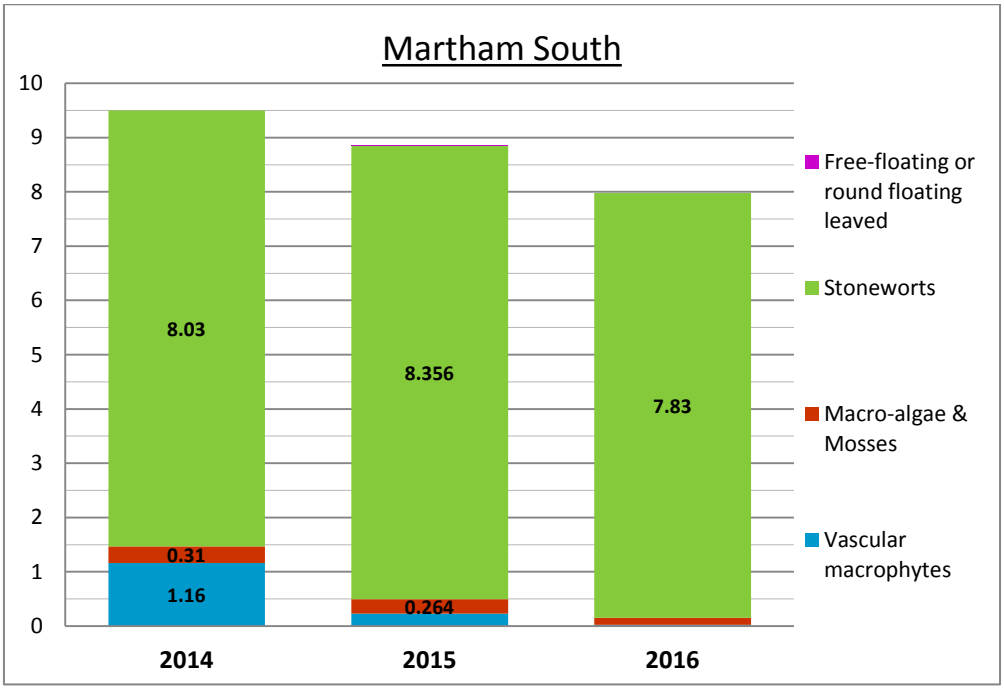


f. Martham South

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Bristly stonewort	*Chara hispida*	6.400	39
Intermediate stonewort	*Chara intermedia*	1.062	7
Filamentous algae	*Zygnematales*	0.128	19
Convergent stonewort	*Chara connivens*	0.120	1
Hedgehog stonewort	*Chara pedunculata*	0.106	7
Rough stonewort	*Chara aspera*	0.080	1
Fragile/convergent stonewort	*Chara globularis/connivens*	0.040	2
Baltic stonewort	*Chara baltica*	0.020	1
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.020	1
Stonewort (Chara) species	*Chara sp.*	0.002	1
Mare's tail	*Hippuris vulgaris*	0.002	1
Total number of species recorded		**11**	**Total samples taken 48**

When Martham South was visited in 2016 the water levels were lower than expected which meant that two samples where not collected. The lower water level could also have contributed to the lower numbers of plants recorded, with the pondweeds and other vascular plants being less prevalent in this years survey. Bristly stonewort was the second

most abundant species in 2015 but topped the adundance table this year. It was also a good year for hedgehog and rough stonewort which were found in more quantities and more locations respectively.



3.3.2 Ant Valley

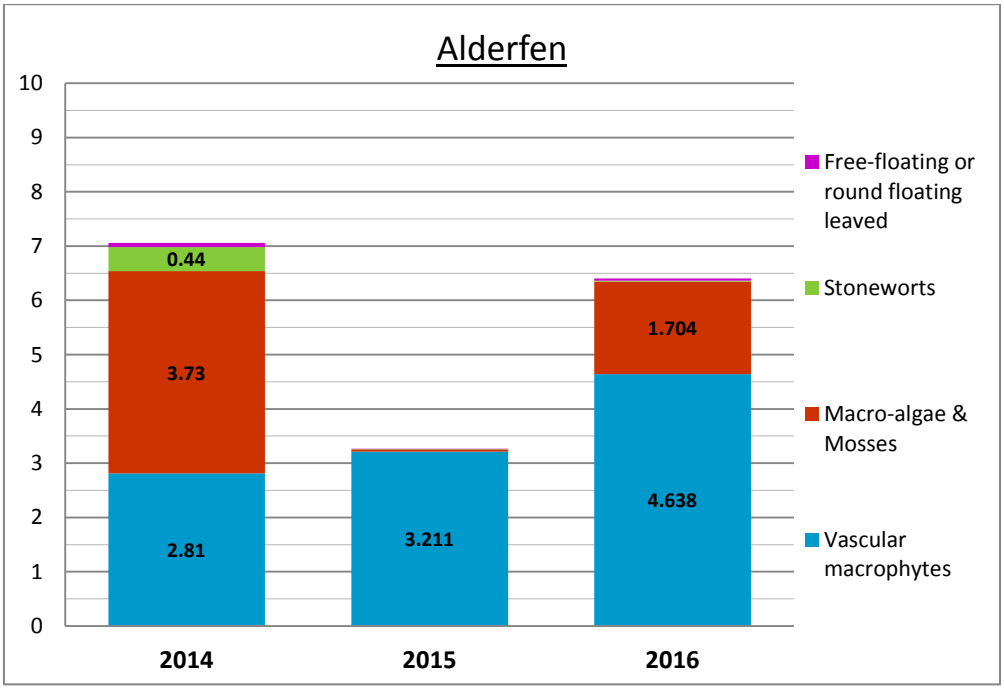
In the Ant Valley, Alderfen, Cromes and Barton broad were some of the first broads surveyed in 1983 and have been regularly surveyed since. These water bodies have been subject to extensive restoration effort over the last 25 years, and all have experienced improved water quality.

g. Alderfen

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Rigid hornwort	*Ceratophyllum demersum*	3.648	46
Filamentous algae	*Zygnematales*	1.704	43
Holly-leaved naiad	*Najas marina*	0.946	37
Ivy-leaved duckweed	*Lemna trisulca*	0.046	3
Intermediate water-starwort	*Callitriche stagnalis*	0.042	1
Stonewort (*Chara*) species	*Chara sp.*	0.010	5
Fragile/convergent stonewort	*Chara globularis/connivens*	0.008	4
Pondweed species	*Potamogeton sp.*	0.002	1
Total number of species recorded		**8**	**Total samples taken 48**

This year Alderfen returns to an overall abundance score similar to that attained in 2014. As such there was an increase in number of species and abundance from the 2015 dip, however there was also an increase in the amount of filamentous algae but thankfully not to the quantities found in 2014. Gelatinous algae was found throughout the broad usually attached to stems of rigid hornwort, however it is a type of microalgae and as such it is not

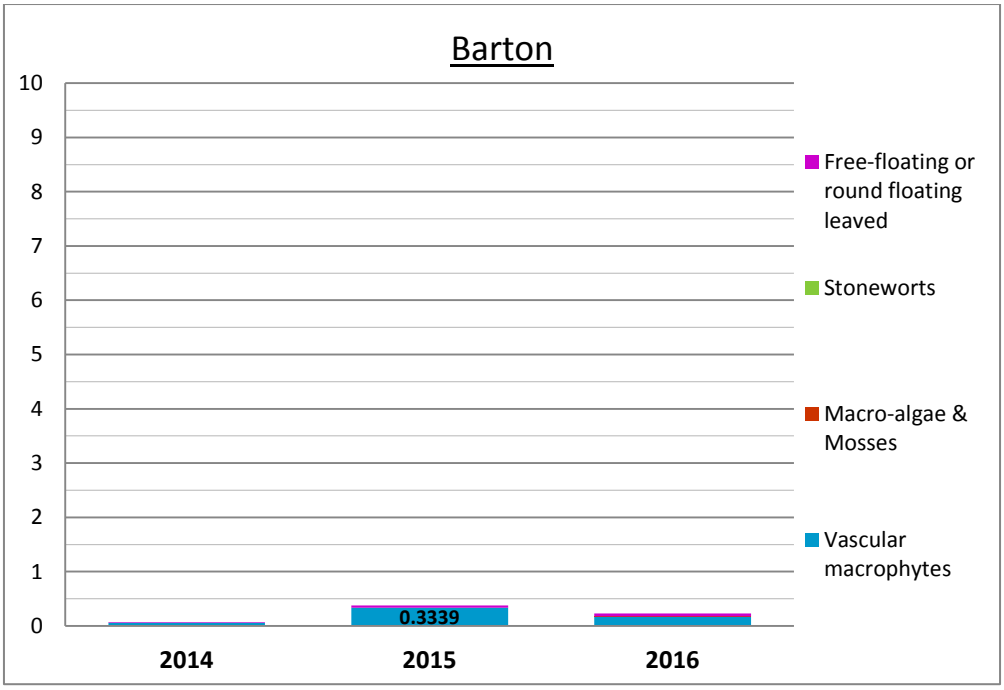
included in this survey. Thick beds of holly-leaved naiad were seen in the north and centre of the broad.



h. Barton

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.111	16
Yellow water lily	*Nuphar lutea*	0.056	2
Nuttall's waterweed	*Elodea nuttallii*	0.043	3
Rigid hornwort	*Ceratophyllum demersum*	0.017	3
Filamentous algae	*Zygnematales*	0.003	2
Perfoliate pondweed	*Potamogeton perfoliatus*	0.001	1
Total number of species recorded		**6**	**Total samples taken 78**

