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RESEARCH

Evidence for a Silesaurid (Archosauria: Dinosauriformes) Holobaramin with a Discussion of Triassic Dinosaurs

J.J. Guzman[1], Matthew A. McLain[2]

[1] Trinity Baptist Bible College, Arlington, TX
[2] The Master's University, Santa Clarita, CA

Abstract

The Silesauridae is a family of non-dinosaurian dinosauriforms thought by some conventional paleontologists to be the evolutionary bridge from non-dinosaurian archosaurs to dinosaurs. Thus, in order to advance the creationist understanding of the silesaurids, we analyzed character datasets from four studies: Nesbitt et al. **(1)**, Martz and Small **(2)**, Müller and Garcia **(3)**, and Norman et al. **(4)** with statistical baraminology using BARCLAY to conduct baraminic distance correlation (BDC), 3D multidimensional scaling (MDS), partitions around medoids (PAM), and fuzzy analysis (FANNY). The results showed evidence of continuity within the Silesauridae and discontinuity surrounding the family. Because of this, we propose that the Silesauridae is a distinct holobaramin. From these analyses, we also tentatively conclude that the Silesauridae holobaramin might include *Lagosuchus (Marasuchus*), and maybe *Pisanosaurus mertii*. We also observed evidence of discontinuity among the stratigraphically lowest dinosaurs, which are found in Upper Triassic rocks.

Keywords Dinosauromorpha, Silesauridae, Baraminology, Paleontology, Dinosauria, Triassic

Introduction

The Silesauridae is a family of fossil archosaur reptiles which was erected upon the discovery of *Silesaurus opolensis* **(5)**. The clade is only represented by fossils from the Middle to Upper Triassic (Anisian-Rhaetian) strata. More than a dozen taxa are currently recognized as silesaurids, including *Asilisaurus kongwe* **(1)**, *Lewisuchus admixtus* **(6)**, *Sacisaurus agudoensis* **(7)**, and *Kwanasaurus williamparkeri* **(2)**. The inclusion of two taxa is disputed: *Pisanosaurus mertii* **(8)** and *Agnosphitys cromhallensis* **(9)**. This group is of interest in the conventional paleontological literature due to its significant role in dinosaur evolution. However, the silesaurids' relationship to the dinosaurs is still unclear **(Fig. 1)**. While most authors consider the Silesauridae as the sister group to Dinosauria (e.g. Baron et al. **(10)**, Benton and Walker **(11)**, Langer et al. **(12)**, Langer et al. **(13)**, Nesbitt et al. **(1)**, Nesbitt et al. **(14)**, Benton **(15)**) others have recovered the Silesauridae as within Dinosauria and Ornithischia as either a true clade (e.g. Cabreira et al. **(16)**; Langer and Ferigolo **(7)**) or a paraphyletic grade leading to classic ornithischians ((e.g., Fonseca, et al. **(17)**; Müller **(18)**; Müller and Garcia **(3)**; Norman et al. **(4)**).

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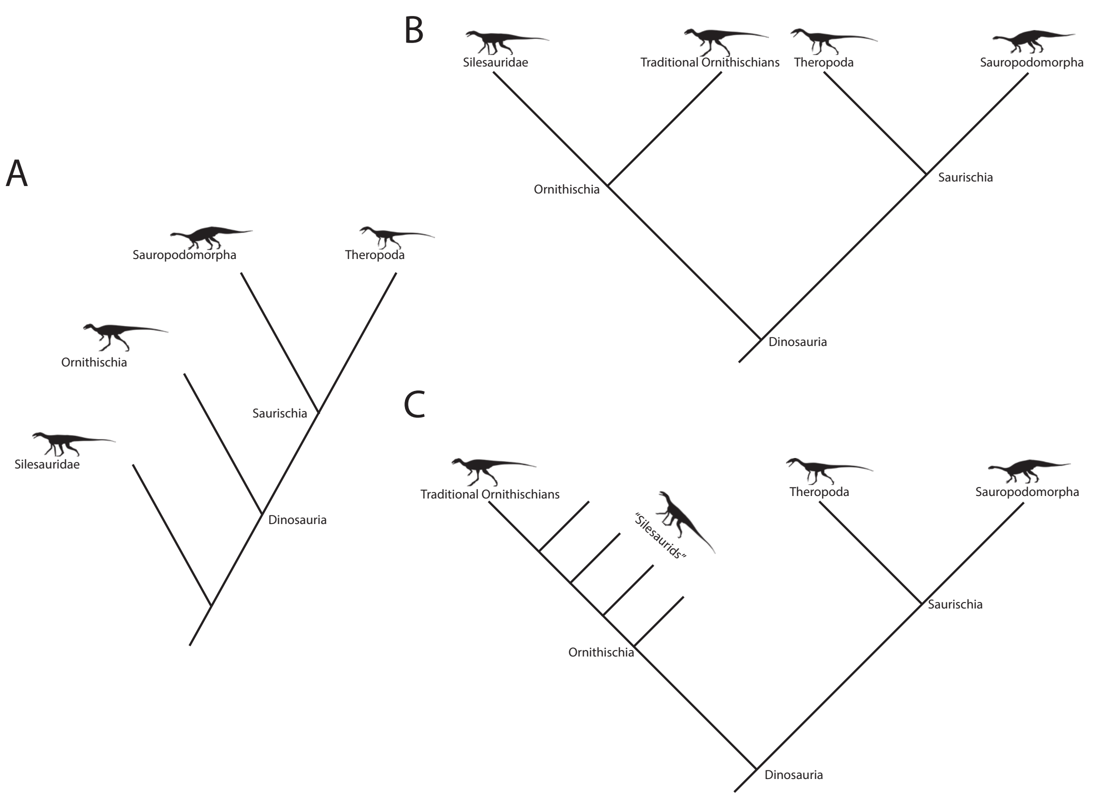

Figure 1. Cladograms showing proposed relationships of silesaurids to dinosaurs in the literature: **A)** Silesauridae as the sister group to Dinosauria, **B)** Silesauridae as a clade of ornithischians; and **C)** "Silesaurids" as an ornithischian grade leading to traditional ornithischians.

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Some baraminological work has been done including members of the Silesauridae, but no analysis has been conducted with the silesaurids as the main focus of the study. Doran et al. **(19)** analyzed a dataset from Baron et al. **(10)** which showed that silesaurids had the tendency to group separately from all of the major dinosaurian groups. McLain, et al. **(20)** found evidence for a Silesauridae holobaramin based on statistical baraminological analysis of a phylogeny of all archosauromorphs through subdividing the dataset into smaller taxonomic groups. Given the results from previous work, we predict that the Silesauridae will be a holobaramin.

Materials and Methods

For the analyses, we employed four datasets. The first dataset was from Nesbitt et al. **(1)**, and it contained 290 characters and 35 taxa (see **Table 1** for a breakdown of taxa). This dataset was analyzed at a 0.2 taxonomic relevance cutoff and a 0.75 character relevance cutoff.

The second dataset was an updated Peecook et al. **(21)** matrix by Martz and Small **(2)**, which contained 294 characters and 39 taxa (**Table 1**). This dataset was analyzed at a 0.2 taxonomic relevance cutoff and a 0.75 character relevance cutoff. This dataset will be referred to as "Martz and Small **(2)**" for the remainder of this paper.

The Müller and Garcia **(3)** dataset contained 266 characters and 62 taxa (**Table 1**). Due to *Asilisaurus kongwe* and *Daemonosaurus chauliodus* not sharing characters in common, this dataset was analyzed at a 0.3 taxonomic relevance cutoff and a 0.75 character relevance cutoff.

Lastly, the Norman et al. **(4)** dataset contained 282 characters and 71 taxa (**Table 1**). Due to *Abrictosaurus consors* and *Agilisaurus louderbacki* not sharing characters in common, this dataset was analyzed at a 0.3 taxonomic relevance cutoff and a 0.75 character relevance cutoff.

To reduce confusion, we refer to *Marasuchus lilloensis* and *Lagosuchus lilloensis* as *Lagosuchus talampayensis*

Table 1. A breakdown of the taxa in each dataset.

COLORS: White - Outgroup; Yellow -Lagerpetidae; Sea Green - Lagosuchidae; Red - Silesauridae; Green - Ornithischia; Orange - Herrerasauridae; Purple - Sauropodomorpha; Blue - Theropoda.

	Nesbitt et al. (1)	Martz & Small (2)	Müller & Garcia (3)	Norman et al. (4)
Erythrosuchus africanus	✓	✓		
Euparkeria capensis	✓	✓	✓	✓
Revueltosaurus callenderi	✓	✓		
Aetosaurus ferratus	✓	✓		
Arizonasaurus babbitti	✓	✓		
Effigia okeeffeae	✓	✓		
Batrachotomus kuperferzellensis	✓	✓		
Postosuchus kirkpatricki	✓	✓		
Dromicosuchus grallator	✓	✓		
Eudimorphodon ranzii	✓	✓		
Dimorphodon macronyx	✓	✓		
Dongusuchus efremovi			✓	
Spondylosoma absconditum			✓	
Teleocrater rhadinus			✓	✓
Dongsuchus efremovi				✓
Spondylosoma absconditum				✓
Yarasuchus deccanensis			✓	✓
Lagerpeton chanarensis	✓	✓	✓	✓
Dromomeron gregorii	✓	✓	✓	✓
Dromomeron romeri	✓	✓	✓	✓
Dromomeron gigas			✓	✓
Ixalerpeton polesinensis				✓
UFSM 11611				✓
PVSJ 883				✓
Lagosuchus/Marasuchus lilloensis	✓	✓	✓	✓
*Saltopus elginensis**			✓	✓
Asilisaurus kongwe	✓	✓	✓	✓
Suomyasaurus aenigmaticus		✓		✓
Diodorus scytobrachion		✓	✓	✓
Eucoelophysis baldwini	✓	✓	✓	✓
Sacisaurus agudoensis	✓	✓	✓	✓
Lewisuchus admixtus	✓			✓
Pseudolagosuchus major	✓			
Lewisuchus/Pseudolagosuchus	✓	✓		
Silesaurus opolensis	✓	✓	✓	
Kwanasaurus williamparkeri			✓	✓
Lutungutali sitwensis			✓	✓
Technosaurus smalli		✓	✓	✓
Soumyasaurus aenigmaticus			✓	✓
Ignotosaurus fragilis		✓	✓	✓
*Pisanosaurus mertii***	✓	✓	✓	✓
Scutellosaurus lawleri			✓	✓
Lesothosaurus diagnosticus	✓	✓	✓	✓
Eocursor parvus			✓	✓
Fruitadens haagarorum			✓	✓
Echinodon becklesii			✓	✓

Tianyulong confuciusi			✓	✓
Heterodontosaurus tucki	✓	✓	✓	✓
Abrictosaurus consors				✓
Manidens condorensis				✓
Emausaurus ernsti				✓
Pegomastax africanus				✓
Chilesaurus diesgosaurezi				✓
Laquintasaura venezulae				✓
Agilisaurus louderbacki				✓
Hexinlusaurus multidens				✓
Scelidosaurus harrisonii				✓
Herrerasaurus ischigualastensis	✓	✓	✓	✓
Staurikosaurus pricei			✓	✓
Sanjuansaurus gordilloi			✓	✓
Gnathovorax cabreirai			✓	✓
Panphagia protos			✓	✓
Eoraptor lunensis	✓	✓	✓	✓
Pampadromaeus barberenai			✓	✓
Buriolestes schultzi			✓	✓
Nhandumirim waldsangae			✓	✓
Saturnalia tupiniquim	✓	✓	✓	✓
Chromogisaurus novasi			✓	✓
Pantydraco caducus			✓	✓
Bagualosaurus agudoensis			✓	✓
Efraasia minor	✓	✓	✓	✓
Macrocollum itaquii			✓	✓
Unaysaurus tolentinoi			✓	✓
Plateosaurus engelhardti	✓	✓	✓	✓
Guaibasaurus candelariensis			✓	✓
Chindesaurus briansmalli			✓	✓
Tawa hallae	✓	✓	✓	✓
Daemonosaurus chauliodus			✓	✓
Eodromaeus murphi			✓	✓
Coelophysis bauri	✓	✓	✓	✓
Liliensternus liliensterni			✓	✓
Syntarsus rhodesiensis			✓	✓
Syntarsus kayentakatae			✓	✓
Zupaysaurus rugeiri			✓	✓
Petrified Forest theropod			✓	✓
Dilophosaurus wetherelli	✓	✓	✓	✓
Allosaurus fragilis	✓	✓		
Velociraptor mongoliensis	✓	✓		

*Here *Saltopus elginensis* is considered as a lagosuchid, however it is difficult to give an exact placement to this taxon.
**Our analysis of *Pisanosaurus* was inconclusive, here we display it as an ornithischian, per its original description (Casamiquela 1967).

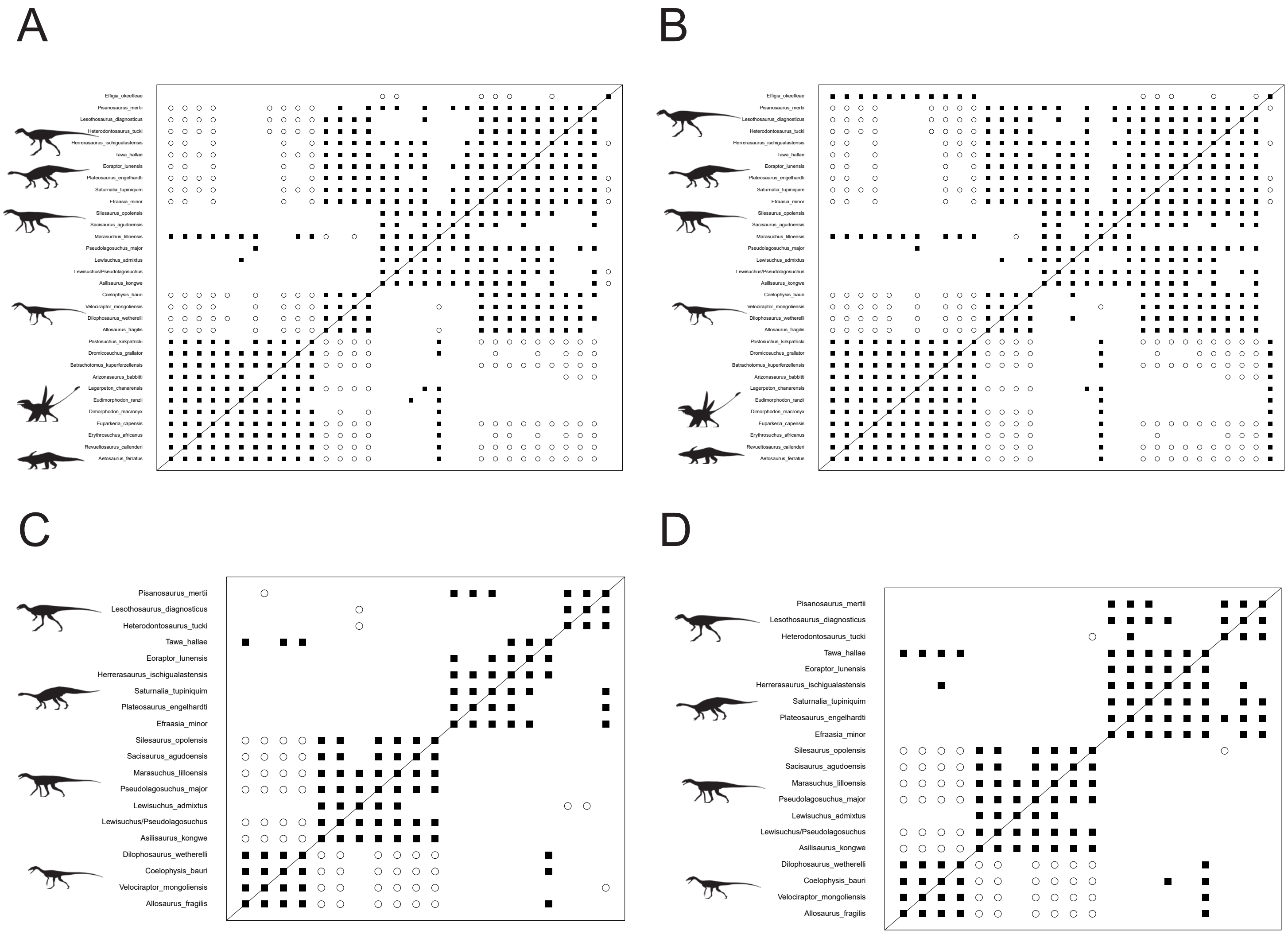

Figure 2. BDC plots of the Nesbitt et al. **(1)** dataset: **A)** Pearson, all taxa; **B)** Spearman, all taxa; **C)** Pearson, only Dinosauromorpha; and **D)** Spearman, only Dinosauromorpha.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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in the text even when a dataset refers to it by a different name (see discussion, *Is Lagosuchus talampayensis a Silesaurid?*).

