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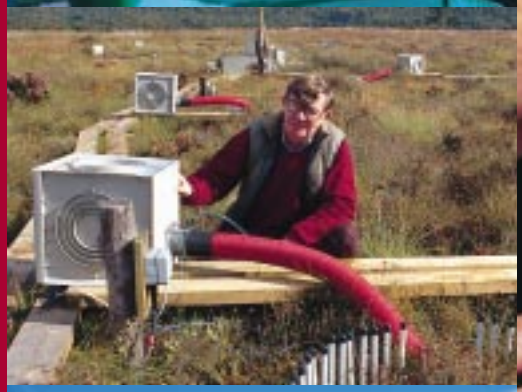

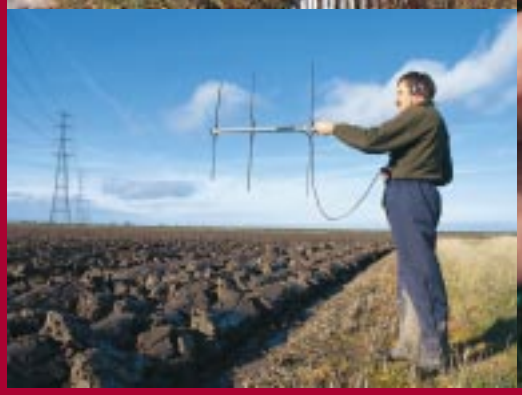

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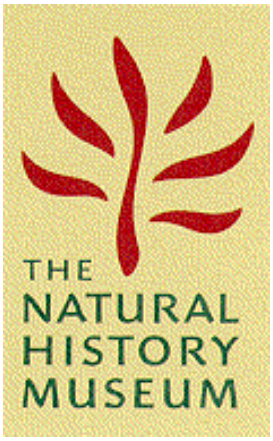
R.N. Bamber, N.J. Evans and P.J. Chimonides



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Summary

Moulton Marsh is a Lincolnshire Wildlife Trust Nature Reserve which lies on the southern bank of the River Welland just downstream of Fosdyke Bridge. The 36.4 ha site includes a number of pools and scrapes running alongside the canalized river embankment. In October 2003, these water features were surveyed by staff of the Natural History Museum (NHM) on behalf of English Nature in order to determine their merit (if any) as coastal saline lagoons. All fieldwork was undertaken with due regard to the recommended practices for sampling in lagoons (eg Bamber, Gilliland & Shardlow, 2001).

Three 'scrapes' (s1, s2 and s3) and four lagoons (numbered 1 to 4) were surveyed. The shallow scrapes had connection to the River Welland via sluices connecting with small streams, allowing water ingress and egress around the tidal cycle. The lagoons have arisen through excavation of material for construction of the embankments for flood protection of the adjacent farmland. They have sluiced pipe connections to each other and to adjacent scrapes, although not all of these connections are now functional. The water levels and quality of the lagoons is controlled by active management:

Salinities were mostly above sea-water normal, reflecting previous weather conditions of low rainfall; pH levels of the lagoon water were within the normal range for sea-water; total phosphate levels were generally high, around 1.0 to 1.5 $mg.l^{-1}$; all the sediments were fine muddy sands; organic contents of the sediments were low for a lagoonal sediment at around 2%.

The only nektonic species found were prawns (*Palaemonetes varians*) and gobies (*Pomatoschistus microps*). The only plants seen in the scrapes were superficial algae (*Cladophora* sp.), while their fauna was very impoverished, comprising little other than enchytraeid oligochaetes and a few shore crabs. Lagoon 3 was similar to these scrapes, although no animals were observed.

Lagoons 1 and 2 contained an extensive beds of *Ruppia*, patchy *Chaetomorpha linum*, and a dense fauna typical of coastal saline lagoons, including one scheduled species, the lagoon sand shrimp *Gammarus insensibilis*, and five other lagoonal specialists, the lagoonal mud snail *Ventrosia ventrosa*, the lagoonal cockle, *Cerastoderma glaucum*, the lagoonal isopod *Idotea chelipes*, the ostracod *Cyprideis torosa*, and the sea-mat *Conopeum seurati*. Lagoon 4 was shallower than these two, and mostly a Phragmites reed-marsh, with open water over 25% of its area, with a reduced but comparable community.

Comparison of the communities of Lagoons 1, 2 and 4 with a database of UK lagoons showed them closely similar to a suite of southern English lagoons of recognized high quality, demonstrating that these three pools at Moulton Marsh are saline lagoons of high conservation merit. Comparison with potential lagoonal habitats around The Wash surveyed during the 1980s showed that the Moulton Marsh lagoons support a higher diversity of lagoonal specialists,

Conclusions

The riverside scrapes at Moulton Marsh are not saline lagoonal habitats. They may have some merit as bird habitat, although their associated fauna is very impoverished. It appears that they are somewhat ephemeral as aquatic habitat.

The basin labelled Lagoon 3 is also impoverished, although the reasons are not apparent.

Lagoons 1 and 2 are fine examples of coastal saline lagoon habitat, of stable structural integrity, of appropriate salinity, shape and size, and they support typical lagoonal communities and biotopes, including one scheduled and seven other lagoonal specialist species.

The community of Lagoon 4 is a reduced version of the above. The site evidently has a greater source of freshwater input, and is progressing towards a *Phragmites* reed-marsh. As such it offers a diversity of habitat with the other lagoons on the reserve.

Overall, the Moulton Marsh saline lagoons are of high conservation merit, being the best examples of this habitat on The Wash and adjacent shoreline, as well as supporting a scheduled species. That they are already within a nature reserve should facilitate their protection.

Dr R N Bamber FLS FZS MIEEM
for The Natural History Museum

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1. Introduction

Moulton Marsh is a Lincolnshire Wildlife Trust Nature Reserve which lies on the southern bank of the River Welland just downstream of Fosdyke Bridge (TF340334). The site lies just outside the boundary of The Wash SSSI, SPA, RAMSAR site and The Wash and Norfolk Coast cSAC. The 36.4 ha site includes 6 ha of woodland and 16 ha of saltmarsh. Southwest of the woodland areas at the 'downstream' end of the reserve, there are a number of pools and scrapes running alongside the canalized river embankment.

