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Distribution and ecology of *Equisetum variegatum* (Variegated Horsetail) (Equisetaceae) on the Sefton Coast sand-dunes, north Merseyside, UK

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Abstract
A 2022 survey of *Equisetum variegatum* Schleich. Ex F. Weber & D. Mohr (Equisetaceae) (Variegated Horsetail) on the Sefton Coast sand-dunes, north Merseyside, found the plant in 19 of 28 known sites for the species. Most extant localities were in relatively young, calcareous dune-slacks and scrapes with short vegetation close to the shore, having ground-water-gley or peaty-gley soils with a high pH. Quadrats in vegetation supporting *E. variegatum* had a total of 78 vascular taxa, 20 of them being regionally or nationally notable and 10 Red-listed. There were only four non-native species. TABLEFIT analysis found that five UK National Vegetation Classification (NVC) dune-slack communities were represented, the most frequent being SD15: *Salix repens-Calliergon cuspidatum* dune-slack, followed by SD16: *Salix repens-Holcus lanatus* dune-slack. However, statistical fits to recognised NVC vegetation types were often poor. Loss of *E. variegatum* from nine sites was considered to be due to overgrowth by coarse vegetation and scrub, while 11 sites appeared to be imminently threatened by scrub development. Management practices that could assist conservation of *E. variegatum* and other notable plants in the Sefton dunes are discussed.

Key words: Calcareous dune-slacks; open habitats; quadrats; rabbits; scrub invasion; UK NVC communities

Introduction

Equisetum variegatum Schleich. *ex* F. Weber & D. Mohr (Equisetaceae) (Variegated Horsetail) is a native, small to medium-sized, unbranched, evergreen, usually prostrate, horsetail found in a wide range of calcareous habitats, including sand-dune slacks, wet limestone grassland, river shingle, upland flushes and stony loch shores that are often winter-flooded. It has a circum-polar distribution in the Northern Hemisphere, occurring in Northern Europe, Asia and North America, including Greenland, Iceland and the Faeroes. The plant is a poor competitor and is therefore largely confined to open habitats (Dixon & Dines, 2023; Merryweather, 2020; Page, 1997; Stace, 2019). Ellenberg Indicator values show that *E. variegatum* is light-loving (L = 8), favours wet soils (F = 8) that are fairly basic (R = 8) and more-or-less infertile (N = 3). It is absent from saline sites (S = 0) (Hill *et al.*, 2004). Although the plant is widely spread throughout the Britain Isles, a recent hectad

map (Dixon & Dines, 2023) shows a concentration of records in the north and west, including in central and northwest Ireland. While the overall distribution of this species has slightly increased in the last two decades, especially in Ireland, this may be due to better recording. Dixon & Dines (2023) mention some evidence of local declines, attributable to overstocking in the uplands and drainage or dune development in lowland sites. *E. variegatum* is said to be rare in central and southern England (Merryweather, 2020; Stace 2019). Indeed, Stroh (2019) describes the plant as: "Vanishingly rare throughout most of lowland England." The Great Britain and England vascular plant Red Lists give the conservation status of *E. variegatum* as 'Least Concern' but note a 38% decline when assessing 1987+ data as a proportion of all records, including pre-1930 data (Cheffings & Farrell, 2005; Stroh *et al*., 2014). This taxon is listed as a 'Species of Conservation Importance in North West England' by the Regional Biodiversity Steering Group (1999).

Equisetum variegatum has long been known as a component of dune-slack vegetation on the Sefton Coast, north Merseyside (formerly part of Lancashire). Thus, Hall (1839) describes the plant as occurring at Bootle and Waterloo "near the round bathing house". Similarly, Dickinson (1851) refers to *E. variegatum* as "plentiful on the sandhills at ....Waterloo and Crosby." These localities on the northern outskirts of Liverpool have long been largely built-up, there being no suitable habitat there now. Thirty years later, referring to members of the genus in dune-slacks of the, then, Lancashire sand-dunes, McNicholl (1883) writes: "The pretty little *variegatum* occurs here." Savidge *et al.* (1963) describe *E. variegatum* as frequent along the coast of South Lancashire (v.c.59), as a typical plant of dune-slacks but very rare inland. The entry for *E. variegatum* in the new *Flora of South Lancashire* (Northwestern Naturalists Union, 2023) states that the plant is frequent on the Sefton Coast between Hightown and Southport, with a former locality on Pendle Moor. Including historical records, the new *Flora* maps the plant in 20 Sefton Coast tetrads. Its habitats in the vice-county are dune-slacks, the lower slopes of dunes and moorland flushes.

