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1 *Replicability in palaeobotany: Toward a standardisation of citation of extant material*

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7

8 **Abstract**

9 Replicability is a key concept in science. The citation of extant material used for comparative
10 purposes in palaeobotanical studies is the *sine qua non* of this replicability. However, there is
11 no standard for citing herbarium sheets, personal collections, or field pictures of specimens.
12 Here, I propose a simple citation guideline for all these cases, emphasizing the citation of the
13 voucher specimens using the collector's name and collection number.

14

15 **Key words:** Replicability, Herbarium, Standardisation, Palaeobotany

16

17 **1 Introduction**

18 The guidelines of the journal *Review of Palaeobotany and Palynology* require that “all the
19 figured studied material has to be adequately curated in a recognized institution, so as to
20 guarantee the replicability of research. State in "Material and methods" the institutional
21 repository of the studied material (samples, thin sections and fossils), and in the figure
22 captions the curatorial museum numbers of all illustrated specimens”. These guidelines aim to
23 achieve one of the most common principles in science: replicability. A study should be
24 replicable to test the accuracy of the research conducted. This principle is especially important
25 in taxonomy. For example, the designation of a holotype allows researchers to refer back to
26 the specimen curated and kept in one herbarium, or other collection or institution (Art. 8.1.
27 and Art. 9.1., Turland et al., 2018), establishing links with concepts such as species, genus, or
28 family.

29 The replicability of a taxonomic study requires that the fossil material studied, as well
30 as the material used for comparisons, is made available to the scientific community. In
31 palaeobotany, fossil specimens are typically deposited in public institutions. Comparisons
32 made to support the identification of a fossil or the definition of a new species can draw upon
33 various sources of information, including paleobotanical and botanical literature, dry extant
34 specimens kept in herbaria, and living specimens observed during fieldwork. These extant
35 specimens must be cited and vouchered to ensure the replicability of the taxonomic research.

36 The aim of this short communication is three-fold: in articles presenting and
37 discussing palaeobotanical results, 1) assess the replicability of comparisons with extant
38 specimens and the way such specimens are cited, 2) propose a standardisation of voucher
39 citation for herbarium specimens, and 3) provide recommendations of best practices for citing
40 personal collections and pictures of living specimens from the field.

41

42 **2 Review of the 2022 Review of Palaeobotany and Palynology papers**

43 The use of extant specimens is not possible in many palaeobotanical studies, such as
44 those involving extinct groups from the Palaeozoic or most of the Mesozoic. Comparisons
45 with extant specimens are especially prevalent in Cainozoic taxonomy, where fossils can
46 often be attributed to extant families or genera. Studies focusing on disciplines other than
47 taxonomy, such as taphonomic experiments or climatic proxy investigations, may also refer to
48 extant specimens.

49 Therefore, among the 144 papers I reviewed published in 2022 in the Review of
50 Palaeobotany and Palynology (excluding discussions, editorial papers, appendix 1), 58 papers
51 employ comparisons with extant specimens. Out of these, 28 papers solely rely on previous
52 literature records, while 30 papers utilize herbarium specimens or specimens newly collected
53 by the authors (from personal or laboratory collections). Twenty-two papers cite the name of
54 the herbarium institution in which the specimens are curated or the personal or laboratory
55 collection name, and 16 papers provide the barcode or QR code numbers associated with the
56 specimens and/or the collector's name and collection number. This means that almost half of
57 the papers do not cite any unique identifier associated with the extant specimens used in
58 comparisons and discussions (see appendix 1).

59 This review highlights the lack of standardisation in the citation of extant specimens,
60 with varying degrees of information provided, ranging from not citing the source of extant
61 specimens, citing only the broad source (herbarium name) without specifying the specimen
62 level, to citing all available information (see appendix 1). The citation of the specimen itself
63 also is inconsistent, with most authors using the barcode or QR code numbers from the

64 herbarium, while others cite a combination of the collector's name and the collection number
65 (see appendix 1).