In October 2003, these water features were surveyed by staff of the Natural History Museum (NHM) on behalf of English Nature in order to determine their merit (if any) as coastal saline lagoons. Priorities for the survey were:

- to identify the appropriate habitat conditions,
- to determine any presence of lagoonal specialist or scheduled species,
- to determine any threats to the habitat, species or communities,
- to gain data sufficient to put the Moulton Marsh lagoons in the context of saline lagoons elsewhere in the UK.

Coastal saline lagoons are a priority habitat under the EC Habitats and Species Directive, and thus a habitat for which Special Areas of Conservation (SACs) should be established. Their conservation priority in the UK includes their supporting communities of plants and animals, some of which are largely or entirely confined to lagoons in the UK; nine such species are currently protected under Schedules 5 and 8 of the Wildlife and Countryside Act 1981.

2. Methods

The site visit, undertaken on 30 October 2003, was planned as an extensive rather than intensive survey. All water bodies were examined *in situ* for submerged plants and signs of animal life (including net sweeping in deeper waters); only sites which were judged from experience, or were observed *in situ* to be likely to support a saline lagoon community, or at least appropriate species, were sampled in detail.

All fieldwork was undertaken with due regard to the recommended practices for sampling in lagoons (eg Bamber, Gilliland & Shardlow, 2001), after appropriate risk assessments. Priorities were to minimize destructive sampling of what is a sensitive habitat, and to identify material *in situ* if possible. With respect to Section 16 (3) (a) of the Wildlife and Countryside Act 1981, all work was carried out under English Nature Licence No. 20031279.

2.1 Benthos

Quantitative samples were taken of the sedimentary fauna where appropriate. Samples were collected using a 0.005 m^2 hand-corer to a depth of 15 cm, ten cores being amalgamated for each sample (total area 0.05 m^2). At sites where the substratum did not allow satisfactory penetration of the core tube, samples were collected from an equivalent area either by surface scrape or using a hand net. Samples were immediately sieved in the field over a 0.5 mm mesh and fixed within 12 hours of collection. Eight quantitative samples were taken in total. Replicate sample sites within a lagoon were identified by the number of the lagoon and a

letter (eg 1A, 1B, etc.). Hard substrata (stones, reed-stems, etc.) were examined *in situ* for bryozoans and hydroids.

2.2 Nekton

Any species observed swimming in the water column were collected by sweeping with a hand net of 0.5 mm mesh, identified and returned to the water.

2.3 Submerged plants

Submerged plants were identified *in situ*. Their associated fauna was assessed by rinsing approximately 1 litre of weed in a bucket of water, then sieving the residual water (0.5 mm mesh). Where species so collected could be identified *in situ* (eg prawns, fish), these specimens were returned to the lagoon.

In the laboratory, samples were sorted under the binocular microscope, and all animals counted and identified to species where possible.

2.4 Sediments

At a representative number of benthic sampling points, a sample of surface sediment was collected for granulometric analysis. Two samples were collected from scrape 1, reflecting cleaner and muddier substrata, and deemed representative of scrapes 2 and 3; single samples were taken from each of Lagoon 1 and Lagoon 2. It was not possible to collect a representative sediment sample from Lagoon 3, where the bottom of firm sand had a patchy veneer of finer clay material, at a depth generally prohibiting safe coring. Samples were analyzed to 0.5Φ fractions by dry sieving of the coarse fraction and use of a particle sizer for the fines. Parameters of the granulometry were calculated as in Buchanan (1984). The organic carbon content of the sediments was calculated as the loss-on-ignition at 450ºC, as a percentage of the sediment dry-weight.

2.5 Physico-chemical parameters

Salinity was measured using a refractometer (to the nearest 0.5‰[1]). In each lagoon, measurements were made of the water at each sampling point, together with as many other points around the system considered necessary to understand the variability. Where depth allowed, surface water and full-depth-mixed water were measured to detect any stratification; in the event, no stratification was found in any of the lagoons studied (possibly relating to the lack of recent freshwater input because of the preceding dry weather). The salinity of the adjacent water source of saline water input, ie the River Welland, was also measured.

Temperature, pH, and total phosphate levels of the water were measured *in situ*, normally once in each lagoon unless variation was detected. Temperature and pH were measured either with a Hanna Instruments Portable Water Test Meter, or an alcohol thermometer and Aquamerck® pH kit; total phosphate was measured to the nearest 0.25 $mg.l^{-1}$ using an Aquamerck® test kit.

[1] Parts-per-thousand; normal full-strength sea-water is at about 35‰.

2.6 Other parameters

In addition, each lagoon was inspected for:

- integrity of structure, extent, bank make-up and apparent stability, depths, as well as for their water inputs and outputs (both freshwater and saline water);
- 'lagoon type' (physiographic type);
- lagoonal biotopes (and their dispersion);
- potential threats to the integrity of the lagoonal habitat.

Position fixing in the field was by GPS. Estimated potential error (EPE) was mainly 3 m.

3. Results

3.1 The lagoons and scrapes

The location of the water bodies investigated is shown in Figure 1 superimposed on an aerial photograph of the site kindly supplied by the client. The map of the site is given as Figure 2, with three 'scrapes' (s1, s2 and s3) and four lagoons (numbered 1 to 4) indicated.

The water bodies alongside the river embankment were shallow (up to 0.25 m), with relatively compact sandy substrata. A number of 'islands' were present, partly as a result of preceding dry weather, although there were areas under water which showed signs, such as superficial cracking, of having dried in the recent past. These scrapes had connection to the River Welland via sluices connecting with small streams, allowing water ingress and egress around the tidal cycle. The three main basins were labelled s1, s2 and s3 (from northeast to southwest) for the purposes of this study (Figure 2). Only scrape s1, the largest of these three at 0.91 ha, was sampled intensively. The water area of the other lagoons was 0.25 and 0.31 ha for s2 and s3 respectively (Table 1).

Four main water bodies were identified inland of the scrapes. These are lagoons 1 to 4 (numbering from northeast to southwest) as shown on Figure 2. These lagoons have arisen through excavation of material for construction of the embankments for flood protection of the adjacent farmland. They have sluiced pipe connections to each other and to adjacent scrapes, although not all of these connections are now functional.

The water levels and quality of the lagoons is controlled by active management: water from the river can be let in at high tide to compensate for losses through evaporation during dry weather.