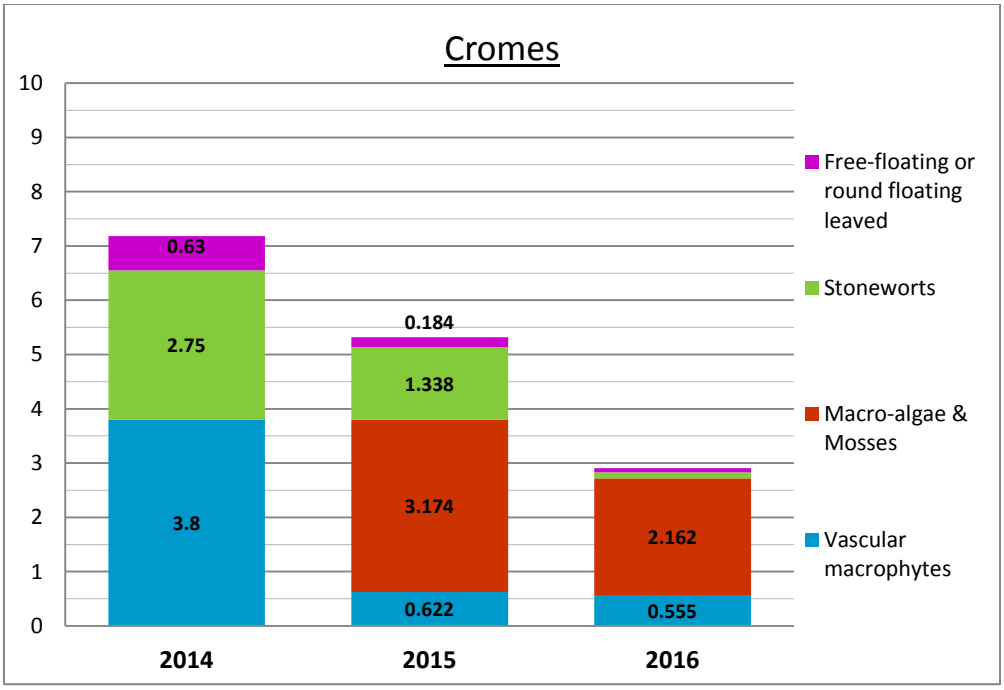
This broad's low species abundance trend continued in 2016, although a new species was recorded this year perfoliate pondweed which is a distinctive broader leaved pondweed. Yellow and white water lilies were seen near the entrance of Hall Dyke but only yellow water lilies were obtained at the rake survey points.



i. Cromes Broad

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Filamentous algae	*Zygnematales*	2.157	31
Water-soldier	*Stratiotes aloides*	0.262	5
Greater bladderwort	*Utricularia vulgaris*	0.171	8
Fragile/convergent stonewort	*Chara globularis/connivens*	0.105	8
White water lily	*Nymphaea alba*	0.071	1
Rigid hornwort	*Ceratophyllum demersum*	0.048	11
Lesser pondweed	*Potamogeton pusillus*	0.026	2
Canadian waterweed	*Elodea canadensis*	0.024	1
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.024	1
Ivy-leaved duckweed	*Lemna trisulca*	0.007	3
Enteromorpha	*Enteromorpha*	0.005	2
Opposite stonewort	*Chara contraria*	0.002	1
Stonewort (*Chara*) species	*Chara sp.*	0.002	1
Stonewort (*Nitella*) species	*Nitella sp.*	0.002	1
Total number of species recorded		**15**	**Total samples taken 42**

Filamentous algae continues to be the most abundant species in Cromes Broad, it appears to be to the detriment of the quantity of other species within the broad. Filamentous algae with some *Enteromorpha* spp. were strewn across the surfaces of the two basins. There is also some reed encroachment at the entrance to the broad. White water lilies were seen on both basins but yellow water lily was only observed on the northern basin. Around the peat baulk which separates the north and south basins greater bladderwort could be seen in flower. A freshwater sponge was found attached to a stem within the northern basin.



3.3.3 Bure Valley

In recent years Upton and Cockshoot Broads, both isolated from the river, have been a stronghold for the rare holly-leaved naiad. Those broads directly connected to the river, such as Wroxham and Hoveton Great tend to have minimal plant diversity. The survey programme for this valley in 2016 also included some other broads which are not directly connected to the river, or detached completely.

j. Burntfen

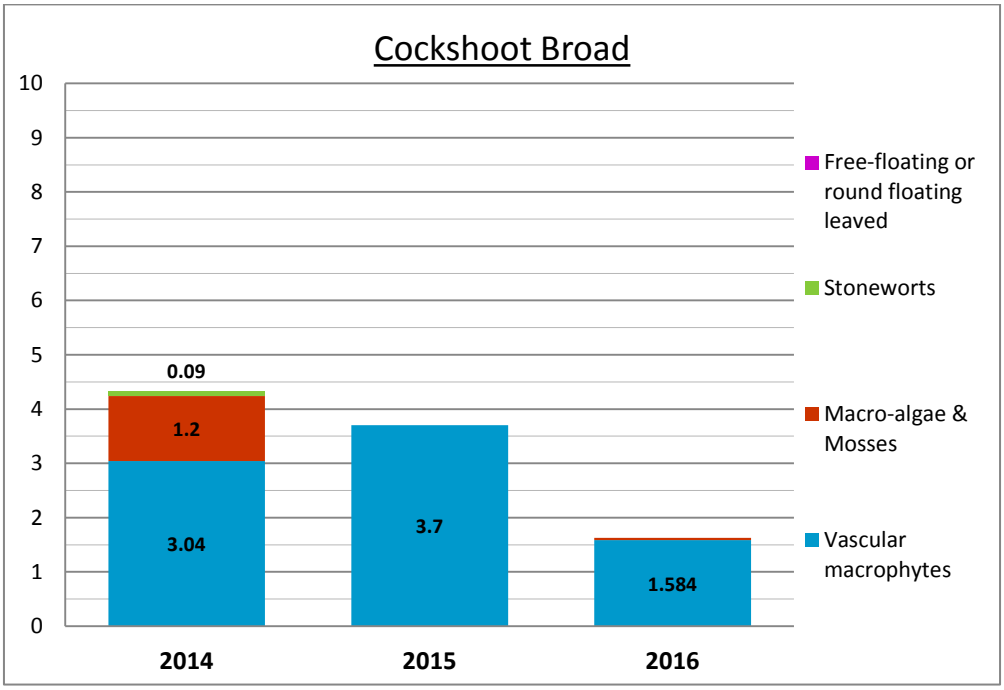
Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Yellow water lily	*Nuphar lutea*	0.158	4
Total number of species recorded		**1**	**Total samples taken 38**

A lovely isolated broad, however water lilies appear to be dominant and only plants which grow on the main water body. Yellow water lilies were the only species obtained on the survey however some white water lilies were also observed in a few areas. The dyke which leads onto the broad has a collection of species such as Greater duckweed (*Spirodela polyrhiza*), common duckweed (*Lemna minor*) and yellow water lily along with some reed encroachment; alas all of this is out of the survey area.

k. Cockshoot Broad

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Holly-leaved naiad	*Najas marina*	1.288	41
Rigid hornwort	*Ceratophyllum demersum*	0.296	21
Filamentous algae	*Zygnematales*	0.042	1
Total number of species recorded		**3**	**Total samples taken 48**

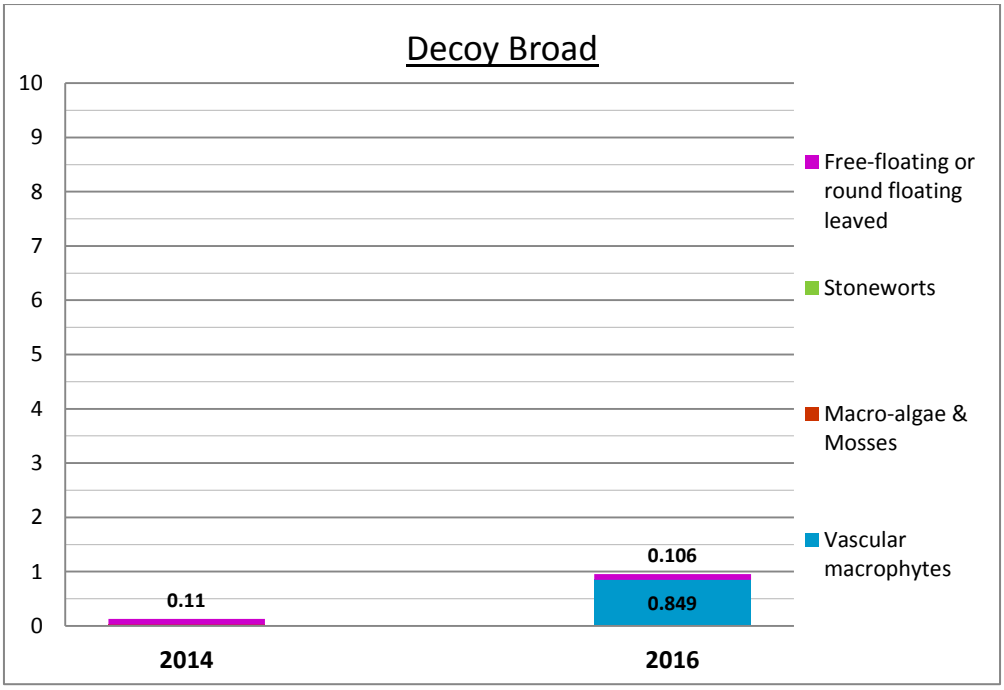
Cockshoot broad continues to be home to large beds of the rare holly-leaved naiad. This year the naiad still dominated but was not as prolific. The second most abundant species, rigid hornwort, had increased its hold slightly this year. The water this year was somewhat cloudy on the day of the survey. Yellow water lily and white water lily were seen on the broad but not gathered during the survey.



l. Decoy

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Rigid hornwort	*Ceratophyllum demersum*	0.839	28
Yellow water lily	*Nuphar lutea*	0.104	9
Nuttall's waterweed	*Elodea nuttallii*	0.004	2
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.004	2
Holly-leaved naiad	*Najas marina*	0.002	1
Total number of species recorded		**5**	**Total samples taken 46**