Equisetum variegatum is scarce in vice-counties adjacent to South Lancashire. Thus, Greenwood (2012) maps this species for only seven tetrads in North Lancashire (largely v.c.60), where it was known from dune slacks at Lytham St. Anne's on the Fylde Coast, Lancashire, and in damp base-rich places elsewhere. He mentions that *E. variegatum* has the capacity to colonise man-made sites, such as a disused railway line and a quarry but soon disappears if closed communities develop. Skelcher (2017) did not find *E. variegatum* during his survey of Fylde sand-dunes in 2016, though he reports that, according to another observer, the plant was still present on Lytham St. Anne's Local Nature Reserve (LNR) in 2015. Greenwood (2023) states that, since it was first noted by Hall (1839), *E. variegatum* has been known from sand-dunes between New Brighton and West Kirby in north Wirral (v.c.58). The most recent record was in 2011. However, some forms of *E. variegatum* are similar to *E. ×meridionale* which also occurs at intervals in the same area. Examination of specimens in the Natural History Museum, London, suggests that Wirral records for *E. variegatum* are identification errors for the hybrid and that all voucher specimens need checking (Greenwood, 2023). There are 19th century records of *E. ×meridionale* from Crosby and Southport in v.c.59 (Rumsey & Spencer, 2012; Stace *et al*., 2015) but none since for this vice-county (Northwestern Naturalists Union, 2023; Savidge *et al*., 1963).

Methods

For about 35 years and especially from 2007, I recorded *E. variegatum* whenever I encountered it during botanical surveys in the Sefton Coast sand-dunes, sightings being entered into a database. In almost all cases, the locations of sites were defined by an existing dune-slack numbering system and a UK National Grid Reference. These data were supplemented by one record from Dr Mary Dean (personal communication) and a more extensive dataset by Hunt (2019) from a study of vegetation in scrapes excavated in the dunes for conservation purposes. The combined total was 44 known sites for *E. variegatum.* From July to December 2022, I visited 28 of those that were readily accessible on foot, making notes on habitat features, including soil type based on descriptions in Hall & Folland (1967) and James (1993), evidence of rabbit (*Oryctolagus cuniculus*) grazing (droppings) and proximity of tall herbaceous vegetation and scrub. National Grid references were determined to an accuracy of about 5 m using a hand-held Garmin Etrex GPS device. It was not possible to count the plants, nor could I obtain an accurate measure of the area of colonies because of their diffuse nature. Therefore, the relative sizes of populations were estimated as large, medium or small, based on their extent and density. At each site supporting *E. variegatum*, a sample of representative vegetation was recorded in a 2 x 2 m quadrat using UK National Vegetation Classification (NVC) methodology. This included estimating % cover for each vascular taxon (Rodwell, 2000). Slack type was determined using Ranwell's (1972) method, based on water-table characteristics. Mean vegetation height was calculated from the average of ten measurements at regular intervals across the area of each quadrat. A small sub-surface soil sample was taken from the centre of the quadrats, pH being determined using a Lutron PH-212 soil pH meter buffered at pH4 and 7. The distance of quadrat sites from the shore was measured on aerial photographs using the *Google Earth* ruler tool. Their age was estimated from personal observations, photographs of scrape creation and known history, such as dates of commercial sand extraction. As some of these variables were not normally distributed, the relationships between them were investigated using Spearman's Rank correlation coefficients. Quadrat samples were analysed using TABLEFIT to determine the degree of fit to known NVC communities and sub-communities (Hill, 2015). Vascular plant nomenclature follows Stace (2019) and subsequent updates.

Results

The distribution of known *E. variegatum* sites on the Sefton dunes is shown in Fig. 1. They extend from Hightown to Southport, a linear distance of about 17 km, within three hectads and nine tetrads of the UK National Grid. However, there was a gap in the occurrence of *E. variegatum* for about 2 km at Formby Point. Nineteen of the 28 sites that were searched supported *E. variegatum*, two being new to the database. The morphology of most populations appeared similar, plants being largely prostrate (Fig. 2), though some upright stands, to 25 cm (Fig. 3), were noted in off-road vehicle ruts at slack no. 27 in the northern Birkdale frontal dunes.

