

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

Annex 1 - Site report for Braunton Burrows

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## Executive Summary

- Dune wetlands at Braunton Burrows 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 1990. Some vegetation quadrats from the 1990 survey were relocated and re-surveyed, and soil samples taken. Hydrological interpretation is provided and hydrological studies are ongoing at this site.
- An extensive (1966 onwards) hydrological record exists at Braunton and this provides an extremely valuable dataset against which to assess current water table trends and variability.
- Analysis of rainfall and groundwater measurements shows a decline in both rainfall and groundwater level from 1966 to 2007. Rainfall no doubt plays a significant role in driving groundwater level. Ongoing studies aim to quantify the impact of land cover, looking in particular at interception and transpiration by different types of vegetation.
- There was a net 27% decrease in area of wetland habitats between 1990 and 2012. This is likely due to a shift from wetter to drier slack communities, and a shift from dry slack communities to dry grassland and scrub.
- Fifty three vegetation quadrats were re-surveyed. Analysis shows a significant decrease in Ellenberg Light scores, suggesting a shift towards taller, less open vegetation; and a decrease in Ellenberg Moisture scores, suggesting a shift from wetter to drier species composition in these quadrats. Species richness increased significantly, but whether this change in species composition is desirable from a conservation perspective is not known.
- Soils are highly calcareous, and are not decalcified. Soil organic matter contents are high, typically > 6% LOI (Loss on Ignition).
- Further research should be undertaken to better understand the reasons for declining water tables and the potential impacts on the vegetation at this site.
- Site management should consider creation of larger areas of early successional slack and wetland habitat in the western half of the site. It should also consider reinstatement of natural dune dynamics in some areas to facilitate natural creation of secondary dune slacks.

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# **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 (2012), repeating where possible mapping and survey work conducted as part of the Sand Dune Survey of Great Britain (SDGB) (Radley 1994). Work conducted at Braunton Burrows 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

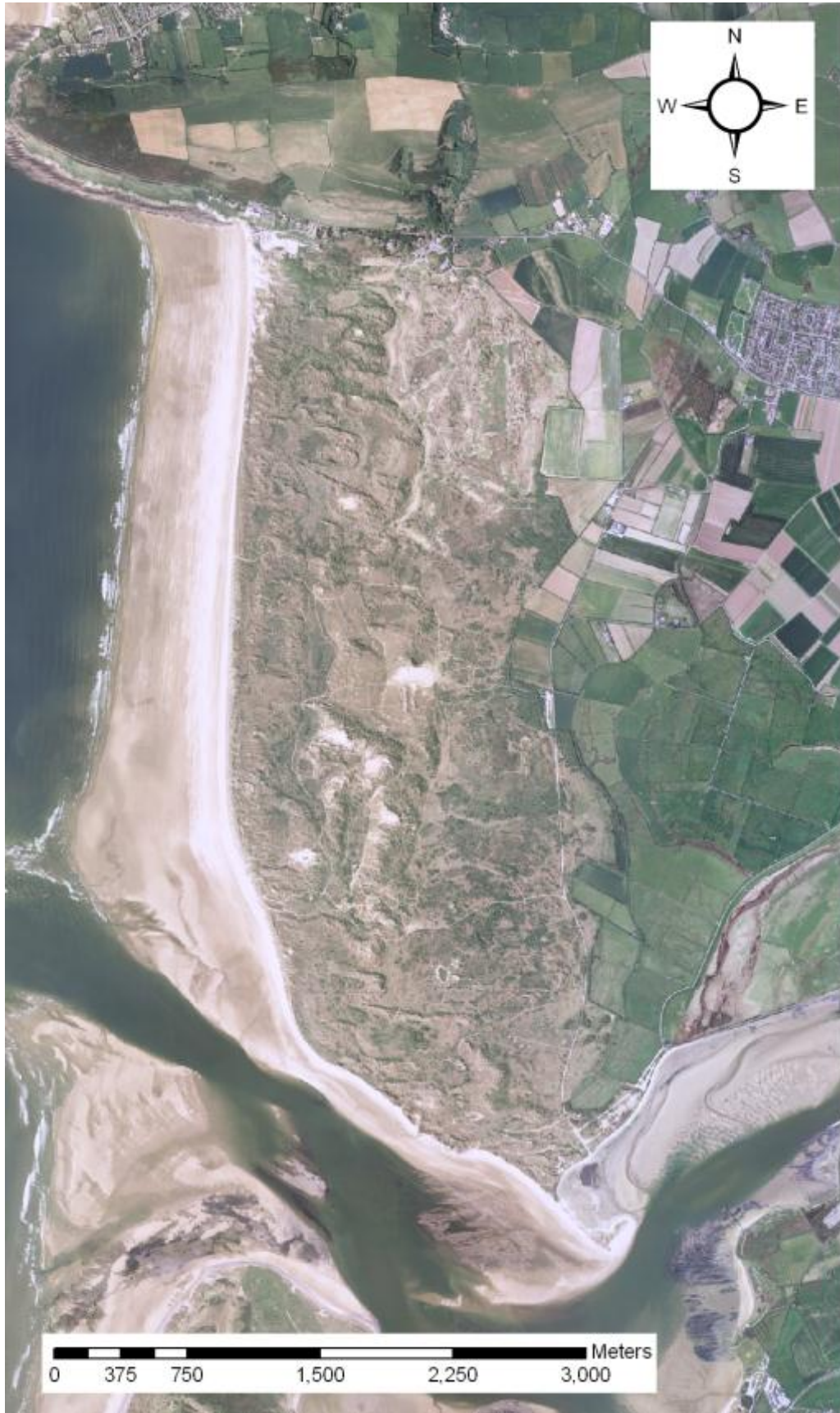
Braunton Burrows (Figure 1) is a hindshore dune system near Bideford in North Devon. Braunton Burrows covers an area some 7 km by 2 km with the long side adjacent to the sea coast (Figure 2). The sand overlies a clay horizon, possibly of lacustrine origin, which is situated over raised beach gravels (Geological Map 292). The area comprises a series of north to south oriented dunes and slacks shaped by the prevailing on-shore winds. It has no significant external influences, other than an apparent long-term decline in rainfall (Davy et al., 2010), and so provides a valuable opportunity to monitor a coastal dune area that is not being affected by anthropogenic or coastal processes.



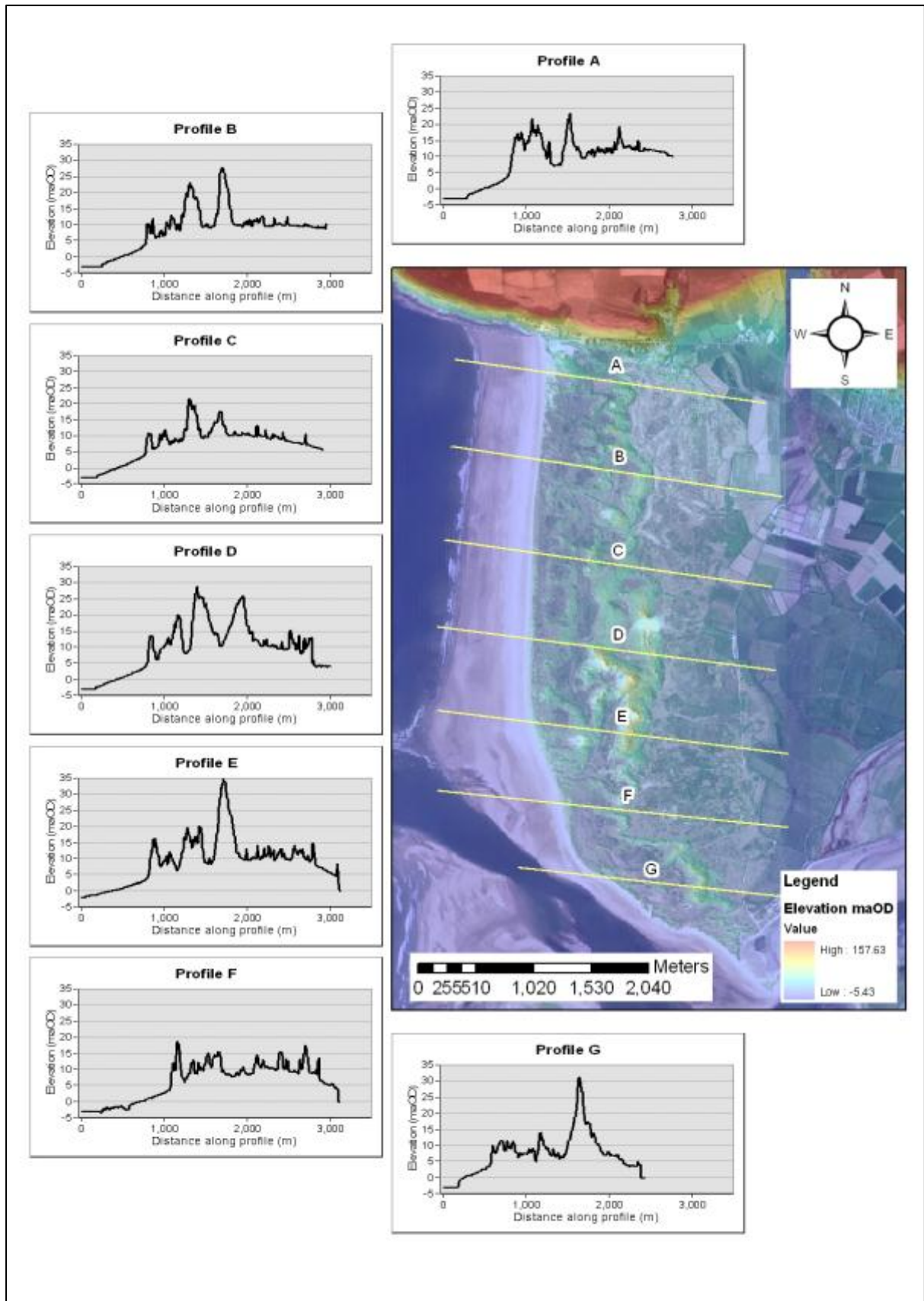
**Figure 1. The location of Braunton Burrows in the UK.**

