Natural England Commissioned Report NECR153

Survey and analysis of vegetation and hydrological change in English dune slack habitats

Annex 2 - Site report for Sefton Coast: Ainsdale NNR, Ainsdale LNR, Birkdale Hills LNR

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Executive Summary

- Dune wetlands at Ainsdale NNR, Ainsdale LNR and Birkdale LNR were surveyed and mapped in the summer of 2012, repeating the wetland component of the earlier Sand Dune Survey of Great Britain (SDGB) at this site in 1989. Some vegetation quadrats from the 1989 survey were relocated and re-surveyed, and soil samples taken. Hydrological interpretation is provided and hydrological studies are ongoing at this site.

- An extensive (1972 onwards) hydrological record exists at Ainsdale and this could provide an extremely valuable dataset against which to assess current water table trends and variability.

- The hydrological record shows periods of wet and dry years, although identifying a single wetting or drying trend throughout the time series is difficult to do with any confidence. However, hydrological modelling at Ainsdale has suggested that over the next 80 years groundwater levels may fall by 1.0 to 1.5 m, and this is likely to have a negative impact on dune wetland flora and fauna.

- At Ainsdale NNR and Ainsdale LNR, there was a substantial decrease of 36% in wetland area between the two time points, with a net decrease in mapped area of 22 ha, 40%. This represents a considerable change at a large site. Much previous wetland habitat has now changed to dry habitat and was therefore not mapped in 2012. This was most apparent on the NNR in the vicinity of the pine plantation, or areas previously occupied by pine plantation.

- Twenty one vegetation quadrats were re-surveyed at Ainsdale NNR, and four re-surveyed at Ainsdale LNR. At Ainsdale NNR, analysis shows a small but significant decline in Ellenberg light scores, suggesting a move away from open communities with light demanding species to a more closed canopy. There was a reasonably large increase in Ellenberg nutrient scores, suggesting that the site has become more eutrophic, probably due to general successional development of vegetation and soils. There were no significant changes in quadrats at Ainsdale LNR.

- At Ainsdale NNR, soil pH was below 7, and approaching the level of pH 6.5 at which one would expect decalcification. It is likely that surface soil pH is already below 6.5. Slack organic matter contents are moderate, at around 6%. At Ainsdale LNR the four quadrats had high pH, >7, while slack soils showed high organic matter contents, ~14%.

- At Birkdale LNR, there was a substantial decrease of 44% in wetland area between the two time points, with a net decrease in mapped area of 14 ha, 45%. This also represents a considerable change at a large site. This was mostly due to 81% declines in dry slack community (SD16) and 96% declines in slack transitions to other dry communities, both probably converting to non-slack habitat such as scrub, and therefore not mapped in 2012. Area of wet slacks did not change substantially.

- Fourteen vegetation quadrats were re-surveyed at Birkdale LNR. There was a highly significant decrease in Ellenberg light scores, suggesting a shift towards taller more rank vegetation, matching the observed increase in scrub across many of the

Birkdale slacks. There was a concurrent increase in Ellenberg nutrient scores, also consistent with greater levels of organic matter under taller vegetation and scrub. There was a large decline in Ellenberg moisture scores, suggesting some drying out of the vegetation in the quadrats.

- Soils at Birkdale LNR showed reasonably high pH, averaging above 7, and moderately high organic matter, ~8% in slacks.
- At all three sites, increased management interventions are probably required to provide a counterbalance to the trend towards more closed vegetation with higher nutrient status.
- Further work is required, including analysis of other local datasets, combined analysis of vegetation and hydrological change, and an understanding of the management history of the three sites, to better understand the spatial pattern to trends observed here, and to explain why they might be occurring.
- New dipwells and hydrological and vegetation monitoring, at a range of locations within Birkdale Hills LNR, would be extremely useful in helping to explain ongoing changes at this site due to scrub encroachment and its subsequent management, and progressive successional development of the green beach. This should include monitoring locations seaward and inland of the coastal road, in a range of wetland communities, and encompassing a geographical spread to capture potential influences of management on water tables.

Contents

1 Introduction

This work was conducted under a Memorandum of Agreement between Natural England and the Centre for Ecology and Hydrology (CEH). It comprised two elements: hydrological studies at key sites and a re-survey of the dune wetland resource, repeating where possible mapping and survey work conducted as part of the Sand Dune Survey of Great Britain (SDGB) (Radley 1994). Of the Sefton Coast sites, it was only possible to survey the main wetland areas within Ainsdale NNR, Ainsdale LNR and Birkdale LNR excluding the majority of the saltmarsh and transitional components of the Birkdale Green Beach. Work conducted at Ainsdale NNR, Ainsdale LNR and Birkdale Hills LNR under these two components is reported here.

2 Site Description

The site description is separated into hydrological and ecological components, both focusing primarily on the wetland features of the site.

2.1 Geological and hydrological setting

The Sefton Coast dunes are situated in north west England, and lie between the estuaries of the Mersey and Ribble (Figure 1). In total the area is approximately 25 km long and in places up to 3 km deep. Within the wider Sefton Coast dunes the areas that form the focus of this study, Ainsdale Sands and Birkdale Hills, are situated just to the south of Southport.

The Sefton dune system is impacted by longshore scour which is eroding the dune front and transporting sediment northwards to deposition grounds off Southport and southwards towards the Mersey estuary. As with the majority of the UK west coast dunes, the sand is underlain by marine clay, which restricts any exchange with the deeper groundwater system (Geological map 74/83).

Figure 1. The location of the Sefton Coast dunes in the UK.

Ainsdale Sand Dunes National Nature Reserve (Figure 2) is located in the central section of the dunes and has been isolated from anthropogenic development since its establishment in 1965. The site is partly forested. In a typical wet winter, approximately 30% of the slack floors flood to a depth of 0.1 to 0.3 m. The majority of the slacks dry out in summer with the water table falling to around 0.5 m below ground level and only 10% of the slacks remain flooded throughout an average year. These dynamic conditions provide environments for rich assemblages of flora (Jones et al. 2011; JNCC, 2007) and breeding grounds for rare amphibians (Steward, 2001).

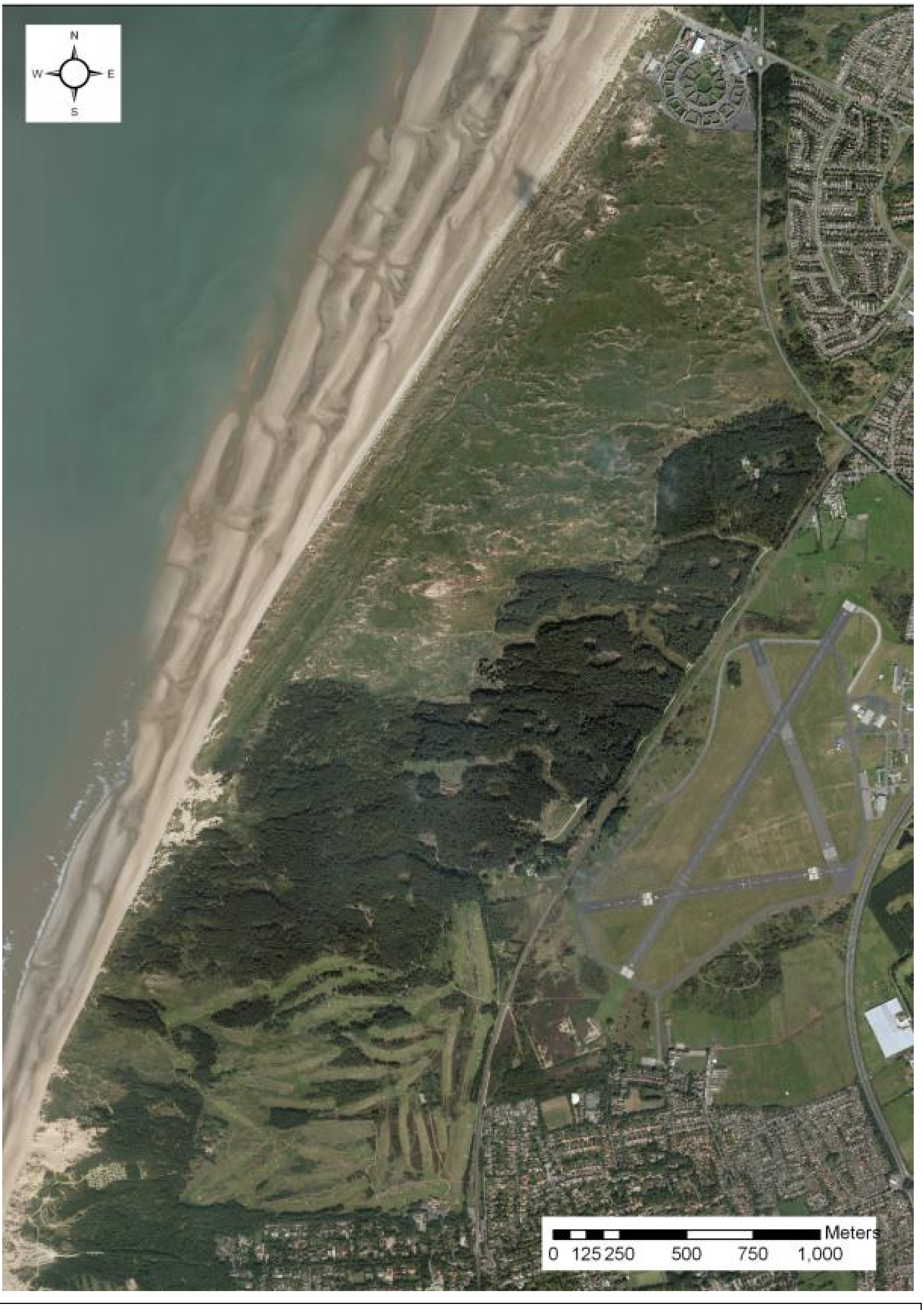

Figure 2. Aerial photo of Ainsdale NNR and Ainsdale LNR, part of the Sefton Coast dunes. © Next Perspectives.

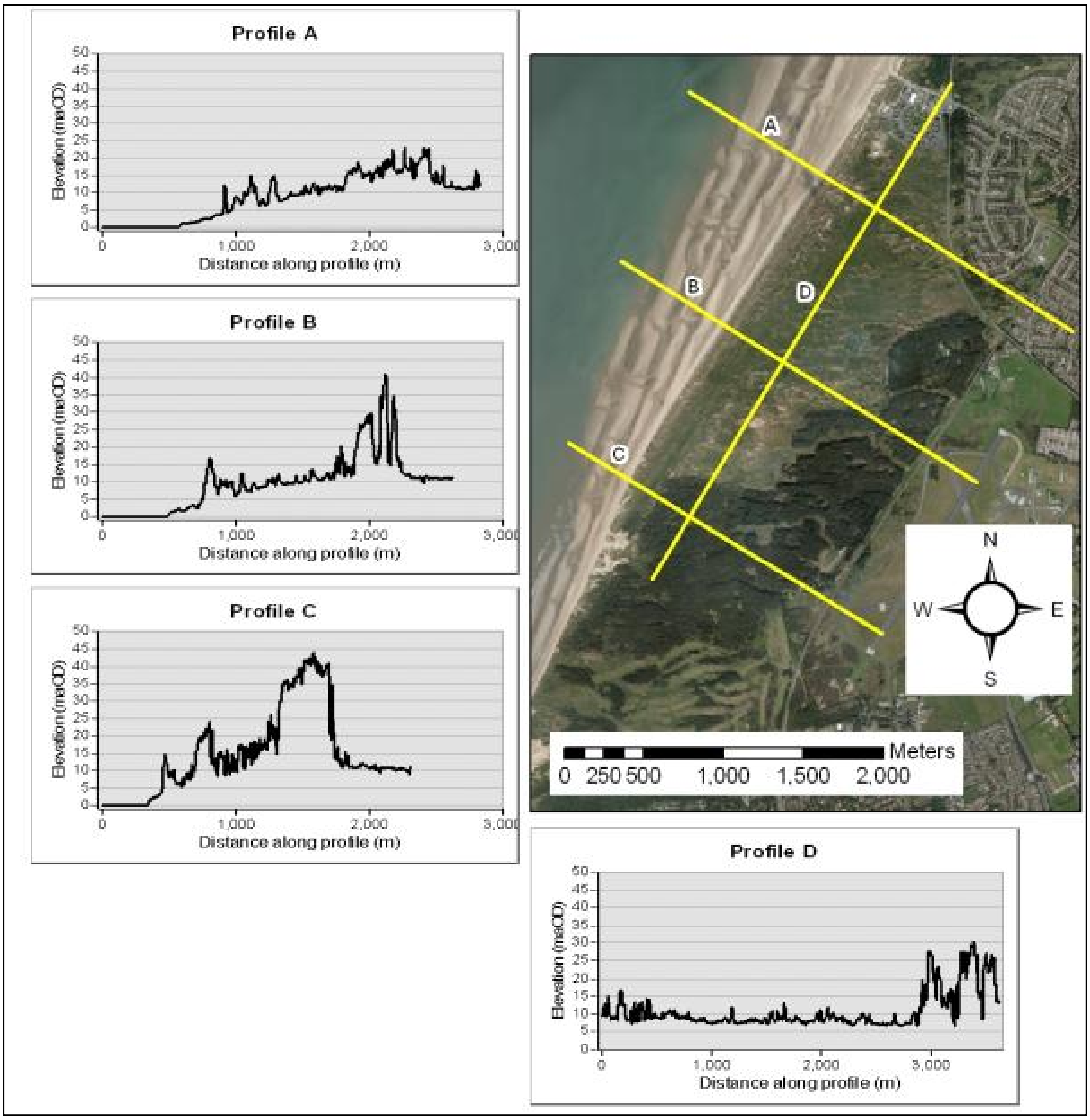

Figure 3. Elevation profiles at several locations along Ainsdale NNR and Ainsdale LNR. Values represent the elevation of the top surface, not the ground surface, so are affected by vegetation height. This is particularly noticeable in profiles B and C. © NERC (CEH) 2013, © Next Perspectives.

Ainsdale dunes is a hindshore system with a frontal dune ridge rising to an elevation of ~15 m AOD. Behind the frontal dunes, the dune floor elevation is between 5 and 7 m AOD, and this rises inland to an elevation of ~15 maOD. The north of the site is largely unforested, whilst pine forest covers a large proportion of the south of the site. The elevation of the tops of the trees is illustrated in Figure 3, profiles B and C.

Long term data for the basic hydrological drivers (rainfall and evaporation) are shown in Figure 4. Whilst evapotranspiration is broadly similar across many of the UK sites, rainfall varies considerably. Ainsdale falls roughly in the middle of the range of average annual rainfall amounts for the dunes in this study. The long term (1961 to 2012) average annual rainfall for this area (area defined as the 40km x 40km grid square calculated using the Meteorological Office Rainfall and Evapotranspiration Calculation System (MORECS)) is 861 mm, and the long term (1961 to 2012) average annual net (rainfall – actual evaporation) is 263 mm. This suggests that in most years, rainfall recharge supports the groundwater system.