Most of the 28 sites visited were situated in younger dunes near the sea (mean and standard deviation 287±216 m from the shore), though two sites at Ainsdale Sand Dunes National Nature Reserve (NNR) were about 1090 m inland (Table 1, 2). Population sizes at the 19 sites with *E. variegatum* were estimated as

follows: large 6, medium 7 and small 6. Habitats were classed as wet-slack (12), dry-slack (4), fixed-dune (3). Two of the wet-slacks contained deep ruts, caused, in 2014, by off-road vehicles. *E. variegatum* was particularly prolific in the ruts. The estimated age of quadrat sites ranged from nine to about 60 years (mean and standard deviation 37±18 years) (Tables 1 and 2).

Sub-surface soil pH in quadrats ranged from 6.00 to 7.83 with a mean and standard deviation of 7.39±0.41 (Tables 1 and 2). Soil types were mostly either groundwater gleys (9 sites) or peaty-gleys (7) of the Greatstone Series, as defined by the Soil Survey of England and Wales (Beard *et al*., 1987). Three samples in drier fixed-dune grassland adjacent to wet-slacks resembled pararendzinas (James, 1993). A total of 78 vascular plants was recorded in the 19 quadrats (range 7-23 per quadrat; mean and standard deviation 14.3±4) (Table 2). Twenty taxa (26%) were regionally or nationally notable, ten being Red-listed (Table 3). Only four were non-native. The most frequent associates of *E. variegatum* in the quadrats were *Salix repens* (Creeping Willow) (16 occurrences), *Agrostis stolonifera* (Creeping Bent) (15), *Hydrocotyle vulgaris* (Marsh Pennywort) (12), *Carex arenaria* (Sand Sedge) (9), *Carex flacca* (Glaucous Sedge) (9) and *Holcus lanatus* (Yorkshire-fog) (9), all being typical dune-slack species (Smith, 2009, 2021).

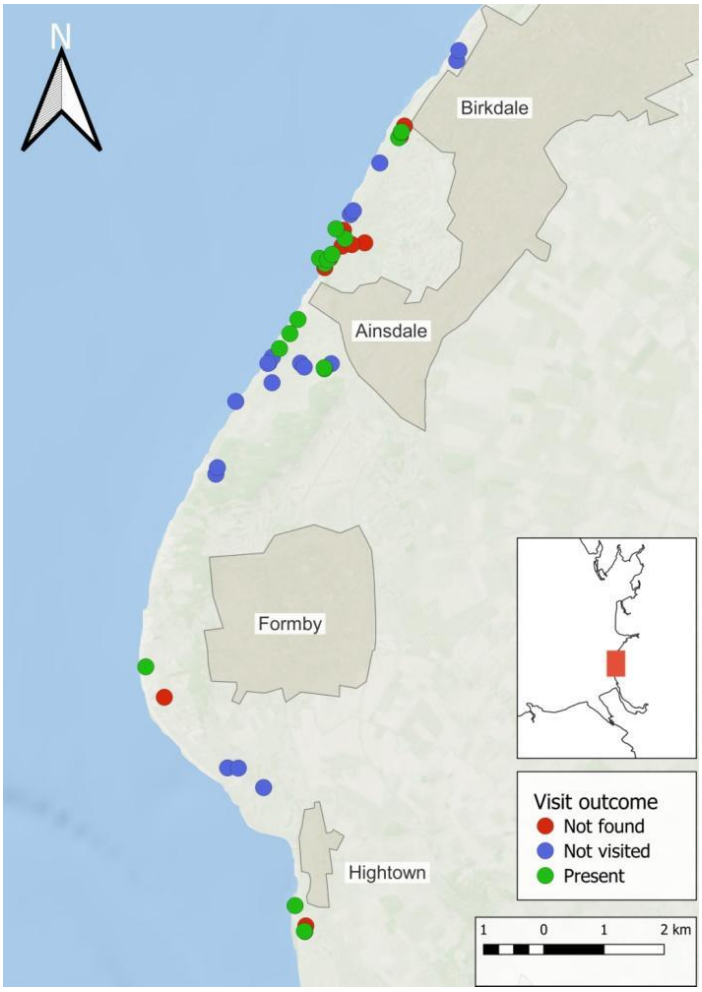

Figure 1. Distribution of *Equisetum variegatum* records in the Sefton dune system