The frontal dunes rise to an elevation of between 10 and 15 m AOD. Behind this lies a continuous belt of slacks and further inland, the dunes rise with a maximum dune ridge height of >30 mAOD in some places (Figure 3). Beyond lies a broad, but poorly defined, belt of lower-lying ground with scattered hillocks and slacks. The slacks are mainly dry but are sensitive to the groundwater elevation, and flood in exceptionally wet winters (Davy, 2010). The elevation of slack floors varies from ~ 5 m AOD near the beach, to ~10 m AOD at the inland point.

Despite the development of a golf course at the northern end of the Burrows the remainder of the site does not appear to have been affected hydrologically by anthropogenic influences and is a good marker of the cumulative effects of climate and management processes. 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. In this study, Braunton is amongst the sites with the highest annual rainfall total. 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 1037 mm, and the long term (1961 to 2012) average annual net (rainfall – actual evaporation) is 453 mm. This suggests that in most years, rainfall recharge supports the groundwater system.



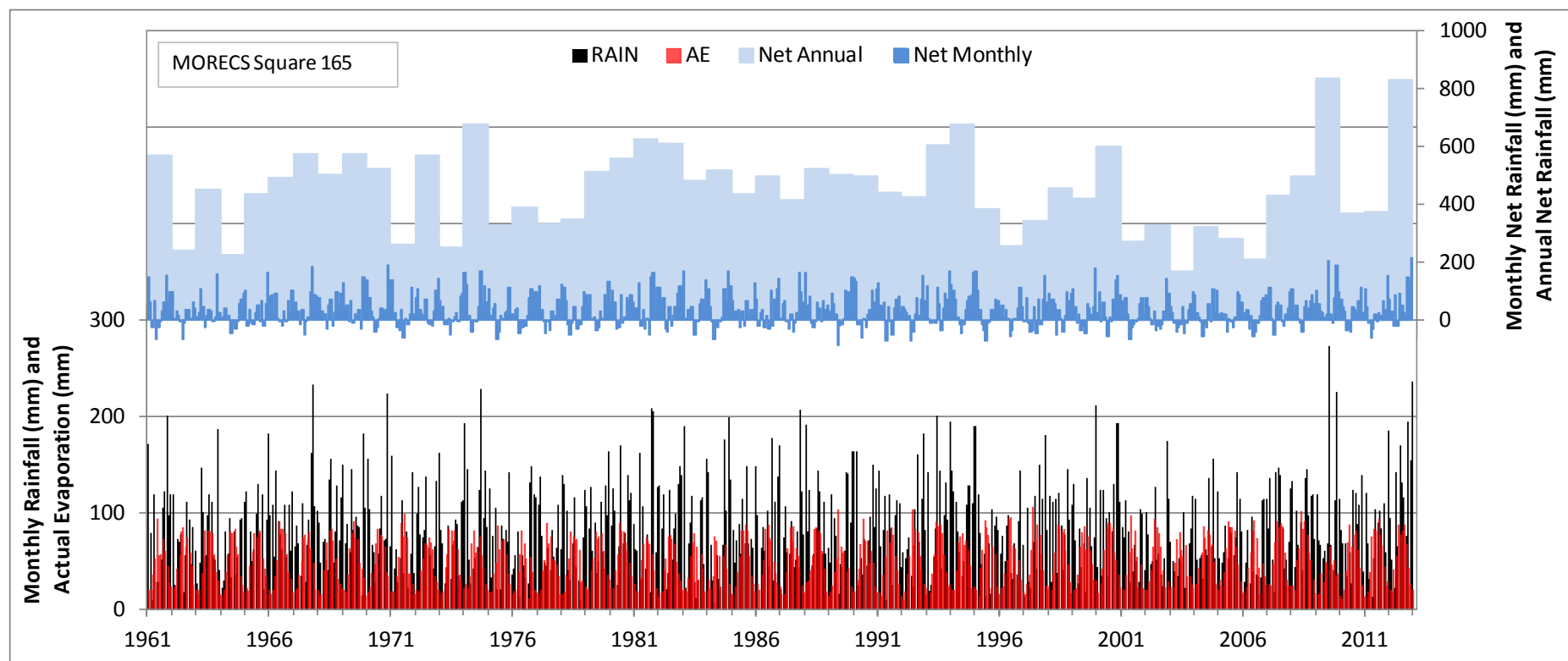
**Figure 2. Aerial photo of Braunton Burrows. © NextPerspectives.**



**Figure 3. Elevation profiles at several locations along Branton Burrows. Elevation values in metres above Ordnance Datum (m AOD) reflect the uppermost surface and are therefore affected by vegetation height. © NERC (CEH) 2013, © NextPerspectives.**



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 165. Net (Rainfall - actual evaporation) monthly and annual totals also shown. MORECS data © Crown copyright 2013, the Met Office.**

A study by Robins (2007), which analysed rainfall data from the nearby Bideford raingauge, found an overall decline in annual rainfall from 960 mm in 1966 to just 900 mm in 2004. A 24 month linear regression best fit line was calculated and this identified a 6.4 % decline in rainfall since the 1960s.

## 2.2 Ecological setting

The habitats and topography of Braunton Burrows were outlined by Gateley and Sturgess (1992) based on survey work conducted in 1990. They judged that, despite the use of the dune system for military training and partially for golf, natural dune vegetation covered much of the site. Comparison of the situations in 1990 and in 2012 indicates that the overall pattern remained essentially unchanged. Toward the seaward edge, there is a short length of a strandline community (SD2 *Honkenya peploides-Cakile maritima*), which gives way to a patchy and narrow foredune zone of SD4 (*Elymus farctus* ssp. *boreali-atlanticus*). The three main dune communities at Braunton comprise a succession of types characteristic respectively of mobile dunes, semi-fixed dunes and fixed dune grassland. The primary mobile dunes toward the sea are covered in a high yellow dune community of SD6 *Ammophila arenaria*, which is only about 50m wide, though in 1990, there were areas where it extended to 150m wide. The main body of the western dunes is a semi-fixed dune community from 400-1100 m wide (Gateley and Sturgess 1992) and referable to the SD7 *Ammophila arenaria-Festuca rubra*, with young slacks interspersed. Apart from the slacks themselves, the eastern portion of the Burrows was largely covered in SD8 *Festuca rubra-Galium verum* fixed dune grassland, with smaller areas of other fixed dune communities.

The general distribution of slacks and their vegetation was similar in 1990 and 2012, with slacks most numerous in the southern half of the Burrows and especially in the landward portion. The predominant vegetation type in the latest survey was SD16 *Salix repens-Holcus lanatus* dune-slack, with SD14 *Salix repens-Campyllum stellatum* and SD15 *Salix repens-Calliargon cuspidatum* dune-slacks much more localised in their distribution. True SD13 (*Sagina nodosa-Bryum pseudotriquetrum* dune-slack) is almost absent, though areas where a slack has been restored by scraping hold this type of vegetation. Toward the sea and further north, the dune-slacks are much fewer in number but tend to be larger in size.

