Dawlish Warren NNR

trampling & nutrient enrichment assessment

2023

December 2023

Contents

1 INTRODUCTION

1.1 BACKGROUND

An assessment of recreational impacts on Dawlish Warren SAC in 2010 by Footprint Ecology (Lake 2010) concluded that trampling from high footfall, eutrophication from dog fouling, and wildfires were the main anthropogenic factors affecting vegetation on site.

In 2019 Devon Biodiversity Record Centre (DBRC) surveyed the habitats and vegetation of Dawlish Warren NNR on behalf of Teignbridge District Council. The report included a mapped assessment of trampling and eutrophication pressures, funded by the South East Devon Habitat Regulations Partnership (SEDHRP), as an adjunct to the main survey (DBRC 2020).

Subsequent study of visitor numbers at the site (Caals, Panter & Liley 2022) indicates a significant increase since 2010 with the implication that this may translate into higher recreational pressures in the form of damage to habitats and species in the NNR through trampling and nutrient enrichment.

In order to keep a continuing monitoring brief on these trends SEDHRP instructed DBRC in 2023 to provide an updated assessment on the pressures of trampling and nutrient enrichment on Dawlish Warren NNR.

1.2 OBJECTIVES

The objectives of this project were to

- Produce detailed, colour coded heat maps of areas of fixed dune and dune slack vegetation subject to significant trampling pressure.

- Identify, and list in order of severity, any areas of fixed dune and/or dune slack vegetation at risk of significant erosion from trampling pressure.

- Identify and map areas of fixed dune and/or dune slack subject to nutrient enrichment from dog fouling.

- Analyse, compare and interpret emerging patterns, trends and/or points of difference between the 2019 survey and the 2023 survey.

2 METHODOLOGY

2.1 STUDY AREA

The objectives of the current study specifically relate to fixed dune and dune slack vegetation. In 2019 the whole dune system within the NNR boundary (i.e. including areas of mobile dune and some other habitats) was included in the primary assessments of trampling risk and nutrient enrichment risk. Mobile dune communities (and mosaics involving them) covered approximately one third of the vegetated area of the NNR in 2019). Impacts on these habitats indirectly, if not directly, affect fixed dune and dune slack habitats and to provide a consistent basis for comparison with the earlier work the same study area was assessed (i.e. not excluding mobile dunes) on the basis that conclusions specific to fixed dune and dune slack habitats could still be drawn.

2.2 TRAMPLING ASSESSMENT

The collection of trampling data followed the same methodology as used in 2019 (DBRC 2020).

The survey area was gridded within a GIS into 25m x 25m cells (see Figure 1). This resolution of study was chosen as being sufficiently fine to illustrate major patterns whilst still being feasible within the space of the project. It also aligns with the earlier study undertaken by Footprint Ecology to identify areas at risk of erosion from trampling (Lake 2010).

A qualitative 5-point scale was defined in order to estimate trampling intensity and erosion risk (as a simple artificial composite score) in each square. This was based primarily on observations of the standard indices of trampling effects on vegetation (Cole & Bayfield 1993): loss of plant cover, reduced vigour or stature and damage (e.g. breakage and bruising of stems). Observations on substrate condition (erosion and compaction) were also used to qualify these, particularly in later ground-truthing of desk-based assessments.

Grid cells were assigned to the 5 categories using the following guidelines:

1. Slight risk/impact areas. <5% bare substrate overall and not obvious generally in air photos, areas usually with continuous cover of semi-natural vegetation. Typically, areas on level ground or gentle slopes (≤3˚). Where no recent grazing, mowing or strimming management, vegetation usually includes elements of tall sward, underscrub or woody features at least locally. Where shorter vegetation-maintained trampling-sensitive plants such as *Sedum* spp., Orchidaceae and fruticose lichens such as *Cladonia* spp. may form vigorous stands. Transition zones between disturbed and undisturbed either not visible or of minimal extent.

2. Lower risk/impact areas. Typically 5%-10% exposed sand or soil area with low density of desire paths of low width (<50cm). Transition zones between disturbed and undisturbed may be evident but not a conspicuous feature, with areas of reduced height vegetation localised around lines of access.

3. Moderate risk/impact areas. Typically <10% exposed sand or soil area due to trampling but diffuse effects more marked. Trampling impacts evident as reduced height sward at least locally. Sward generally not abraded so far as to cause erosion except localised at pinch points, path junctions etc. Areas usually traversed by significant (≥1m wide) formal tracks or paths or well-established desire paths. Transition zones obvious and occupying significant areas, with secondary effects of larger formal paths and trackways evident on adjacent vegetation. Paths in areas of fixed dunes with broad trample zones characterised by very short vegetation but not extensively re-mobilising sand. Tall herbs scrub and underscrub may be present but if so scattered and localised, with average distance between woody vegetation patches ≥10m. Increased abundance of trampling resistant genera in sward (e.g. *Poa* and *Plantago coronopus* and *Carex arenaria*) relative to 1 and 2.

4. High risk/impact areas. Intermediate to 3 and 5. May be some incipient braiding of desire paths in transition zones. Trampling resistant species usually abundant.

5. Very high risk/impact areas. Usually >15% exposed sand or soil. Typically, but not exclusively, areas on steeper slopes (>7˚). Typically high density of desire paths through semi-natural vegetation some of which broad (≥50cm) with obvious secondary erosion including heavily compacted transition zones and braiding effects where path users avoid mobile sand of main line to walk on fixed or semi fixed turf adjacent. Marked erosion hotspots at path junctions. Vegetation height clearly reduced in significant (>10%) proportions of the area. Reduced vegetation cover and vigour effects extend to trample-resistant species (e.g. *Poa* and *Plantago coronopus* and *Carex arenaria*).

Initially cells within the grid were assessed with reference to high resolution aerial imagery (GetMapping, Google Earth and Bing Maps) from the years 2019 to 2022. In total 573 cells covering the entire site were assessed.

A sample of 183 cells were then ‘ground-truthed’ between July and September 2023, with each cell being re-assessed using the same criteria in the field. The cells ground-truthed were selected to include a representative range of the values determined by aerial photo interpretation. It was found that the seasonal variation in aerial imagery and impacts of drought in the summer of 2022 meant that certain cells were considered ambiguous or determined with low levels of certainty. These areas were therefore included in the list of squares to be assessed in the field. The Locus GIS app was used in the field to collect photos and data whilst displaying the 25m x 25m grid and surveyor’s GPS position.

Of the ground-truthed squares 39 were changed from the initial API scoring, giving it an accuracy of around 79%. Since the necessary adjustments were all minor in scale this was considered an acceptable degree of accuracy for the purposes of the survey, particularly as all squares that were flagged as being of low certainty at the desk-based stage were checked on the ground.

Photographs of each ground-truthed cell were taken within the Locus GIS App. The intention was to provide ground level photographic evidence of trampling which could be used for future reference and comparison. These data are provided as an appendix to the report.

Sand dunes are dynamic systems, which are influenced by both human and natural processes. As a result, some areas of naturally mobile sand may have been incorrectly assigned a higher trampling value. However, the ground truthing of the site by a surveyor aimed to reduce the likelihood of this effect. For example, in transition zones between beach and dune, only the dune area was considered during the assessment.

The area overlying the Geotube located at ‘The Neck’ of the warren was not assessed due to the limited presence of vegetation and access for walkers and other users of the warren.