Figure 2. Typical prostrate form of *Equisetum variegatum*, Birkdale dunes

Figure 3. Upright form of *E. variegatum* in wheel rut, Birkdale dunes

Table 1. Recorded sites for *Equisetum variegatum* on the Sefton Coast in 2022
Size of population: S = small; M = medium; L = large; sc = scrape; sl = slack; yr = year

Quadrat no.	Location	Grid reference	Habitat	Pop. size	Distance from shore (m)	Soil pH	Estimated age (yr)
1	Newest Green Beach	SD29981335	Wet-slack	S	86	7.83	18
2	Birkdale sl. 49	SD30001331	Wet-slack	L	215	7.4	47
3	Birkdale sl. 49	SD30071326	Wet-slack	L	215	7.41	47
4	Hightown sc. 1	SD29730215	Wet-slack	S	150	7.67	10
5	Hightown sc. 1	SD29730216	Wet-slack	L	149	7.57	10
6	Birkdale sl. 27	SD31331544	Wet-slack	L	200	7.32	47
7	Birkdale sl. 27	SD31341545	Wet-slack	L	200	7.37	47
8	Birkdale Green Beach	SD30251384	Wet-slack	M	127	7.16	22
9	Hightown sc. 13	SD29570259	Wet-slack	L	87	7.65	9
10	Lifeboat Rd. sc. 6	SD27090657	Wet-slack	M	95	7.75	9
11	Birkdale sl. 39a	SD31291535	Dry-slack	S	220	6	47
12	Ainsdale NNR sl. 143	SD30061151	Dry-slack	M	1060	7.65	32
13	Ainsdale NNR sl. 143	SD30061153	Dry-slack	M	1090	7	32
14	Ainsdale LNR sl. 170	SD29621233	Wet-slack	M	245	7.2	60
15	Ainsdale LNR sl. 164	SD29311185	Dry-slack	S	218	7.62	60
16	Birkdale sl. 46	SD30401367	Fixed-dune	S	330	7.53	50
17	Ainsdale LNR sl. 168	SD29471210	Wet-slack	M	246	7.74	60
18	Birkdale sl. 49	SD30111332	Fixed-dune	S	230	7.17	47
19	Birkdale sl. 48	SD30201341	Fixed-dune	M	278	7.4	47

Table 2. Summary of *Equisetum variegatum* quadrat data

	Vegetation height (cm)	Soil pH	Distance from sea (m)	Estimated age (yr)	No. of vascular plants
Maximum	25	7.83	1090	60	23
Minimum	6	6.00	86	9	7
Mean	15.3	7.39	287	37	14.3
Standard Deviation	5.52	0.41	385	18.4	4
Median	15.3	7.41	216	47	15

TABLEFIT analysis of quadrats shows that five dune-slack communities were represented, of which SD16: *Salix repens-Holcus lanatus* dune-slack (seven quadrats) was most common, followed by SD15: *Salix repens-Calliergon cuspidatum* (now *Calliergonella cuspidata*) dune-slack (six quadrats) (Table 4). However, twelve of the quadrats had poor or very poor statistical fits to known NVC community types, only three having good or very good matches. Percentage cover of *E. variegatum* in quadrats ranged from 3 to 60 (mean and standard deviation 14.9±14.2), while the range of vegetation height was 6.0 to 23.9 cm (mean and standard deviation 14.7±8.1 cm).

Spearman's Rank correlation coefficients mostly reveal weak to very weak correlations between the habitat variables, though significant p-values were obtained for site age vs. sward height and site age vs. % cover of *E. variegatum*, the latter being a negative relationship (Table 5).

