A303 Amesbury to Berwick Down

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6.3 Environmental Statement Appendices

Appendix 8.2A Stonehenge lichen report

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A303 Stonehenge

Amesbury to Berwick Down

Lichen Survey Report 2017

Arup Atkins Joint Venture

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Foreword

The A303/A358 corridor is a vital connection between the South West and London and the South East. While the majority of the road has been dualled, there are still over 35 miles of single carriageway. These sections act as bottlenecks for users of the route resulting in congestion, particularly in the summer months and at weekends, delays to traffic travelling between the M3 and the South West and an increased risk of accidents. The A303 passes through the Stonehenge, Avebury and Associated Sites World Heritage Site, separating the stones from other scheduled monuments and severely limiting the enjoyment of the wider site.

The A303 Stonehenge (Amesbury to Berwick Down) scheme is part of the wider package of proposals for the A303/A358 corridor designed to transform the connectivity to and from the South West by creating an expressway. This would comprise of consistently good dual carriageway roads with grade-separated junctions, giving most users a motorway-quality journey. The A303/A358 package was identified in the 2014 National Infrastructure Plan as one of the country's Top 40 priority infrastructure projects.

The proposals by Highways England to upgrade the A303 past Stonehenge consist of an eight mile (13 kilometre) stretch from Amesbury in the east, through the Stonehenge World Heritage Site (WHS) and the village of Winterbourne Stoke, to Berwick Down in the west. Proposals include a 1.8 mile (2.9 kilometre) tunnel with approach roads inside the WHS, a new bypass for Winterbourne Stoke (passing either north or south of the village) and improvements to existing junctions with the A345 and A360.

Highways England (HE) commissioned the Arup-Atkins Joint Venture (AAJV) to undertake the Options Phase for the scheme starting in January 2016. The AAJV was also commissioned by HE to undertake a lichen survey of Stonehenge, in order to de-risk the next stages of the project, due to the fast-tracked nature of the scheme. This report presents the findings of the lichen survey, which was undertaken by specialist lichenologist Mark Powell on behalf of the AAJV. The AAJV and Mark Powell would like to thank English Heritage for their help and consideration during the course of the survey.

Executive Summary

The AAJV were commissioned by Highways England to undertake a lichen survey as part of a programme of ecological surveys to inform the design of the proposed A303 Stonehenge (Amesbury to Berwick Down) Scheme.

This report presents the baseline survey results recorded during the lichen survey of Stonehenge, undertaken over the course of two days in September 2017 It is intended that the information in this report will be used to identify and assess the potential implications of the Scheme and inform mitigation and compensation for the species.

A framework of European and national legislation, and planning policy guidance exists to protect and conserve lichens.

The 2017 survey confirms that the internationally important lichen communities of Stonehenge have not changed in any significant way since the last surveys which were conducted between 2002 and 2004. This survey fulfilled its objectives in surveying the lichen communities at Stonehenge. A complete assessment of potential impacts to lichens will be undertaken within the Environmental Impact Assessment (EIA) for the preferred route option, along with details of mitigation and compensation measures as appropriate.

1 Introduction

1.1 Project Background

1.1.1 The A303 Stonehenge (Amesbury to Berwick Down) Scheme forms part of the A303/A30 trunk route, which provides vital east-west connectivity between London and the South West and is also part of the Trans-European Network-Transport (TEN-T). The A303, which runs for approximately 150 kilometres from Junction 8 of the M3 near Basingstoke towards Taunton and Exeter, serves not only long distance traffic but also intermediate regional destinations via connecting major north-south route options as well as local small and medium sized settlements along the route.

1.1.2 Recognising the importance of the A303/A358 Corridor and the problems along it, the Government has committed in its Road Investment Strategy (RIS) to create an 'Expressway' to the South West via the A303/A358 route by 2029. The A303 Stonehenge scheme, involving dualling the A303 between Amesbury and Berwick Down, including the construction of a tunnel at least 1.8 miles (2.9 kilometres) long as the road passes Stonehenge, has been prioritised within the first RIS period (2015/16 to 2019/20).

1.1.1 Following public consultation in January 2017, three routes were recommended for detailed assessment during 2017, Route Options 1Na, 1Sa and 1Nd. The survey site (Stonehenge) lies north of these options.

1.2 Scope of the Document

1.2.1 This report presents the baseline survey results recorded during the 2017 lichen survey. It is intended that the information in this report will be used with the results of other ecological surveys to identify and assess the potential implications of the scheme and inform mitigation and compensation for impacts to lichens.

1.2.2 This baseline report can be used to accompany any future Development Consent Order (DCO) and associated Environmental Impact Assessment (EIA) for the Scheme.

1.2.3 Mark Powell, lichenologist, was commissioned to undertake this survey on behalf of the AAJV. The full survey report which details the methodology used and describes the results of the 2017 lichen survey can be found in Annex 1 of this report.

Annexes

Annex 1 - 2017 Lichen Survey report prepared by Mark Powell, lichenologist

LICHENS AT STONEHENGE
AMESBURY, WILTSHIRE

A report prepared by
Mark Powell
October 2017

Anaptychia runcinata, one of the distinctive and enigmatic maritime lichens which grows at Stonehenge.