We used BARCLAY **(22)** to evaluate the datasets using statistical baraminological methods: 1) baraminic distance correlation (BDC) with both Pearson and Spearman correlation coefficients, 2) 3D multidimensional scaling (MDS), 3) partitions around medoids (PAM), and 4) fuzzy analysis (FANNY). We filtered all the datasets following the above listed constraints. In BDC, black squares are interpreted as significant positive correlation, while open circles are interpreted as significant negative correlation. In MDS points of close clustering are interpreted as positive correlation, while points which are farther from each other are interpreted as negative or weak correlation. For a greater discussion of the newer PAM and FANNY methods, see Wood **(23)** and Sinclair and Wood **(24)**.

Results

Nesbitt et al. (1)

When following the above listed constraints for the Nesbitt et al. (1) dataset, 32 of the 35 taxa were preserved (*Dromomeron gregorii, D. romeri*, and *Eucoelophysis baldwini* were dropped due to not meeting the taxonomic relevance cutoff) and 161 characters were retained. Three groups (the outgroup, Theropoda, and the rest of the Dinosauromorpha) were distinguishable in the Pearson BDC plot (**Fig. 2A**), in addition to the shuvosaurid *Effigia*, which did not share positive correlation with any other taxon. In the Spearman BDC plot (**Fig. 2B**), the theropod block is positively correlated with the other dinosauromorph taxa, and *Effigia* is positively correlated with the outgroup taxa.

In order to recover clearer results, we conducted this same analysis exclusively with Dinosauromorpha (**Fig. 2C-D**). The results here showed four distinguishable groups in Pearson (**Fig. 2C**): the bottom left corner was occupied by the Theropoda, the next group up was the Silesauridae (not including *Pisanosaurus mertii*) + *Lagosuchus talampayensis*, the third group was the Herrerasauridae + Sauropodomorpha, and the last group (upper right corner) was occupied by the Ornithischia + *Pisanosaurus mertii*. *P. mertii* shared significant positive correlation with *Efraasia minor*, *Plateosaurus engelhardti*, and *Saturnalia tupiniquim*, while *Tawa hallae* shared significant positive correlation with *Dilophosaurus wetherelli*, *Coelophysis bauri*, and *Allosaurus fragilis*. The Spearman BDC plot (**Fig. 2D**) showed the same blocks of positive correlation, but the Ornithischia block shared more extensive positive correlation with the Sauropodomorpha + Herrerasauridae block. The Silesauridae + *Lagosuchus* block did not share positive correlation with any other taxa, but they did share negative correlation with the Theropoda block (and *Silesaurus* shared negative correlation with *Plateosaurus*). There were a few examples of shared positive correlation between the Theropoda block and the Sauropodomorpha + Herrerasauridae block (*Coelophysis* with *Herrerasaurus* and all of the theropods with *Tawa* (which is probably a theropod anyway).

The MDS results (**Fig. 3**) for the Dinosauromorpha subset of the Nesbitt et al. (1) dataset show four clusters of taxa: 1) Silesauridae + *Marasuchus*, 2) Ornithischia + *Pisanosaurus*, 3) Sauropodomorpha + *Herrerasaurus* + *Tawa*, and 4) Theropoda. Both the theropod and silesaurid clusters appear as biological trajectories, whereas the Sauropodomorpha + *Herrerasaurus* + *Tawa* cluster is found in the center between them. The two ornithischian taxa, although close in morphological space to *Pisanosaurus*, do not form a trajectory with it.

The PAM model with the highest average silhouette value is at five groups (0.42), followed by three groups (0.39), four groups (0.36) and finally two groups (0.16). The three-group model (**Fig. 4A**) divides up the taxa into: 1) Theropoda, 2) Silesauridae + *Marasuchus* + *Eoraptor*, and 3) Ornithischia + Sauropodomorpha + *Pisanosaurus* + *Herrerasaurus*. *Eoraptor* has a negative silhouette value in the silesaurid group. The four-group

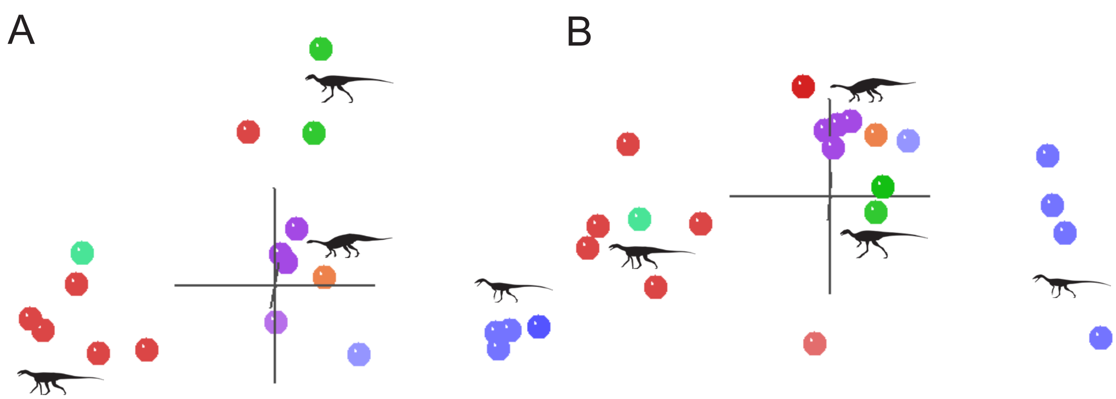

Figure 3. MDS plots of the Dinosauromorpha subset of the Nesbitt et al. (1) dataset in two rotated views **A)** and **B**).

Colors: red - Silesauridae; light green - Ornithischia; purple - Sauropodomorpha; orange - Herrerasauridae; blue - Theropoda.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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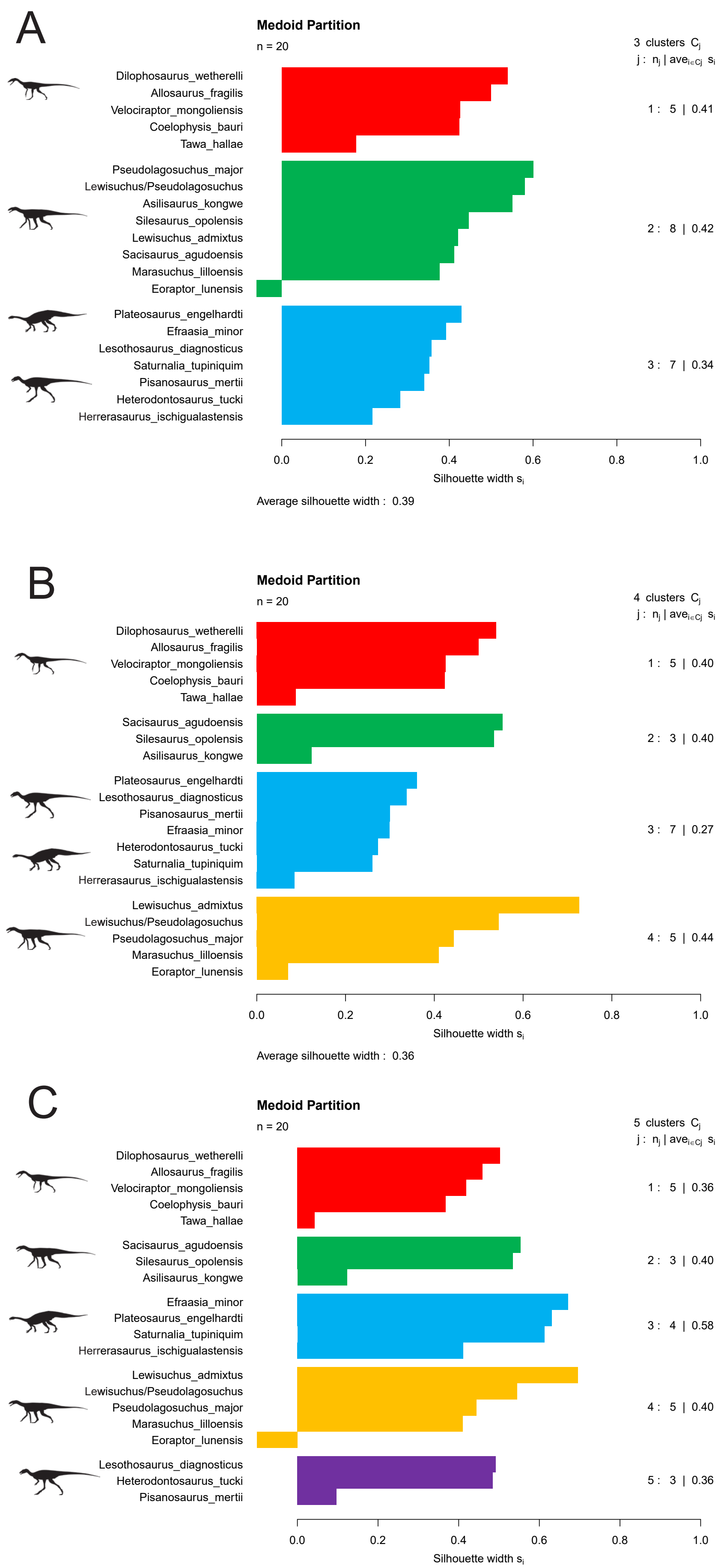

Figure 4. PAM analysis of the Dinosauromorpha subset of the Nesbitt et al. (1) dataset: **A)** PAM in three groups; **B)** PAM in four groups; **C)** PAM in five groups. Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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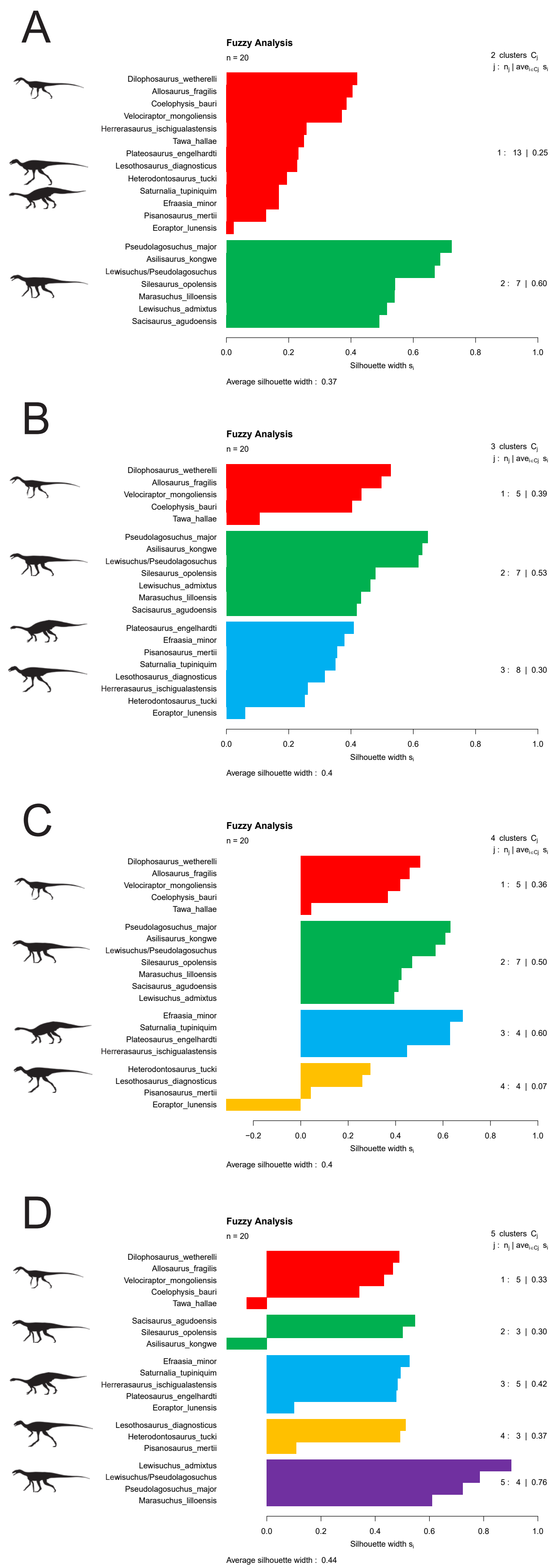

Figure 5. FANNY analysis of the Dinosauromorpha subset of the Nesbitt et al. **(1)** dataset: **A)** FANNY in two groups; **B)** FANNY in three groups; **C)** FANNY in four groups; and **D)** FANNY in five groups.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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model (**Fig. 4B**) surprisingly divides the Silesauridae group into two groups with *Sacisaurus*, *Silesaurus*, and *Asilisaurus* forming their own group instead of splitting up the ornithischians from the sauropodomorphs. The five-group model (**Fig. 4C**) is the one to split Ornithischia + *Pisanosaurus* into its own group. *Eoraptor* is still included among the silesaurids (and *Marasuchus*) in both the four- and five-group models.

