ABLE MARINE ENERGY PARK 2013 DATA REVIEW AND TARGET SETTING

14/10/2013	COMPENSATION SITE BENTHIC TARGETS DERIVED FROM THE NORTH KILLINGHOLME MARSH 2013 SURVEY

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CONTENTS

LIST OF TABLES

1. North Killingholme Marsh Baseline

1.1. October 2013 update -

1.1.1. Appendix A to this report represents an addendum that uses multivariate analyses to directly compare 2010 and 2013 spring datasets and illustrates that any differences are not significant. It is provided to give comfort, and confidence, that there is no significant difference between the surveys conducted to inform the EIA (spring 2010) and those conducted in 2013 against which intra-annual (within year) increases in abundance and biomass can be estimated.

1.2. Introduction

1.2.1. The following report provides a summary of the site specific North Killingholme Marsh (NKM) benthic data obtained during the 2013 pre-construction surveys detailed in the Marine Environmental Management and Monitoring Plan (MEMMP) for Able Marine Energy Park (AMEP). These surveys together with context added by the 2010 data obtained for the purposes of the EIA and other regional data are used to provide provisional benthic targets for the compensation site. As defined during discussions with Natural England and contained within the agreed Compensation Environmental Management and Monitoring Plan (CEMMP):

'The (benthic) *target will be set using the mean value (e.g., abundance, biomass) obtained during the NKM baseline survey(s), within a range defined by the standard deviation from the mean abundance of the preferred BW* [Black-tailed Godwits] *foraging area'*, (Annex 3, pg 50, para 3)).

1.2.2. This is further defined as:

'The community target will be set as the average benthic community recorded at NKM. Species targets will be set as the average abundance and biomass density (ind/m^2, g/m^2 the latter then being converted to AFDW g/m^2 using standard conversion factors) recorded at NKM', (Annex 3, pg 49, para 2)

1.2.3. This report initially presents information available from other developments within the Humber Estuary relating to realignment and intertidal mudflat development. This is followed by a comparison of the May spring survey conducted in 2013 with the characterisation survey conducted in 2010 in order to provide a longer term comparison of any discrete changes in community that may influence the representativeness of the 2013 target setting survey. Finally, there is a discussion summarising the findings of the 2013 autumn survey conducted at NKM and on the opposite side of the Humber at Cherry Cobb Sands.

1.2.4. The rationale behind the presentation and discussion of this data is to answer three primary questions to relating to risk, these are:

1. Is there a substantial risk that the biomass and abundance of the benthic community present at North Killingholme Marsh is of such exceptional quality that it is unlikely to be replaced?

2. Is there a substantial risk that Cherry Cobb Sands Regulated Tidal Exchange (RTE) compensation site will not have sufficient larval supply from the surrounding area to allow settlement of the target species?
3. Is there a substantial risk that the food resource associated with tidal inundation will be depleted in its entirety during the managed inundation?

1.2.5. A number of assumptions are made and terms used within this report that require clarification as follows:

- **Hotspot**: the term hotspot was used during various discussions with Natural England to describe areas of peak abundance/biomass that may be targeted by Black-tailed godwits (BTG). As will become apparent the areas of peak abundance for relevant species[1] are present in several areas at NKM, Cherry Cobb Sands and at Paul Holme Strays realignment site. The term 'hotspot' is retained for ease of reference with the caveat that hotspots in other areas are comparable and as such the presence of hotspots (and areas of very low abundance) is typical of estuarine habitats; thus, a 'hotspot' should not be understood in the context of this report to be an exceptional area within the context of the estuary as a whole.
- **Intra-annual seasonal variation**: The variation, within year, of abundance and biomass may be used as an indicator of the impact of predation on benthic communities. The available data are from 2013 and as such the increase from spring to autumn can only be used as a suggestion of the rate of depletion likely to occur from autumn to spring rather than the depletion during a specific season (eg winter 2013/2014).
- **Methodology of target setting:** The agreed methodology is defined within the CEMMP, Annex 3 "Target Setting Protocol" , and in summary:
  - **The main biotopes:** the main biotopes present in NKM are to be present at the compensation site and the dominant biotope at NKM should also be dominant at the compensation site.
  - **Species targets:** will be set as the average abundance and biomass density (individuals/m^2, g/m^2, the latter then being converted to ash free dry Weight (AFDW) g/m^2 using standard conversion factors) recorded at NKM.

1.3. Evidence from Paul Holme Strays (PHS)

1.3.1. The 2008 Paull Holme Strays Benthic Invertebrate Monitoring Programme report (2009)[2] presents the findings of the 5 year post breach survey for the managed

[1] The relevant species have been identified by RSPB and NE as *Hediste diversicolor* and *Macoma balthica*

[2] K. Mazik, E. Solyanko & S. Thomson. 2009. Paull Holme Strays Monitoring Programme 2008: Benthic Invertebrate Monitoring Report to Halcrow Group Ltd.

realignment site which was breached in September 2003. In short, the report concludes that:

- The total number of species found inside the managed realignment site is now comparable to that found outside;
- The abundance and biomass in both areas is dominated by the polychaete *Hediste diversicolor* with Enchytraeidae, nematodes, *Streblospio shrubsolii* and *Macoma balthica* also being found in both areas;
- Due to elevation, restrictions in tidal inundation and colonisation by saltmarsh plants, it is suggested that the communities in certain areas will remain in an early stage of development with low species diversity, abundance and biomass;
- Mean biomass within the realignment site is 49.6 g/m^2;
- Mean abundance within the realignment site is 4,204 individuals/m^2;
- Outside of the site the mean biomass and abundance are 59.1g/m^2 and 11,099.2 ind/m^2 respectively;
- In terms of both abundance and biomass, the community inside the site (as a whole) was dominated by the polychaete *Hediste diversicolor*. This species accounted for 41% of the abundance and 87% of the biomass. *M. balthica* accounted for 10% of the biomass, so 97% collectively with *H. diversicolor*;

1.3.2. As can be seen, the biomass and abundance is dominated by those key species that are commonly accepted to be the key pre species for BTGs using the intertidal habitat of the Humber Estuary. It is also noted that due to the restrictions in inundation and colonisation by saltmarsh plants at PHS, areas within the managed realignment site may remain in an early stage of development. This latter issue is proposed to be addressed within the compensation site Regulated Tidal Exchange (RTE) at Cherry Cobb Sands (CCS) by ensuring inundation of the mudflat even during neap tides, a period when the high water level is comparatively low within the estuary. This inundation regime will serve to maintain a soft mud and preventing saltmarsh development within the RTE site.

1.3.3. Similar evidence of the rate of settlement and dominant species may also be available from the site at Welwick, also within the Humber. Unfortunately this data is generally not publically available being the copyright of Associated British Ports.

1.4. Spring 2010 and Spring 2013

1.4.1. The requirement for an inter-annual comparison was discussed during the development of the compensation site and MEMMP. It was discussed that a comparison would illustrate the representativeness of the 2010/13 data, and provide a calculation of the intra-annual (seasonal) increase in key prey items for the black-tailed godwit, namely the polychaete work *Hediste diversicolor* and the bivalve *Macoma balthica*. The data can also then be compared to the autumn peak abundance for these species to provide an estimate of the depletion that may be attributable to predation by the bird community. The spatial distribution of the data also allows a comparison of areas of higher abundance/biomass and any variation in the location of them. The figures comparing the distribution of abundance and biomass in 2010/2013, 2013 spring and autumn, and spring 2013 NKM and CCS are presented in Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6 at the end of this report.

1.4.2. The 2010 and 2013 survey data indicated that the average biomass and abundance across each shore level (upper (generally above MHWN), middle (c. MLWN-MHWN) and lower (generally below MLWN)) was as follows:

Upper shore

1.4.3. The top five dominant species in terms of abundance on the upper shore are presented in Table 1 with recorded abundance per sample and per m^2.

Species	2010 Abundance ($12x0.01m^2$ samples)	2010 Abundance ($1m^2$)	Species	2013 Abundance (mean/$0.01m^2$)	2013 Abundance ($1m^2$)
Tubificoides benedii	268 (mean = 22.3)	2233	*Tubificoides agg. (Pseudogaster)*	27	2661
Hediste diversicolor	114 (mean = 9.5)	950	*Corophium volutator*	20	2025
Corophium volutator	109 (mean = 9.1)	908	*Tubificoides benedii*	17	1722
Streblospio shrubsolii	50 (mean = 4.1)	417	*Hediste diversicolor*	16	1594
Nematoda	49 (mean = 4.1)	408	Enchytraeidae	9	878

Table 1 2010 v 2013 Upper shore abundance

1.4.4. The top five dominant species in terms of biomass (blotted wet weight) on the upper shore are presented in Table 2, again with recorded biomass per sample and per m^2.

Species	2010 Biomass (g) ($12x0.01m^2$ samples)	2010 Biomass (g) ($1m^2$)	Species	2013 Biomass (mean/$0.01 m^2$)	2013 Biomass ($1m^2$)
Hediste diversicolor	2.86 (mean = 0.24)	23.83	*Hediste diversicolor*	0.39	39.25
Corophium volutator	0.42 (mean = 0.035)	3.50	*Corophium volutator*	0.06	5.83
Macoma	0.27 (n=13)	2.25	*Tubificoides*	0.03	3.04

balthica	(mean = 0.02)		*agg. (pseudogaster)*		
Tubificoides benedii	0.17 (mean = 0.014)	1.42	*Macoma balthica*	0.02	1.63
Streblospio shrubsolii	0.01 (mean = 0.008)	0.83	*Tubificoides benedii*	0.02	1.51

Table 2 2010 v 2013 Upper shore biomass

Midshore

1.4.5. The top five dominant species in terms of abundance on the mid shore are presented in Table 3 with recorded abundance per sample and per m^2.

Species	2010 Abundance ($12x0.01m^2$ samples)	2010 Abundance ($1m^2$)	Species	2013 Abundance (mean/$0.01m^2$)	2013 Abundance ($1m^2$)
Tubificoides benedii	271 (mean = 22.6)	2258	*Tubificoides benedii*	55	5481
Corophium volutator	202 (mean = 16.8)	1683	*Corophium volutator*	26	2575
Nematoda	93 (mean = 7.75)	775	*Streblospio shrubsolii*	5	547
Streblospio shrubsolii	50 (mean = 4.17)	417	*Nematoda*	4	353
Macoma balthica	47 (mean = 3.92)	392	*Macoma balthica*	1	147

Table 3 2010 v 2013 Midshore abundance

1.4.6. The top five dominant species in terms of biomass on the mid shore are presented in Table 4 with recorded abundance per sample and per m^2.

Species	2010 Biomass (g) in the mid shore ($12x0.01m^2$ samples)	2010 Biomass (g) ($1m^2$)	Species	2013 Biomass(g) (mean/$0.01m^2$)	2013 Biomass (g) ($1m^2$)
Macoma balthica	1.55 (mean = 0.13)	12.92	*Macoma balthica*	0.09	8.71
Corophium volutator	0.45 (mean = 0.04)	3.75	*Tubificoides benedii*	0.06	5.95

Tubificoides benedii	0.2 (mean = 0.02)	1.67	*Corophium volutator*	0.05	5.45
Hydrobia ulvae	0.02 (mean = 0.0)	0.17	*Hediste diversicolor*	0.04	3.55
Streblospio shrubsolii	0.01 (mean = 0.0)	0.08	*Streblospio shrubsolii*	0.00	0.20

Table 4 2010 v 2013 Midshore biomass

Lower shore

1.4.7. The top five dominant species in terms of abundance on the lower shore are presented in Table 5 with recorded abundance per sample and per m^2.