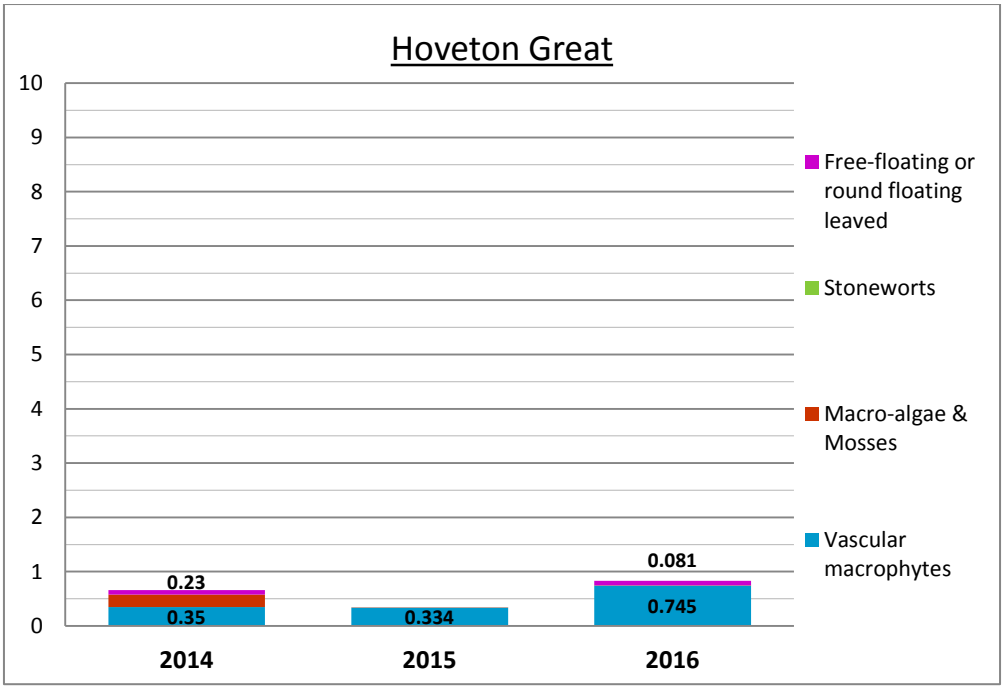
This private broad typically has a stable plant abundance level. This year is no exception; there was a slight increase from the last time it was surveyed in 2014 with increase species numbers, one of which was the rare holly-leaved naiad. White water lily was also seen but not recorded, usually in sheltered areas and in the dykes which connect the broad to the river. In addition some sponges were found attached to the stems of rigid hornwort and an otter was observed skirting around the eastern edge of the broad.



m. Hoveton Great

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Rigid hornwort	*Ceratophyllum demersum*	0.721	54
Yellow water lily	*Nuphar lutea*	0.081	1
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.019	3
Filamentous algae	*Zygnematales*	0.005	3
Nuttall's waterweed	*Elodea nuttallii*	0.003	2
Curled pondweed	*Potamogeton crispus*	0.002	1
Total number of species recorded		**6**	**Total samples taken 60**

This broad is stable at a low plant abundance level. Last year saw a slight dip in the number of species found; this year it has returned the usual six species, with an increase in the number of places where rigid hornwort was found. Other species which were observed but not picked up in the survey include Unbranched bur-reed (*Sparganium emersum*) which was near the entrance to the area known as the Dam which links the broad to the river and is home to big rafts of water lilies. White water lily was seen in one of the southern bays. There was also some reed encroachment at the northern tip of the broad.



n. Little

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Filamentous algae	*Zygnematales*	3.582	23
Bristly stonewort	*Chara hispida*	2.579	15
Greater bladderwort	*Utricularia vulgaris*	0.107	3
Ivy-leaved duckweed	*Lemna trisulca*	0.007	2
Total number of species recorded		**4**	**Total samples taken 28**

This broad was last surveyed in 2013, it was noticed then that there had been a decline in species number with only two species found, the dominant one being filamentous algae. Things are more positive this year, four species were found. Alas filamentous algae is still the most abundant but the nationally important bristly stonewort is the next most abundant species. Hopefully the decline seen in 2013 has halted and the spread of filamentous algae will decrease to a more acceptable level. Interestingly a red freshwater sponge was found growing on a bristly stonewort stem.

o. Mautby Decoy

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Rigid hornwort	*Ceratophyllum demersum*	3.513	40
Filamentous algae	*Zygnematales*	2.055	36
Ivy-leaved duckweed	*Lemna trisulca*	0.245	34
Common duckweed	*Lemna minor*	0.080	14
Stonewort (*Nitella*) species	*Nitella sp.*	0.003	1
Amphibious bistort	*Polygonum amphibium*	0.003	1
Lesser pondweed	*Potamogeton pusillus*	0.003	1
Pondweed species	*Potamogeton sp.*	0.003	1
Total number of species recorded		**8**	**Total samples taken 40**

Mautby Decoy was last surveyed in 2010, the number of species found there has increased, but there has been a loss in the diversity and abundance of stoneworts. The once dominant opposite stonewort is gone, replaced by rigid hornwort and filamentous algae. Both of these in the quantities found would indicate that the broad is suffering from nutrient enrichment. On a positive note a small amount of a *Nitella* stonewort was found within the broad, a sponge was also found attached to a stem.

---

p. Nortons

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Filamentous algae	*Zygnematales*	3.550	23
Nuttall's waterweed	*Elodea nuttallii*	1.258	19
Common duckweed	*Lemna minor*	0.204	17
Yellow water lily	*Nuphar lutea*	0.042	2
Starwort species	*Callitriche sp*	0.012	3
Enteromorpha	*Enteromorpha*	0.008	2
Total number of species recorded		**6**	**Total samples taken 26**

This broad is usually surveyed in conjunction with Belaugh Broad; however we were only able to access Nortons this year. This broad was last surveyed in 2011 then the most abundant species was a starwort. Filamentous algae has outcompeted the starwort and now covers much of the broad, yellow water lilies have also established themselves. The quantity of the filamentous algae, does indicate that perhaps there is some enrichment happening.

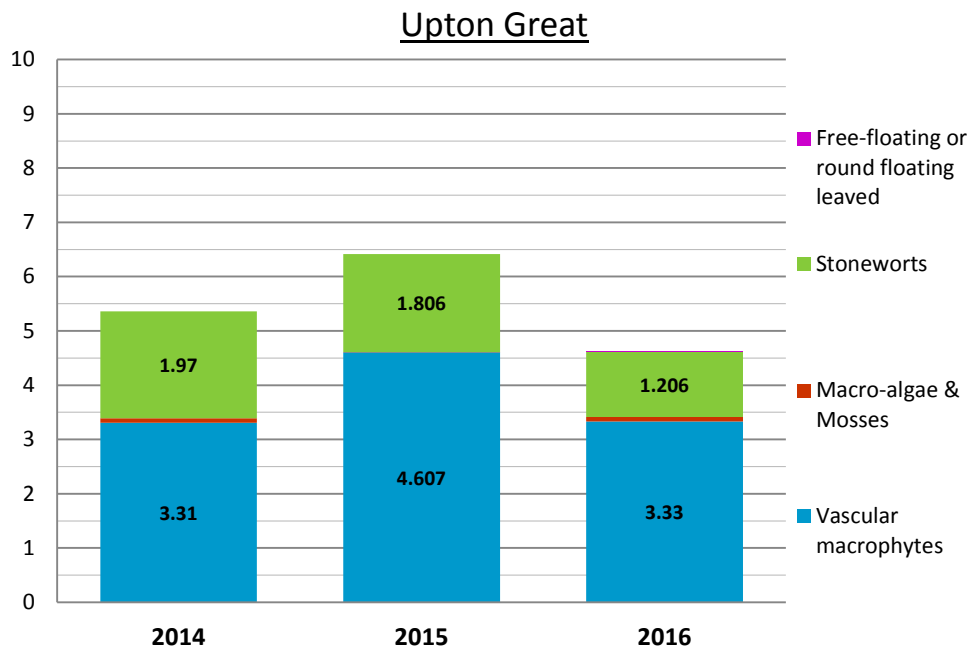
---

q. Upton Great

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Holly-leaved naiad	*Najas marina*	3.330	29
Opposite stonewort	*Chara contraria*	1.089	12
Smooth stonewort	*Nitella flexilis*	0.370	2
Filamentous algae	*Zygnematales*	0.083	11
Bristly stonewort	*Chara hispida*	0.065	1
Rough stonewort	*Chara aspera*	0.043	1
Stonewort (*Chara*) species	*Chara sp.*	0.009	4
Common duckweed	*Lemna minor*	0.002	1
Rootless duckweed	*Wolffia arrhiza*	0.002	1
Total number of species recorded		**9**	**Total samples taken 46**

Upton Great has been relatively consistent over the years; usually diversity of plants within the broad is generally low, but with relatively high abundances. This broad still has relatively high abundance, but this year there has be an increase in species number, with duckweeds recorded in small quantities.

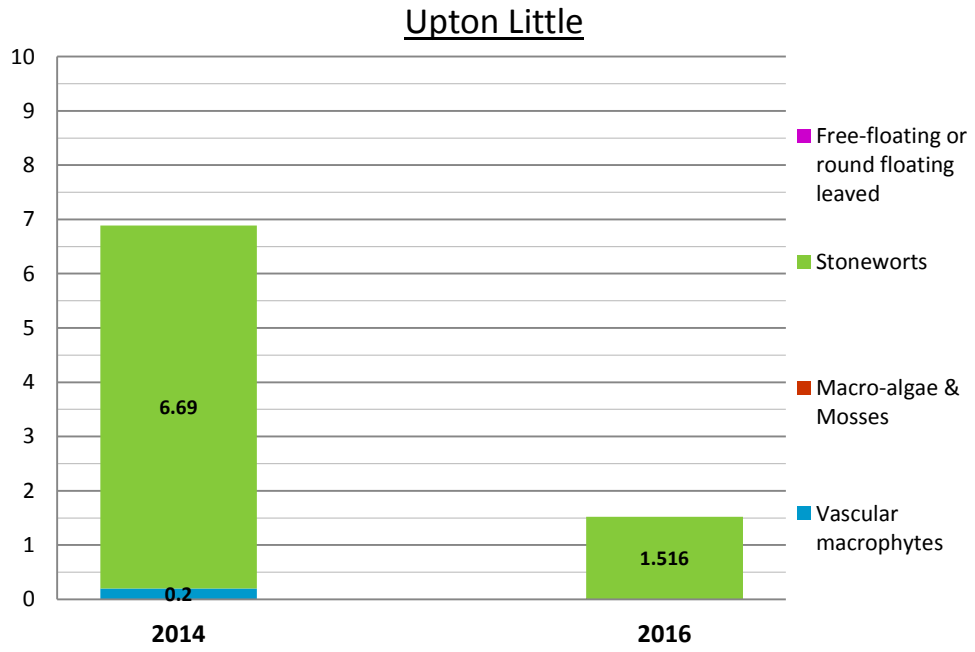
This broad is also a stable stronghold for holly-leaved naiad however this year it appears that there was a reduction in the number of locations where it was found and an increase in the amount of filamentous algae.



r. Upton Little

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Bristly stonewort	*Chara hispida*	1.450	21
Common stonewort	*Chara vulgaris*	0.063	1
Baltic stonewort	*Chara baltica*	0.003	1
Holly-leaved naiad	*Najas marina*	0.003	1
Filamentous algae	*Zygnematales*	0.003	1
Total number of species recorded		**5**	**Total samples taken 32**

While there has been an increase in number of species at Upton Little Broad, most of these were found in small amounts at single locations. Bristly stonewort appears to be the dominant species; however its abundance has decreased since 2014 when it was last surveyed. Vascular macrophytes other than holly-leaved naiad were not found this year. Gelatinous micro-algae was recovered at a few sites within the broad, the infrequent wisp of blue green algae was also seen.

