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MORPHOLOGICAL VARIATION AND SPECIATION OF ACAVIDAE FAMILY: A CASE STUDY FROM FOSSIL AND LIVING SPECIES OF BATADOMBALENA CAVE PRE-HISTORIC SITE IN SRI LANKA

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Abstract

A sufficient knowledge on prehistoric culture and habitat of earliest *Homo sapiens* (Balangoda man) is available in Batadomba-lena cave, a noticeable rock shelter in lowland rainforest of southwestern Sri Lanka goes upto Pleistocene and Holocene eras. Late Pleistocene inhabitants of Batadombalena cave's foraged for a broad spectrum of plant and mainly arboreal animal resources such as, monkeys, squirrels and rainforest snails etc. Archaeo-faunal evidence would help to describe the prehistoric man eating behavior as well as availability of nature pre-historic flora, fauna and environmental status. The family Acavidae is very sensitive to climatic variations, hence used as a bio-indicator to describe the variations of paleo-climatic nature. This study examined the morphological features of 20 samples of Acavidae family (living/fossil samples of *Acavus superbus*, and sub fossil samples of *Oligospira waltoni*) collected from soils by digger method in 2005 and compared with 20 samples from the same area at presently available. The shell characters of snails such as, height, width, diameter of mouth, thickness of lip, and angular of axis were measured and subjected to multivariate analysis to understand how climatic variability and nature of paleo-diet contribute survival of Acavidae species. Results showed that *Acavus superbus* living species had large shell characteristics than the sub fossils. Results of similar study in the same climatic status in 2000 showed that the shell measurements of *Acavus superbus* are relatively larger than both living and sub fossils in Batadobalena cave. Ordination diagram derived from species shell characteristics showed that *Acavus superbus* living species grouped as scattered /diffuse clusters, while sub fossil species grouped as a single cluster at the center of the ordination diagram. It is imply a trend of speciation /diversification of *Acavus* species from Pleistocene era to date. Multivariate analyses prove that, a strong positive correlation of species characteristics, such as height ($r = 0.62$), thickness of lip ($r = 0.544$) and angular of axis ($r = 0.744$), and a strong negative relationship ($r = 0.832$) for shell width for the species were observed. Our results are useful to compare with other fossil snails to see whether the climate change influence for changing body size. In conclusion, palaeo-environment, and present environment variation has been occurred in minimum way without much changes to observed Acavidae species compositions present and past.

Keywords: Acavidae, Paleoecology, Batadombalena Cave, Sabaragamuwa Basin, Sri Lanka

1. INTRODUCTION

Paleoecology uses geological and biological evidences from fossil deposits to investigate the past occurrence, distribution, and abundance of different ecological units on a variety of time scales, which provides scientific evidence for present and future. The Sabaragamuwa Basin, Sri Lanka provides dominant type of natural Palaeo-eco-evidences (Deraniyagala 1958). The cultural remains of early man of this area were discovered together with the skeletal fragments and geometric microliths. Other detections include various types of fauna and flora that are thought to have formed part of human diet, also the animal bones, which was fossilized adjoining the Sabaragamuwa Basin called “Rathnapura Fauna” (Fig. 1). As a result of the palaeo-diet of Balangoda man (*Homo sapiens*),who lived in cave of pre historic site, Batadombalena cave (38,000 BP) which was the proper harbor life station(Aravinda et al 2016), accumulated many snails (Acavidae species), such as *Acavus phoenix*, *Acavus superbus,* and *Oligospira walton*ias fossil deposits.

Figure 1. Historic overview of Batadobalena cave in Sabaragamuwa Basin. *A: Paronomic view (west to east) of the Sabaragamuwa Basin, B: Batadobalena cave Pre Historic Site, C: Batadobalena cave rock shelter and excavation trench, D: Biththipodi Ella (BDA1) and D1-D3 represent the Faunal Diversity of BDA1 , E:Paranomic view of Sabaragamuwa Basin (During the Pleistocene epoch, Sri Lanka has experienced heavy rainfall and the entire island was covered with rain forests. These heavy showers created large lakes and marshes in Sabaragamuwa Basin providing habitats for a number of marsh loving mammals and other animals). F: A synthesis representation of the Balangoda man, G: Pre historic artifacts and microlithic*

The Batadombalena cave measures approximately 15 m high, 18 m wide, and 25 m in length, totaling the internal cave area to 6,800 m^2. It is located at 5 km away from the town of Kuruwita, Sabaragamuwa Province of Sri Lanka (Fig. 2).