Species	2010 Abundance ($12x0.01m^2$ samples)	2010 Abundance ($1m^2$)	Species	2013 Abundance ($mean/0.01m^2$)	2013 Abundance ($1m^2$)
Streblospio shrubsolii	91 (mean = 7.58)	758	*Corophium volutator*	15	1489
Corophium volutator	88 (mean = 7.33)	733	*Streblospio shrubsolii*	8	781
Nematoda	21 (mean = 1.75)	175	*Nematoda*	2	225
Tubificoides swirencoides	16 (mean = 1.33)	133	*Tubificoides benedii*	2	222
Tubificoides benedii	15 (mean = 1.25)	125	*Tubificoides swirencoides*	1	94

Table 5 2010 v 2013 Lower shore abundance

1.4.8. The top five dominant species in terms of biomass on the lower shore are presented in Table 6 with recorded abundance per sample and per m^2.

Species	2010 Biomass (g) ($12x0.01m^2$ samples)	2010 Biomass (g) ($1m^2$)	Species	2013 Biomass(g) ($mean/0.01m^2$)	2013 Biomass (g) ($1m^2$)
Macoma balthica	0.21 (mean = 0.02)	1.75	*Macoma balthica*	0.03	3.50
Corophium volutator	0.13 (mean = 0.01)	1.08	*Corophium volutator*	0.02	2.24
Hediste diversicolor	0.07 (mean = 0.0)	0.58	*Streblospio shrubsolii*	0.00	0.28

Mysella bidentata	0.06 (mean = 0.0)	0.50	*Hediste diversicolor*	0.00	0.25
Streblospio shrubsolii	0.03 Mean = 0.0)	0.25	*Nephtys hombergii*	0.00	0.18

Table 6 2010 v 2013 Lower shore biomass

1.4.9. The comparison of the spring 2010 and spring 2013 survey data highlights that both years are broadly comparable with very similar, if not identical, species dominating each intertidal zone in terms of both abundance and biomass.

1.4.10. It is of note that for certain species the abundance and biomass has increased, such as the crustacean Corophium volutator which has been recorded in 2013 as higher both in number and biomass in the upper shore. A similar pattern is also present for the general assemblage with numbers and biomass being higher in the upper shore in 2013. The same trend is observed in the mid shore, the exception being for *Macoma balthica* which is lower in 2013 than 2010 in number and biomass.

1.4.11. The biomass of Macoma balthica in the lower shore is higher in 2013 than 2010, and the same is true for other species within the lower shore. The variation between 2010 and 2013 is not outside of the natural variation that is reasonably expected and both datasets can be considered typical of mid-estuarine habitats, and specifically the mid Humber Estuary.

1.5. Spring 2013 and Autumn 2013

1.5.1. The comparison between the spring and autumn 2013 survey data is presented in the following tables.

Upper shore

1.5.2. The top five dominant species in terms of abundance on the upper shore are presented in Table 7 with recorded abundance per sample and per m^2.

Species	Spring 2013 mean 0.01m^2 samples)	Spring 2013 Abundance (1m^2)	Species	Autumn 2013 abundance (0.01m^2 samples)	Autumn 2013 Abundance (1m^2)
Tubificoides agg. (Pseudogaster)	27	2661	*Corophium volutator*	103.9375	10393.75
Corophium volutator	20	2025	*Tubificoides benedii*	44.8125	4481.25
Tubificoides benedii	17	1722	*Hediste diversicolor*	18.8125	1881.25
Hediste diversicolor	16	1594	Enchytraeidae	17.1875	1718.75

Enchytraeidae	9	878	Nematoda	6	600

Table 7 2013 spring vs autumn Upper shore abundance

1.5.3. The top five dominant species in terms of biomass (blotted wet weight) on the upper shore are presented in Table 8 with recorded abundance per sample and per m^2.

species	Spring 2013 biomass (per $0.01m^2$)	Spring 2013 biomass ($1m^2$)	Species	Autumn 2013 Biomass (g) ($0.01m^2$ samples)	Autumn 2013 Biomass (g) (1m2)
Hediste diversicolor	0.39	39.25	*Hediste diversicolor*	0.5109	51.09
Corophium volutator	0.06	5.83	*Corophium volutator*	0.0707	7.07
Tubificoides agg. (pseudogaster)	0.03	3.04	*Tubificoides benedii*	0.0348	3.48
Macoma balthica	0.02	1.63	*Macoma balthica*	0.0057	0.57
Tubificoides benedii	0.02	1.51	*Diptera larvae*	0.0022	0.22

Table 8 2013 spring vs autumn Upper shore biomass

Midshore

1.5.4. The top five dominant species in terms of abundance on the mid shore are presented in Table 9 with recorded abundance per sample and per m^2.

Species	Spring 2013 Abundance (mean/$0.01m^2$ samples)	Spring Abundance ($1m^2$)	Species	Autumn 2013 Abundance ($0.01m^2$ samples)	Autumn 2013 Abundance ($1m^2$)
Tubificoides benedii	55	5481	*Corophium volutator*	154.25	15425
Corophium volutator	26	2575	*Tubificoides benedii*	53.375	5337.5
Streblospio shrubsolii	5	547	*Nematoda*	8.375	837.5
Nematoda	4	353	*Macoma balthica*	8.1875	818.75
Macoma balthica	1	147	*Streblospio shrubsolii*	3.8125	381.25

Table 9 2013 spring vs autumn Midshore abundance

1.5.5. The top five dominant species in terms of biomass on the mid shore are presented in Table 10 with recorded abundance per sample and per m^2.

Species	Spring 2013 biomass (per $0.01m^2$)	Spring biomass ($1m^2$)	Species	Autumn 2013 Biomass (g) ($0.01m^2$ samples)	Autumn 2013 Biomass (g) (1m2)
Macoma balthica	0.09	8.71	*Corophium volutator*	0.092306	9.23
Tubificoides benedii	0.06	5.95	*Tubificoides benedii*	0.049475	4.95
Corophium volutator	0.05	5.45	*Macoma balthica*	0.040075	4.01
Hediste diversicolor	0.04	3.55	*Hediste diversicolor*	0.032456	3.25
Streblospio shrubsolii	0.00	0.20	Nematoda	0.004388	0.44

Table 10 2013 spring vs autumn Midshore biomass

Lower shore

1.5.6. The top five dominant species in terms of abundance on the lower shore are presented in Table 11 with recorded abundance per sample and per m^2.

Species	Spring 2013 Abundance (0.01m2 samples)	Spring 2013 Abundance (1m2)	Species	Autumn 2013 Abundance ($0.01m^2$ samples)	Autumn 2013 Abundance (1m2)
Corophium volutator	15	1489	*Corophium volutator*	68.9375	6893.75
Streblospio shrubsolii	8	781	*Streblospio shrubsolii*	15.125	1512.5
Nematoda	2	225	*Nematoda*	8	800
Tubificoides benedii	2	222	*Tubificoides benedii*	6.0625	606.25
Tubificoides swirencoides	1	94	*Macoma balthica*	0.75	75

Table 11 2013 spring vs autumn Lower shore abundance

1.5.7. The top five dominant species in terms of biomass on the lower shore are presented in Table 12 with recorded biomass per sample and per m^2.

Species	Spring 2013 Biomass(g) (mean/$0.01m^2$)	2013 Spring (g) ($1m^2$)	Species	Autumn 2013 Biomass (g) in the lower shore ($0.01m^2$	Autumn 2013 Biomass (g) ($1m^2$)

				samples)	
Macoma balthica	0.03	3.50	*Macoma balthica*	0.21	1.75
Corophium volutator	0.02	2.24	*Corophium volutator*	0.13	1.08
Streblospio shrubsolii	0.00	0.28	*Hediste diversicolor*	0.07	0.58
Hediste diversicolor	0.00	0.25	*Mysella bidentata*	0.06	0.50
Nephtys hombergii	0.00	0.18	*Streblospio shrubsolii*	0.03	0.25

Table 12 2013 spring vs autumn Lower shore biomass

1.5.8. As is demonstrated there is generally an increase in both abundance and biomass in the upper shore between the spring and autumn, with certain species such as *Tubificoides* doubling in abundance whilst *Hediste diversicolor* increases more modestly from 1594 ind/m^2 to 1881 ind/m^2. In terms of biomass in the upper shore there is an increase for most of the species with *Hediste diversicolor* increasing from a mean 39.2g/m^2 to 51g/m^2.

1.5.9. As presented within the detailed summary report (Allen, 2013), the peak locations for abundance and biomass in the spring 2013 survey are in the control sites to the north and in the direct impact zone itself. The location of the most abundant stations in terms of both individuals for abundance and biomass are presented below:

Zone	Station	Location on Shore	Abundance (ind/m^2)
Control North	CN2U	Upper	38800
Direct Impact	DI3U	Upper	29433
Control North	CN2M	Middle	13133
Control North	CN3L	Low	12900
Direct Impact	DI3M	Middle	11333
Control North	CN2L	Low	10733

Table 13 Stations with peak abundance during the spring 2013 survey

Zone	Station	Location on Shore	Biomass (g/m^2)
Direct Impact	DI1U	Upper	173.58

Control North	CN2U	Upper	139.16
Direct Impact	DI3U	Upper	71.06
Direct Impact	DI2U	Upper	55.16
Direct Impact	DI3M	Middle	50.89
Control North	CN1U	Upper	50.74

Table 14 Stations with peak biomass during the spring 2013 survey

1.5.10. From the summary tables above it is evident that whilst the areas of peak species abundance in spring 2013 are distributed evenly across the upper, middle and lower NKM foreshore, there are slightly more areas of peak abundance in the Control zone to the north of the direct impact zone. When considering the stations containing the peak biomass the direct impact zone contains the majority of the stations with the highest biomass and these are predominantly in the upper shore.

1.5.11. Further analysis of the results also indicates that the prey species of interest (*Hediste diversicolor* and *Macoma balthica*) are the primary dominant species in terms of abundance and (biomass) as provided in the following table. The other dominant species is the crustacean *Corophium volutator.*

Station	Total Biomass (g/m^2)	*Hediste diversicolor* ind/m^2 (g/m^2)	*Macoma balthica* ind/m^2 (g/m^2)
DI1U	173.58	3900 (170.2)	0 (0)
CN2U	139.16	1266 (97.6)	0 (0)
DI3U	71.06	2066 (18)	100 (1.6)
DI2U	55.16	4000 (52.2)	0 (0)
DI3M	50.89	0 (0)	500 (40.5)

Table 15 Dominant species within the peak biomass stations (Spring 2013)

1.5.12. As is apparent by the summary of the spring and autumn 2013 data (presented in full in Allen, 2013) the upper and mid shore within the Direct Impact Zone represent the majority of the stations containing peak biomass on the NKM foreshore, but abundance is distributed more evenly across NKM.