Lagoons 1 and 2 were very similar, linear pools to a depth of >1 m, and incorporating islands with shored banks; the area of each was 1.15 and 1.08 ha respectively. Common reed (*Phragmites*) beds extended along the southern, eastern and northern banks of both lagoons. A 250 mm diameter pipe centrally sited in the southwestern bank of Lagoon 1 connects to Lagoon 2; this equalises the water level of the two lagoons within 12 hours. There are apparently non-functional pipes connecting through the western bank to scrape 1. A further pipe connects from the westernmost corner of Lagoon 2 to a drainage ditch which leads to the

River Welland. Some control over the water in these two lagoons is enabled by operation of sluicing on this pipe.

Lagoon 3 (0.47 ha) appears both in location and structure somewhere between the scrapes and the lagoons; it again incorporates islands, has a depth exceeding 0.5 m and, while apparently isolated from the adjacent Lagoons 2 and 4, has a drainage ditch connection to the River Welland from its southwestern end.

Lagoon 4 is, by contrast, principally a shallow reed-bed, with an extensive area of *Phragmites* on either wet muddy sand of in shallow water (<0.1 m except for a small pool halfway along the northwestern side which sinks to a muddy bottom at some 0.5 m); while the reeds have apparently encroached over recent years (and are still doing so) a narrow band of open water extends down the centre of the southwestern two-thirds of the basin (see Figure 2); thus, while the basin area was 1.19 ha, the area of open water was only 0.31 ha. There is a small pipe feed into the lagoon in its northern corner.

No connections were found to landward sources of freshwater (ditches or streams), although groundwater flow cannot be excluded.

Full descriptions of the lagoons are given below (Appendix 1) in the format of the English Nature lagoons directory (Downie, 1996).

3.2 Physico-chemical conditions

The water quality parameters are presented in Table 1. No stratification was detected.

Salinities were mostly above sea-water normal, reflecting previous weather conditions of low rainfall. The ideal range for specialist lagoonal species/communities is between 20 and 40‰ (Bamber and others 2001). At the time of sampling, the adjacent river water was at 36‰.

Data from salinity monitoring of Lagoons 1, 2 and 4 over 2003 has been gathered by the reserve managers, and is presented as Figure 3. Abrupt rises in salinity relate to active topping up of the lagoons, marked falls are a consequence of rainfall. As can be seen, both Lagoon 4 and the connected pair of Lagoons 1 and 2 show a seasonal pattern, with low salinity in the late winter and hyperhaline water in the autumn. Equally, variation in salinity is greater in Lagoon 4, and the actual salinity is generally lower.

Table 1. Physical and water-quality parameters of the lagoons and scrapes at Moulton Marsh

Pool	**Area, ha**	Salinity, ‰	Temperature, ℃	pH	Phosphate, $mg.l^{-1}$
Lagoon 1	1.15	38	10	8	1.5
Lagoon 2	1.08	38	8	8	1
Lagoon 3	0.47	36.5			
Lagoon 4	1.19 (0.31)	27	9	8	
Scrape 1	0.91	37	8	7	1.25
Scrape 2	0.25	36			
Scrape 3	0.31	36			

pH levels of the lagoon water were within the normal range for sea-water (7.8 to 8.3), slightly lower in scrape 1. pH in coastal lagoons can range widely between 6 and 10, in response to decomposition of organic material on the one hand and photosynthetic activity of submerged plants or algal blooms on the other.

Total phosphate levels were generally high, around levels suggested to be disadvantageous for foxtail stonewort, *Lamprothamnium papulosum* (mooted upper tolerance level 1.0 $mg.l^{-1}$; Bamber and others 2001). The source may be the widespread agricultural activities of the surrounding land (including the catchment of the River Welland).

The results from the sediment granulometry analysis are shown in Table 2. All the sediments were fine muddy sands. The size frequency showed a bimodal distribution, with a normally-distributed peak of fine sand from the local soil (peaking around 70µm) and a secondary peak of fine silt and clay particles which would represent deposition of fines into the lagoon over time. Sample s1B, from scrape 1, was at the centre of the landward side of the lagoon, furthest from the sluices, and representing the least water flow; here the silt-clay fraction was substantially larger, and the sediment a sandy mud, reflecting greater deposition of material.

Table 2. Sediment granulometry and organic content (as % loss-on-ignition) forn lagoons 1 and 2, and two sites in scrape 1.

Pool	% gravel	% sand	% silt/clay	Median diameter, µm	% organics (LOI)
Lagoon 1	0	77.88	22.13	89.37	2.1
Lagoon 2	0	67.87	32.13	58.76	2.0
Scrape 1, s1B	0	33.04	66.96	20.90	6.7
Scrape 1, s1C	0	67.06	32.94	61.63	2.5

The organic contents of the sediments were low for a lagoonal sediment at around 2%, although higher in the siltier depositional sediments at s1B.

The remaining scrapes were judged to have a similar sediment to that of scrape 1; Lagoon 4 had a similar sediment to that of lagoons 1 and 2. The appearance of the sediment in Lagoon 3 was similar to that at Scrape 1, s1C.

Table 3. Species recorded from 0.05 m^2 infaunal (sediment) samples at Moulton Marsh; sample 4C was a non-quantitative collection of gastropods from the mud in the *Ruppia*-pool of Lagoon 4.

Sample:	S1A	S1B	S1C	1B	1C	2A	4A	4B	4C*
Annelida									
Eteone longa				1					
Nereis diversicolor				253	33	15	1	10	
Aphelochaeta marioni				406	605	710			
Polydora cornuta				3	87	30			
Pygospio elegans				3	9	5			
Enchytraeidae	12	103	49					2	
Tubificoides pseudogaster						407	10	82	
Arthropoda									
Crustacea									
Praunus flexuosus					1				
Gammarus insensibilis					15	5			
Idotea chelipes					69	312	41		
Lekanesphaera rugicauda							1		
Carcinus maenas		2							
Insecta									
Collembola	1	2	1						
Chironomidae larvae				74	157	25	1	66	
Mollusca									
Hydrobia ulvae							2		21
Ventrosia ventrosa				370	78		13		2
Potamopyrgus antipodarum							4		9
Cerastoderma glaucum				2					

3.3 Fauna and flora

The nomenclature, common names where they exist, and significance to lagoonal communities for all species recorded are given in Appendix 2. "Scheduled" refers to the Wildlife and Countryside Act 1981.

The species recorded from benthic samples in each water body are shown in Table 3. The species recorded from submerged plants are shown in Table 4.