The flora of Braunton Burrows is amongst the richest of any dune system in Great Britain with several species that are nationally rare or scarce in the UK. Some of these species are more typical of the drier dune communities, such as *Matthiola sinuata* in the SD6 mobile dunes and the established alien *Linaria arenaria* in the SD7 semi-fixed dunes. However the slacks themselves have a remarkable flora with *Scirpoides holoschoenus* in one of its two native locations, and *Teucrium scordium* surviving in slacks at Braunton and across the Taw/Torridge estuary at Northam, as well as one pit in Cambridgeshire (though reintroduced in other locations – Beecroft *et al.* 2007). The dune slack form of the Fen Orchid (*Liparis loeselii* var *ovata*) was recorded here in Preston *et al.* (2002) for the period 1987-1999 but is now evidently extinct. *Juncus acutus* is frequent around the margins of slacks in several parts of the Burrows and *Pyrola rotundifolia* ssp *maritima* has its southernmost British population within the Braunton dune wetlands. There is also a large population of *Petalophyllum ralfsii* (“petalwort”) at Braunton that depend on more open dune slacks. During the 22 years following the original survey, the management of Braunton Burrows went through two distinct phases. In the first decade the site became increasingly overgrown by woody growth, resulting in “biological drying” through increased evapotranspiration and declines have been noted in *Petalophyllum* and *T. scordium*; the disappearance of *Liparis* has also been scribed to this cause. Since 1999, restorative action has been taken through excavation of slacks and scrub removal, as well as some localised mowing. The core part of Braunton Burrows SSSI (586 ha) was entered into Higher Level Stewardship in 2008, with the adoption of management options to re-introduce grazing (requiring some internal stock-proof barriers) and to facilitate public access.

### 3 Hydrological work

Water level time series data have been collected at various locations on Braunton Burrows since 1966 (Figure 5). Over time, some of these dipwells fell in to disrepair, and three additional dipwell transects were installed in 1992. These have been monitored on a monthly basis ever since. Additional monitoring wells were installed by CEH and BGS in 2010 and 2011 and water level loggers were installed in these.

Robins (2007) carried out analysis of rainfall data (from the nearby Bideford raingauge) and water level data from dipwells in the burrows. 24 month moving average of both rainfall and water level showed a steady decline in the period from 1966 to 2007. Overall water levels in the sand aquifer have receded by about 0.7 m in the winter and slightly more in the summer months illustrating a link between effective rainfall, recharge and water table elevation.

Whilst the decline in water table is no doubt related to the decline in rainfall, additional factors may also be significant. Change in land cover from open, mobile dunes with large areas of bare sand, to densely vegetated, fixed dunes, will increase evapotranspiration. Increased interception by the vegetation canopy will reduce the amount of rainfall that gets through to the ground surface. Transpiration of soil water will result in increased losses of groundwater to the atmosphere. These processes are the focus of an ongoing study at Braunton, where hourly measurements of moisture down a 1 m profile, groundwater table elevation, and rainfall, are being collected. These measurements, combined with lab analysis of soil and vegetation samples, can be used to calculate the net groundwater recharge. The next stage of this work is to operate systems in different types of dune land cover, in order to develop robust estimates of recharge across the dune system.

The groundwater system at Braunton was conceptualised by Robins (2007). The following text is adapted from that report:

'The groundwater levels from the monitoring network indicate that there is a broad groundwater divide to the east of a line running approximately along the centre of the dunes (Figure 6). This suggests that under natural drainage conditions the Burrows drain largely towards the west and the coast, discharging as the fresh to brackish water that issues from the foreshore at low tide. Only a small area of the Burrows naturally drains to the east towards Braunton Marsh as the sands thin towards the alluvium and the permeability of the medium is greatly reduced. Some of the eastward flow is intercepted by the West Boundary Drain (not marked on Figure 6) but this is as yet unquantified. Although the local supply boreholes used by the Saunton Sands golf club draw from confined water in the Pilton Shale i.e. are not in hydraulic contact with the sand aquifer, the effect of irrigation of the golf course and also the extensive network of drains within the golf course, some very deep, have not been studied.

The long term average (LTA) water balance for the Burrows derives from the LTA effective annual rainfall of 478.6 mm. This input is balanced by discharge along the foreshore and drainage to the West Boundary Drain (not marked on Figure 6 but this runs to the east of the dunes, between the dunes and Braunton Marsh). Measurement of the water level in piezometer 6N (Figure 5) at ten minute intervals during a spring tide showed no effect from the sea tide (Burden, 1998). The water level in piezometer 6N, which is only 250 m from the dune front, rarely falls below 6 m AOD. This illustrates how the mounded water table falls to the foreshore to an almost common datum somewhere about mean sea water level. The diurnal rise and fall of the tide only affects the water table nearest the dune front and probably then only for a few tens of metres inland.

In creating cross sections of the water table along the dipwell transects, it is assumed that there is a consistent hydraulic relationship between the high dune areas and beneath the dune slacks. This may not be the case as the hydraulic conductivity of the dune slack floors and the material beneath the floors is lower than that in the high dune areas, and it is likely that the water table beneath the high dunes will not necessarily always be higher than in the slack areas, e.g. during the onset of rain following a long dry period. This hypothesis remains to be tested, however the recently installed CEH/BGS monitoring points along the north transect hope to shed more light on the groundwater elevation under both slack floors and dune ridges.

The available time series data do not allow 'joining up' of water level contours throughout the whole of the dune area (c.f. Burden, 1998). However, this could be done efficiently with assistance from geophysical surveying such as ground penetrating radar although additional piezometers through the high dunes would provide useful additional monitoring points.'



**Figure 5. Dipwell monitoring network at Braunton Burrows. Both historic and current monitoring points are shown. The yellow boxes indicate the focus areas that will be discussed in more detail in future reports. © NERC (CEH) 2013, © NextPerspectives.**



**Figure 6. Braunton Burrows conceptual groundwater flow diagram. The yellow arrows indicate the direction of groundwater flow. © NERC (CEH) 2013, © NextPerspectives.**

## 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.**

<b>Field</b>	<b>Data entry method</b>
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 Figure 9.

#### **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  $\pm 5$  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 physiognomical 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.**

<b>Category</b>	<b>Sub-category</b>	<b>Data entry method</b>
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 all areas that were mapped as wetland in 1990, mapping dune wetland vegetation, including new wetland features e.g. ponds or scrapes noticed while on site, and were guided by a map of slack areas provided by the site manager for additional information, as well as the 1990 map.

Change in mapped area was assessed for all mapped dune wetlands. Polygons for wetlands in 1990 which corresponded to areas mapped or revisited in 2012, were digitised from the scanned and georeferenced hard copy vegetation survey map of 1990. The area comparison included the following:

- Locations mapped as wetland in 1990, 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.
- Locations mapped as wetland in both 1990 and 2012.
- New wetland features mapped in 2012.

Each polygon (1990 and 2012) was assigned a code for broad vegetation type (Table 3) for ease of interpretation of multiple vegetation classes and communities. The 1990 survey used the final version of the NVC for coastal habitats (Rodwell, 2000), which allowed a more detailed comparison of changes between time periods than was possible for many other sites. Polygons mapped in 2012 are shown in Figures 10-16.

**Table 3. Broad vegetation codes used for reporting of change in mapped area.**

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 <i>Juncus</i> 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 Braunton due to extensive scrub)
t	trees or scrub (most sites this will be conifer plantations)
s/w	Slack to wet transitional

Patches of *Calamagrostis epigejos* were classed as 'wet pasture'. Coastal *Ligustrum* scrub (CLS) and patches of *Elymus pycnanthus* were classed as 'dry'. Scrub was coded separately to 'sc', but transitions to scrub coded as 's/d'. Transitions to wet pasture (MG inundation grasslands) were classed as 's/d'. Transitions to *Molinia* fen or swamp/mire communities were classed as 's/w'.

Change in vegetation composition was assessed by analysis of a number of quadrats from 1990 in wetland areas which were resurveyed in 2012. Quadrats were relocated based on maps from 1990 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 1990 was entered by hand from floristic tables in the Gateley and Sturgess (1992) report. Some floristic tables were missing from the report copy provided by Natural England. 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

### 4.2.1 Change in mapped area of dune wetlands

Changes in mapped area of dune wetlands at Braunton between 1990 and 2012 are summarised in Table 4 below. Figures 10-16 show the extent of the area mapped in 2012, with polygons colour-coded by broad vegetation code (Table 4), and labelled with the NVC communities assigned.

**Table 4. Braunton Burrows. Mapped area (ha) of broad vegetation classes in 1990 and 2012, showing net change, and percentage change for classes with area > 1 ha in 1990.**

<b>Area summaries</b>	<b>1990</b>	<b>2012</b>	<b>Net change</b>	<b>%change</b>
Bare sand and early successional	1.1	3.3	2.2	207.9
Wet slacks+slack/wet transitions	40.9	12.8	-28.1	-68.7
Dry slacks	62.8	38.5	-24.3	-38.7
Slack/dry transitions	6.7	27.9	21.2	315.4
Dry habitats, including scrub	16.5	12.5	-4.0	-24.0
Other wetlands	1.3	2.1	0.8	65.8
Total slacks	111.5	82.5	-32.2	-28.9
Total slacks and other wetlands	112.7	81.3	-31.4	-27.9
(Total Mapped Area)	129.2	96.6	-32.7	-25.3

There was a net decline in wetland area of around 30 ha, around 27% of the wetland area in 1990. 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 were apparent from this analysis.