1.6. Autumn 2013

1.6.1. The autumn 2013 survey data as summarised above illustrate that the upper and middle shore represents the peaks in terms of abundance and biomass. The top ten stations in terms of the peak abundance and biomass within the autumn 2013 survey are as follows in Table 16 and Table 17:

Zone	**Station**	**Total abundance (ind/sample)**	**Abundance (ind/m^2)**

Direct Impact	1.7UB	456	45600
Control North	3.3UB	394	39400
South of Impact Zone	1.1MB	357	35700
Direct Impact	1.3MB	348	34800
Direct Impact	1.7MB	348	34800
Direct Impact	1.6UB	341	34100
Direct Impact	1.3UB	328	32800
Control North	3.3MB	311	31100
Control North	3.3LB	283	28300
Direct Impact	1.6MB	271	27100

Table 16 Autumn 2013 stations containing peak abundance

Zone	Station	Total Biomass (g/sample)	Biomass(g/m^2)
Direct Impact	2.2UB	1.3758	137.58
Direct Impact	1.4UB	1.2349	123.49
Direct Impact	1.6UB	1.0275	102.75
Control North	3.3UB	0.8702	87.02
Direct Impact	2.4UB	0.8276	82.76
Direct Impact	1.5UB	0.7241	72.41
Direct Impact	1.7UB	0.7132	71.32
Direct Impact	1.3UB	0.6915	69.15
Control North	3.3MB	0.5361	53.61
Direct Impact	1.8UB	0.5193	51.93

Table 17 Autumn 2013 stations containing peak biomass

1.6.2. The Tables above illustrate the presence of the majority of stations of peak abundance and biomass during the autumn 2013 survey as being located within the upper and middle shore within the Direct Impact zone. 40% of the top ten stations in terms of abundance occurs outside of the direct impact zone, whilst 20% of the peak biomass stations occur outside of the direct impact zone.

1.6.3. Further analysis of the individual station data indicates that the dominant species within the direct impact zone in terms of abundance are, as illustrated within the full benthic ecology report and in order of dominance: *Corophium volutator, Tubificoides benedii, Streblospio shrubsolii and Hediste diversicolor* and to a lesser degree (6th dominant species*) Macoma balthica*.

1.6.4. In terms of biomass the dominant species within the direct impact zone are *Hediste diversicolor, Corophium volutator, Tubificoides benedii*, *Macoma balthica*, and *Streblospio shrubsolii*.

1.6.5. The area of direct impact is therefore considered to be higher than the immediately surrounding areas in terms of biomass, and to a lesser degree the same is true for abundance. The Control sites to the north of the development site illustrate that there are a number of locations within the North Killingholme Marsh intertidal zone of comparable biomass and abundance, with the same species being seen to be dominant.

1.7. Cherry Cobb Sands Control Sites

1.7.1. The spring 2013 survey included sampling on the opposite side of the estuary at Cherry Cobb Sands, to provide a baseline from which to assess the impact of the breach at that location. It provides a useful comparison in terms of the community present, biomass, abundance and the dominant species elsewhere in the Middle Estuary. The results of the CCS survey indicate a broadly similar range of values for numbers of taxa, individuals and biomass to those described for the spring NKM survey and generally corresponds to other surveys in the middle Humber.

1.7.2. In summary the mean abundance and biomass of the top 6 stations at CCS is presented below in Table 18 and Table 19. With the top 6 stations during the spring 2013 NKM survey and the autumn 2013 NKM survey.

Location	Station	2013 Spring Abundance (ind/m^2)	Location	Station	2013 Spring Abundance (ind/m^2)	Station	2013 Autumn Abundance (ind/m^2)
CCS	CN2U A	40500	NKM	CN2U	38800	1.7UB	45600
CCS	I1U C	39600	NKM	DI3U	29433	3.3UB	39400
CCS	CN2U C	37400	NKM	CN2M	13133	1.1MB	35700
CCS	I1U A	37000	NKM	CN3L	12900	1.3MB	34800
CCS	I1M B	36700	NKM	DI3M	11333	1.7MB	34800
CCS	I2M A	36200	NKM	CN2L	10733	1.6UB	34100

Table 18 Comparison of the 2013 top 6 stations (abundance) at CCS with NKM

Location	Station	2013 Spring Biomass (g/m^2)	Location	Station	2013 Spring Biomass (ind/m^2)	Station	2013 Autumn biomass (g/m^2)
CCS	CS1U A	395.71	NKM	DI1U	173.58	2.2UB	137.58
CCS	I1M B	375.51	NKM	CN2U	139.16	1.4UB	123.49
CCS	CS3U C	326.08	NKM	DI3U	71.06	1.6UB	102.75

CCS	CS2U C	322.22	NKM	DI2U	55.16	3.3UB	87.02
CCS	CS1U B	321.46	NKM	DI3M	50.89	2.4UB	82.76
CCS	CS3U A	313.45	NKM	CN1U	50.74	1.5UB	72.41

Table 19 Comparison of the 2013 top 6 stations (biomass) at CCS with NKM

1.7.3. As can be seen, the surveys that have taken place in 2013 illustrate that there are areas of peak abundance and biomass present within the North Killingholme Marsh that are higher than the immediate surroundings but broadly comparable with those found further to the north at the control sites, and on the opposite side of the estuary at Cherry Cobb Sands.

1.7.4. Referring back to the results at PHS, it is of note that the top five stations of peak biomass values recorded within the site during the 2008 survey were 100.8 g/m^2, 97.38 g/m^2, 87.98 g/m^2, 87.48 g/m^2, and 64.48 g/m^2.

1.8. Indicative Target setting

1.8.1. Whilst the NKM Autumn surveys have not been fully processed yet (one of the three replicate samples has been processed for each site), there is sufficient information to make informed estimates of the final benthic targets for the compensatory habitat.

1.8.2. The target setting as identified in the MEMMP and above in Section 1.2.2 is to be based on the mean biomass present within the North Killingholme Marsh. This would, if using the stations present within the impact zone and relying on the (part processed) autumn survey data, result in a target for abundance of 18,828 individuals/m^2 and a biomass of 32.88g/m^2.

1.8.3. In recognition however of the presence of regions of higher abundance, though not exceptional by comparison to control sites and existing realignment sites, it is proposed to focus on those stations present within the upper and middle shore in order to provide an enhanced compensation target. This also correlates with the peak bird count surveys which indicate that the peak BTG numbers occur at high tide in the upper shore. This would mean ignoring approximately the lower shore of the intertidal at NKM and focussing on the upper and middle shore, thereby creating a higher target, with the intention of capturing the areas of peak functional habitat whilst also recognising that intertidal estuarine habitats are highly variable both in spatial and temporal terms.

1.8.4. Selectively focussing on the upper and middle shore gives a target abundance of 23,572 individuals/m^2 (standard deviation 10,562) and a target biomass of 46.56g/m^2 (standard deviation 38.54 g/m^2).

1.8.5. This target can be seen to capture the variation within the impact zone whilst focussing on the areas of highest abundance and biomass. The variation around this target as discussed during the development of the target setting protocol is the standard deviation around the mean. This is presented above with the targets. It is acknowledged that the range was also discussed as being the standard deviation around the mean present at the peak stations or ‘hotspots’. Whilst the top 6 hotspots present are comparable with those at other locations in the middle Humber estuary reducing the range at these top 6 sites provides a range around the mean of 27g/m^2 for the biomass target and 6006 ind/m2 for abundance.

1.8.6. This provides target ranges of:

- **Abundance:** 23,572 (+/- 6006) individuals/m^2
- **Biomass:** 46.56 (+/- 27) g(WW)/m^2

1.8.7. The biomass target is demonstrably comparable with the mean biomass found at the Paull Holme Strays realignment site (49.6g/m^2) 5 years after its breach.

1.8.8. This target is also approximately half the mean biomass found at the Cherry Cobb Sands intertidal environment (97.13 g/m^2) which is primarily due to the presence of greater numbers of the important bivalve *Macoma balthica* (up to 320 g/m^2 at CS1U) and the large numbers of *Hediste diversicolor* resulting stations having up to a biomass of 116g/m^2 (station CN2U A). This gives reassurance that the presence of these species within the foreshore at Cherry Cobb Sands will provide adequate larval supply to ensure that success of the CCS RTE. It also provides assurance that the autumn biomass and abundance at the NKM foreshore is comparable with that of CCS, from the preliminary results of the spring and autumn surveys.

1.8.9. It is noted that this target is for discussion and subject to alteration following the publication of the full dataset from the autumn survey at NKM.

2. Assessment of Risk

2.8.1. Returning to the questions posed at the beginning of this report the following section seeks to address the uncertainty and risk associated with the AMEP development.

2.9. Is there substantial risk that the biomass and abundance of the benthic community present at North Killingholme Marsh is of such exceptional quality that it is unlikely to be replaced?

2.9.1. The evidence from Paull Home Strays, the 2010 benthic characterisation survey, 2013 NKM spring benthic baseline survey, 2013 NKM autumn 'bird food' survey, and the 2013 CCS spring survey has been presented in the above sections of this report and in detail within the Allen (2013) technical benthic survey reports. The evidence shows that the area within which it is proposed to construct the Able Marine Energy Park contains areas of high abundance and biomass when compared to the immediate area but that the levels are comparable to those found further north-west in the area used as the NKM control sites (North). Further to this the mean levels found are comparable to those found during the autumn benthic surveys at Paull Home Strays. Finally the levels of abundance and biomass are lower at North Killingholme Marsh in the autumn than those recorded at Cherry Cobb Sands during the spring; this is of particular relevance as it is reasonable to predict that the levels at Cherry Cobb Sands will increase seasonally in much the same way as was recorded at North Killingholme Marsh.

2.9.2. The evidence therefore justifies a high level of confidence in the finding that there is no substantial risk that NKM is of such exceptional quality that a compensation site would not be able to meet its biomass and abundance targets. Such a risk must reasonably be considered as being low.

2.10. Is there a substantial risk that Cherry Cobb Sands Regulated Tidal Exchange compensation site will not have sufficient larval supply from the surrounding area to allow settlement of the target species?

2.10.1. The evidence presented herein for Cherry Cobb Sands suggests that there is a substantial intertidal benthic community, dominated by the primary target species from which larvae and juveniles will migrate.

2.10.2. The larvae of *Macoma balthica* are considered to be long term planktonic larvae with a dispersal potential greater than 10km. Reproduction is annual and episodic, usually taking place in spring or autumn; females are capable of expelling 10,000-30,000 eggs. Adult migration can cover distances up to 1 km.

2.10.3. *Hediste diversicolor* has a single annual episodic spawning after which it dies. The number of eggs released is reported to be between 1,000 and 49,000. After fertilisation, the eggs develop into a planktonic larval phase which lasts from 1-2 months and a dispersal potential of between 1 and 10km.

2.10.4. There is high confidence therefore that there is not a substantial risk that Cherry Cobb Sands will have inadequate benthic faunal larvae. Such a risk is must reasonably be considered low.

2.11. Is there a substantial risk that the food resource associated with tidal inundation will be depleted in its entirety as a result of the managed inundation?

2.11.1. The risk of this is primarily addressed in accompanying notes describing the process of RTE management. In summary daily management will be required over about half of the spring-neap cycle. On one day of the spring tide period water will be required to be impounded in one of the RTE fields. As the neap tide period is approached daily management will be required to ensure that the fields sequentially retain, drain and refill until during the subsequent rising tides, the tide levels are sufficient for this to happen without alteration of the sluices.

2.11.2. The impounded water will therefore occur within the neap cycle with the spring cycle of inundation remaining largely unhindered. In terms of the stress on the system it should be noted that during neap cycles, areas of the upper shore in natural intertidal areas will not be inundated at all, a period of impounding will therefore provide greater protection both from predation and desiccation. In terms of the available food resource given the high suspended material concentration within the estuarine water that will be flooding the area, and the limited period of impounding between natural inundation then the risk of insufficient food being available must reasonably be considered to be low.