LICHENS AT STONEHENGE

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Summary

- The 2017 survey confirms that the internationally important lichen communities of Stonehenge have not changed in any significant way since the last surveys which were conducted between 2002 and 2004 (Giavarini & James 2003, Nicholas Pearson Associates 2003, 2005a, 2005b).
- The lichen communities of Stonehenge include many maritime species which are rare or absent inland, other than on sarsen stone in the Wiltshire and Berkshire Downs (O'Dare & Laundon 1986, Giavarini & James 2003).
- The Near Threatened *Buellia saxorum* is restricted in Britain to this habitat (Wright *et al*. 1997, Gilbert 2000, Coppins *et al.* 2009).
- Occurrences of similar maritime lichen communities are notably present at Fyfield Down and Avebury stone circle. Stonehenge supports a greater range of rare and notable lichen species than at any other sarsen stone site in the region (O'Dare & Laundon 1986, Gilbert 2000, Giavarini & James 2003).
- Lichens are sensitive to changes in the environment and have often been used as environmental indicators (Hawksworth & Rose 1970, Nimis *et al.* 2002).
- The environmental changes which might be caused by the proposed works (upgrading of the A303, Amesbury to Berwick Down) are predicted to be slightly beneficial to the lichen communities of Stonehenge due to the removal of surface traffic on the current course of the A303. Traffic creates dust and gaseous compounds of nitrogen, which can cause changes in lichen communities leading to a predominance of nitrophilic ruderal species (Angold 1997).
- Activities associated with the proposed works may temporarily cause dust and other atmospheric pollution. Where necessary, mitigation measures could reduce these to an acceptable level.
- Lichen communities have changed dramatically in lowland England in the past two decades due to the reduction in acidic atmospheric pollution (especially sulphur dioxide from coal burning) and the increasing influence of compounds of nitrogen (especially from the burning of fossil fuels and agricultural activities). The changes are most marked on relatively young bark of trees (Vilsholm *et al.* 2009, Skinner 2016).
- The lack of significant change in the lichens of Stonehenge between 2003/4 and 2017 suggests a degree of resilience.
- Pollution on a geographical scale, or that from agricultural activities, is likely to have a greater potential effect on the lichen communities than carefully mitigated construction works of limited duration.

1. Introduction

This document provides the results of the lichen survey conducted by Mark Powell and Paula Shipway in 2017 on the stones at Stonehenge, Amesbury. This survey has been undertaken to establish an understanding of the baseline constraints associated with proposed A303 Stonehenge Scheme, and to establish whether the lichens of Stonehenge have significantly changed since the surveys carried out in 2003/2004.

Legislation

None of the lichen species that have been found at Stonehenge are specially protected by law (none are listed on Schedule 8 of the Wildlife & Countryside Act 1981).

All the species that have been identified with certainty have an IUCN (2001) threat status of Least Concern (LC) except for one case of a species (*Buellia saxorum*) classified as near threatened (NT).

Background of lichens at Stonehenge

A survey undertaken in 1973 was the first to identify the presence of a strong maritime element which included *Anaptychia runcinata*, *Buellia subdisciformis, Buellia leptoclinoides* (erroneously recorded as *Fuscidea cyathoides*), *Lecanora gangaleoides*, *Ramalina siliquosa*, *Ramalina subfarinacea*, *Rinodina confragosa* and *Rinodina beccariana* [unpublished records which are referred to by Giavarini & James (2003) and which are archived in the British Lichen Society database (data extracted 4th July 2017).

Rose & James (1994) discovered *Aspicilia epiglypta, Aspicilia leprosescens, Lecanora fugiens* and *Rinodina orculariopsis* at Stonehenge. These are all species with a predominantly coastal distribution in Britain and further strengthened the view that this 'sea-cliff assemblage' was without doubt, the most widespread and conspicuous feature of the monument.

Although the presence of a specialized maritime lichen flora is highly unusual this far inland, Stonehenge is not alone in supporting these assemblages; a similar situation occurs at Avebury Stone Circle, some 30 km north of Stonehenge (O'Dare & Laundon 1986, Giavarini & James 2003). However, of the two sites, Stonehenge has the greatest diversity of maritime species and a remarkable dominance of coastal cliff species. The lichen communities are considered to be of international importance (Giavarini & James, 2003), adding significantly to its status as a World Heritage Site.

A thorough survey was undertaken by Vince Giavarini and Peter W. James in 2003 (accompanied for one day by Dr Oliver Gilbert) during the week 12th to 17th May 2003. Apart from two half days of poor weather, the 2003 survey consisted of six hours each day of fieldwork (Giavarini & James 2003). During the period 2001 to 2004 Dr David Hill set up a quantitative baseline survey of the lichens at Stonehenge, establishing 62 quadrats. The quadrat records made in 2004 were compared statistically with those previously collected in 2001/2002 and in 2003 (Nicholas Pearson Associates 2005b).

Giavarini and James (2003) identified six communities of lichen species, one of which (the Ramalinetum) contributes to the uniqueness of this site by supporting many rare species, with the overall assemblage giving the Stones significance in an international context. These communities are also of notable importance within Wiltshire. Many species (such as *Anaptychia runcinata*, *Aspicilia leprosescens*, *Buellia saxorum*, *Candelariella coralliza*, *Lecanora andrewii*, *Rinodina confragosa* and *R. orculariopsis)* are present at Stonehenge, yet are not present on sandstone gravestones in Wiltshire churchyards, despite the rock type being apparently similar.

This lichen community, called the *Ramalinetum scopularis* (James *et al* 1977), is dominated by the conspicuous shrubby lichen *Ramalina siliquosa*, which forms dense, shaggy colonies on the sides, faces and tops of most of the standing stones and lintels. They are easily visible from the pedestrian walkway. Cover is especially abundant on those stones that have remained relatively undisturbed during the last hundred years.

Phaeophyscia sciastra, a mainly upland species of tarns and lake margins was first discovered on the Slaughter Stone in 1994 (Rose & James 1994) and was monitored by Dr David Hill between 2002 and 2004 (Nicholas Pearson Associates 2005b). It requires periodic flushing with mildly enriched rainwater that has collected in shallow rock hollows. When examined in September 2017, the material present on the Slaughter Stone was found not to possess any of the characteristic isidia of *P. sciastra*. Confirmation of the identity of a sample taken from the Slaughter Stone awaits analysis using molecular methods.

The lichen species at Stonehenge are of notable importance, as there is a diversity and abundance of lichen species present which are usually confined to a north-western, or rocky coastal distribution. For example, the Near Threatened (Woods & Coppins 2012) *Buellia saxorum* is restricted in Britain to sarsen stones in Wiltshire and Berkshire (Wright *et al*. 1997). *Phaeophyscia sciastra* is normally associated with hollows in siliceous boulders in upland districts. Furthermore, some maritime lichens are abundant at Stonehenge, for example *Ramalina siliquosa* was recorded from 57 individual stones by Giavarini & James (2003), and on many of the stones it dominates extensive areas. See Appendix B for a summary of the maritime element and Appendix C for selected British distribution maps.