Table 3. Notable vascular plants in quadrats. S41 = Section 41 of NERC Act 2006; NS = Nationally Scarce; VU = Vulnerable; NT = Near Threatened (italics = England Red List); SCI = Species of Conservation Importance in North West England

Taxon	English name	Conservation status	No. of quadrats
Blysmus compressus	Flat-sedge	S41, *VU*, SCI	1
Carex viridula	Small-fruited Yellow-sedge	SCI	3
Carlina vulgaris	Carline Thistle	SCI	1
Centaurium littorale	Seaside Centaury	NS, SCI	1
Dactylorhiza incarnata subsp. *coccinea*	Early Marsh-orchid	NS, *NT*, SCI	5
Eleocharis quinqueflora	Few-flowered Spike-rush	SCI	1
Epipactis palustris	Marsh Helleborine	*NT*, SCI	8
Equisetum variegatum	Variegated Horsetail	SCI	19
Hydrocotyle vulgaris	Marsh Pennywort	*NT*	12
Juncus balticus	Baltic Rush	NS, *VU*, SCI	1

Juncus maritimus	Sea Rush	SCI	1
Parnassia palustris	Grass-of-Parnassus	*VU*, SCI	3
Pyrola rotundifolia subsp. *maritima*	Round-leaved Wintergreen	NS, SCI	3
Ranunculus flammula	Lesser Spearwort	*VU*	6
Sagina nodosa	Knotted Pearlwort	*VU*	2
Salix repens	Creeping Willow	*NT*	16
Samolus valerandi	Brookweed	SCI	1
Schoenoplectus tabernaemontani	Grey Club-rush	SCI	1
Trifolium fragiferum	Strawberry Clover	*VU*, SCI	1
Vicia lathyroides	Spring Vetch	SCI	1

Table 4. National Vegetation Classification of quadrat vegetation

No.	NVC code	Community	Sub-community	% fit	Match
1	SD13b	*Sagina nodosa-Bryum pseudotriquetrum* dune-slack	*Holcus lanatus-Trifolium repens*	18	Very poor
2	SD15	*Salix repens-Calliergon cuspidatum* dune-slack		85	Very good
3	SD15	*Salix repens-Calliergon cuspidatum* dune-slack		76	Good
4	SD15c	*Salix repens-Calliergon cuspidatum* dune-slack	*Carex flacca-Pulicaria dysenterica*	48	Very poor
5	SD16d	*Salix repens-Holcus lanatus* dune-slack	*Agrostis stolonifera*	57	Poor
6	SD15	*Salix repens-Calliergon cuspidatum* dune-slack		56	Poor
7	SD15	*Salix repens-Calliergon cuspidatum* dune-slack		63	Fair
8	SD14d	*Salix repens-Campylium stellatum* dune-slack	*Festuca rubra*	41	Very poor
9	SD14	*Salix repens-Campylium stellatum* dune-slack		39	Very poor
10	SD14	*Salix repens-Campylium stellatum* dune-slack		46	Very poor
11	SD14d	*Salix repens-Campylium stellatum* dune-slack	*Festuca rubra*	42	Very poor

12	SD16d	*Salix repens-Holcus lanatus* dune-slack	*Agrostis stolonifera*	67	Fair
13	SD16d	*Salix repens-Holcus lanatus* dune-slack	*Agrostis stolonifera*	65	Fair
14	SD15	*Salix repens-Calliergon cuspidatum* dune-slack		59	Fair
15	SD16d	*Salix repens-Holcus lanatus* dune-slack	*Agrostis stolonifera*	75	Good
16	SD16a	*Salix repens-Holcus lanatus* dune-slack	*Ononis repens*	39	Very poor
17	SD17d	*Potentilla anserina-Carex nigra* dune-slack	*Hydrocotyle vulgaris-Ranunculus flammula*	64	Fair
18	SD16c	*Salix repens-Holcus lanatus* dune-slack	*Prunella vulgaris-Equisetum variegatum*	30	Very poor
19	SD16	*Salix repens-Holcus lanatus* dune-slack		32	Very poor

Table 5. Spearman Rank correlation coefficients (above) and p-values (below) for relationships between habitat variables in quadrats

	Species no.	**Sward height**	**Site age**	**% cover *E. variegatum***	**Distance from sea**	**Soil pH**
Species no.	_	-0.36 0.13	-0.19 0.44	-0.31 0.20	0.27 0.26	0.00 0.99
Sward height	-0.36 0.13	_	0.75 0.00	-0.18 0.46	0.12 0.62	0.25 0.29
Site age	-0.19 0.44	0.75 0.00	_	-0.52 0.02	0.22 0.36	0.11 0.66
% cover *E. variegatum*	-0.31 0.20	-0.18 0.46	-0.52 0.02	_	-0.46 0.05	-0.12 0.64
Distance from sea	0.27 0.26	0.12 0.62	0.22 0.36	-0.46 0.05	_	-0.35 0.14
Soil pH	0.00 0.99	0.25 0.29	0.11 0.66	-0.12 0.64	-0.35 0.14	_