There were fragmented human remains and stone artifacts were discovered by Deraniyagala (1938) at Batadombalena cave by his excavation. This study site was excavated up to four feet and assigned the assemblage of stone artifacts, in particular the association of microliths and human remains, related to the *Balangoda* phase. Then, a preliminary examination was made in 1979 was explored rich occupational deposit in the site. Thereafter, the strait graphic sequence of seven main occupational layers and three underlying strata directly above the bedrock has been described by Daraniyagala in 1982 by an excavation of 2.6 meters. Layers 1 – 3 from top downwards were considered to have been described in resent time. The occupational deposited in layer 4 was described as a massive homogenous stratum with brownish sand and silt containing stone artifacts and faunal remains. Layers 5 and 6 were very important and considered to be the site’s major occupational layer. In addition, layer 7 contains many stone artifacts including geometric microliths which were radiocarbon dated to Ca. 30 000 years BP.

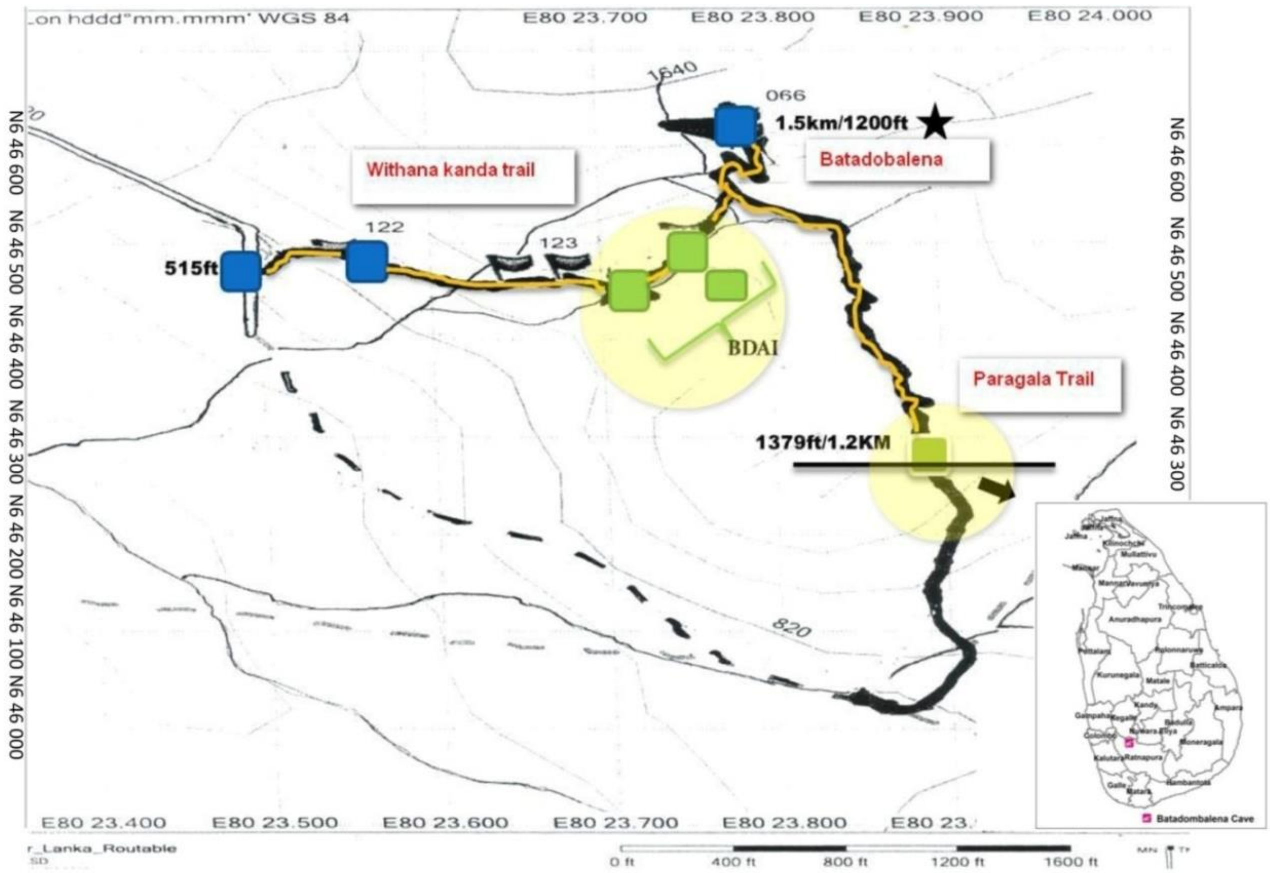

Figure 2. A detail map of Batadombalena Cave located at the Kuruwita in Sabaragamuwa province in Sri Lanka

Acavidae is a taxonomic family of air-breathing land snails, terrestrial pulmonate gastropod mollusks in the super family Acavoidea (Bouchet and Rocroi 2005). Acavidea has been surviving and adapting to the terrestrial life in wet zone from the pre-historic time. Sub fossils of Acavidae have recorded as a dominant place from the optimal fossils, which were found in every excavation in Batadombalena cave. Occupation of Acavoidea species in different soil strata proved that the Acavidae members were been lived continually throughout each paleo-era Batadombalena area. There are number of different Acavidae species of snails are most abundant dispersal surrounding, 76 acres of Batadombalena cave forest area at present. The objective of this study is to compare morphological characteristics of shell of existing species of Acavidae family live in surrounding areas at Batadombalena cave with that of fossils of Acavidae members.

2. METHODS

