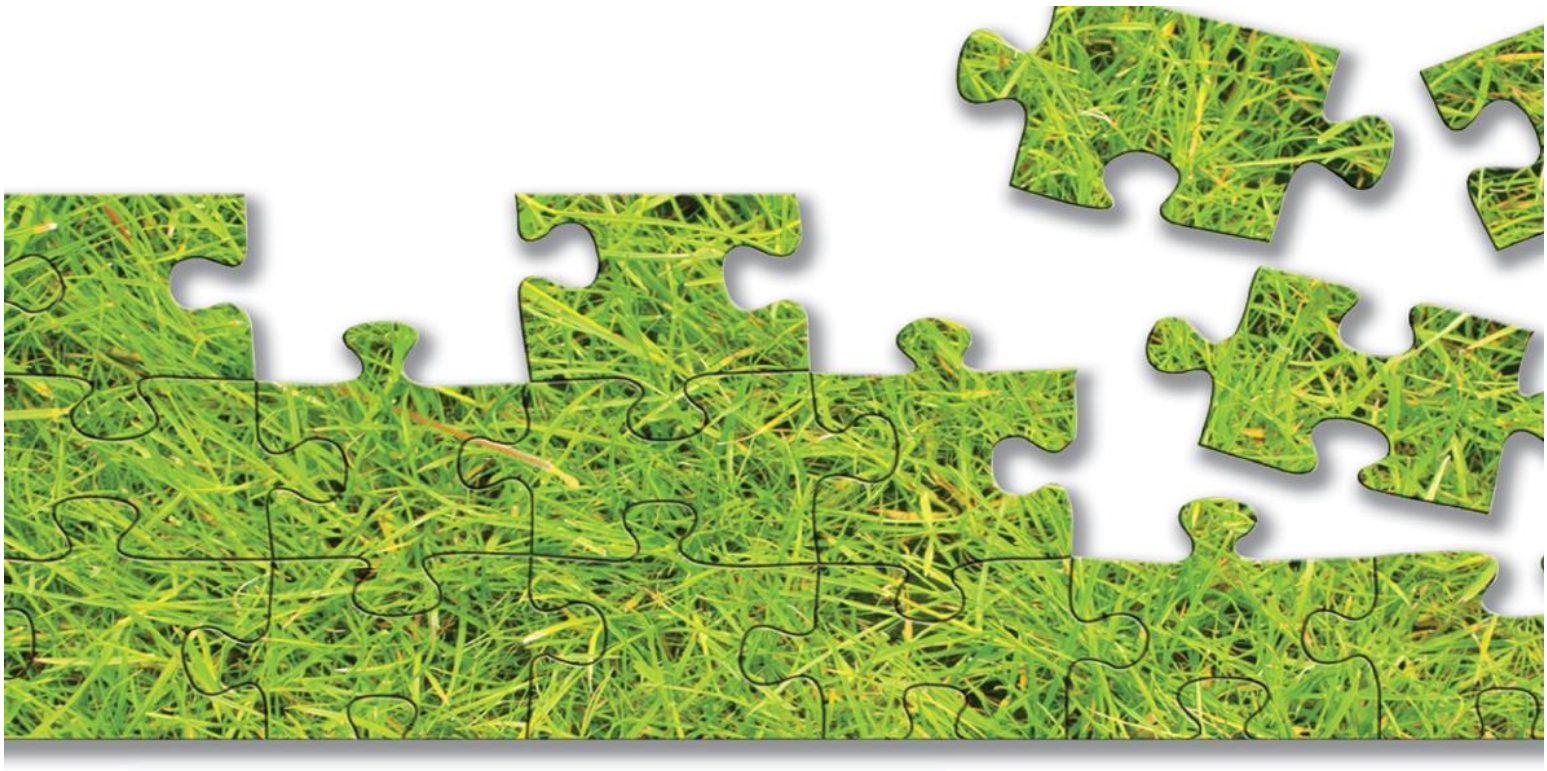

VEGETATION SURVEY & ASSESSMENT

SIZEWELL C NUCLEAR POWER STATION

BASELINE BRYOPHYTE ASSESSMENT

A REPORT PREPARED FOR HYDER CRESSWELL LTD

July 2015

CONTENTS

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1. SUMMARY

An assessment of the communities of bryophyte in habitats within a zone of likely nitrogen deposition from Sizewell C Power Station emissions evaluated dune grassland, sand dune, woodland and vegetated shingle.