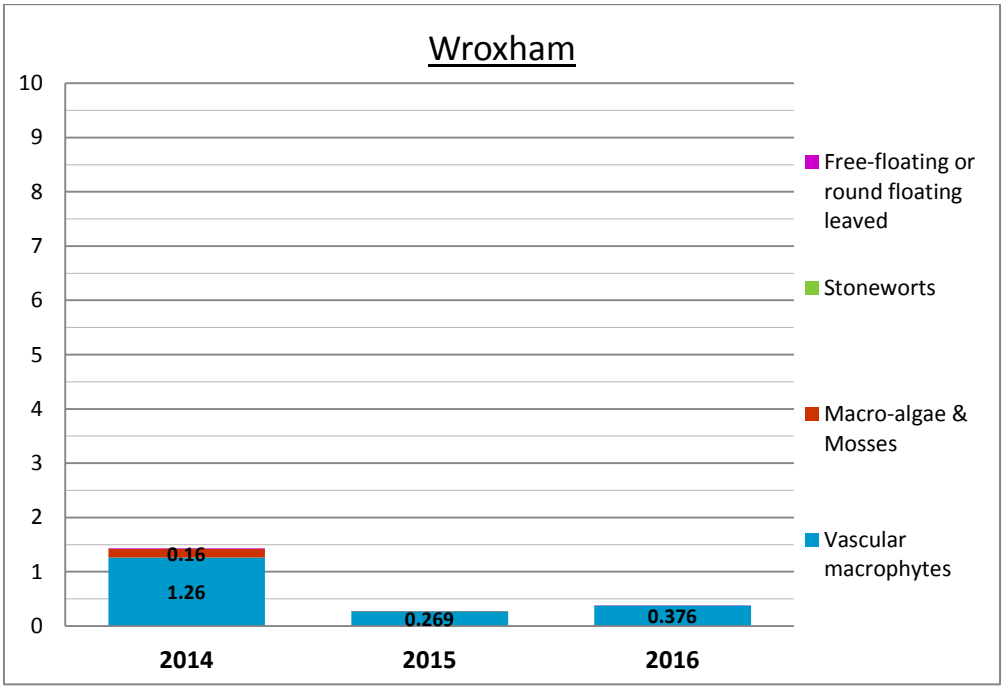


s. Wroxham

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Rigid hornwort	*Ceratophyllum demersum*	0.316	21
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.053	16
Horned pondweed	*Zannichellia palustris*	0.005	3
Nuttall's waterweed	*Elodea nuttallii*	0.002	1
Yellow water lily	*Nuphar lutea*	0.002	1
Total number of species recorded		**5**	**Total samples taken 64**

Species abundance is remains quite low within Wroxham broad. Rigid hornwort is still the most common species. An interesting addition this year is horned pondweed (*Zannichellia*

palustris) which resembles a fine leaved Potamogeton and has not been recorded here since 2011.



3.3.4 Yare Valley

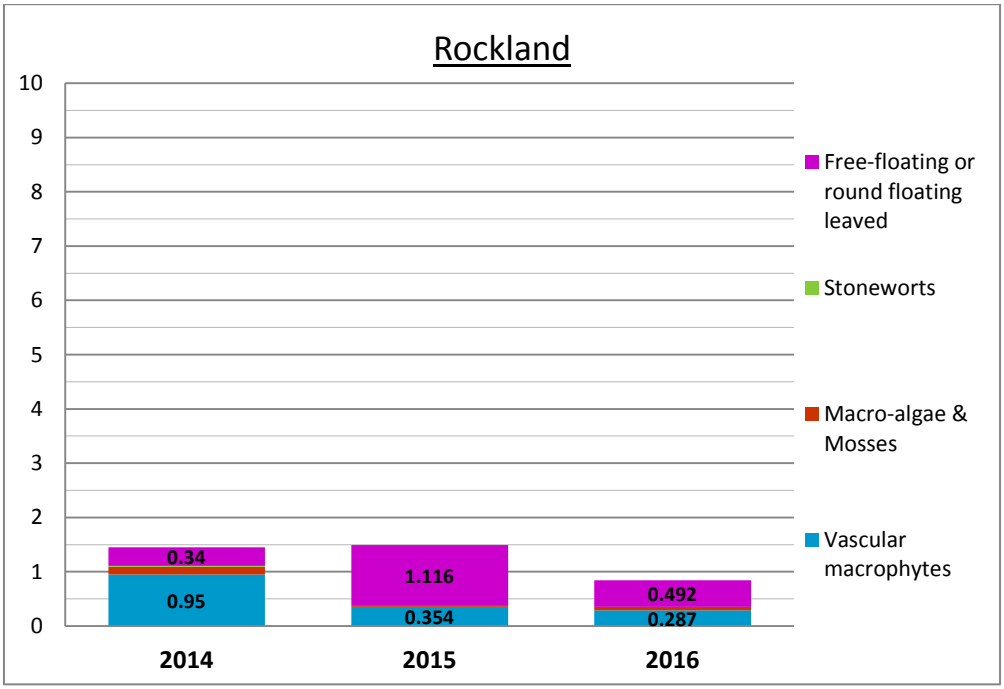
The majority of the broads within the Yare valley are isolated from the main river, with only Rockland and Wheatfen having a direct hydrological connection.

t. Rockland

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Yellow water lily	*Nuphar lutea*	0.492	20
Spiked water milfoil	*Myriophyllum spicatum*	0.142	29
Rigid hornwort	*Ceratophyllum demersum*	0.094	35
Common Water moss	*Fontinalis antipyretica*	0.055	8
Unbranched bur-reed	*Sparganium emersum*	0.026	8
Nuttall's waterweed	*Elodea nuttallii*	0.014	9
Filamentous algae	*Zygnematales*	0.009	6
Crowfoot species	*Ranunculus sp.*	0.003	2
Starwort species	*Callitriche sp*	0.002	1
Intermediate water-starwort	*Callitriche stagnalis*	0.002	1
Holly-leaved naiad	*Najas marina*	0.002	1
Stonewort (*Nitella*) species	*Nitella sp.*	0.002	1
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.002	1
Total number of species recorded		**13**	**Total samples taken 62**

The most dominant species on Rockland broad is yellow water lily, rafts of make it difficult to access some of the survey points, particularly near the bird hide. There has been an increase in the number of species found this year; a nice addition was a small piece of a *Nitella* stonewort species which was found at one of the last points. Unbranched bur-reed

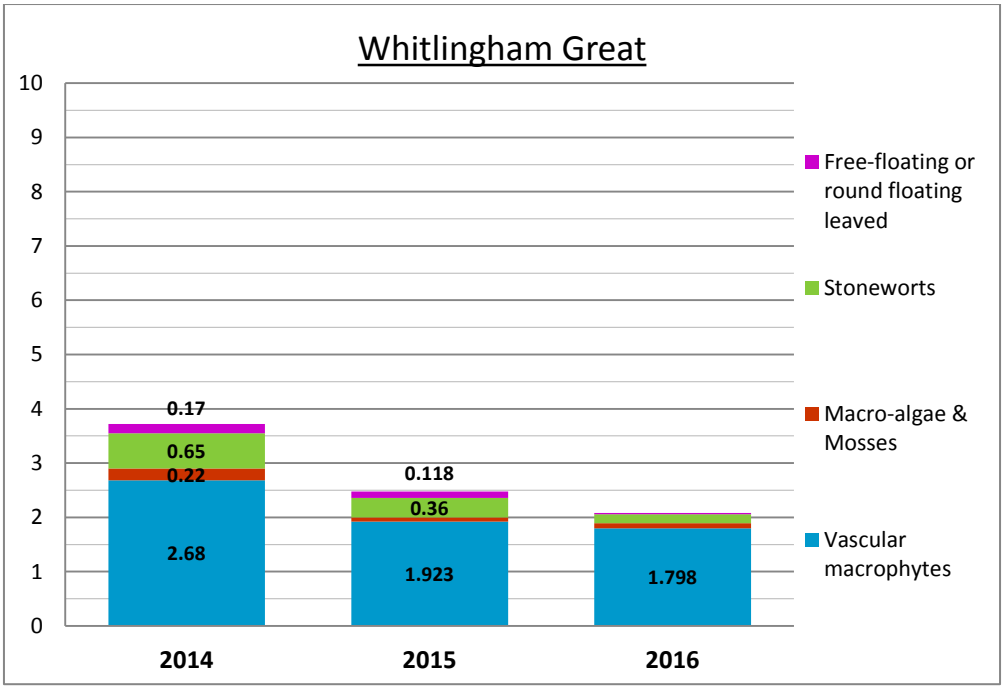
was found where the river enters the broad; this species is more typically found within the slow moving rivers.



u. Whitlingham Great

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Nuttall's waterweed	*Elodea nuttallii*	1.181	39
Flat-stalked pondweed	*Potamogeton friesii*	0.316	21
Lesser pondweed	*Potamogeton pusillus*	0.191	7
Rough stonewort	*Chara aspera*	0.095	3
Filamentous algae	*Zygnematales*	0.095	23
Common stonewort	*Chara vulgaris*	0.064	2
Small pondweed	*Potamogeton berchtoldii*	0.063	2
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.031	2
Ivy-leaved duckweed	*Lemna trisulca*	0.023	15
Rigid hornwort	*Ceratophyllum demersum*	0.008	5
Canadian waterweed	*Elodea canadensis*	0.005	3
Stonewort (Nitella) species	*Nitella sp.*	0.003	2
Curled pondweed	*Potamogeton crispus*	0.003	2
Delicate stonewort	*Chara virgata*	0.002	1
Total number of species recorded		**14**	**Total samples taken 64**