2. Methodology

The 2017 lichen survey was conducted by two lichenologists (Mark Powell and Paula Shipway) for two hours on the 25th September 2017 and two hours on the 26th September (07:00 to 09:00 on both days). On the 25th September the weather was damp and gloomy with a light drizzle. The 26th September saw brighter conditions although the lichens were still hydrated from overnight moisture resulting in the usual problems of identification of saxicolous crusts when wet. All lichens and lichenicolous fungi that were encountered were recorded using the names currently listed in the BLS Taxon Dictionary[1].

The survey was conducted with the aid of a x10 hand lens and a set of three spot chemicals. Where relevant, the methodology recommended by British Lichen Society (2006) were followed. Some of the notable lichen species cannot be reliably identified in the field, requiring microscopic examination. Several very frugal specimens were pared off. Crustose lichens were stuck to card using the adhesive Copydex. *Phaeophyscia sciastra* was collected loose into paper packets. Specimens were dried gently but swiftly to prevent degradation and subsequently stored in dry condition. Standard light microscope techniques (British Lichen Society 2006) were used to confirm some of the cryptic notable lichens as well as some of the difficult non-notables.

To make best use of the limited time available at Stonehenge, two days of familiarisation were spent at Avebury Stone Circle in August 2017 (see Appendix D). Time available on site did not allow quantitative (quadrat) survey to be conducted at Stonehenge. Instead, the recommendations of Giavarini & James (2003) were followed with detailed examinations of Stones 54, 60, Slaughter Stone and Heel Stone. The colonies of two vulnerable specialists of Stonehenge (*Anaptychia runcinata* and *Phaeophyscia sciastra*) were examined to reveal whether any significant changes to their abundances had taken place since 2003. A ladder was used to briefly examine the top surfaces of the lintels of the outer ring of stones to see if any *Xanthoria* species had appeared since 2004 (when they were stated to be absent). Finally, a search was made on the lower portions of the standing stones to see if the conspicuous and easily recognised *Diploicia canescens* had increased in abundance.

[1] http://www.britishlichensociety.org.uk/resources/lichen-taxon-database

Recommendations made by Giavarini and James (2003) heavily influenced the methodology used during this 2017 survey, with regards to which stones and lichen species should be focussed on. The quadrat monitoring set up by Hill (2003, 2005a, 2005b) was not repeated (due to lack of available time on site) but two observations made during his survey proved particularly useful, with regards to potential indicator species for calcareous dust (*Diploicia canescens*), and use of irrigation water, fertilisers, or herbicides near the Slaughter Stone (*Phaeophyscia sciastra*).

The compounded four hours spent on site were used as follows:

- An examination of the lower two metres of Stones 54, 60 and the Heel Stone.
- An assessment of the presence and health of *Anaptychia runcinata* on Stone 25.
- An assessment of the identity and abundance of *Phaeophyscia sciastra* on the Slaughter Stone.
- A brief examination of the upper surface of the lintels of the outer ring.
- An assessment of the abundance of *Diploicia canescens* at Stonehenge.
- A general walkabout survey to observe the general state and composition of the lichen communities at Stonehenge.

Limitations

English Heritage imposes strict time constraints on access to ensure that surveyors and ground workers are off site before the site opens to the public. This lack of unrestricted access resulted in the completion of a well-informed qualitative survey rather than a quantitative assessment of the lichen communities. The surveyors have considerable previous experience with studying the specialist lichen communities of sarsen stone. If there had been any dramatic or significant changes to the lichen communities at Stonehenge, this would have been recognised during the recent survey. More subtle changes, if any have taken place, may not have been detected with the amount of time available on site.

3. Results

Stones 54, 60 and Heel Stone

Giavarini & James (2003) provide lists of lichen species for each of these stones. It is known that they had a ladder on site during the survey and it is very likely that this was used to gain access to those parts of the stones above head height. Due to modern restrictions, the 2017 survey of these stones was restricted to the lowest 1.8 metres. Tables 1, 2 and 3 below list the species recorded in 2003 and in 2017.

A comparison of the records shows some differences but a general similarity in the lichens recorded. Some differences are likely to be recording artefacts. Several of the notable lichens present in the sarsen community are cryptic species, being difficult or impossible to distinguish in the field. Due to the importance of the site, the collection of specimens is limited, both at the request of English Heritage and self-imposed by recorders in the interests of conservation. The same is true of chemical spot tests which kill the small patch of lichen tested. Hence the identification of cryptic and semi-cryptic lichens at a site such as Stonehenge will always be somewhat problematic. Gradually, over several surveys spanning decades, the basic taxonomy of the species involved is refined but the identification of each individual thallus is not always possible. *Buellia saxorum* was not recognised as being present at Stonehenge in 2003, despite it being a well-known member of the sarsen community elsewhere. It was not until David Hill's surveys (e.g. Nicholas Pearson Associates 2005b) that the presence of *Buellia saxorum* was recognised as being present at Stonehenge after a fragment of it was sent to Brian Coppins for specialist appraisal. *B. subdisciformis* is very similar in appearance to *B. saxorum*, both are present at Stonehenge, but unless each individual thallus was collected, or tested with chemicals, the identity of each individual remains uncertain. *Lecanora gangaleoides* is difficult to separate reliably in the field from *Tephromela atra* unless a razor blade is used to assess the pigmentation within the apothecia. A sample of individuals (*c*. 20%) were sectioned in this way in the field during the recent survey. Giavarini & James (2003) do not specify whether they separated these two species 'on sight' (using the useful but not completely reliable 'neatness' of *Lecanora gangaleoides* compared with *Tephromela atra*) or if they sectioned individuals in the field.

Table 1. Lichen species recorded on Stone 54, in 2003 and 2017.

