




1 RMAVIS v1.0: a R Shiny application for the analysis of
2 vegetation survey data and assignment to GB NVC
3 communities.

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10 Summary

11 RMAVIS is a R Shiny application for the assignment of vegetation sample plot data to British
12 National Vegetation Classification (NVC) communities ([Rodwell, 1991](#), [1992a](#), [1992b](#), [1995](#),
13 [2000](#)).

14 The assignment of vegetation sample plot data to established vegetation classification units
15 using computational methods is a well established and recognised practice ([Maciejewski et al.](#),
16 [2020](#)). The results of this assignment process are used in various ways, including assisting in
17 the phase 2 habitat survey (or NVC survey) ([Rodwell, 2006](#)) process; establishing an ecological
18 baseline and identifying important ecological features such as protected habitats ([CIEEM](#),
19 [2022](#)); and in ecological restoration by providing a proxy for historical reference ecosystems
20 to target and against which to measure restoration progress ([Gann et al.](#), [2019](#); [Pywell et al.](#),
21 [2002](#); [Sturbois et al.](#), [2023](#)).

22 In the Great Britain (GB) the development of computational methods and programs for the
23 assignment of vegetation survey data to NVC communities began with the development of
24 TABLEFIT ([Hill, 1989](#); [Marrs, 2019](#)) and was followed by MATCH ([Malloch, 1998](#)). The
25 most recent program, the Modular Analysis of Vegetation Information System (MAVIS), was
26 developed as a windows application in 2000 and was a DEFRA-funded output of the ECOFACT
27 project ([Bunce et al.](#), [1999](#)), with the latest version released in 2016 ([Smart et al.](#), [2016](#)).

28 Statement of need

29 The requirement for a new program in the form of a R Shiny ([Chang et al.](#), [2024](#)) application
30 arises from several needs, namely to: 1) accommodate updates to the NVC; 2) provide a
31 means to easily reproduce and attribute the results of the NVC assignment process; 3) broaden
32 and simplify access through the provision of a web-based Graphical User Interface (GUI); and
33 4) facilitate the continuous development of such NVC assignment software. We developed
34 RMAVIS considering these needs, with the view to providing a reliable system for use by the GB
35 ecology and conservation community, analogous to the Engine for Relevés to Irish Communities
36 Assignment (ERICA) tool ([Perrin et al.](#), [2018](#); [Perrin, 2019](#)) developed for Ireland.

37 **Application structure**

38 Inspired by the extensible structure of the species niche and distribution modelling R shiny
 39 application wallace (Kass et al., 2023), we constructed RMAVIS with a modular architecture,
 40 enabling both the easy maintenance of existing modules, and easy development of additional
 41 modules in the future.

42 RMAVIS currently contains a total of eighteen modules, with the fourteen main modules
 43 summarised in the following table.

Module	Description
Sidebar	Acts as the control module, containing the options for each module.
Data Input	Facilitates the entry of data, three methods are provided: manual, upload, and example.
Data Validation	Checks the format of the inputted data and provides means to adjust incorrectly formatted entries.
Data Structure	Checks the structure of the inputted data, displaying the availability of data by species and number of plots per year and group.
NVC Assignment	Displays the results of the NVC assignment process.
Habitat Correspondence	Displays the habitats from alternative habitat classifications associated with the top-fitted NVC communities.
Floristic Tables	Allows the comparison of floristic tables composed from the inputted data with the NVC's floristic tables.
Frequency	Summarises the frequency of occurrence of each species across all plots over time.
EIVs	Displays the mean Hill-Ellenberg ecological indicator values (EIVs) for each plot, group of plots, and all plots.
Diversity	Displays a number of diversity metrics for each plot and group of plots.
MVA National	Constructs an ordination space using all NVC pseudo-quadrats, with sample plots added in passively.
MVA Local, restricted	Constructs an ordination space using the top-fitted NVC communities pseudo-quadrats, with sample plots added in passively.
MVA Local, unrestricted	Constructs an ordination space using the top-fitted NVC communities pseudo-quadrats and sample plots.
Report	Provides the user with a downloadable report, containing user-selected outputs from the app session.