Bryophytes were found to be a significant component of some of these habitats, especially in dune grassland within part of Minsmere to Walberswick Heaths and Marshes SAC, where cover of ground-dwelling mosses was typically 30% or more. However, the bryophyte communities lacked the diversity of the associated vascular plants and species found were considered to be relatively common and widespread species.

A review of species-specific nitrogen (fertility) values confirmed that the characteristic mosses of the dune grassland, which was by far the most extensive kind of vegetation in the study area, were restricted to habitats with low or very low soil fertility. Although there has been some research into the effects of nitrogen deposition on bryophytes, it has not always been directly relevant to the bryophyte-supporting habitats assessed in the current survey. However, given what is known about the response of bryophytes to nutrient enrichment, it was concluded that dune grassland and sand-dune species are likely to be very sensitive to increased nitrogen deposition and that long-term operation of Sizewell C may prompt a shift to bryophytes characteristic of more fertile places within these vegetation types.

2. INTRODUCTION

Vegetation Survey & Assessment Ltd (hereafter referred to as 'VSA') was commissioned by Hyder Cresswell Ltd to assess the nature and value of bryophyte communities in part of Minsmere to Walberswick Heaths and Marshes Special Area of Conservation (SAC) and in undesignated habitats close to Sizewell B Power Station. A key objective of the assessment was to identify any species/communities of moss or liverwort that would be sensitive to elevated levels of atmospheric pollutants calculated to be emitted during the operational phase of the proposed new Sizewell C Nuclear Power Station.

3. METHODS

The survey was undertaken over the period 22 – 24 June 2015 when weather conditions were fine and dry. An initial walkover of the defined survey area (Figure 1) defined particular vegetation communities where bryophytes were present and where survey effort should be sampled. These included:

- Dune grassland;
- Sand-dunes;
- Vegetated shingle; and
- Woodland.

Reed-bed was also present but after an initial visual evaluation, was considered to support few, if any bryophytes and was therefore not sampled.

Various localities within each habitat were sampled in order to gain a comprehensive baseline of the species present. This involved recording the presence and estimated abundance[1] of all mosses and liverworts within a 2-3m radius of a number of sampling points within representative areas of different vegetation stands. A hand-held GPS receiver (Garmin eTrex HCX) connected to the European Geostationary Navigation Overlay Service (EGNOS) was used to record such areas; when the receiver's averaging function is used (as it was for the current survey) it is generally accurate to within 2-3 m.

[1] Measured using the DAFOR scale where D=Dominant; A=Abundant; F=Frequent; O=Occasional; R=Rare.

All species of bryophyte were identified where possible in the field. Samples of some particularly small and/or difficult species were collected and verified under the microscope later.

Nomenclature used for bryophytes in this report follows Hill *et al* (2008), whilst vascular plants follow Stace (2010).