As with PAM, the FANNY model with the highest average silhouette value is the five-group model (0.44), followed by the three- and four-group models (both at 0.4), and then finally the two-group model (0.37). The two-group model (**Fig. 5A**) splits the taxa into Silesauridae + *Marasuchus* (green) and the rest of the taxa (red). At three groups (**Fig. 5B**), the Silesauridae + *Marasuchus* block is retained, but the remaining taxa are split into Theropoda (red) and the rest of the dinosaurs (blue). The four-group model (**Fig. 5C**) further splits up the non-theropod dinosaur taxa into Sauropodomorpha (blue) and Ornithischia + *Pisanosaurus* + *Eoraptor* (yellow). *Eoraptor* has a very negative silhouette width value. Finally, the five-group model (**Fig. 5D**) is the only one that splits up the Silesauridae into two groups: a green one containing *Sacisaurus*, *Silesaurus*, and *Asilisaurus* (although *Asilisaurus* has a negative silhouette value) and a purple one containing the rest of the silesaurids and *Marasuchus*. *Eoraptor* is included with the sauropodomorphs (blue) in the five-group model, and *Tawa* has a negative silhouette value among the theropods (red).

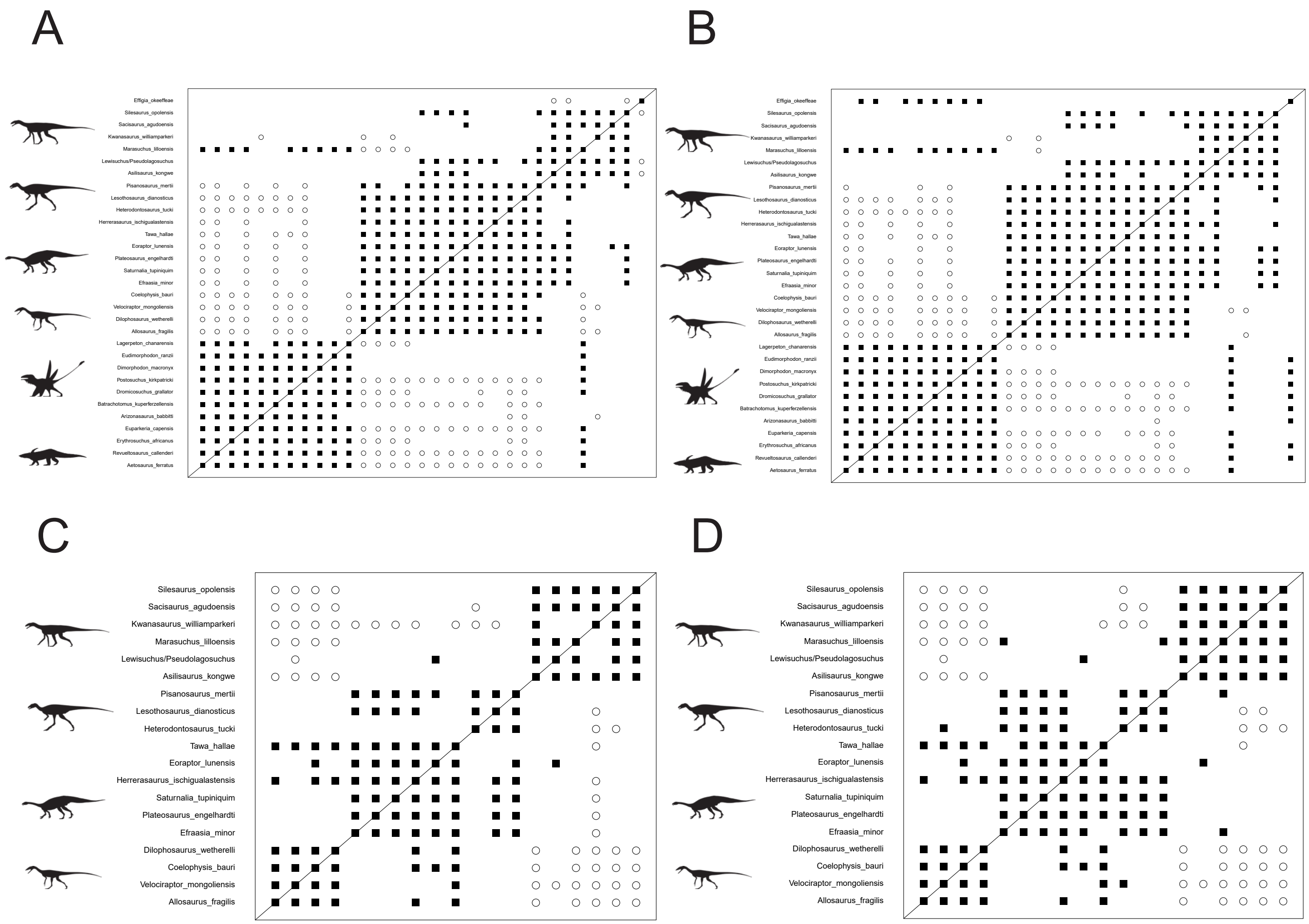

Figure 6. BDC plots of the Martz and Small (2) dataset: **A)** Pearson, all taxa; **B)** Spearman, all taxa; **C)** Pearson, only Dinosauromorpha; and **D)** Spearman, only Dinosauromorpha.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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Martz & Small (2)

When following the above listed constraints for the Martz and Small (2) dataset, 31 of the original 39 taxa were preserved (*Diodorus scytobrachion, Eucoelophysis baldwini, Dromomeron gregorii, romeri, Lutungutali sitwensis, Ignotosaurus fragilis, Technosaurus smalli,* and *Soumyasaurus aenigmaticus* were dropped due to not meeting the taxonomic relevance cutoff) and 125 characters were retained. The BDC results (**Fig. 6A-B**) are similar to the ones in the first analysis. Two large blocks are distinguishable in both the Pearson and Spearman BDC plots: the outgroup and the Dinosauromorpha. *Effigia*, once again, clustered with no taxa. The Silesauridae, in this analysis, lack any significant negative correlation with the Dinosauria. In the Pearson BDC (**Fig. 6A**), *"Lewisuchus/Pseudolagosuchus"*, *Asilisaurus kongwe*, *Pisanosaurus mertii*, *Silesaurus opolensis*, *Sacisaurus agudoensis*, and *Lagosuchus* (*Marasuchus lilloensis*) all exhibit significant positive correlation with dinosaurian taxa. *P. mertii* shares significant positive correlation with all of the Dinosauria except *Velociraptor mongoliensis*. There are more examples of shared positive correlation between silesaurids and dinosaurs in the Spearman BDC plot (**Fig. 6B**).

We also analyzed this dataset with only dinosauromorph taxa (**Fig. 6C-D**). In this Pearson BDC analysis (**Fig. 6C)** *Asilisaurus kongwe* does not exhibit positive correlation with the dinosaurian cluster, nor does *Lewisuchus/Pseudolagosuchus* with the exception of *Eoraptor lunensis*. *Pisanosaurus mertii*, on the other hand shares positive correlation with *Eoraptor lunensis*, *Herrerasaurus ischigualastensis*, *Saturnalia tupiniquim*,

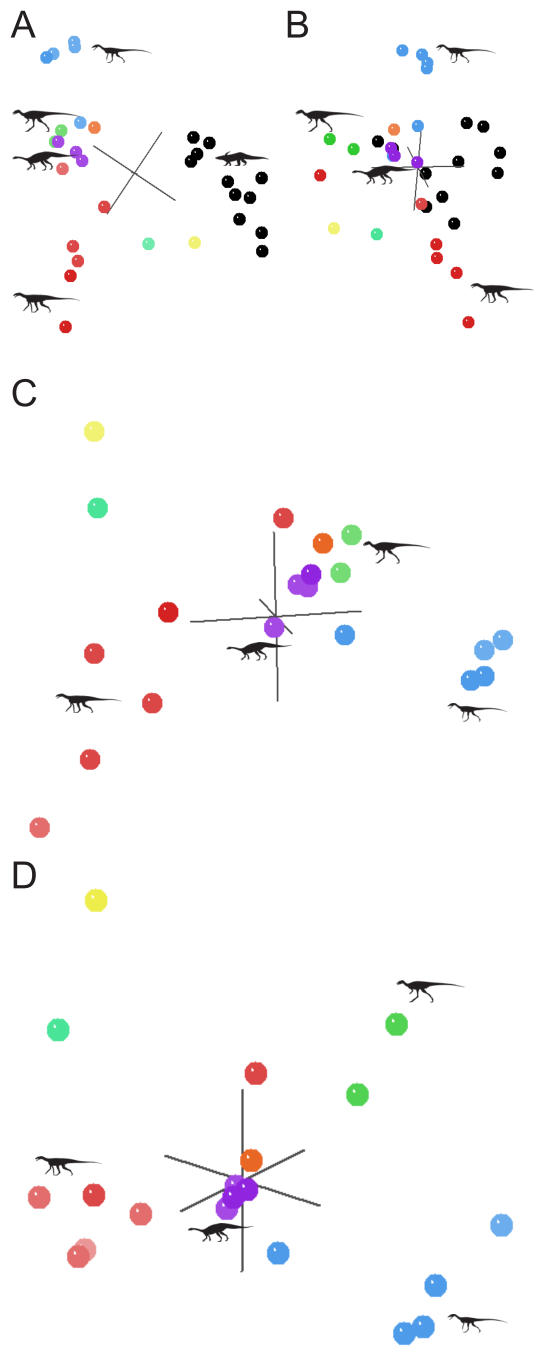

Figure 7. MDS plots of the Martz and Small **(2)** dataset: All taxa in two rotated views **A)** and **B**) and the Dinosauromorpha subset in two rotated views **C)** and **D**).

Colors: black - outgroup; yellow - Lagerpetidae; red - Silesauridae; light green - Ornithischia; purple - Sauropodomorpha; orange - Herrerasauridae; blue - Theropoda.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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Plateosaurus engelhardti, and *Efraasia minor*. Also, *Lagosuchus* (*Marasuchus lilloensis*) groups within the silesaurid block. The Spearman BDC plot (**Fig. 6D**) is similar except that there are a couple more examples of shared positive correlation between the silesaurid block and the dinosaurs (the non-silesaurid *Lagosuchus* (*Marasuchus lilloensis*) positively correlates with *Efraasia* and *Pisanosaurus*) and amongst the dinosaurs.

The 3D MDS plot yields similar results (**Fig. 7A-B**). The non-dinosaurian dinosauromorphs are distinguishable from the outgroup (shown in black) and Dinosauria (blue, purple, light green, and orange). The Silesauridae (shown in red) group separately from the dinosaurian clusters, except for one taxon (the putative silesaurid *Pisanosaurus mertii*), which clusters with the ornithischians. *Lagosuchus* (green) is the closest taxon to the silesaurid cluster.

Another MDS analysis was conducted excluding the outgroup (**Fig. 7C-D**), the results of which show the Silesauridae (red) grouped more distantly from the larger dinosaurian cluster (except for *P. mertii*) and more closely with *Lagerpeton* and *Lagosuchus*. As with the MDS plot involving all of the taxa, the theropod cluster is distinct (except for *Tawa*, which groups closer to the other dinosaurs), but in this subset analysis, the ornithischians are also distant from the other dinosaur taxa.

The PAM results (**Fig. 8A-B**) for the Martz and Small **(2)** dataset have the highest silhouette values at two and four groups (both at 0.34). At two groups (**Fig. 8A**), the split is between the non-dinosauriform taxa (red) and Dinosauriformes (green), with *Lagosuchus* in the non-dinosauriform group. At four groups (**Fig. 8B**), the taxa are split into the non-dinosauriforms (red), theropods (green), silesaurids (blue), and other dinosauriforms (yellow). *Pisanosaurus* and *Lewisuchus* are in the yellow group, although *Lewisuchus* has a negative silhouette value.

The FANNY results (**Fig. 8C**) for the Martz and Small **(2)** dataset have the highest silhouette value (0.36) at three groups, with the taxa split into non-dinosauriforms (red), dinosaurs (green), and silesaurids (blue). *Lewisuchus* is included in the silesaurid group with a silhouette value near 0.2, whereas *Pisanosaurus* is in the dinosaur group. *Lagosuchus* is included in the non-dinosauriform outgroup cluster, but it has a negative silhouette value.

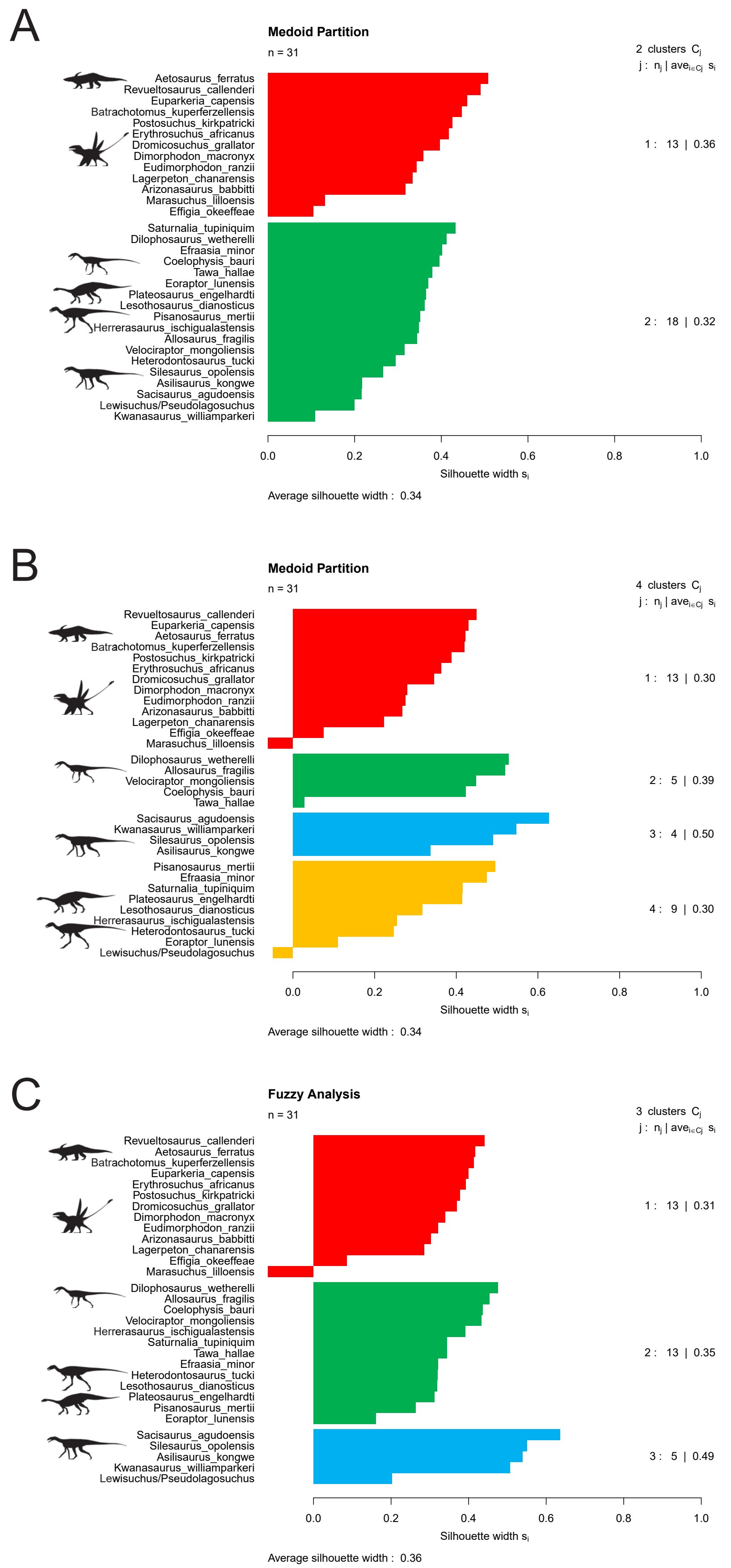

Figure 8. PAM and FANNY analysis of the Martz and Small (2) dataset:

A) PAM in two groups; **B)** PAM in four groups; and **C)** FANNY in three groups.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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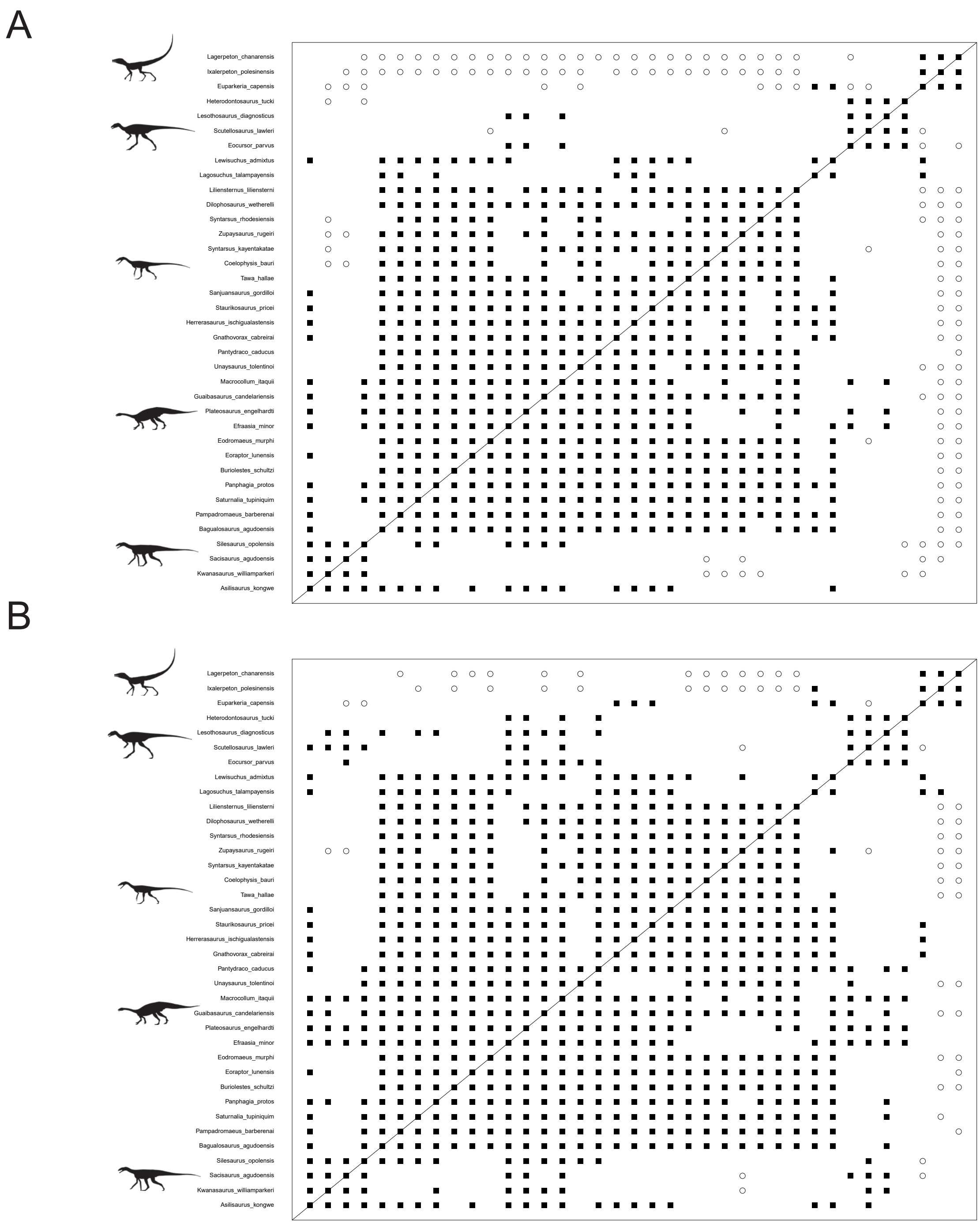

Figure 9. BDC plots of the Müller and Garcia (3) dataset: **A)** Pearson and **B)** Spearman.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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Müller and Garcia (3)

The BDC analysis (**Fig. 9A-B**) for the Müller and Garcia (3) dataset (conducted at a ≥0.3 taxic relevance cutoff) preserved 37 of the 62 taxa (*Chromogisaurus novasi*, *Daemonosaurus chauliodus*, *Diodorus scytobrachion*, *Dongusuchus efremovi*, *Dromomeron gigas, Dromomeron gregorii, Dromomeron romeri*, *Echinodon becklesii*, *Eucoelophysis baldwini*, *Fruitadens haagarorum*, *Ignotosaurus fragilis*, *Lutungutali sitwensis*, *Nhandumirim waldsangae*, PVSJ 883, Petrified forest theropod, *Pisanosaurus mertii*, *Saltopus elginenis*, *Soumyasaurus aenigmaticus*, *Spondylosoma absconditum*, *Yarasuchus deccanensis* were dropped due to not meeting the taxonomic relevance cutoff) and 186 characters were retained. Four blocks of positive correlation are apparent

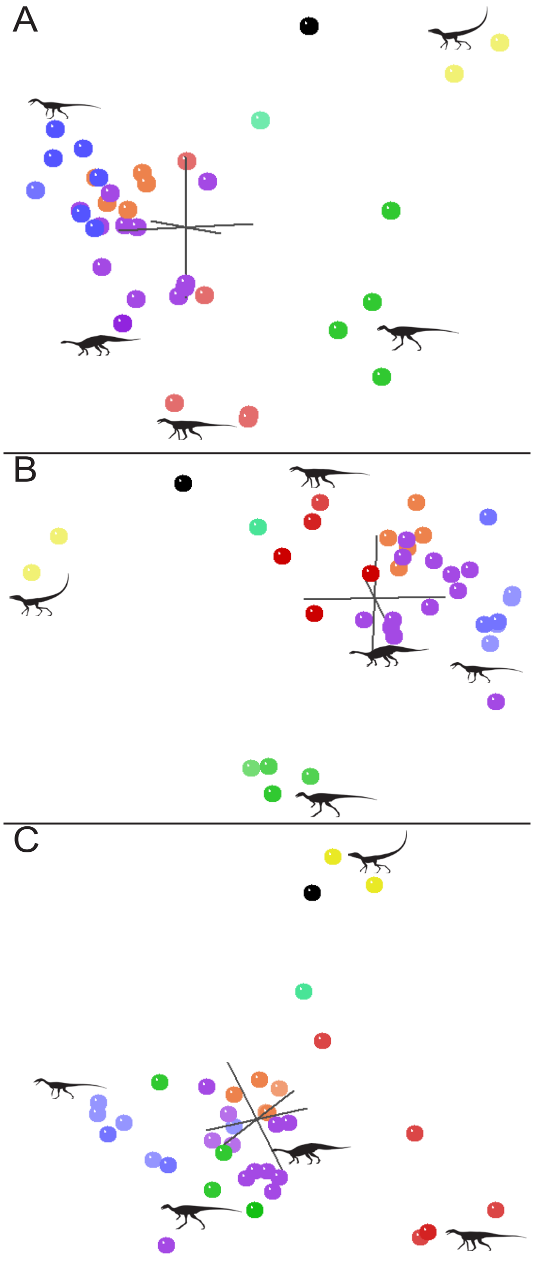

Figure 10. MDS plot of the Müller and Garcia (3) dataset in three rotated views (**A, B**, and **C**).

Colors: black - outgroup (*Euparkeria*); yellow - Lagerpetidae; red - Silesauridae; light green - Ornithischia; purple - Sauropodomorpha; orange - Herrerasauridae; blue - Theropoda.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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in the Pearson BDC (**Fig. 9A**): Silesauridae (lower left corner), Saurischia, Ornithischia, and the outgroup (*Euparkeria*) + Lagerpetidae. *Lewisuchus admixtus* + *Lagosuchus talampayensis* appear in a small block at the very tip of the larger Dinosauria block, while *Lewisuchus admixtus* also shares positive correlation with *Asilisaurus kongwe*. *A. kongwe* shares positive correlation with many members in the dinosaurian block. None of the taxa in the Silesauridae block share positive correlation with the Ornithischia or outgroup, and only *A. kongwe* shared positive correlation with any taxa outside the group. The Spearman BDC results (**Fig. 9B**) are similar except there are more examples of shared positive correlation between the silesaurid taxa and the dinosaurs (including the ornithischian block).

The MDS plot yielded interesting results as well (**Fig. 10**). The Silesauridae (red) forms a diffuse cluster and is separated from the larger, more tightly clustered dinosaurian group. The Ornithischia (light green) is also quite distant from the larger dinosaurian group. These results conform well to the BDC plot (**Fig. 9**). The likely silesaurid *Lewisuchus* is farthest from the main silesaurid cluster, closer to *Lagosuchus* (green) and the herrerasaurids (orange) than it is to the next closest silesaurid (*Asilisaurus*).

The models with the highest average silhouette values in PAM (**Fig. 11A-B**) for the Müller and Garcia (3) dataset are for four groups (0.22) and five groups (0.29). Four groups (**Fig.11A**) split the silesaurids (red) apart from the non-dinosauromorphs (yellow) and two groups of non-silesaurid dinosauromorphs (green and blue). The ornithischian dinosaur *Scutellosaurus* is in the silesaurid group, but it has a negative silhouette value. *Lewisuchus* is in the green group of dinosauromorphs as is *Lagosuchus*. The five-group model (**Fig. 11B**) splits the ornithischians (yellow) away from the rest of the dinosauromorphs, and *Scutellosaurus* is correctly grouped with the ornithischians rather than the silesaurids. The blue group mainly consists of theropods, as well as two herrerasaurids (*Gnathovorax* and *Herrerasaurus*) and the sauropodomorph *Panytdraco*, which have large negative silhouette values.

FANNY only correctly ran results in two groups with an average silhouette value of 0.23 (**Fig. 11C**). Silesaurids are in the red group along with ornithischians, lagerpetids, *Euparkeria*, *Lagosuchus*, and some sauropodomorphs. The green group is made up of various saurischian taxa.