Family Acavidaeis very sensitive to climatic variations and therefore, it can be used as a bio-indicator to describe the variations of paleo-climatic nature and present. This study examined the morphological features of 20 samples of Acavidae family collected from soils by digger method in 2005. The shell characters of Acavidae such as, shell height, width, diameter of mouth, thickness of lip, and angular of axis were measured. Then, fossil record data were compared with 20 samples from the same area at presently available (Fig. 3). The shell characters in each individual were used to create a data matrix for multivariate analyzing. The ordination methods of Detrended Correspondence Analysis (DCA) were tested using PC-ORD 4 software to select the best correlation between ordination axes and shell characters.

Figure 3. Family Acavidae samples from Batadombalena cave (A block: Living samples of *Acavus superbus*: A1,A2,A3, A4; B block: samples from 2005 excavation of *Acavus superbus*,B1,B2,B3,B4; and C1: *Oligospira waltoni*

3 RESULTS AND DISCUSSION

Sri Lanka has a variety of forest types which provide habitats for different snail species. The wet south-western region and the central highlands are covered with tropical rain forests, sub-montane forests and wet evergreen forests particularly at higher elevations. Tropical semi-evergreen forests are present in the transition zone between the wet zone and the dry zone. The lowland wet zone forests, the study site Batadombalena cave belongs, occupy only less than 20% of the landmass of the country with more than 55% of human population. The major part of the dry zone has tropical dry mixed evergreen forests. There are number of studies carried out to recognize the effect of global climatic changes on natural forests of Sri Lanka. Kuruppuarachchi et al. (2016) recognized that dry zone forests are more vulnerable for future global climatic changes. Similarly, it has been predicted that there would be a northward shift of tropical wet forest into areas currently occupied by tropical dry forest (Somaratne and Danapala 1996). Thus, it is clear that more interactions with climatic parameters would arise in the tropical forests in the future climatic change scenarios. Thus, due to drastic changes of climatic conditions may seriously affect to the composition or abundance of snail living in Batadombalena cave, wet lowland tropical area of Sri Lanka.