No nektonic species were caught during net-sweeps, although both prawns and gobies were observed *in situ*.

TABLE 4. Species recorded from weed samples in Lagoons 1, 2 and 4 (SACFOR scale: S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare**)**

	1A	2A	4C
Weed:	*Ruppia*	*Chaetomorpha*	*Ruppia*
Annelida			
Nereis diversicolor			C
Polydora cornuta			O
Arthropoda			
Crustacea			
(Cyprideis torosa)			
Praunus flexuosus	R		
Gammarus insensibilis		C	
Idotea chelipes	S	S	C
Lekanesphaera rugicauda			R
Chironomidae larvae		R	
Sigara sp.			R
Mollusca			
Hydrobia ulvae		F	
Ventrosia ventrosa	C		F
Bryozoa			
Conopeum seurati	A		A

The only plants seen in the scrapes were superficial algae (*Cladophora* sp.). The fauna of the scrapes was very impoverished, comprising little other than enchytraeid oligochaetes. A few shore crabs, the isopod *Lekanesphaera rugicauda* (observed *in situ* but not taken in the samples) and the common goby (*Pomatoschistus microps*) were present in scrape 1; the collembolans (springtails) were probably of terrestrial origin. Scrape 3 was observed to have a similar sparse fauna; scrape 2 was not examined.

Lagoon 1 contained an extensive and dense bed of *Ruppia*[2]. Sample 1A was within the *Ruppia* bed, and only the weed-associated fauna could be collected owing to the density of the plant growth (Table 4). The associated species other than the common mysid *Praunus flexuosus* were lagoonal specialists, with the isopod *Idotea chelipes* in very large numbers, including brooding females and juveniles, while the lagoonal hydrobiid snail *Ventrosia ventrosa* was also common. The encrusting bryozoan *Conopeum seurati* grew abundantly on the stems of the *Ruppia* plants. These species are typical of the ENLag.Veg lagoonal biotope of Bamber (1997).

Sample 1B was from the shallow fine sandy sediment, where lugworm (*Arenicola marina*) was seen to be common (although not taken in the sample), and 1C from deeper water where the substratum was black mud within the *Ruppia* bed. Both sites were dominated by ragworm, chironomid larvae, the cirratulid polychaete *Aphelochaeta marioni* and the lagoonal mud snail *Ventrosia ventrosa* (Table 3). The shallower site also supported the lagoonal cockle, *Cerastoderma glaucum*. The deeper site generally had a denser fauna, with a higher population of the infaunal spionid polychaete *Polydora cornuta*, although fewer

[2] Both *Ruppia maritima* and *R. cirrhosa* may be present in this system; however, it is not feasible to distinguish these in the field when they are not in flower. These species are thus referred to herein by the genus name only.

ragworm or *V. ventrosa*; cockles were not found in this sample (but may be expected to be widespread across the lagoon: a number of dead shells were found), but, owing to the adjacent *Ruppia*, large numbers of the lagoonal isopod *Idotea chelipes* and specimens of the scheduled "lagoon sand shrimp" *Gammarus insensibilis*. This community is a typical example of the ENLag.IMS.Ann biotope, with lagoonal specialists.

The lagoonal ostracod *Cyprideis torosa* was also recorded from Lagoon 1, although owing to its small size it would have been undersampled.

Lagoon 2 was similar in morphology to Lagoon 1, with a bed of *Ruppia* in the deeper water (not easily accessible by wading), but additionally with floating clumps of the lagoonal specialist form of the alga *Chaetomorpha linum*. The substratum was slightly muddier. The lagoon supported a similar typical saline lagoonal specialist community. Sample 2A, within the *Chaetomorpha*, included very large numbers of *Idotea chelipes*, and *Gammarus insensibilis* was common (this species is thought to live preferentially on *Chaetomorpha*); the only hydrobiid snail present was the common estuarine *Hydrobia ulvae*.

The sediment sample (2B) was taken adjacent to the weed clump of sample 2A. The community was closely similar to that found in the deeper sample 1C, although with an abundance of oligochaetes and no molluscs. The lagoonal isopod *Idotea chelipes* and *Gammarus insensibilis* were again present.

Repeated sampling in Lagoon 3 of the water column and of the bottom mud by net-sweeping discovered no evident animals at all. The substratum was similar to that of the scrapes, although this pool was much deeper.

Lagoon 4 was essentially a *Phragmites* reed-marsh. Prawns (*Palaemonetes varians*) and water boatmen (*Sigara* spp.) were identified *in situ* swimming in more open-water-areas amongst the reeds. Sampling of the sediments within the reed and in the open water to the southern end revealed a similar community to Lagoons 1 and 2, although a comparatively sparser fauna; three hydrobiid snail species were present, including the lagoonal *Ventrosia ventrosa* but also the lower-salinity-tolerant *Potamopyrgus antipodarum*, suggesting a greater freshwater influence in this lagoon. The reed *Phragmites* also prefers low salinity to freshwater, and at the time of sampling the water here was some 10‰ fresher than that in Lagoons 1 to 3.

The *Ruppia* present in the small, deeper 'side-pool' had a diverse associated fauna, including *Idotea chelipes* and *Ventrosia ventrosa*, while *Conopeum seurati* was again abundant on the stems.

4. Comparisons with other lagoons

4.1 General comparison

Problems in the interpretation of the conservation "quality" of saline lagoons include the patchiness of specialist species distribution both in time and space, including the inherent variability in communities. One technique being employed to classify lagoons in the UK is to compare the whole community structure with that of a standard suite of UK lagoons, based on quantitative data. This can interpret appropriate-quality communities even when specialist species are not well represented (ie where they have not had the opportunity to recruit).

The Moulton Marsh Lagoons 1, 2 and 4 were analyzed against the standard UK database held at the NHM by cluster-analysis of Bray-Curtis similarity, based on log-transformed data owing to the overdominance of certain species in lagoonal communities. The resulting dendrogram is shown as Figure 4.

Within the standard lagoon suite, two clusters of "good" lagoons exist characterized by their dominant oligochaete species, viz the higher salinity, *Tubificoides pseudogaster* communities typical of southern England (Cluster HAN, including Fort Gilkicker Lagoon, regarded as the second best lagoon in the UK from the point of view of its flora and fauna) and the lower salinity *Heterochaeta costata* communities found in Wales (Cluster WAL). The surrounding sites are impoverished lagoons and paralagoonal, estuarine or freshwater habitats.