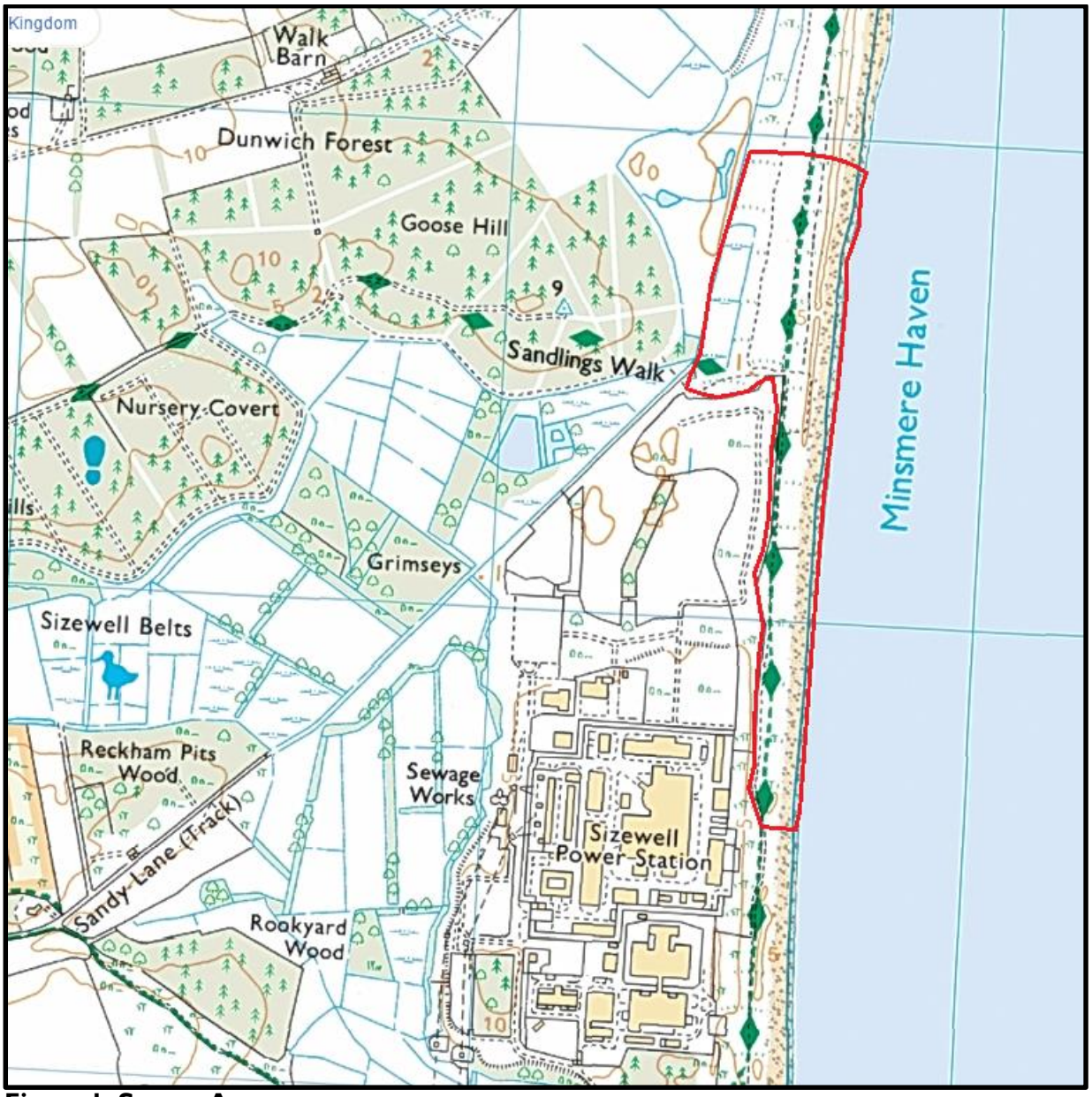

Figure 1. Survey Area

4. RESULTS

A total of 23 sampling points were recorded across the survey area; 13 from dune grassland including 6 from trampled ground/unmade tracks; 7 from sand-dunes, 1 from vegetated shingle on the beach and 2 from woodland. All sampling points are shown in Figure 2.

4.1 Bryophyte Communities

Tabulated results by vegetation type are presented as Appendix I, with the bryophyte communities described subjectively in Sections 4.1.1 to 4.1.4. In total, 26 bryophytes (24 mosses and 2 liverworts) were recorded across all habitats.

4.1.1 Dune Grassland

SAC Grassland

The majority of the survey area comprised acid dune grassland which occupied level to slightly undulating ground behind the dune ridge. Its structure and floristic composition varied greatly and samples were taken from representative stands, including relatively undisturbed grassland, trampled ground in unmade tracks and paths across it and shingle-sided depressions within it (these are probably remnants of shell craters).

On the whole, the dune grassland within the SAC was less disturbed than its counterpart to the south. It also supported a scattered element of dwarf shrub heath comprising mature bushes of *Calluna vulgaris* (Ling) and *Erica cinerea* (Bell Heather), which were absent to the south. Samples 01, 04 and 06 were taken in undisturbed SAC grassland and confirmed the presence of a well-developed bryophyte element (often with cover >30%) though lacking species diversity. 9 mosses were recorded, the most abundant of which were *Dicranum scoparium*, *Campylopus introflexus* and *Hypnum cupressiforme* var. *lacunosum*. *Pseudoscleropodium purum*, *Polytrichum juniperinum* and *Hypnum jutlandicum* were more local.