The comparison analyzing between palaeo-environment and present environment of Batadombalena cave was reproduced by variation of species composition of snails at said eras. We compare shell characters of *Acavus superbus* for living species (A1- A4) and sub fossils (B1 – B4) and the results are shown in Fig. 3 and Table 1.The results showed that, the Acavidae species, which was lived early period can be identify in the same zone at present.

Measurements: *Acavus superbus* living species: (n=20); Diameter of mouth (D): 26.7-39.3 mm, $\bar{x}$ = 32.3± 5.4 mm; Height (H): 31.2 -36.8 mm, $\bar{x}$ = 33.3 ± 2.4 mm; D/H: 0.85-1.07 mm, $\bar{x}$ = 0.97 ± 0.10 mm.

Acavus superbus sub fossils: (n=20); D: 30.6-34.4 mm, $\bar{x}$ = 32.1 ± 1.6 mm; H: 30.3-33.2 mm, $\bar{x}$ = 32.1 ± 1.3 mm; D/H: 0.95-1.05 mm, $\bar{x}$ = 1.0 ± 0.10 mm.

Table 1. Comparison characters of living Acavidae species with relevant fossil Acavidaea samples of Batadombalena cave (Living species = 1#,Sub fossils =1, Non-foramen of shell = 2#, Foramen of shell =2)

Reference Number	Fossil species	Living species/ sub fossils	Height (mm)	Width (mm)	Diameter of mouth (mm)	Thickness of lip (mm)	Angular of axis	Special features
A1	*Acavus superbus*	1#	32.2	41.12	33.27	10.75	52°	2#
A2	*Acavus superbus*	1#	36.76	50.47	39.26	5.898	52°	2#
A3	*Acavus superbus*	1#	33.22	42.93	30.01	5.624	54°	2#
A4	*Acavus superbus*	1#	31.18	44.34	26.70	4.231	52°	2#
B1	*Acavus superbus*	1	33.04	54.36	34.44	5.865	53°	2
B2	*Acavus superbus*	1	30.32	47.86	31.96	5.817	50°	2
B3	*Acavus superbus*	1	31.71	52.30	30.63	7.278	52°	2
B4	*Acavus superbus*	1	33.2	48.33	31.56	7.038	53°	2
C1	*Oligospira waltoni*	1	22.63	53.01	26.51	5.333	40°	2#

According to the above measurements, *Acavus superbus* living species had large shell characteristics than the sub fossils. In addition, we compared our species shell characteristics of the same species with research finding of Hausdore and Perera (2000) at Rakwana which is belong to the same eco-climatic region. The results showed that the shell measurements of *Acavus superbus* in Rakwana (D: 33.6-52.5 mm, $\bar{x}$ = 47.2± 3.7 mm; H: 33.9-47.8 mm, $\bar{x}$ = 42.7 ± 2.9 mm; D/H: 0.88-1.35 mm, $\bar{x}$ = 1.11 ± 0.108 mm) was relatively larger than both living and sub fossils in Batadobalena cave. Therefore, it can be concluded that, palaeo-environment, and present environment variation has been occurred in minimum way without much changes to the snail compositions present and past. If snails are comparatively environmental sensitive, changes of environmental parameters of study area for last Ca. 30,000 years period were not been considerable affect for change of morphology of shell or snail species.

We compared the shell characteristics, such as height, width, diameter and thickness of living Acavidae species with relevant fossil Acavidae samples (Fig. 4). The fossil Acavidae samples showed a less variability among individuals of shell characteristics except width. In contrast, living Acavidae species showed a distinct variability of individual shells except thickness.