As can be seen, the Moulton Marsh lagoons associate most closely with the typical southern England "good-lagoons" cluster; indeed, they only lie to the side of this cluster owing to their lack of two lagoonal specialists which occur at the remaining sites. This analysis confirms that these three pools at Moulton Marsh are saline lagoons of high conservation merit.

4.2 Local comparison

Potential lagoonal habitats around The Wash were surveyed in the 1980s, although Moulton Marsh was not one of these sites (Smith & Laffoley, 1992). There appears to be no published account of more recent surveys. The lagoon at Snettisham Gravel Pits was part of the recent RSPB-led LIFE project on coastal lagoons, but no invertebrate or aquatic plant data have been reported from that work, which mainly concentrated on restructuring the site in relation to its use as a bird reserve.

Those studies did not involve quantitative sampling, so the sites could not be included in the multivariate cluster-analysis above. The occurrence of lagoonal specialist species in these lagoons is compared with those at Moulton Marsh in Table 5.

As is evident, Moulton Marsh lagoons support a higher diversity of lagoonal specialists, and the site is one of only two in this sequence at which the scheduled 'lagoon sand shrimp', *Gammarus insensibilis*, has been recorded. Even when the under-recorded ostracod *Cyprideis torosa* (probably present at most of these sites) is excluded, Moulton Marsh supports seven lagoonal specialists, while no other lagoon supports more than four.

Table 5. Recorded presence of lagoonal specialist species around The Wash

	(Cyprideis torosa)	*Gammarus insensibilis*	*Idotea chelipes*	*Hydrobia arcana*	*Ventrosia ventrosa*	*Cerastoderma glaucum*	*Conopeum seurati*	*Chaetomorpha linum*	*Ruppia* spp.
Bulldog Bank, Skegness					*				
New Marsh Drain, Skegness			*						*
Wyberton Marsh, Lincs					*				*
Sandholme Farm, Lincs					*	*			
Lamming's Marsh Farm, Lincs					*				
Moulton Marsh Lagoons	*	*	*		*	*	*	*	*
Ward's Farm, Lincs					*	*			
Lundy's Farm, Lincs									
Lawyer's Farm Pool, Lincs		*	*			*		*	
RAF Holbeach, Lincs						*			
Oldershaw Farm, Lincs									
Lutton Leam Seabank, Lincs			*		*			*	*
Snettisham Gravel Pits, Norfolk			*	*					

Further east, the North Norfolk lagoons from Broadwater to the extensive system along the Blakeney coastline were re-surveyed in 1996 (Bamber, 1997). Some of those lagoons are of high conservation merit, and include the northernmost sites for the scheduled starlet sea-anemone, *Nematostella vectensis*.

5. Conclusions

The riverside scrapes at Moulton Marsh are not saline lagoonal habitats. They may have some merit as bird habitat, although their associated fauna is very impoverished. It appears that they are somewhat ephemeral as aquatic habitat.

The basin labelled Lagoon 3 is also impoverished, although the reasons are not apparent. The water was relatively deep at the time of the October visit, yet no fauna or flora were found. It may be that the direct creek connection from the southwestern end of this basin causes this pool also to drain significantly on each low tide (or over a longer cycle).

Lagoons 1 and 2 are fine examples of coastal saline lagoon habitat, of stable structural integrity, of appropriate salinity, shape and size, and they support typical lagoonal communities and biotopes, including one scheduled and seven other lagoonal specialist species. That some species were only recorded in one of these lagoons is considered merely a result of the few samples taken, and more intensive sampling would find a common fauna and flora in both of these lagoons.

The community of Lagoon 4 is a reduced version of the above. The site evidently has a greater source of freshwater input, and is progressing towards a *Phragmites* reed-marsh. As such it offers a diversity of habitat with the other lagoons on the reserve. Increasing the proportion of saline water input in comparison with the freshwater input, and maintaining a greater depth of water, perhaps by judicious excavation, should cause this basin to become more like Lagoons 1 and 2, should that be desired. However, the degree of water management at present required to maintain the current salinity regime suggests that such an effort may not be practical.

Overall, the Moulton Marsh saline lagoons are of high conservation merit, being the best examples of this habitat on The Wash and adjacent shoreline, as well as supporting a scheduled species. That they are already within a nature reserve should facilitate their protection.

6. References

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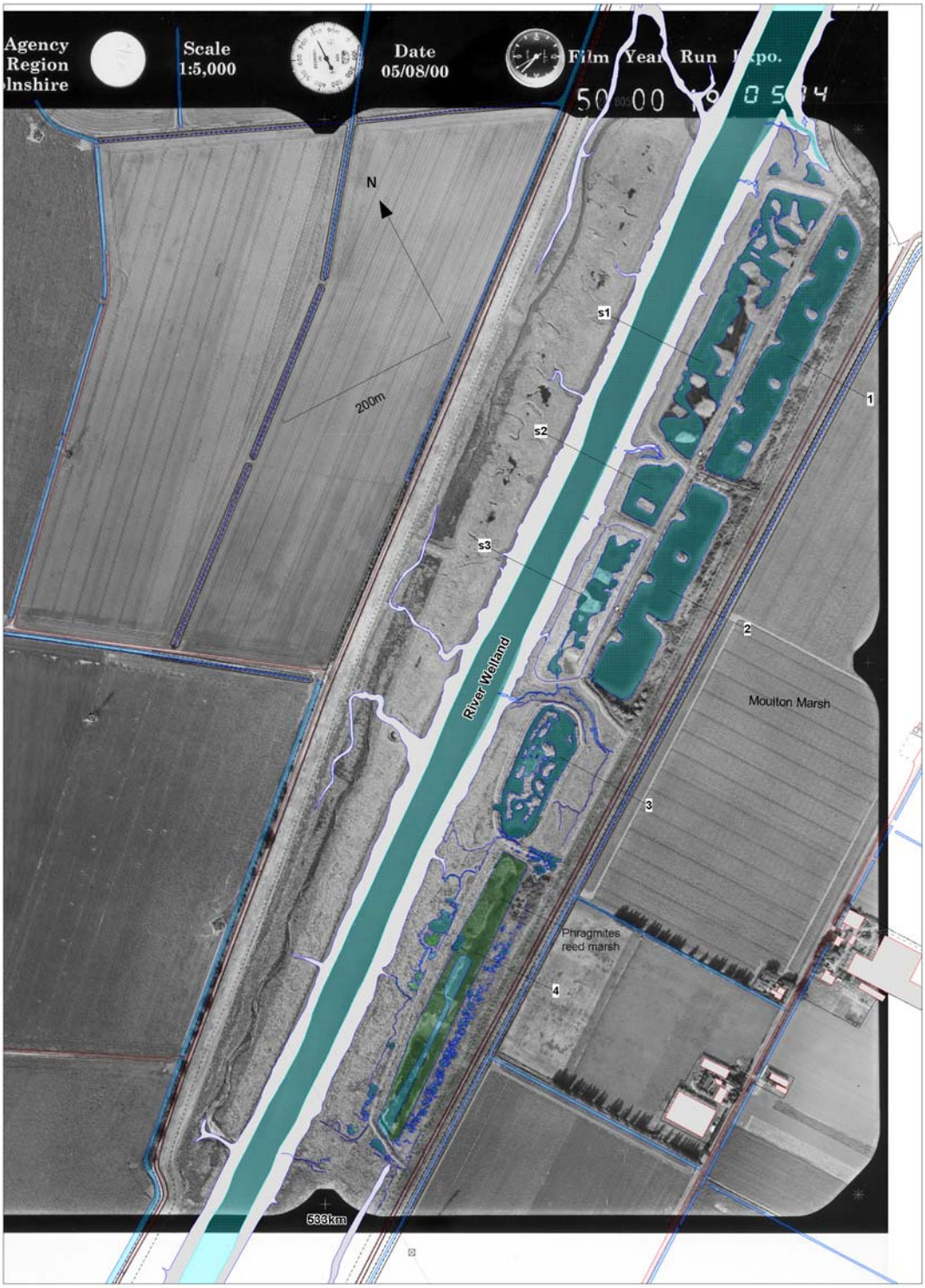