The dataset from this assessment was processed in QGIS (QGIS Development Team 2019) using Inverse Distance Weighting (IDW) Interpolation on the revised (ground-truthed) trampling scores and a distance coefficient of 2. The interpolated dataset was then rendered as a ‘Heatmap’ covering the survey area and a 30 metre buffer to provide a continuous graphical surface for visualisation of trampling impacts. The source GIS data are retained.

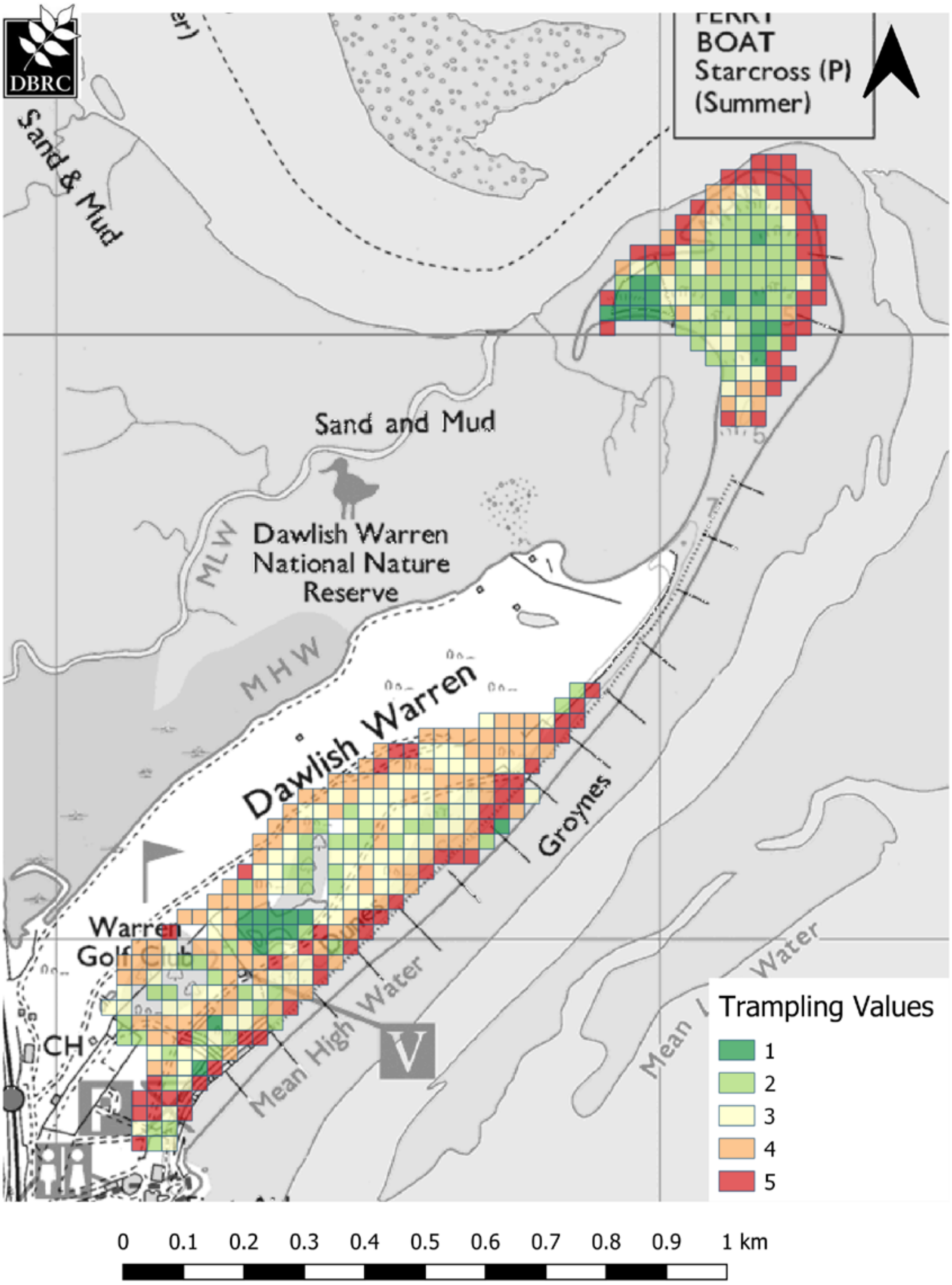


Figure 1. Grid used to determine levels of trampling and for recording vegetation composition (sampled squares only). Trampling values shown for illustrative purposes only.

2.3 NUTRIENT ENRICHMENT ASSESSMENT

In order to standardise collection of data on eutrophication risk on the site, the methodology from the 2019 survey (which drew on vegetation quadrat data from NVC surveys in 2012 and 2019) was adapted. An approach that was relatively simple, did not necessitate the labour-intensive collection of large volumes of vegetation data and could be integrated with the grid-based trampling assessment was needed.

Initially squares from the 25m x 25m grid were selected for vegetation assessment based on the location of quadrats used in previous assessments. This selection was then expanded to provide a wider and representative coverage of the site.

As in the trampling assessment, the surveyor utilised Locus GIS to determine the location of squares, and their own GPS position. The surveyor would then compile a species list from the centre of the square, and take photographs of the vegetation present. Species abundance was estimated and noted using the DAFOR scale.

2.3.1 INDICATIVE MAPPING OF SOIL FERTILITY

An indicative measure of fertility was derived using an adapted Ellenberg score for nitrogen, which provides a general indicator of soil fertility (Hill *et al*. 1999). The Ellenberg score for each species within a square was weighted using the DAFOR value it had been assigned with:

D = 5

A = 4

F = 3

O = 2

R = 1

Weighted score for each square= Sum (E*c) / No. species

E = Ellenberg score for each species

c= DAFOR value

IDW interpolation was then used to generate a heat map visualisation which would indicate areas of nutrient enrichment throughout the site.

In addition to this, anecdotal records of dog fouling were recorded spatially to provide supplementary information to be used alongside the heatmap. This was superimposed on the heat map to provide additional context and aid interpretation of the vegetation data.

Previous surveys included specific locations of nutrient-tolerant grass species for similar purposes. These have not been mapped spatially in the present work, as they were already included within the species data.

2.3.2 MAPPING OF ANTHROPOGENIC NUTRIENT ENRICHMENT INDICATORS AND RISK ZONES

Analysis of composite Ellenberg scores does not in itself distinguish between nutrient enrichment caused by recreational use of the site and pockets of soil and habitat which have naturally developed fertility through autogenic processes (accumulation of soil organic matter, N fixation etc).

To further develop the proxy information on fertility available for interpretation a second stage of analysis using indicator species was taken. A subset of the species recorded in the survey samples (above) were identified as generalists known to be indicative of soil 'improvement', and enrichment from anthropogenic nutrient inputs in the context of the low nutrient habitats historically characterising the dune grassland of the site. These were either species of intermediate to high Ellenberg N values or generalist species known to invade and out-compete low nutrient adapted specialists under conditions of nutrient enrichment. The list excluded native woody species and tall herbs characteristic of specialist semi-natural habitats.

Anisantha sterilis	Barren Brome
Anthriscus sylvestris	Cow Parsley
Arrhenatherum elatius	False Oat-grass
Cirsium arvense	Creeping Thistle
Galium aparine	Cleavers
Heracleum sphondylium	Hogweed
Hordeum murinum	Wall Barley
Lolium perenne	Perennial Rye-grass
Plantago lanceolata	Ribwort Plantain
Plantago major	Greater Plantain
Ranunculus repens	Creeping Buttercup
Rumex obtusifolius	Broad-leaved Dock
Trifolium repens	White Clover
Urtica dioica	Common Nettle

For each grid square a composite indicator score based on the relative abundances of any indicator species present was calculated by summing their DAFOR values (D = 5, A = 4, F = 3, O = 2, R = 1).