These bryophytes were characteristic of acid dune grassland among a sparse community of vascular plants e.g. *Festuca ovina* (Sheep's-fescue), *F. filiformis* (Fine-leaved Sheep's-fescue), *Anthoxanthum odoratum* (Sweet Vernal-grass), *Carex arenaria* (Sand Sedge), *Agrostis capillaris* (Common Bent), *Rumex acetosella* (Sheep's Sorrel) and *Hypochaeris radicata* (Cat's-ear).

Disturbed ground in tracks across the SAC dune grassland (Plate 1) supported nearly all of same species, though most were less abundant than in adjacent undisturbed grassland. Sample numbers 02, 03, 07 and 10 were located in this microhabitat. *Campylopus introflexus* was particularly abundant, along with *D. scoparium*, *H. cupressiforme* var. *lacunosum* and *P. juniperinum*.

Plate 1. This track at Sample no. 03 supported high cover of mosses

Other Grassland

Dune grassland between the sand dunes and the perimeter fence of Sizewell B Power Station was more variable than its counterpart in the SAC and may have been reprofiled in the past. There were significant areas of shingle-rich ground (including within probable shell craters) indicated by a very diverse high plant and lichen community (samples 12, 13 and 15) as well as longer, species-poor grassland dominated by mixtures of grasses with few bryophytes (sample 23).

Despite its rich higher plant vegetation, the shingle-rich dune grassland supported a small number of bryophytes (6), the commonest of which was *H. cupressiforme* var. *lacunosum*, which characteristically formed quite large mats on the ground. It was frequently joined by *D. scoparium* and *P. juniperinum*, whilst both *Bryum capillare* and *Ceratodon purpureus* occurred in small patches. Vascular associates of these bryophytes included *Sedum anglicum* (English Stonecrop), *A. odoratum*, *F. ovina*, *Ononis repens* (Common Restharrow), *R. acetosella*, *Pilosella officinarum* (Mouse-ear Hawkweed), *Aira praecox* (Early Hair-grass), *Galium verum* (Lady's Bedstraw) and *Rhinanthus minor* (Yellow-rattle). Plate 2 shows a typical example of this grassland.

Plate 2. *Dicranum scoparium* and *Hypnum cupressiforme* var. *lacunosum* were abundant at Sample no. 12

Closed-sward dune grassland was typically very poor in bryophytes. Sample 23, for example, only supported 3 mosses: the large pleurocarps *P. purum* and *H. cupressiforme* var. *lacunosum* sprawling among the grasses, accompanied by scattered *D. scoparium*.

Trampled ground across the dune grassland was represented by samples 18 and 20. This micro-habitat supported very few bryophytes; like the adjacent dune grassland *H. cupressiforme* var. *lacunosum* formed extensive mats where levels of trampling were not too high. *P. juniperinum* and *C. purpureus* were frequent associates, whilst small colonies of the acrocarpous moss *Syntrichia ruralis* var. *ruraliformis* appeared occasionally. Because of the trampling, there was considerable bare ground in the tracks and the vascular community was quite sparse. Among the species present were *C. arenaria*, *Phleum arenarium* (Sand Cat's-tail), *Festuca rubra* (Red Fescue), *Jasione montana* (Sheep's-bit), mouse-ears (*Cerastium* spp.), *O. repens* and *Trifolium arvense* (Hare's-foot Clover).

4.1.2 Sand Dune

A narrow dune ridge of dunes occupied the length of the survey area, delimiting the shingle beach from dune grassland behind. In the part of the SAC that was surveyed, the dunes were poorly developed and very narrow; it is possible that erosion had been at work here. Further south (outside the SAC) the dunes were better developed and supported more intact examples of dune vegetation. Most bryophyte sampling locations (11, 14, 16, 17, 19 and 21) were therefore outside the SAC.