Figure 1. Moulton Marsh Lagoons, GIS mapping superimposed on an August 2000 aerial photograph of the site (aerial photograph courtesy of the Environment Agency).

Figure 2. Map of Moulton Marsh Lagoons 1 to 4, and the adjacent scrapes s1 to s3.

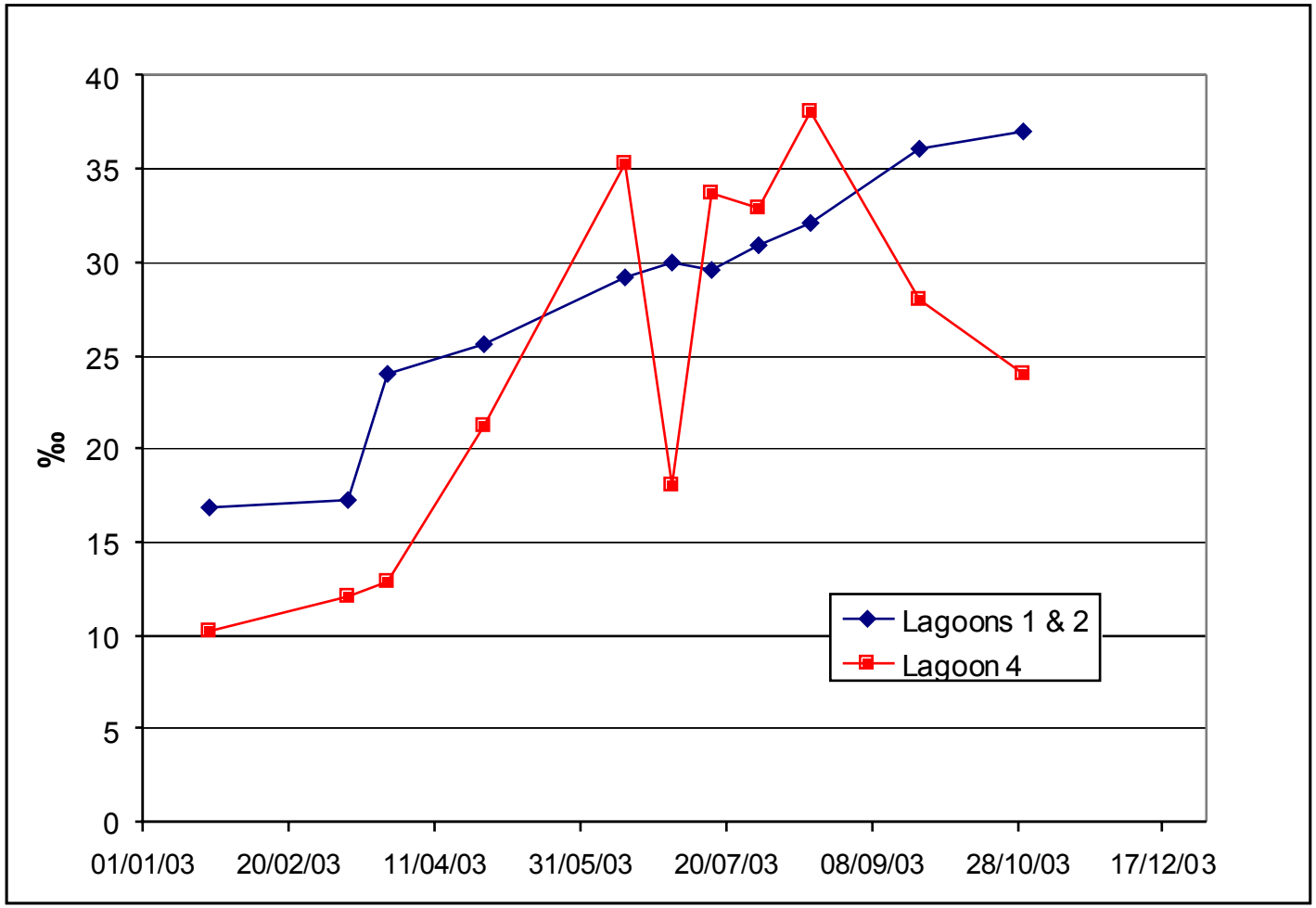

Figure 3. Salinities of the lagoon water for Lagoons 1 and 2 (measured at their connecting pipe) and Lagoon 4 during 2003 (data courtesy of R & K Heath).