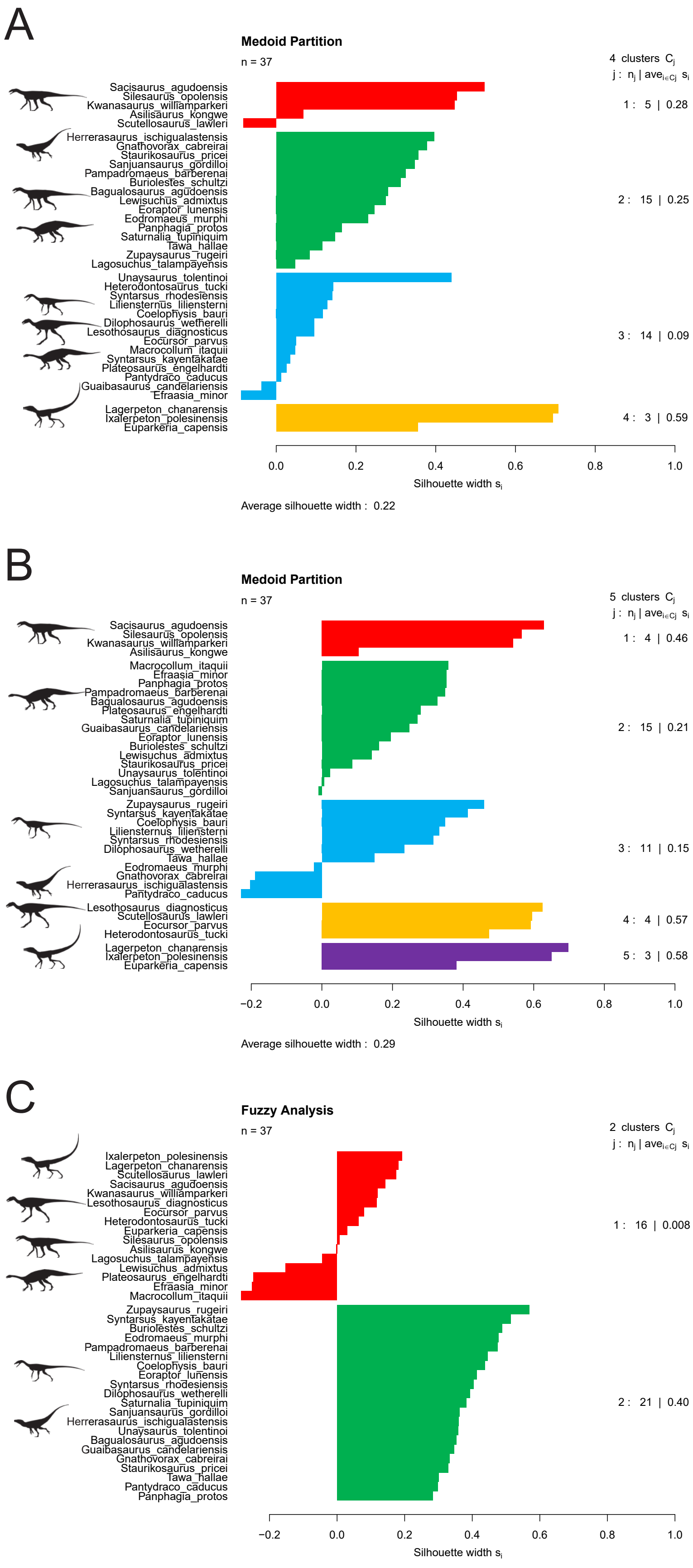

Figure 11. PAM and FANNY analysis of the Müller and Garcia (3) dataset: **A)** PAM in four groups; **B)** PAM in five groups; **C)** FANNY in two groups.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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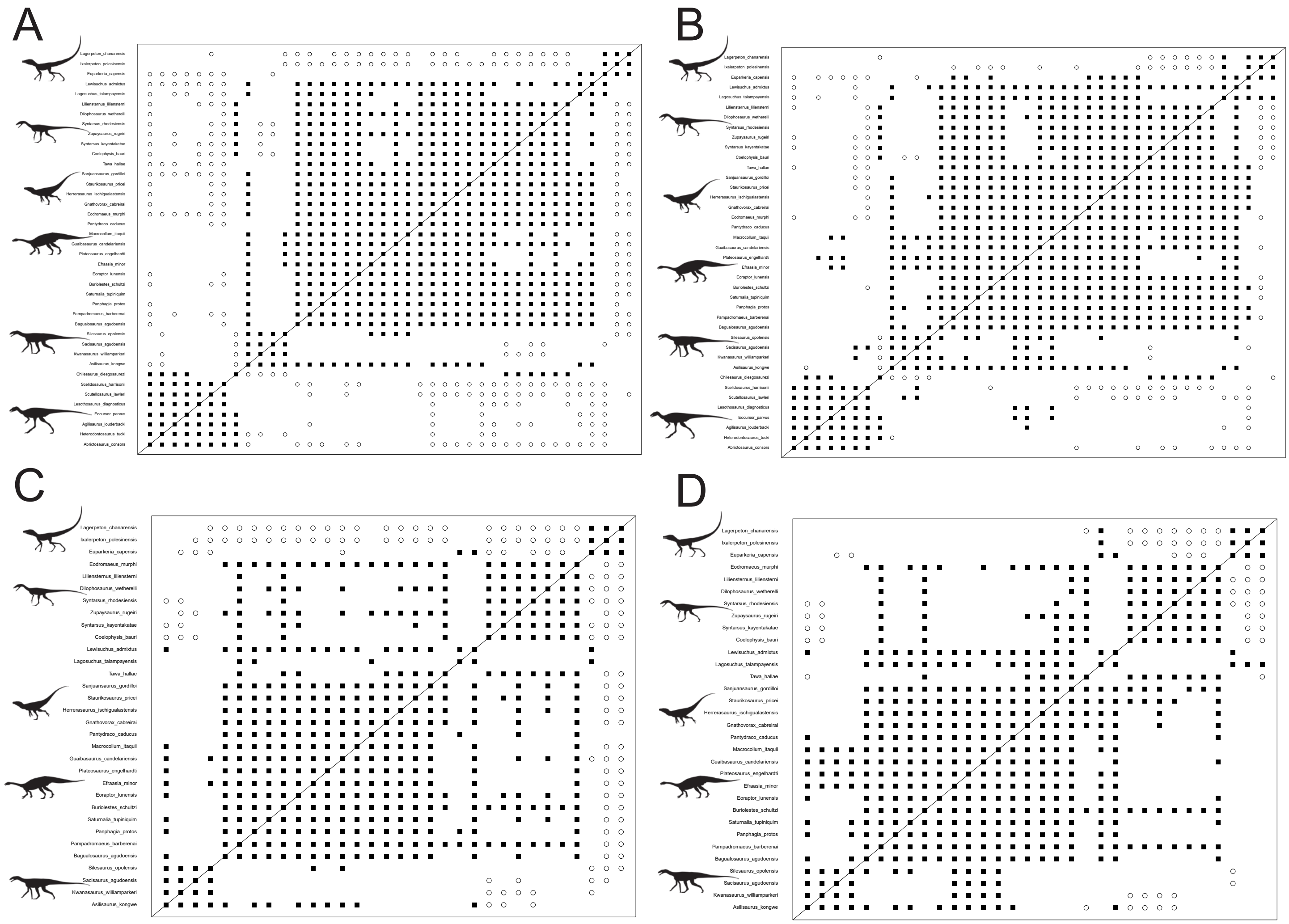

Figure 12. BDC plot of the Norman et al. (4) dataset: **A)** Pearson, all taxa; **B)** Spearman, all taxa; **C)** Pearson, Ornithischia and *Chilesaurus* removed; and **D)** Spearman, Ornithischia and *Chilesaurus* removed.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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Norman et al. (4)

When following the above listed constraints, 40 of the original 71 taxa were preserved (*Dromomeron gregorii, Dromomeron romeri, Dromomeron gigas,* UFSM 11611, PVSJ 883, *Saltopus elginenis, Diodorus scytobrachion, Eucoelophysis baldwini, Lutungutali sitwensisl, Technosaurus smalli, Soumyasaurus aenigmaticus, Ignotosaurus fragilis, Pisanosaurus mertii, Fruitadens haagarorum, Echinodon becklesii, Nhandumirim waldsangae, Chromogisaurus novasi, Chindesaurus briansmalli, Daemonosaurus chauliodus,* Petrified forest theropod, *Dilophosaurus wetherelli, Teleocrater rhadinus, Dongusuchus efremovi, Spondylosoma absconditum, Yarasuchus deccanensis, Manidens condorensis, Emausaurus ernsti, Pegomastax africanus, Laquintasaura venezulae,* and *Hexinlusaurus multidens* were dropped due to not meeting the taxonomic relevance cutoff) and 91 characters were retained.

The BDC analysis (**Fig. 12A-B**) for Norman et al. (4) yielded four or five blocks of positive correlation in Pearson (**Fig. 12A**). From left to right, bottom to top, they are as follows: Ornithischia, Silesauridae, Saurischia, *Lagosuchus* + *Euparkeria*, and possibly Lagerpetidae. The ornithischian block is well-defined, however, *Chilesaurus diegosuarezi* shows no correlation with *Lesothosaurus diagnosticus*, *Scutellosaurus lawleri*, or *Scelidosaurus harrisonii*, and it shares positive correlation with some saurischian taxa (*Coelophysis bauri*, *Syntarsus kayentakatae*, *Zupaysaurus rugeiri*, *Syntarsus rhodesiensis*, *Dilophosaurus wetherelli*, and *Liliensternus liliensterni*). In the Silesauridae block, *Asilisaurus kongwe* shares positive correlation with *Lagosuchus*

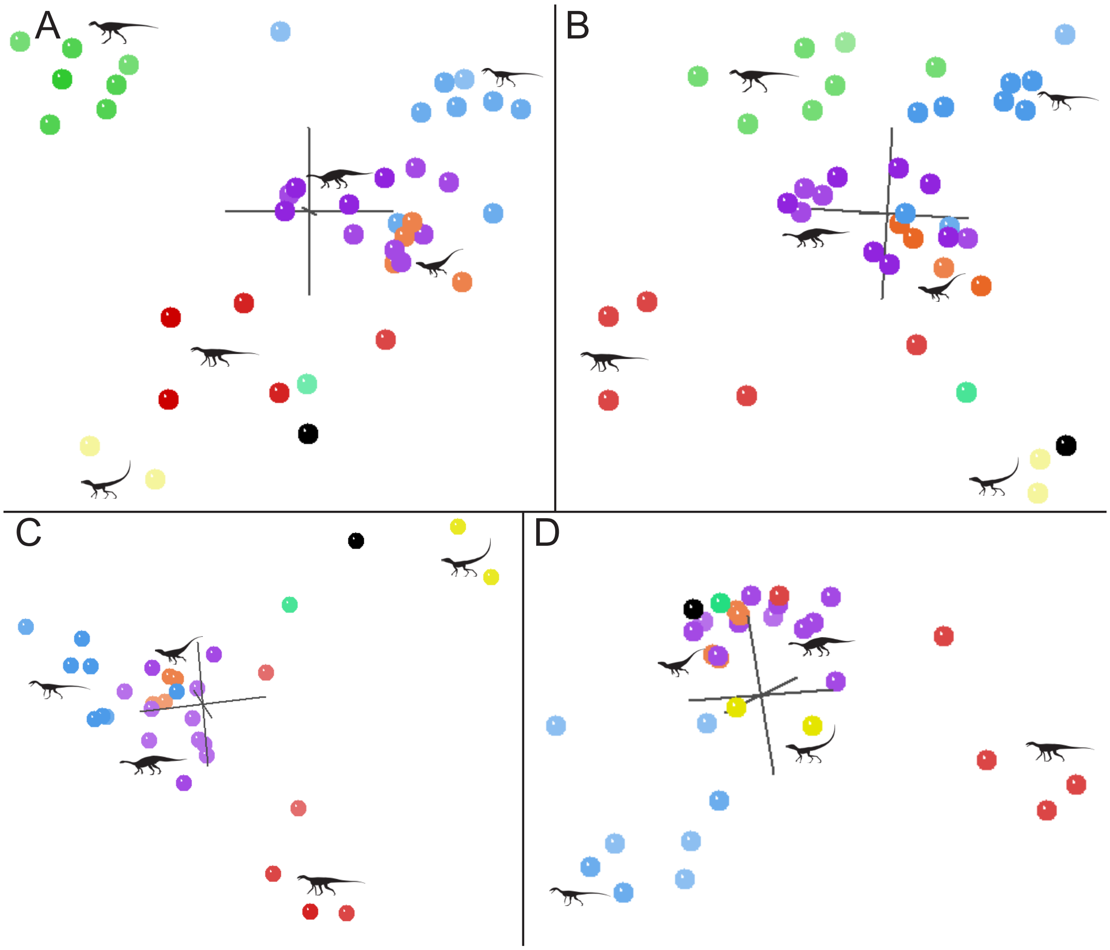

Figure 13. MDS plots of the Norman et al. (4) dataset: All taxa in two rotated views **A)** and **B**) and the subset excluding Ornithischia and *Chilesaurus* in two rotated views **C)** and **D**).

Colors:
black - outgroup (*Euparkeria*);
yellow - Lagerpetidae;
red - Silesauridae;
green - Lagosuchus;
light green - Ornithischia;
purple - Sauropodomorpha;
orange - Herrerasauridae;
and blue - Theropoda.

Taxonomic relevance cutoff = 0.2; character relevance cutoff = 0.75.

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talampayensis and *Lewisuchus admixtus* (which is grouped in the saurischian block) and 15 other saurischian taxa (*Bagualosaurus agudoensis*, *Pampadromaeus barberenai*, *Panphagia protos*, *Saturnalia tupiniquim*, *Buriolestes schultzi*, *Eoraptor lunensis*, *Efraasia minor*, *Plateosaurus engelhardti*, *Guaibasaurus candelariensis*, *Macrocollum itaquii*, *Eodromaeus murphi*, *Gnathovorax cabreirai*, *Herrerasaurus ischigualastensis*, *Staurikosaurus pricei*, and *Sanjuansaurus gordilloi*). *Silesaurus opolensis* shares positive correlation with four saurischian taxa (*Efraasia minor*, *Plateosaurus engelhardti*, *Guaibasaurus candelariensis*, and *Macrocollum itaquii*). *Euparkeria capensis* unites the lagerpetid and lagosuchid blocks, and *Lewisuchus admixtus* connects the lagosuchid block to the saurischian block. The Spearman BDC (**Fig. 12B**) still shows a relatively distinct Ornithischia, although it is positively correlated with a few other taxa, whereas the silesaurids show much greater positive correlation shared with other taxa.

The MDS results for Norman et al. (4) show the ornithischians clustered together at a distance from all of the other taxa (**Fig. 13A-B**). The bizarre and taxonomically controversial dinosaur *Chilesaurus diegosuarezi* splits the gulf between the ornithischians and the theropods (**Fig. 13A**). The remaining taxa fall into a V-shaped pattern in character space (**Fig. 13B**). The saurischians form the vertex of the V with the silesaurids on one end and the lagerpetids on the other. The silesaurids, except for *Lewisuchus*, are all clustered together at a distance from the other taxa. *Lewisuchus*, by contrast, falls at the edge of the saurischian cluster close to *Lagosuchus*.

Given how distinct the ornithischians were from the rest of the taxa in both BDC and MDS, we decided to remove them (and *Chilesaurus diegosuarezi*) and run the analyses again. The new BDC has three blocks of

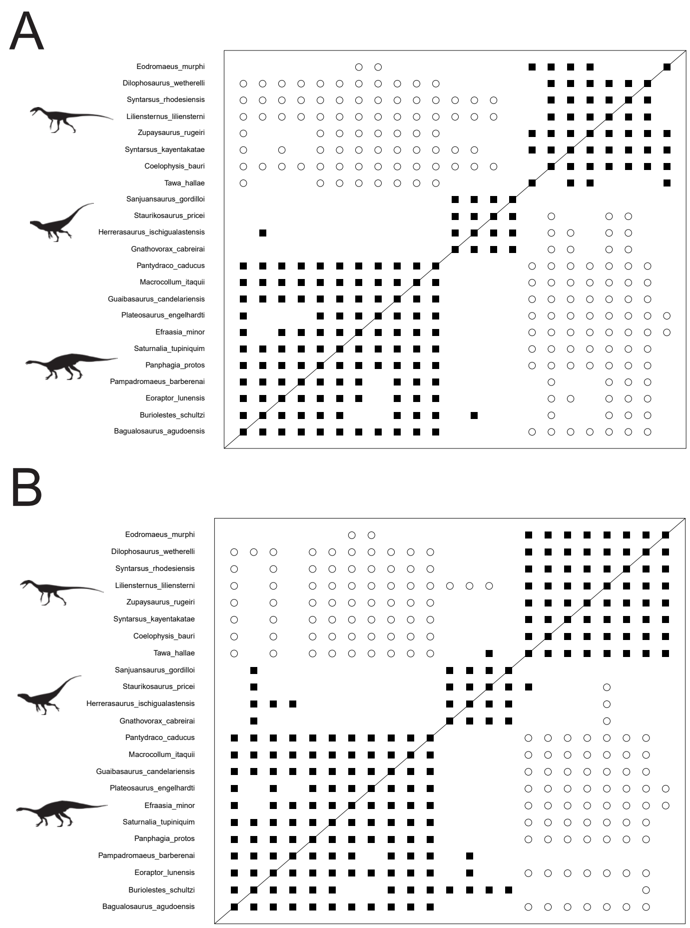

Figure 14 (Left). BDC plots of the Saurischia subset of the Norman et al. **(4)** dataset: **A)** Pearson and **B)** Spearman.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain.

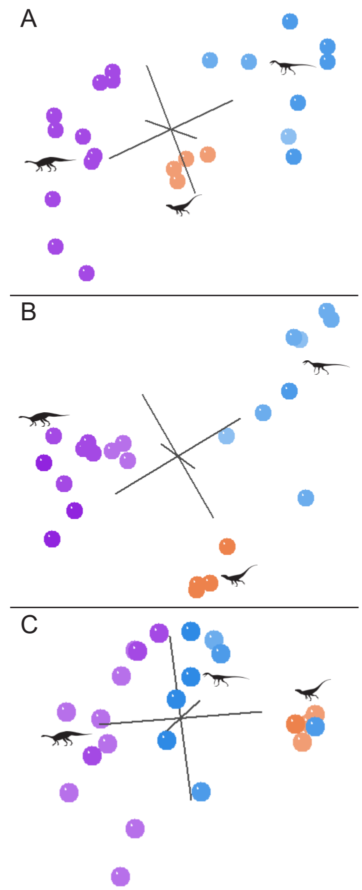

Figure 15 (Right). MDS plot of the Saurischia subset of the Norman et al. **(4)** dataset in three rotated views (**A**, **B**, and **C**).

Colors:
purple - Sauropodomorpha;
orange - Herrerasauridae;
blue - Theropoda.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain.

positive correlation with only slight differences between the Pearson **(Fig. 12C)** and Spearman (**Fig. 12D**) versions. The silesaurid block is in the lower left, with *Asilisaurus kongwe* still sharing positive correlation with some saurischians and *Silesaurus* sharing positive correlation with *Efraasia* and *Guaibasaurus*. The lagerpetid + outgroup block is in the upper right, and it shares negative correlation with almost every other taxon in the analysis. However, there are two examples of shared positive correlation between *Euparkeria capensis* and *Lagosuchus talampayensis* and *Tawa hallae*.