There was a decrease of 28 ha in wet slack or slack transitions to other wetland types. There was also a decrease of 24 ha in dry slack area. However, there was a 21 ha increase in area of vegetation recorded as transitional between slack and other dry habitats, which at Braunton included transitions to both scrub and woodland types, but also mesotrophic grassland types. It is likely that this pattern, combined with the total decrease in mapped area, represents a broad shift of wet slack types to dry slack types and a shift from dry slack types to dry non-wetland habitats, or transitions to them. This usually involved a shrinkage of the wetland area within existing topographical slack or wetland features rather than a wholesale change of one community type to another, although there are instances where this has occurred.

There was a small increase in area of bare sand (in wetland areas) and early successional communities (SD13, or transitions involving SD13). This is largely a result of active management to create new scrapes or pools across the site, which also accounts for the small increase in area of other wetland types. These small increases in early successional and other wetland types amount to only 3 ha compared with a net loss of slack and wetland vegetation of 30 ha at this site.

## 4.2.2 Vegetation change revealed through analysis of repeated quadrats

In 2012, 55 quadrats were surveyed at Braunton Burrows. Of these, 53 could be used for analysis of vegetation change between 1990 and 2012. These are listed, together with basic descriptive information in Table 6 at the end of this report, with locations shown in Figure 9.

Changes in Ellenberg environmental and climate indicators are summarised in Table 5. There was a significant decline in Ellenberg Light scores, suggesting vegetation has become less open, probably linked to observed increases in scrub and taller vegetation. There was also a significant decline in Ellenberg Moisture indicator score, which is consistent with the outcomes from change in mapped area of habitats, and indications of long-term fall in water levels at the site. Indicators for soil pH and nutrient levels did not change significantly. There were highly significant decreases in salinity and January temperature scores. The reasons for these two changes are unknown. Species richness increased, but the nature of the change in species composition has not been investigated. For example, there may be an increase in undesirable or weedy species.

**Table 5. Braunton Burrows. Change in environmental and climatic indicators between 1990 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 = 53	Indicator	1990	2012	Significance
<b>Mean</b>	<b>Light</b>	<b>7.42</b>	<b>7.32</b>	<b>**</b>
<b>Mean</b>	<b>Moisture</b>	<b>6.08</b>	<b>5.86</b>	<b>*</b>
Mean	pH	6.30	6.24	
Mean	Nutrients	4.03	4.05	
<b>Mean</b>	<b>Salinity</b>	<b>0.50</b>	<b>0.35</b>	<b>***</b>
<b>Mean</b>	<b>JanTemp</b>	<b>3.7</b>	<b>3.6</b>	<b>***</b>
Mean	JulTemp	14.7	14.6	
Mean	Precipitation	1064	1063	
<b>Mean</b>	<b>Spp Richness</b>	<b>17.92</b>	<b>23.08</b>	<b>***</b>
s.d.	Light	0.21	0.20	
s.d.	Moisture	0.71	0.80	
s.d.	pH	0.20	0.18	
s.d.	Nutrients	0.43	0.41	
s.d.	Salinity	0.21	0.13	
s.d.	JanTemp	0.09	0.04	
s.d.	JulTemp	0.09	0.10	
s.d.	Precipitation	18.58	23.13	
s.d.	Spp Richness	5.90	6.62	

## 4.2.3 Analysis of soils data

Simple physical data from soil cores are shown in Figure 7 and Figure 8 below, grouped by broad vegetation type. Soil pH (Figure 7) was higher in dry slacks and dry habitats, falling slightly in the transitions from dry slack to other habitats, frequently scrub, and in scrub habitats, where the surface soil horizons may have started to decalcify slightly. However, these pH values are still high and the site shows no overall trend towards decalcification, but it should be noted that the soils are sampled to a depth of 15 cm, and decalcification would need to occur throughout that depth before these measured pH values would drop much below pH 6.5.

Organic matter contents (Figure 8) are high in the majority of vegetation types, all above 6%. Values above 6% in slack soils are typical of slacks over 60 years old (Jones et al. 2008), and are higher than typical values for a range of 9 west coast UK dune systems (Jones et al. 2010). They are highest in the scrub and in transitions to dry/scrub habitats, where organic matter builds up rapidly through litterfall.

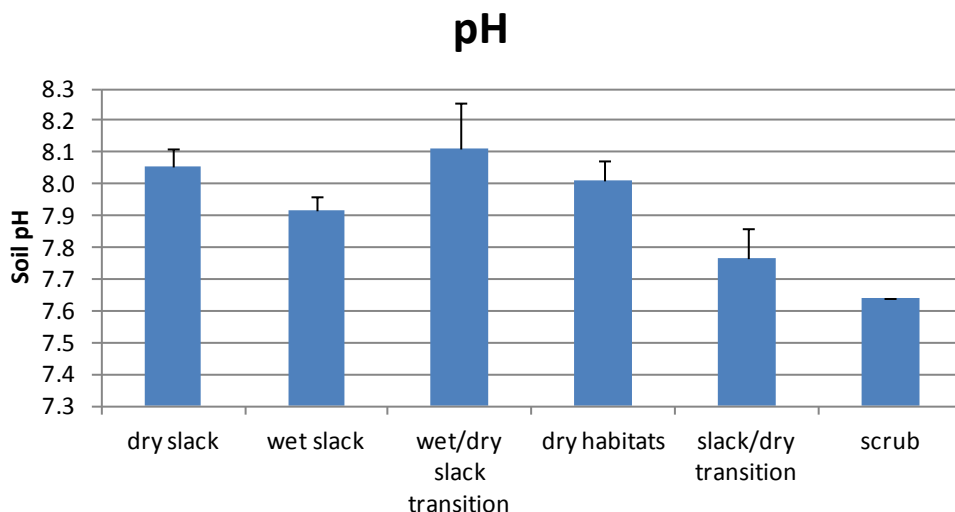


Figure 7. Branton Burrows. Soil pH, by broad vegetation type. Dry slack = SD16; wet slack = SD13, SD14, SD15, SD17.

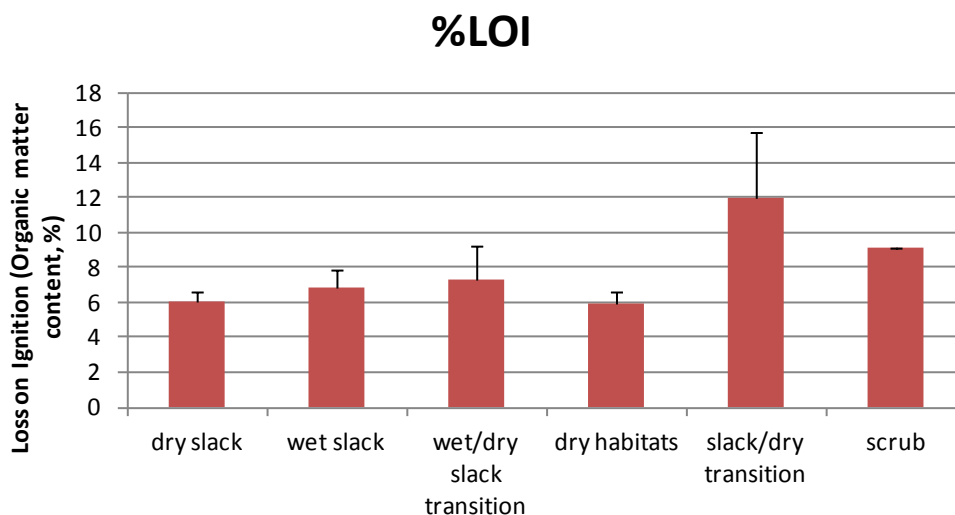


Figure 8. Branton Burrows. Organic matter (as Loss On Ignition, %), by broad vegetation type. Dry slack = SD16; wet slack = SD13, SD14, SD15, SD17.