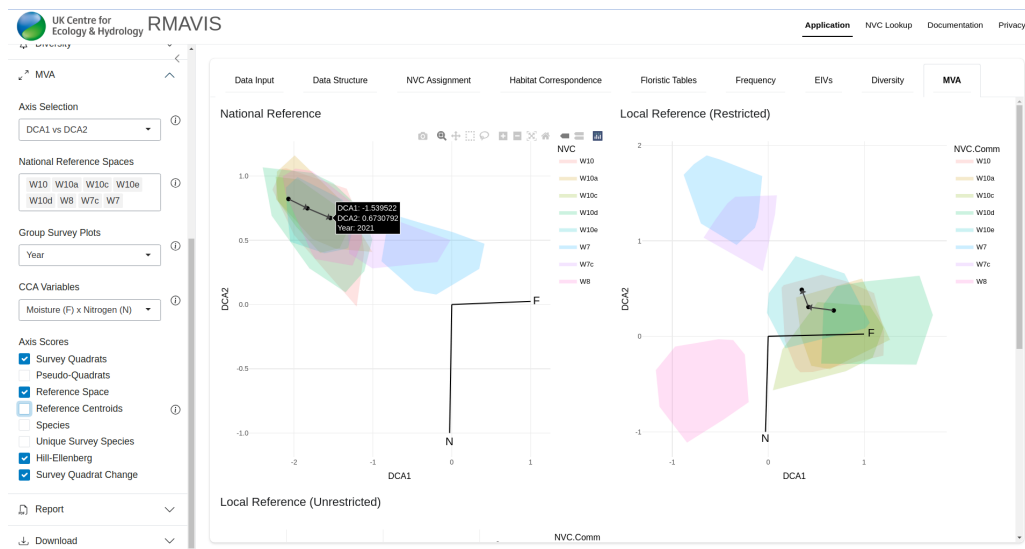


Figure 1: The MVA module of RMAVIS, showing the trajectory of all sample plots from the Leith Hill Wood example dataset in the ordination spaces over time.

44 Data sources and dependencies

45 RMAVIS depends on a number of individual datasets. The list of accepted species was constructed
 46 using the vascular plant (*Tracheophyta* and *Pteridophyta*), moss (*Bryophyta*), liverwort
 47 (*Marchantiophyta*), and hornwort (*Anthocerotophyta*) taxa present in the UKSI, retrieved
 48 from the National Biodiversity Network (NBN), (NBN Trust, 2024d, 2024e, 2024b, 2024c,
 49 2024a) filtered to include taxa at the species, species hybrid, species aggregate, subspecies,
 50 species sensu lato, and genus ranks; and the limited number of lichen (*Lecanoromycetes*)
 51 and charophyte (*Charophyta*) taxa, along with one unspecified ‘algae’ taxon present in the
 52 NVC floristic tables. The NVC communities present in RMAVIS are composed from Rodwell
 53 (1991), Rodwell (1992a), Rodwell (1992b), Rodwell (1995), Rodwell (2000), Wallace & Prosser
 54 (2017), Prosser et al. (2023), and Wallace et al. (2023). Data for habitat correspondences
 55 is derived from: the Joint Nature Conservation Committee (JNCC) Spreadsheet of Habitat
 56 Correspondences (JNCC, 2008), UKHab V1.1 (Butcher et al., 2020), and the National Plant
 57 Monitoring Scheme (NPMS) habitat correspondences (Pescott et al., 2019). Data for the
 58 vascular plant Hill-Ellenberg values were retrieved from the BSBI checklists, specifically the
 59 Nitrogen Score (N) (BSBI, 2017c), Moisture Score (F) (BSBI, 2017d), Reaction Score (R)
 60 (BSBI, 2017a), Salinity Score (S) (BSBI, 2017b), and Light Score (L) (BSBI, 2017e) checklists.
 61 The corresponding data for bryophytes was taken from BRYOATT (Hill et al., 2007). Four
 62 example datasets are bundled with RMAVIS: 1) Parsonage Down (Ridding et al., 2020), 2) Leith
 63 Hill Place Wood (Smart et al., 2024; Wood et al., 2015), 3) Whitwell Common (Smart, 2000),
 64 and 4) Newborough Warren (Wallace & Jones, 2018).