A second heatmap showing the relative concentrations of indicators of anthropogenic enrichment was generated from this dataset in the same way as above (2.3.1) and annotated with localised records of recent dog fouling which could be used to aid interpretation of the indicative soil fertility map.

3 RESULTS

The results of the surveys and investigation into trampling and eutrophication rates are shown in graphical form as grid maps and heat maps. These outputs are discussed in section 4.

3.1 TRAMPLING

The pattern of trampling and erosion risk throughout the site remains complex (Figure 2). The majority of hotspots are centred around access points to the reserve, path nodes and corridors between the amenity beach and the interior of the site. The broad spatial distribution of these risk areas is the same as in 2019. Changes are discussed in section 4.3. There has been significant erosion around the edge of Warren Point. A large number of squares assessed in the previous survey no longer contain vegetation and the 2019 pattern of linear pressure from walkers that follow the edge of the beach and dunes around the point has simply been replicated along the newly eroded edges of established SD6 and SD7 vegetation (mobile and semi-fixed Marram grass habitats).

3.2 NUTRIENT ENRICHMENT

The results of the indicative soil fertility mapping (Figure 4, 2.3.1) show higher levels of fertility:

1. in and around the southern end of the site near the entrance gates and in a corridor between the entrance and the visitor centre
2. in the dune slack to the west of the main trackway
3. At the narrowing west of groynes 8 to 10.
4. in some diffuse areas within the Marram grassland on Warren Point

Examination of the information on species considered indicative of dog fouling (Figure 5, 2.3.2) indicates that 1 (above) is the key area of risk with some more moderate effects scattered along the back path and in the area of grassland between the main trackway/Greenland Lake and the dune ridge level with groynes 5 to 8.

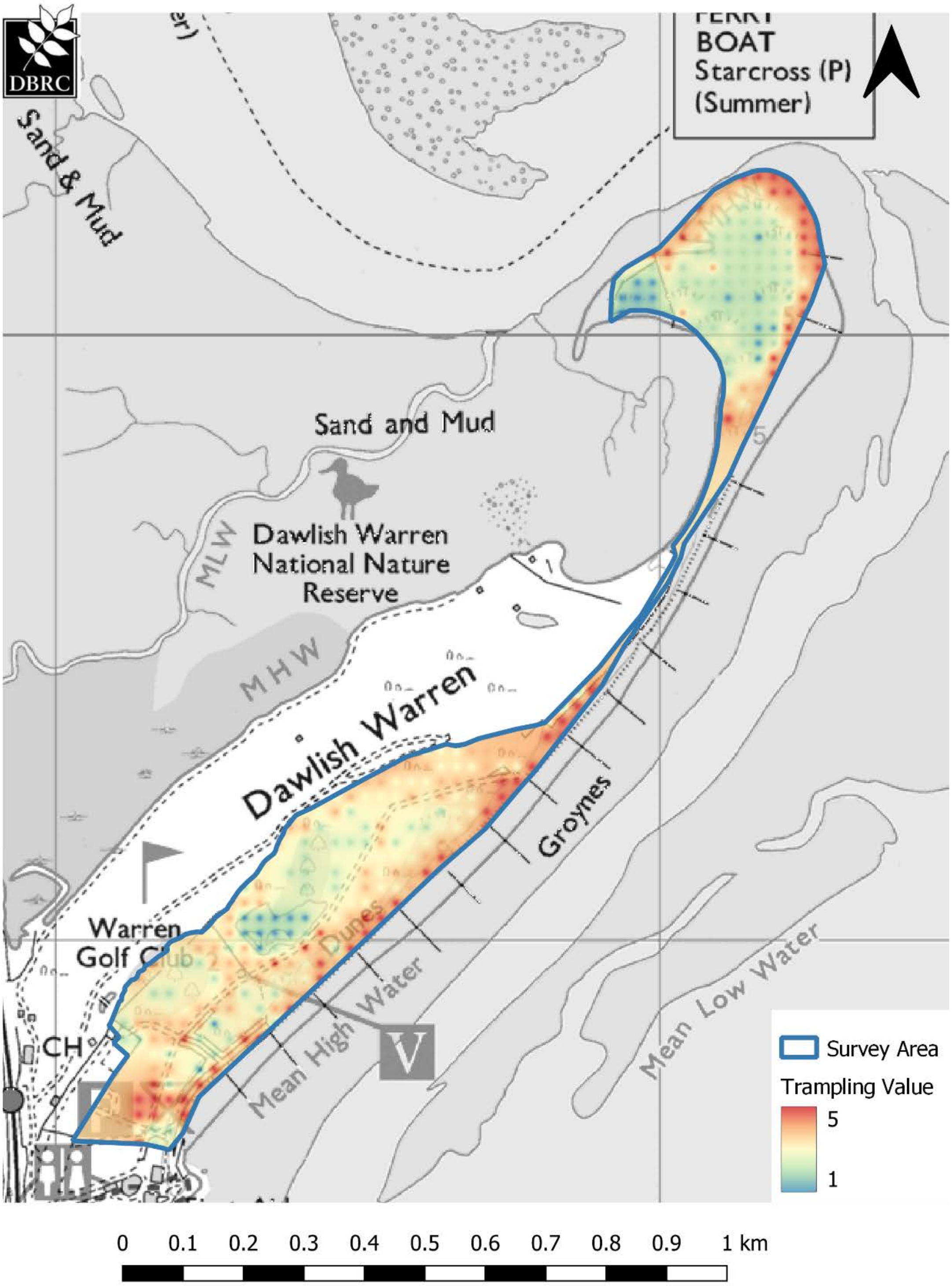


Figure 2. Heatmap showing estimated trampling levels throughout Dawlish Warren based off of the 5 point scoring, with reds representing higher levels of trampling.