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

The evidence builds up a reasonably consistent picture for the wetland element of Braunton Burrows of a mature system, with well developed soils and very small areas of new, early successional wetland habitat. This is consistent with the broader vegetation trends observed across the site of a site becoming over-stabilised, and perhaps in danger of losing some of the rare species of high conservation interest for which the site is well known. While military activities are introducing a degree of disturbance to some areas of the site, generally these activities are deliberately targeted away from the delicate slack and wetland areas. New scrapes and excavations are very small-scale. Given the preponderance of older, stable plant communities on the site, there is a strong argument for creation of early successional habitat in some larger areas on the site. The hydrological evidence also supports this, with the assumption that a reduction in dense vegetation cover will reduce interception and will help to increase net groundwater recharge. The lack of significant change in Ellenberg nutrient scores from the quadrat analysis suggests that nutrient levels have not changed significantly since 1990 at this site.

The second element which is clear from the broad range of measures reported here, is a consistent picture of movement towards drier vegetation communities, both in the change in mapped area of different wetland types, and in the analysis of quadrat indicator scores over time. This is consistent with observations of falling water tables in the order of 70 cm. According to Curreli et al. (2013), this may be enough to shift communities from wet dune slack (SD15 type) to dry dune communities, and there is evidence of fairly substantial changes in vegetation at the site, with a net loss of 27% of wetland area since 1990. The reasons for these changes may be linked to declines in effective rainfall, but further influences such as management of drainage at the site should be investigated.

## 5 Implications for management

- It is recommended that, due to the large majority of older successional wetland communities on the site, consideration be given to active management options which would substantially increase the area of early successional wetland communities. This could include management to re-instate natural dynamic processes through dune remobilisation on the western half of the site.
- Ongoing monitoring of groundwater levels is strongly recommended. Braunton has a rare and valuable long term hydrological dataset and this provides a very useful backdrop for assessment of current conditions. It would, for example, be very useful in properly understanding the impact of any trial vegetation management scenarios – assuming the experimental areas are located close to existing monitoring points.
- Further research is recommended to better understand the reasons for the observed lowering of water tables, and its effects on the vegetation. This would ideally look at the whole site and investigate further the likely impact of the golf course in the north of the site.

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## 7 Quadrat information

Table 6. List of quadrats resurveyed at Braunton Burrows, with associated environmental data. 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
Q75	245127	136675	0	0	12.2	5	7.93	6.17	RepeatQuadrat
Q58	245210	137213	5	180	24.8	4	7.98	4.51	RepeatQuadrat
Q57	245110	137165	0	270	16	4	8.39	3.03	RepeatQuadrat
Q61	244972	137110	0	0	21.2	6	7.75	6.79	RepeatQuadrat
Q60	245201	137020	10	45	7	6	7.9	7.78	RepeatQuadrat
Q74	245041	136701	0	0	28.4	6	8	6.35	RepeatQuadrat
Q95	245267	135995	10	180	27.4	3	8.1	7.15	RepeatQuadrat
Q99	245211	135737	5	45	22.4	6	7.82	5.00	RepeatQuadrat
Q90	244825	135779	10	180	33.2	5	8.1	4.02	RepeatQuadrat
Q181	244990	135192	10	225	19	7	7.99	6.04	RepeatQuadrat
Q185	244960	134915	5	90	19	9	8.07	7.23	RepeatQuadrat
Q200	245375	134886	0	0	3.2	0	8.2	2.28	RepeatQuadrat
Q166	245390	135107	0	0	14.2	8	8.17	5.86	RepeatQuadrat
Q299	245763	135047	10	45	38.2	0.5	7.89	6.70	RepeatQuadrat
Q300	245780	135077	0	0	35.6	0	7.82	8.09	RepeatQuadrat
Q160	245660	135397	15	315	10	4	7.93	4.31	RepeatQuadrat
Q119	245515	135811	0	0	10.4	6	7.91	5.79	RepeatQuadrat
Q123	245806	135650	0	0	33.6	9	7.6	6.04	RepeatQuadrat
Q108	245912	135568	0	0	23	1	7.74	8.03	RepeatQuadrat
Q109	245968	135544	15	180	32.8	10	7.92	9.01	RepeatQuadrat
Q156	245851	135295	0	0	10.2	0	8	7.91	RepeatQuadrat
Q226	245875	135160	15	0	45.6	5	8.02	5.52	RepeatQuadrat

Quad Code	x	y	ANGLE SLOPE (degrees)	ASPECT (degrees)	Veg Height (cm)	OM thickness (cm)	Soil pH	LOI %	Quad Type
Q292	245908	135116	0	0	50	0	7.97	12.49	RepeatQuadrat
Q293	245973	135074	0	0	52.6	0	7.44	7.22	RepeatQuadrat
Q294	246088	134918	15	0	18.6	0	7.7	2.82	RepeatQuadrat
Q250	246310	134746	0	0	12.4				RepeatQuadrat
Q256	246112	134706	0	0	81.2	2	7.63	4.98	RepeatQuadrat
Q257	246108	134777	0	0	45.8	10	7.78	5.98	RepeatQuadrat
Q468	246492	134299	5	45	3	3	7.94	3.54	RepeatQuadrat
Q267	246544	134342	10	180	8.2	10	8.04	7.56	RepeatQuadrat
Q464	246420	134565	0	0	6.4	10	8.03	5.16	RepeatQuadrat
Q316	245942	134665	0	0	43.4	12	7.85	26.57	RepeatQuadrat
Q235	245870	134635	0	0	43.2	2	7.89	11.17	RepeatQuadrat
Q332	245985	134428	0	0	32.6	5	7.87	15.57	RepeatQuadrat
Q353	245854	134267	0	0	24.6	3	7.95	7.74	RepeatQuadrat
Q348	245915	134036	0	0	7.6	11	8.06	7.60	RepeatQuadrat
Q240	245828	133945	0	0	31	10	8.06	6.31	RepeatQuadrat
Q420	245580	133933	20	45	7.6	0	8.03	3.38	RepeatQuadrat
Q435	246009	133847	0	0	7.6	1	8.06	1.92	RepeatQuadrat
Q9	245242	137470				6	7.64	9.18	RepeatQuadrat
Q27	245551	137329	0	0	2.4				RepeatQuadrat
Q32	245728	137127	0	0	32.4	11	7.8	7.46	RepeatQuadrat
Q39	246205	137074	0	0	38.2	2	7.73	11.50	RepeatQuadrat
Q136	245794	136672	0	0	29.8	4	7.96	7.56	RepeatQuadrat
Q403	246155	134083	5	45	17	5	7.67	9.57	RepeatQuadrat
Q410	246175	134123	0	0	2.5	6	8.1	4.29	RepeatQuadrat
Q400	246117	134222	0	0	3	7	8.09	7.03	RepeatQuadrat
Q401	246217	134233	2	0	2	11	8.12	6.99	RepeatQuadrat
Q341	244927	134528	2	210	17.4	8	8.27	7.73	RepeatQuadrat

<b>Quad Code</b>	<b>x</b>	<b>y</b>	<b>ANGLE SLOPE (degrees)</b>	<b>ASPECT (degrees)</b>	<b>Veg Height (cm)</b>	<b>OM thickness (cm)</b>	<b>Soil pH</b>	<b>LOI %</b>	<b>Quad Type</b>
Q196	244949	134674	0	0	8.6	3	8.5	2.48	RepeatQuadrat
Q343	245039	134364	2	120	58	4	8.35	4.97	RepeatQuadrat
Q344	244850	134284	4	70	13.8	4	8.52	3.50	RepeatQuadrat
Q320	246224	134413	2	45	28.4	10	7.88	10.99	RepeatQuadrat
Q330	246110	134528	3	90	44	10	7.71	8.71	RepeatQuadrat
Q329	246208	134494	0	0	45	15	7.6	12.22	RepeatQuadrat



Figure 9. Locations of quadrats surveyed at Braunton Burrows. © NERC (CEH) 2013, © NextPerspectives.