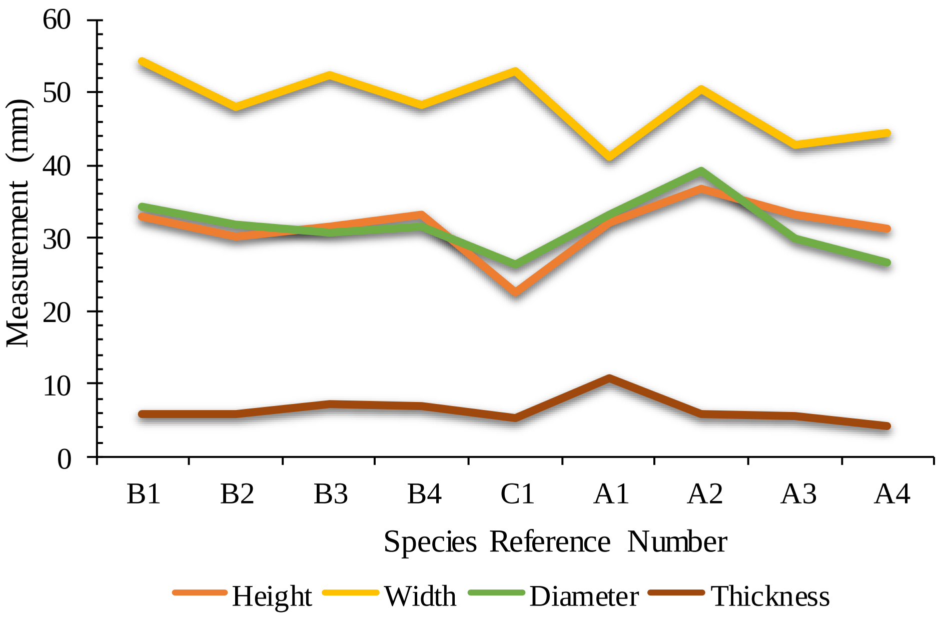

Figure 4. Comparison characteristic chart of living Acavidae species with relevant fossil Acavidae samples of Batadombalena cave

Due comparison characteristic of living Acvidae species with relevant fossil acavidae samples of Batadombalena cave, there are minimum variations between limitation factors of pre historic and present condition of Sabaragamuwa Basin. According to calculation of structured of snails shell, direction of the heat flow of depend on angular of axis (Fig. 5). Comparison calculation in between angular of axis, height, thickness of lip, diameter of mouth and width of living with fossil Acavidae samples are dominantly delineating approximately conformation.

The relationship of Acvidae species and its shell characters were compared using ordination axes 1 and 2 by overlaying species main matrix with each characteristics (Figs. 6a, 6b, 6c, 6d, and 6e). In the ordination diagram, *Acavus superbus* living species (A1- A4) grouped as separate /diffuse clusters, while *A. superbus* sub fossil species grouped as a single cluster at the center of the ordination diagram. Figures 6a to 6d showed that a speciation /diversification trend of *Acavus* species from Pleistocene era to date. This signifies that the living species have more structural variability than fossil species. On the other hand, *Oligospira waltoni* separated along Aix 1 remarkably than those *A. superbus* living/sub fossil species. There are strong positive correlation of species characteristics, such as height (r = 0.62), thickness of lip (r = 0.544) and angular of axis (r = 0.744). In contrast, shell width showed a strong negative relationship (r = 0.832) among species.

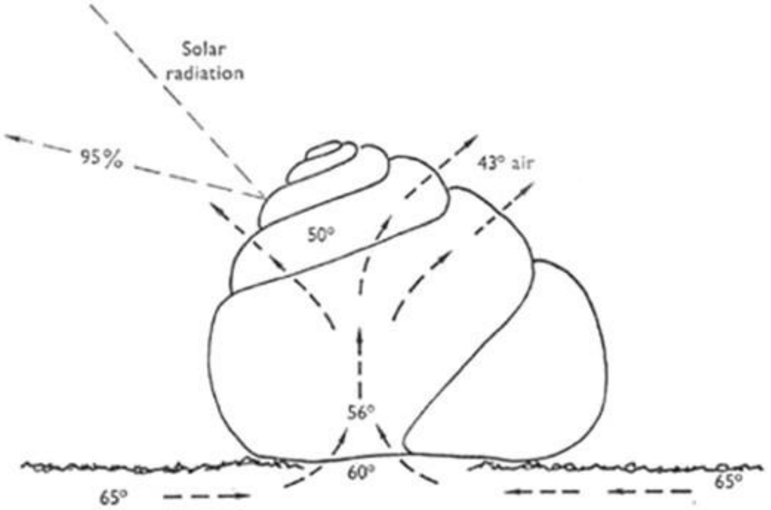

Figure 5. The temperature distribution and heat flow in and around a snail exposed to sun on the dry and wet surface. Direction of the heat flow indicated by broken arrows