65 RMAVIS depends on the rhandsontable (Owen, 2021), reactable (Lin, 2024), bslib (Sievert
 66 et al., 2024), shinyWidgets (Perrier et al., 2024), shinyjs (Attali, 2023), shinybusy (Meyer
 67 & Perrier, 2024), rmarkdown (Allaire et al., 2023), bookdown (Xie, 2024), tidyverse (Wickham
 68 et al., 2019), plotly (Sievert, 2020), kableExtra (Zhu, 2024), writexl (Ooms, 2024),
 69 and vegan (Oksanen et al., 2022) R packages.

70 Conclusion

71 RMAVIS provides a web-based, easily accessible GUI for the assignment of vegetation sample plot
 72 data to GB NVC communities. RMAVIS also provides a number of other exploratory analyses,

73 which compliment the NVC assignment results. We plan to maintain, optimise, and expand
74 the functionality found in v1.0 of RMAVIS and hope that it acts as a useful tool for the GB
75 ecology and conservation community.

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84 References

- 85 Allaire, J., Xie, Y., Dervieux, C., McPherson, J., Luraschi, J., Ushey, K., Atkins, A., Wickham,
86 H., Cheng, J., Chang, W., & Iannone, R. (2023). *Rmarkdown: Dynamic Documents for R*.
87 <https://github.com/rstudio/rmarkdown>
- 88 Attali, D. (2023). *Shinyjs: Easily Improve the User Experience of Your Shiny Apps in Seconds*.
89 <https://deanattali.com/shinyjs/>
- 90 BSBI. (2017a). *Ellenberg indicator r (reaction)*. [https://database.bsbi.org/object.php?
91 entityid=2cd4p9h.2cg1m1&class=ChecklistInstance](https://database.bsbi.org/object.php?entityid=2cd4p9h.2cg1m1&class=ChecklistInstance)
- 92 BSBI. (2017b). *Ellenberg indicator s (salt tolerance)*. [https://database.bsbi.org/object.php?
93 entityid=2cd4p9h.2cg1s5&class=ChecklistInstance](https://database.bsbi.org/object.php?entityid=2cd4p9h.2cg1s5&class=ChecklistInstance)
- 94 BSBI. (2017c). *Ellenberg indicator n (nitrogen)*. [https://database.bsbi.org/object.php?
95 entityid=2cd4p9h.2cg1yq&class=ChecklistInstance](https://database.bsbi.org/object.php?entityid=2cd4p9h.2cg1yq&class=ChecklistInstance)
- 96 BSBI. (2017d). *Ellenberg indicator f (moisture)*. [https://database.bsbi.org/object.php?
97 entityid=2cd4p9h.2cg1kd&class=ChecklistInstance](https://database.bsbi.org/object.php?entityid=2cd4p9h.2cg1kd&class=ChecklistInstance)
- 98 BSBI. (2017e). *Ellenberg indicator l (light)*. [https://database.bsbi.org/object.php?entityid=
99 2cd4p9h.2cg1v7&class=ChecklistInstance](https://database.bsbi.org/object.php?entityid=2cd4p9h.2cg1v7&class=ChecklistInstance)
- 100 Bunce, R. G. H., Barr, C. J., Gillespie, M. K., Howard, D. C., Scott, W. A., Smart, S. M.,
101 Van de Poll, H. M., & Watkins, J. W. (1999). *Vegetation of the British countryside -
102 the Countryside Vegetation System. ECOFACT Volume 1* (Vol. 1). DETR. ISBN: 978-1-
103 85112-155-7
- 104 Butcher, B., Carey, P., Edmonds, R., Norton, L., & Treweek, J. (2020). *UK habitats
105 classification user manual version 1.1*. Stockport: UKHab Ltd.
- 106 Chang, W., Cheng, J., Allaire, J., Sievert, C., Schloerke, B., Xie, Y., Allen, J., McPherson,
107 J., Dipert, A., & Borges, B. (2024). *Shiny: Web application framework for r*. [https:
108 //shiny.posit.co/](https://shiny.posit.co/)
- 109 CIEEM. (2022). *Guidelines for ecological impact assessment in the UK and ire-
110 land. Terrestrial, freshwater, coastal and marine. September 2018. Ver-
111 sion 1.2 - updates april 2022*. PDF. [https://cieem.net/wp-content/uploads/
112 2018/08/ECIA-Guidelines-2018-Terrestrial-Freshwater-Coastal-and-Marine-V1.
113 2-April-22-Compressed.pdf](https://cieem.net/wp-content/uploads/2018/08/ECIA-Guidelines-2018-Terrestrial-Freshwater-Coastal-and-Marine-V1.2-April-22-Compressed.pdf)
- 114 Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J.
115 G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw,