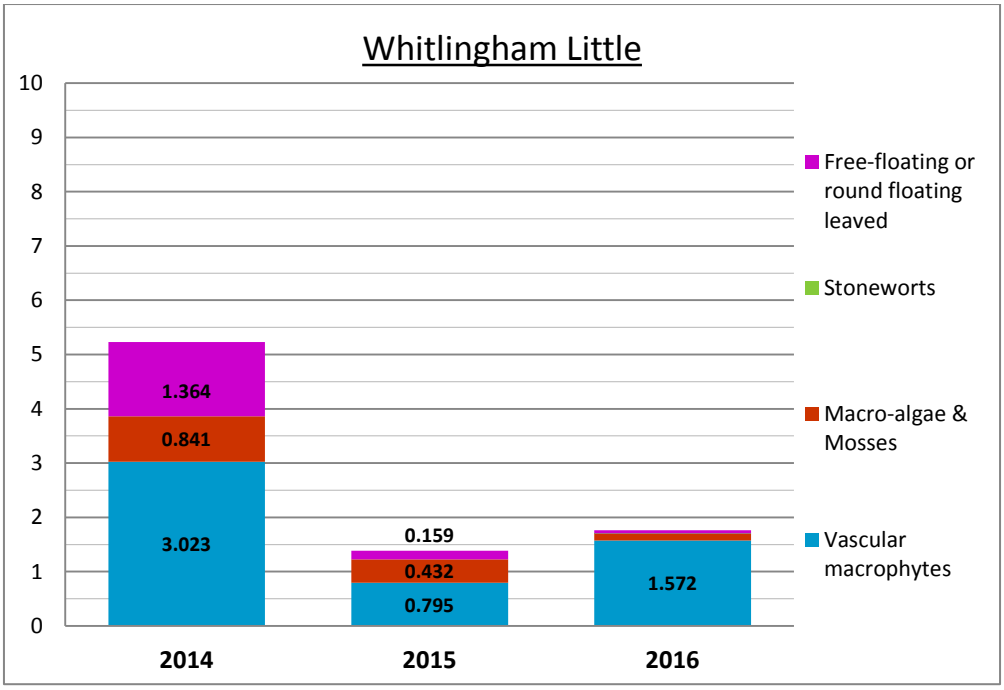
The species abundance at Whitlingham Great Broad is similar to the score given in 2015. The stonewort numbers have slightly decreased, lesser pondweed, on the other hand, has increased. The island within the broad is surrounded by large beds of stonewort, and the near the south east of the broad a raft of amphibious bistort was observed.



v. Whitlingham Little

Common Name	Scientific Name	Summary Abundance	Number of samples where recorded
Nuttall's waterweed	*Elodea nuttallii*	1.239	36
Curled pondweed	*Potamogeton crispus*	0.161	5
Filamentous algae	*Zygnematales*	0.132	31
Fennel-leaved pondweed	*Potamogeton pectinatus*	0.093	2
Rigid hornwort	*Ceratophyllum demersum*	0.075	6
Common stonewort	*Chara vulgaris*	0.055	5
Ivy-leaved duckweed	*Lemna trisulca*	0.055	15
Stonewort (*Chara*) species	*Chara sp.*	0.025	2
Fragile/convergent stonewort	*Chara globularis/connivens*	0.007	3
Delicate stonewort	*Chara virgata*	0.005	2
Canadian waterweed	*Elodea canadensis*	0.002	1
Amphibious bistort	*Polygonum amphibium*	0.002	1
Total number of species recorded		**12**	**Total samples taken 44**

This broad has previously been subject harmful blue-green algae blooms. To combat this, floating nets of barley straw were used in 2015 to eliminate a spring bloom. This year the nets were deployed before the beginning of the growing season thus creating inhospitable conditions for blue-green algae. As such the summary abundance score has increased and there is an increase in the number of different species within the broad. In addition very small amount of stoneworts have returned to the broad. The numbers still have not returned to those found in 2014, but with the continued treatment, the health of the broad should improve.



3.3.5 Waveney Valley

There are six broads along the Waveney valley which are within the Broads Authority executive area, these are; Barnby, Spratt's Water, Woolner's Carr, Round Water, Flixton Decoy and Oulton Broad. The surveying of these broads was centred on monitoring the progress of the broads following restoration programmes. Round Water, Spratt's Water and Woolner's Carr were surveyed this year are some of the smaller ones within the Norfolk and Suffolk Broads, but they are superb, with unique plant communities.

w. Round Water

Common Name	Scientific Name	Summery Abundance	Number of samples where recorded
Ivy-leaved duckweed	*Lemna trisulca*	4.625	7
Rootless duckweed	*Wolffia arrhiza*	0.500	1
Total number of species recorded		**2**	**Total samples taken 8**

The middle broad in this collection, the water here is very clear the ivy-leaved duckweed could be seen suspended within the water column along with the occasional plume of frogbit, which sadly was not captured in the survey. There was some reed encroachment at the southern point of the broad.

x. Spratt's Water

Common Name	Scientific Name	Summery Abundance	Number of samples where recorded
Common duckweed	*Lemna minor*	1.538	16
Ivy-leaved duckweed	*Lemna trisulca*	0.606	14
Enteromorpha	*Enteromorpha*	0.375	15
Total number of species recorded		3	Total samples taken 16

This is the northern most broad in this collection and the only broad without any shading from nearby trees. It also had very clear water, once the duckweed and floating algae was parted, although it was difficult to do this as common duckweed covered this broad. This broad also had ribbons of bright green algae (*Enteromorpha* spp.) on the surface.

---

y. Woolner's Carr

Common Name	Scientific Name	Summery Abundance	Number of samples where recorded
Ivy-leaved duckweed	*Lemna trisulca*	3.625	8
Common duckweed	*Lemna minor*	0.650	6
Total number of species recorded		2	Total samples taken 8

Ivy-leaved duckweed dominates here, unlike the other two broads the water clarity here is poor and the sediment which is inevitably collected on the rake when conducting the survey is quite pungent. This broad also had some reed encroachment.

3.4 Conclusions

- This year has seen a shift in dominant species in a few of the regularly surveyed broads. However, it must be noted that water plants can be very variable between years and between broads, hence the value of a long-term monitoring strategy. The underlying cause why a certain plant species outcompetes another in a particular year can be related to a whole host of reasons including; competition for light early in the growth season; water levels; nutrient availability, etc. Those broads which had a change in dominant species were; Decoy Broad, Mautby Decoy, Rockland Broad, and Whitlingham Little Broad.
- The broads which showed a noticeable decrease in abundance scores over the past three years include Cockshoot Broad, Cromes Broad and Upton Little Broad.
  - Cockshoot appeared to have had a 64% decrease in holly-leaved naiad abundance compared to 2015. This could be due to the natural environmental conditions not being ideal here in 2016.
  - Cromes has had a decrease in the abundance of stoneworts over the past three years, over 50% from 2014 to 2015 and then a further decrease in 2016. The increased levels of filamentous algae found in 2015 and 2016 appear to have been at the expense of the vascular plants and stoneworts. Due to this increase in filamentous algae and decrease in the rarer plants, nutrient enrichment may be one possible cause, alongside natural variability in plant species abundances. An

investigation into the water quality data is suggested to help determine the significance of external nutrient sources on water plant growth.

  - Upton Little has had a large decrease in the quantity of stoneworts surveyed since 2014. This trend is suggestive of an on-going stabilisation of the plant community following the huge explosion of stoneworts immediately following the mudpumping in 2011.

- Many of the other broads have either stayed at a level close to or just below the summery abundance score obtained in 2015.
- Over the past three years broads which showed a noticeable increase in their abundance scores include; Alderfen Broad, Decoy Broad and Little Broad. Alderfen has returned to a condition similar to that from 2014 although without the same quantity of stonewort. Decoy has an increased number of species recorded and the quantities therein. At Little Broad, stoneworts have returned in moderate numbers although not to the same peak in growth found in 2010 and the years immediately after mud pumping in 2008.

4 River Plant Survey

4.1 Introduction

The aim of the river plant survey is similar with the Broads water plant survey, which is to monitor water plants within specified lengths of river or man-made watercourse, along previously defined sections between early June and late July, using the methodology outlined in section 5.2 below. Ideally the river plant survey should be completed, or near enough completed, before the commencement of the Broads water plant survey in July.

The river plant survey is a point based system similar to the broad's plant survey. The results are used to inform maintenance work which is carried out within these waterways, such as weedcutting.

4.2 Survey Methodology

4.2.1 Selection

a. The waterways surveyed need to meet a few criteria in order to be selected:

   - Foremost the section must be within the Broads executive area
   - The section must be publically navigable thus excluding private dykes or cuts

b. Once a section is chosen, it is measured using a mapping tool and the number of 10 m lengths at 5% of the total potential survey length is plotted, acquiring a representational coverage of the waterway.

c. Sectors are then plotted at each end of these 10 m lengths. A sector is a cross section of the watercourse.

d. Each sector will contain points where the sampling is conducted these range from two to five depending on the width of the watercourse.

e. An aerial photograph of each selected site was produced on which each of the sectors was marked. On the reverse there is a list of the grid references for each numbered sector.

4.2.2 Field method

a. In the field, surveyors used the grid references of each plotted point to identify the point's location. The survey boat navigated to each point using a handheld GPS device.

b. Once within 5 m of the plotted grid reference, a decision is made on the number of points to use within the sector.

c. Mud weights were deployed to keep the boat in the correct location at each of the cross section of points.

d. A double headed survey rake was thrown downstream a distance of 5m from the boat edge. The rake was left for 10 seconds to sink to the bottom after which the rake was pulled slowly and steadily along the bed of the broad, back towards the boat. For points that were in deeper water, additional rope was thrown to allow the rake to sink and rest on the bed of the lake at a distance of 5m from the edge of the boat. Each sample was recorded separately, for subsequent analysis.

e. On retrieval of each rake, the plants attached to the rake head were collected in a white survey tray. If necessary, plants were washed to remove excess sediment to aid identification.

f. All the live plant material was identified to species level wherever possible. For example, some particularly difficult groups e.g. any non-fruiting starworts were only identified to genus level 'Starwort species'.

g. Any plant specimens where identification in the field was uncertain were collected in plastic bags, labelled using the station number reference and the direction of the throw which is the point. This is then taken for subsequent observation using a high powered microscope, or to be sent for expert identification. Wherever possible, voucher specimens were pressed and dried using standard herbarium techniques.

h. To assign a level of abundance, the same methodology as per the Broads point survey was used.