Equisetum variegatum was not found at nine sites (32%) that had previously held populations. In all but one of these, field descriptions referred to overgrowth by coarse vegetation and scrub, especially of *Hippophae rhamnoides* (Sea Buckthorn), *Salix repens* and *S. cinerea* (Grey Willow). The exception was slack no. 13, Birkdale Sandhills LNR. Although recorded by Hunt (2019) as supporting *E. variegatum*, this site had since been churned into bare sand by heavy recreational trampling (Fig. 4). Eleven (58%) of the quadrat sites were considered to be threatened by scrub

development, mainly of the above species, together with *Betula* sp. (birch), and one (6%) by *Phragmites australis* (Common Reed), while seven sites (37%) did not appear to be imminently threatened. Only two quadrat sites (11%) showed evidence of rabbit grazing; these had mean sward heights of 6 and 14.2 cm, respectively, compared with the overall mean of 15.3 cm. No quadrats were situated in compartments grazed by livestock.

Discussion

Despite losses to historical urbanisation in the south of its range, *E. variegatum* can still be found sporadically in slacks and scrapes along most of the Sefton frontal dunes from Hightown to Southport, with the exception of a 2 km stretch at Formby Point. The latter coincides with an area of duneland used in the past for growing asparagus (*Asparagus officinalis* subsp. *officinalis*), which involved levelling dunes and filling in slacks to create arable fields (Yorke & Yorke, 2008).

Figure 4. Slack 13, Birkdale Sandhills LNR; vegetation, including *Equisetum variegatum*, destroyed by public pressure

Stark (1991) and Page (1997) point out that the morphology of *E. variegatum* is variable, named varieties being identified by various authors. Thus, Page (1997) describes var. *variegatum* found in most of England, Scotland, Wales and some Irish localities; var. *arenarium*, a prostrate form of coastal dunes; var. *wilsonii*, with smooth stem internodes, described in the 19th century from Co. Kerry and var. *majus* a robust, strongly erect plant, with shoots up to 80 cm high, this being the more usual type in Ireland. However, Stark (1991) concludes that morphological grounds for separating ecotypes of *E. variegatum* are slim. During the present study, an upright form to about 25 cm was noted in vehicle ruts at one site. Rodwell (2000) refers to a striking tussocky growth-form in places where *E. variegatum* is

particularly abundant, perhaps due to rapid shoot proliferation in early stages of colonisation. The vehicle ruts were only eight years old at the time of the study.

Equisetum variegatum was most often found in calcareous dune-slacks, a habitat known to be favoured by this species (Dixon & Dines, 2023; Merryweather, 2020; Page, 1997; Stace, 2019). The second most frequent habitat was excavated scrapes that hold surface water for part of the year. Those supporting *E. variegatum* were reprofiled in 2012 or 2013 and therefore have early stage successional slack vegetation. Hunt (2019) reported the presence of *E. variegatum* in 13 of 42 scrapes studied in Ainsdale NNR, Ainsdale LNR and Birkdale LNR. However, the plant was assessed as 'rare' in eight of these scrapes (62%), being 'occasional' in four and 'abundant' in only one. Also, many of Hunt's sites were older scrapes, supporting tall vegetation.

The present study suggests that *E. variegatum* favours younger habitats with an average age of 37±18 years and shorter vegetation (mean height 15.3±5.5 cm). Some of the sites were thought to be up to 60 years old, indicating that *E. variegatum* can survive for long periods in slack vegetation, provided that sward heights remain low. However, older sites tended to have taller swards, presumably resulting from ecological succession in the absence, in most cases, of grazing. The presence of gley or peaty-gley soils with a relatively high sub-surface pH (mean 7.39±0.41) accords with the description of Sefton dune-slack soils given by James (1993).