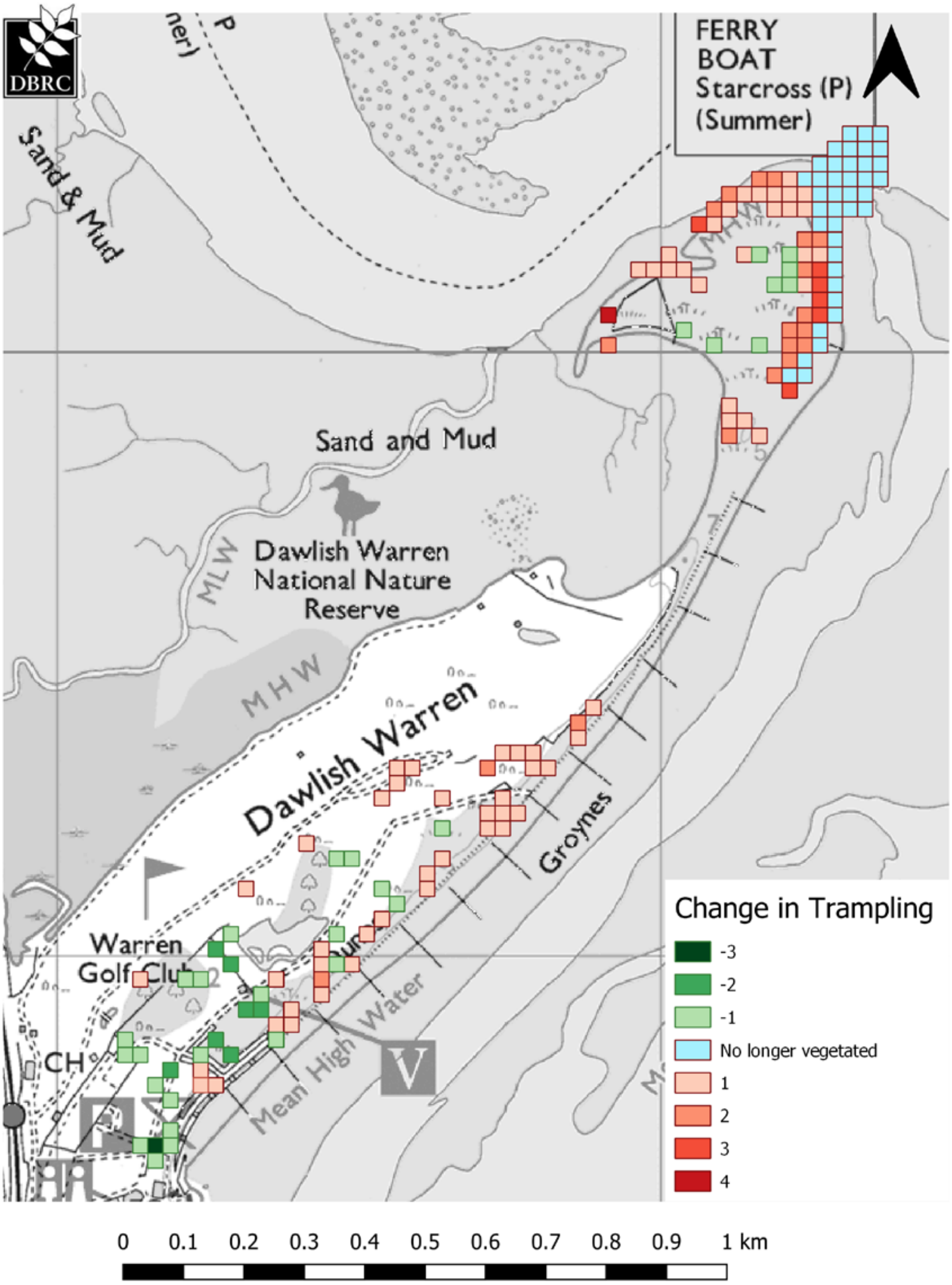
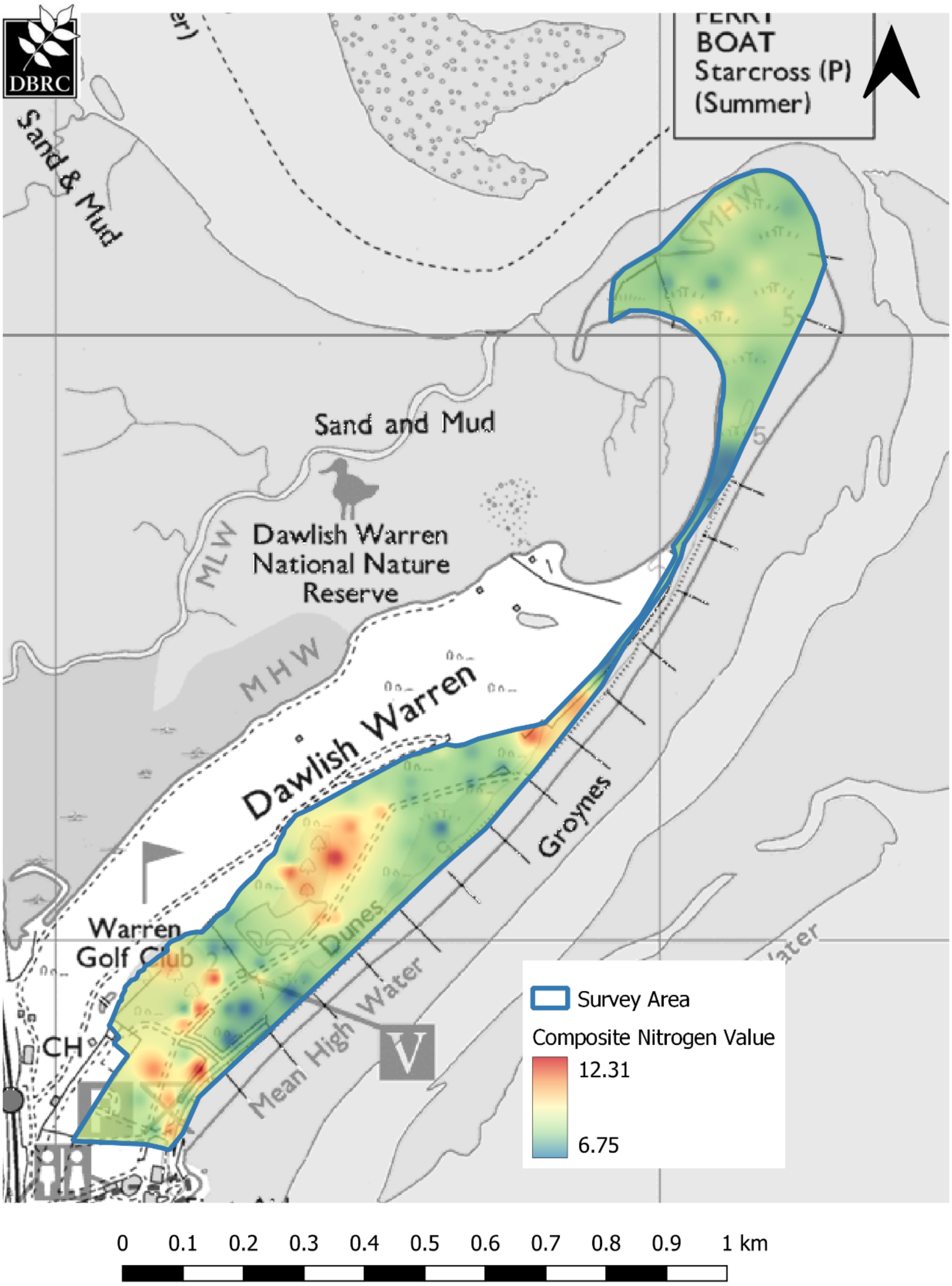


Figure 3. Grid squares that have either shown a reduction or increase in trampling and erosion since 2019. Note that reduction need not imply removal of risk.



 Map produced 2023.

Figure 4. Heatmap showing estimated fertility levels as expressed in vegetation composition across the site. Reds correspond to higher N values. Graphic is based on interpolation of abundance-weighted N values derived from species composition of 91 25m square sample plots. Note that high N values may have multiple causes. The weighted N values ranged from 6.75 to 12.31 (mean 8.65) – this scale is arbitrary and for comparative purposes only.