Figure 1 Spring 2010 and 2013 comparison (abundance)

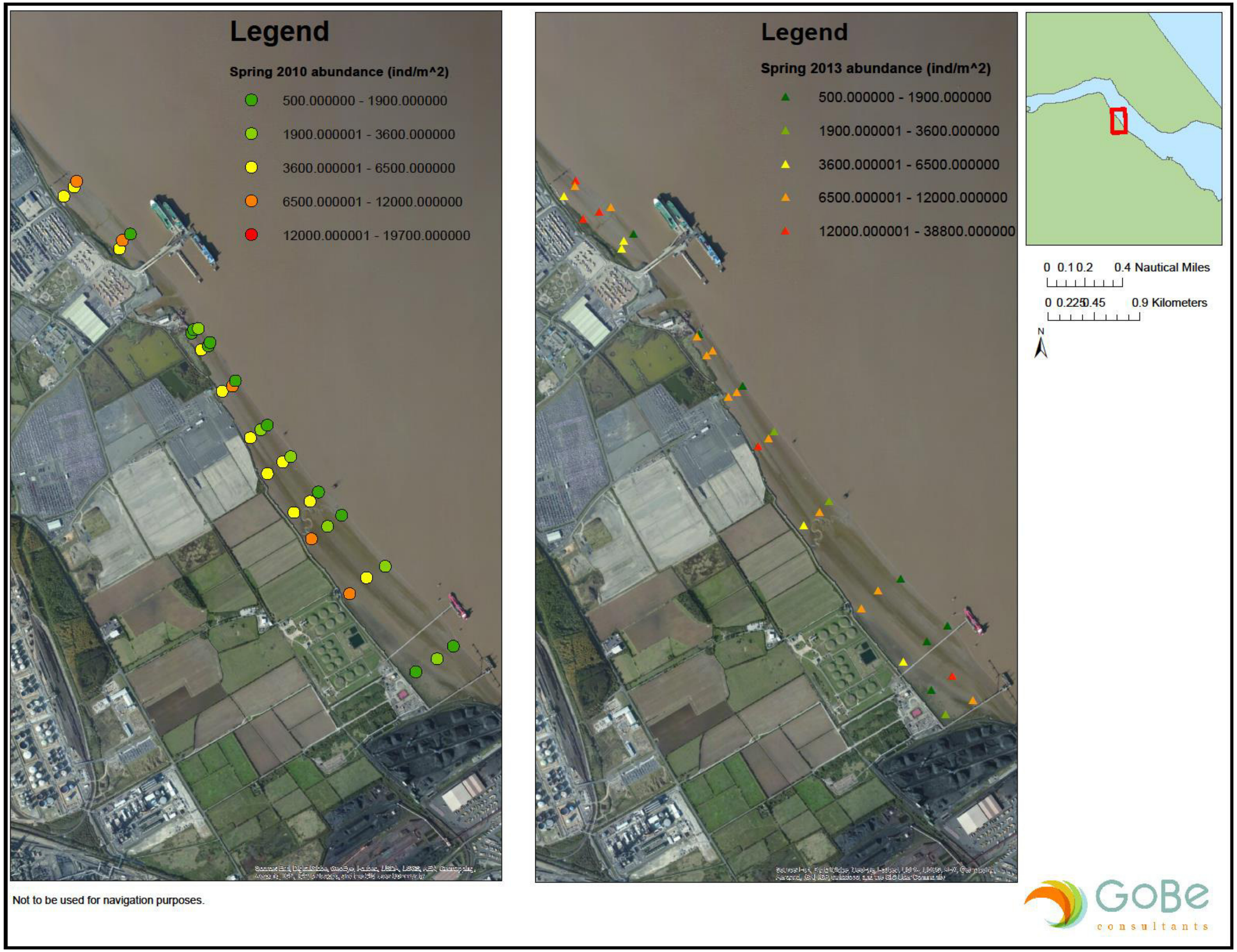


Figure 2 Spring 2010 and 2013 comparison (biomass)

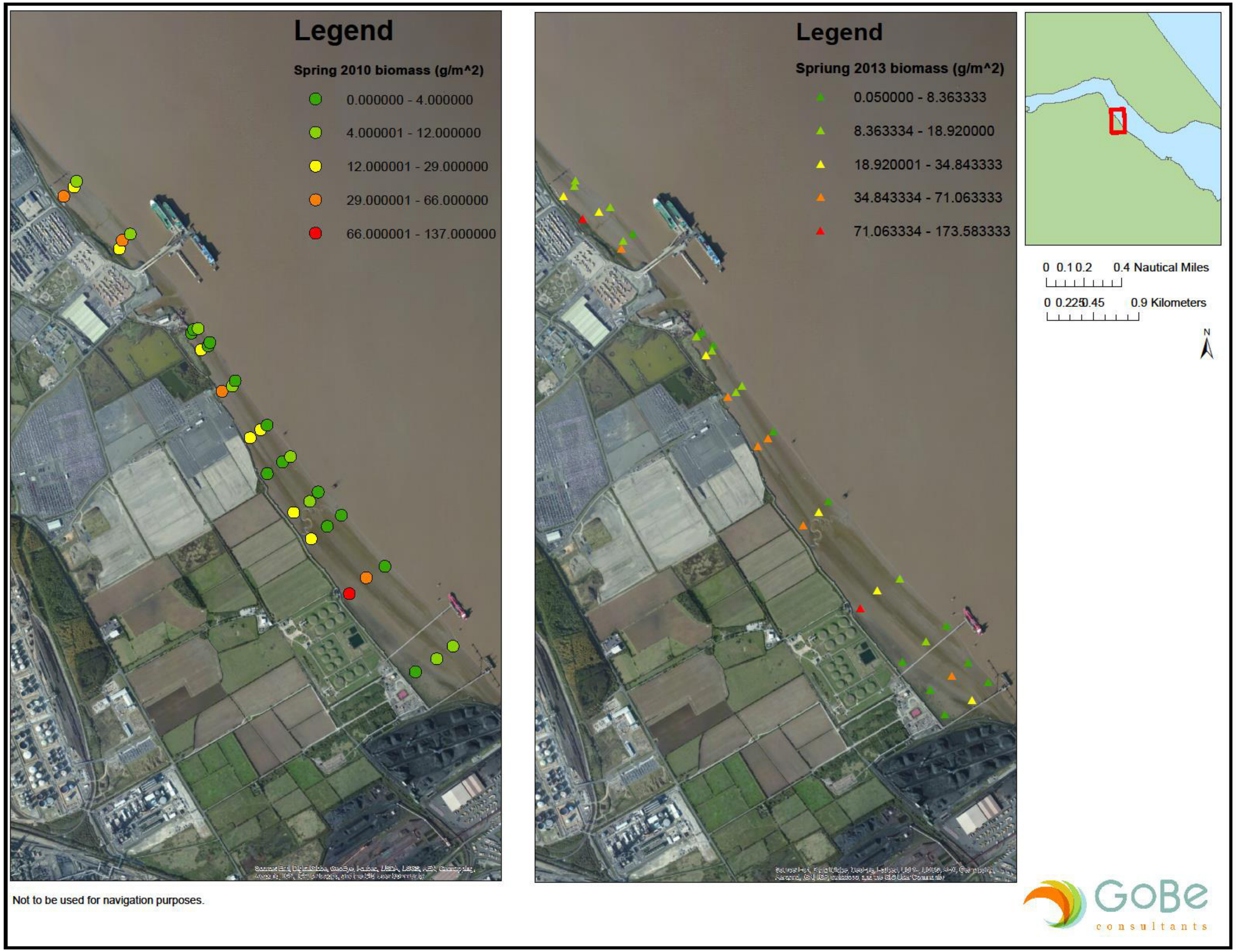


Figure 3 Spring 2013 Peak abundance (NKM and CCS)

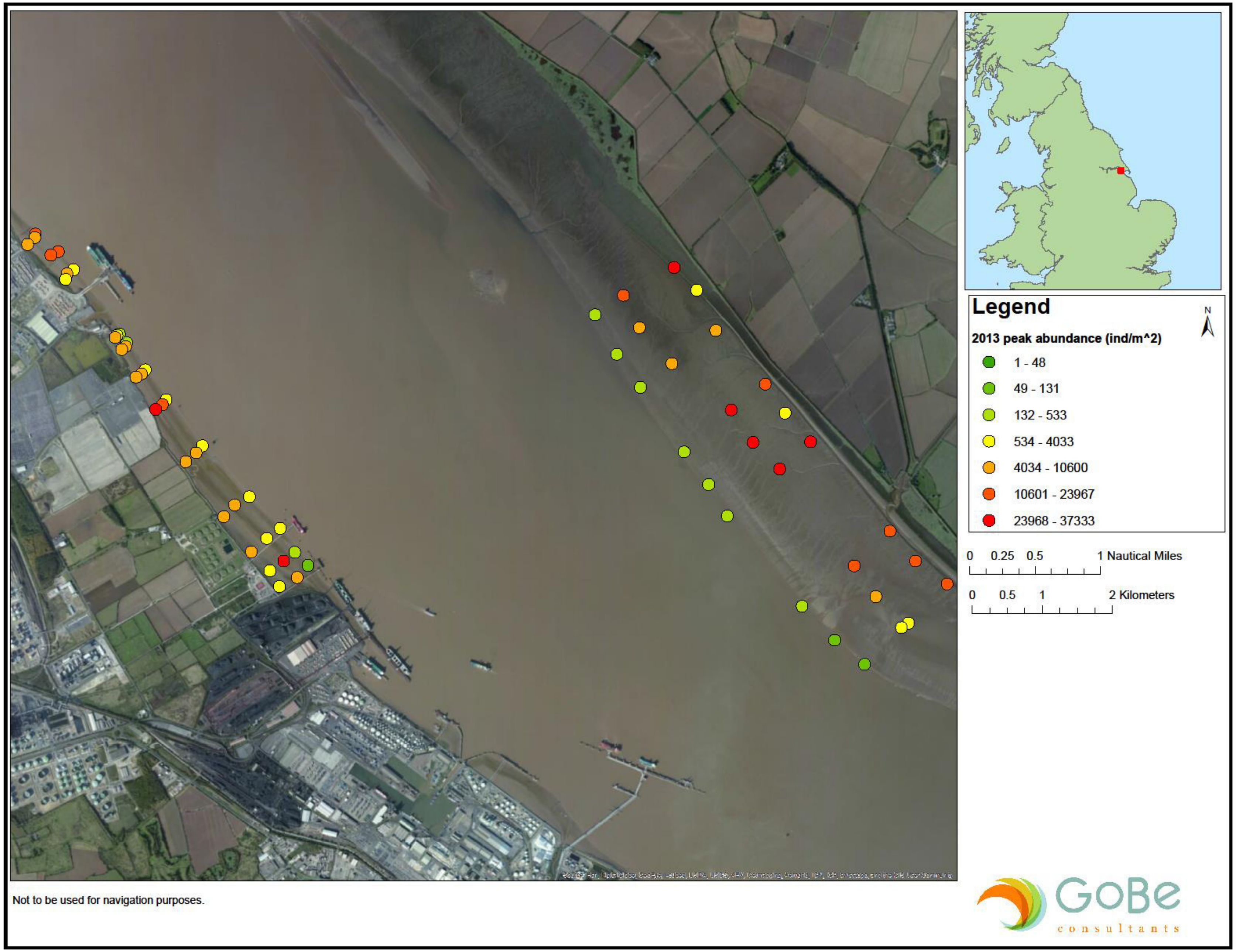


Figure 4 Spring 2013 Peak Biomass (NKM and CCS)