- 116 N., Decler, K., & Dixon, K. W. (2019). International principles and standards for the
117 practice of ecological restoration. Second edition. *Restoration Ecology*, 27(S1), S1–S46.
118 <https://doi.org/10.1111/rec.13035>
- 119 Hill, M. O. (1989). Computerized matching of relevés and association tables, with an
120 application to the British National Vegetation Classification. *Vegetatio*, 83(1), 187–194.
121 <https://doi.org/10.1007/BF00031691>
- 122 Hill, M. O., Preston, C. D., Bosaquet, S. D. S., & B., R. D. (2007). *BRYOATT - attributes of*
123 *british and irish mosses, liverworts and hornworts - spreadsheet*. Centre for Ecology; Hydrol-
124 ogy. <https://www.brc.ac.uk/biblio/bryoatt-attributes-british-and-irish-mosses-liverworts-and-hornwo>
- 125 JNCC. (2008). *Spreadsheet of habitat correspondences*. [https://hub.jncc.gov.uk/assets/](https://hub.jncc.gov.uk/assets/9e70531b-5467-4136-88f6-3b3dd905b56d)
126 [9e70531b-5467-4136-88f6-3b3dd905b56d](https://hub.jncc.gov.uk/assets/9e70531b-5467-4136-88f6-3b3dd905b56d)
- 127 Kass, J. M., Pinilla-Buitrago, G. E., Paz, A., Johnson, B. A., Grisales-Betancur, V., Meenan,
128 S. I., Attali, D., Broennimann, O., Galante, P. J., Maitner, B. S., Owens, H. L., Varela, S.,
129 Aiello-Lammens, M. E., Merow, C., Blair, M. E., & Anderson, R. P. (2023). Wallace 2: A
130 shiny app for modeling species niches and distributions redesigned to facilitate expansion via
131 module contributions. *Ecography*, 2023(3), e06547. <https://doi.org/10.1111/ecog.06547>
- 132 Lin, G. (2024). *Reactable: Interactive Data Tables for R*. <https://glin.github.io/reactable/>
- 133 Maciejewski, L., Pinto, P. E., Wurpillot, S., Drapier, J., Cadet, S., Muller, S., Agou, P., Renaux,
134 B., & Gégout, J.-C. (2020). Vegetation unit assignments: Phytosociology experts and
135 classification programs show similar performance but low convergence. *Applied Vegetation*
136 *Science*, 23(4), 698–709. <https://doi.org/10.1111/avsc.12516>
- 137 Malloch, A. J. C. (1998). *MATCH version 2*. University of Lancaster.
- 138 Marrs, R. H. (2019). *TABLEFIT v. 3.0 & v.4, programs for the identification of vegetation types*
139 *according to the British National Vegetation Classification Includes software [Other]*. Centre
140 for Ecology & Hydrology. <https://www.ceh.ac.uk/sites/default/files/Tablefit-Aug2016.zip>
- 141 Meyer, F., & Perrier, V. (2024). *Shinybusy: Busy Indicators and Notifications for 'Shiny'*
142 *Applications*. <https://github.com/dreamRs/shinybusy>
- 143 NBN Trust. (2024a). *Anthocerotophyta child taxa*. [https://species.nbnatlas.org/species/](https://species.nbnatlas.org/species/NHMSYS0021386659#classification)
144 [NHMSYS0021386659#classification](https://species.nbnatlas.org/species/NHMSYS0021386659#classification)
- 145 NBN Trust. (2024b). *Bryophyta child taxa*. [https://species.nbnatlas.org/species/](https://species.nbnatlas.org/species/NBNSYS0000172125#classification)
146 [NBNSYS0000172125#classification](https://species.nbnatlas.org/species/NBNSYS0000172125#classification)
- 147 NBN Trust. (2024c). *Marchantiophyta child taxa*. [https://species.nbnatlas.org/species/](https://species.nbnatlas.org/species/NHMSYS0020796639#classification)
148 [NHMSYS0020796639#classification](https://species.nbnatlas.org/species/NHMSYS0020796639#classification)
- 149 NBN Trust. (2024d). *Pteridophyta child taxa*. [https://species.nbnatlas.org/species/](https://species.nbnatlas.org/species/NHMSYS0001747256#classification)
150 [NHMSYS0001747256#classification](https://species.nbnatlas.org/species/NHMSYS0001747256#classification)
- 151 NBN Trust. (2024e). *Tracheophyta child taxa*. [https://species.nbnatlas.org/species/](https://species.nbnatlas.org/species/NHMSYS0020787695#classification)
152 [NHMSYS0020787695#classification](https://species.nbnatlas.org/species/NHMSYS0020787695#classification)
- 153 Oksanen, J., Simpson, G., Solymos, P., Lahti, L., Hannigan, G., Weedon, J., Szöcs, E.,
154 McGlenn, D., Legendre, P., Zhihong, Bolker, B., Chirico, M., Friendly, M., Stier, A., Borcard,
155 D., Dunné, F. van, Bengtsson, H., Andersen, K. S., Barbour, M., ... brendanf. (2022).
156 *Vegan: Community Ecology Package*. Zenodo. <https://doi.org/10.5281/zenodo.7185692>
- 157 Ooms, J. (2024). *Writexl: Export Data Frames to Excel 'xlsx' Format*. [https://ropensci-r-](https://ropensci-r-universe.dev/writexl)
158 [universe.dev/writexl](https://docs.ropensci.org/writexl/) <https://docs.ropensci.org/writexl/>
- 159 Owen, J. (2021). *Rhandsontable*. <https://github.com/jrowen/rhandsontable>
- 160 Perrier, V., Meyer, F., & Granjon, D. (2024). *shinyWidgets: Custom Inputs Widgets for Shiny*.
161 <https://github.com/dreamRs/shinyWidgets>

