**Supplementary Text**

**Use of formations in diversity estimates**

The use of formations in diversity studies, both as units of analysis and as proxies for sampling. Formations are extremely arbitrary in their definition, varying both in volume and spatial extent [1-3]. Variation in their thickness will vary the extent to which each formation represents a time-averaged assemblage of taxa rather than a true fauna [3]. The variation in geographic extent of formations (some being single quarries, while some, like the Beaufort Group, covering hundreds of square kilometers) may be affecting alpha diversity estimates through the species-area effect; sampling larger areas tends to increase the number of species observed [4].

However, to a certain extent the heterogeneity in geographic extent is accounted for with the removal of formations with low numbers of localities. Empirical data shows that many theoretical criticisms of formation counts are not justified [5], and it has been shown that formations better represent an entire fauna than individual localities/collections [6], which frequently represent sampling events (and often in the case of Paleozoic tetrapods contain a single species rather than a community) rather than bioregions/communities.

There are also practical limitations in the use of formations/collections as the unit of analysis with this particular dataset. Subsampling within collections would require data on numbers of individuals rather than occurrence data, which is frequently not recorded in the literature. Also, as mentioned above, many Paleozoic tetrapod collections contain single individuals, which would require large amounts of useful data to be deleted (Coverage-based methods like SQS cannot be applied to collections containing one specimen). For these reasons, we use formations to represent individual faunas, while acknowledging that these are affected by time-averaging and the species-area effect

**Sensitivity tests for estimates of plant diversity**

The fossil record of plants has numerous issues which may affect both the reliability of diversity estimates and the comparability of their diversity estimates to those of tetrapod herbivores. To examine whether these issues might affect the results or interpretations, a number of sensitivity analyses have been carried out.

*Plant organs and parataxonomy*

The alpha taxonomy of fossil plants has long been recognised to be problematic in terms of reflecting biological species. Frequent fragmentation of plants prior to fossilisation and different modes of preservation selectively preserving different plant organs make it difficult to accurately assess the number of species observed in any formation [7,8]. While this problem does also exist for vertebrate fossils, it is exacerbated for plants in their extreme fragmentability, with several organs being specifically adapted to be shed or dispersed e.g. seeds, leaves and pollen [7]. This can result in different organs of the same plant being assigned different taxon names (parataxonomy), artificially inflating diversity estimates.

To examine the impact of this potential pitfall, data regarding the plant organ preserved at each formation was downloaded from the Paleobiology Database (PBDB; note that this is not available for every occurrence). Since the organ classification scheme varied by collection, the available data was grouped into six categories: seed, leaf, axis, root, wood, and palynomorph. The plant dataset was culled to those formations which preserved fossils from only a single category. This would hopefully limit instances where separate fragments of the same species would be assigned to different taxa. Estimates of alpha diversity were then calculated in the same manner as detailed in the main text.

This procedure unfortunately results in substantial amounts of data being removed, particularly from the Carboniferous and early Permian. Nevertheless, the pattern obtained from the remaining data (Fig. S1a) is similar to that produced by the total dataset: high alpha diversity of plants during the late Carboniferous, a substantial drop across the Carboniferous/Permian boundary, and diversity remaining low throughout the Permian

An alternative solution to the issue of parataxonomies would be to base plant diversity solely on palynological data (pollen and spores). This has a great advantage over other forms of plant data, since palynomorphs are readily preserved, abundant and diagnostic [9]. However, a disadvantage of using this data is that the assemblages will rarely be representative of local floras, due to the ease of dispersal of pollen and spores [10]. In the case of the current dataset, there are actually few occurrences classified as palynological data; to what extent this is due to a lack of occurrences input into the PBDB, or simply a lack of occurrences assigned a plant organ classification will require a thorough revision of Paleozoic palynological data, and is an avenue for future research. Nevertheless, the available palynological data does still support the substantial decrease in alpha diversity of plants across the Carboniferous/Permian boundary and the low diversity maintained throughout the Permian (Fig S1b). It should be noted however that the palynological data suggests that the highest Carboniferous diversity was not reached until the latter stages; Mississippian palynomoph diversity is lower.

*Comparability of plant and animal data*

The analyses presented in the main text include all plant and tetrapod-bearing formations which met the sampling criteria, and thus includes numerous formations containing just one or the other. One might therefore question whether the formations tested adequately represent the diversity changes in floras actually evolving alongside tetrapod herbivores. The approach in the main text was used to maximise data inclusivity; there are only 10 plant-bearing formations in the dataset that both meet the sampling criteria and contain tetrapods (Table S1). Nevertheless, a qualitative discussion of these formations would be useful.