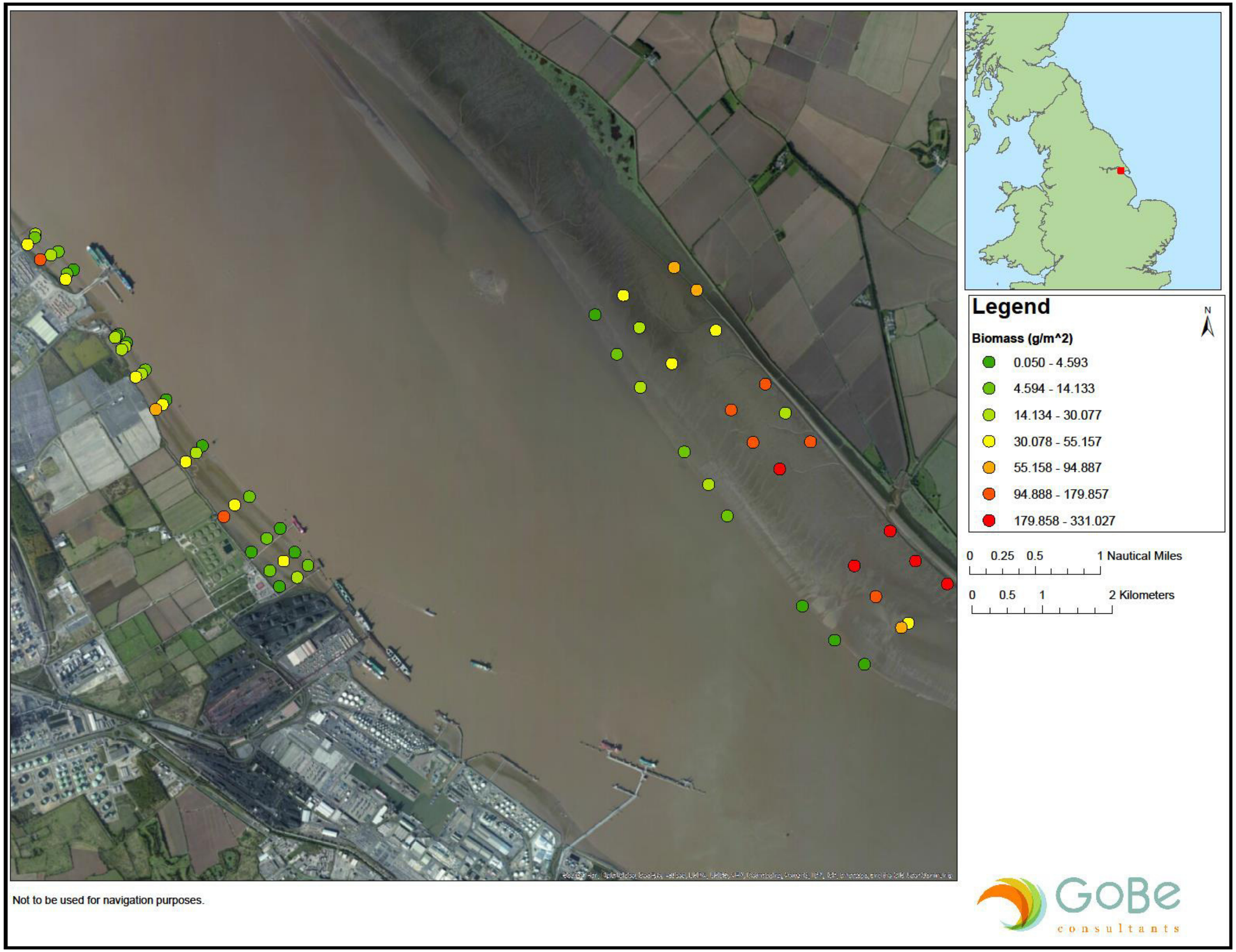


Figure 5 Autumn 2013 Peak Abundance

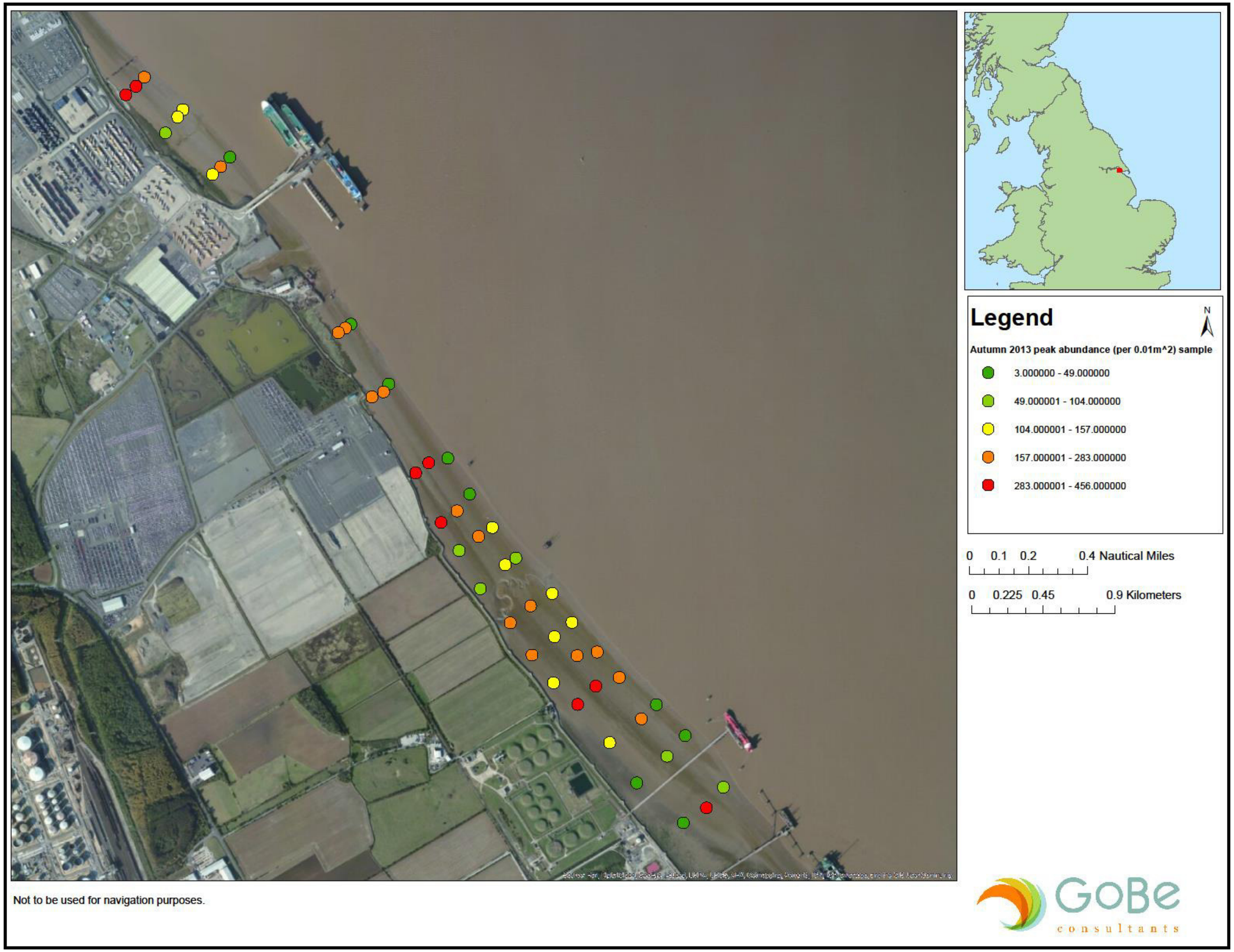
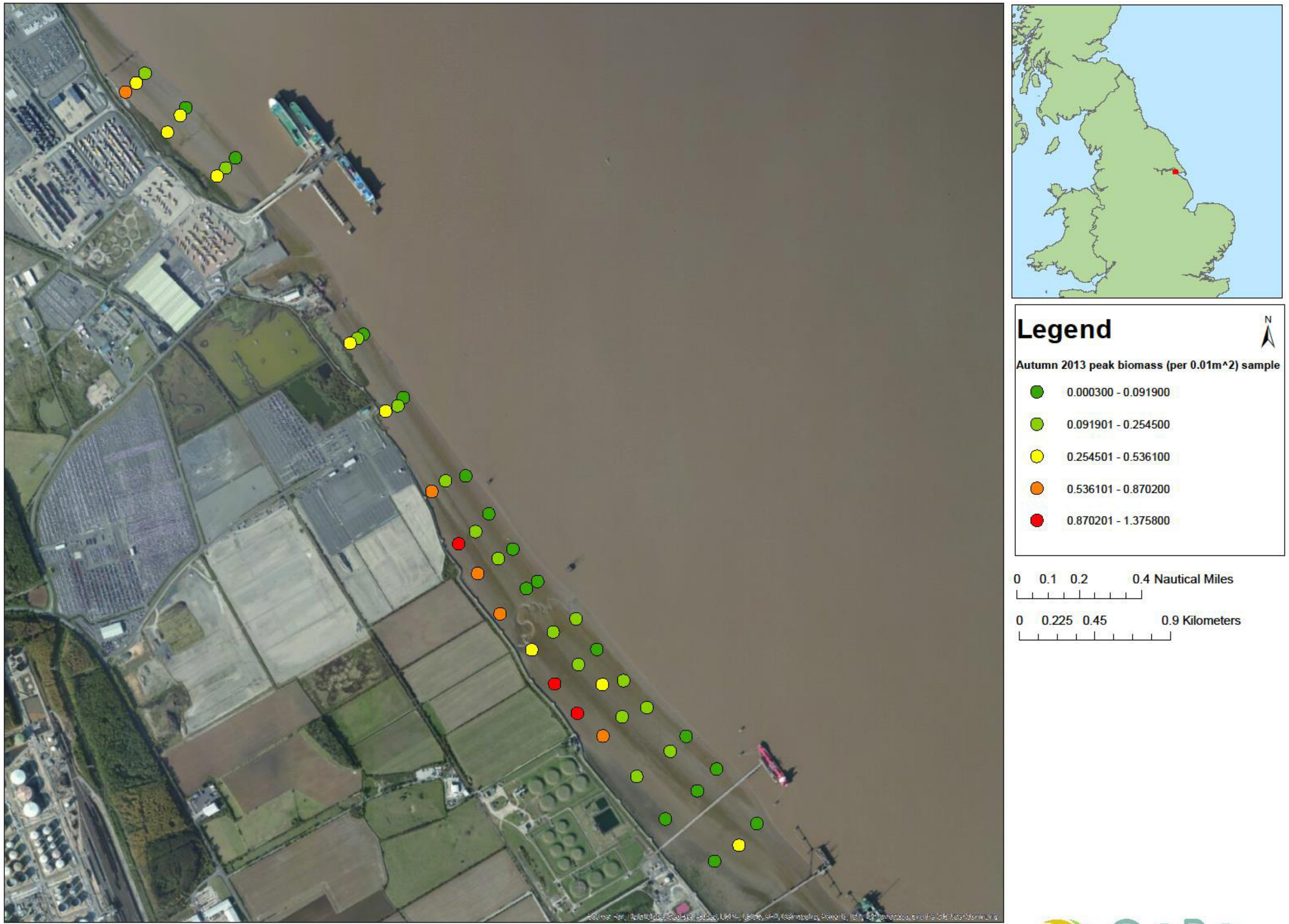


Figure 6 Autumn 2013 Peak Biomass



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Appendix A – Multivariate Analysis of the Spring 2010 and Spring 2013 benthic surveys

1. Addenda to October 2013 target setting analysis.

1.3.1. The following is an analysis of the North Killingholme Marsh spring 2013 and spring 2010 intertidal benthic invertebrate survey data.