Interpretation of MORECS data must remember that the data reflect the average conditions for the whole grid square. It is quite possible the conditions at a single coastal dune system will not be accurately represented by MORECS data and the results should therefore only be used as very broad indicator.

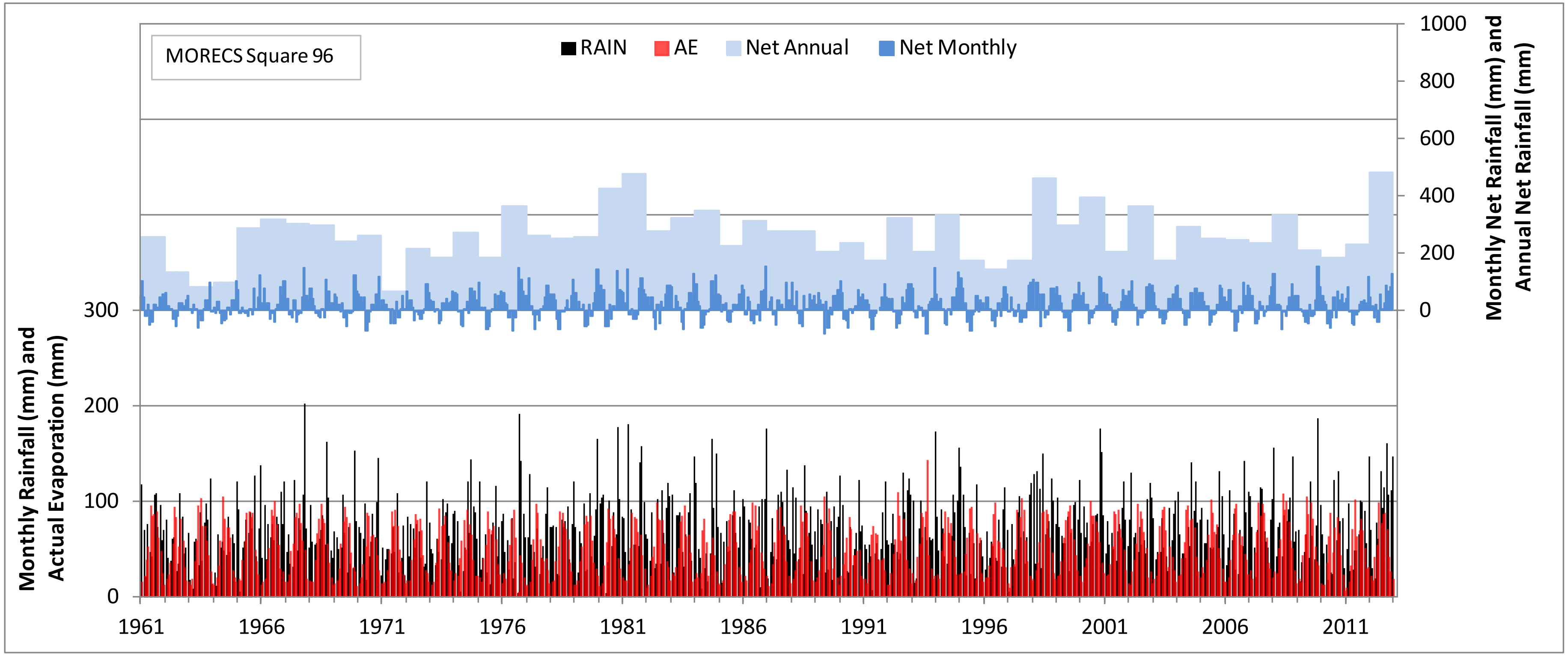

Figure 4. Monthly Rainfall and Evaporation data for MORECS square 96. Net (Rainfall - actual evaporation) monthly and annual totals also shown. MORECS data © Crown copyright 2013, the Met Office.

In addition to inter-annual climatic variation there are other local issues such as the development of the pumped agricultural drainage system behind the dune system and the expansion of nearby areas of urbanisation with an associated road drainage system which intercepts water that would otherwise drain to the water table (Clarke & Sanitwong, 2010).

2.2 Ecological setting

The Sefton coast dunes were previously surveyed in 1988-1989 by Edmondson et al. (1989), and were subsequently re-surveyed in 2003-2004 (Gateley and Michell, 2004). The Sefton Coast is considered the most important dune system in northwest England, and amongst the most diverse and extensive areas of sand dune in the UK. The habitats of the Sefton Coast were described in detail as part of the National Sand Dune Vegetation Survey (Edmondson et al. 1989). As with other surveyed dunes, these early reports constitute the baseline to which the present survey of 2012 is compared. The results of the 1989 survey were translated from the provisional NVC classification to that which was published and used subsequently (Rodwell 2000) as part of a EU LIFE project, allowing more direct comparison of vegetation change under a consistent NVC classification.

Strandline vegetation related to both the SD2 *Honkenya peploides-Cakile maritima* and SD3 *Matricaria maritima-Galium aparine* communities has been recorded, although these types may be either transient (dependant on weather and erosion due to storms) or liable to destruction through “beach-cleaning”. Foredune vegetation of SD4 *Elymus farctus* was present all along the coast, although the 1989 survey described it as being more extensive in the southern sections where the coast was accreting. Mobile dune vegetation was quite varied along the Sefton Coast with SD6 *Ammophila arenaria* especially common, whilst SD5 *Leymus arenarius* was rather more localised and especially typical of the extreme ends of the Sefton Coast. Further inland both SD7 *Ammophila arenaria-Festuca rubra* semi-fixed dunes and SD8 *Festuca rubra-Galium verum* fixed dune swards were described as variable on these Lancashire dunes but SD7 appeared commoner in 1989 (Edmondson et al. 1989). The Sefton coast has areas of dune heath and woodland, as well as calicfuge grassland and some important mesotrophic grassland areas, especially near to the golf courses.

In 1989, the dune slack vegetation was described mainly within the SD15 *Salix repens-Calliergon cuspidatum* and SD16 *Salix repens-Holcus lanatus* types (with considerable variation), although the larger slacks appeared to have significant areas of SD17 *Potentilla anserina-Carex nigra*. When mapped in 2012, the slacks were variable in size and shape. Broadly speaking SD16 was the most abundant slack type throughout the Sefton Coast, although SD15 *Salix repens-Calliergon cuspidatum* was also well represented and in the central parts often more extensive. SD17 remained widespread, especially in the northern sections. The arrangement of the slacks also varied in the different parts of the coast, being often parallel to the coast in the north and closer to the sea, but frequently aligned at right-angles to the coast further south or inland.

Nationally rare and scarce species are well-represented on the Sefton Coast, although the spread of the Merseyside conurbation, of Southport and of the intervening settlements, coupled with the direct impact of conifer plantation, has led to the decline or even extinction of some species. *Centaurium latifolium* was probably only a dune-slack variant of C. erythraea but became extinct through urbanisation and enclosure (Savidge et al. 1963). *Schoenoplectus pungens* was also a dune-slack plant, which become extinct in its own mainland British site in 1972, although it has been re-introduced from the same stock on the Sefton Green Shore. Other rarities of the dune-slacks include *Pyrola rotundifolia maritima*, which is common here, *Juncus balticus* (together with hybrids) in its only English site and *Epipactis dunensis*. Other notable plants are associated with drier more open dune habitats (*Coincya m. monensis* and *Mibora minima*) or of the forested dunes (*Epipactis phyllanthes*).

The impacts of urbanisation and afforestation have had important impacts on the dune and dune-slack vegetation of the Sefton Coast (Edmondson et al. 1989), although other factors include sea defence works, mining of sand from the dunes for industry, dumping of waste materials and the extensive conversion of dunes into gold courses. However, conservation action to restore dune slacks and of the Green Beach has significantly increased the extent of species-rich dune-slack vegetation.

3 Hydrological work

This hydrological summary focuses on the Ainsdale Sands area of the Sefton Coast and is based almost entirely on the work of Derek Clarke, who installed a network of dip wells in 1972 (Figure 5) and has overseen the monthly monitoring of water table levels ever since. For more detail, the reader is recommended to refer to the following publications: Clarke (1980), Clarke and Pegg (1992), Clarke and Sanitwong (2007), Clarke and Sanitwong (2010), Clarke and Stratford (2011) and Stratford *et al*. (2013b).

The water table measured in the slack dip wells throughout the site typically rises from sea level at +0.2 m AOD (above Ordnance Datum) beneath slacks nearest to the sea to a maximum +10.5 m AOD beneath slacks situated up to 2 km inland. Groundwater flow is perpendicular to the coast, running in a north westerly direction (Figure 6). The observed annual water table levels (1972 to 2007) rise and fall with an amplitude of 1.5 m, which is in line with the hydrological regime of dune slacks identified by Ranwell (1959) for wet and transitional communities.

The water table regime is largely driven by rainfall and evaporation and land cover has an additional impact both by leaves and scrub intercepting rainfall and by root systems accessing soil moisture/groundwater. Clarke and Sanitwong (2007) calculate that the evaporation from dune areas covered in pine trees is 214 mm/yr greater than that on open dunes and that this results in the water table under the trees being 0.5 to 1.0 m lower than that under the open dunes. An additional factor impacting on the dune water table is progressive foreshortening of parts of the dune coastline (up to 3 m per year), which has impacted the groundwater levels nearest the coast.

In order to quantify the effect of tree cover on the water table level, a trial clearance was conducted in the 1990s and monitoring and assessment was reported by Atkins (2004). The following text is adapted from Stratford *et al.* (2006):

‘Two phases of scrub and woodland clearance were carried out: the first in 1992 cleared a total of 11 ha, of which 4.5 ha was pine forest, at the northern end of the frontal woodland, and the second phase in 1995/1996 cleared a total of 16 ha of scrub and woodland. Prior to the experimental clearance the mainly Corsican Pine woodland covered 176 ha and was divided into 28 ha of poor quality seaward frontal woodland and 148 ha of more healthy landward rearward woodland.

Monitoring boreholes were established in various types of dune cover, ranging from open fixed dunes to coniferous woodland, outside the areas where clearfelling would occur. These were designated as control boreholes. Additionally, boreholes were established in the same range of dune cover types in an area where clearfelling would occur. Clearance was undertaken in 1992 and 1996 and the impact on the water table of these schemes monitored. However, groundwater monitoring was only conducted between 1991 and 1993 and then again between 2001 and 2003 leaving no data for the period from 1994 to 2000.

Over the monitoring period the average rise in water level in the clearfelled area was 0.82m and 0.51m in the control areas. The higher water levels in the clearfell fixed dunes in comparison to the fixed dune control boreholes indicates that the clearfell of the pinewoods within the dune restoration area has had an impact on the water levels in the associated surrounding fixed dunes. The increase in water levels within the clearfell area occurs against a background of a general groundwater rise along the Sefton Coast independent of management of the reserve. Within the clearfell boreholes, water level rises in those boreholes originally within the woodland vegetation are greater than those in the open fixed dune system. However for the control boreholes, the vegetation type does not appear to have any relationship with the water level rise over time. There are two issues which make the effect less clear. First, there were two episodes of water level monitoring – 1991 to 1993 and 2001 to 2003. No levels are presented for the period between these two episodes. Without these additional data it is not possible to comment on how quickly the water table rise occurred. Secondly, the early 1990s exhibited low rainfall and winter 2000/1 was very wet, so it is difficult to conclusively state that the reduction in forest area has improved the groundwater situation.

The overall conclusion of this study is that boreholes within the original 11 ha clearance area, of which 4.5 ha was pine woodland showed a rise in groundwater level of around 0.3 m compared to the boreholes in the control areas. The lack of continuous water level time series data makes more detailed analysis of the factors impacting on the water level rise difficult.'

Groundwater modelling carried out by Clarke and Sanitwong (2007), suggest that groundwater levels may decrease by 1.0 to 1.5 m over the next 90 years, as a result of increased temperatures and changing rainfall patterns. This shift in hydrological conditions would impact negatively on the dune wetland flora and fauna (Curreli et al. 2012). Sea level rise, which would increase the overall groundwater system elevation, will only mitigate this to a small extent (Clarke and Sanitwong, 2010).

The long time series of water levels at Ainsdale is a rare and valuable dataset and provides an important backdrop against which to assess dynamics and extremes. For instance, the past 18 months have seen some of the wettest conditions ever recorded at Ainsdale.

Figure 5. Dipwell monitoring network at Ainsdale NNR and Ainsdale LNR. © NERC (CEH) 2013, © Next Perspectives.

Figure 6. Ainsdale NNR and Ainsdale LNR conceptual groundwater flow diagram. The yellow arrows indicate the direction of groundwater flow. © NERC (CEH) 2013, © Next Perspectives.

4 Vegetation Survey

4.1 Methodology

4.1.1 Field Mapping

The use of GPS-linked portable electronic tablet PCs in the field equipped with Arcpad GIS software enabled a variety of layers to be loaded simultaneously and selected or made semi-transparent as required. GIS layers included aerial photos covering the extent of the dunes, scanned and geo-referenced copies of the original survey maps, the editable layers for mapping and, where available, additional survey information for dune slacks recorded since the SDGB survey.

As the project focused very specifically on dune wetlands, there was no scope to map the more widely distributed (dry) dune communities. For each prioritised area surveyed, every slack or wetland mapped in the original survey was revisited as far as possible, aided by printed copies of the SDGB survey maps with wetland habitats highlighted. Additional slacks were then located by covering as much of the intervening ground on foot as possible, and using georeferenced aerial photos as guidance. To aid the surveyors in distinguishing boundaries between dune wetlands and dry dune communities, it was helpful to identify certain indicator species that could be used to help delineate the edge of dune slacks. The basic premise that dune slacks are influenced by the water table meant that in many cases the extent of species strongly associated with damp habitats provided a useful guide. The relative significance of species differed slightly with each site, but usually included *Hydrocotyle vulgaris* (Marsh pennywort), *Carex nigra* (Common sedge), *Agrostis stolonifera* (Creeping bent), *Eleocharis* sp. (Spike-rush) and *Epipactis palustris* (Marsh helleborine) as well as a range of bryophytes. *Calliergonella cuspidata* was particularly useful where it occurred (particularly in NVC communities SD14-15 and SD17) due to its abundance and mat-forming habit. Conversely, certain species strongly associated with dry habitats such as *Ammophila arenaria* (Marram grass) and *Chamerion angustifolium* (Rosebay willowherb) usually helped identify areas outside the extent of the slack.

Once a dune slack was located and delineated, surveyors identified apparently homogenous stands of vegetation, following NVC guidance (Rodwell, 2006). The boundaries of each stand were walked and digitised using the GPS-tracking functionality in Arcpad. Occasionally the GPS accuracy could drop to as low as 20m, at which point the aerial photos were helpful in confirming the location. Associated with each polygon drawn, the information listed in Table 1 was captured.

Table 1. Digital mapping data collection form filled in for each polygon digitised.