Stone 54	2003	2017
Buellia saxorum		x
Buellia subdisciformis	x	
Caloplaca limonia		x
Candelariella vitellina	x	x
Cresponea premnea	x	x
Diploicia canescens	x	x
Haematomma ochroleucum var. ochroleucum		x
Haematomma ochroleucum var. porphyrium	x	
Lecania cf. hutchinsiae	x	
Lecanora gangaleoides	x	
Lecanora orosthea	x	x
Marchandiomyces corallinus (LF)		x
Melanelixia fuliginosa	x	x
Opegrapha areniseda	x	
Opegrapha zonata	x	
Pachnolepia (Arthonia) pruinata	x	x
Ramalina siliquosa	x	x
Rinodina confragosa		x
Tephromela atra		x
Xanthoria parietina	x	

Figure 1. The base of Stone 54 showing the sheltered alcove in which grows species more typical of the trunks of veteran trees (especially *Pachnolepia* (*Arthonia*) *pruinata* and *Cresponea premnea*).

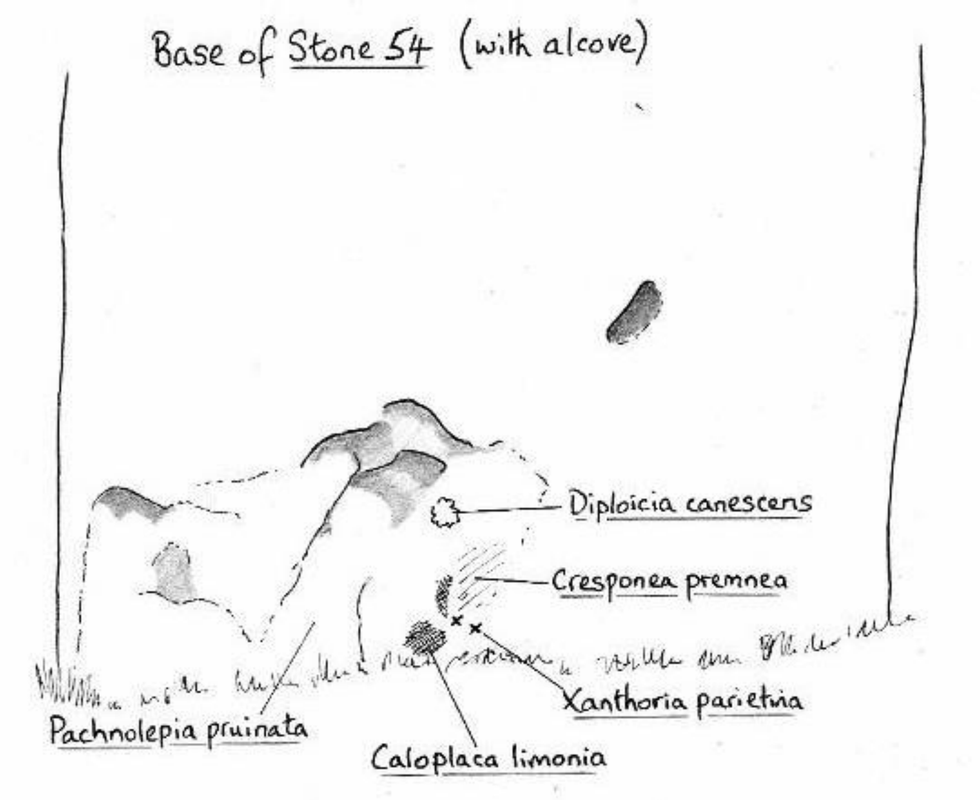

Figure 2. The 'alcove' at the base of Stone 54.

The 'alcove' at the base of Stone 54 is particularly interesting. *Cresponea premnea* and *Pachnolepia pruinata* are more typical of sheltered bark on old tree trunks. In 2003 Giavarini & James also recorded *Lecania* cf. hutchinsiae, *Opegrapha areniseda* and *O. zonata* from this sheltered recess. The presence of *Caloplaca limonia*, *Diploicia canescens* and *Xanthoria parietina* may indicate that the stone here becomes locally enriched with nutrients. Localised discolouration of lichen thalli after solstice activities has been interpreted as being due to some of the stones being used as informal urinals (Druce pers. comm. 2017). The presence of *Diploicia canescens* and *Xanthoria parietina*, and the appearance of *Calopaca limonia*, all species which either favour or tolerate nutrient-enrichment, may be caused by fertilisation during the unsupervised public access at the solstices.

Table 2. Lichen species present on Stone 60, in 2003 and in 2017.

Stone 60	2003	2017
Buellia sp.		x
Buellia saxorum		x
Buellia subdisciformis	x	
Caloplaca flavocitrina	x	
Caloplaca holocarpa s. lat.	x	x
Candelariella vitellina	x	x
Haematomma ochroleucum var. ochroleucum	x	x
Haematomma ochroleucum var. porphyrium	x	
Lecania erysibe s. lat.	x	
Lecanora dispersa s. lat.	x	x
Lecanora gangaleoides	x	
Lecanora orosthea	x	x
Melanelixia fuliginosa	x	x
Ochrolechia parella	x	
Phaeophyscia orbicularis	x	

Stone 60	2003	2017
Physcia adscendens	x	
Physcia caesia	x	
Ramalina siliquosa	x	x
Rinodina confragosa	x	x
Rinodina oleae	x	
Rinodina oculariopsis	x	
Scoliciosporum umbrinum	x	
Xanthoria calcicola	x	x
Xanthoria parietina	x	

Table 3. Lichen species present on the Heel Stone, in 2003 and in 2017.

Heel Stone	2003	2017
Aspicilia caesiocinerea	x	
Aspicilia cf. leprosescens		x
Buellia saxorum		x
Buellia subdisciformis	x	
Caloplaca holocarpa	x	x
Candelariella vitellina	x	x
Catillaria chalybeia		x
Cresponea premnea		x
Haematomma ochroleucum var. ochroleucum	x	x
Haematomma ochroleucum var. porphyrium	x	
Lecanora andrewii		x
Lecanora fugiens	x	
Lecanora gangaleoides	x	
Lecanora orosthea	x	x
Lecidella scabra	x	x
Melanelixia fuliginosa	x	x
Ochrolechia parella	x	x
Phaeophyscia orbicularis		x
Physcia caesia	x	x
Physcia dubia	x	
Ramalina siliquosa	x	x
Rinodina confragosa	x	x
Rinodina oculariopsis	x	
Rinodina teichophila	x	
Scoliciosporum umbrinum	x	x
Tephromela atra		x
Xanthoria parietina	x	x
Unidentified crust		x

Anaptychia runcinata on Stone 25

Anaptychia runcinata occurs as two healthy thalli on the side of Stone 25, which is consistent with the findings of Giavarini and James (2003).