The habitat features associated with *E. variegatum* are similar to those found in other studies of notable plants in Sefton dune-slacks, such as *Blysmus compressus* (Flat-sedge) (Smith, 2019), *Carex viridula* (Small-fruited Yellow-sedge) (Smith, 2017) and *Parnassia palustris* (Grass-of-Parnassus) (Smith & Deed, 2014): namely, relatively young calcareous dune-slacks, with short swards and high soil pH values. The poor correlations between most habitat variables for *E. variegatum* may be partly attributable to the small number of samples, correlations based on small sample sizes being quite unreliable (Steel *et al.*, 2013). A significant positive relationship between site age and sward height may be attributed to vegetation development and biomass accumulation during succession (Grootjans *et al.*, 1998). Similarly, the negative relationship between site age and % cover of *E. variegatum* may be due to succession producing less favourable conditions for a plant thought to have a low competitive ability (Dixon & Dines, 2023).

The high vascular species-richness of 78 taxa in the quadrats, including 26% notable plants, is characteristic of relatively young dune-slack vegetation on the Sefton Coast (Smith, 2009) and, more generally, in Northwest Europe (Grootjans *et al.*, 1998). Thus, Smith (2006) identified 150 vascular plants in 26 slacks in the Birkdale frontal dunes. Most of these slacks were then only about 10 years old, having been formed by wind-erosion. Twenty (13%) of his plants were considered notable but this was before revised Red-listings became widely available. Thus, Stroh *et al.* (2014) increased the number of 'notable' vascular taxa for the Sefton dune system from 177 to 208, many of these being slack plants (Smith, 2015).

Only 5% of the vascular associates of *E. variegatum* were non-native, a much lower proportion than the 37% aliens for the dune flora as a whole (Smith, 2015). Smith (2020) found that Sefton dune wetlands supported a significantly lower number of non-natives than native vascular plants. He suggested that this is because alien plants are less likely to have evolved the adaptations needed to thrive

in soils that are subjected to seasonal flooding and waterlogging, with associated low oxygen levels and high sulphide concentrations.

As found in the present study, Rodwell (2000) reported that *E. variegatum* occurs in all the NVC slack communities: SD13, 14, 15, 16 and 17. In Sefton, a majority of quadrat samples (seven) showed accordance with SD16: *Salix repens-Holcus lanatus* dune-slack. This type is typically associated with older, drier slacks, rarely flooded to any great extent, even in wetter winters, and is the most extensive slack vegetation around the coasts of England, Wales and south-east Scotland. Where grazing is absent or limited, as in the study sites, the community is susceptible to tree and shrub invasion (Rodwell, 2000). SD15: *Salix repens-Calliergon cuspidatum* dune-slack was the second most frequent community (six quadrats). This is a widely distributed type around UK dune coasts, especially in older slacks kept wet by prolonged flooding of circum-neutral ground-water. The presence of *E. variegatum* implies more base-rich soils. In drier conditions, succession towards shrubs and trees may occur, especially in the absence of grazing by rabbits and livestock. Rodwell (2000) mentions *Salix cinerea* and *Betula* as early colonists of SD15, these being noted at several of the study sites (Fig. 5). SD13: *Sagina nodosa-Bryum pseudotriquetrum* dune-slack had accordance with only one sample. It is characterised by short, open swards of early-stage, calcicole vegetation in young slacks that are briefly flooded in winter but dry in summer. Maintaining their open character may depend on rabbit and/or livestock grazing. SD13 has been described for relatively few dunelands around the British coast. Similarly, SD17: *Potentilla anserina-Carex nigra* dune-slack was found in only one quadrat. This vegetation is associated with damp or wet-slacks kept moist by fluctuations of less base-rich ground waters. It is widespread, especially in northern Britain where it is often the most extensive slack community. Livestock grazing may help to restrict invasion by scrub and trees (Rodwell, 2000).

Figure 5. Quadrat site on Birkdale Green Beach, showing wheel ruts and encroaching scrub

Eleven (58%) of the quadrats had poor or very poor statistical fits to NVC vegetation types. Poor accordance with NVC communities has been found in several previous studies of Sefton Coast vegetation. Smith (2019) discusses possible reasons for this, including the complex environmental gradients associated with dune-systems, the difficulty of selecting 'typical' stands in vegetation mosaics and the limited number of quadrats used to define NVC dune communities (Natural England, 2014). Hill (2015) recommends that, if goodness-of-fit is 'very poor', the vegetation should probably not be assigned to any NVC type. This apples to nine (47%) of the quadrats, with SD13, SD14, SD15 and SD16 being represented (Table 4). That leaves four SD15 quadrats, five SD16 and one SD17 with acceptable levels of fit, nevertheless confirming that *E. variegatum* grows in a wide range of dune-slack community types (Rodwell, 2000).