Field	*Data entry method*
ID	Unique polygon ID generated by Arcpad
NVC community	Selected from list OR free text
NVC sub-community	Selected from list OR free text
Notes	Free text field for target notes relevant to each polygon; surveyors included dominant species and previous slack ID where relevant
NVC community 2 (mosaic)	Selected from list OR free text
Proportion NVC community 1	Where a mosaic of two habitats occurs the proportion of each was specified
Proportion NVC community 2	

Due to the time constraints of the survey, it was not possible to follow the standard NVC guidance to record at least 5 quadrats in each stand of vegetation (Rodwell, 2006). A variety of resources were used to identify communities, including surveyors' personal experience, NVC habitat keys & descriptions, NVC floristic tables and the use of TABLEFIT software *in situ*. TABLEFIT can perform a useful function with reduced species lists with or without cover data (as well as single or multiple full quadrats), so mappers were able to make use of this for guidance throughout the survey, where the scale of the project otherwise precluded the recording of full quadrats. Close contact throughout the survey of the mappers with those surveyors who were recording quadrats provided an extra level of quality assurance in the mapping exercise.

All wetland communities within the interior of the dune system were mapped at the NVC sub-community level where possible with a minimum mappable unit of 10 x 10m. Although dry dune and other habitats were not mapped, transitions between wet and dry communities were. Former slacks that are now dry and no longer contain slack vegetation were identified by target notes, but their boundaries were not mapped.

4.1.2 Location of vegetation quadrats

Using the GIS resources described above in the mapping methodology, SDGB quadrats for which data were available were re-located. Some expert judgement by the surveyors was required to re-locate the original quadrat position, particularly where error or distortion in the SDGB survey map was evident. Additional quadrats were recorded adjacent to grid referenced hydrological monitoring locations (dip wells). Occasionally it was not possible to locate the exact position of dip wells in which case the quadrat was positioned as close as possible. Where dipwells were fenced, and either could not be located or the fenced area was impenetrable due to scrub, quadrats were placed outside the fence touching its SW corner. Where dip wells were not visible at all quadrats were located according to the grid reference. Where possible, additional new quadrats were recorded in less common habitats and young natural slacks formed since the SDGB survey. Locations of quadrats recorded in 2012 are shown in Figures 13 & 14.

4.1.3 Vegetation quadrat recording methodology

Once quadrat positions were located, a 2x2m quadrat oriented north-south was surveyed. The location of the centre of the quadrat was recorded using a Garmin Etrex GPS, to around ±5 m accuracy. Within the quadrats all vascular plants and bryophytes were identified and percentage cover recorded. Where cover of a species was <1%, a value of 0.1% was recorded where a single individual was present, and 0.5% where more than one individual was present, to enable conversion to Domin values (+ and 1 respectively). Cover values between 1 and 10 were recorded to the nearest 1%, and above that to the nearest 5%. Where species identification was not possible in the field (primarily bryophytes), samples were collected and later verified by a specialist.

Additional parameters such as bare ground, aspect, slope, as well as data regarding management in evidence such as grazing, dunging, urine patches, evidence of scrub clearance, etc. were recorded (Table 2). Vegetation height was measured by placing a metre ruler at 5 random locations within the quadrat, and estimating the sward height to which 80 % of the vegetation reached, within a 20 cm radius of the ruler. A unique ID number was assigned to each quadrat within the database, and where relevant the associated quadrat number from the SDGB survey was noted within the recording form. Two photographs were taken at each quadrat facing North; one looking down on the sward, and the other including the surrounding habitat for context. Unique quadrat ID and a four letter site code were included within photographs. Quadrats were allocated to a NVC community following the methodology described for mapping above, though if required TABLEFIT analysis could be delayed until later on with reference to the full species list.

Table 2. Data collected associated with each quadrat.

Category	*Sub-category*	*Data entry method*
ID	Unique quadrat ID generated by arcpad	n/a
1990 ID	Quadrat number assigned in 1990 survey	Free text
Characteristics	GPS location	Free text
	Angle of slope (degrees)	
	Aspect (compass degrees)	
	Vegetation height (cm; 5 measurements)	
Management	Grazed?; Rabbit; Sheep; Cattle; Horse; Other animal (specify); Mown; Scrub-cut; Trampled by people; Evidence of fires; Other disturbance (specify)	Choice (yes/no/don't know) & free text to specify 'other'
Additional info.	Flooded at time of survey; Soil sample taken	Choice (yes/no)
	Depth(cm); Photographic record; Soil features	Free text
NVC community	NVC community description	Free text
Vegetation data	Name and % cover for each species	Drop down choice for name and free text for %cover

4.1.4 Soil sampling

A soil sample was taken from the SW corner of each quadrat recorded. A plastic corer of 5 cm diameter and 15 cm depth, labelled with quadrat ID and date was hammered into the ground and removed using pliers, and the tube and soil sample within were placed in a plastic bag and sealed. Samples were kept in portable cool boxes with ice packs before being returned to CEH Bangor, where they were stored in cold rooms at 5˚C prior to analysis.

4.1.5 Species nomenclature

Plant species nomenclature follows that of Stace (2010) for vascular plants and Smith (2004) for bryophytes. Biological Records Centre (BRC) species codes are associated with all vegetation data within the database.

4.1.6 Analysis of change in vegetation

As described above, the survey team in 2012 re-visited the majority of areas that were mapped as wetland in 1989. As described in the introduction, only the main wetland resource at Ainsdale NNR, Ainsdale LNR and Birkdale Hills LNR was surveyed for the Sefton Coast. Even within these sites it was not possible to survey every single unit of dune wetland, although this was the aim. Selection of wetland areas to resurvey were based on a GIS layer of numbered dune slacks provided by Sefton Council, which covered the majority of the resource. Occasionally, some slacks were surveyed which were not recorded on this GIS layer, but which were deemed sufficiently large that they should be included. Change in mapped area was assessed for all mapped dune wetlands following the criteria below. Polygons for wetlands in 1989 which corresponded to areas mapped or revisited in 2012, were selected from the GIS layer of the 1989 survey, kindly made available by Sefton Council. The area comparison included the following:

- Locations mapped as wetland in 1989, but deemed no longer to be wetland vegetation in 2012 based on lack of slack vegetation indicator species (see main report Stratford et al. (2013a), and methods section above). Note that only wetland vegetation types were mapped in 2012, so where vegetation had changed to a non-wetland type this was noted in a target note, but the extent was not mapped. These therefore represent a contraction in the area of wetland at the site. A substantial area in the vicinity of the pine woodland, or previously cleared areas of pine woodland within Ainsdale NNR fell into this category, and we discuss the implications of this below.

- Locations mapped as wetland in both 1989 and 2012.
- New wetland features mapped in 2012, predominantly scrapes.

Each polygon (1989 and 2012) was assigned a code for broad vegetation type (Table 3) for ease of interpretation of multiple vegetation classes and communities. The 1989 survey used the draft version of the NVC for coastal habitats. However, this was subsequently translated into the final NVC classification (Rodwell, 2000) based on re-analysis of quadrats and target note information. GIS mapped layers of the 1989 and subsequent 2005 surveys were kindly made available by Sefton Council and this facilitated analysis and interpretation of change. However, differences in surveyor opinion of both vegetation unit boundaries and assignment to vegetation types make such analysis difficult. Within the resources of the project it was not possible to incorporate change analysis for the 2005 mapped GIS layers. Polygons mapped in 2012 are shown in Figures 15-25.

Table 3. Broad vegetation codes used for reporting of change in mapped area, using the final NVC classification (Rodwell, 2000).

Code	Vegetation type
bs	Bare sand
ce	Early successional calcareous slack type (SD13, or transitions involving SD13)
cw	Wet Calcareous slack type (SD14, SD15)
cd	Dry Calcareous slack type (SD16)
a	Acid slack type (SD17)
s/d	Slack to dry transitional
d	Dry dune vegetation (SD6 to SD12; SD18), or other dry habitat
sm	Saltmarsh
wp	Wet pasture (frequent Juncus spp, or inundation grasslands: M23, MG8, MG10, MG11, MG12, OV28)
w	Other wetland type (incl. swamp, mire, open water, wet woodland, ponds etc.)
sc	Scrub (additional category used at Birkdale due to extensive scrub)
t	Trees or scrub (most sites this will be conifer plantations)
s/w	Slack to wet transitional

Change in vegetation composition was assessed by analysis of a number of quadrats from 1989 in wetland areas which were resurveyed in 2012. Quadrats were relocated based on maps from 1989 and interpretation of likely location on the ground in combination with maps and high resolution orthorectified recent aerial photography. GPS grid-references were taken for quadrat locations in 2012, accuracy + 5m. We estimate that the majority of these quadrats were relocated within 5m of the original quadrat location, but it is likely that some were not so accurately relocated. At each quadrat, vegetation height was recorded and a soil sample taken for basic physical description (organic horizon thickness, pH, moisture content and organic matter content) and archiving for future chemical analysis, should resources become available.

Where available, species composition of quadrats from 1989 was entered by hand from floristic tables in the Edmondson et al. (1989) report. Species names were harmonised to Biological Recording Centre (BRC) names, and mean Ellenberg indices for environmental indicators (L=Light; F=Moisture; R=Reaction/pH; N=Nutrients; S=Salinity) and for climate indicators (Tjan=Minimum January temperature; Tjul=Maximum July temperature;

Prec=Annual precipitation) were calculated for each quadrat in each time period based on the presence/absence of species in the quadrat. Percentage abundance data for 2012 were converted to 10-point DOMIN as in Rodwell (2006).

4.2 Results

Results are reported separately for the three sites where possible, or are combined for reporting of mapped area of Ainsdale NNR and Ainsdale LNR. Figures 15-25 show the extent of the area mapped in 2012, with polygons colour-coded by broad vegetation code (Table 3), and labelled with the NVC communities assigned.

4.2.1 Change in mapped area of dune wetlands

Ainsdale NNR and Ainsdale LNR

Comparison of changes in mapped area of dune wetlands covered both Ainsdale NNR and Ainsdale LNR due to the difficulties in separating where individual mapped slacks lie across the site boundaries. Changes between 1989 and 2012 are summarised in Table 4 below.

Table 4. Ainsdale NNR and Ainsdale LNR. Mapped area (ha) of broad vegetation classes in 1989 and 2012, showing net change, and percentage change for classes with area > 1 ha in 1989.

Area summaries	1989	2012	Net change	%change
Bare sand and early successional	2.7	0.3	-2.5	-90.2
Wet slacks+slack/wet transitions	14.6	13.0	-1.7	-11.3
Dry slacks	15.5	16.8	1.3	8.5
Slack/dry transitions	15.7	1.3	-14.5	-92.0
Dry habitats, including scrub	3.6	0.7	-2.9	-81.3
Other wetlands	2.6	1.3	-1.3	-48.8
Total slacks	48.6	31.3	-17.3	-35.6
Total slacks and other wetlands	51.2	32.6	-18.6	-36.3
(Total Mapped Area)	55.4	33.3	-22.1	-39.9

There was a large decrease of 36% in wetland area between the two time points, with a net decrease in mapped area of 22 ha, 40%. This represents a substantial change at a large site. Detailed change analysis using a change matrix was not possible within the scope of this study. However, based on Table 4 and interpretation of the maps and database (available electronically from Natural England), the following broad changes are apparent from this analysis.

There was a substantial decline of 90% in the relatively small area of bare sand and early successional habitat, despite numerous small management scrapes of varying ages on both sites. Individually, and in total, these were all of very small area, with early successional habitat, or transitions from early successional (SD13) to other communities, usually SD14, occupying in total only 0.3 ha in 2012. There was an 11% decline in area of wet slacks and transitions to other wetland types. There was a substantial decline in area of communities in transition between slack and other dry habitats, of 14 ha (92% of the 1989 resource), coupled with a small increase of 1.3 ha in dry slacks. It is not possible to say for certain what each community has changed to, however, the large decline in mapped area suggests that much previous wetland habitat has now changed to dry habitat and was therefore not mapped in 2012. This was most apparent on the NNR in the vicinity of the pine plantation, or areas previously occupied by pine plantation, where features which were topographically dune slacks and which had been mapped as slack previously no longer contained any wetland or dune slack indicator species other than *Salix repens*. The extent of *S. repens* cover across these former slacks ranged from ~10% to 60% coverage in total of the former slack floor. However, survey notes suggest the majority of other species indicated communities of SD8 fixed dune grassland, SD12 decalcified fixed dune grassland or intermediates between them on the former slack floors, and not slack vegetation.

Birkdale LNR

Comparison of changes in mapped area of dune wetlands at Birkdale LNR between 1989 and 2012 are summarised in Table 5 below.

Table 5. Birkdale LNR. Mapped area (ha) of broad vegetation classes in 1989 and 2012, showing net change, and percentage change for classes with area > 1 ha in 1989.

Area summaries	1989	2012	Net change	%change
Bare sand and early successional	1.5	0.0	-1.5	-100.0
Wet slacks+slack/wet transitions	11.0	11.2	0.3	2.3
Dry slacks	7.0	1.3	-5.7	-81.0
Slack/dry transitions	7.1	0.3	-6.8	-96.4
Dry habitats, including scrub	0.4	0.0	-0.4	-
Other wetlands	3.7	4.0	0.3	8.2
Total slacks	26.6	12.8	-13.7	-51.7
Total slacks and other wetlands	30.3	16.8	-13.4	-44.4
(Total Mapped Area)	30.9	16.8	-14.0	-45.5

There was a substantial decrease of 44% in wetland area between the two time points, with a net decrease in mapped area of 14 ha, 45%. This represents a considerable change at a large site. Detailed change analysis using a change matrix was not possible within the scope of this study. However, based on Table 5 and interpretation of the maps and database (available electronically from Natural England), the following broad changes are apparent from this analysis.

At Birkdale, as at Ainsdale, there was a strong decline in area of early successional habitat. There were fringes of such habitat around management scrapes, but no discretely mapped units of this community type. The fairly extensive area of wet slack or transitions to other wetland communities (11.0 ha in 1989) did not alter appreciably. There were 81% declines in dry slack community (SD16) and 96% declines in slack transitions to other dry communities, in total amounting to a loss of 12.5 ha. It is likely that this constituted the majority of slack area not mapped in 2012, and represents a change from dry slack types to non-wetland community. Although there was little change involving mapped areas of scrub within slacks it should be noted that this only covers partial areas of scrub occurring as mosaics within slacks. Slacks which are no longer slack vegetation but completely covered in scrub, which were fairly common at Birkdale, would not have been mapped in 2012. Surveyor notes show that this was a frequent occurrence, and in many cases it was very difficult to penetrate the scrub to establish whether wetland indicator species were able to persist under the canopy or not.

4.2.2 Vegetation change revealed through analysis of repeated quadrats

Ainsdale NNR

In 2012, 30 quadrats were surveyed at Ainsdale NNR. These included 27 which were repeat quadrats, for which 21 had data from 1989 and could be used for analysis of change over time. All quadrats are listed, together with basic descriptive information in Table 9 at the end of this report. Figures 13-14 comprise maps showing the locations of all quadrats.