66

67 **3 Toward a standardisation of citation of extant specimens**

68 **3.1 From Herbaria**

69 A herbarium collection consists mostly of herbarium sheets (Fig.1). I propose that a citation
70 of a sheet should include the following information, if available:

71 *Genus name and specific epithet* Authorship of the species name, *voucher = collector's name*
72 + *collection number*, year of collection, Country of collection, number of the barcode or QR
73 code followed by “!” or “dir. obs.” if the specimen was seen by the author(s) of the paper or
74 “(image!) or (dig. img.)” if only the online picture was consulted, (URL link of the page of
75 the specimen on the official institution website).

76 In the example of the fig. 1, the complete citation of this specimen will be:

77 *Hymenophyllum soriemersum* Rouhan & C.Del Rio, *H.S. MacKee 21864*, 1970, New
78 Caledonia, P01471595! (<http://coldb.mnhn.fr/catalognumber/mnhn/p/p01471595>)

79 This way of citing the information relative to the specimen has the advantage of
80 including all the necessary information and precisely identifying the specimen with no
81 ambiguity. It also partly follows the botanical and paleobotanical tradition (e.g., Hareesh and
82 Sabu, 2023; Rozefelds et al., 2020). This citation should be included in the supplementary
83 data of the article. In the main content of the article, I suggest referring to the sheets by the
84 voucher (e.g., here, a combination of the collector's name and the collection number). For
85 example, in Fig. 1: *Hymenophyllum soriemersum* Rouhan & C. Del Rio (*MacKee 21864*). The
86 citation of the barcode or QR code is widely used instead of the collector's name and

87 collection number (see appendix 1). However, the latter acknowledges the collection work
88 and the contribution of the collectors to the study (e.g., identification). Additionally, it
89 provides a more stable system over time: the collector's name and collection number will
90 remain the same, but the catalog number may change based on institutional history or new
91 innovations (e.g., a switch from a barcode system to a QR code system). In the case of
92 palynology study, in addition to the source of the herbarium specimen proposed above, the
93 author(s) should indicate 1) the repository of the prepared slide or SEM stub, and eventually
94 the coordinates of the observed pollen grain(s) on the slide.

95 The citation of a herbarium specimen is independent of the use of an online picture of
96 it. If the picture used in the article is derived from the digitization of the herbarium collection,
97 the figure caption should additionally include the credits for the picture based on the
98 requirements of each herbarium.

99

100 **3.2 Personal collection**

101 The author(s) are encouraged to deposit their personal collection in an institution at the time
102 of publication to facilitate replicability and conservation of the data through time. The use of a
103 personal collection implies that its management does not depend on an official institution such
104 as a herbarium, and it may not be accessible to researchers other than the author(s) or to
105 researchers outside the authors' laboratory. If the collections cannot be deposited for practical
106 reasons, a specimen belonging to a personal collection should be cited the same way than a
107 herbarium sheet. Thus, the collection should have a numeration system for each specimen,
108 and a public or private database should be associated with it. The possibility of permanently
109 storing data online, such as with the InDoRES system for French research institutes
110 (<https://www.indores.fr/>), may be a solution for storing the personal database online and

111 regularly updating it. In the data availability statement, the author(s) should include a
112 statement about the personal collection and ensure that ultimately this collection will be
113 donated to a public institution or will be permanently available in the hosting laboratory.

114

115 **3.3 From living specimens**

116 During fieldwork, pictures of living specimens taken independently of any collection are
117 sometimes used for comparison. However, utilising this type of material for comparisons
118 prevents the application of the proposed standardisation. Living specimens can naturally
119 disappear or be affected by human disturbances, making the living material unstable over
120 time. Comparisons with living specimens are similar to comparisons with online pictures. The
121 pictures should be submitted to citizen science websites, such as iNaturalist
122 (<https://www.inaturalist.org/>) hosted by the California Academy of Sciences and National
123 Geographic Society, to ensure virtual curation of the observations. I propose that the picture
124 citation should include all relevant information available on iNaturalist, such as the name of
125 the person owning the copyright of the picture, the day, month, and year when the picture was
126 taken, as well as the precise GPS location of the specimen.

127

128 **4 Conclusion**

129 Standardisation in the citation of extant specimens is crucial for ensuring replicability in
130 paleobotanical research. The aim of this guide is to standardise the citations of herbarium
131 specimens, personal collections and living specimens. Its goal is to reduce the heterogeneity
132 of information available for comparison specimens in the palaeobotany literature.