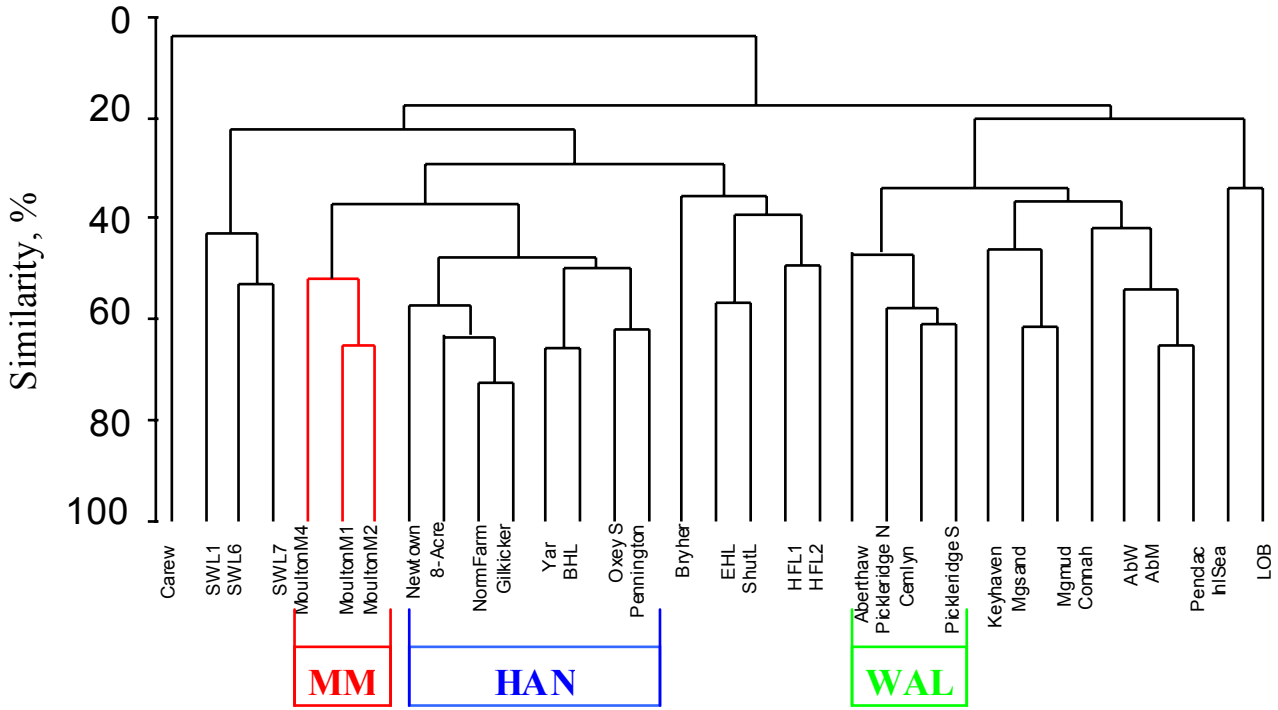

Figure 4. Dendrogram of Bray Curtis similarities between quantitative samples from the standard UK database of coastal saline lagoons, with the Moulton Marsh sites shown in red (MM). HAN = the higher salinity, southern England "good-lagoons" cluster; WAL = the lower salinity, Welsh "good-lagoons" cluster.

Appendix 1. Moulton Marsh lagoons descriptions

SITE NAME:	Moulton Marsh Lagoon No. 1
LOCATION:	Moulton, Lincolnshire
GRID REFERENCE:	TF33863338
TYPE/CLASSIFICATION:	Sluiced pool
DESIGNATION:	Local Nature Reserve
AREA:	1.15 ha
MAX DEPTH (m):	>1 m
SALINITY (‰):	38
ADJACENT HABITATS:	Mixed woodland, *Salicornia* saltmarsh, scrapes
SURVEY DATE:	29 October 2003

Lagoon description

Lagoon 1 is one of two similar linear pools in Moulton Marsh Nature Reserve, lying between Middle Marsh Road and the River Welland. The lagoon basin is surrounded by a steep embankment on which grow shrubs and mixed woodland. Saline water ingress is via a sluiced pipe connecting with Lagoon No. 2; pipes connecting to adjacent scrapes appear non-functional; there may be some groundwater percolation from the River Welland. There is an extensive bed of tasselweed (*Ruppia*) over most of the lagoon. The southwestern, southeastern and northeastern margins are lined with common reed, *Phragmites*. The fine sand substrata supported a dense fauna of lugworm, ragworm, chironomids and *Aphelochaeta marioni*, with *Idotea chelipes*, *Ventrosia ventrosa* and the scheduled 'lagoon sand shrimp' *Gammarus insensibilis* in the vicinity of the submerged tasselweed, while the submerged tasselweed *Ruppia* was also exploited by the bryozoan *Conopeum seurati*.

The presence of *Gammarus insensibilis*, together with the most diverse lagoonal specialist community of any saline lagoon around The Wash, makes this and the adjacent lagoon of high conservation importance.

Species present

Nereis diversicolor
Aphelochaeta marioni
Polydora cornuta
Pygospio elegans
Cyprideis torosa
Praunus flexuosus
Gammarus insensibilis
Idotea chelipes
Chironomidae larvae
Ventrosia ventrosa
Cerastoderma glaucum
Conopeum seurati
Ruppia spp.

SITE NAME: Moulton Marsh Lagoon No. 2

LOCATION: Moulton, Lincolnshire
GRID REFERENCE: TF33633324
TYPE/CLASSIFICATION: Sluiced pool
DESIGNATION: Local Nature Reserve
AREA: 1.08 ha
MAX DEPTH (m): >1 m
SALINITY (‰): 38
ADJACENT HABITATS: Mixed woodland, *Salicornia* saltmarsh, scrapes
SURVEY DATE: 29 October 2003

Lagoon description

Lagoon 2 is the second of two similar linear pools in Moulton Marsh Nature Reserve, of very similar size, shape, morphology and environment as Lagoon 1, to which it is connected by a pipe in the centre of its northeastern margin. Saline water ingress is via a sluiced pipe connecting through the western corner of the lagoon to a ditch which fills from the River Welland on high tides; there may be some groundwater percolation from the River. There is an extensive bed of tasselweed (*Ruppia*) over the deeper parts of the lagoon, with patches of drift *Chaetomorpha linum* occurring around the margins. The southwestern, southeastern and northeastern margins are lined with common reed *Phragmites*. The fine muddy-sand substrata supported a community closely similar to that in the adjacent Lagoon 1, comprising a dense fauna of oligochaetes, lugworm, ragworm, spionids, chironomids and *Aphelochaeta marioni*, with *Idotea chelipes* and the scheduled 'lagoon sand shrimp' *Gammarus insensibilis*.