Changes in Ellenberg environmental and climate indicators are summarised in Table 6. There was a small but significant decline in Ellenberg light scores, suggesting a move away from open communities with light demanding species to a more closed canopy. There was a reasonably large increase in Ellenberg nutrient scores, suggesting that the site has become more eutrophic. There are a number of reasons for this. Accumulated N in soils due to atmospheric N deposition may be one reason. A second reason may be natural successional development of soils over time, leading to increases in soil organic matter content. This would be exacerbated by tendencies to taller, scrubbier vegetation which lead to increased organic matter accumulation and greater soil fertility, particularly around N-fixing species such as sea buckthorn, but also more generally under scrub species such as birch, willow and hawthorn. Surprisingly, given the change in habitat area reported in the mapping comparison, there is no significant decline in Ellenberg moisture scores. This may be due to the lack of quadrats near to where the majority of observed changes occurred, which was near the pine plantation. There were no changes in the climate indicator scores or in species richness at Ainsdale NNR.

Table 6. Ainsdale NNR. Change in environmental and climatic indicators at Ainsdale NNR between 1989 and 2012, showing mean, standard deviation (s.d.) for each year, and whether there was a significant difference over time (in bold, * <0.05, ** <0.01, * < 0.001). N = number of quadrats. See methods for description of indicators.**

N=21	Indicator	1989	2012	Significance
Mean	**Light**	**7.42**	**7.29**	*
Mean	Moisture	5.94	5.84	
Mean	pH	5.91	5.99	
Mean	**Nutrients**	**3.77**	**4.09**	**
Mean	Salinity	0.33	0.30	
Mean	JanTemp	3.61	3.60	
Mean	JulTemp	14.57	14.59	
Mean	Precipitation	1076	1074	
Mean	Spp Richness	24.14	23.33	
s.d.	Light	0.22	0.16	
s.d.	Moisture	1.32	0.90	
s.d.	pH	0.26	0.26	
s.d.	Nutrients	0.33	0.42	
s.d.	Salinity	0.15	0.18	
s.d.	JanTemp	0.08	0.03	
s.d.	JulTemp	0.12	0.07	
s.d.	Precipitation	31.77	15.60	
s.d.	Spp Richness	11.24	6.30	

Ainsdale LNR
In 2012, 4 quadrats were surveyed at Ainsdale LNR (Figure 14). These were used for analysis of change over time. All quadrats are listed, together with basic descriptive information in Table 10 at the end of this report.

Changes in Ellenberg environmental and climate indicators are summarised in Table 7. There was no significant change in environmental indicator scores, climate indicator scores or species richness.

Table 7. Ainsdale LNR. Change in environmental and climatic indicators at Ainsdale LNR between 1989 and 2012, showing mean, standard deviation (s.d.) for each year, and whether there was a significant difference over time (in bold, * <0.05, ** <0.01, * < 0.001). N = number of quadrats. See methods for description of indicators.**

N=4	Indicator	1989	2012	Significance
Mean	Light	7.47	7.30	
Mean	Moisture	7.06	6.46	
Mean	pH	6.05	6.11	
Mean	Nutrients	3.90	4.18	
Mean	Salinity	0.42	0.38	
Mean	JanTemp	3.62	3.55	
Mean	JulTemp	14.49	14.54	
Mean	Precipitation	1102	1085	
Mean	Spp Richness	19.25	23.00	
s.d.	Light	0.15	0.18	
s.d.	Moisture	1.20	1.07	
s.d.	pH	0.12	0.14	
s.d.	Nutrients	0.39	0.36	
s.d.	Salinity	0.10	0.14	
s.d.	JanTemp	0.03	0.04	
s.d.	JulTemp	0.14	0.06	
s.d.	Precipitation	34.06	13.80	
s.d.	Spp Richness	2.22	3.92	

Birkdale Hills LNR
In 2012, 18 quadrats were surveyed at Birkdale Hills LNR (Figure13). These included 16 which were repeat quadrats, for which 14 had data from 1989 and could be used for analysis of change over time. All quadrats are listed, together with basic descriptive information in Table 11 at the end of this report.

Changes in Ellenberg environmental and climate indicators are summarised in Table 8. There was a highly significant decrease in Ellenberg light scores, suggesting a shift towards taller more rank vegetation. This matches the observed increase in scrub across many of the Birkdale slacks. There was a concurrent increase in Ellenberg nutrient scores which is also consistent with greater levels of organic matter under taller vegetation and scrub. There was also a large decline in Ellenberg moisture scores, suggesting some drying out of the vegetation in the quadrats. There was no significant change in climate indicator scores or species richness.

Table 8. Birkdale Hills LNR. Change in environmental and climatic indicators at Birkdale LNR between 1989 and 2012, showing mean, standard deviation (s.d.) for each year, and whether there was a significant difference over time (in bold, * <0.05, ** <0.01, * < 0.001). N = number of quadrats. See methods for description of indicators.**

N=14	Indicator	1989	2012	Significance
Mean	**Light**	**7.51**	**7.27**	***
Mean	**Moisture**	**7.79**	**7.01**	*
Mean	pH	5.99	6.03	
Mean	**Nutrients**	**3.68**	**4.24**	**
Mean	Salinity	0.38	0.30	
Mean	JanTemp	3.62	3.60	
Mean	JulTemp	14.56	14.58	
Mean	Precipitation	1085	1079	
Mean	Spp Richness	15.64	15.86	
s.d.	Light	0.12	0.18	
s.d.	Moisture	0.81	0.88	
s.d.	pH	0.24	0.23	
s.d.	Nutrients	0.29	0.45	
s.d.	Salinity	0.14	0.19	
s.d.	JanTemp	0.04	0.05	
s.d.	JulTemp	0.11	0.08	
s.d.	Precipitation	31.75	19.11	
s.d.	Spp Richness	4.34	5.59	

4.2.3 Analysis of soils data

Simple physical data from soil cores are shown in the Figures below, grouped by broad vegetation type.

Ainsdale NNR

Soil pH (Figure 7) was highest in the wet calcareous slacks, where the soil is well buffered by the groundwater. Soil pH was below 7, and approaching the level of pH 6.5 at which one would expect decalcification. It is likely that surface soil pH is already below 6.5, since these are measures of pH of the full soil profile to 15 cm.

Organic matter contents (Figure 8) are reasonably high in the slack vegetation types, around 6%, but are much lower in the dry habitats, around 2%.

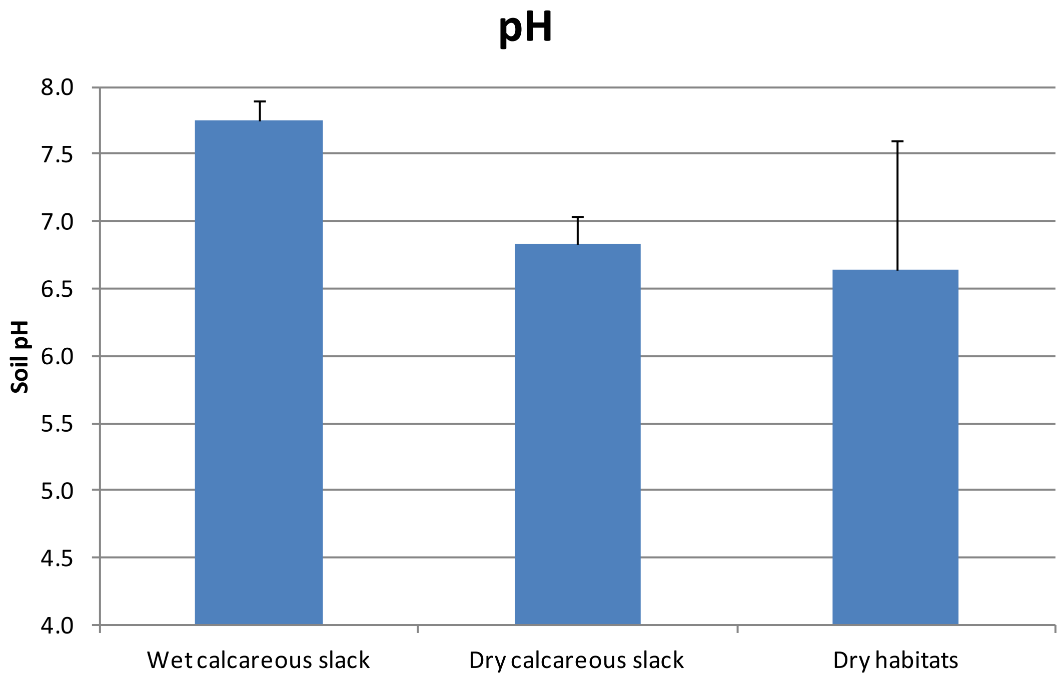

Figure 7. Ainsdale NNR. Soil pH, by broad vegetation type.

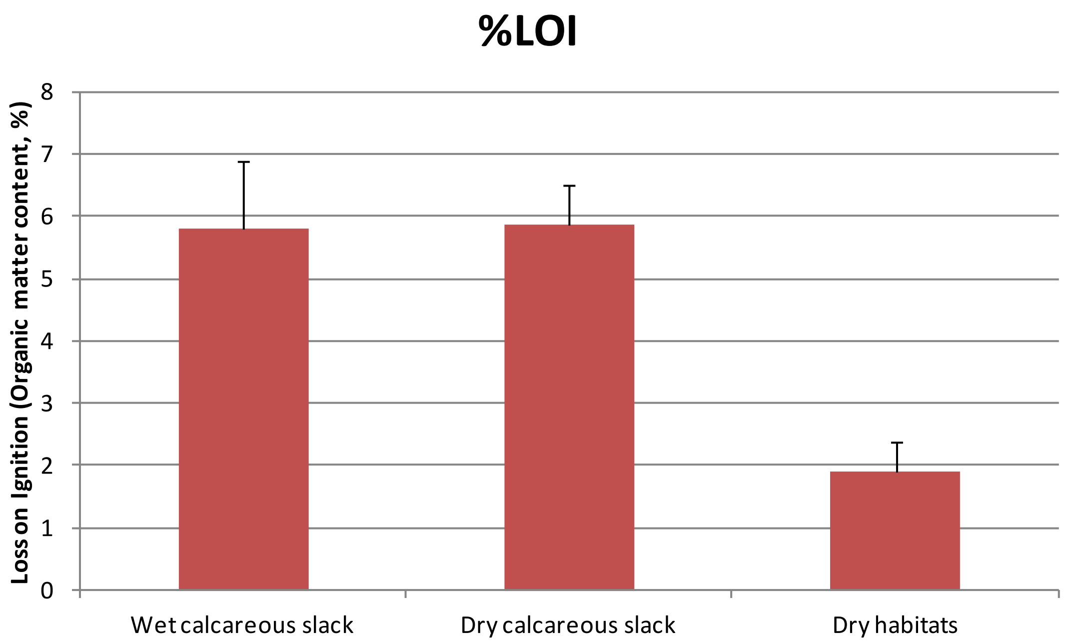

Figure 8. Ainsdale NNR. Organic matter (as Loss On Ignition, %), by broad vegetation type.

Ainsdale LNR
Soil pH (Figure 9) was high in all habitats, above 7.5, suggesting relatively young soils in these four quadrats, with no decalcification.

Organic matter contents (Figure 10) were high in the wet slack vegetation type, around 14%, but were rather lower in the drier habitats, under 4%.

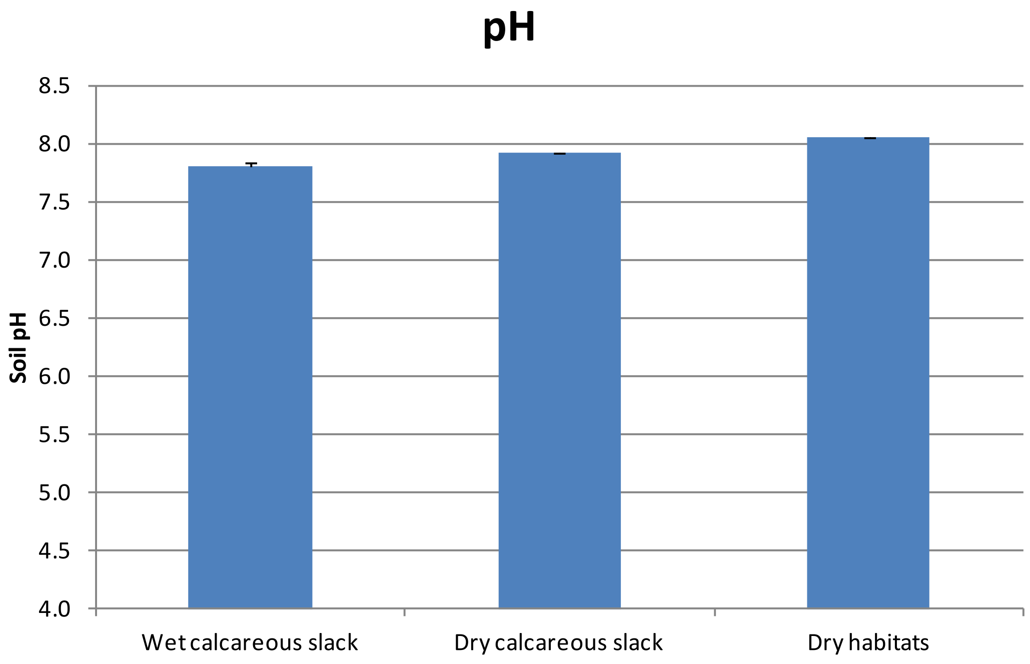

Figure 9. Ainsdale LNR. Soil pH, by broad vegetation type.

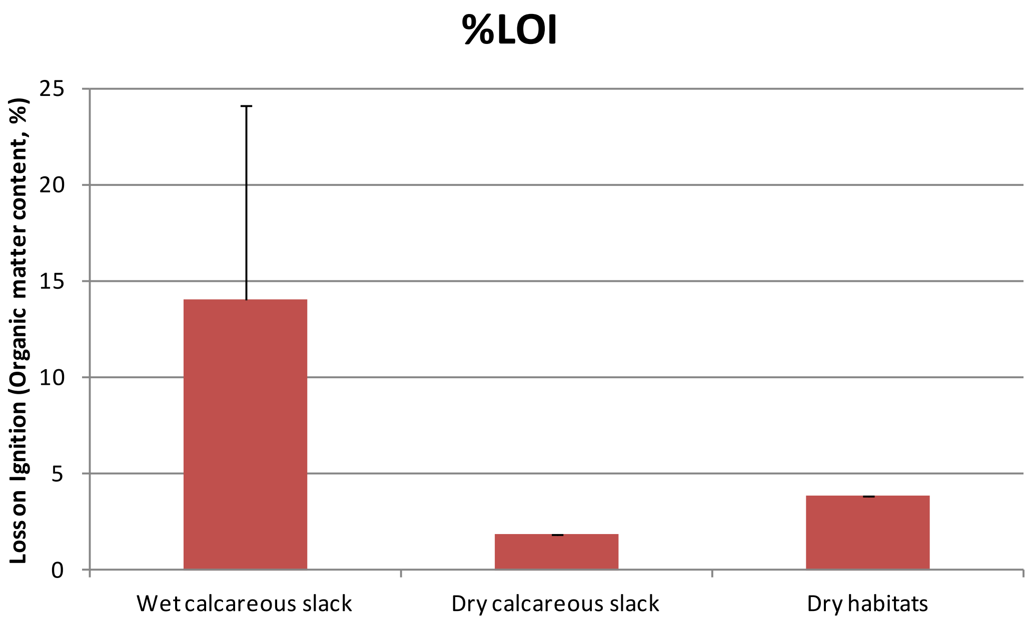

Figure 10. Ainsdale LNR. Organic matter (as Loss On Ignition, %), by broad vegetation type.