Figure 3. ***Anaptychia runcinata*** **occurring as two conspicuous dark green circular thalli (superficially resembling patches of moss) on the side of Stone 25.**

Phaeophyscia sciastra

The 2017 survey confirmed that two species of *Phaeophyscia* are present on the Slaughter Stone. *P. orbicularis* is present as just a few pale thalli amongst an abundance of darker green material which is presumed to be *P. sciastra*. Curiously no isidia, normally a characteristic feature (e.g. Edwards & Coppins 2009), were observed on the putative *P. sciastra*. In previous surveys, the identification of this Slaughter Stone material as a species of *Phaeophyscia* has relied on its morphological features, with David Hill (Nicholas Pearson Associates 2005b) noting a dramatic reduction in *P. sciastra* on the Slaughter Stone between 2002 and 2004 (see Fig. 5 below). However, the presence of the lichenicolous fungus *Buelliella physciicola* provides additional confidence that it belongs in *Phaeophyscia*. *B. physciicola* appears to be confined to lichens in the genera *Phaeophyscia* and *Physcia* (Lawrey & Diederich 2017). The Slaughter Stone material is separated from *Physcia* due to lack of K+ yellow upper cortex (Edwards & Coppins 2009). A small specimen was taken in order to confirm the identity of the *Phaeophyscia* species present on the Slaughter Stone through molecular analysis. This specimen will be directly compared to a specimen of *Phaeophyscia sciastra* that was recently collected from a location in Scotland. Until the results of this analysis are known, it is considered that *P. sciastra* should continue to be considered reliably recorded for Stonehenge.

Figure 4. *Phaeophyscia* species on the Slaughter Stone. Above the arrow is the pale sorediate thallus of the ubiquitous *P. orbicularis*. Below is the darker green material which is presumed to be *P. sciastra*.

Figure 5. *Phaeophyscia sciastra* in 2002 (above) and 2004 (below) in quadrat 12 on the Slaughter Stone. The 'Blu-Tack'® marks the corners of the 25cm x 25 cm quadrat. At the centre is a depression in the stone that fills with water during rainfall. In 2002 *P. sciastra* (showing up dark green to blackish in the photograph) occupied the whole of the bottom of the depression but by 2004 the thalli had completely disappeared with only a few residual thalli surrounding the depression surviving. (Taken from Nicholas Pearson Associates 2005b).

Figure 6. The Slaughter Stone depression (shown in Fig. 5) as photographed in 2017. The dark green material around the edges of the depression is *P. sciastra*. In 2002, *P. sciastra* dominated the bottom of the pool, by 2004 it had markedly declined and was present sparsely outside the rim of the pool. In 2017 it is present in abundance both above and below the full-level of the pool.

Phaeophyscia sciastra appears to wax and wane in its abundance on the Slaughter Stone. This is perhaps due to different rainfall patterns in different years, or surveys conducted at different times of year. *P. sciastra* may retreat to the bottom of the pools in drier seasons. Its abundance on the Slaughter Stone in 2017 suggests that conditions remain favourable for it.

The absence of *Xanthoria* species on the lintels

A ladder was used to view the lintels on the outer ring of stones and no thalli of *Xanthoria* were observed, which is consistent with the findings of Nicholas Pearson Associates (2005b).

Diploicia canescens at Stonehenge

In the 1994 survey *D. canescens* was observed on stones 28 and 29, and in the 2003 survey, this species was observed on stones 2 and 54. A short but intense search for this conspicuous species was made during the 2017 survey. It was only observed on Stone 54. The lack of time prevented every stone being searched in detail. However, *D. canescens* is conspicuous and instantly recognisable and if it had significantly increased in abundance since 2003, it would certainly have been noticed on more than one of the stones examined in 2017. *D. canescens* is a species which is favoured by dusty nutrient enrichment (including windblown dust from agriculture). The continued rarity of this lichen at Stonehenge suggests that dust pollution has not been a significant factor in recent years.

Lichenicolous fungi

These fungi grow on or in lichens, they are often host-specific and pathogenic. They represent a wealth of under-recorded and undescribed diversity. Two lichenicolous fungi were recorded at Stonehenge, *Buelliella physciicola* which is new to VC 8 (South Wiltshire) and *Marchandiomyces corallinus* on Stone 54. Most British records of *B. physciicola* have *Phaeophyscia orbicularis* as their host. At Stonehenge, *P. sciastra* was considered to be the host (on the Slaughter Stone).

New to VC 8 (South Wiltshire)

The following taxa are believed to be new to the Vice-county (the download available on the BLS website 'BLS Lichen records by VC Jan 2016' was used as the resource to decide which records are 'new').
Buelliella physciicola (lichenicolous fungus, host *Phaeophyscia sciastra*, on the Slaughter Stone).
Rhizocarpon distinctum (lichen, on Slaughter Stone).

New to Stonehenge

The species mentioned in the last section (*Buelliella physciicola* and *Rhizocarpon distinctum*) are both new to Stonehenge and both are present on the Slaughter Stone. *Caloplaca limonia* is present in the alcove at the base of Stone 54 and is new to the Stonehenge monument. *Verrucaria nigrescens* f. *tectorum* is present on the Slaughter Stone; previous surveys did not distinguish the two forma of *V. nigrescens*. *Sarcopyrenia gibba* is present on the bluestone 'Touching Stone' near the new Visitor Centre and is new to the wider Stonehenge site.