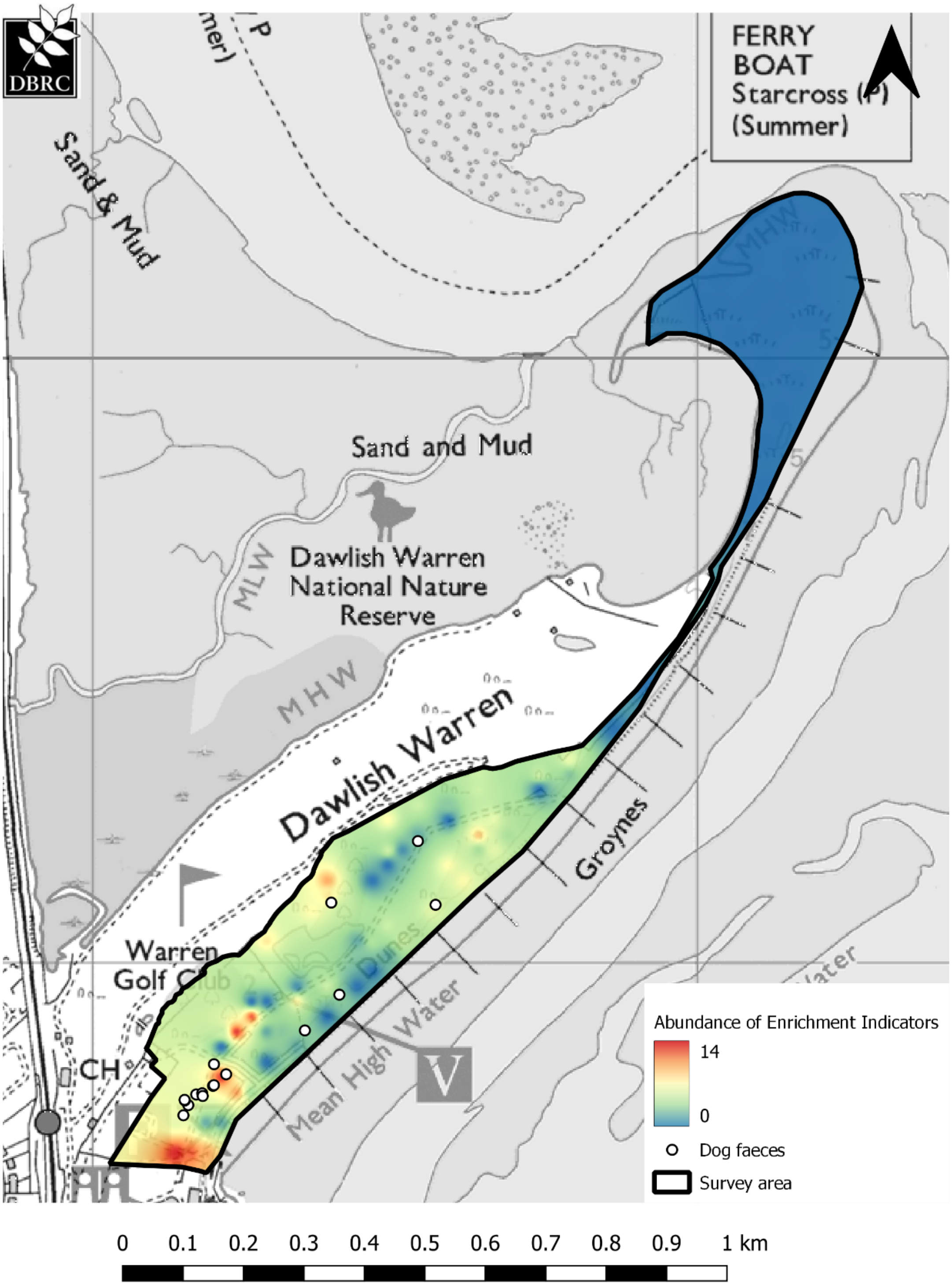


Figure 5. Heatmap showing indicative abundance and distribution of vascular plant species indicative of anthropogenic nutrient enrichment in the context of dune grassland and dune slack habitats at Dawlish Warren. The location of recent dog faeces recorded during the fieldwork are shown for added context. Note this map is interpolated from samples (see text) not based on a full vegetation survey.

4 CONCLUSIONS AND DISCUSSION

4.1 AREAS AT RISK OF SIGNIFICANT EROSION FROM TRAMPLING PRESSURE

The significant areas of risk from erosion from recreational trampling pressure are mostly associated with the frontal dune ridge. These are often in areas which technically belong to mobile dune vegetation types but are partially stabilised. Specifically for fixed dune and dune slack habitats the risk areas in order of decreasing severity are:

1) A small area of dune grassland at the extreme south end of the reserve next to the pedestrian entrance and adjacent to the buffer zone.

2) A particularly high density of path nodes and desire lines concentrates pressure on a relatively small area where the site narrows to the dune ridge level with groyne 8. Here there are a mixture of grassland types including dry and damp communities with the dune slack habitat reaching its northern limit flanked by areas of both fixed and semi-fixed turf.

3) The SD12 turf in a corridor on both sides of the main access track and footpath from the south end of the reserve to the visitor centre. Abrasion is frequent in these areas and is necessary to maintain the habitat suitable for some notable species present but risk of abrasion turning to net erosion and habitat loss is still significant.

4) The SD12 turf along the back path and in a corridor linking the back path and main trackway between the visitor center and pond (i.e. along south edge of flood bank). Impacts are more diffuse in these areas but moderately high locally.

Reference to Figure 1 and Figure 2 will provide further spatial detail on specific pressure spots.

4.2 AREAS SUBJECT TO NUTRIENT ENRICHMENT FROM DOG FOULING

The impact of dog waste (including urine and faeces) deposited on the low nutrient soils of sand dune habitats is not well understood. There is little empirical evidence or research from which to draw on for mitigation or management strategies. Jones et al. (2004) found that the varying habitats and soils within a sand dune system responded to atmospheric N deposition in complex and non-linear ways. An assumption that dog fouling causes increasing levels of plant-available Nitrogen (and Phosphorous) has been anecdotally correlated with observations of the spread of generalist or nutrient demanding forbs, grasses and shrubs (at the expense of specialist less competitive species of more open habitats).

There is an expectation in the succession of duneland habitats that nutrient status will naturally accrue - with relatively low levels in mobile sand communities gradually increasing inland. Ultimately old fixed dune grassland (as on the acid fairways of the golf course adjacent) may become very nutrient depleted due to leaching. Areas of fen or tall herb vegetation including some of the habitats found within maturing dune slacks (such as around Greenland Lake) may naturally have higher fertility values due to the significant accumulation of organic matter into the soil system in comparison to the intrinsically low-nutrient sand-derived substrates of the grassland habitats lying seaward in the zonation.

It should be noted that species 'Ellenberg N values', as published, were primarily derived from descriptive relationships between species distribution and soil fertility, not upon experimental data. A high N value can be seen as a general indicator of soil fertility rather than as a nitrogen index (Hill and Carey 1997). Whilst N values have been used in this study as a proxy for mapping fertility it should be noted that it is an untested assumption that a causal relationship between dog fouling and increased N values exists in dune vegetation.

The map at Figure 4 therefore gives context on the distribution of species and vegetation associated with higher fertility soils but does not necessarily indicate anthropogenic nutrient enrichment (from recreational use and dog fouling). A further layer of interpretation drawing on the incidence of indicator species (Figure 5) has been applied to interpret the areas listed at 3.2.

1. the southern end of the site near the entrance gates and in a corridor between the entrance and the visitor centre

Although no systematic survey of dog use was undertaken, the occurrence of visible dog fouling was recorded during the survey and this broadly coincided with the areas where dog faeces were most encountered and the highest recorded abundance of indicator species (Figure 5). It is also a high-pressure area for trampling.

2. the dune slack to the west of the main trackway

Contrary to Figure 4 indicator species were not abundant in this area. The vegetation data indicate that the apparent fertility here is more likely to be driven by autogenic than anthropogenic processes with the development of tall herb communities and willow regeneration. However, it is possible that dog fouling does contribute and that nutrients deposited in adjacent areas of higher usage may collect here.