The presence of *Gammarus insensibilis*, together with the most diverse lagoonal specialist community of any saline lagoon around The Wash, makes this and the adjacent Lagoon 1 of high conservation importance.

Species present

Tubificoides pseudogaster
Nereis diversicolor
Aphelochaeta marioni
Polydora cornuta
Pygospio elegans
Praunus flexuosus
Gammarus insensibilis
Idotea chelipes
Chironomidae larvae
Hydrobia ulvae
Chaetomorpha linumi
Ruppia spp.

SITE NAME:	Moulton Marsh Lagoon No. 3 and shore scrapes
LOCATION:	Moulton, Lincolnshire
GRID REFERENCE:	TF33863346
TYPE/CLASSIFICATION:	Sluiced pools
DESIGNATION:	Local Nature Reserve
AREA:	1.94 ha
MAX DEPTH (m):	>1 m
SALINITY (‰):	38
ADJACENT HABITATS:	Shrub and grassland, *Salicornia* saltmarsh, scrapes
SURVEY DATE:	29 October 2003

Lagoon Description

Lagoon 3 is a round pool, about 1 m deep at its deepest, with extensive islands in the centre, lying southwest of Lagoon 2 and nearer to the River Welland. The lagoon basin is surrounded by a lower embankment on which grow shrubs and grasses, while to the northwest saltmarsh grassland extends to the river. Saline water ingress is via a ditch connecting with the River Welland, and there may be some groundwater percolation.

Northeast of this lagoon are three further scrapes in *Salicornia* saltmarsh between Lagoons 1 and 2 and the River. These are much shallower and have their own sluiced connections to drainage streams to the River. No submerged plants, and almost no fauna, was found in these pools, the only common species being enchytraeid oligochaetes. It is suspected that the pools may be prone to drying out.

While these sites act as bird habitat, and may develop a more diverse fauna eventually, at present they have no intrinsic conservation merit.

Species present

Enchytraeidae
Carcinus maenas
Collembola
Lekanesphaera rugicauda
Pomatoschistus microps
Cladophora sp.

SITE NAME: Moulton Marsh Lagoon No. 4

LOCATION: Moulton, Lincolnshire
GRID REFERENCE: TF33253295
TYPE/CLASSIFICATION: Sluiced pool
DESIGNATION: Local Nature Reserve
AREA: 1.19 ha (water area 0.31 ha)
MAX DEPTH (m): >1 m
SALINITY (‰): 27
ADJACENT HABITATS: Mixed woodland, *Salicornia* saltmarsh
SURVEY DATE: 29 October 2003

Lagoon description

Lagoon 4 is a further rectangular linear pools at the southwestern end of Moulton Marsh Nature Reserve, its basin surrounded by a steep embankment on which grow shrubs and mixed woodland. Saline water ingress is via a sluiced pipe connecting with the river; there may be some groundwater percolation from the River Welland. The lagoon is very shallow, and *Phragmites* has encroached over most of the basin leaving only about a third of the area as open water. There is a small deeper area of the pool two-thirds of the way up the northwestern side in which there is a small bed of tasselweed (*Ruppia*) in which *Idotea chelipes* and *Ventrosia ventrosa* were common.

The fine sand substrata, including amongst the reed stems, supported a sparser fauna than Lagoons 1 and 2, with ragworm, oligochaetes, chironomids and *Polydora cornuta* with three hydrobiid species on the sediment surface as well as in the submerged weed, including the lower-salinity-tolerant *Potamopyrgus antipodarum*; reed stems and *Ruppia* stalks were exploited by the bryozoan *Conopeum seurati*.

The fauna is a reduced version of the specialist community present in Lagoons 1 and 2. This site offers a lower salinity regime, and the progressive encroachment of *Phragmites* is likely to continue, reducing the effective lagoon area further. At present it complements Lagoons 1 and 2, enhancing the conservation merit of the lagoonal aspects of the nature reserve.

Species present

Nereis diversicolor
Tubificoides pseudogaster
Polydora cornuta
Enchytraeidae
Lekanesphaera rugicauda
Idotea chelipes
Palaemonetes varians
Chironomidae larvae
Sigara spp.
Hydrobia ulvae
Ventrosia ventrosa
Potamopyrgus antipodarum
Conopeum seurati
Ruppia spp.

Appendix 2. List of all species recorded from Moulton Marsh lagoons, with common names where available and lagoonal significance

List of all species recorded from Moulton Marsh lagoons, with common names where available and lagoonal significance

Species	Common Name	Status
Annelida		
Eteone longa		
Nereis diversicolor	ragworm	
Aphelochaeta marioni		
Polydora cornuta		
Pygospio elegans		
Arenicola marina	lugworm	
Enchytraeidae		
Tubificoides pseudogaster		
Arthropoda		
Crustacea		
Cyprideis torosa	an ostracod	Lagoonal specialist[3]
Praunus flexuosus	an opposum shrimp	
Gammarus insensibilis	lagoonal sand shrimp	Scheduled lagoonal specialist
Idotea chelipes		Lagoonal specialist
Lekanesphaera rugicauda		
Palaemonetes varians	a prawn	
Carcinus maenas	shore crab	
Insecta		
Collembola	springtails	
Chironomidae larvae	midge larvae	
Sigara sp.	water boatmen	
Mollusca		
Hydrobia ulvae		
Ventrosia ventrosa	lagoonal mud snail	Lagoonal specialist
Potamopyrgus antipodarum		
Cerastoderma glaucum	lagoon cockle	Lagoonal specialist
Bryozoa		
Conopeum seurati	a sea mat	Lagoonal specialist
Fish		
Pomatoschistus microps	common goby	
Plants		
Cladophora spp.		
Chaetomorpha linum	wireweed	Lagoonal specialist
Ruppia spp.	tasselweed	Lagoonal specialist

[3] As defined in Bamber *et al.*, 2001, Table 3A: "Species distinctly more characteristic of lagoons and lagoon-like habitats than of other habitats".

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Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888