4. Discussion / Recommendations

Potential threats to the notable lichen communities at Stonehenge

- Inappropriate management of grassland near the stones. Rank vegetation is deleterious to lichens on stone structures. If the mowing regime became less regular this would almost certainly result in additional invertebrate browsing of the lichens, which would be especially intense on the lower stones and near the bases of the uprights.
- The large numbers of visitors during solstice periods allows the potential for some damage by abrasion, urination, application of artificial substances to the stones and graffiti.
- Background atmospheric pollution. Many lichen species are sensitive to atmospheric pollution. From the Industrial Revolution until the late 20th century, sulphur dioxide pollution (largely arising from the burning of coal) caused extensive damage to lichen communities across much of lowland England. From the 1980s onwards, the increased influence of compounds of nitrogen has resulted in a new and evolving pollution regime. Compounds of nitrogen are deleterious to many lichens growing on siliceous rocks (exceptions are the specialized communities which grow under the influence of bird droppings associated with bird perches). The presence of significant growths of free-living algal crusts on Stonehenge may be caused, in part at least, by the current high background levels of compounds of nitrogen.
- Pollution from nearby sources. The A303 road carries heavy traffic which will be a source of some dust and compounds and particulates from vehicle exhausts.
- Pollution from construction works.

Background atmospheric effects are likely to be the most insidious threat to lichens at Stonehenge; currently the atmospheric concentration of nitrogen compounds is the cause for concern. The two main sources of atmospheric nitrogen compounds are considered to be the burning of fossil fuels and agricultural activities. Fortunately, well-established lichen communities (such as those on natural outcrops, ancient stonework and veteran trees) appear to have some resilience and a large proportion of their species can survive in suboptimal conditions over moderate time scales. It is reasonable to speculate that atmospheric concentrations of nitrogen compounds are likely to decrease in future. There is a recognition that diesel engines generally produce more particulate and nitrogen pollution than other types of engine. Electric vehicles are predicted to form an increasing proportion of the nation's fleet of motor vehicles (such vehicles produce low emissions in use compared with exhaust pipe emissions from internal combustion engines). The emissions of nitrogen compounds from the agricultural industry is likely to decrease due to a combination of better technology, economy and regulation.

The management of the grassland at Stonehenge is very important in conserving the lichens, especially those growing on the low stones (see Appendix E). The open and unsupervised access to large numbers of people at the solstices and equinoxes is a mild concern but the carefully supervised access (with no direct contact with the stones) for the rest of the year appears to be sufficient to allow the slight to locally moderate damage during the short open access periods to recover.

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APPENDICES

APPENDIX A. List of all lichens accepted as occurring at Stonehenge since 1973

This list includes all stones associated with the main circle and its outliers but does not include species recorded from the Touching Stones (formerly known as the Carpark Stones).

Key to the table
Column A gives the standard British Lichen Society number for each taxon.
Column B gives the name for each taxon (as currently listed in the British Lichen Society Taxon Dictionary).
Column C indicates those species which are considered extinct at Stonehenge (Ex) and taxa added to the list in September 2017 (New).
Column D gives the conservation evaluation and rarity as listed by Woods & Coppins (2012).
LC = Least Concern, IR = species for which the UK has international responsibility (mainly species that are present in the UK in significant populations, but very rare elsewhere in Europe), NT = Near Threatened, Sc = relevant to Scottish sites, NR = Nationally Rare (occurring in 1-15 hectads in the UK), NS = Nationally Scarce (occurring in 16-100 hectads in the UK).

A	B	C	D
10	*Acarospora fuscata*		LC
1292	*Amandinea pelidna*		LC
212	*Amandinea punctata*		LC
47	*Anaptychia runcinata*		LC
102	*Aspicilia caesiocinerea*		LC
109	*Aspicilia epiglypta*		LC NS
116	*Aspicilia leprosescens*		LC
200	*Buellia aethalea*		LC
210	*Buellia leptoclinoides*		LC NR
219	*Buellia ocellata*		LC
214	*Buellia saxorum*		NT NR
217	*Buellia subdisciformis*		LC
263	*Caloplaca chlorina*		LC
253	*Caloplaca crenularia*		LC
2315	*Caloplaca flavocitrina*		LC
261	*Caloplaca holocarpa s. lat.*		LC
2607	*Caloplaca limonia*	New	LC
292	*Candelariella coralliza*		LC
294	*Candelariella vitellina f. flavovirella*		LC
298	*Candelariella vitellina f. vitellina*		LC
1609	*Catillaria atomarioides*		LC NS
306	*Catillaria chalybeia var. chalybeia*		LC
371	*Cladonia chlorophaea s. lat.*	Ex	LC
410	*Cladonia pyxidata*	Ex	LC
605	*Cresponea premnea*		LC Sc IR
491	*Diploicia canescens*		LC
987	*Flavoparmelia caperata*		LC

A	B	C	D
521	*Fuscidea lightfootii*		LC
554	*Haematomma ochroleucum var. ochroleucum*		LC
555	*Haematomma ochroleucum var. porphyrium*		LC
582	*Hypogymnia physodes*		LC
1013	*Hypotrachyna revoluta s. lat.*		
591	*Lasallia pustulata*	Ex	LC
2551	*Lecania erysibe s. lat.*		
629	*Lecanora andrewii*		LC NS
635	*Lecanora campestris subsp. campestris*		LC
643	*Lecanora conizaeoides f. conizaeoides*		LC
646	*Lecanora dispersa*		LC
652	*Lecanora fugiens*		LC
653	*Lecanora gangaleoides*		LC
661	*Lecanora muralis*		LC
757	*Lecanora orosthea*		LC
674	*Lecanora rupicola var. rupicola*		LC
783	*Lecanora sulphurea*		LC
724	*Lecidea fuscoatra s. lat.*		
802	*Lecidella scabra*		LC
803	*Lecidella stigmatea*		LC
820	*Lepraria incana s. lat.*		
998	*Melanelixia fuliginosa*		LC
1020	*Melanelixia subaurifera*		LC
926	*Ochrolechia parella*		LC
937	*Opegrapha areniseda*		LC NS Sc
947	*Opegrapha gyrocarpa*		LC
967	*Opegrapha zonata*		LC
63	*Pachnolepia pruinata*		LC
1015	*Parmelia saxatilis*		LC
1022	*Parmelia sulcata*		LC
1057	*Pertusaria albescens var. corallina*		LC
1058	*Pertusaria amara f. amara*		LC
1087	*Pertusaria pertusa*		LC
1089	*Pertusaria pseudocorallina*		LC
1107	*Phaeophyscia orbicularis*		LC
1108	*Phaeophyscia sciastra*		LC NS
1112	*Physcia adscendens*		LC
1114	*Physcia caesia*		LC
1116	*Physcia dubia*		LC
1122	*Physcia tribacia*	Ex	LC
1127	*Physconia grisea*		LC
1167	*Polysporina simplex*		LC
1171	*Porina chlorotica f. chlorotica*		LC
572	*Porpidia tuberculosa*		LC
633	*Protoparmelia badia*	Ex	LC