Out of curiosity, we decided to run just the saurischians to see what results we might get in BDC and MDS. The BDC results (**Fig. 14**) showed three very separate blocks of positive correlation (Sauropodomorpha, Herrerasauridae, and Theropoda), with only one example of shared positive correlation between blocks (*Herrerasaurus ischigualastensis* and *Buriolestes schultzi*) in Pearson (**Fig. 14A**) and a few more shared positive correlations in Spearman (**Fig. 14B**). The 3D MDS results (**Fig. 15**) revealed an interesting triangular pattern, where each group from the BDC results occupied a corner in multidimensional character space (**Fig. 15B**).

We also ran all of these versions of the Norman, et al. **(4)** dataset through PAM and FANNY. Analyzing all of the taxa with PAM resulted in two options that had an equal average silhouette width of 0.31: two groups and five groups (**Fig. 16A-B**). Not surprisingly, the two group version (**Fig. 16A**) separated mainly between Ornithischia and the rest of the taxa, and the five group version showed Ornithischia (red), Silesauridae (green), Sauropodomorpha (blue), Theropoda + Herrerasauridae + *Pantydraco* (yellow), and Lagerpetidae + *Euparkeria capensis* (purple). Within the yellow group, three taxa had negative silhouette values (two herrerasaurids and the sauropodomorph *Pantydraco caducus*). FANNY would only run with two groups, and the two groups do not seem to reveal anything of value (**Fig. 16C**).

Figure 16. PAM and FANNY analysis of the Norman et al. (4) dataset: **A)** PAM in two groups; **B)** PAM in five groups; and **C)** FANNY in two groups.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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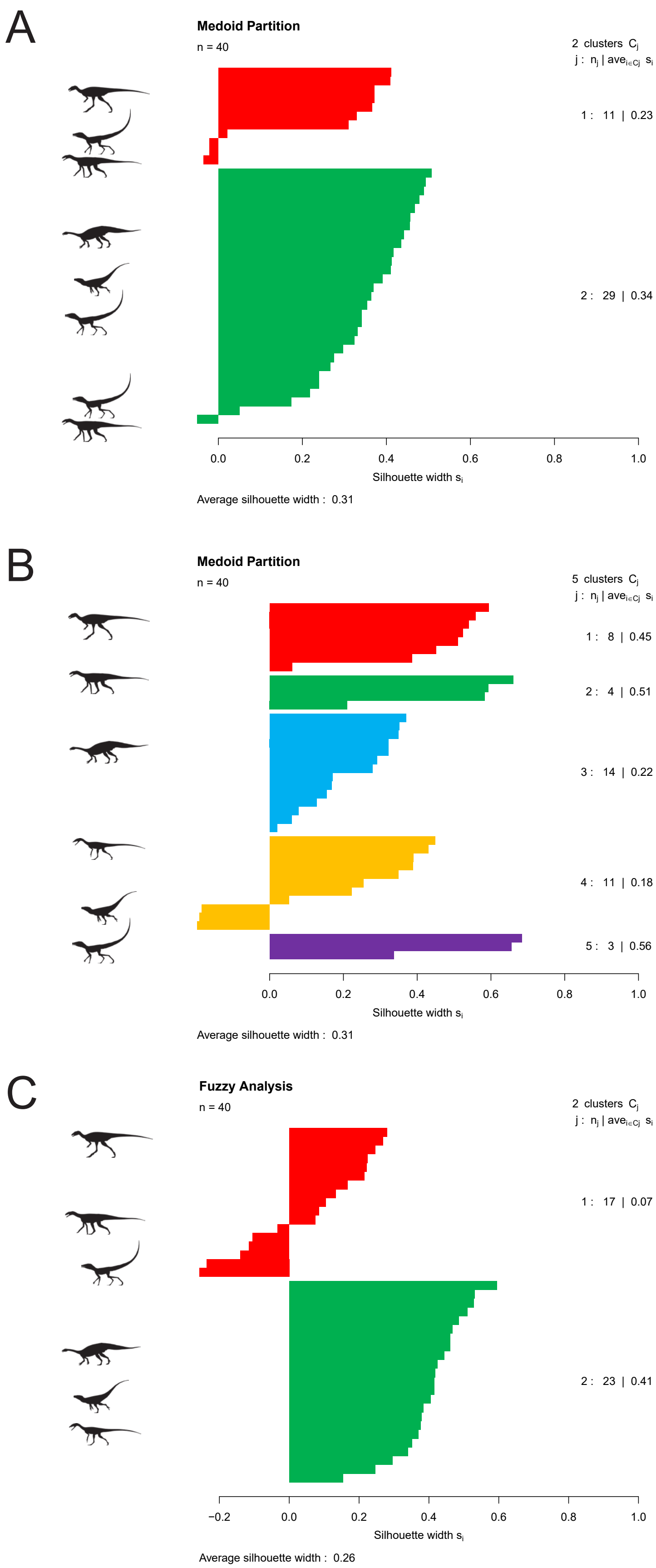

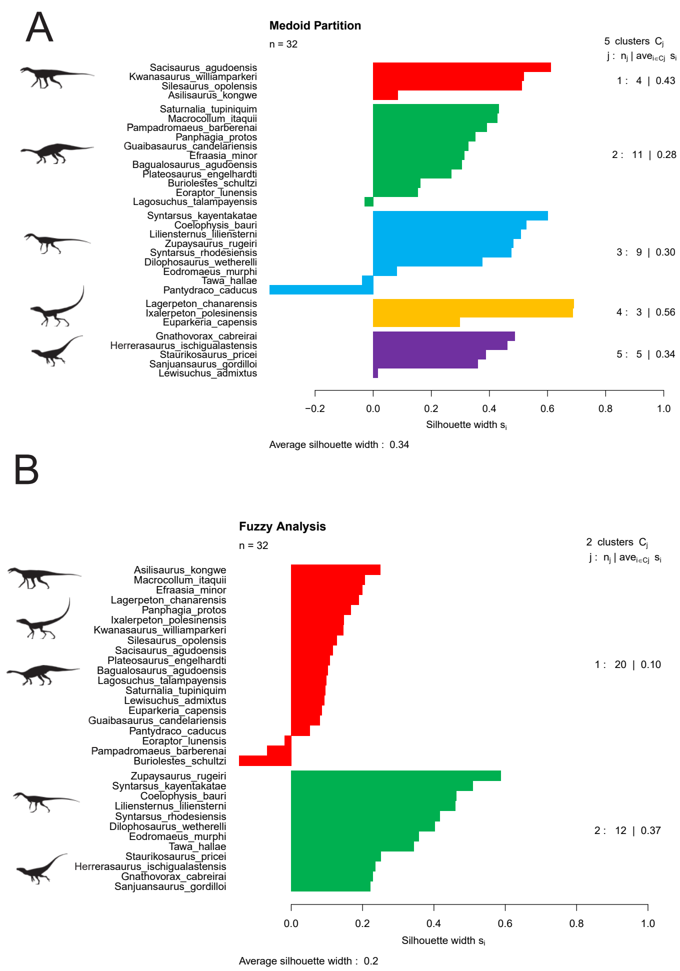

Figure 17. PAM and FANNY analysis of the subset of the Norman et al. **(4)** dataset lacking ornithischians and Chilesaurus: **A)** PAM in five groups and **B)** FANNY in two groups.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

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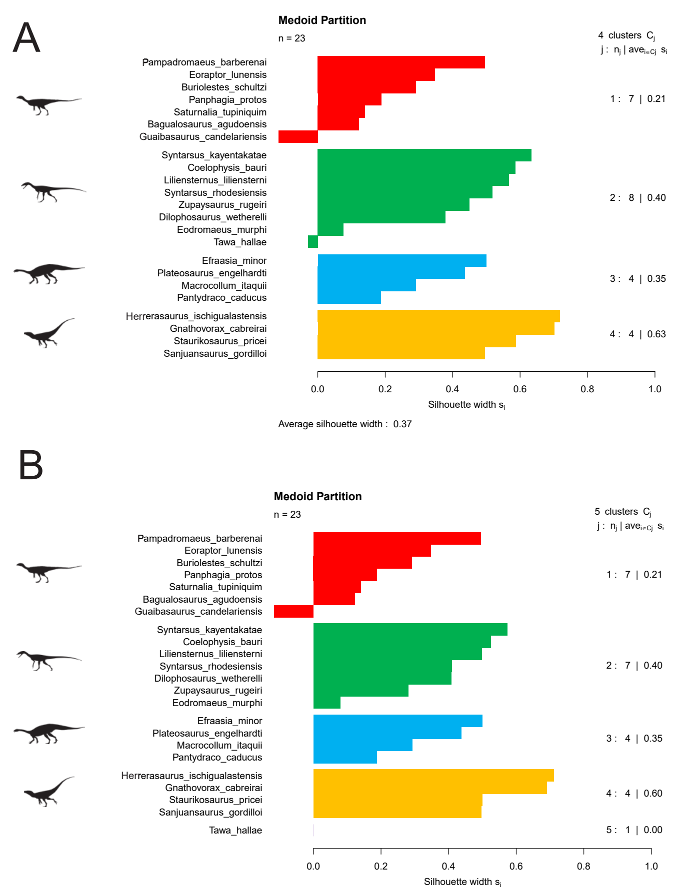

Figure 18. PAM analysis of the Saurischia subset of the Norman et al. **(4)** dataset: **A)** PAM in four groups and **B)** PAM in five groups.

Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain .

When the ornithischians and *Chilesaurus diegosuarezi* were excluded, the PAM version with the highest average silhouette width value (0.34) was 5 groups (**Fig. 17A**). The five groups were Silesauridae (red), Sauropodomorpha (green), Theropoda (blue), Lagerpetidae + *Euparkeria capensis* (yellow), and Herrerasauridae (purple). *Tawa hallae* and *Pantydraco caducus* were in the theropod group, but with negative silhouette values. Likewise, *Lagosuchus talampayensis* grouped with the sauropodomorphs, but with a negative silhouette value. *Lewisuchus admixtus* grouped with the herrerasaurids, but its silhouette value was 0.02. FANNY would not run correctly for any model with more than two groups (**Fig. 17B**). The two group model had an average silhouette width value of 0.2. The red group contained the silesaurids, sauropodomorphs, lagerpetids, *Euparkeria capensis*, *Lagosuchus talampayensis*, and *Lewisuchus admixtus*, whereas the green group included the herrerasaurids and theropods. Three sauropodomorph taxa in the red group have negative silhouette values (*Eoraptor lunensis*, *Pampadromaeus barberenai*, and *Buriolestes schultzi*).

Finally, the saurischian subset of Norman et al. **(4)** was also analyzed with PAM (**Fig. 18**) and FANNY (**Fig. 19**). The PAM average silhouette value was highest for four groups (0.37, **Fig. 18A**) and then five groups (0.35, **Fig. 18B**). The four-group model includes Herrerasauridae (yellow), Theropoda (green), and two sauropodomorph groups: "basal" Sauropodomorpha (red) and "classic prosauropods" (blue). *Guaiabasaurus candelariensis* and *Tawa hallae* have negative

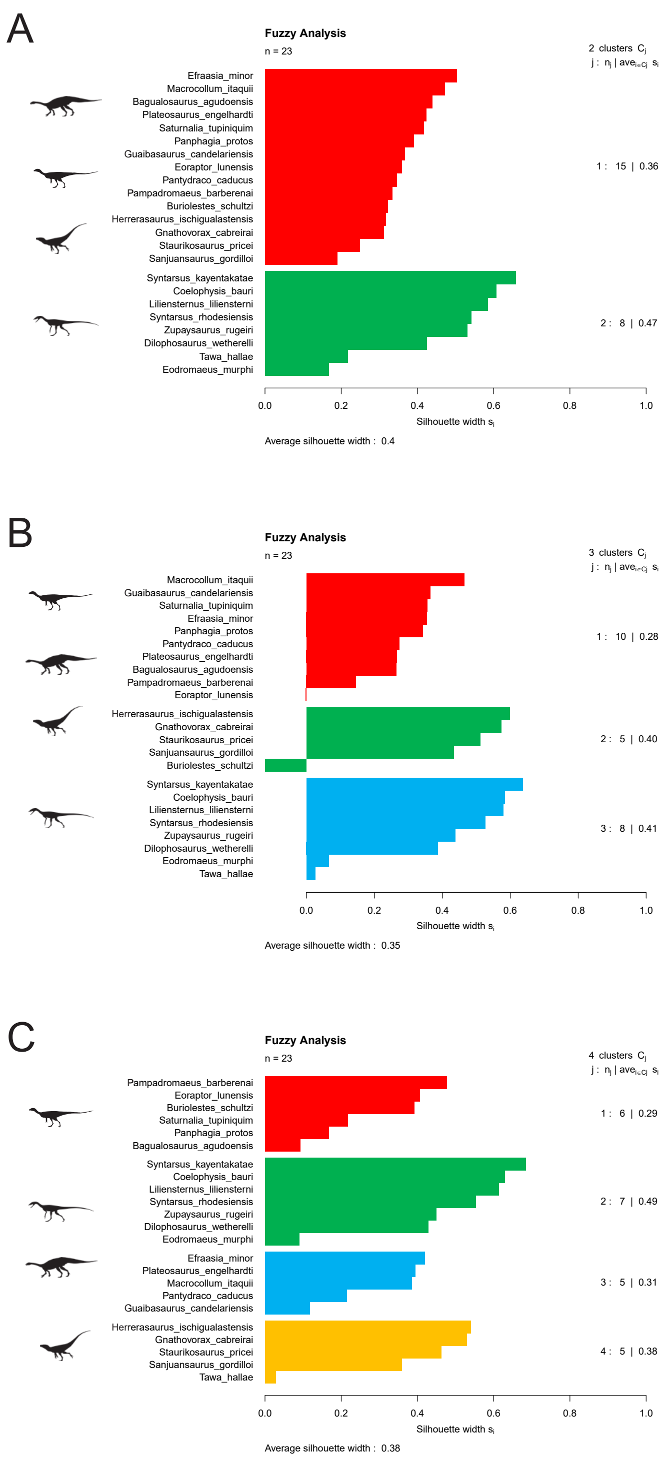

Figure 19. FANNY analysis of the Saurischia subset of the Norman et al. (4) dataset: **A)** FANNY in two groups; **B)** FANNY in three groups; and **C)** FANNY in four groups. Taxonomic relevance cutoff = 0.3; character relevance cutoff = 0.75.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain .

silhouette values in their groups (red and green, respectively). The five group model is nearly identical except that *Tawa hallae* is placed in its own group. FANNY would not run correctly at five groups, but it did work for two groups (0.4, **Fig. 19A**), three groups (0.35, **Fig. 19B**), and four groups (0.38, **Fig. 19C**). The two-group model separates theropods (green) from sauropodomorphs and herrerasaurids (red). The three-group model splits up the larger group into Herrersauridae (green) and Sauropodomorpha (red). *Buriolestes schultzi* is in the herrerasaurid group, but with a negative silhouette value, whereas *Eoraptor lunensis* is in the sauropodomorph group with a very small positive silhouette value. Four groups, like its equivalent in PAM, splits up the sauropodomorphs into the same two groups, except that *Guaibasaurus candelariensis* groups with the "classic prosauropods." *Tawa hallae* groups with the herrerasaurids (yellow), but with a very small silhouette value.