Birkdale LNR
Soil pH (Figure 11) was reasonably high in all habitats, averaging above 7.0, however some individual quadrats had pH values as low as pH 6.

Organic matter content (Figure 12) was high in the wet slack vegetation type, around 8%, but rather lower in the dry habitats and other wetlands, around 4-5%.

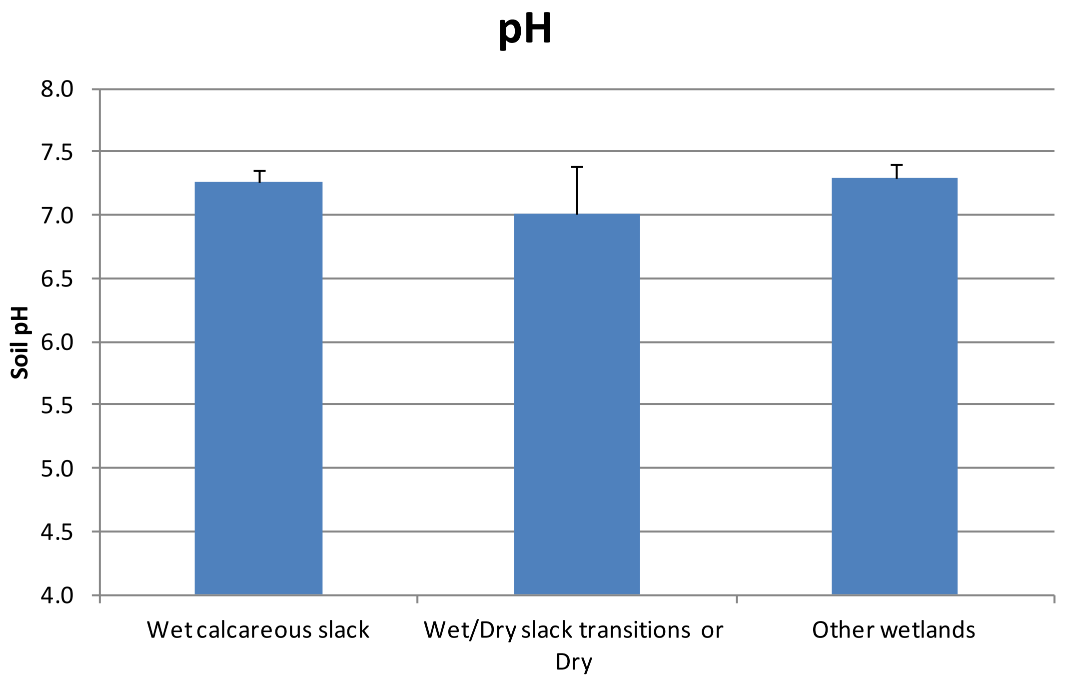

Figure 11. Birkdale LNR. Soil pH, by broad vegetation type.

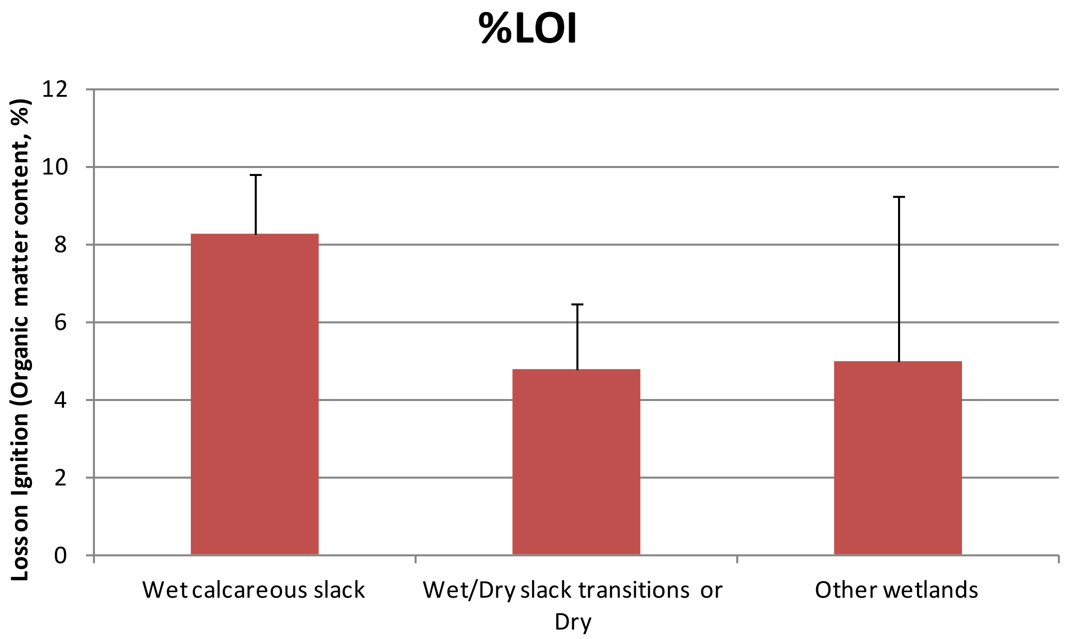

Figure 12. Birkdale LNR. Organic matter (as Loss On Ignition, %), by broad vegetation type.

4.3 Discussion (in context of hydrological & other key local drivers)

Across the sites, at Ainsdale NNR and Birkdale where there were sufficient quadrats for a robust analysis, there was an increase in Ellenberg nutrient scores and a decrease in Ellenberg light scores. This is consistent with a move towards taller vegetation and more mature soils.

Ellenberg moisture scores declined only at Birkdale, which could potentially be linked to scrub development, and was the site which showed the largest decline in wetland area. The analysis of mapped area suggests that the very wet sites at Birkdale retained roughly the same area overall, but there was a large decline in the drier slack types, and it may be these changes which are represented in the quadrat analysis. The lack of decline in Ellenberg moisture scores at Ainsdale NNR where slacks adjacent to the forest clearly no longer support slack vegetation was a surprise. This is in contrast to the area change analysis which showed a strong decline in area of wet slacks in favour of drier habitats, which no longer supported slack vegetation and were therefore not mapped in 2012. The changes seen over the full time period 1988 – 2012 are consistent with those revealed in the Gateley and Michell (2004) survey. Analysis of change across the full extent of dune habitats within the wider Sefton Coast dune system over the period 1988-2004 (Sefton Coast Partnership, 2006) suggested an increase in dry slack vegetation at the expense of wet slack vegetation, with a net decline of 37% in wet dune habitat (SD15) and an increase in the drier slack vegetation (SD16) of 26%. Total slack area however only declined by 8%, compared with the decline in wetland area of 39 % observed in this study for combined area of wetlands surveyed at Ainsdale NNR, Ainsdale LNR and Birkdale LNR. Further analysis of the data, including change analysis of the 2004 data for the polygons surveyed in this study, and incorporating information on spatial context, hydrological data, and management history at the sites, and other recorded vegetation change (e.g. Smith 2006), would be required to understand these trends better.

Soil characteristics across the sites showed that pH values were moderate to high at Ainsdale LNR and Birkdale, but low in the dry slacks and dry habitats at Ainsdale NNR. Organic matter contents were generally high in the wet slack types and lower in the dry slacks and dry vegetation communities. Values above 6% in slack soils are typical of slacks over 60 years old (Jones et al. 2008), and the values recorded here are higher than those for a range of 9 west coast UK dune systems (Jones et al. 2010).

5 Implications for management

- At all three sites, increased intensity and scale of management interventions are probably required to provide a counterbalance to the trend towards more closed vegetation with higher nutrient status.

- Further work is required, including analysis of other local datasets, combined analysis of vegetation and hydrological change, and an understanding of the management history of the three sites, to better understand the spatial pattern to trends observed here, and to explain why they might be occurring.

- Monitoring of water levels should be continued and future surveys should be sure to include quadrats co-located with dipwells, so that the impact of water table patterns on vegetation communities can be properly assessed.

- Installation of dipwells and subsequent regular monitoring would be extremely useful at Birkdale Hills LNR, in order to help explain previous changes and monitor ongoing changes including proposed changes to the management regime. A number of locations should be monitored to capture the wide range of changes, and should include locations seaward and landward of the coastal road, and north and south of the site to capture changes in management around the wetter and the drier scrubbed-over slacks, and potential effects of the expanding green beach on the hydrological profile.

6 References

Atkins. 2004. Ainsdale Sand Dunes National Nature Reserve: Environmental Impact Assessment of options for management of seaward areas. Environmental statement. W S Atkins Consultants Ltd, Warrington, UK.

Clarke, D. 1980. The groundwater balance of a coastal sand dune system. Unpub. PhD thesis, University of Liverpool, UK.

Clarke, D. and Pegg, R.K. 1993. Hydrological investigations in the Ainsdale Sand Dunes National Nature Reserve. In, Atkinson, David and Houston, John (eds.) *Sand Dunes of the Sefton Coast: Proceedings of the Sefton Coast Research Seminar, Liverpool, 31 May 1991. Sefton Coast Research Seminar* Liverpool, GB, National Museums & Galleries on Merseyside, 55-58.

Clarke, D. and Sanitwong Na A. 2007. A probabilistic assessment of future coastal groundwater levels in a dune system in England. Int. Conf. Management and Restoration of Coastal Dunes, Santander, Spain 03 - 05 Oct 2007.

Clarke, D. and Sanitwong Na A. 2010. Predicted effects of climate change, vegetation and tree cover on dune slack habitats at Ainsdale on the Sefton Coast, UK. Journal of Coastal Conservation 14(2): 115–125.

Clarke, D. and Stratford, C. 2010. Climate change and the eco-hydrological implications for shallow freshwater systems in un-drained coastal areas. British Hydrological Society Third International Symposium. Newcastle 2010.

Curreli, A., Wallace, H., Freeman, C., Hollingham, M., Stratford, C., Johnson, H., Jones, L. 2013. Eco-hydrological requirements of dune slack vegetation and the implications of climate change. Science of the Total Environment 443, 910-919.

Edmondson, S.E., Gateley, P.S. and Nissenbaum, D.A. 1989. *National sand dune vegetation survey. Sefron Coast, Merseyside. Coastwide Seaforth-Southport.* Peterborough: Joint Nature Conservation Committee [Associated reports include: Division 6 Ainsdale Sand Dunes National Nature Reserve; Division 7 Ainsdale Local Nature Reserve and outlying dunes; and Division 8 Birkdale Local Nature Reserve, Royal Birkdale Golf Club, Hillside Golf Club, Southport & Ainsdale Golf Club]

Gateley, P.S. and Michell, P.E. 2004. Sand Dune Survey of the Sefton Coast. Report by TEP, Warrington to Sefton Metropolitan Borough Council.

JNCC. 2007. Second report by the UK under Article 17 on the Implementation of the Habitats Directive from January 2001 to December 2006. Joint Nature Conservation Committee, Peterborough (www.jncc.gov.uk/article17)

Jones, M.L.M., Sowerby, A., Williams, D.L., Jones, R.E. 2008. Factors controlling soil development in sand dunes: evidence from a coastal dune soil chronosequence. *Plant and Soil* **307** (1-2): 219-234.

Jones, M.L.M., Sowerby, A., Rhind, P.M. 2010. Factors affecting vegetation establishment and development in a sand dune chronosequence at Newborough Warren, North Wales. J. Coastal Conservation 14 (2), 127-137.

Jones, M.L.M., Angus, S., Cooper, A., Doody, P., Everard, M., Garbutt, A., Gilchrist, P., Hansom, G., Nicholls, R., Pye, K., Ravenscroft, N., Rees, S., Rhind, P. & Whitehouse, A. 2011. Coastal margins [chapter 11]. In: UK National Ecosystem Assessment. Understanding nature's value to society. Technical Report. Cambridge, UNEP-WCMC, 411-457.

Radley, G.P. 1994. *Sand Dune Survey of Great Britain: A national inventory*. *Part 1: England*. JNCC.

Ranwell, D. S. 1959. Newborough Warren Anglesey 1. The dune system and dune slack habitat. Journal of Ecology, 47, 571 –601.

Rodwell, J.S., (Ed). 2000. British plant communities. Maritime communities and vegetation of open habitats. Cambridge University Press.

Rodwell, J.S. 2006. *National Vegetation Classification: Users' handbook*, JNCC.

Savidge, J. P., Heywood, V. H. & Gordon, V. 1963. Travis's Flora of South Lancashire.Liverpool Botanical Society, Liverpool.

Sefton Coast Partnership. 2006. Sefton Coast Nature Conservation Strategy and Biodiversity Delivery Plan. Issues Report for consultation. Prepared by the Sefton Coast Partnership Nature Conservation Task Group, February 2006. Available online http://www.seftoncoast.org.uk/pdf/natconsissues.pdf [Accessed December 2013].

Smith, A.J.E. 2004. *The Moss Flora of Britain and Ireland, 2nd ed*, Cambridge University Press, Cambridge.

Smith, P.H. 2006. Changes in the floristic composition of sand-dune slacks over a twenty-year period. Watsonia 26: 41-49.

Stace, C. 2010. *New Flora of the British Isles, 3rd ed*, Cambridge University Press, Cambridge.

Steward, H. 2001. Quality of Coastal Towns. Merseyside Coast Visitor Research 2000. Formby Council Offices, Formby.

Stratford, C.J., Hughes, A., Roberts, J. and Robins, N.S. 2006. Review of Hydrological Reports for Newborough Warren NNR, Anglesey. Report to the Countryside Council for Wales. 40pp.

Stratford, C., Jones, L., Robins, N., Mountford, O., Amy, S., Peyton, J., Hulmes, L. Hulmes S., Jones, F., Redhead, J., Dean, H. 2013a. Hydro-Ecological survey and analysis of vegetation change in English dune slack habitats. Report to Natural England, August 2013.

Stratford, C., Robins, N.S., Clarke, D., Jones, L. & Weaver, G. 2013b. Hydroecology of fragile coastal dune slacks on the west coast of England and Wales. Ecohydrology 6 (1), 162-171.

7 Quadrat information

Table 9. Ainsdale NNR. List of quadrats surveyed, with associated environmental data. Quadrats coded Q represent 1989 quadrat codes. OM (organic matter) = organic horizon thickness. LOI% (Loss On Ignition) = % organic matter content.