A	B	C	D
1021	*Punctelia subrudecta s. lat.*		
1240	*Ramalina siliquosa*		LC
1241	*Ramalina subfarinacea*	Ex	LC
1251	*Rhizocarpon distinctum*	New	LC
1257	*Rhizocarpon geographicum*		LC
1266	*Rhizocarpon reductum*		LC
1281	*Rinodina atrocinerea*		LC
1299	*Rinodina beccariana*		LC NS
1285	*Rinodina confragosa*		LC NS
1289	*Rinodina oleae*		LC
1727	*Rinodina orculariopsis*		LC NS
1295	*Rinodina oxydata*		LC NS
1300	*Rinodina teichophila*		LC
1305	*Sarcogyne hypophaea*		LC NS
1320	*Scoliciosporum chlorococcum*		LC
1322	*Scoliciosporum umbrinum*		LC
630	*Tephromela atra var. atra*		LC
1431	*Trapelia coarctata*		LC
1077	*Varicellaria lactea*		LC
1510	*Verrucaria nigrescens f. nigrescens*		LC
2514	*Verrucaria nigrescens f. tectorum*	New	LC
988	*Xanthoparmelia conspersa*	Ex	LC
1003	*Xanthoparmelia loxodes*		LC
1005	*Xanthoparmelia mougeotii*		LC
1026	*Xanthoparmelia verruculifera*		LC
1526	*Xanthoria calcicola*		LC
1527	*Xanthoria candelaria s. lat.*		LC
1530	*Xanthoria parietina*		LC
1531	*Xanthoria polycarpa*		LC

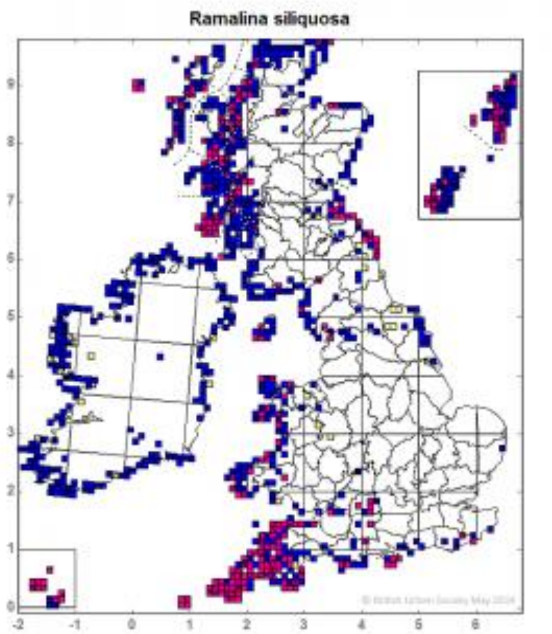
APPENDIX B. The abundance of the maritime lichens at Stonehenge

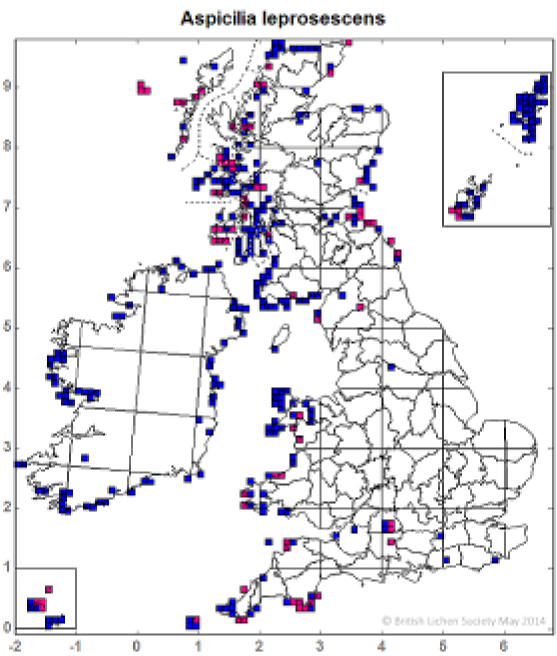
Giavarini & James (2003) provided the following summary of the maritime element at Stonehenge giving the total number of stones on which they found each species. The figure in brackets relates to the presence on individual stones, hence (25) = Stone 25 (using the standard recognised numbering of the stones) and (SS) = Slaughter Stone.