The two of these formations in Table S1 from the late Carboniferous are the Carbondale Formation and the Conemaugh Group. Both are among the most diverse of the formations tested in terms of their plant diversity. The Carbondale Formation also yields a diverse tetrapod fauna (the Mazon Creek fauna [11,12]), but no tetrapod herbivores. The Conemaugh Group contains a diverse assemblage of tetrapods, one species of which may reliably be considered a herbivore: the diadectid *Desmatodon* [13]. The Permian formations in table S1, as found in the analyses in the main text, mostly contain an increased diversity of herbivores but a reduced diversity of plants. Of these eight Permian formations, only one produces a diversity of plants within the range of that of the Carboniferous formations: the Wellington Formation. The Wellington Formation may be an outlier: apart from some captorhinids of uncertain diet (Supplementary Data 1), the only herbivore known from this formation is *Edaphosaurus pogonias*, the largest species of *Edaphosaurus* [14]. As discussed in the main text, larger herbivores, being less selective in their diet, increase local plant diversity; it may be that the prevalence of large tetrapod herbivores in this formation is responsible for its plant diversity being higher than other Permian formations.

The data for formations containing both herbivorous tetrapods and plants is too restricted to be used in large-scale macroevolutionary analyses, hence the decision in the main text to include all formations that met the sampling criteria. Nevertheless, those formations that do preserve both plants and tetrapods provide a similar signal to the more inclusive analyses: increasing alpha diversity of herbivores in the early Permian coinciding with decreasing diversity of plants.

*Lack of precision in the Paleobiology Database data*

The PBDB currently represents the most comprehensive source of data on plant diversity during the Palaeozoic. However, it is recognised that the PBDB data, being uploaded by multiple independent researchers, is incomplete and is frequently not updated with regards to collection ages and taxonomy [15]. While our tetrapod data was based on the expert knowledge of the authors and personal examination of many of the relevant specimens, with the PBDB being used as one of many sources of data, the plant data is entirely based on the PBDB. One area where this may be affecting the results is in the ages of the formations. As may be seen in Fig 1 (main text) a number of the plant-bearing formations are assigned extremely long ages. Many of these have been assigned more precise ages in the literature, but this precision has not been input into the PBDB. A complete revision of the plant data in the PBDB would be a massive undertaking, but to test the impact of this imprecision a further analysis was undertaken. For each formation an age was drawn from a uniform distribution within the boundaries. As in the main text, the formations were then assigned to time bins and a median alpha diversity curve through time was calculated. This was repeated 100 times, and a mean of the 100 resulting curves was produced (Fig S2). This curve shows much the same signal as that presented in the main text. An interesting difference is a brief diversity decrease at the start of the Moscovian, in addition to the more dramatic decrease across the Carboniferous/Permian boundary. It is possible that this trough is related to the shift in floras observed during the Carboniferous rainforest collapse [16], but such a conclusion would require more detailed study.

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Table S1: Diversity (calculated with SQS) within plant-bearing formations that meet the sampling criteria and also contain tetrapods.

|  |  |  |  |
| --- | --- | --- | --- |
| Formation | Age | Subsampled plant diversity | Subsampled herbivore diversity |
| Carbondale Formation | Latest Moscovian | 20.27 | 0 |
| Conemaugh Group | Kasimovian | 9.17 | 1 |
| Belle Plains Formation | Early Artinskian | 9.04 | 4.53 |
| Wellington Formation | Early Artinskian | 13.39 | 2.78 |
| Vale Formation | Latest Kungurian | 3.33 | 3.94 |
| Rio Do Rasto Formation | Capitanian | 6.5 | 4.14 |
| Upper Madumabisa Formation | Middle Wuchiapingian | 6.77 | 10.77 |
| Werra Formation | Middle Wuchiapingian | 4.018 | 1 |
| Lower Sakamena Formation | Changhsingian | 9.16 | NA (coverage of herbivores too low to calculate diversity with SQS)  |
| Heshanggou Formation | Olenekian | 9.14 | 2.17 |

**Supplementary Figure Captions**

Figure S1: A) Subsampled diversity of plants from formations containing only a single category of plant organ. B) Subsampled diversity of palynomorphs.

Figure S2: Estimates of subsampled Alpha diversity of plants using stochastic methods to account for uncertainty in the ages of formations. Each point represents one of the 100 point-ages assigned to each formation. The thick line represents the mean of the 100 alpha diversity curves produced.