3. the narrowing west of groynes 8 to 10.

Although this is an area of elevated trampling pressure (with the potential for dog fouling effects to be concentrated) the apparent fertility is thought to be related more to vegetation and disturbance history in this area than direct effects of dog fouling. This area has supported rank *Arrhenatherum* grassland and scrub in the past (Wheeler and Wilson 2013, DBRC 2020) and subsequent management or the persistence of woody vegetation may influence nutrient levels.

4. some diffuse areas within the Marram grassland on Warren Point

It is unlikely that this is directly influenced by recreation, due to the limited footfall (and dog ban) within the area. When reviewing the species data of high scoring quadrats within Warren Point, the majority of them supported frequent populations of bramble and evening primrose (*Oenothera* spp.), which both score 5 on the Ellenberg scale. The abundance of these species has weighted the scores towards the upper end of the scale and could suggest that the lack of disturbance or over stabilization of dune grassland in these areas is resulting in succession and attendant accumulation of organic matter and nutrients – i.e. autogenic rather than anthropogenic enrichment (although atmospheric nitrogen deposition may also be a factor in this vegetation).

Figure 6, below, is based on interpretation of the data presented in Figure 4 and Figure 5 alongside knowledge of vegetation community sensitivity and patterns of trampling risk and pressure.

4.2.1 AREAS SUBJECT TO HIGH AND MODERATE RISK FROM DOG FOULING

High

1) In conclusion an area of dune grassland (comprising a mixture of NVC communities SD7 and SD12) approximately 0.25 ha in size at the SE corner of the reserve (immediately east of the main access path) is the part of the site most prone to nutrient enrichment. It is also significantly more affected than the rest of the site. Floristically, this area was observed to be in a process of shifting from dune grassland towards mesotrophic grassland in the 2019 vegetation survey (DBRC 2020). It supports the Nationally Scarce species, *Trifolium glomeratum* (Clustered Clover), which is also scarce on the reserve. The level of nutrient enrichment here is comparable with that in the buffer zone immediately to the SE of this area (included on the maps for comparison). The relative limitation of this area within the reserve does demonstrate the function of a buffer zone in mitigating inputs.

Moderate (in order of decreasing severity)

2) The area of SD12 fixed dune grassland adjacent to the above (west of the main access path) and extending in a wedge shape northeast towards the visitor centre is not as severely affected but considered high-moderate risk and this also supports notable species.

3) The strip of dry SD12 which runs along the ridge between Greenland Lake and the golf course shows discontinuous but moderate nutrient impacts.

4) The area of mostly SD7 grassland between the main trackway/Greenland Lake and the frontal dune ridge level with groynes 5 to 8 and extending in a narrow strip on the landward face of the dune ridge towards the visitor centre also exhibits scattered evidence of nutrient enrichment potentially linked to long term effects of dog fouling.

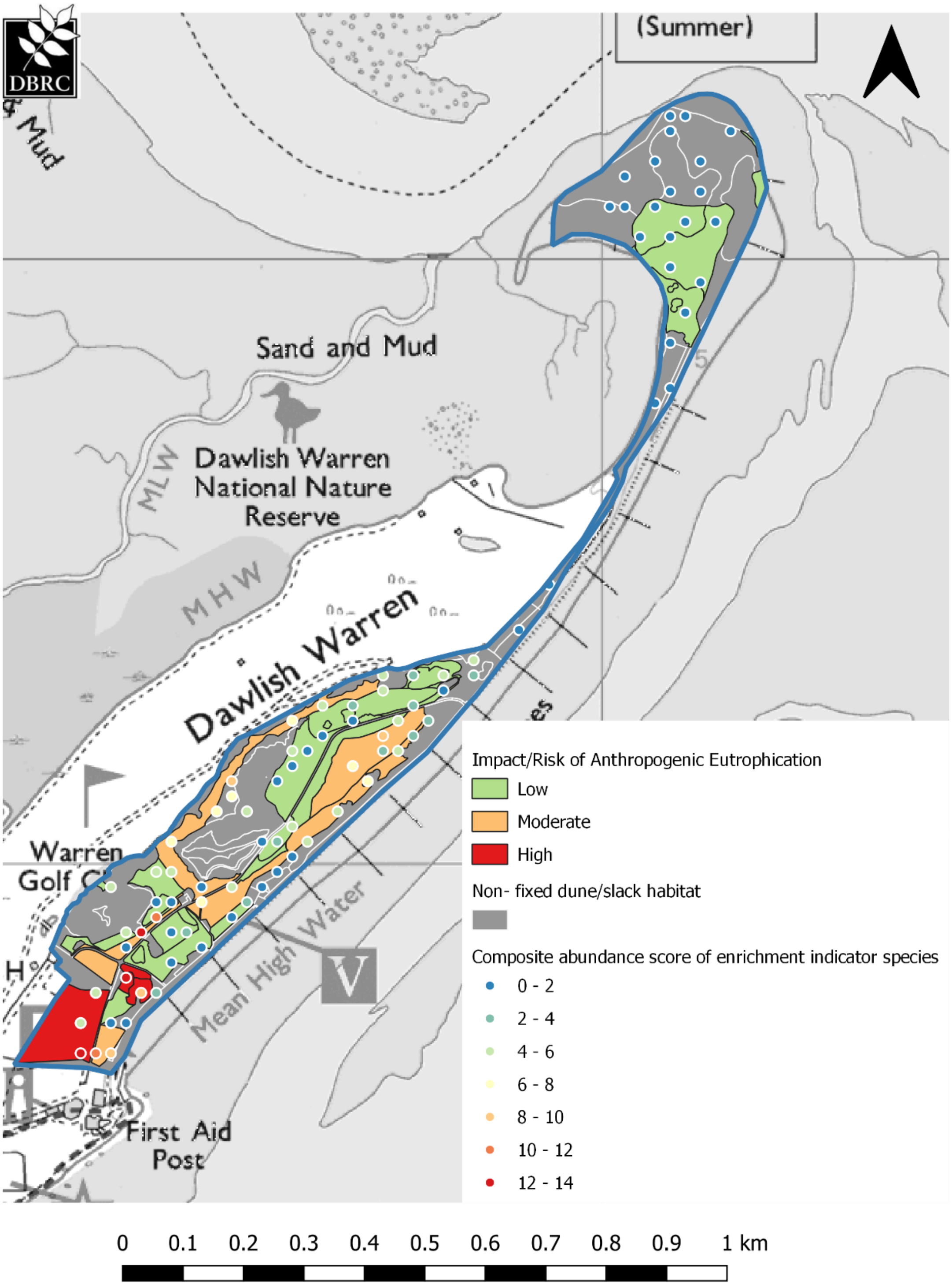


Figure 6. Areas of fixed dune and/or dune slack subject to nutrient enrichment from dog fouling. Derived from interpretation of heatmaps produced from grid-based recording of vegetation in 2023, other observations and pre-existing NVC mapping.

4.3 CHANGE SINCE THE 2019 ASSESSMENT

The survey has attempted to provide a comparable dataset to the previous assessments of trampling and eutrophication, to help managers and decision makers visualise and understand the possible impacts that they have had over time. Additionally, the survey sought to develop a means of data collection that can be relatively easily repeated. Monitoring the effects of nutrient enrichment does however pose significant challenges which are discussed below.