Quad Code	x	y	ANGLE SLOPE (degrees)	ASPECT (degrees)	Veg Height (cm)	OM thickness (cm)	Soil pH	LOI %	Quad Type
Q1	330377	411350	20	45	28.8	2	7.92	1.28	RepeatQuadrat
Q13	330165	411528	0	0	27.6	0	8.17	0.68	RepeatQuadrat
Q14	330114	411567	0	0	15.6	8	7.94	7.46	RepeatQuadrat
Q15	330046	411533	0	0	3	1.5	8.2	1.10	RepeatQuadrat
Q17	329967	411630	0	0	37.4	10	7.23	8.20	RepeatQuadrat
Q19	329946	411556	0	0	38.8	5	7.88	4.02	RepeatQuadrat
Q22	329864	411456	15	270	39.2	6	5.79	4.17	RepeatQuadrat
Q23	329905	411486	0	0	32	7	7.03	3.38	RepeatQuadrat
Q29	329898	411407	0	0	21.2	6	6.98	2.17	RepeatQuadrat
Q3	330300	411409	0	0	13.6	4	7.5	3.39	RepeatQuadrat
Q36	329848	411692	15	270	32.8	5	7.5	4.11	RepeatQuadrat
Q38	329686	411751	0	0	39.4	10	6.5	8.39	RepeatQuadrat
Q39	329602	411773	10	45	8.2	14	7.74	8.82	RepeatQuadrat
Q4	330313	411389	5	180	3.8	1.5	7.81	1.04	RepeatQuadrat
Q41	329406	411607	0	0	18.8	12	7.84	7.94	RepeatQuadrat
Q47	329628	411501	0	0	15.4	9	6.67	10.39	RepeatQuadrat
Q48	329619	411432	0	0	17.6	7	7.01	10.27	RepeatQuadrat
Q5	330212	411451	15	135		3	7.24	2.42	RepeatQuadrat
Q53	329321	411325	0	0	3.6	9	7.8	4.09	RepeatQuadrat
Q54	329356	411330	0	0	8	9	7.48	6.39	RepeatQuadrat
Q63	329584	410997	0	0	7.4	6	5.9	5.17	RepeatQuadrat
Q64	328486	410627	0	0	10.2	0.5	7.45	4.36	RepeatQuadrat

Quad Code	x	y	ANGLE SLOPE (degrees)	ASPECT (degrees)	Veg Height (cm)	OM thickness (cm)	Soil pH	LOI %	Quad Type
Q66	329422	411141	0	0	11.4	6	6.27	5.86	RepeatQuadrat
Q69	329522	410845	2	45	13.2	5	5.72	3.66	RepeatQuadrat
Q76	328784	410614	0	0	11.6	11	8.23	8.96	RepeatQuadrat
Q82	329141	410561	2	45	85	5	6.31	3.65	RepeatQuadrat
Q85	329059	410440	1	0	5				RepeatQuadrat
N1	328359	410413	1	180	35.2	0	7.36	3.28	NewQuadrat
N2	328427	410516	0	0	6.8	0	7.6	3.41	NewQuadrat
N3	328553	410716	2	180	4.6	0	7.7	5.56	NewQuadrat

Table 10. Ainsdale LNR. List of quadrats surveyed, with associated environmental data. Quadrats coded Q represent 1989 quadrat codes. OM (organic matter) = organic horizon thickness. LOI% (Loss On Ignition) = % organic matter content.

Quad Code	x	y	ANGLE SLOPE (degrees)	ASPECT (degrees)	Veg Height (cm)	OM thickness (cm)	Soil pH	LOI %	Quad Type
Q1	328785	411184	0	0	20.2	0	7.92	1.87	RepeatQuadrat
Q3	329628	412402	0	0	13.6	4	7.84	3.94	RepeatQuadrat
Q4	329743	411847	0	0	15.6	11	7.78	24.06	RepeatQuadrat
Q5	330172	411685	0	0	34.6	1.5	8.05	3.84	RepeatQuadrat

Table 11. Birkdale Hills LNR. List of quadrats surveyed at Birkdale LNR, with associated environmental data. Quadrats coded Q represent 1989 quadrat codes. Q20b is a second possible (but less likely) location for 1989 quadrat Q20. OM (organic matter) = organic horizon thickness. LOI% (Loss On Ignition) = % organic matter content.

Quad Code	x	y	ANGLE SLOPE (degrees)	ASPECT (degrees)	Veg Height (cm)	OM thickness (cm)	Soil pH	LOI %	Quad Type
Q13	330020	413110	0	0	23.8	2	7.36	2.76	RepeatQuadrat
Q15	330302	413186	0	0	60.6	13	7.14	8.79	RepeatQuadrat
Q16	330308	413142	45	225	39.6	0.5	7.74	2.53	RepeatQuadrat
Q17	330556	412966	0	0	63	1	7.55	4.28	RepeatQuadrat
Q19	330841	413502	0	0	104	12	7.6	5.48	RepeatQuadrat
Q20	330595	413511	2	180	64	12	7.67	6.01	RepeatQuadrat
Q20b	330614	413504	0	0	76.6	12	7.04	8.62	RepeatQuadrat
Q21	330726	413477	0	0	29.8	9	7	6.82	RepeatQuadrat
Q22	330345	413319	0	0	41.4	8	7.38	10.60	RepeatQuadrat
Q23	330590	413740	0	0	19.8	11	7.26	9.00	RepeatQuadrat
Q29	330661	413787	0	0	20.4	12	7.2	9.38	RepeatQuadrat
Q31	330926	414521	0	0	46.4	4	7.55	4.34	RepeatQuadrat
Q32	330935	414515	0	0	52	13	6.61	8.17	RepeatQuadrat
Q36	331072	415074	2	60	37.2	14	6.84	23.32	RepeatQuadrat
Q7	330901	413353	45	135	14.2	0	5.94	1.53	RepeatQuadrat
Q9	329997	412966	0	0	35	9	7.3	6.55	RepeatQuadrat
N1	330185	413775	0	0	46.4	0	7.4	0.67	NewQuadrat
N2	331594	416066	0	0	49	9	7.2	9.26	NewQuadrat

Figure 13. Locations of quadrats surveyed at Birkdale Hills LNR. © NERC (CEH) 2013, © Next Perspectives.

Figure 14. Locations of quadrats surveyed at Ainsdale NNR & Ainsdale LNR. © NERC (CEH) 2013, © Next Perspectives.

8 Survey maps

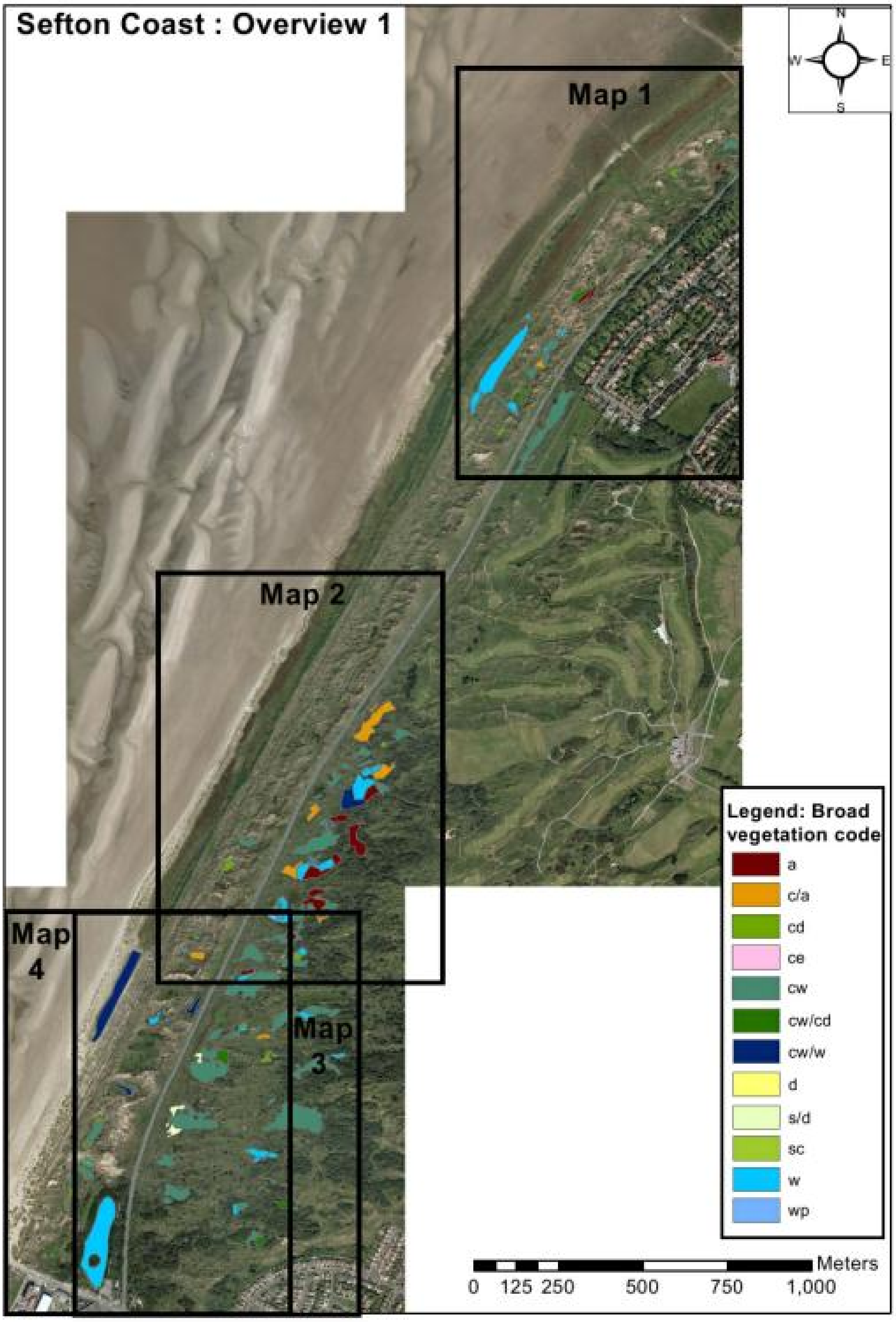

Figure 15. Birkdale Hills LNR. Overview of NVC communities mapped during 2012 vegetation survey, with reference to areas covered by maps 1-4 (Figures 16-19). Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

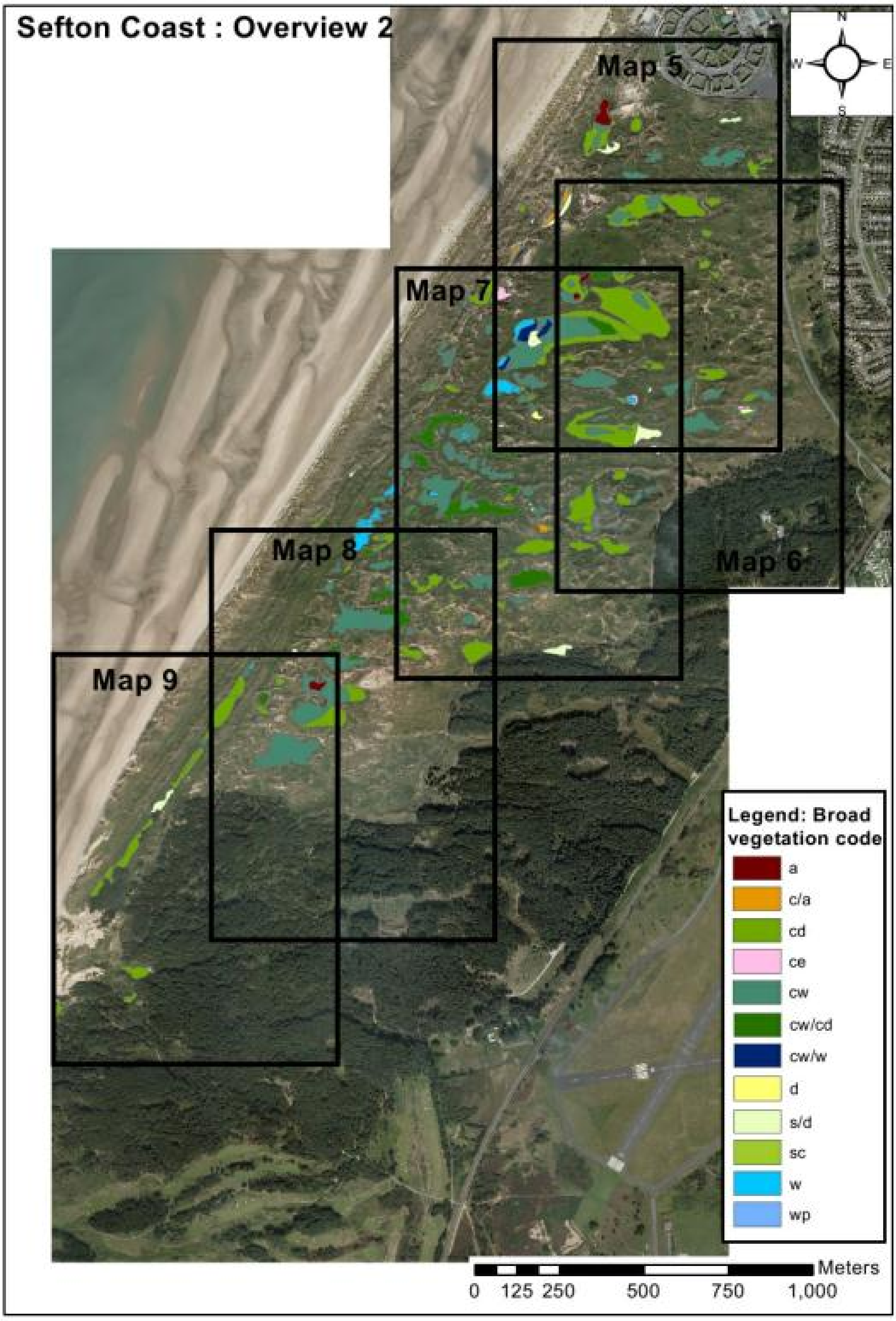

Figure 16. Ainsdale Sands LNR. Overview of NVC communities mapped during the 2012 vegetation survey, with reference to areas covered by maps 4-10 (Figures 19-24). Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