- 162 Perrin, P. (2019). *ERICA - Engine for Relevés to Irish Communities Assignment V5.0*
163 *User's Manual*. BEC Consultants Ltd. [https://biodiversityireland.shinyapps.io/](https://biodiversityireland.shinyapps.io/vegetation-classification/_w_6fddd58f/manual.pdf)
164 [vegetation-classification/_w_6fddd58f/manual.pdf](https://biodiversityireland.shinyapps.io/vegetation-classification/_w_6fddd58f/manual.pdf)
- 165 Perrin, P., Fitzpatrick, Ú., & Lynn, D. (2018). The Irish Vegetation Classification - an
166 overview of concepts, structure and tools. *CIEEM in Practice*, 102, 14–19. [http://www.](http://www.botanicalenvironmental.com/wp-content/uploads/2018/12/IVC-CIEEM-Article.pdf)
167 [botanicalenvironmental.com/wp-content/uploads/2018/12/IVC-CIEEM-Article.pdf](http://www.botanicalenvironmental.com/wp-content/uploads/2018/12/IVC-CIEEM-Article.pdf)
- 168 Pescott, O., Walker, K., Harris, F., New, H., Cheffings, C., Newton, N., Jitlal, M., Redhead,
169 J., Smart, S. M., & Roy, D. B. (2019). *S1 file* [Data set]. [https://www.researchgate.net/](https://www.researchgate.net/publication/333011121_S1_File)
170 [publication/333011121_S1_File](https://www.researchgate.net/publication/333011121_S1_File)
- 171 Prosser, M., Wallace, H., & Gowing, D. (2023). Phytosociology informs the conservation
172 of species-rich meadows in hydrologically dynamic habitats: an example from British
173 floodplains in a wider European context. *British & Irish Botany*, 5(1). [https://doi.org/10.](https://doi.org/10.33928/bib.2023.05.001)
174 [33928/bib.2023.05.001](https://doi.org/10.33928/bib.2023.05.001)
- 175 Pywell, R. F., Bullock, J. M., Hopkins, A., Walker, K. J., Sparks, T. H., Burke, M. J. W., &
176 Peel, S. (2002). Restoration of species-rich grassland on arable land: Assessing the limiting
177 processes using a multi-site experiment. *Journal of Applied Ecology*, 39(2), 294–309.
178 <https://doi.org/10.1046/j.1365-2664.2002.00718.x>
- 179 Ridding, L. E., Bullock, J. M., Pescott, O. L., Hawes, P., Walls, R., Pereira, M. G., Thacker, S.
180 A., Keenan, P. O., Dragosits, U., & Pywell, R. F. (2020). Long-term change in calcareous
181 grassland vegetation and drivers over three time periods between 1970 and 2016. *Plant*
182 *Ecology*, 221(5), 377–394. <https://doi.org/10.1007/s11258-020-01016-1>
- 183 Rodwell, J. S. (Ed.). (1991). *British Plant Communities: Volume 1: Woodlands and Scrub*