4.3.1 TRAMPLING

For trampling risk and impact a direct comparison between data collected in 2019 and 2023 is possible as the methodology was repeated without adaptation. Figure 3 summarises the detection of change in trampling pressure and risk as defined in the methodology. A number of squares which were assessed in 2019 were not assessed in 2023, for example where land has been lost to coastal erosion at Warren Point in the interim. These have been excluded from consideration in making the following comments which refer to squares with an available trampling assessment score in both years.

71% of the area has not changed in terms of its trampling assessment (319 of 447 squares). Approximately 20% of the area is assessed as experiencing higher trampling pressure and risk than in 2019 and 9% with some relaxation of trampling.

93 squares (21% of the area) changed to a minor degree of one scale increment (for example the assessment score altered from 2 to 3 or 5 to 4 between 2019 and 2023). Only 8% of the area (35 squares) changed by 2 or more increments. Changes detected at the lower end of the scale are likely to include some natural fluctuations and can be ascribed to recreational pressure with somewhat less confidence.

The net increase in trampling risk and pressure over the whole site (the sum of all changes to individually assessed squares) equates to a mean increase in the trampling index of 16%. This figure is derived from the qualitative 5 point scale used in the assessment and it is not suggested to demonstrate an absolute index of recreational pressure. Nevertheless, it suggests a small but significant increase since the previous assessment. It would be interesting to explore whether this correlates with visitor number estimates or records.

The overall spatial pattern of trampling risk has, unsurprisingly, not changed since 2019 (see 3.1) and the heatmaps produced for 2019 (DBRC 2020) and 2023 are very similar. However, there is evidence that some pressures have been slightly redistributed within the site. The principal areas of change (Figure 3) are:

1. the southern end of the site between the beach, pedestrian entrance and visitor centre. A new path and fencing has been installed. This may have encouraged greater use of the path for visitors wishing to access the amenity beach via the nature reserve but it has also provided an obstacle to using some of the adjacent parts of the site for recreation. Thus

some mitigation of trampling pressure in this area seems to have been achieved although it remains the highest risk part of the reserve for fixed dune habitats.

2. The vegetated margins of Warren Point. The mapped increase in pressure here is caused by a reduction in the extent of habitat so that the route navigated by walkers to circuit the point passes through squares which were formerly in the interior of the dunes and less accessible.
3. The beach front and dune ridge between groynes 4 and 8 appears to have experienced a slight increase in pressure with an increasing number of squares assessed in the 4 and 5 classes. However, the pattern of severity is identical to that shown by the 2019 assessment.

Additionally, there are a few squares within the warren point that have seen a reduction in trampling and erosion, this is likely through lack of use, with people sticking to the more worn paths.

121 squares showed an apparent increase in trampling and erosion. However, 78 of those are located around the northern edge of warren point and are likely to be attributed, predominantly at least, to natural processes. The other 43 squares are predominantly located along the edge of the main path through the dunes, which is more susceptible to erosion from footfall and environmental conditions, with another cluster of squares also located within the centre of the site at a main pinch point between those accessing the beach and the central areas of the reserve.

Although the survey's objectives were focused on anthropogenic erosion, it has effectively 'logged' the scale of natural erosion occurring around the northern extent of Warren Point, with many of the previously surveyed squares no longer existing, or now being occupied by beach sand or bare mobile sand. The current beech-vegetation front around Warren Point is still mapped as high risk for trampling. Although this part of the system may have the appearance of being under control of natural processes, even relatively low levels of trampling around the upper beach-foredune transition have potential to impact the dune habitat succession profoundly. There is evidence that past trampling pressure on the Point has interfered with or prevented the initiation of embryo dunes around the strandline (de Lemos 1992, Lake 2010). Trampling of the circuit around Warren Point is still evident and to what extent historical trampling has affected the resilience of the habitats to storm damage or impacted the ability of the dune system to migrate is unknown. A neat disentanglement of coastal erosion processes and trampling impact on the embryo and foredune habitat is probably not possible.

4.3.2 NUTRIENT ENRICHMENT

Analysis of change in the effects of nutrient enrichment since 2019 is more limited as no absolute comparison is possible between the 2019 and 2023 datasets.

Detection of change is dependent on identifying significant differences in the spatial distribution of indicative nutrient enrichment derived from vegetation attributes and supplementary observations.

The broad scale pattern shown on indicative fertility maps produced in 2019 and 2023 is very similar. Small differences are as likely to stem from differences in the way the data were collected (derived from vegetation data collected for other purposes in 2019 and the result of a more limited but purposely collected dataset in 2023) as change. The only significant discrepancy between these maps is that in 2019 the reedbeds are shown as a fertility hotspot but show as a neutral area in 2023. This is because they were sampled for NVC work in 2012 and 2019 but not prioritised under the objectives of the present survey.

Another significant difference is the apparent loss of a hotspot on the inner ridge approximately in line with groyne 7. This is thought be a very localised effect that the approach adopted in 2023 – essentially using 25m square samples to produce a more generalised picture of the site was spatially too insensitive to detect.

The application of heatmapping to a complex mosaic of habitats such as occurs on Dawlish Warren where the source data are samples rather than complete will always tend to smooth away heterogeneity in conditions.

Our best judgement from the available data is that the spatial distribution of nutrient enrichment effects from dog fouling is substantially the same as in 2019. These data do not allow an assessment of whether there have been any significant changes in severity, either at individual locations or for the whole site.

The ecology of dog-fouling derived nutrient inputs in sand dunes is complex and not yet well studied (see Rhodes 2012). A future assessment employing the same approach as used in the present survey could be capable of detecting changes if they were sizeable. However, it is likely that a more labour-intensive design of study, possibly employing direct measurement of nutrient loads and probably entailing a more complete inventory of the vegetation, would be needed to meaningfully monitor these impacts.

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6 ACKNOWLEDGEMENTS

This work was commissioned by the South East Devon Habitat Regulations Partnership. We are grateful to Neil Harris (Habitat Regulations Delivery Manager) and Phil Chambers (Senior Ranger at Dawlish Warren National Nature Reserve) for their advice and feedback.

7 APPENDICES

7.1 EXAMPLE PHOTOS OF TRAMPLING CATEGORIES

7.1.1 CATEGORY 5

7.1.2 CATEGORY 4

7.1.3 CATEGORY 3

7.1.4 CATEGORY 2

7.1.5 CATEGORY 1

7.2 LIST OF SPECIES RECORDED AND USED IN THE ANALYSIS WITH ELLENBERG VALUES (AFTER HILL ET AL. 1999) FOR NITROGEN

Species	Common Name	Ellenberg N Value
Acer pseudoplatanus	Sycamore	6
Achillea millefolium	Yarrow	4
Agrimonia eupatoria	Agrimony	4
Agrostis canina sens. lat.	Creeping bent	3
Agrostis capillaris	Common Bent	4
Aira praecox	Early Hair-grass	2
Ajuga reptans	Bugle	5
Alnus glutinosa	Alder	6
Ammophila arenaria	Marram	3
Angelica sylvestris	Wild Angelica	5
Anisantha sterilis	Barren Brome	5
Anthoxanthum odoratum	Sweet Vernal-grass	3
Anthriscus sylvestris	Cow Parsley	7
Arrhenatherum elatius	False Oat-grass	7
Artemisia vulgaris	Mugwort	7