Ellenberg Indicator Values show that *E. variegatum* is associated with wet, oligotrophic conditions (Hill *et al.*, 2004). However, there is evidence that the Sefton dunes are becoming drier and more eutrophic, with less slack habitat. Thus, Natural England (2014) found a 26% and 44% reduction in wetland area at Ainsdale and Birkdale dunes, respectively, between 1989 and 2012, due to slack habitats becoming drier. In their NVC studies of the Sefton Coast, Gateley & Michell (2004) reported large declines in the young slack types SD13 and SD14 during the 15 years between 1988/89 and 2003/04. They attributed this to vegetation maturation and the lack of new slack formation caused by vegetation overgrowth and nutrient enrichment. They also found a marked loss of older slack types: SD15 and SD16, perhaps due to the spread of dune scrub, mesotrophic swards and swamp communities, as well as dune drying (Natural England, 2014). Such trends may adversely impact the habitat of *E. variegatum.*

Aerial deposition of nitrogen from domestic, industrial and agricultural sources has been identified as an important factor leading to eutrophication of dune-slacks (Jones *et al*., 2004). With an Ellenberg Indicator Value for nitrogen of 3, *E. variegatum* is adapted to infertile conditions. This species is therefore likely to be adversely affected by eutrophication. Jones *et al.* (2004) recorded N-deposition in the range of 10-29 $kgNha^{-1}yr^{-1}$, suggesting a critical load for UK coastal dunes of 10-20 $kgNha^{-1}yr^{-1}$. Pakeman *et al.* (2016) found that coastal vegetation was highly sensitive to aerial N-deposition, with mobile dune, semi-fixed dune and dune-slacks amongst the most susceptible habitats. However, Kammer *et al.* (2022) pointed out that N-deposition in Europe reached a peak in about 1990 and has decreased since by about 25%. His study of grasslands in Switzerland showed that the number of oligotrophic plant species increased at sites showing a large decrease in N-deposition. Despite the post-1990 reduction, the rate of N-deposition may still be above the critical level for oligotrophic dune habitats (Pakeman *et al.*, 2016).

It is evident that *E. variegatum* is associated with habitats of high nature conservation value in the study area. However, it is concerning that only six (32%) of the populations surveyed were described as 'large' and that the plant has been lost from nine localities that recently supported it, while 58% of extant sites were considered threatened by coarse vegetation and scrub invasion. The latter problem has been highlighted in several ecological studies of scarce vascular plants on the Sefton Coast (Smith, 2021), being attributed to a range of factors, especially the decline in rabbits, abandonment of livestock grazing, aerial deposition of nitrogen,

introduction of non-native trees and shrubs and climate change. Rabbits, in particular, are known to have a major influence on sand-dune vegetation, being described as a 'keystone species' (van der Hagen, 2022). However, this grazer tends to be excluded once coarse vegetation becomes established (Drees & Olff, 2001). Only two of the *E. variegatum* sites showed evidence of rabbit grazing.

Re-introduction of grazing by traditional breeds of sheep and cattle on some Sefton duneland properties since the early 1990s has helped to maintain shorter swards (personal observations) but grazed areas exclude the frontal dunes where most of the slacks supporting *E. variegatum* are found. Also, livestock tend to avoid seasonally flooded slacks, with the result that, over time, these are invaded by scrub and trees (Pye *et al.*, 2020). Populations of *E. variegatum* threatened by scrub invasion, especially by *H. rhamnoides*, *S. cinerea* and *S. repens*, require targeted scrub control. Austerity policies over the last decade have led to increasing reliance on volunteers to control scrub using hand-tools, rather than the machinery needed to tackle older and larger scrub patches. It is hoped that recent large-scale mechanised scrub clearance by land-owners, land managers and especially the national *Dynamic Dunescapes* project, will improve the condition of slacks and assist conservation of species that require open conditions, including *E. variegatum*. However, the latter project is limited in time and resources; there is a requirement for consistent, reliable funding so that planned vegetation management can be carried out on a long-term basis. The recent adoption of 'Countryside Stewardship Higher Tier' in parts of the dune system (G. White, personal communication) may assist with that objective.

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