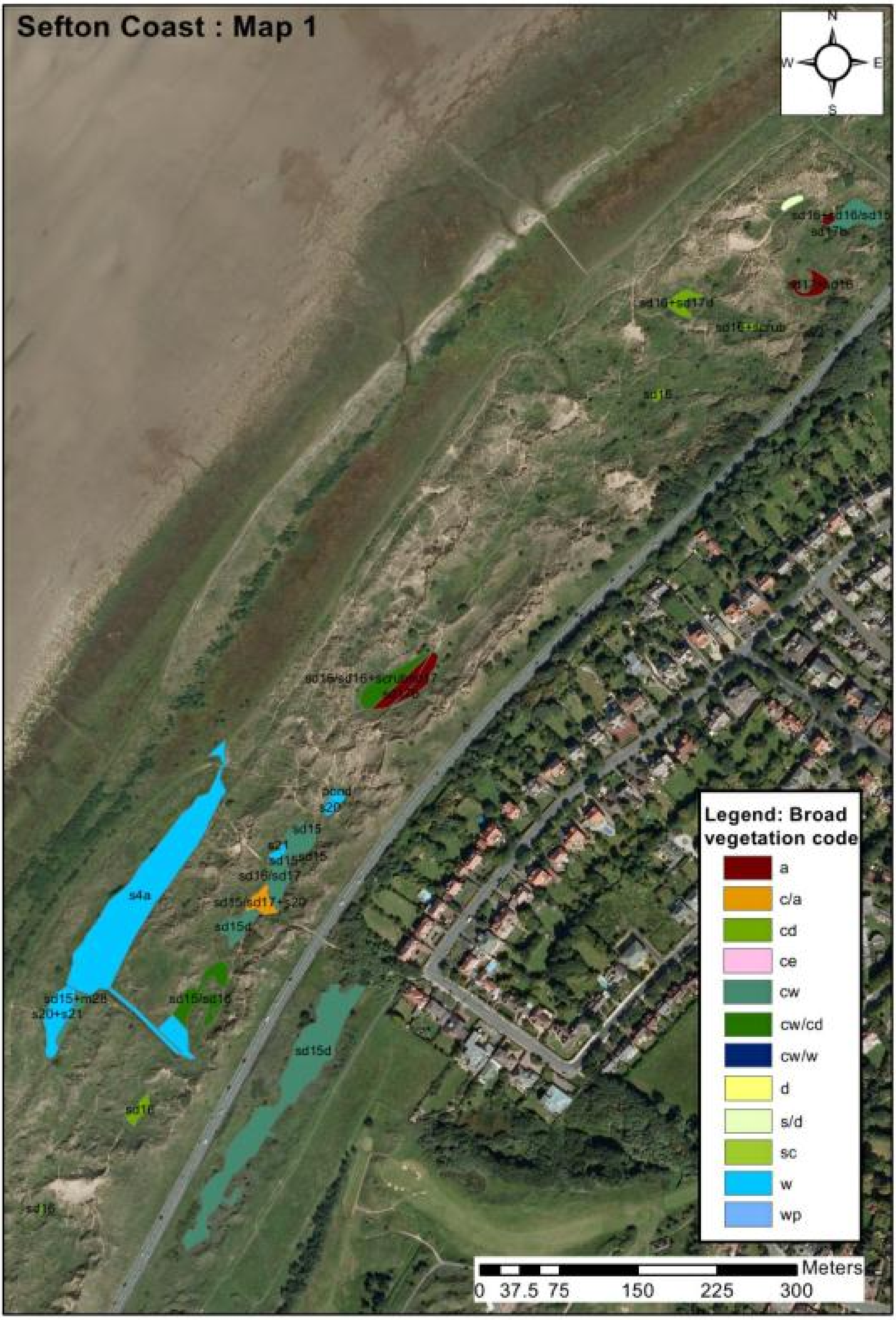

Figure 17. Sefton Coast Map 1; Birkdale Hills LNR (north). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

Figure 18. Sefton Coast Map 2; Birkdale Hills LNR (central). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

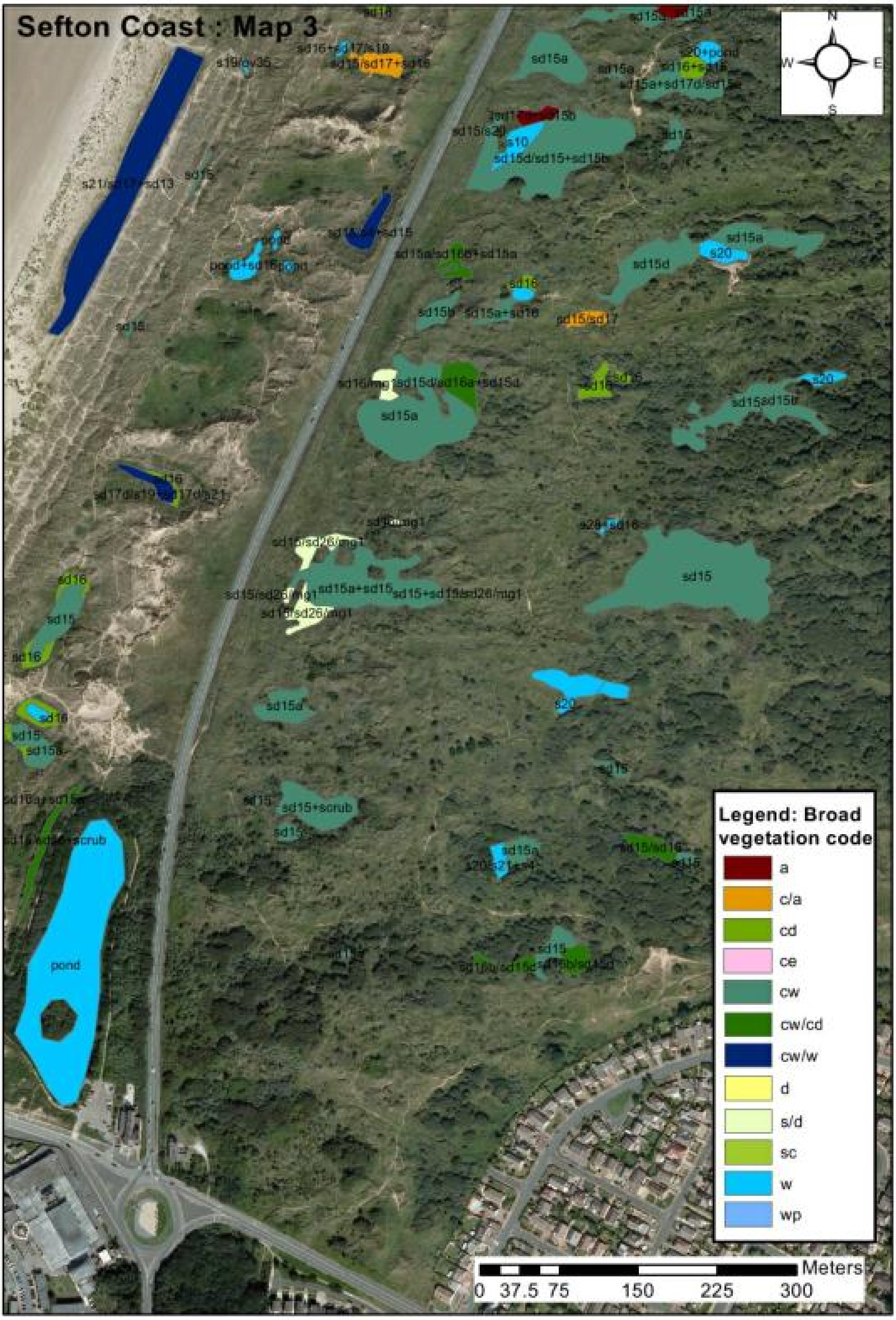

Figure 19. Sefton Coast Map 3; Birkdale Hills LNR (south east). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

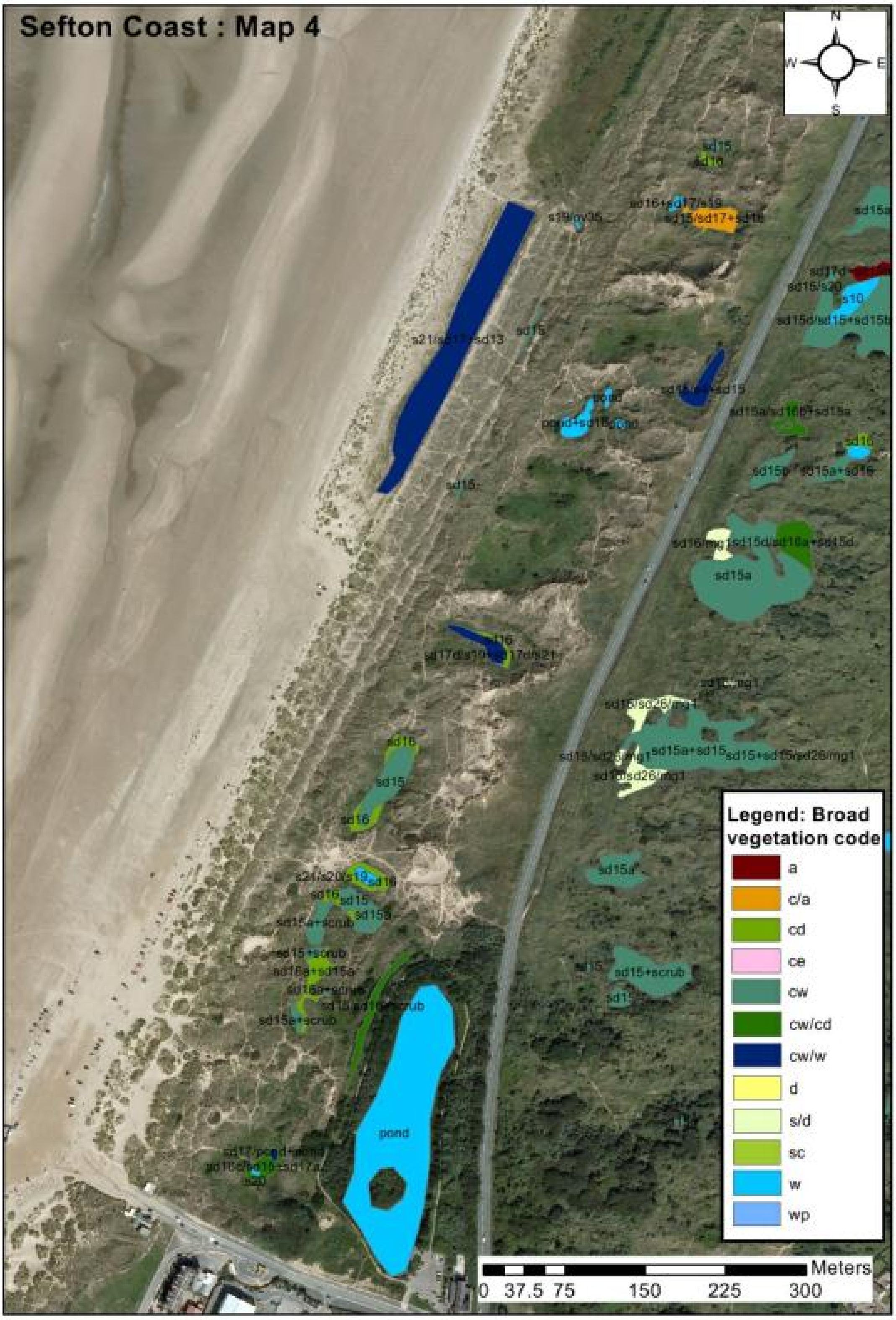

Figure 20. Sefton Coast Map 4; Birkdale Hills LNR (south west). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

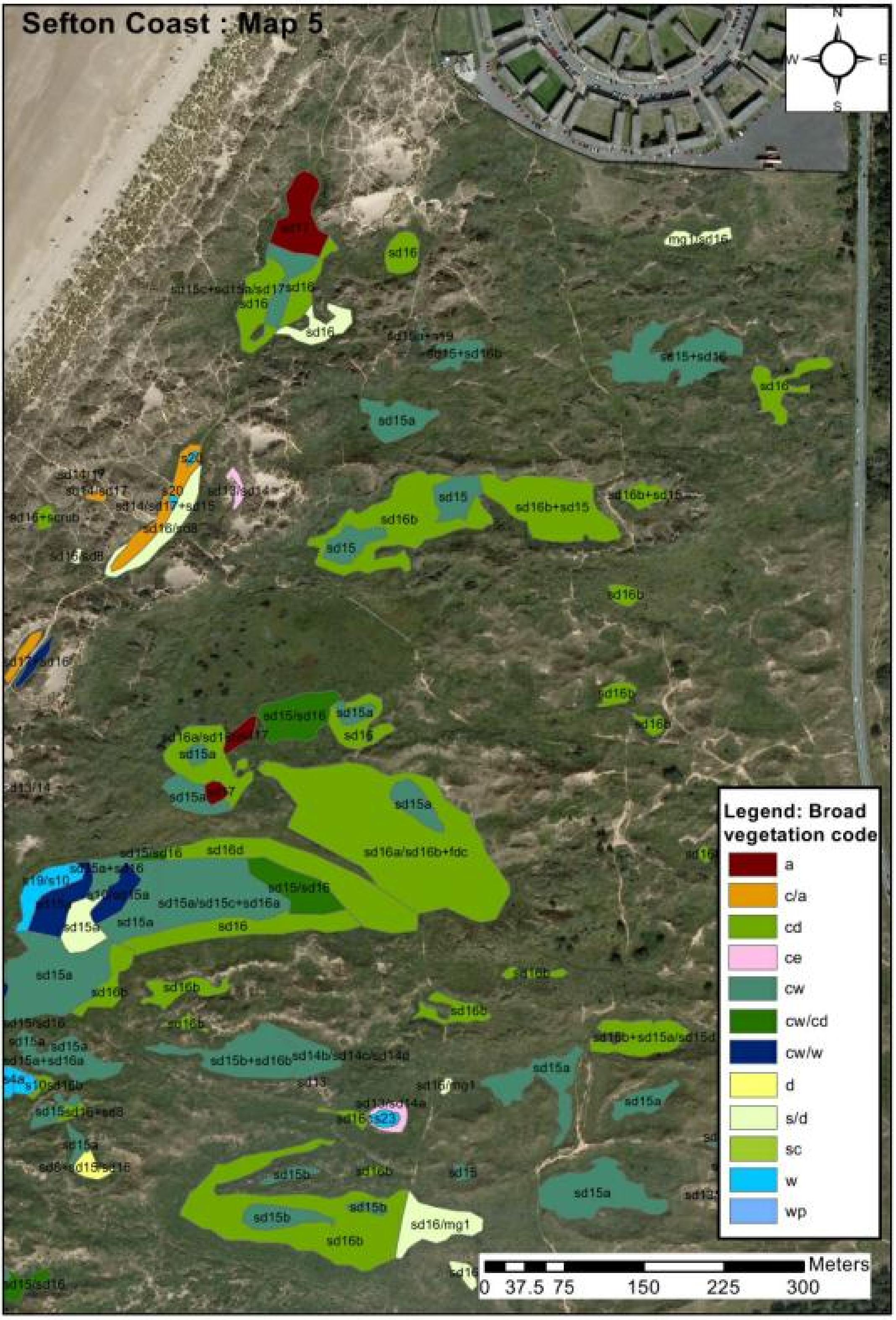

Figure 21. Sefton Coast Map 5; Ainsdale HIlls LNR & Ainsdale NNR (north). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