There are still many more unidentified variables can be influenced for speciation and distribution of modern-day animal and plant communities. Studies on this field are provide constantly improving understanding of interactions among and between communities and species due to climatic variability are important for recognizing future trends and sustainable conservation of sensitive species such as Acavidae. Niche theory has attempted to salve these questions some extent regarding living communities. The development of concepts, such as niche width and overlap, specialization and inter and intra-specific competition would be described the said problems. Increases in the mean body size of the individuals, fluctuations in availability of food supply and in rainfall, competition (intra or inter-specific), predation and the environment in which the animals live are all suggested as factors would be affected for the mammal populations. These concepts have provided explanations for the behavior observed within many animal communities with competition appearing to be a significant driving force behind species diversity and density.

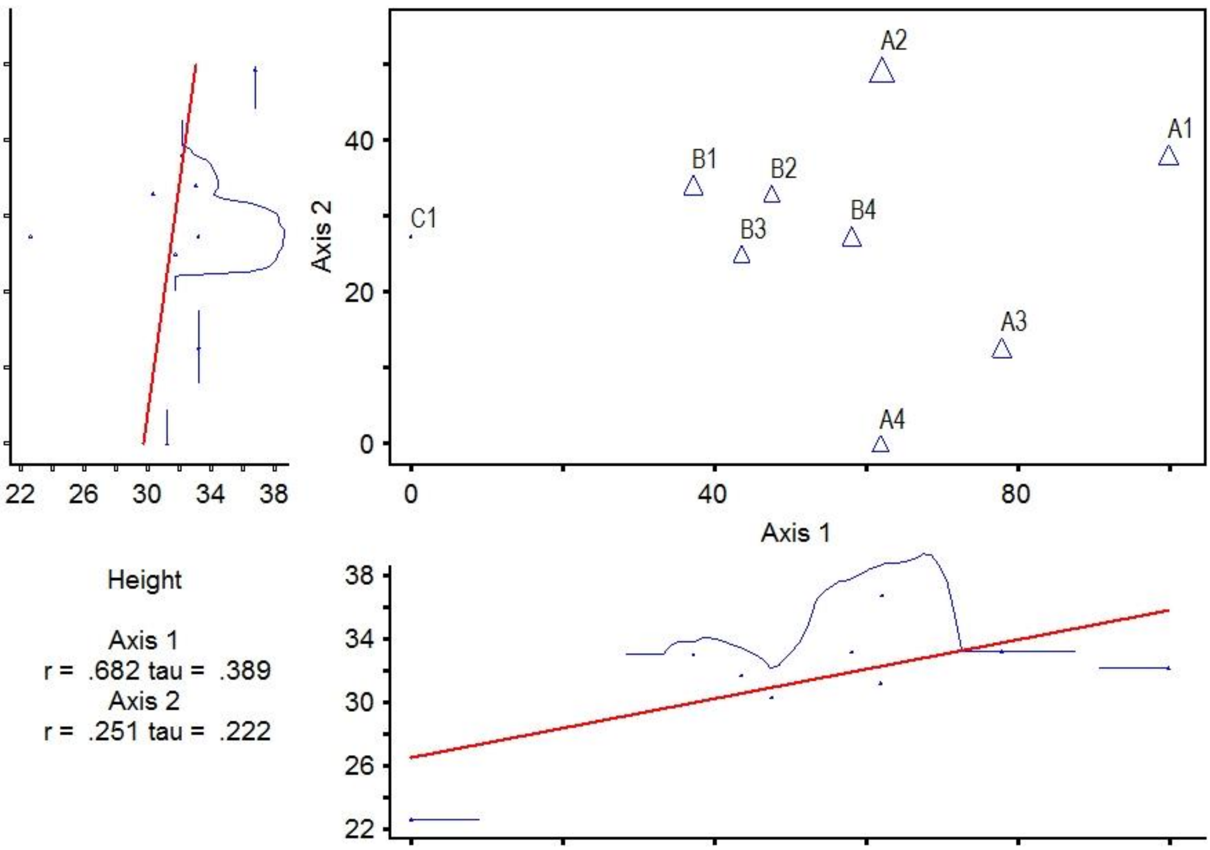

Figure 6a. Ordination living/ sub-fossil Acavidae species overlaid by height to show their correlation along ordination axes.