4.2.3 Data processing

a. For each sample, species abundance scores can be totalled, to produce the total abundance score for each sample. Sum of all sample abundance scores produces the site total abundance. Assuming maximum plant abundance on the site, the site abundance score should have a maximum of 10 (± 10%).

b. For data comparison, the results have been calculated to show the species richness (number of species recorded) and the species abundance scores. Species abundance is calculated by summing all the abundance scores for a particular species at each site and dividing by the number of samples, which were surveyed for that site. Within each sites results table, the species abundances have been displayed in descending order so that the most abundant species in 2015 are listed at the top of each site table.

4.3 Results

4.3.1 River Waveney

The upper navigable reaches of this river were surveyed, this included Geldeston Dyke and the stretch of river which goes through Beccles. Both of which are areas which require the river plants to be cut by the weed harvester.

Common Name	Scientific Name	Summary Abundance 2016	Number of samples where recorded
Unbranched bur-reed	*Sparganium emersum*	1.558	26
Yellow water lily	*Nuphar lutea*	0.085	4
Arrowhead	*Saggitaria sagittifolia*	0.038	10
Nuttall's waterweed	*Elodea nuttallii*	0.015	4
Pondweed species	*Potamogeton sp.*	0.015	4
Stonewort (*Chara*) species	*Chara sp.*	0.008	2
Starwort species	*Callitriche sp.*	0.004	1
Common Water moss	*Fontinalis antipyretica*	0.004	1
Spiked water milfoil	*Myriophyllum spicatum*	0.004	1
Total number of species recorded		**9**	**Total samples taken 39**

The clarity of water within these sections was predominantly good; they were some areas where the dark sediment and leaf litter may have obscured the bed, but on the whole very clear water. Some of the stems from the waterweed had freshwater sponges growing on them.

4.4 Conclusions

Compared to the survey conducted last year on Waxham Cut, the species obtained are somewhat different and represent a waterway which has a stronger flow. The summary abundance score is not an exceptional one but more data is needed to fully gauge the health of these upper waterways.

5 Hydroacoustic Surveys

5.1 Introduction

Hydroacoustic survey equipment, utilising sonar technology, is commonly used for detection, assessment, and monitoring of underwater physical and biological objects. Boat-mounted hydro-acoustic equipment can be utilised to detect the depth of a water body (bathymetry), as well as the presence or absence, 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

5.2 Method

5.2.1 Survey technique

The hydroacoustic survey involves navigation a survey boat along set transect routes within a broad, to provide an insight into the vegetative growth over the bed. The transects pass over the same grid based point survey for rake sampling of water plants, thus enabling some level of validation and comparison between the surveys.

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

To assist with data processing and ground-truthing the bathymetric measurements, notes were made about the distribution of plants within each transect e.g. where plants were seen at the surface of the water, or the species observed.

5.2.2 Data Analysis

Using the Sonar5-Pro software, the sediment surface of each transect file was identified, as well as the less intense 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 of lake bed covered by plants; and percent volume of lake inhabited by plants or PVI. All water depth data was corrected for variation through reference to local water level datums. Only features taller than 8 cm above the inferred sediment surface were recorded as water plants during the data processing, to reduce the likelihood of recording false positive results.

This cut-off figure was calculated by selecting a transect with negligible plant growth, and adjusting the height threshold to determine the optimal (lowest) figure that minimised false reporting (Table 4).

Table 4. Percent plant coverage of bed, based on different height thresholds

Height threshold (m)	% of bed covered in plants
0.05	10.3
0.06	10.3
0.07	10.3
0.08	7.4
0.09	7.4
0.10	7.4
0.11	7.4
0.12	7.4
0.13	7.4
0.14	7.4
0.15	5.0

5.3 Barton Broad

As in the previous year there was plant growth in June along the western edge of the broad near the swing moorings; and along the northern and southern sides of Limekiln Dyke. Figure 2 depicts the location of transects used on Barton Broad in 2016.

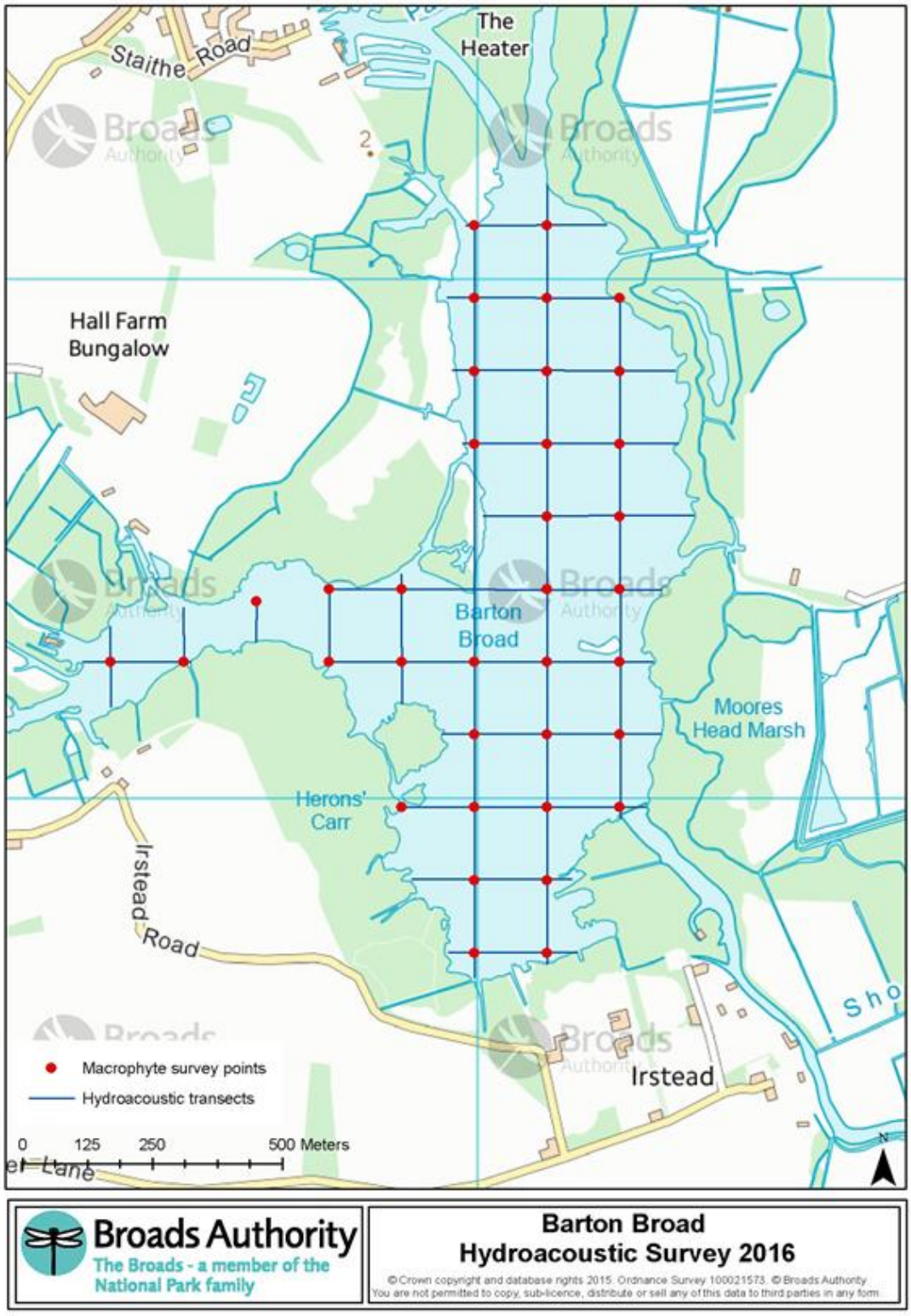


Figure 2. Distribution of grid lines for hydroacoustic survey in Barton Broad

5.3.1 Results

In general Barton Broad had negligible plant growth throughout. Transects with the greatest volume of plants as a percentage of the water column were transects H, F and U. The average percent volume inhabited (PVI) of water plants for these transects did not exceed 15% PVI. Average PVI for remaining transects range from 0% to 7% PVI, reflecting the general lack of aquatic macrophytes.

Table 5. Hydroacoustic survey results from Barton Broad

Barton Broad	June 2016
Mean Water base depth (m)	0.99
Max Water Depth In Meter (m)	2.15
Mean plant height (m)	0.19
Max plant height (m)	1.55
Bed covered by plants (%)	17.9
Plants as a percentage of water column (PVI) (%)	6.80

Table 5 shows the figures for the whole broad with average plant height at 0.19 m. Maximum plant height recorded was 1.55 m. Despite the few locations with noticeable water plant growth, the main body of the broad had no observed water plants, which resulted in an average PVI of 6.8%.

5.3.2 Conclusion

The hydroacoustic survey has shown water plant growth in Barton Broad is localised and overall has a relatively low amount of growth for a typical shallow lake. This general low abundance of water plants with limited distribution across the broad was also reflected in the rake based water plant survey. The current Natural England assessment of the SSSI unit that encompasses the open water of Barton Broad is 'unfavourable – recovering', indicating that some recovery is evident, but not yet reaching expected targets. Similarly, the Environment Agency Water body classification in 2015 was described as 'overall – poor' mainly based on paucity of water plants and abundance of phytoplankton (green algae). However, the Environment Agency's prediction for 2027 is that the direction of travel is not improving, and that 'poor' ecological quality will still be present at this time, based on the currently available evidence and measures in place to improve conditions.

Overall, the new transect grid layout has given a better overview of plant abundance across the broad and successfully highlighted areas that have particular abundant growth.

5.4 Hickling

Compared to the low abundance of plants in Barton Broad, Hickling has had periods of intense plant growth with a plethora of different species.

Figure 3 is a typical screenshot of the post processing information, which shows transect H running west-east (left to right). The black line marks the sediment surface, and the red line the height of the aquatic macrophytes. The area between the red and black lines is the volume occupied by water plants.