1.1. Methods

1.1.1. The first step taken was to conduct a cluster analysis of the raw untransformed 2013 and 2010 survey data and construct a dendrogram. The cluster analysis, or hierarchical agglomerative clustering, describes a process where similar samples are fused into larger and larger groups. This grouping is based on group-averaging or nearest neighbour sorting of a matrix of samples' similarities, using the Bray-Curtis similarity measure. The results are displayed in a tree-like dendrogram (Figure 1). The cluster analysis is best used in conjunction with Multi-Dimensional Scaling (MDS) or ordination analysis thus allowing a check on the 'goodness of fit' of the clusters produced by both types of analyses (Figure 2).

1.1.2. The dendrogram in Figure 1 is labelled according to year, however whilst running the cluster analysis a SIMPROF analysis was run in parallel. A SIMPROF analysis allows the identification of 'true' groupings by testing for evidence of structure in an *a priori* unstructured set of samples. In combination with clustering this can generate trees/dendrograms that illustrate objectively-defined groups. The SIMPROF groupings are illustrated in Figure 3, the species contributing to the similarity within these groupings (a result of a SIMPER analysis) are then presented in Section 1.3 .

1.2. Results

1.2.1. The results of the analysis illustrate that there are no clear differences between the spring 2010 and spring 2013 survey datasets.

1.2.2. The SIMPROF analysis suggests that the differences between the groups are based on slight differences in the abundance of certain species, it is apparent through analysis of the SIMPER outputs that many of the same species are contributing to the groupings, though in slightly different abundances.

1.2.3. It is of note that the MDS illustrated in Figure 2 has a stress level of 0.19 which indicates that whilst it is a useful 2-dimensional plot it is necessary to cross-reference with the dendrogram. A stress level of <0.1 would be considered a good ordination with no prospect of a misleading interpretation. Cross-reference with the dendrogram illustrates clear groupings that are not attributable to differences between years. The differences between groups are, as would be expected, more generally attributable to shore level the lower shore, and those samples from the middle and upper shore (Figure 4).

1.2.4. A square root transformation of the data, to reduce the influence of numerically dominant species such as *Tubificoides* and *Corophium volutator*, further illustrates the similarities between years and are presented in Figure 5, Figure 6 and Figure 7.

1.2.5. The pattern in groupings becomes less complex with no apparent groupings according to year, but three distinct faunal groups. The primary species that are contributing to similarity appear to be *Diptera* in Group A, whilst *Corophium* contributes to Group B and *Streblospio* contributes to Group C.

1.2.6. A final analysis between years was conducted to give a single measure of similarity between samples (ANOSIM) to test the null hypothesis that there are no differences between years. The result of an ANOSIM test, referred to as sample statistic "R", gives a single measure of the similarity (or difference) between any two samples, based on a large number (set at 9,999 in the present study) of permutations of the replicate samples. When the value of R approaches 0, differences between samples are small and can be considered insignificant. When R approaches ±1, the samples will contain communities that are significantly different and which may be associated with disturbance and chance that they fall outside of natural variability.

1.2.7. The results are as follows and illustrate that the differences between samples are very small.

Global Test
Sample statistic (Global R): 0.078
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

1.2.8. This brief analysis confirms that the differences between 2010 and 2013 are *insignificant* and indiscernible through standard statistical methods.

1.2.9. Conversely, and as illustrated through the CLUSTER/SIMPROF analyses differences between shore levels are seen to be more significant. As shore level has more than 2 pairs of samples a global R result suggests samples differences that may be worth examining further. These pairwise tests are provided below and again highlight differences between upper and lower shore samples, and lesser differences between middle and upper shore. The lower and middle shore samples are also seen to have an R statistic that indicates the difference in communities present.

Global Test
Sample statistic (Global R): 0.199
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >=Observed
lower, middle	0.168	0.1	Very large	999	0
lower, upper	0.304	0.1	Very large	999	0
middle, upper	0.131	0.1	Very large	999	0

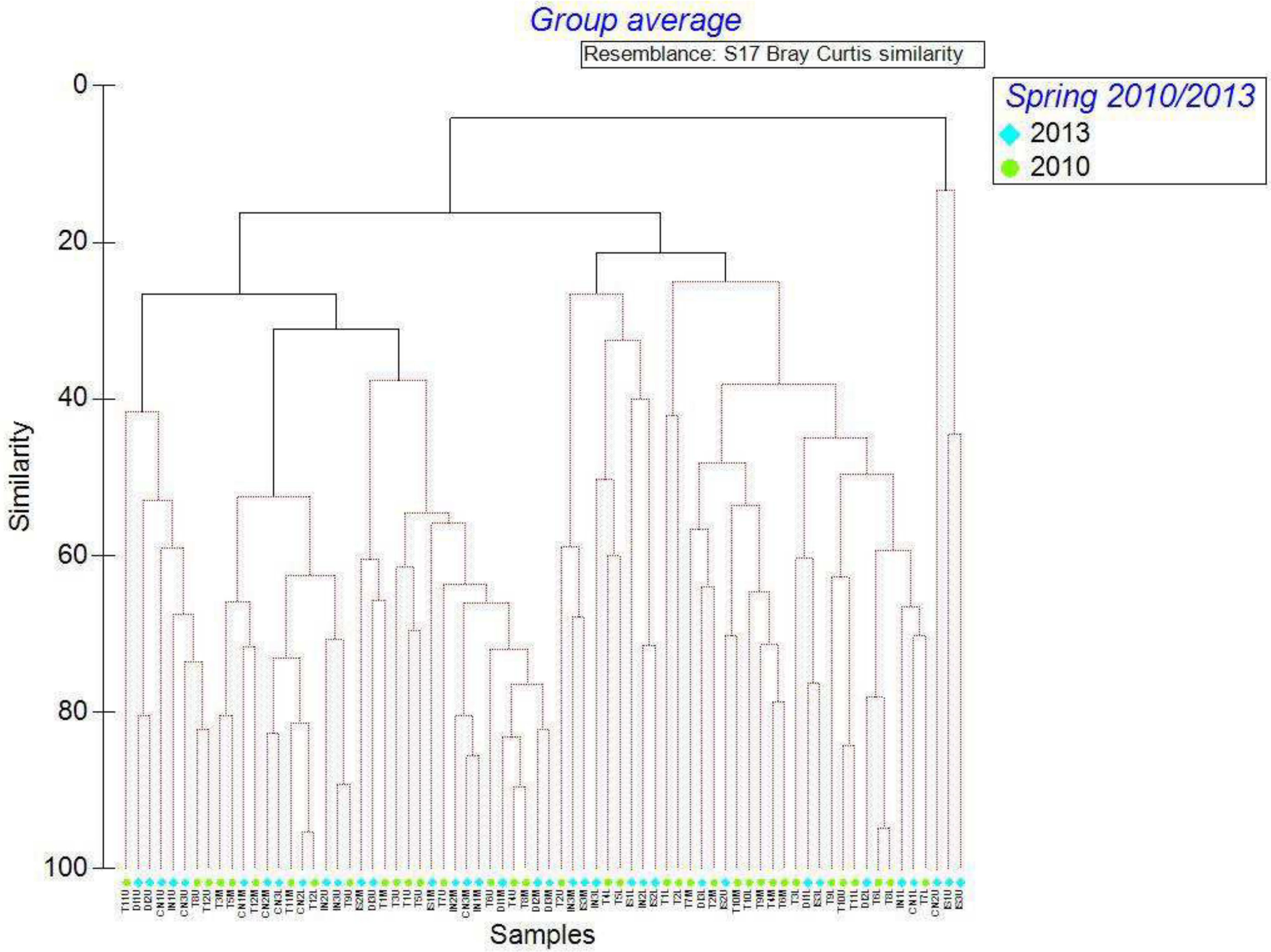

Figure 1 North Killingholme Marsh CLUSTER output illustrating 2010 and 2013 abundance data

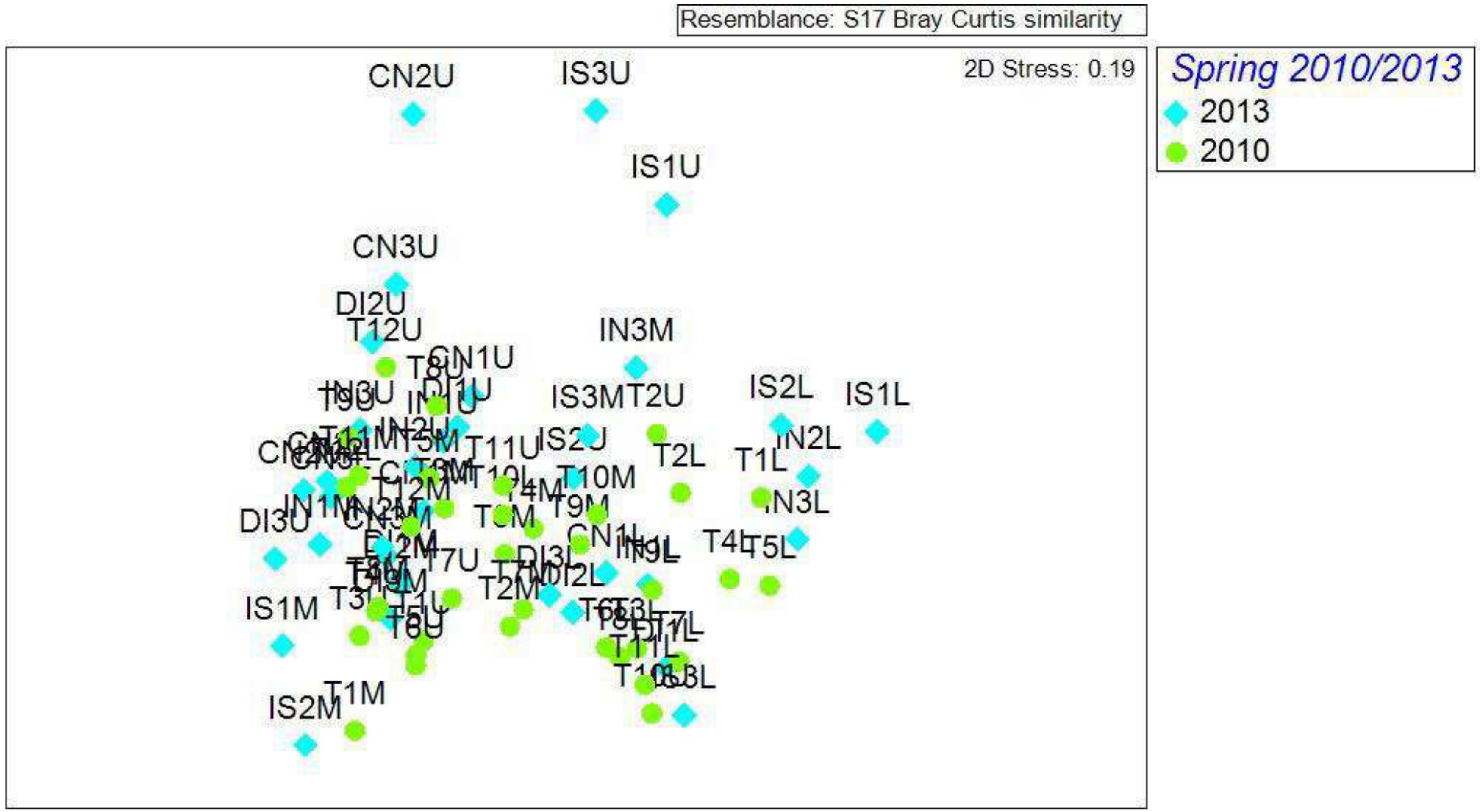

Figure 2 North Killingholme Marsh raw data MDS output illustrating the 2010 and 2013 abundance data