184 (Vol. 1). Cambridge University Press. <https://doi.org/10.1017/9780521235587>
- 185 Rodwell, J. S. (Ed.). (1992a). *British Plant Communities: Volume 2: Mires and Heaths* (Vol.
186 2). Cambridge University Press. <https://doi.org/10.1017/9780521391658>
- 187 Rodwell, J. S. (Ed.). (1992b). *British Plant Communities: Volume 3: Grasslands and*
188 *Montane Communities* (Vol. 3). Cambridge University Press. [https://doi.org/10.1017/](https://doi.org/10.1017/9780521391665)
189 [9780521391665](https://doi.org/10.1017/9780521391665)
- 190 Rodwell, J. S. (Ed.). (1995). *British Plant Communities: Volume 4: Aquatic Communities,*
191 *Swamps and Tall-Herb Fens* (Vol. 4). Cambridge University Press. [https://doi.org/10.](https://doi.org/10.1017/9781107340817)
192 [1017/9781107340817](https://doi.org/10.1017/9781107340817)
- 193 Rodwell, J. S. (Ed.). (2000). *British Plant Communities: Volume 5: Maritime Communities*
194 *and Vegetation of Open Habitats* (Vol. 5). Cambridge University Press. [https://doi.org/](https://doi.org/10.1017/CBO9780511541834)
195 [10.1017/CBO9780511541834](https://doi.org/10.1017/CBO9780511541834)
- 196 Rodwell, J. S. (Ed.). (2006). *National vegetation classification: Users' handbook*. Joint
197 Nature Conservation Committee (JNCC) Peterborough. [https://data.jncc.gov.uk/data/](https://data.jncc.gov.uk/data/a407ebfc-2859-49cf-9710-1bde9c8e28c7/JNCC-NVC-UsersHandbook-2006.pdf)
198 [a407ebfc-2859-49cf-9710-1bde9c8e28c7/JNCC-NVC-UsersHandbook-2006.pdf](https://data.jncc.gov.uk/data/a407ebfc-2859-49cf-9710-1bde9c8e28c7/JNCC-NVC-UsersHandbook-2006.pdf)
- 199 Sievert, C. (2020). *Interactive Web-Based Data Visualization with R, plotly, and shiny*.
200 Chapman and Hall/CRC. <https://doi.org/10.1201/9780429447273>
- 201 Sievert, C., Cheng, J., & Aden-Buie, G. (2024). *Bslib: Custom 'Bootstrap' 'Sass' Themes for*
202 *'shiny' and 'rmarkdown'*. <https://rstudio.github.io/bslib/>
- 203 Smart, S. M. (2000). Ecological assessment of vegetation from a nature reserve using
204 regional reference data and indicator scores. *Biodiversity and Conservation*, 9(6), 811–832.
205 <https://doi.org/10.1023/a:1008948602316>
- 206 Smart, S. M., Goodwin, A., & Wallace, H. (2016). *MAVIS (ver 1.03) user manual* (S. M.
207 Smart, Ed.). <https://www.ceh.ac.uk/sites/default/files/Mavis-Desktop-Help.pdf>