## 8 Survey maps

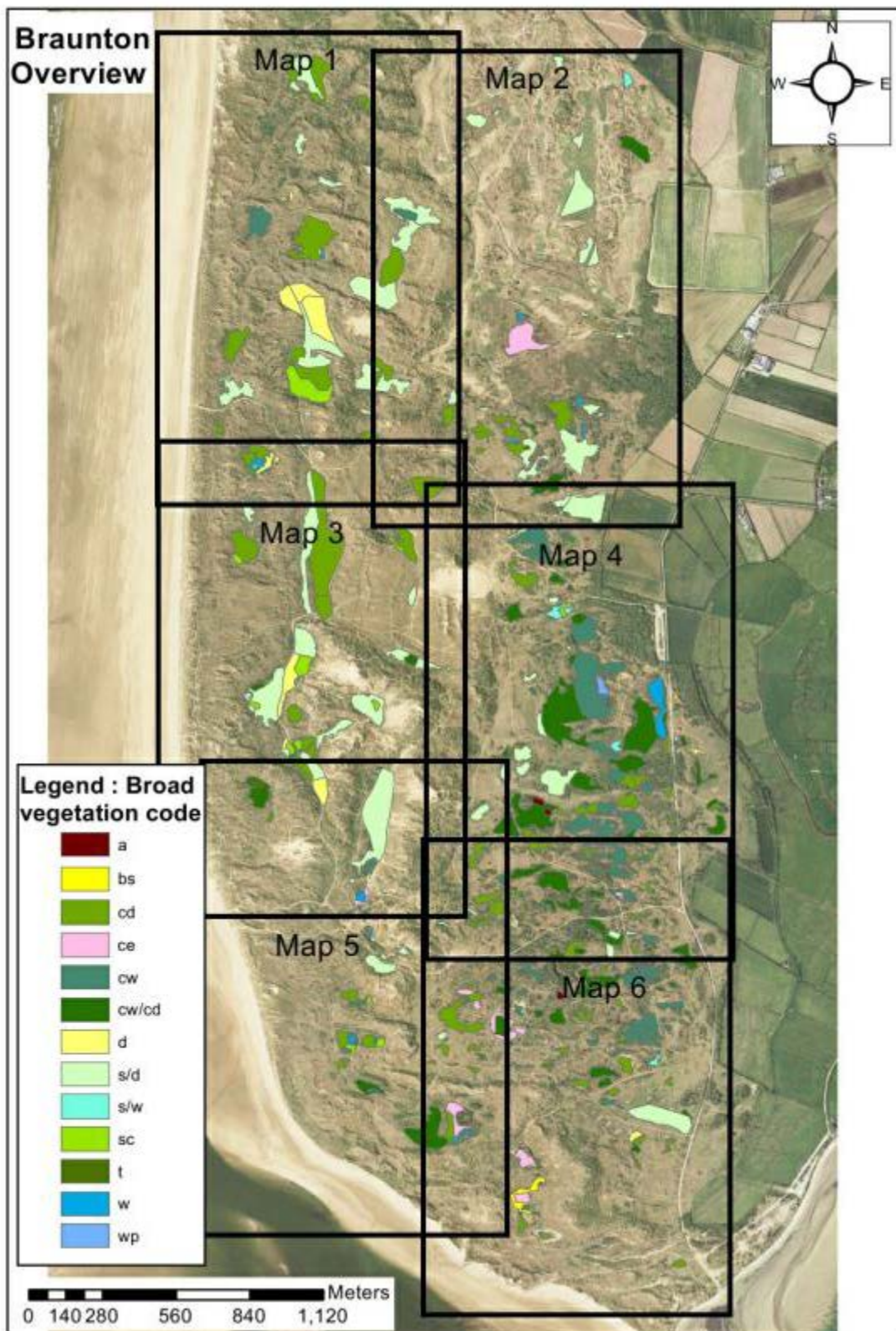


Figure 10. Braunton Burrows. Overview of NVC communities mapped during 2012 vegetation survey, with reference to areas covered by maps 1-6 (Figures 11-16). Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.

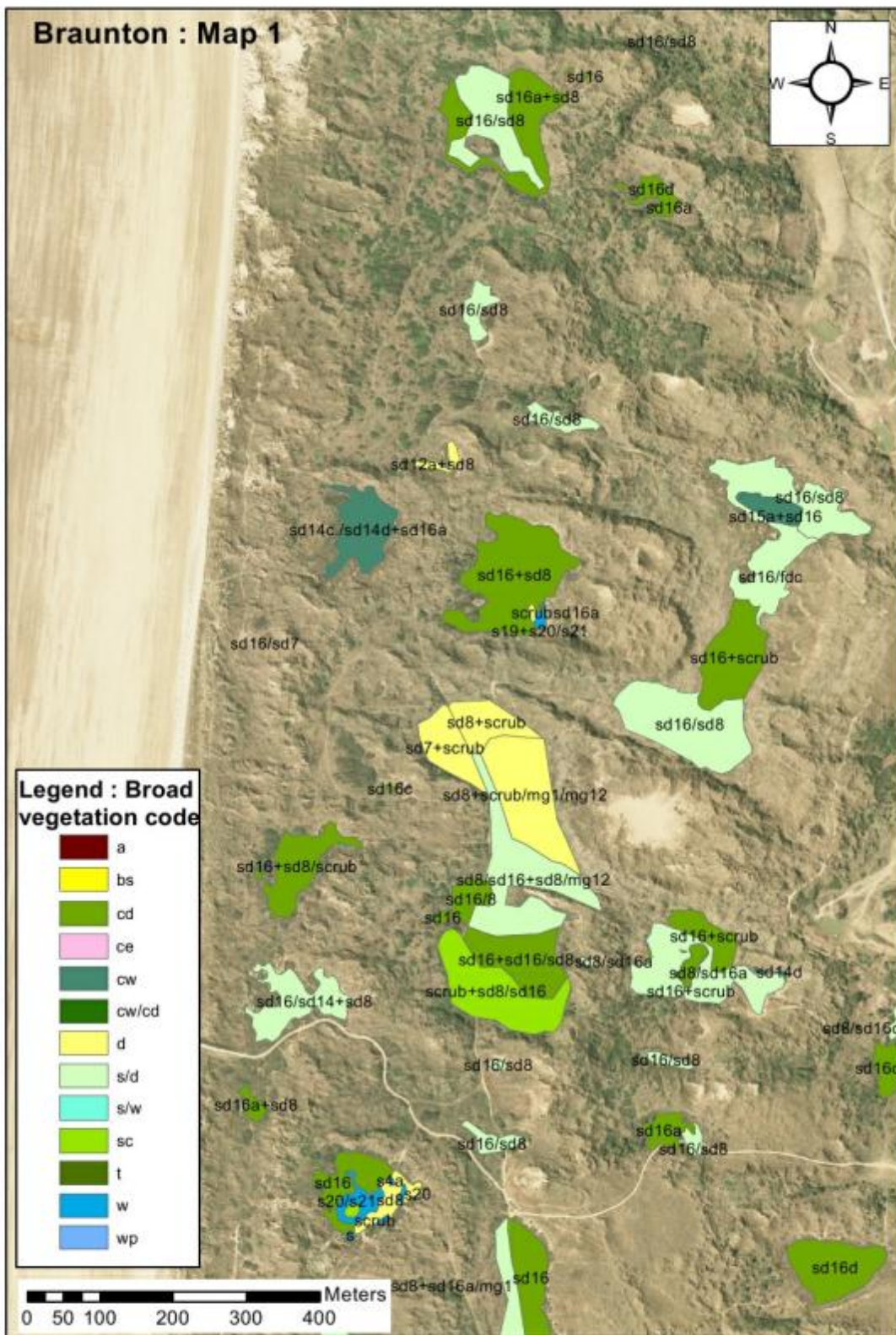


Figure 11. Braunton Burrows Map 1. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.