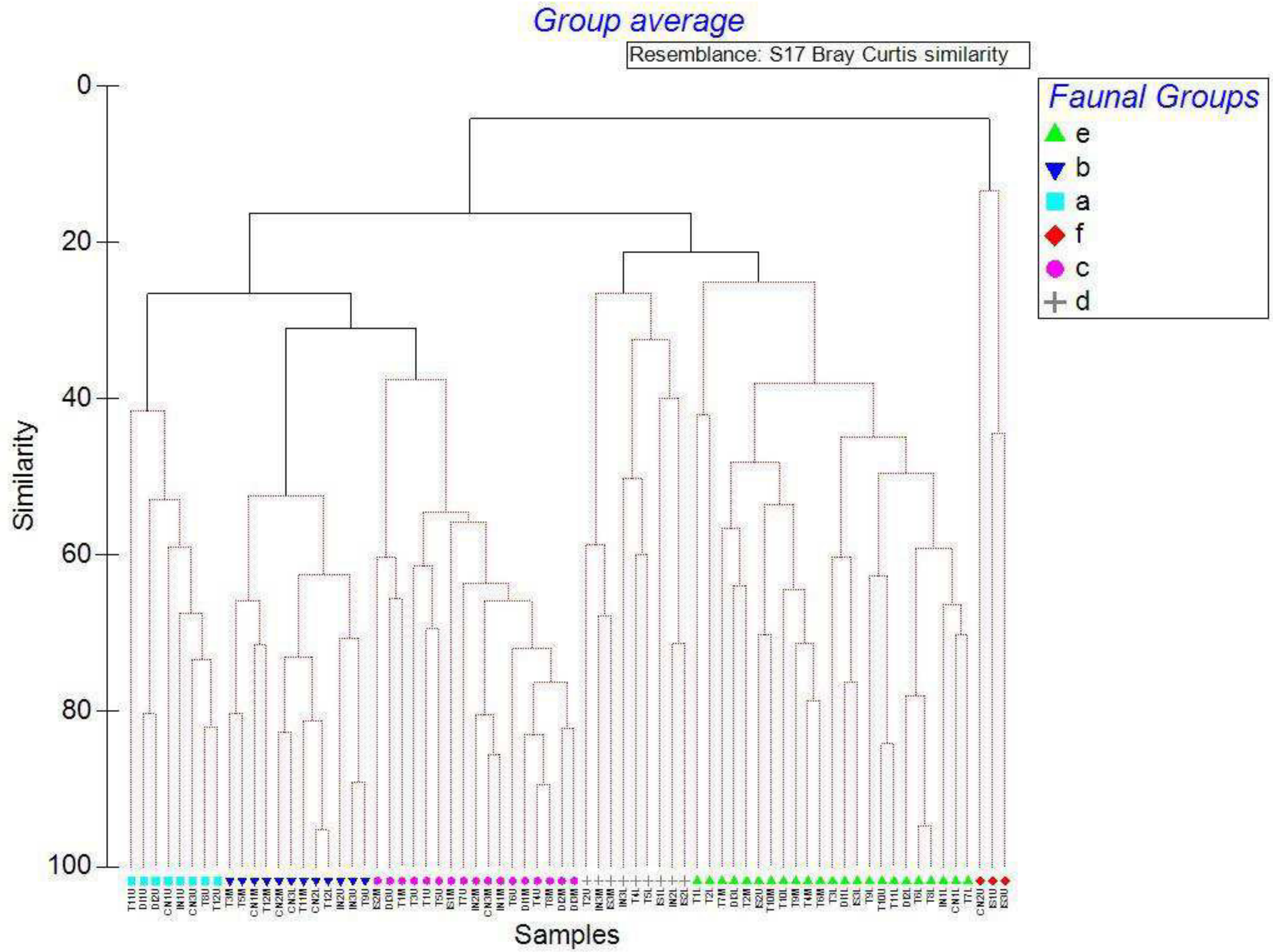

Figure 3 North Killingholme Marsh 2010 and 2013 data with SIMPROF faunal groups

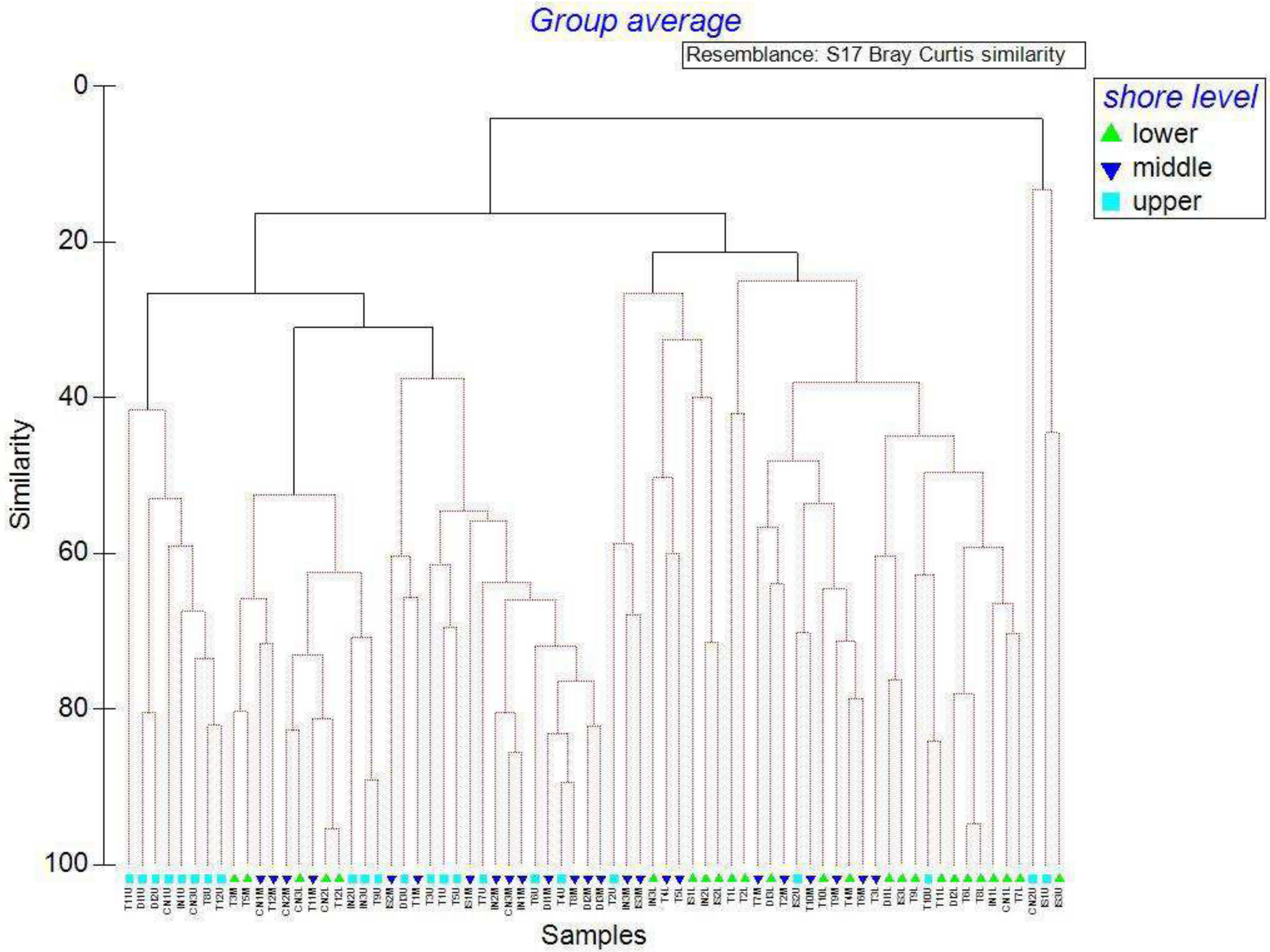

Figure 4 North Killingholme Marsh 2010 and 2013 data presented with shore level

1.3. SIMPER outputs of species contributing most to SIMPROF group similarity

Group e
Average similarity: 42.16

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Streblospio shrubsolii	6.19	21.51	1.34	51.03	51.03
Tubificoides benedii	3.64	6.75	0.96	16.02	67.05
Nematoda	2.78	5.92	0.93	14.05	81.10
Macoma balthica	1.64	5.19	0.91	12.32	93.42

Group b
Average similarity: 61.24

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophium volutator	56.64	49.64	3.83	81.05	81.05
Tubificoides benedii	6.25	3.72	0.97	6.08	87.13
Streblospio shrubsolii	8.14	3.33	0.79	5.43	92.57

Group a
Average similarity: 56.02

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hediste diversicolor	26.21	34.90	2.41	62.30	62.30
Corophium volutator	9.75	10.43	1.14	18.61	80.91
Tubificoides benedii	6.54	3.48	0.71	6.21	87.12
Nematoda	4.33	3.03	1.50	5.41	92.53

Group f
Average similarity: 23.74

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides agg. (pseudogaster)	96.00	18.17	1.04	76.54	76.54
Collembola sp.	20.89	4.33	1.16	18.24	94.78

Group c
Average similarity: 55.00

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides benedii	71.53	41.26	3.27	75.03	75.03
Corophium volutator	18.45	6.04	0.68	10.99	86.02
Streblospio shrubsolii	6.63	2.90	1.04	5.27	91.29

Group d
Average similarity: 35.23

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides benedii	1.78	21.38	1.97	60.71	60.71
Streblospio shrubsolii	0.78	6.13	0.63	17.41	78.12
Macoma balthica	0.19	3.37	0.52	9.58	87.70
Corophium volutator	0.96	3.15	0.36	8.95	96.65