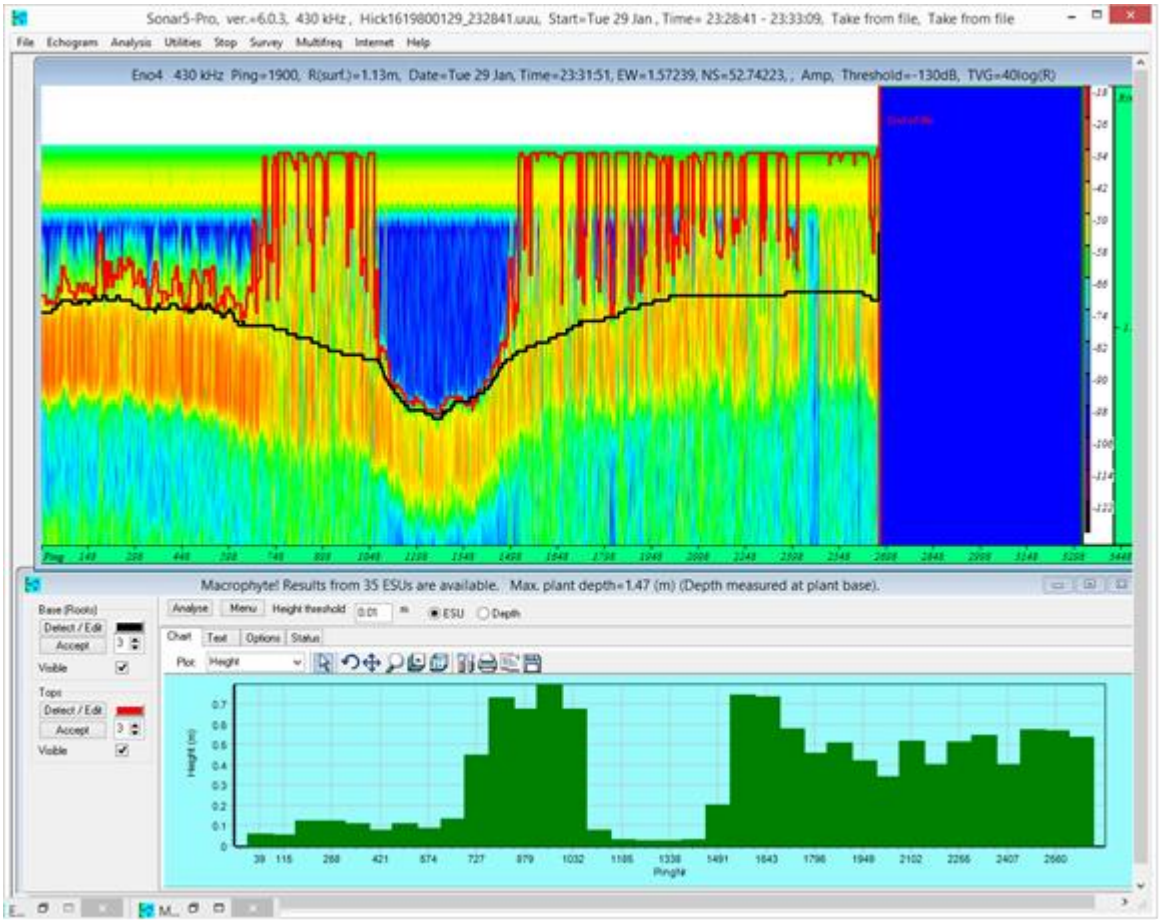


Figure 3. Screenshot of the post-processing visual output of data from Transect H.

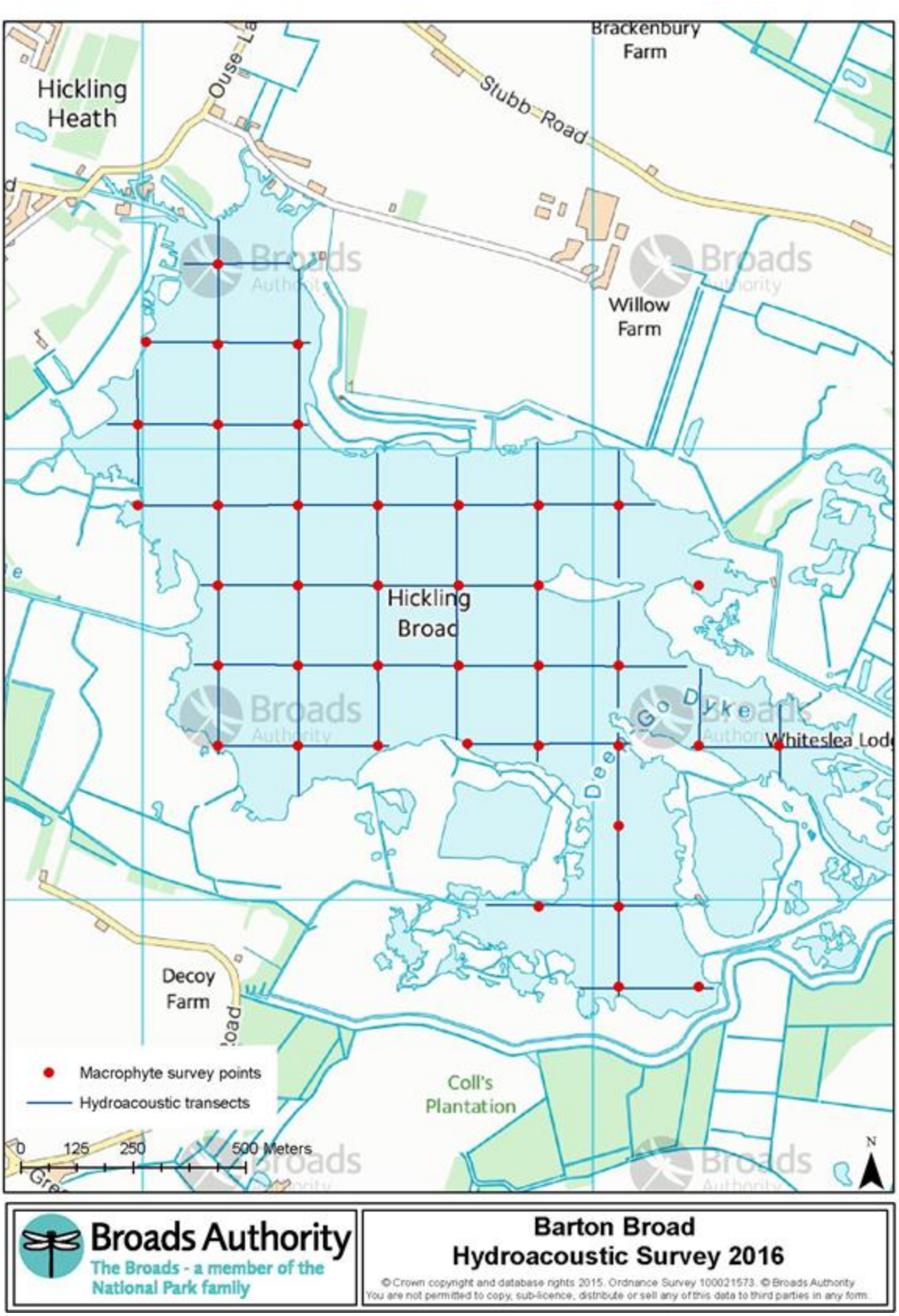


Figure 4. Transects used in 2016 to gain a representative sample of water plant growth in Hickling Broad.

5.4.1 Results

During June in Hickling broad, the areas of most intense plant growth were the bay north of Pleasure Island and the western margins between the NWT swing moorings and Churchill's Bay. Figure 4 shows this distribution in the contoured map of available water depth above the plant growth, which the Authority produced for sailors, using the June data. This information aimed to guide local users as to the location of plants and there height in the column.

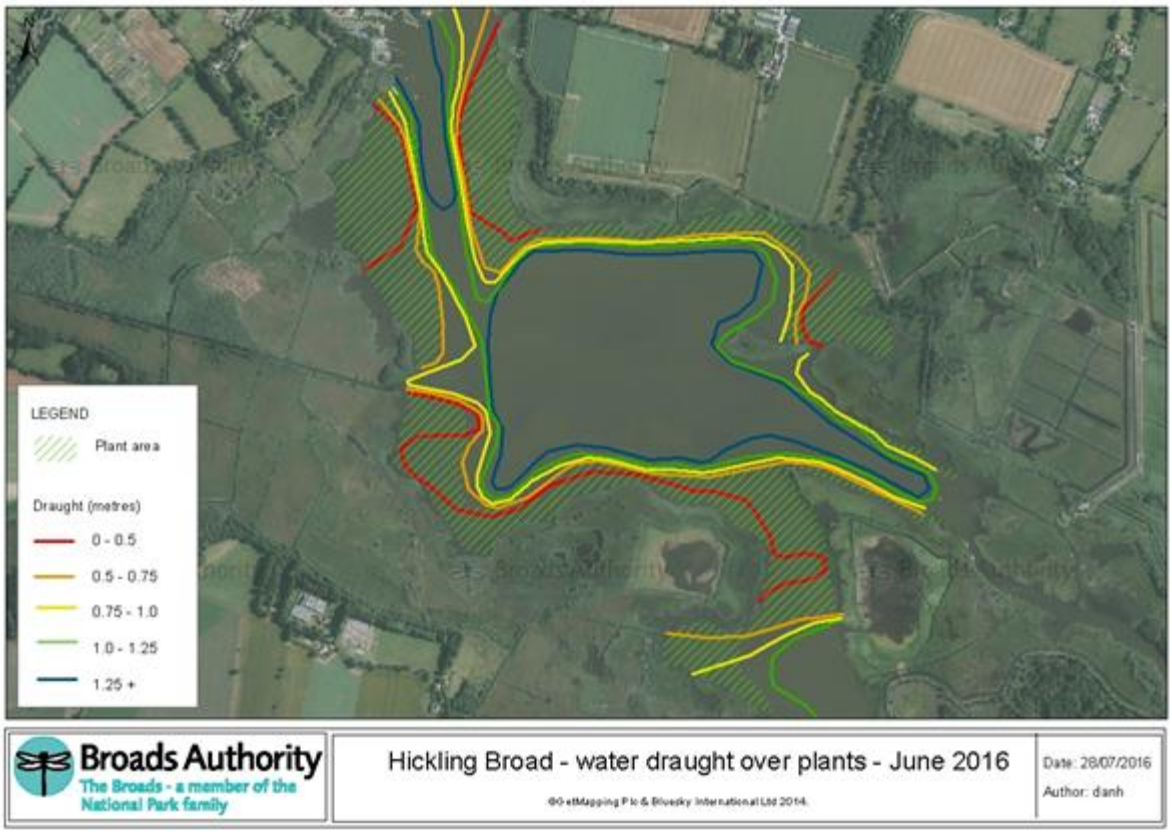


Figure 5. Contoured map of water depth above plant growth in Hickling Broad, June 2016 data

For example, the north side of Pleasure Island had an average of 60% percentage volume inhabited (PVI) by plants, compared to about 8% on the southern side towards the marked channel. Only transects K, H and I had a relatively high PVI figures, with all the high values coming from the western side of the broad. The remaining transects across the rest of the broad ranged from 0% - 14% with the majority falling under 6% PVI. The areas where very few or no plants were observed, were the length of the navigation channel and the central body of the broad (see area bounded within the blue contour line in Figure 4).