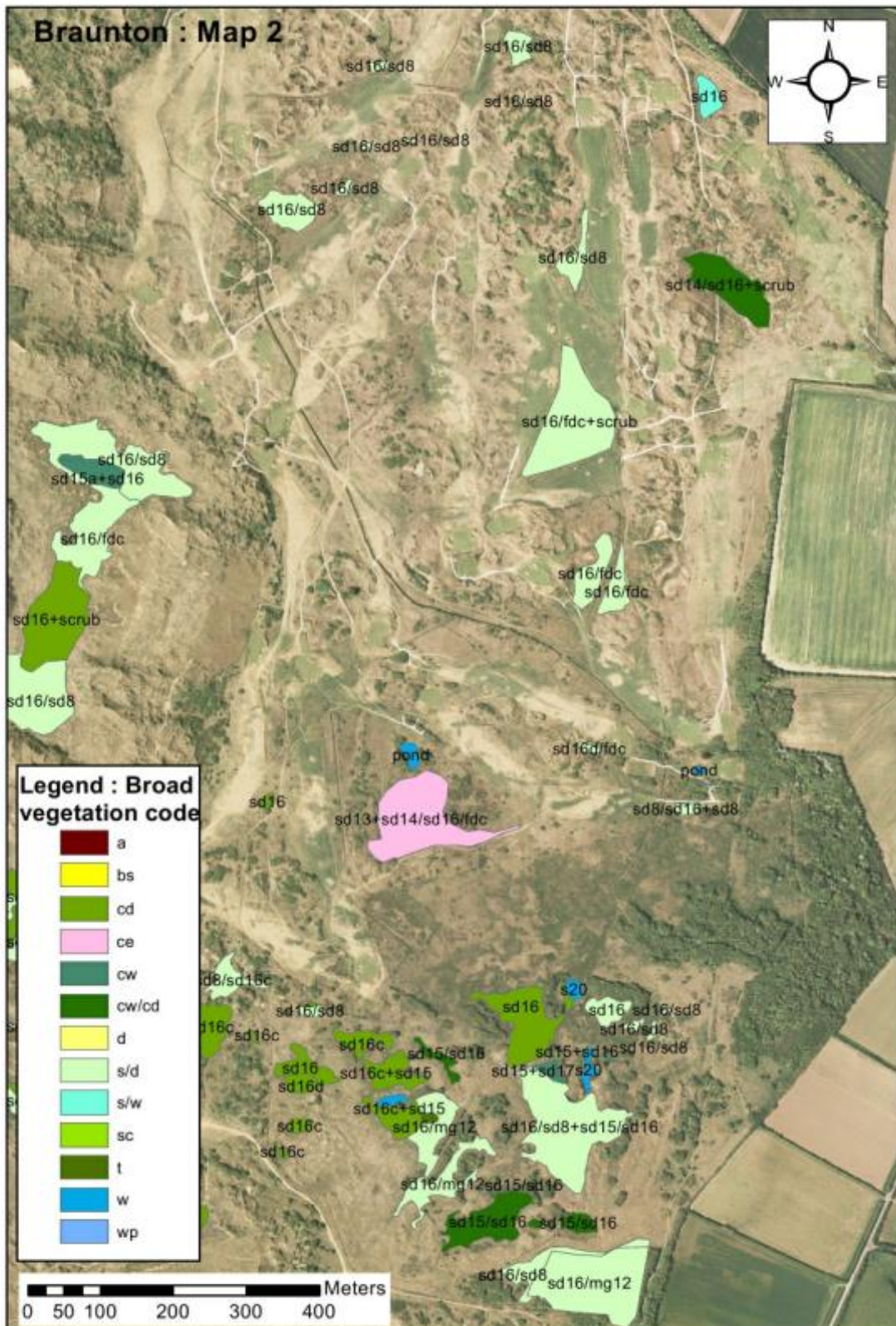


Figure 12. Braunton Burrows Map 2. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.

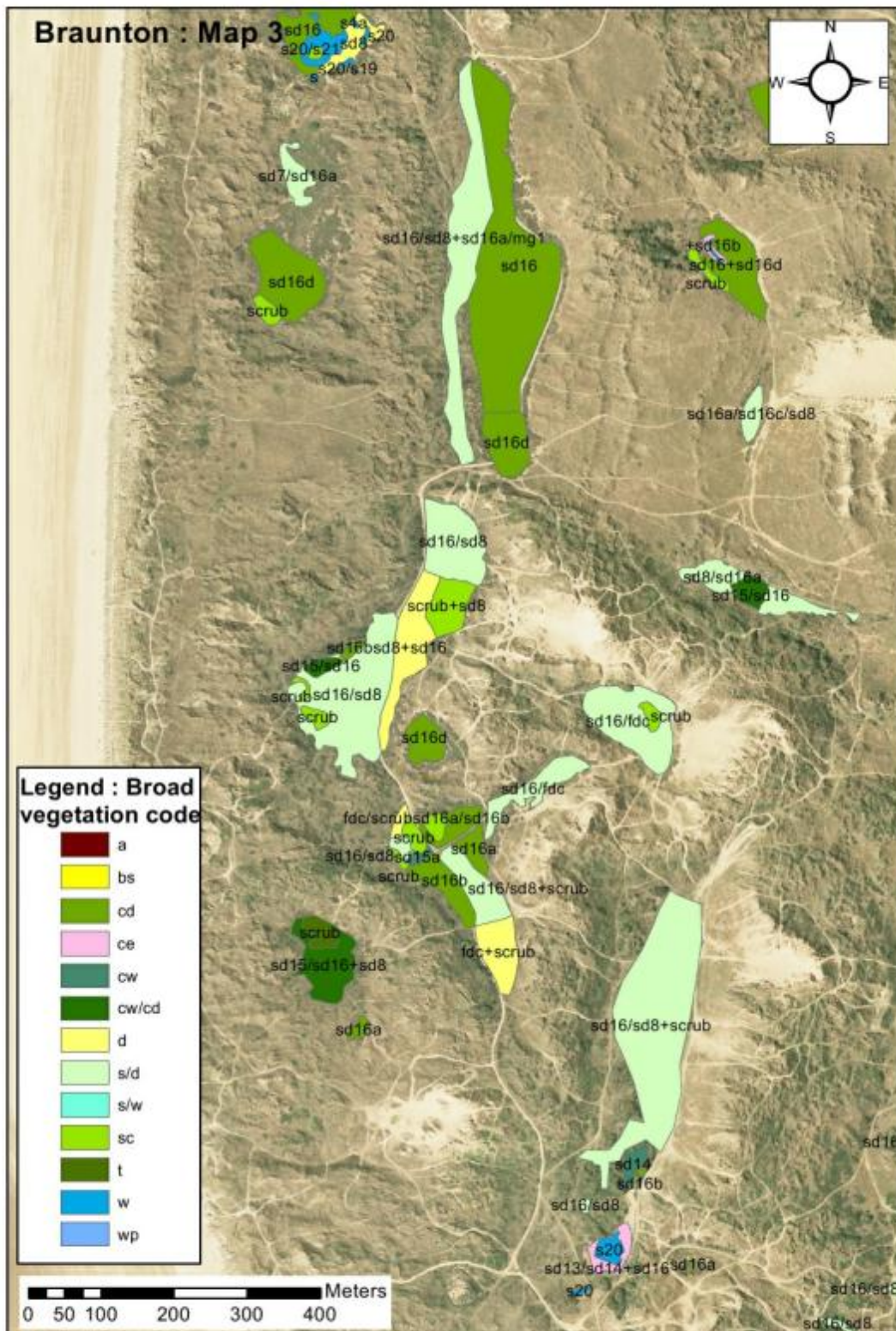


Figure 13. Braunton Burrows Map 3. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.



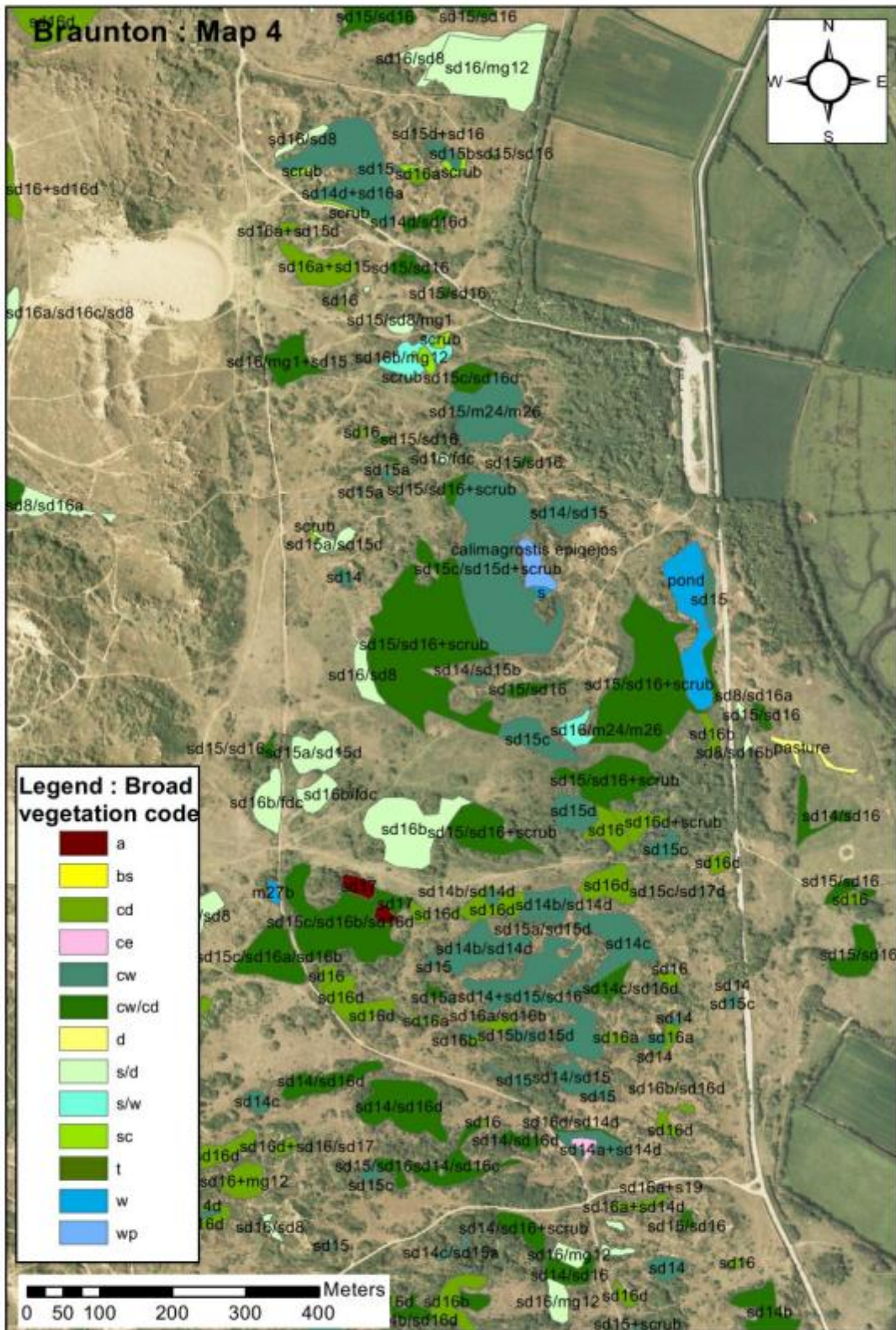


Figure 14. Braunton Burrows Map 4. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.