Much of the bryophyte interest of the dunes was confined to informal foot tracks or areas where the dune face had been grazed low by Rabbits *Oryctolagus cuniculus* (Plate 3). Elsewhere, the tall grasses of the dunes were too dense to allow much bryophyte interest among them. The dune bryophyte community was a little more diverse than that of the dune grassland, with a total of 12 mosses recorded there. These included the majority of the species present in the dune grassland (with the exception of *Dicranella heteromalla*) together with a few additional species. Five species were particularly characteristic of the sand-dune community: *Brachythecium rutabulum, B. albicans*, *B. capillare*, *D. scoparium* and *P. purum*.

The bryophytes grew within a diverse matrix of vascular species including *C. arenaria*, *Glaux maritima* (Sea-milkwort), *A. capillaris*, *A. praecox*, *Ammophila arenaria* (Marram), *Elytrigia juncea* (Sand Couch), *G. verum*, *F. rubra* and many others.

Plate 3. *Bryum capillare* and *Brachythecium albicans* were very frequent in disturbed places in the dunes as here at Sample no. 21

4.1.3 Vegetated Shingle

The vegetated shingle strand-line community was well-developed only on the beach near Sizewell B Power Station and was not present within the part of the SAC that was surveyed. Although rich in definitive shingle plants, this vegetation community mostly lacked bryophytes, except in a few places where it was consolidated with a little sand. As such, only 1 sample (no. 22) was recorded – see Plate 4. It supported a community of 5 mosses, 3 of which – *B. albicans*, *B. capillare* and *S. ruralis* var. *ruraliformis* – occurred at quite high cover in that particular locality. *C. purpureus* and *Bryum algovicum* var. *rutheanum* were occasional associates.

Associated vascular species within this shingle community included *F. rubra*, *E. juncea*, *Lathyrus japonicus* (Sea Pea), *Silene uniflora* (Sea Campion), *Vulpia fasciculata* (Dune Fescue), *Leontodon saxatilis* (Lesser Hawkbit), *Rumex crispus* ssp. *littoreus* (Curled Dock), *Glaucium flavum* (Yellow Horned-poppy) and *Crambe maritima* (Sea-kale).

Plate 4. Sample no. 22 supported a restricted community of bryophytes in shingle vegetation

4.1.4 Woodland

Woodland was not a major habitat within the survey area but nonetheless a belt of mixed plantation grading into willow carr at the edge of reed-bed habitat in the SAC was sampled in two places (sample no's 08 and 09). 9 mosses and 1 liverwort were recorded, 8 of which were epiphytes growing on the trunks and branches of trees and shrubs in the woodland. Bryophytes were quite sparse in the woodland, with many trees supporting no bryophytes or only a few. However, several species were relatively common, including *Orthotrichum affine*, *Metzgeria furcata*, *Cryphaea heteromalla* and *Hypnum* cf. *andoi*.

Bryophytes were most frequent on *Salix cinerea* (Grey Willow) growing close to the reed-bed, especially where wet channels lay below the canopy, raising local humidity. Sample no. 08 was recorded within a strip of mixed plantation dominated by *Betula* spp. (birches), *Pinus* spp. (pines) and *Ulex europaeus* (Gorse) where many trees and shrubs were devoid of epiphytes. Sample 09 was from more humid *S. cinerea* carr and recorded more species, including *Orthotrichum striatum*, an uncommon but increasing epiphyte in Suffolk.

4.2 Bryophyte Species

In total, 26 bryophytes (24 mosses and 2 liverworts) were noted in the different kinds of vegetation that were sampled. Table 1 lists these species with an indication of current national status according to Blockeel et al (2014).