Table 6. Hydroacoustic survey results from Hickling Broad, 2016

Hickling Broad	June 2016	October 2016
Mean Water depth (m)	0.68	0.63
Max Water Depth In Meter (m)	1.58	1.52
Mean plant height (m)	0.18	0.20
Max plant height (m)	1.11	0.95
Bed covered by plants (%)	17.40	33.6
Plants as a percentage of the water column (PVI%)	5.50	13.50

Table 6 shows the average figures for the whole broad for June and a late season survey in October. By October, the plant beds had thickened up considerably, with more of these areas having plants reaching the water surface. The average plant height figures are useful for comparison between surveys, but give little indication of the typical height of visible plants. The percentage of the bed of the Broad covered in plants also increased by October. To qualify as having the bed covered by plants, as discussed in the methodology section, these plants could have only been as tall as 10 cm.

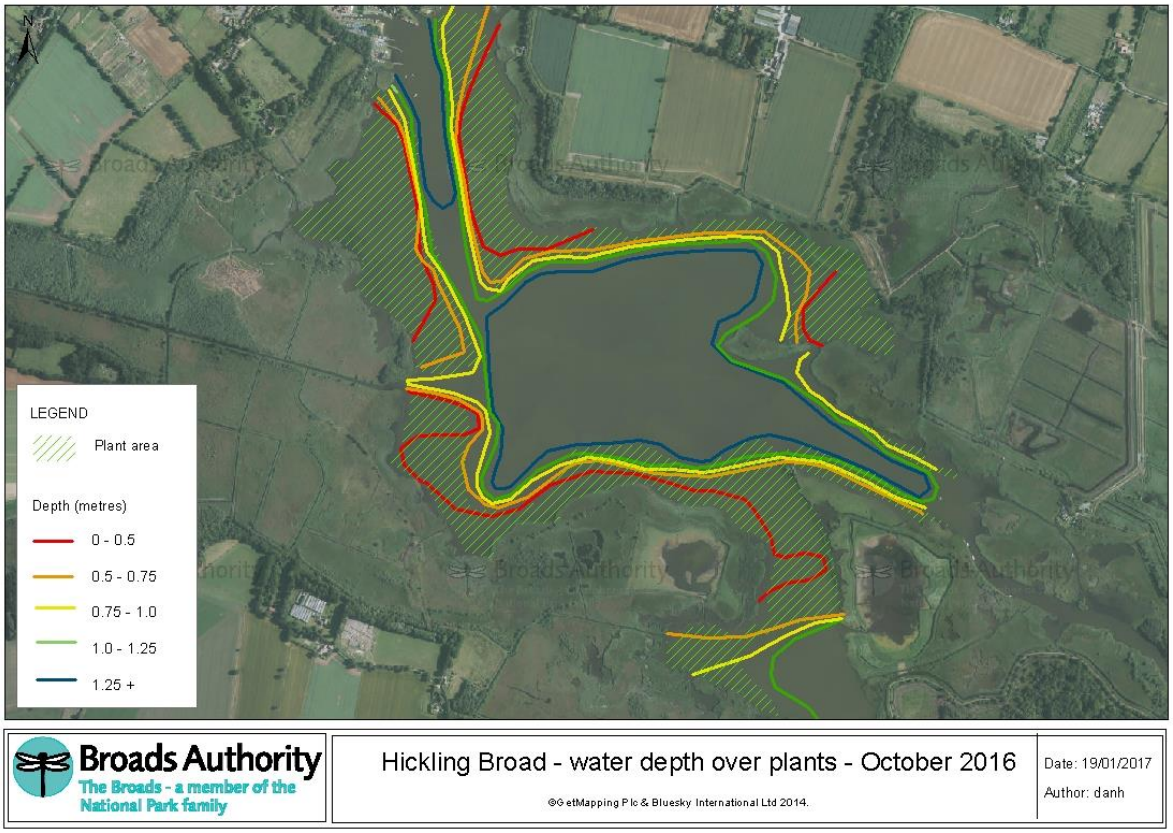


Figure 6 Contoured map of water depth above plant growth in Hickling Broad, Oct 2016 data

The most useful figures for direct comparison of the amount of total plant abundance in the waterbody are the PVI%. As this measure represents the percentage volume inhabited, it gives the proportional volume occupied by water plants within the waterbody. The increase from 5.5% to 13.5% shows how rapidly water plants can respond to optimal growing conditions.

In terms of methodological limitations, as the surveys are based on a grid system, there will inevitably be areas not surveyed. With an even distribution of the grid lines, and sufficient total transect length, the overall effort is seen as appropriate to give a robust overview.

The survey grid doesn't have the resolution to identify every small patch of plants, and indeed, there was one patch on the south side of the Broad, between transects D and E which had aquatic macrophytes growing very close to the surface.

In October the results showed that there had been an expansion of the area covered by plants (see Figure 6). This was manifested predominantly through thickening up and covering bare areas within the area hatched by green in June (see Figure 5). Outward expansion of the plant beds was observed between June and October, particularly out from Churchill's Bay, and towards the marked channel in North Bay, approaching the village. Some small areas also expanded out into the main broad in the northern and southern shores.

Overall the results indicated that the navigation channel and middle of the broad had very limited plant growth, in stark contrast to the vigorous growth to the surface on the western side of the Broad, North Bay and north of Pleasure Island.

The current Natural England assessment last carried out in 2013 of the SSSI unit that encompasses the open water of Hickling Broad is 'unfavourable – declining', indicated that overall the site is moving away from the target conditions. This assessment was based on a failure to meet characteristic species targets and poor water quality. Similarly, the Environment Agency Water body classification in 2015 was described as 'overall – poor' mainly based on the abundance of phytoplankton (green algae). However, the Environment Agency's prediction for 2021 is that the direction of travel is improving, given the range of remedial measures in place, and the objective of 'good' ecological quality will be met by that time.

5.4.2 Conclusion

It is important to note that the methodology changed this year, leading to a larger area being surveyed on the broad. Increasing the amount of data collected resulted in an improved accuracy and we were able to refine further the picture of the distribution of aquatic macrophytes. With the improvements in data gathering and processing it is hoped with sufficient resource that mapping of these results will be available for all surveys in future years

6 Conclusions

Now that there is a three year data set for the point based survey method, recent trends can be looked at more easily. However this data set is still only three years old and caution is advised in inferring longer term patterns from the sometimes high variability in growth of particular species between years.

The comparison of plant abundance between sites has been facilitated through adopting the point based sampling methodology. The graphs presented in section 3.3 of the main report highlight for example the relatively poor growth of water plants in Barton Broad and Horsey Mere, which are a long way off meeting their SSSI conservation targets. At the other end of the scale Martham South and North broads both had very strong stonewort populations over the majority of their beds, as is expected for shallow lake sites with good water quality.

The forward plan to rotationally survey two river sites each year is an important aim for these surveys. There has been increasing demand on the weed harvester operation and continued reports on increased water plant growth having an impacting on navigational access in specific areas. The key sites include the River Bure (Coltishall Lock to Belaugh); River Thurne (West Somerton to Martham Ferry; Waxham Cut & Catfield Dyke); River Ant (Tyler's Cut); River Wensum/Yare (New Mills to Whitlingham Broad); River Waveney (Geldeston Lock to Beccles). Observing the trends and species present at these sites will assist the sustainable management of these areas and strike a good balance between navigational access and ecological functioning. As water quality continues to improve and water plant growth responds accordingly, the challenge of managing appropriate water depth and safe navigation also continues.

The combination of rake based surveys and hydroacoustic surveys continue to be a very powerful tool for guiding site management, such as prioritisation of areas for restoration and ecological enhancement, e.g. Churchill's Bay at Hickling Broad. Water plant growth has been raised as an impact on navigational access, particularly sailing in Hickling Broad. The analysis of plant growth over the whole site is critical in establishing any likely impacts on this European Protected site and the conservation interest features at Hickling, before considering the possibility of managing the height of plant growth outside of the marked channel.

7 Acknowledgements

The Broads Authority wishes to thank all those individuals and organisations who assisted during the 2016 survey season by providing their time, boats, identification skills or permissions.

Many thanks must be expressed to the landowners who kindly granted permission to access the privately owned & managed broads.

Many thanks to those individuals who facilitated access the broads this year; John Blackburn, Eloise Downs, Adam Pimble, Jamie Nickerson, Rick Southwood, David Woollard, Matt Gooch, Richard Starling, Mike Roper, Richard Gay, John Hopes, Robin Buxton, Jim Papworth, Andy Ellson, Edgar Hoddy, Chris Morphew & Andy Cullum.

Most of all many thank all those who gave up their time to collect and assist with analysing the water plant and hydroacoustic data; Emma Harris, Sue Stephenson, Jonathon Cook, Hannah Southon, Vicky Short, Dan Hoare, Beth Williams, Elaine Green, Chris Morphew, Tom Hunter, Lawrence Smith, Nicky Talbot, Oliver Howlett, Pete Jermy, Rob Rogers, Colin Hart, Andrea Kelly, Emily Pratt, Amy Larter, Paul Wilson, Susan Bramer, Steve Hart, Nikki Jones, Chris Glasel, & Ben Hogg.

A special thanks to Vicky Short all the GIS work involved.

8 References

Cheffings, C. and Farrell, L. (Editors), (2005), The Vascular Plant Red Data List for Great Britain, ISSN 1473-0154

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.

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

Appendix 1. Macrophyte groupings based on form

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

Appendix 2a. 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 nuttallii	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

Latin	Common
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 crispus	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	Greater bladderwort
Veronica catenata	Pink water speedwell
Zannichellia palustris	Horned pondweed

Appendix 2b. Common to Latin plant names.

Common	*Latin*
Amphibious bistort	*Persicaria amphibia*
Arrowhead	*Saggitaria sagittifolia*
ltic stonewort	*Chara baltica*
Greater 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	*Zannichellia palustris*
Inflated duckweed	*Lemna gibba*
Intermediate stonewort	*Chara intermedia*
Intermediate water-starwort	*Callitriche stagnalis*

Common	*Latin*
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 nuttallii*
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*
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*