Summary of the maritime element which renders the site of international importance:

Species	No. of stones the species occurs on	Comments
Anaptychia runcinata	1 (25)	Vulnerable to shading and abrasion
Aspicilia epiglypta	3 (12, 14 & SS)	Grass management important
Aspicilia leprosescens	10	Up- facing surfaces favoured
Buellia leptoclinoides	31	Mostly on vertical, shaded surfaces
Buellia subdisciformis	51	On sunny, exposed surfaces
Lecanora andrewii	1(1)	Low on vertical face, easily missed
Lecanora fugiens	6	Recumbent rocks favoured
Neofuscelia aff. loxodes	5	Atypical material, under investigation
Ramalina siliquosa	57	Widespread, a fast coloniser
Rinodina confragosa	56	Pioneer crust, uprights favoured
Rinodina orculariopsis	37	On wide range of stones

APPENDIX C: Selected distribution maps





Distribution maps of *Ramalina siliquosa* and *Aspicilia leprosescens* showing the anomalous inland occurrences on the sarsen stones of Wiltshire. Pink squares are post-2000 records. Further distribution maps can be viewed on the British Lichen Society website, e.g. http://www.britishlichensociety.org.uk/resources/species-accounts/phaeophyscia-sciastra

APPENDIX D: Surveys at Avebury

Avebury Stone Circle – a training session and comparison
Access to Stonehenge is tightly restricted. Two days in advance of the 2017 Stonehenge survey were spent at Avebury as a training session. The Stone Circle at Avebury comprises large standing sarsen stones of the same type of sandstone as the sarsens of Stonehenge. The lichen communities at Avebury are very similar to those at Stonehenge and include the important 'maritime' component and the Near Threatened *Buellia saxorum*. *B. saxorum* is a good example of a lichen species which is not easily recognised in the field and its appearance is almost identical to some other members of the genus *Buellia* and also to some species belonging to other genera. At Stonehenge, collecting and the application of 'spot-test' chemicals must be performed in an extremely frugal manner. It is hence unsurprising that the presence of *B. saxorum* at Stonehenge was not discovered until David Hill's survey work (Nicholas Pearson Associates, 2003, 2005a, 2005b), despite this species being a well-known feature of the Avebury stones and being observed to be frequent at Stonehenge during the 2017 survey. Time spent at Avebury allowed a detailed study of *B. saxorum* resulting in the discovery of anatomical characters which are not mentioned in the published literature (e.g. Coppins *et al*., 2009). The presence of microscopic yellow crystalline matter in the thallus imparts a slight pastel yellow tinge in the field (especially where abraded or browsed). This has proved useful in recognising candidates for *B. saxorum* (among look-alikes) which can then be confirmed in the field by the C+ red spot test. Experimentation with Avebury material showed that this C test is weak and could easily be missed in the field. The test is best performed with strong bleach (e.g. Parazone) on the exposed medulla close to the growing edge of the thallus. The use of a cocktail stick allows the transfer of a minimum quantity of reagent while the reaction is observed through a lens. (Note that C will kill the portion of thallus to which it is applied and hence it is important that the reaction is performed in this focussed, effective and frugal manner.)

The two days spent at Avebury provided a re-familiarization for the surveyors of the appearance and ecology of lichen species that are rarely encountered in other habitats.

Avebury revisited
During the first recording session at Stonehenge (25th September 2017) the incredible abundance of mites was noted. These hard-bodied oribatids are voracious consumers of lichens forming a significant part of the ecology of many lichen species. Browsing by mites results in a fretwork or pitted appearance of the lichen thalli (in contrast to the browsing by molluscs which results in a striated, planed-off appearance due to their rasping radulae). Lichens on the lower parts of many stones at Stonehenge were observed to have considerable mite damage. The morning of 25th September was dull and damp with a light drizzle. After leaving Stonehenge at 09:30, the surveyors drove to Avebury to see if the same abundance of mites was present on the stones there. The difference was remarkable; mites were difficult to find and their damage very slight. There is currently no way of knowing for sure why the damage by mites is more intense at Stonehenge than it is at Avebury, or whether the intensity of damage at Stonehenge is a recent phenomenon or part of the natural dynamics of the community.

The return to Avebury also allowed a confirmation that the algal growth on crustose lichens noted at Stonehenge was also present at Avebury. In the wet conditions at Stonehenge the amount of bright green algal overgrowth on lichens such as *Haematomma ochroleucum* and *Lecanora orosthea* seemed alarming. Lichenologists normally chose dry conditions to record lichens as they are much easier to identify when not hydrated. When dry, algal crusts are much less conspicuous and go almost unnoticed on lichen crusts. A spray bottle was used to demonstrate how dramatically different algal crusts appear when wet (swollen, gelatinous and bright in colour) compared with when they are dry. It is not possible to say whether the algal crusts are now more abundant on Stonehenge than previously (their abundance has never been measured) nor whether they are a sign of deleterious conditions.

Algal crusts on siliceous rock are often an indicator of nutrient enrichment and were also formerly suppressed when more acidic atmospheric conditions resulted from coal burning and industry. The gritstone walls of the Pennines have seen a remarkable (and probably unwelcome) colonisation by the alga *Klebsormidium*. My suspicion is that the current background levels of atmospheric nitrogen compounds, perhaps enhanced by those from nearby roads and farming activities, are likely to be having a mildly to moderately deleterious effect on the lichens.

APPENDIX E: Management and lichens at Stonehenge

The public now has no direct contact with the stones which constitute the monument of Stonehenge (except during short periods at solstice and equinox dates). This restriction is partly due to concerns that abrasion from visitors would adversely affect the lichen communities. This level of care is desirable even though the unrestricted access to the Stone Circle at Avebury does not appear to be causing significant damage. The situation is slightly different at Stonehenge where there are fallen and other low stones of importance (those present at Avebury are almost all standing) and visitors might damage the lichens by sitting and climbing on these. The unlimited and largely unregulated access, particularly at the solstices, results in many thousands of visitors having direct access to the stones for short periods. Using stones as urinals and the anointing of stones with oil during solstice celebrations has caused some noticeable, but mainly temporary damage to the lichen communities. An abundance of apparently undamaged *Phaeophyscia sciastra* survives on the Slaughter Stone, despite this stone being very vulnerable to being sat and climbed upon during the short periods of unrestricted access.

The grassland in and around the Stonehenge monument is currently managed mechanically. A short, regularly mown sward is advantageous over a longer, ranker sward. This is frequently observed in churchyards where gravestones in overgrown parts usually have suppressed and relatively species-poor communities. Not only does the taller vegetation create shade, more significantly it boosts the population of invertebrate browsers (particularly molluscs) which can cause considerable damage. Historically the grassland surrounding Stonehenge is likely to have been close-cropped turf grazed by sheep. Nowadays, the grassland is managed mechanically, a time-consuming process since the workers are required to put shuttering boards around the stones before mowing and strimming.

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