Table 1. Species of moss and liverwort present in the Survey Area

Species	National Status	Remarks
Brachythecium albicans	Common	
Brachythecium rutabulum	Common	
Bryum algovicum var. rutheanum	Frequent	Most characteristic of coastal sand habitats
Bryum capillare	Common	
Campylopus introflexus	Common	Introduced moss
Campylopus pyriformis	Common	
Ceratodon purpureus	Common	
Cryphaea heteromalla	Common	Epiphyte with high sensitivity to airborne SO_2
Dicranella heteromalla	Common	
Dicranum scoparium	Common	
Hypnum cupressiforme cf. andoi	Common	
Hypnum cupressiforme var. lacunosum	Common	
Hypnum jutlandicum	Common	
Kindbergia praelonga	Common	
Leptodictyum riparium	Common	
Metzgeria furcata	Common	
Orthotrichum affine	Common	
Orthotrichum diaphanum	Common	
Orthotrichum striatum	Common	Epiphyte with high sensitivity to airborne SO_2; Most common in N and W Britain but increasing in the east
Oxyrrhynchium hians	Common	
Polytrichum juniperinum	Common	
Pseudoscleropodium purum	Common	
Radula complanata	Common	Epiphyte with high sensitivity to SO_2 and some other airborne pollutants
Syntrichia ruralis var. ruraliformis	Common	Most characteristic of coastal sand habitats
Syntrichia ruralis var. ruralis	Common	
Ulota bruchii	Common	

5. DISCUSSION

5.1 Nitrogen Requirements

Bryophytes are among the most sensitive components of vegetation communities with respect to pollutant deposition and can be sensitive to nitrogen. Too much nitrogen can change morphology, often leading to growth-forms that are desiccation prone and less efficient at suppressing competitors; photosynthesis can be compromised along with membrane integrity and sexual reproduction may also be suppressed.

Ellenberg values for bryophytes are among the attribute data that has been published by the Centre for Ecology and Hydrology (Hill *et al* 2007). BRYOATT classifies species by a number of major scales (Ellenberg *et al* 1991) as modified by Hill *et al* (1999). Of relevance to this assessment is the scale for nitrogen (N), which is a general indication of fertility, grouping species associated with sites from the extremely infertile through to those of richly fertile places (Table 2).

Table 2. Ellenberg values of Nitrogen (N)

Code	Explanation
1	Species characteristic of extremely infertile sites; almost all are calcifuges but there are a few exceptions.
2	Indicator of infertile sites; these include calcifuges, middling species and calcicoles.
3	Indicator of moderately infertile sites; these include a range of calcifuges, middling species and calcicoles
4	Between 3 and 5; these plants are found mainly in the lowlands but include calcifuges as well as species of more basic substrates.
5	Indicator of moderately fertile sites; these are almost without exception lowland species with a few calcifuges but most are tolerant of basic conditions.
6	Between 5 and 7; these are mostly plants of eutrophic lowlands, apart from a few taxa on upland dung and carcases.
7	Species characteristic of richly fertile places.

Table 3 lists the values of N given by Hill *et al* (2007) for all of the bryophytes found in the current assessment, together with the habitat(s) which supported populations of each species and an estimate of the frequency of the species in those habitats. The more common species have been highlighted.

Table 3.

Species	Nitrogen N	Vegetation Classes	Estimated Frequency
Brachythecium albicans	3	Dune/Dune grassland	Locally frequent
Brachythecium rutabulum	6	Dune	Rare
Bryum algovicum var. rutheanum	4	Shingle	Rare
Bryum capillare	4	Dune/Dune grassland/Shingle	Frequent in dunes
Campylopus introflexus	2	Dune/Dune grassland	Frequent
Campylopus pyriformis	2	Dune grassland	Rare
Ceratodon purpureus	3	Dune/Dune grassland/Shingle	Frequent
Cryphaea heteromalla	5	Woodland (epiphyte)	Occasional
Dicranella heteromalla	3	Dune grassland	Rare
Dicranum scoparium	2	Dune/Dune grassland	Very common
Hypnum cf. andoi	3	Woodland (epiphyte)	Rare
Hypnum cupressiforme var. lacunosum	2	Dune/Dune grassland	Common
Hypnum jutlandicum	2	Dune grassland	Locally common
Kindbergia praelonga	5	Dune/Woodland	Rare
Leptodictyum riparium	7	Woodland (ground)	Rare
Metzgeria furcata	3	Woodland	Occasional
Orthotrichum affine	5	Woodland (epiphyte)	Occasional
Orthotrichum diaphanum	5	Woodland (epiphyte)	Occasional
Orthotrichum striatum	4	Woodland (epiphyte)	Rare
Oxyrrhynchium hians	6	Dune	Rare
Polytrichum juniperinum	2	Dune grassland	Common
Pseudoscleropodium purum	3	Dune/Dune grassland	Locally frequent
Radula complanata	3	Woodland (epiphyte)	Rare
Syntrichia ruralis var. ruraliformis	3	Dune/Dune grassland/Shingle	Rare
Syntrichia ruralis var. ruralis	4	Dune	Rare
Ulota bruchii	4	Woodland (epiphyte)	Rare