133

134 **Declaration of Competing Interest**

135 The author declared that he has no conflicts of interest to this work.

136

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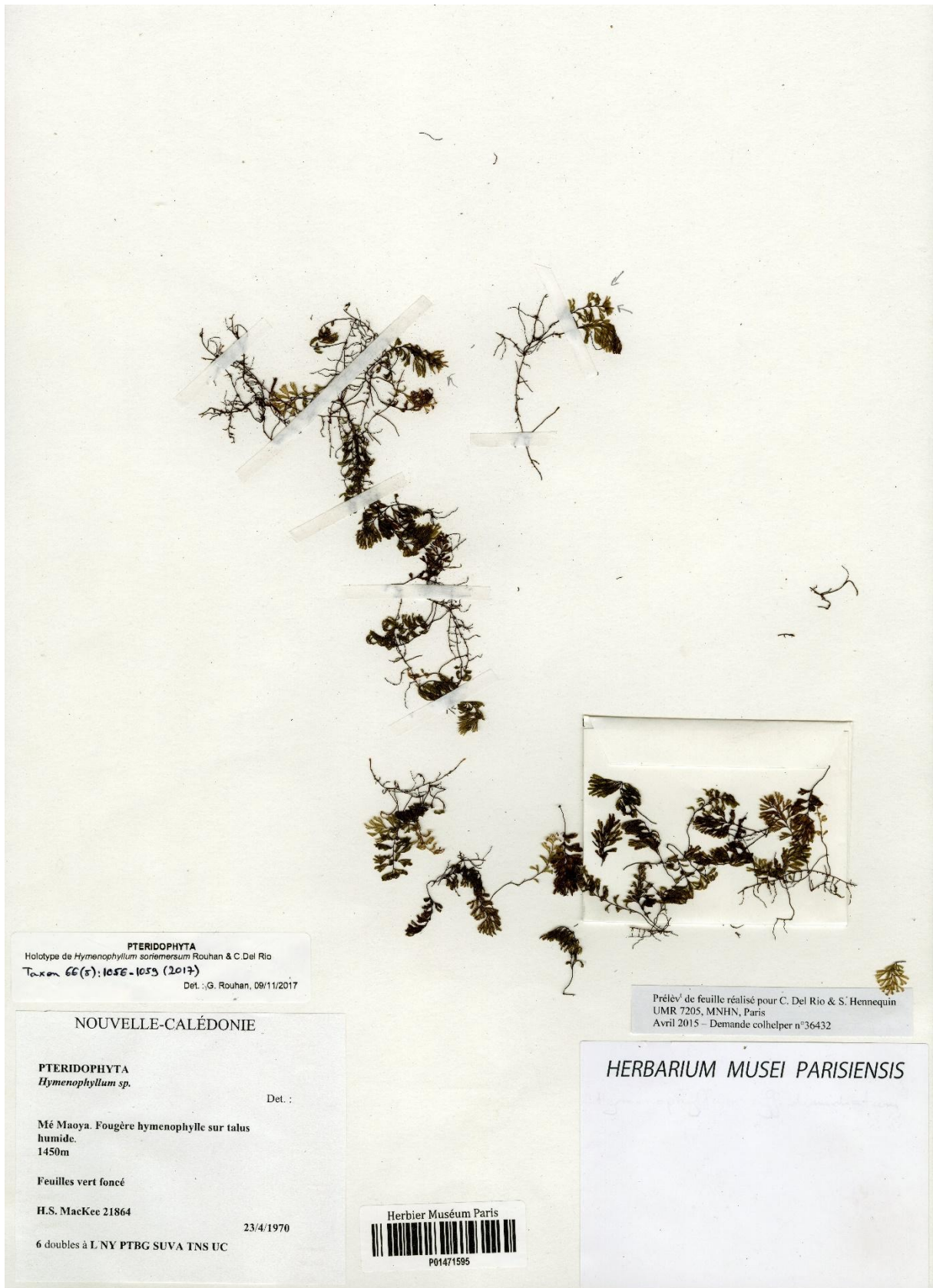
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158

159 Fig.1 Sheet of *Hymenophyllum soriemersum* Rouhan & C.Del Rio (*MacKee 21864*,

160 P01471595!). Credits: MNHN - V. Durand - 2017