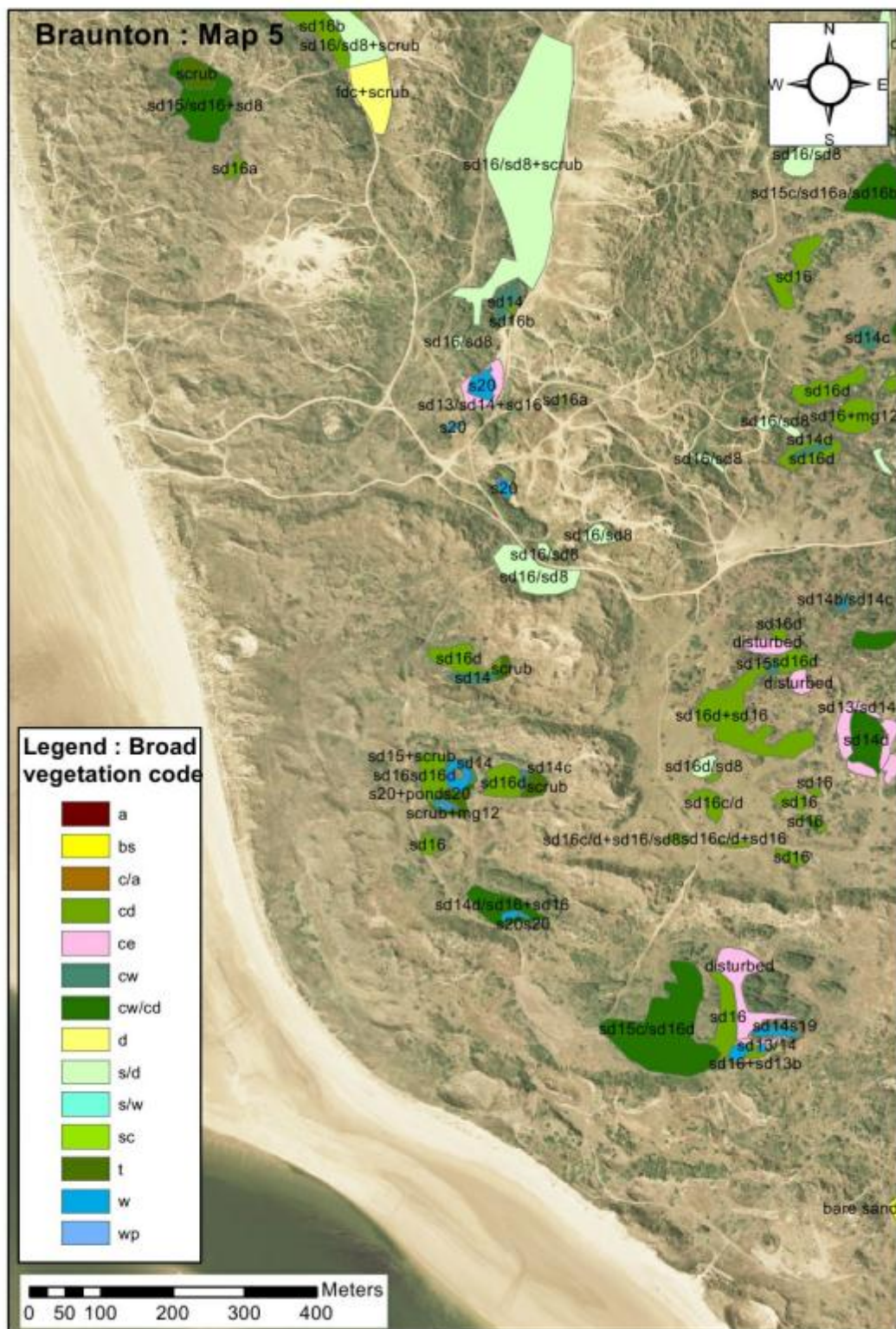


Figure 15. Braunton Burrows Map 5. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.

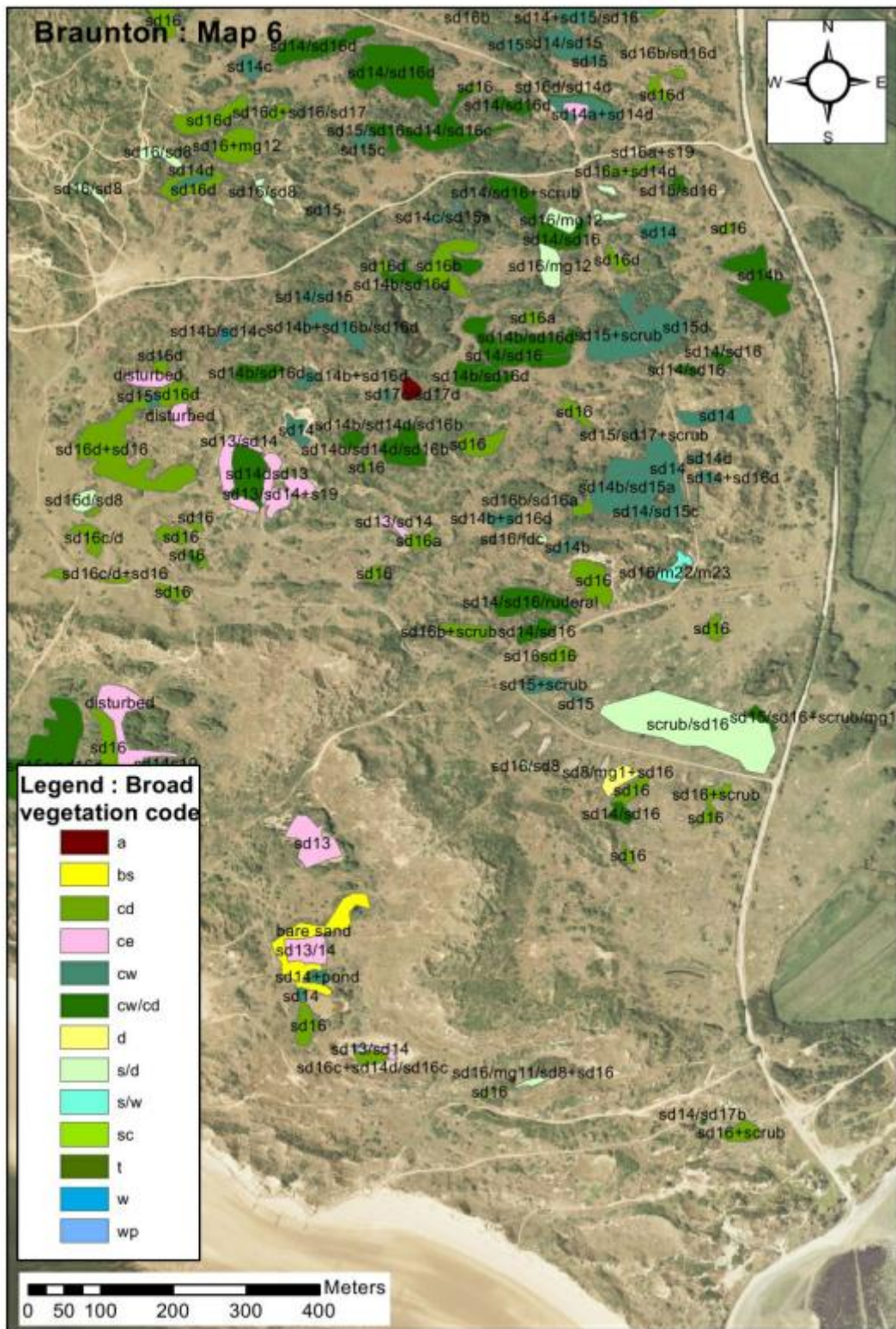


Figure 16. Braunton Burrows Map 6. NVC communities mapped during the 2012 vegetation survey. Broad vegetation codes are described in Table 4. © NERC (CEH) 2013, © NextPerspectives.