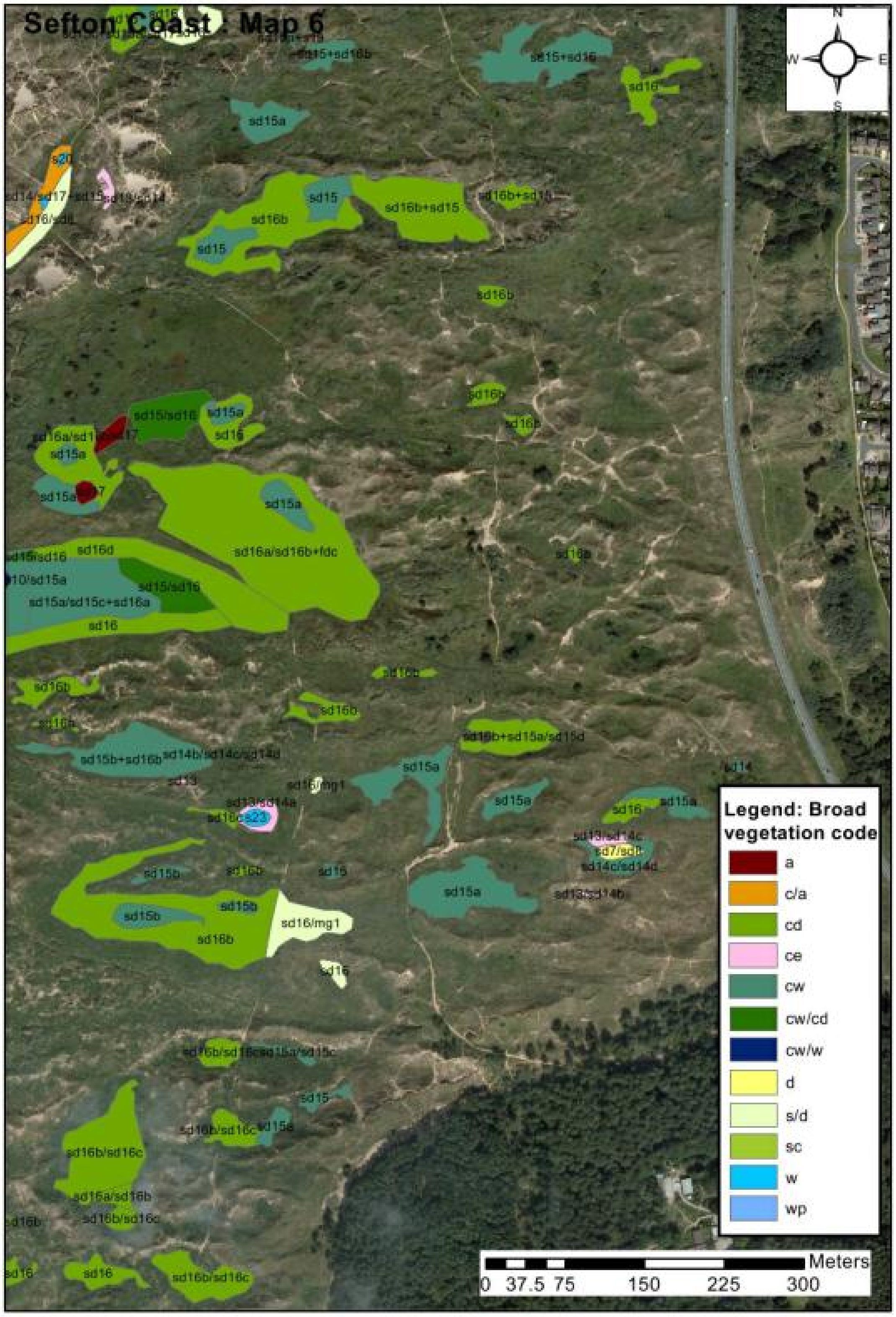

Figure 22. Sefton Coast Map 6; Ainsdale N. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

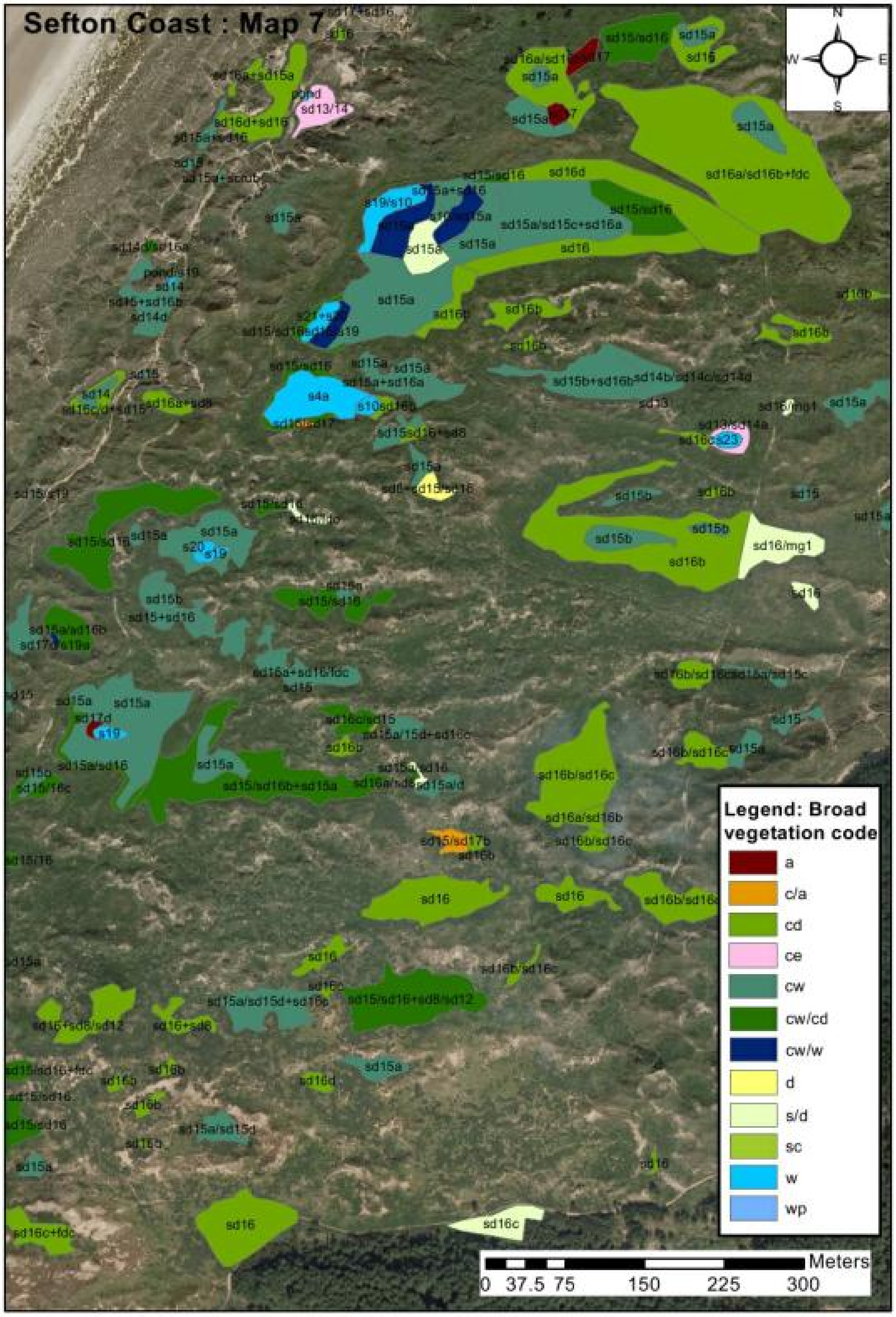

Figure 23. Sefton Coast Map 7; Ainsdale NNR. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

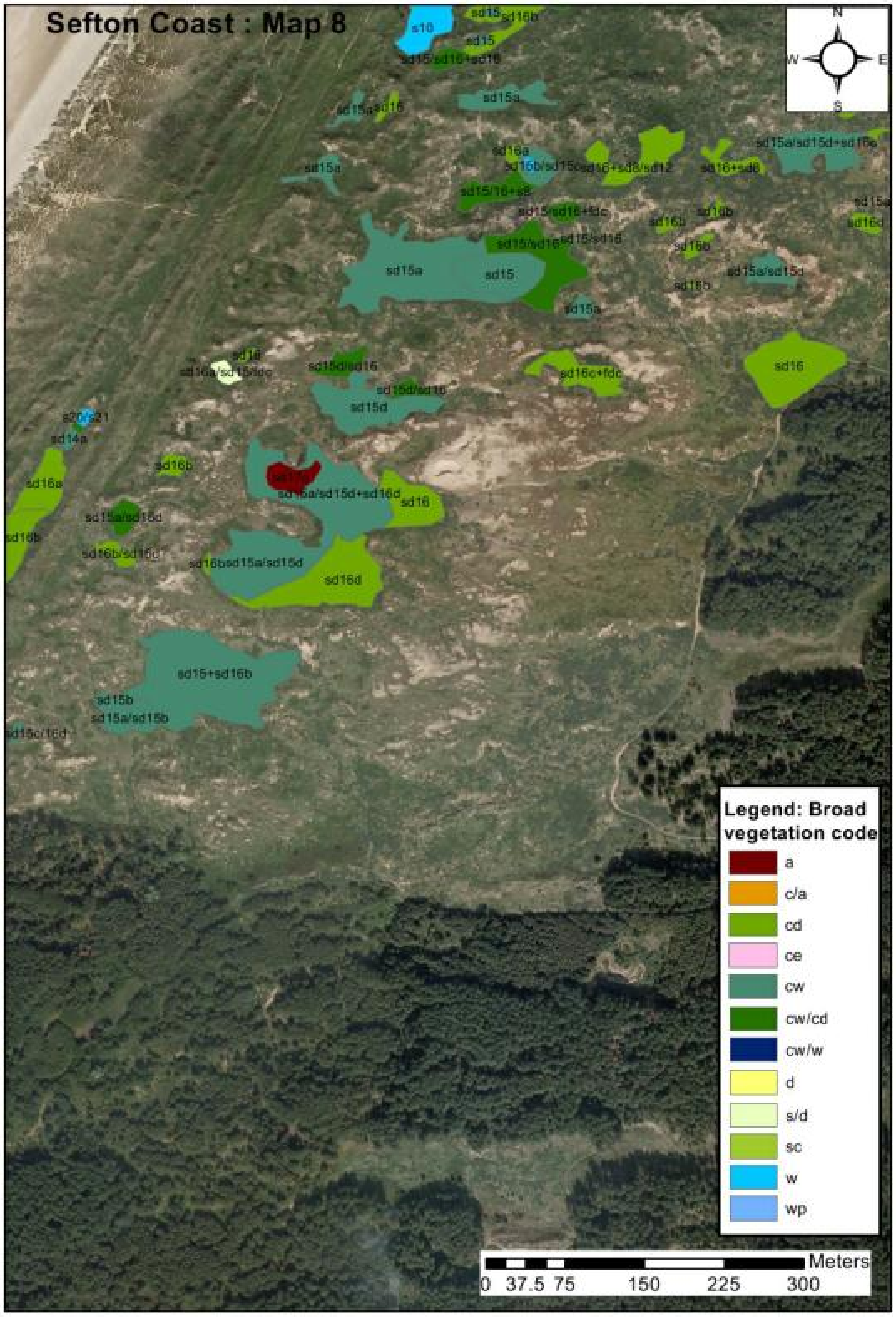

Figure 24. Sefton Coast Map 8; Ainsdale NNR. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.

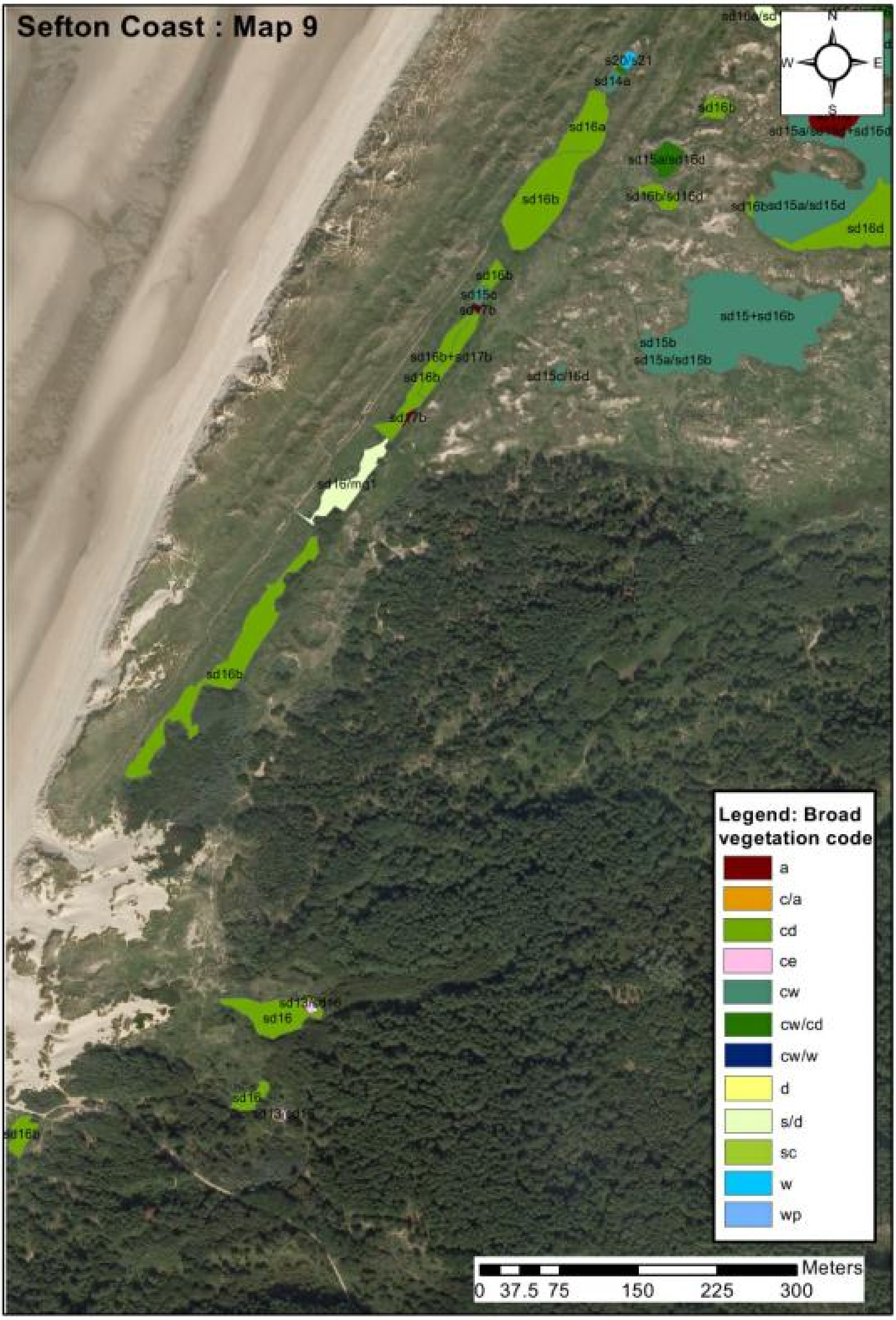

Figure 25. Sefton Coast Map 9; Ainsdale NNR (south). NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 3. © NERC (CEH) 2013, © Next Perspectives.