- 208 Smart, S. M., Wood, C. M., Seaton, F. M., McMullen, A., Ward, S. E., Ward, R.,
209 O'Reilly, J., Ruffino, L., Losse, P., Stroh, P., Pilkington, S., Saunders, L., Wal-
210 lace, H. L., O'Rourke, C., Long, C. E., Potter, R., Maskell, L. C., Sier, A. R.
211 J., Norton, L. R., ... Vallis-Wilks, M. (2024). *Broadleaved woodland survey of
212 great britain, 2020-2022*. NERC EDS Environmental Information Data Centre.
213 <https://doi.org/10.5285/42C203C8-44DE-40E2-A694-B1E8CBD4C8E1>
- 214 Sturbois, A., De Cáceres, M., Bifulchi, A., Bioret, F., Boyé, A., Gauthier, O., Grall, J., Grémare,
215 A., Labrune, C., Robert, A., Schaal, G., & Desroy, N. (2023). Ecological quality assessment:
216 A framework to report ecosystems quality and their dynamics from reference conditions.
217 *Ecosphere*, 14(12), e4726. <https://doi.org/10.1002/ecs2.4726>
- 218 Wallace, H., Gowing, D., Lawson, C., Rothero, E., & Strachan, I. (2023). An exploration of
219 oceanic wet grasslands in the Scottish coastal lowlands. *British Wildlife*. [https://www.
220 britishwildlife.com/article/article-volume-35-number-3-page-193-200/](https://www.britishwildlife.com/article/article-volume-35-number-3-page-193-200/)
- 221 Wallace, H., & Jones, L. (2018). *Monitoring of forest removal and groundworks to rejuvenate
222 dunes at newborough warren - ynys llanddwyn SSSI. Vegetation change, third year results for
223 2017*. NERC/Centre for Ecology & Hydrology. <http://nora.nerc.ac.uk/id/eprint/524094/>
- 224 Wallace, H., & Prosser, M. (2017). *A review of the national vegetation classification for
225 the calthion group of plant communities in england and wales (JP021)*. Natural England.
226 <https://publications.naturalengland.org.uk/publication/5839929072943104>
- 227 Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Golemund,
228 G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S.
229 M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., ... Yutani, H. (2019).
230 Welcome to the Tidyverse. *Journal of Open Source Software*, 4(43), 1686. [https://doi.
231 org/10.21105/joss.01686](https://doi.org/10.21105/joss.01686)
- 232 Wood, C. M., Smart, S. M., & Bunce, R. G. H. (2015). Woodland survey of great
233 britain 1971-2001. *Earth System Science Data*, 7(2), 203–214. [https://doi.org/10.
234 5194/essd-7-203-2015](https://doi.org/10.5194/essd-7-203-2015)
- 235 Xie, Y. (2024). *Bookdown: Authoring Books and Technical Documents with R Markdown*.
236 <https://github.com/rstudio/bookdown>
- 237 Zhu, H. (2024). *kableExtra*. <https://github.com/haozhu233/kableExtra>