Discussion

The Silesaurid Holobaramin

In our survey of the silesaurid datasets we used BDC, MDS, PAM, and FANNY to identify continuity and discontinuity between groups. Throughout our analyses, we observed evidence of continuity within the Silesauridae, as interpreted via positive correlation in BDC and close clustering in MDS, and placement in the same groups in PAM and FANNY. We also observed evidence of discontinuity surrounding the Silesauridae via negative correlation with non-silesaurid taxa in BDC, lack of clustering with non-silesaurid taxa in MDS, and separation of silesaurids into their own groups in PAM and FANNY. For instance, in the Nesbitt **(1)** subset analysis, the silesaurid block did not share positive correlation with any other taxa in Pearson or Spearman BDC, and they shared negative correlation with the theropods (**Fig. 2C-D**). This evidence for discontinuity is supported by their separate clustering from the other taxa in MDS (**Fig. 3**), and in how they were grouped in PAM and FANNY (although two of the group models did split up Silesauridae in PAM and one in FANNY; **Figs. 4-5**).

Likewise, in the Martz and Small **(2)** subset BDC (**Fig. 6C-D**), the silesaurid block is set apart from the rest of the taxa by no correlation or negative correlation (except for one instance of shared positive correlation in Pearson and three in Spearman). These results suggest discontinuity surrounding Silesauridae, which is supported by their unique trajectory in MDS (**Fig. 7**), and their separate grouping in FANNY (**Fig. 8C**). The two- and four-group models of PAM for this analysis had equal average silhouette values (0.34), but this is likely because of the inclusion of so many non-dinosauromorph taxa in the analysis. Regardless, the four-group model did separate out the silesaurids from the other taxa (**Fig. 8B**).

The Müller and Garcia **(3)** BDC plots (**Fig. 9**) do not show strong evidence for discontinuity between silesaurids and the rest of the taxa, especially with *Asilisaurus kongwe*. However, this is likely due to the inclusion of so many disparate groups of taxa. They do appear to be somewhat set apart from the other taxa in MDS space (**Fig. 10**), and the two PAM models with the highest values separate them out from the rest of the taxa.

Even in the full Norman et al. **(4)** analysis BDC plots (**Fig. 12A-B**), the silesaurid block is distinct, but after removing the ornithischians it becomes even more distinct (**Fig. 12C-D**), with *Asilisaurus kongwe* again showing positive correlation with some saurischians. The MDS results lend support to discontinuity surrounding Silesauridae in the large separation between them and the rest of the taxa (except for *Lewisuchus*) whether the ornithischians were included (**Fig. 13A-B**) or not (**Fig. 13C-D**). Similarly, silesaurids were recovered as their own group in PAM whether ornithischians were included (**Fig. 16B**) or not (**Fig. 17A**) in the higher group models.

Because the Silesauridae seems to be continuous within itself and discontinuous with outside groups, we interpret it to be a holobaramin. However, this designation is dependent upon which taxa are included. In our analyses, we found the silesaurid holobaramin contains *Silesaurus opolensis*, *Sacisaurus agudoensis*, *Asilisaurus kongwe*, *Kwanasaurus williamparkeri*, and likely *Lewisuchus admixtus* (*Pseudolagosuchus major*), but excluding *Pisanosaurus mertii*. *Pseudolagosuchus major* and *Lewisuchus admixtus* are sometimes treated as separate taxa, but a new specimen of *Lewisuchus admixtus* described in 2019 demonstrated that they are the same species **(25)**. This was previously suspected (e.g. Norman et al. **(1)**), but the two species previously had very few overlapping elements (only a tibia). All of the datasets we used had them combined, although Nesbitt **(1)** listed them as separate taxa and as a combined taxon, all of which were included in our analyses. However, we obtained conflicting results as to its placement. In the Nesbitt **(1)** BDC (**Fig. 2**) and in the Martz and Small **(2)** BDC (**Fig. 6**), MDS (**Fig. 7**), and FANNY (**Fig. 8C**), *Lewisuchus* clusters very nicely with other silesaurids. However, in the Norman et al. **(4)** and Müller and Garcia **(3)** analyses, the connections between *Lewisuchus* and the silesaurids are weak if visible at all. We think that it is likely that, with the data from the new specimen described by Ezcurra et al. **(25)** *Lewisuchus* will cluster nicely with other silesaurids in future analyses. The many poorly known silesaurid taxa (e.g., *Diodorus*, *Lutungutali*, *Technosaurus*, *Ignotosaurus*, etc.) will likely turn out to be within the silesaurid holobaramin, but it is difficult to say without better fossils.

Pisanosaurus mertii, Ornithischian or Silesaurid?

The results for *Pisanosaurus mertii* have raised interesting questions as to how it relates to the rest of the Silesauridae. Originally, *P. mertii* was described as an ornithischian dinosaur **(8)**, which was followed by later authors (e.g., Bonaparte **(26)**, Butler et al. **(27)**, Ryan **(28)**). Agnolín and Rozadilla **(29)** and Baron et al.**(10)** recognized similarities between *P. mertii* and silesaurids, and recovered it within Silesauridae using phylogenetic analyses. However, its position remains unresolved and contentious. Müller and Garcia **(3)** have posited that *P. mertii* may be the most derived member of the Silesauridae, thereby bridging the gap between the Silesauridae and the "basal" Ornithischia.

The problem with forming a solid taxonomic conclusion on *P. mertii* is that it is a very poorly known taxon. The species is known from only one specimen, the holotype, PVL 2577 (housed in the Colección de Paleontologıa de Vertebrados, Instituto Miguel Lillo, Tucuman, Argentina) and it is still debated on how many elements of *P. mertii* are represented in that specimen (26, 29–33). Because of the poor nature of the specimen, *Pisanosaurus* falls out of our analyses when conducted at a taxonomic relevance cutoff of 0.3 (as occurred in Müller and Garcia **(3)**; Norman et al. **(4)**). However, the limited results listed here support placing *P. mertii* outside the silesaurid holobaramin and perhaps the Silesauridae. Given its close clustering with ornithischian taxa in the Nesbitt **(1)** and Martz and Small **(2)** analyses, it seems likely that it will belong to an ornithischian holobaramin. Nevertheless, there are a number of alternative hypotheses that can be formulated to explain why *P. mertii* may be clustering with the Ornithischia:

1. *P. mertii* is too poorly known.

   When a taxon is solely known from fragments, it becomes frustrating to assign it to a specific group. Not only is PVL 2577 the only specimen known, but the number of elements associated with the specimen is debated, and some elements have been lost **(29)**.

2. The ornithischian sample is too low.

   Perhaps the dataset uses too few ornithischian taxa, which may cause some characters to be emphasized, whereas others are diminished. The Norman et al. **(4)** dataset contains a larger ornithischian sample size, but *P. mertii* fell under the 0.2 taxonomic relevance cutoff, so its relationship was not tested.

3. Homoplasy

   Perhaps *P. mertii* is a silesaurid with ornithischian traits, or vice versa. Homoplasy is difficult to identify in fossil taxa (especially fragmentary taxa). Because of this, it is most likely safe to say that we lack sufficient material to conclusively show homoplasy is a major factor.

4. *P. mertii* is a chimeric taxon

   This was a hypothesis originally put forth by Sereno **(32)** and supported by other authors (33,34). However, this hypothesis has fallen out of favor in recent years (27,30).

In order to possibly gain clarity, we ran a version of the Norman et al. **(4)** dataset with *Pisanosaurus* and as many silesaurid taxa as possible (**Supplemental Figs. 1-2**, analysis details in Supplemental Data). These results recovered *Pisanosaurus* as clustering closer to silesaurids than ornithischians. For even more clarity, we ran a subset of the Norman et al. **(4)** dataset with the same parameters that only included Silesauridae, Ornithischia, *Lagosuchus*, and *Chilesaurus* (a possible ornithischian). These results strongly supported *Pisanosaurus* as in the silesaurid cluster and not the ornithischian cluster (**Supplemental Figs. 3-4**). However, it should be noted that these analyses were run with very fragmentary specimens included. While these results are intriguing, they do leave a number of unanswered questions. If *P. mertii* is truly an ornithischian, then why does it cluster with silesaurids in these specialized analyses? There are no definite Triassic ornithischians, which has been discussed by many authors (e.g. Baron **(35)**, Müller and Garcia **(3)**), thus if *P. mertii* is an ornithischian, it would then fill this gap; but if it is a Triassic ornithischian, then where are the others? *P. mertii* as a silesaurid makes sense of its stratigraphic placement, but if *P. mertii* is a silesaurid, then why does it cluster with ornithischians in some of the analyses? It is necessary to answer these questions, but they will require further work with new fossils of *Pisanosaurus*. Not only is there a need for more *P. mertii* specimens, but for more Triassic ornithischians and silesaurids in general.

It is worth noting that *Pisanosaurus* is far from the only potential silesaurid to have a curious mixture of traits from different groups. *Asilisaurus* and *Lewisuchus*, despite being avemetatarsalians and ornithodirans, possess crocodile-normal ankle joints, which might seem fitting given their basal status in phylogenies closer to *Lagosuchus*, aphanosaurs, and pseudosuchians, which all possess this joint **(14)**. However, pterosauromorphs (both pterosaurs and lagerpetids) possess "advanced mesotarsal" ankles also seen in dinosaurs and *Silesaurus*, even though the Pterosauromorpha/Dinosauromorpha split occurs prior to the Silesauridae/Dinosauria split **(1,14)**. Thus, in the evolutionary model, either the "advanced mesotarsal" ankle evolved separately two to three times or *Asilisaurus* and *Lewisuchus* reverted back to the crocodile-normal ankle joint. These kinds of surprises should lead creationists to consider how a creation model might better explain the diversity we see in organisms.

Is *Lagosuchus talampayensis* a Silesaurid?

Alfred Romer described two species of *Lagosuchus* in 1972, *L. talampayensis* and *L. lilloensis* **(6)**. A subsequent reanalysis of the fossil material by Sereno and Arcucci **(36)** concluded *Lagosuchus talampayensis* to be a *nominum dubium* due to its lack of autapomorphies. However, the authors found a number of features which would distinguish '*Lagosuchus*' *lillioensis* enough to name a separate species. They renamed it *Marasuchus lillioensis*, and considered it to be a non-dinosaurian dinosauromorph. More recently, Agnolin and Ezcurra **(37)** reassessed the holotype of *L. talampayensis* and found it to have features which would make it unique from other avemetatarsalians, but would not distinguish it from *Marasuchus lilloensis*, making *Marasuchus lilloensis* a junior synonym of *Lagosuchus talampayensis*. If *Marasuchus lilloensis* is a junior synonym of *Lagosuchus talampayensis*, it would follow that the two 'taxa' would group closely in our BDC or MDS analyses. None of our analyses were able to verify this since none of the datasets included both "species" as different taxa.

While *Lagosuchus* (*Marasuchus*) displayed positive correlation with some silesaurids in some analyses (Norman et al. **(4)** with *Asilisaurus*; Martz and Small **(2)** with *Asilisaurus*, *Lewisuchus*, *Sacisaurus*, and *Silesaurus*; Nesbitt et al. **(1)** with *Asilisaurus*, *Lewisuchus*, *Pseudolagosuchus*, *Marasuchus*, *Sacisaurus*, and *Silesaurus*), it also showed positive correlation with outgroup taxa (including *Eudimorphodon*), herrerasaurids, and basal sauropodomorphs. This further gives us less confidence to say *Lagosuchus* is of the silesaurid holobaramin. Furthermore, in more recent datasets, the only silesaurid *Lagosuchus* correlates with is *Lewisuchus*, a taxon that has the tendency to correlate with non-silesaurids. The early Nesbitt et al. **(1)** dataset gives *Lagosuchus* the best example of shared positive correlation with the silesaurids of any other dataset, which is possibly some kind of artifact of older, less complete data.

On the Silesauridae as a Paraphyletic Group within the Ornithischia

Müller and Garcia **(3)** proposed a paraphyletic grouping of the silesaurids within the Ornithischia. As we have seen prior, this is not the consensus. Although Müller and Garcia's **(3)** hypothesis is interesting (one that the authors claim to be more parsimonious than competing hypotheses), the results here do not show evidence for continuity between silesaurids and ornithischians, not even the results for the Müller and Garcia **(3)** dataset. The Silesauridae consistently grouped separately from the ornithischian taxa, except when considering *Pisanosaurus*, although even with its inclusion in the specialized subset of Norman et al . **(4)** there was a clear demarcation between silesaurids and ornithischians (**Supplemental Figs. 1-4**). It is important to point out that Ornithischia appears to contain multiple holobaramins **(19)**, and the results here do not necessarily preclude a hypothesis that recovers the Silesauridae as a group taxonomically within Ornithischia (as taxonomy and baraminology are not the same thing).

Insights into Saurischian Baraminology

Although we were not seeking to understand the baraminological relationships of saurischians, our analysis of Norman et al. **(4)** revealed some fascinating insights. We see clear evidence of discontinuity between Herrerasauridae, Sauropodomorpha, and Theropoda, even when only considering Upper Triassic/Lower Jurassic taxa. This could potentially raise challenges to a progressive evolutionary explanation for the Triassic origin of the Dinosauria. We hope that this small insight will be an encouragement to creationist paleontologists to investigate Triassic dinosaurs in an attempt to discern why there are so many similarities between these three saurischian groups and how we might explain the patterns we see from a creationist model, especially given the likelihood of these fossils being deposited during Noah's Flood.

Conclusion

The results we present here almost unanimously support a distinct silesaurid holobaramin containing *Silesaurus opolensis*, *Sacisaurus agudoensis*, *Asilisaurus kongwe*, *Kwanasaurus williamparkeri*, and possibly *Lewisuchus admixtus* (*Pseudolagosuchus major*). Given the incompleteness of the only known specimen of *Pisanosaurus mertii*, we recognize its baraminic status as inconclusive. *Lagosuchus* (*Marasuchus*) may be a member of the silesaurid holobaramin, however more research must be done into its exact placement. We also recognize the desperate need for more complete specimens to be discovered of both the Silesauridae and Triassic Ornithischia (if they do exist).

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Supplemental Information

In order to test the baraminic relationships of *Pisanosaurus* with a large ornithischian and silesaurid dataset, we decided to re-run the Norman et al. (4) dataset with a character relevance cutoff of 0 and a taxonomic relevance cutoff of 0.2 for most taxa, but a 0.1 for silesaurids. This allowed us to include additional silesaurids (*Pisanosaurus mertii*, *Lutungutali sitwensis*, *Eucoelophysis baldwini*, and *Diodorus scytobrachion*). However, in order to run this analysis, we had to remove some non-silesaurid taxa that had a taxonomic relevance score higher than 0.2, as the analysis would not run including them as they shared no characters in common with other taxa in the dataset: the likely theropod *Daemonosaurus chauliodus*, the sauropodomorph *Nhandumirim waldsangae*, and the thyreophoran (ornithischian) *Emausaurus ernsti*.