Asparagus officinalis	Asparagus	3 (based on subsp. *prostratus*)
Atriplex sp.	Orache	7 (based on *A. laciniata*)
Beta vulgaris subsp. maritima	Sea beet	8
Betula pendula	Silver Birch	4
Betula pubescens	Downy Birch	4
Bolboschoenus maritimus	Sea Club-rush	7
Bromus hordeaceus	Soft brome	4
Buddleja davidii	Butterfly-bush	5
Calystegia sepium	Hedge Bindweed	7
Calystegia soldanella	Sea bindweed	4
Carex arenaria	Sand Sedge	2
Carex distans	Distant sedge	5
Carex echinata	Star Sedge	2
Carex flacca	Glaucous Sedge	2
Carex leporina	Oval Sedge	4
Carex nigra	Common Sedge	2
Carex otrubae	False Fox-sedge	7
Carex panicea	Carnation sedge	2
Carex remota	Remote Sedge	6
Carex sylvatica	Wood-sedge	5
Centaurium erythraea	Common Centaury	3
Cerastium diffusum	Sea Mouse-ear	3
Circaea lutetiana	Enchanter's-nightshade	6
Cirsium arvense	Creeping Thistle	6
Clematis vitalba	Traveller's-joy	5
Cotoneaster agg.	Cotoneasters	4 (most cotoneasters)
Crataegus monogyna	Hawthorn	6
Cynoglossum officinale	Hound's-tongue	6
Cynosurus cristatus	Crested Dog's-tail	4
Dactylis glomerata	Cock's-foot	6
Daucus carota	Wild carrot	3
Deschampsia cespitosa	Tufted Hair-grass	4
Digitalis purpurea	Foxglove	5
Dryopteris dilatata	Broad Buckler-fern	5
Elytrigia repens	Common Couch	7
Epilobium spp.	Willowherbs	6 (based on an average)
Epipactis palustris	Marsh helleborine	4
Equisetum palustre	Marsh Horsetail	3
Erigeron canadensis	Canadian fleabane	No value
Erodium maritimum	Sea Stork's-bill	6
Eryngium maritimum	Sea holly	5
Euphorbia portlandica	Portland spurge	3
Euphrasia agg.	Eyebright	3
Festuca rubra agg.	Red Fescue	5
Filipendula ulmaria	Meadowsweet	5
Fraxinus excelsior	Ash	6
Galium aparine	Cleavers	8

Galium mollugo	Hedge Bedstraw	4
Galium palustre	Marsh-bedstraw	4
Galium uliginosum	Fen Bedstraw	4
Galium verum	Lady's Bedstraw	2
Geranium dissectum	Cut-leaved Crane's-bill	6
Geranium molle	Dove's-foot Crane's-bill	5
Geranium robertianum	Herb-Robert	6
Geum urbanum	Wood Avens	7
Hedera helix	Common Ivy	6
Heracleum sphondylium	Hogweed	7
Holcus lanatus	Yorkshire-fog	5
Honckenya peploides	Sea Sandwort	6
Hordeum murinum	Wall Barley	6
Hydrocotyle vulgaris	Marsh Pennywort	3
Hypericum perforatum	Perforate St John's-wort	5
Hypericum tetrapterum	Square-stalked St John's-wort	4
Hypochaeris radicata	Cat's-ear	3
Iris foetidissima	Stinking Iris	5
Iris pseudacorus	Yellow Iris	6
Juncus acutiflorus	Sharp-flowered Rush	2
Juncus articulatus	Jointed Rush	3
Juncus bufonius agg.	Toad rush	5
Juncus conglomeratus	Compact Rush	3
Juncus effusus	Soft-rush	4
Juncus maritimus	Sea Rush	5
Lagurus ovatus	Hare'stail	No value
Lapsana communis	Nipplewort	7
Leontodon hispidus	Rough Hawkbit	3
Lichen undiff.		No value
Linaria vulgaris	Common Toadflax	6
Linum catharticum	Fairy Flax	2
Lolium perenne	Perennial Rye-grass	6
Lonicera periclymenum	Honeysuckle	5
Lotus corniculatus	Common Bird's-foot-trefoil	2
Lotus pedunculatus	Greater Birds-foot trefoil	4
Lupinus arboreus	Tree Lupin	3
Luzula campestris	Field Wood-rush	2
Lycopus europaeus	Gypsywort	6
Lythrum salicaria	Purple-loosestrife	5
Malus domestica	Apple	7
Medicago lupulina	Black Medick	4
Mentha aquatica	Water Mint	5
Molinia caerulea	Purple Moor-grass	2
Odontites vernus	Red Bartsia	5
Oenanthe crocata	Hemlock Water-dropwort	7
Oenanthe lachenalii	Parsley Water-dropwort	5
Oenothera	Evening primrose	4 (average)
Ononis repens	Common Restharrow	3
Origanum vulgare	Wild Marjoram	4
Phleum arenarium	Sand cat's-tail	3
Phragmites australis	Common Reed	6
Plantago coronopus	Buck's-horn Plantain	4

Plantago lanceolata	Ribwort Plantain	4
Plantago major	Greater Plantain	7
Poa annua	Annual Meadow-grass	7
Poa bulbosa	Bulbous meadow grass	2
Polypodium vulgare	Polypody	3
Populus alba	White Poplar	6
Potentilla erecta	Tormentil	2
Prunella vulgaris	Self-heal	4
Pulicaria dysenterica	Common Fleabane	4
Quercus cerris	Turkey Oak	6
Ranunculus acris	Meadow Buttercup	4
Ranunculus repens	Creeping Buttercup	7
Raphanus raphanistrum	Sea radish	5
Rhinanthus minor	Yellow-rattle	4
Rosa arvensis	Field-rose	5
Rosa canina agg.	Dog Rose	6
Rubia peregrina	Wild Madder	5
Rubus fruticosus agg.	Bramble	6
Rumex acetosa	Common Sorrel	4
Rumex acetosella	Sheep's Sorrel	3
Rumex obtusifolius	Broad-leaved Dock	9
Rumex sanguineus	Wood Dock	7
Salix caprea	Goat Willow	7
Salix cinerea	Grey Willow	5
Sambucus nigra	Elder	7
Scorzoneroides autumnalis	Autumn Hawkbit	4
Sedum acre	Biting Stonecrop	2
Sedum anglicum	English Stonecrop	2
Senecio jacobaea	Common Ragwort	4
Silene dioica	Red Campion	7
Silene flos-cuculi	Ragged-Robin	4
Sisymbrium officinale	Hedge Mustard	7
Sisyrinchium bermudiana	Blue-eyed-grass	3
Solanum dulcamara	Bittersweet	7
Solidago virgaurea	Goldenrod	3
Sonchus asper	Sow-thistle	6
Spergularia rubra	Sand Spurrey	2
Spiranthes spiralis	Autumn Lady's-tresses	3
Symphyotrichum	Michaelmas daisy	6
Tamus communis	Black Bryony	6
Tanacetum vulgare	Tansy	7
Taraxacum officinale agg.	Dandelion	6
Teucrium scorodonia	Wood Sage	3
Trifolium arvense	Hare's-foot Clover	2
Trifolium dubium	Lesser Trefoil	5
Trifolium pratense	Red Clover	5
Trifolium repens	White Clover	6
Trifolium subterraneum	Subterranean Clover	2
Ulex europaeus	Gorse	3
Umbilicus rupestris	Navelwort	4
Urtica dioica	Common Nettle	8
Veronica chamaedrys	Germander Speedwell	5

Vicia cracca	Tufted Vetch	5
Vicia hirsuta	Hairy Tare	6
Vicia sativa	Common vetch	4
Viola riviniana	Common Dog-violet	4
Vulpia bromoides	Squirreltail Fescue	3
Vulpia ciliata	Bearded Fescue	2

Report produced by:

Devon Biodiversity Records Centre

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