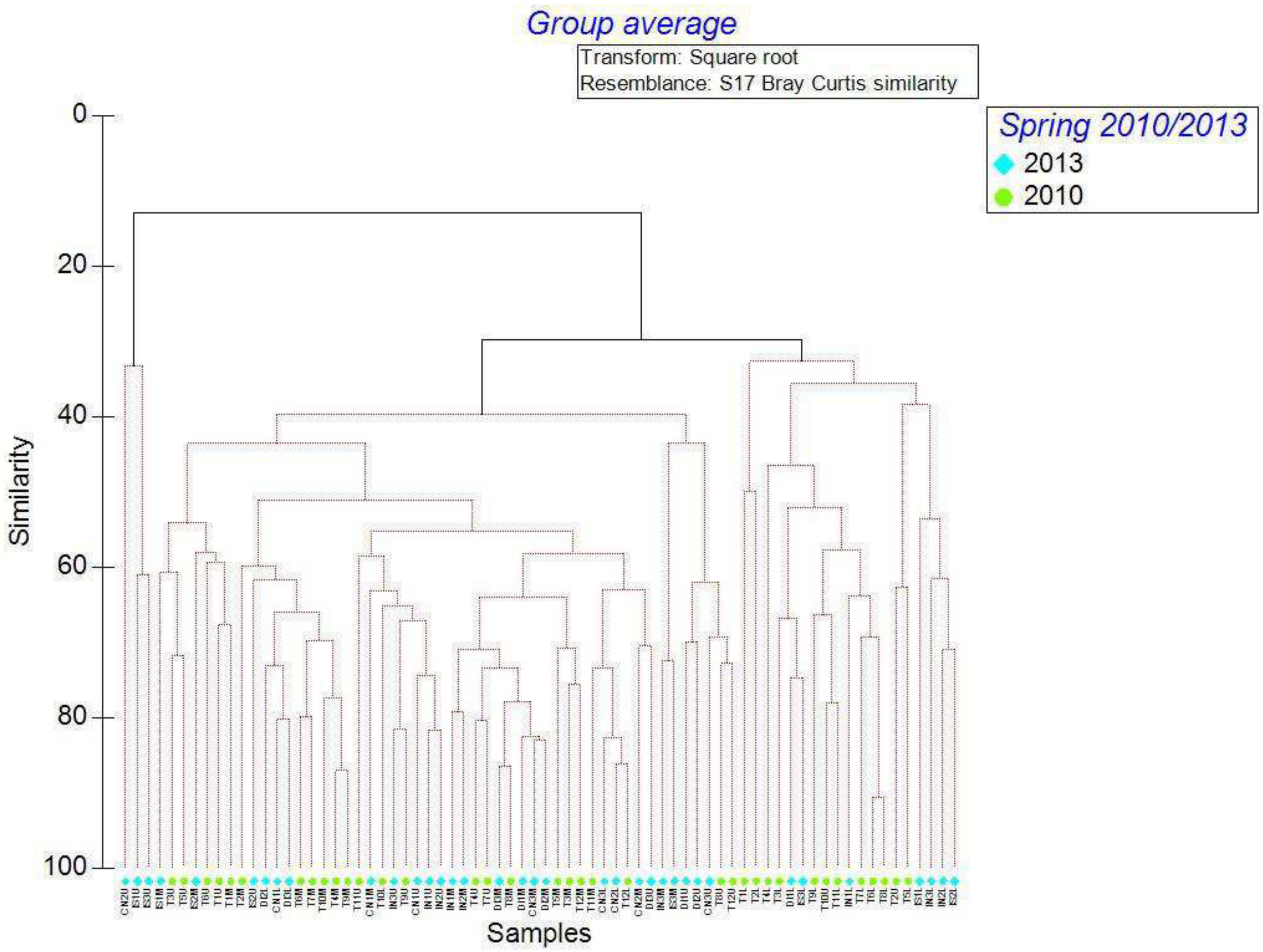

Figure 5 North Killingholme Marsh (SQRT transformation) 2010 and 2013

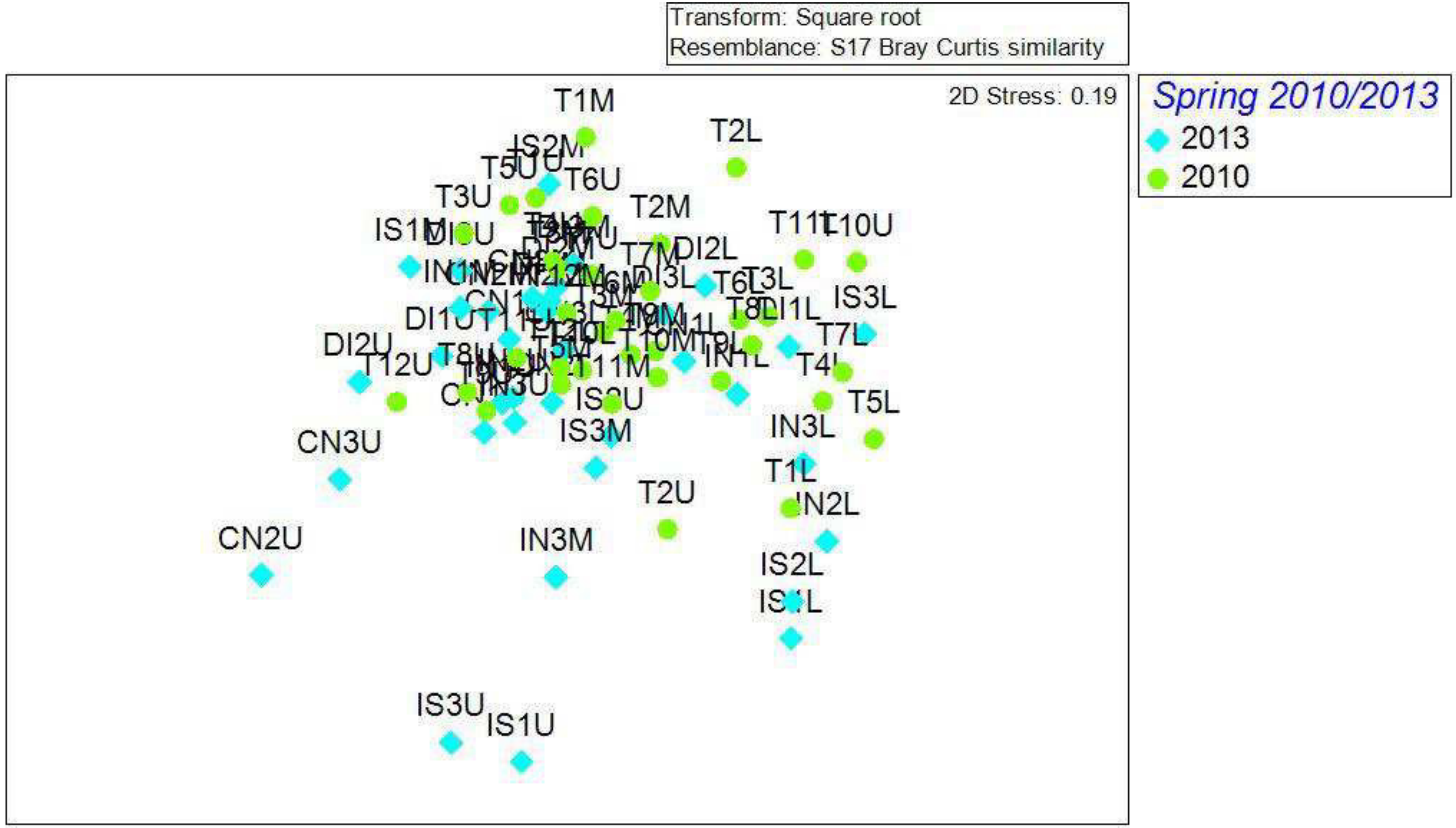

Figure 6 North Killingholme Marsh SQRT transformed data MDS (2010 and 2013)

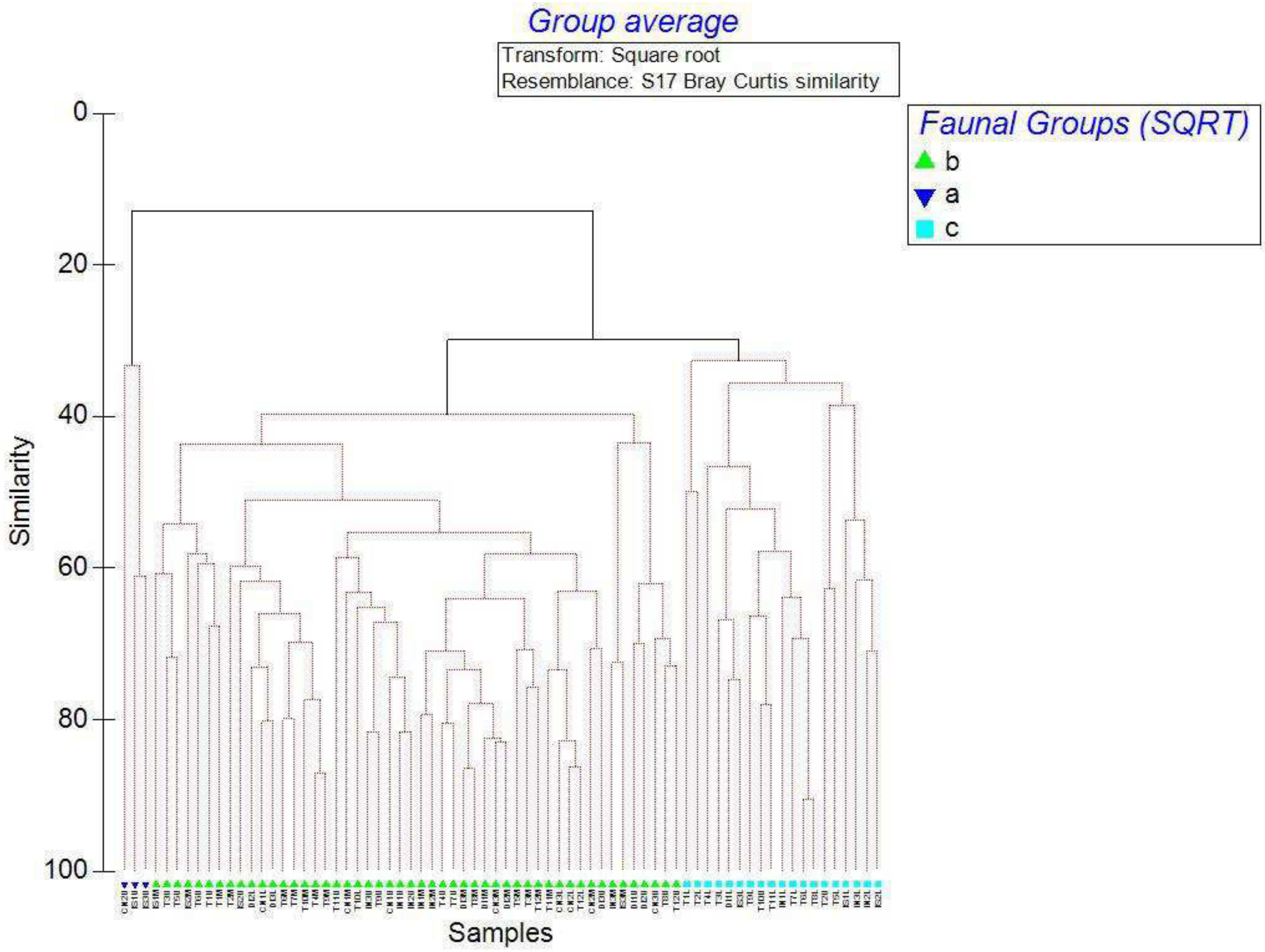

Figure 7 North Killingholme Marsh SQRT transformed data with SIMPROF Faunal Groups

Group b
Average similarity: 50.11

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides benedii	4.19	14.11	1.61	28.15	28.15
Corophium volutator	3.77	12.63	1.20	25.20	53.35
Nematoda	1.94	7.91	1.62	15.79	69.14
Streblospio shrubsolii	2.06	7.56	1.28	15.10	84.23
Macoma balthica	0.99	3.25	1.00	6.49	90.73

Group a
Average similarity: 42.67

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tubificoides agg. (pseudogaster)	8.09	23.36	2.01	54.75	54.75
Collembola sp.	4.04	11.19	2.02	26.22	80.97
Diptera sp.	1.08	4.90	2.18	11.49	92.47

Group c
Average similarity: 42.96

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Streblospio shrubsolii	1.69	16.88	1.07	39.29	39.29
Tubificoides benedii	0.87	12.15	1.20	28.28	67.57
Macoma balthica	0.84	8.56	0.96	19.94	87.51
Nematoda	0.54	3.02	0.50	7.03	94.54