Analysis of Table 3 shows that the range of N values across all species is large – from 2 up to 7. This is to be expected, as samples were taken from widely differing habitats. Wet woodland in particular is likely to have higher levels of soil fertility than dry open acid habitats and the bark of trees and shrubs is often naturally high in nitrogen and other plant nutrients. However, if dune grassland is considered to be the dominant vegetation type across the survey area, it can be seen that the species that are most characteristic i.e. *D. scoparium*, *H. cupressiforme* var. *lacunosum* and *C. introflexus* all have N values of 2-3, indicating a preference for infertile to moderately infertile sites.

5.2 Predicted Response to increased Nitrogen Deposition

The characteristics of certain kinds of vegetation can make them potentially sensitive to nutrient deposition. Habitats most likely to be sensitive to nutrient enrichment include those with low levels of nutrients in their soils, those dominated by stress tolerant species and those that depend on atmospheric inputs as their primary source of nutrients.

Stevens *et al* (2009) studied the nitrogen sensitivity of a number of habitats. They reasoned that coastal vegetated shingle is a pioneer community composed of many nutrient loving ruderal species. Close to the sea the nutrients are mainly supplied by organic matter deposited by the sea. Bryophytes (and vascular plants) in this community are therefore unlikely to be sensitive to atmospheric nitrogen deposition as the supply of nutrients is primarily driven by the sea.

The same researchers concluded that sand dunes are more sensitive to nitrogen deposition. They drew together a number of studies which demonstrated a negative relationship between (vascular) plant species richness and atmospheric nitrogen deposition, along with changes in species composition where certain species have been identified as being stimulated by deposition of airborne nitrogen. However, the equivalent response of sand-dune bryophytes was not described in any detail.

They did not analyse dune grassland but found that lowland dry acid grasslands – which are broadly equivalent in nutrient and soil reaction terms - are very sensitive to eutrophication. The soils are poorly buffered against changes in pH and toxic metals are commonly mobilised.

Other studies of lowland species have identified both nitrogen sensitive and nitrogen tolerant mosses. For example, Leith *et al* (2005) studied woodland affected by ammonia deposition and found *Kindbergia praelonga* and *Brachythecium rutabulum* tolerant of very high tissue nitrogen concentrations. The majority of bryophytes present in the woodlands in the survey area were epiphytes, growing directly on the bark of trees and shrubs and more typical of moderately fertile conditions. These species are therefore much more likely to be tolerant of slight increases in atmospheric nitrogen.

6. CONCLUSIONS

The current survey shows that dune grassland vegetation within both the SAC and elsewhere supports populations of common mosses which are strongly preferential to habitats which have infertile acid soils. These species are likely to be sensitive to increased nitrogen deposition from predicted Sizewell C emissions although it is not possible to quantify the predicted response. However, higher levels of atmospheric nitrogen deposition may promote a long-term decline in abundance of stress-tolerant species such as *D. scoparium*, *H. jutlandicum*, *H. cupressiforme* var. *lacunosum*, *B. albicans* and *C. purpureus* toward those which prefer more fertile conditions e.g. *B. rutabulum* and *K. praelonga*.