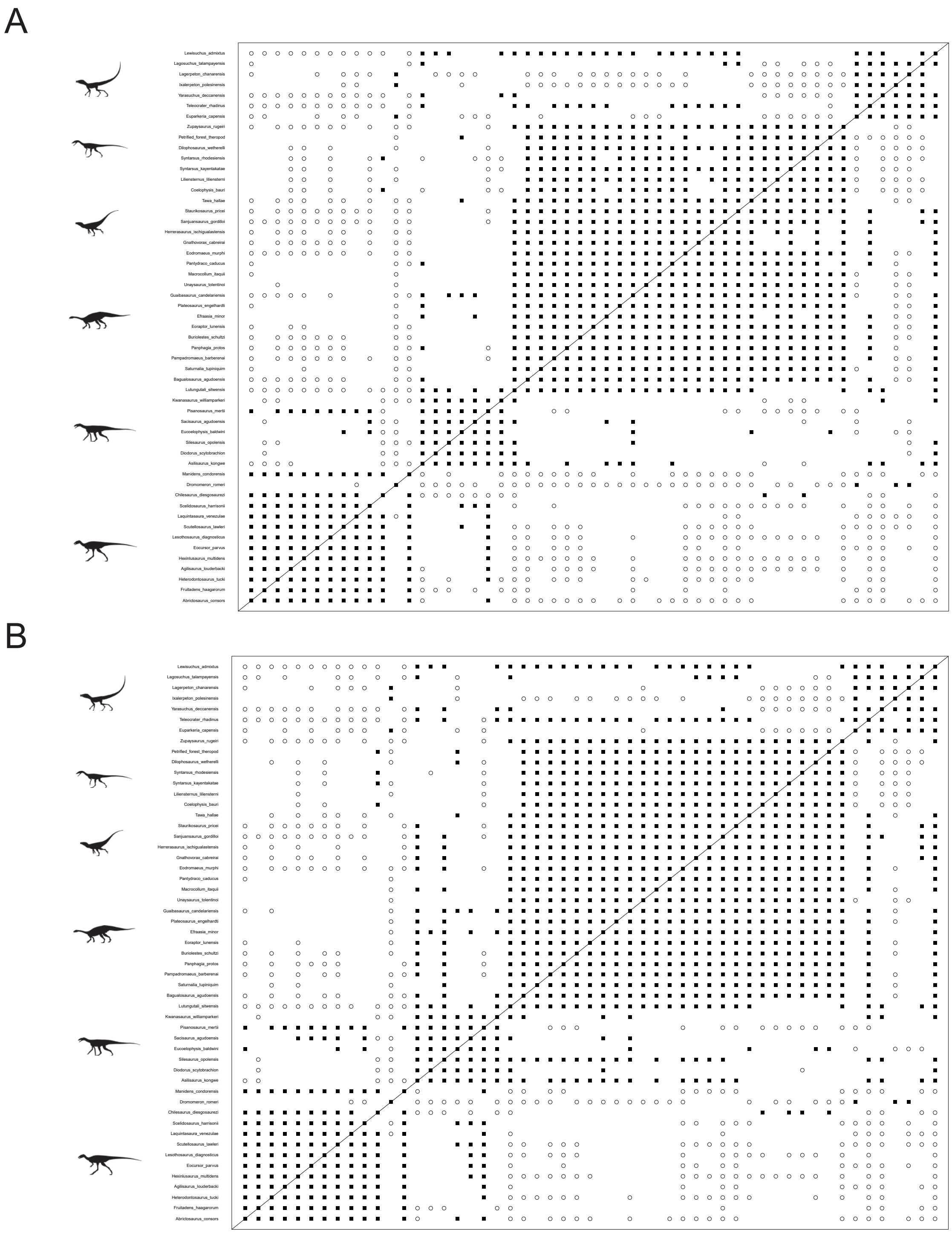
The Pearson and Spearman BDC results show four blocks of positive correlation with more examples of shared positive correlation between the blocks in the Spearman BDC **(Supp. Fig. 1)**. The lower left block contains ornithischians, the next block diagonally contains silesaurids, then a large block of saurischians, and finally a smaller block containing non-dinosauriform taxa. The enigmatic dinosaur *Chilesaurus* shares positive correlation with the ornithischians and a few theropods. *Pisanosaurus* shares positive correlation with the silesaurids and the ornithischians. *Lewisuchus* shares positive correlation with some silesaurids, with many saurischians, and with most of the non-dinosauriform taxa.

PAM results (Supp. Fig 2A) for this special dataset have the highest silhouette value at five groups (0.38, Supp. Fig. 2). *Pisanosaurus* is grouped with the silesaurids (green) with a silhouette value of 0.29. *Lewisuchus* is grouped with the sauropodomorphs and herrerasaurids (blue) with the low silhouette value of 0.04. FANNY (Supp. Fig 2B) only ran at two groups (average silhouette value = 0.26), with the ornithischians and silesaurids in one group (red) and the rest of the taxa in the other group (green), although *Lewisuchus* is in the green group.

Because we wanted more clarity on the baraminic relationship between Silesauridae and Ornithischia, especially as it relates to *Pisanosaurus*, we made a subset of this modified dataset that only included the silesaurids, ornithischians, *Chilesaurus* (since it keeps clustering with ornithischians), and *Lagosuchus* (since it sometimes clusters with silesaurids). The resulting BDC plots are almost identical between the Pearson and Spearman coefficients **(Supp. Fig. 3)**. The silesaurid and ornithischian blocks of positive correlation share no positive correlation between each other, and they are mainly separated by instances of negative correlation. *Chilesaurus* is positively correlated with the ornithischians, and *Pisanosaurus* only positively correlates with silesaurids, although it is not negatively correlated with any taxa except *Chilesaurus*. *Lewisuchus* shares positive correlation with other silesaurids and with *Lagosuchus*, which only positively correlates with one other taxon: *Asilisaurus*.

The PAM results **(Supp. Fig. 4A)** for this silesaurid and ornithischian subset of the Norman et al. (4) dataset had the highest silhouette value at two groups (0.46), which was the same case for FANNY **(Supp. Fig. 4B)**. In both PAM and FANNY, the two groups were Ornithischia + *Chilesaurus* (red) and Silesauridae + *Lagosuchus* (green). *Pisanosaurus* and *Lewisuchus* were both included in the silesauridae group.

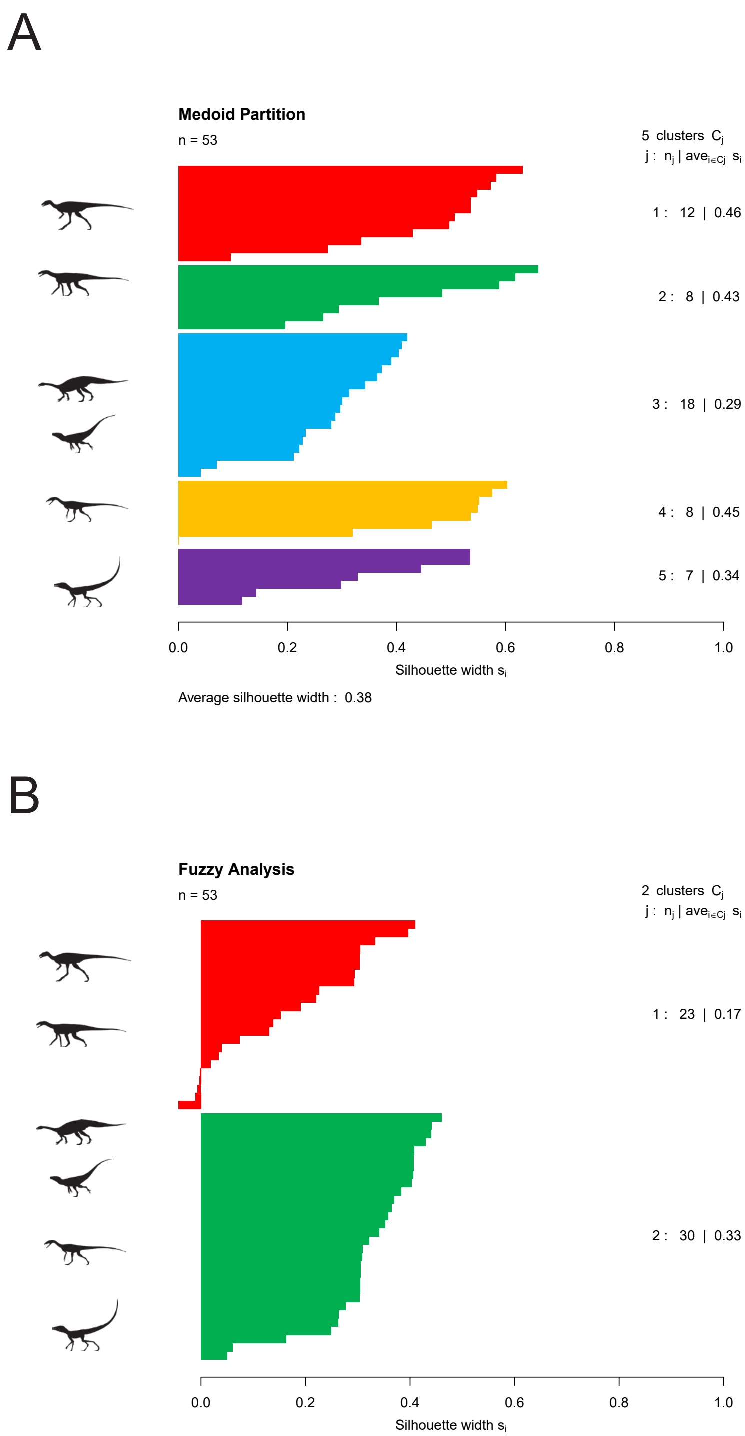
We did not include separate 3D MDS plots for these analyses since the component plots on the PAM and FANNY analyses provided ample representations of those plots.



Supplemental Figure 1. BDC plots of the special subset of the Norman et al. (4) dataset: **A)** Pearson and **B)** Spearman.

Taxonomic relevance cutoff = 0.2 with additional modifications (see text for description); character relevance cutoff = 0.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain except for *Asilisaurus* by Scott Hartman, CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en).



Supplemental Figure 2. PAM and FANNY analyses of the special subset of the Norman et al. **(4)** dataset: **A)** PAM at five groups and **B)** FANNY at two groups.

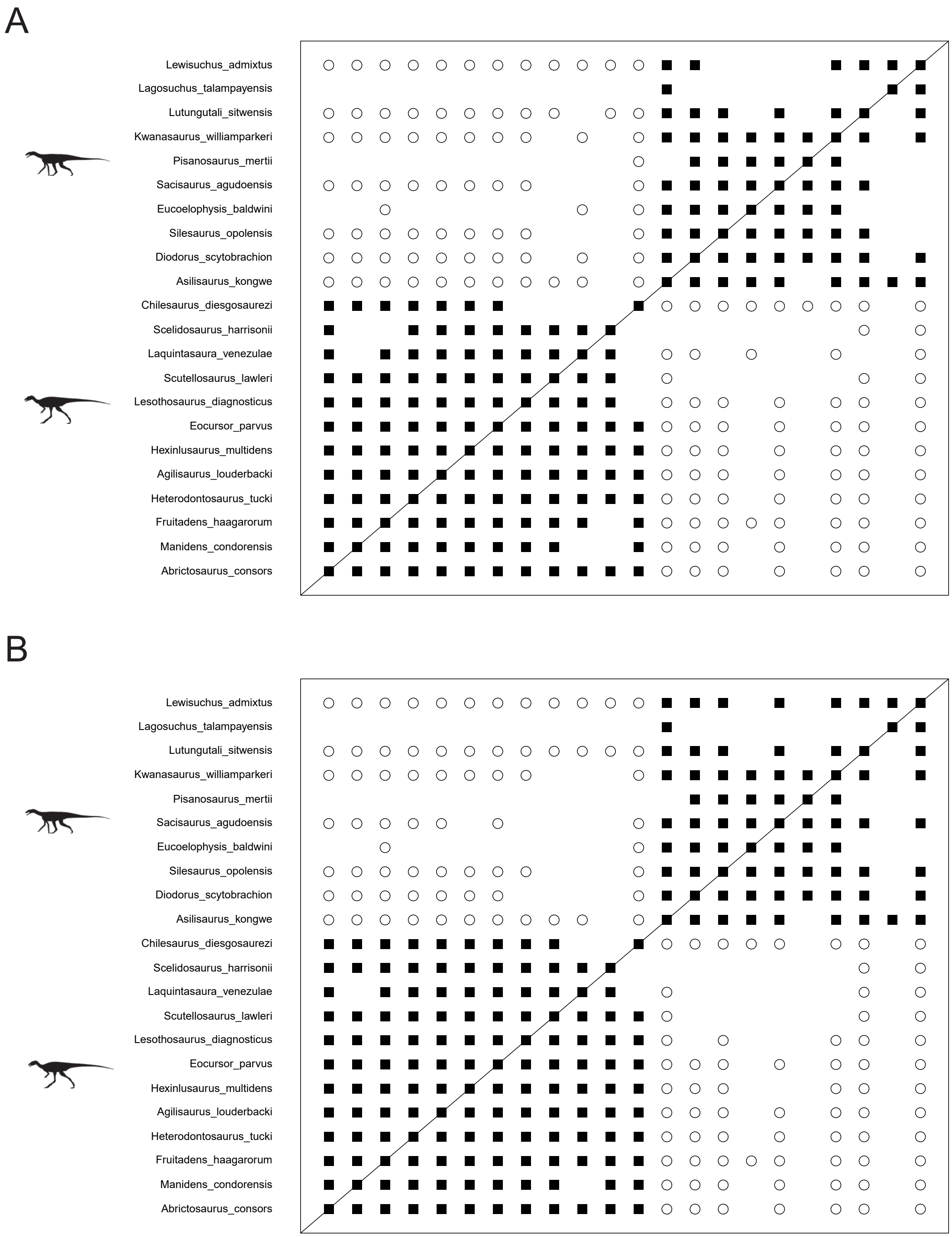
Taxonomic relevance cutoff = 0.2 with additional modifications (see text for description); character relevance cutoff = 0.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain except for *Asilisaurus* by Scott Hartman, CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en).

Supplemental Figure 3. BDC plots of the Silesauridae and Ornithischia subset of the Norman et al. (4) dataset: **A)** Pearson and **B)** Spearman.

Taxonomic relevance cutoff = 0.2 with additional modifications (see text for description); character relevance cutoff = 0.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain except for *Asilisaurus* by Scott Hartman, CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en).



Supplemental Figure 4. PAM and FANNY analyses of the Silesauridae and Ornithischia subset of the Norman et al. **(4)** dataset: **A)** PAM at two groups and **B)** FANNY at two groups.

Taxonomic relevance cutoff = 0.2 with additional modifications (see text for description); character relevance cutoff = 0.

Silhouettes from Phylopic (https://www.phylopic.org/). All silhouettes are public domain except for *Asilisaurus* by Scott Hartman, CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en).