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APPENDIX I: SURVEY RESULTS

Sample no.	Vegetation type	Species	Abundance (DAFOR)
01	Dune grassland	Brachythecium albicans	R
		Campylopus introflexus	F
		Campylopus pyriformis	R
		Dicranella heteromalla	O
		Dicranum scoparium	A
02	Dune grassland (track)	Campylopus introflexus	A
		Campylopus pyriformis	O
		Ceratodon purpureus	O
		Dicranum scoparium	O
		Polytrichum juniperinum	F
03	Dune grassland (track)	Campylopus introflexus	F
		Ceratodon purpureus	O
		Dicranum scoparium	A
		Hypnum cupressiforme var. lacunosum	F
		Hypnum jutlandicum	O
		Polytrichum juniperinum	F
		Pseudoscleropodium purum	O
04	Dune grassland	Dicranum scoparium	A
		Pseudoscleropodium purum	A
05	Dune	Brachythecium rutabulum	F
		Bryum capillare	O
		Campylopus introflexus	O
		Ceratodon purpureus	O
		Dicranum scoparium	O
		Hypnum cupressiforme var. lacunosum	O
		Oxyrrhynchium hians	O
06	Dune grassland	Campylopus introflexus	O
		Dicranum scoparium	A
		Hypnum cupressiforme var. lacunosum	F
		Hypnum jutlandicum	R
		Polytrichum juniperinum	O
07	Dune grassland (track)	Campylopus introflexus	D
		Dicranum scoparium	F
		Hypnum cupressiforme var. lacunosum	A
		Hypnum jutlandicum	O
		Polytrichum juniperinum	A
08	Woodland	Cryphaea heteromalla	R
		Hypnum cf. andoi	O
		Metzgeria furcata	R
		Orthotrichum affine	R
		Ulota bruchii	R
09	Woodland	Cryphaea heteromalla	O
		Kindbergia praelonga	R
		Leptodictyum riparium	R
		Metzgeria furcata	O
		Orthotrichum affine	O
		Orthotrichum diaphanum	R
		Orthotrichum striatum	R
		Radula complanata	R

Sample no.	Vegetation type	Species	Abundance (DAFOR)
10	Dune grassland (track)	Bryum capillare	R
		Campylopus introflexus	O
		Ceratodon purpureus	F
		Dicranum scoparium	R
		Hypnum cupressiforme var. lacunosum	A
		Polytrichum juniperinum	A
		Pseudoscleropodium purum	R
11	Dune	Bryum capillare	O
		Campylopus introflexus	R
12	Dune grassland	Bryum capillare	O
		Ceratodon purpureus	O
		Dicranum scoparium	A
		Hypnum cupressiforme var. lacunosum	F
		Polytrichum juniperinum	R
		Pseudoscleropodium purum	O
13	Dune grassland	Bryum capillare	O
		Dicranum scoparium	A
		Hypnum cupressiforme var. lacunosum	F
		Polytrichum juniperinum	F
14	Dune	Brachythecium albicans	F
		Bryum capillare	R
		Kindbergia praelonga	O
		Pseudoscleropodium purum	F
15	Dune grassland	Hypnum cupressiforme var. lacunosum	A
		Polytrichum juniperinum	O
16	Dune	Brachythecium rutabulum	O
		Bryum capillare	F
		Ceratodon purpureus	O
		Dicranum scoparium	F
		Hypnum cupressiforme var. lacunosum	O
17	Dune	Brachythecium albicans	A
		Bryum capillare	F
		Campylopus introflexus	R
		Hypnum cupressiforme var. lacunosum	O
		Kindbergia praelonga	O
18	Dune grassland (track)	Ceratodon purpureus	F
		Hypnum cupressiforme var. lacunosum	A
		Polytrichum juniperinum	F
19	Dune	Brachythecium albicans	F
		Brachythecium rutabulum	F
		Bryum capillare	F
		Ceratodon purpureus	O
		Hypnum cupressiforme var. lacunosum	O
		Syntrichia ruralis var. ruraliformis	O
		Syntrichia ruralis var. ruralis	O
20	Dune grassland (track)	Hypnum cupressiforme var. lacunosum	D
		Syntrichia ruralis var. ruraliformis	R
21	Dune	Brachythecium albicans	O
		Bryum capillare	A
		Ceratodon purpureus	O
		Hypnum cupressiforme var. lacunosum	O
		Syntrichia ruralis var. ruraliformis	O

Sample no.	Vegetation type	Species	Abundance (DAFOR)
22	Vegetated shingle	Brachythecium albicans	F
		Bryum algovicum var. rutheanum	O
		Bryum capillare	A
		Ceratodon purpureus	O
		Syntrichia ruralis var. ruraliformis	F
23	Dune grassland	Dicranum scoparium	O
		Hypnum cupressiforme var. lacunosum	F
		Pseudoscleropodium purum	F