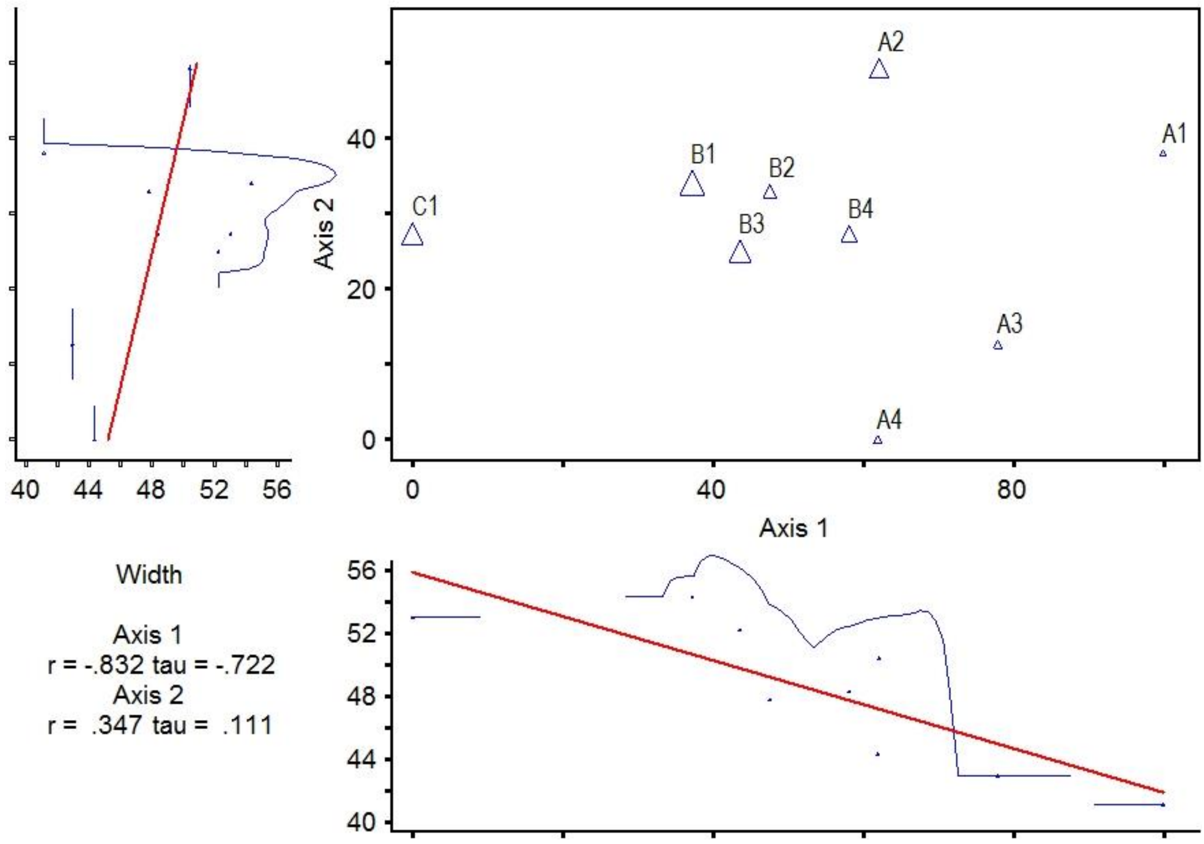

Figure 6b. Ordination living/ sub-fossil Acavidae species overlaid by width to show their correlation along ordination axes.

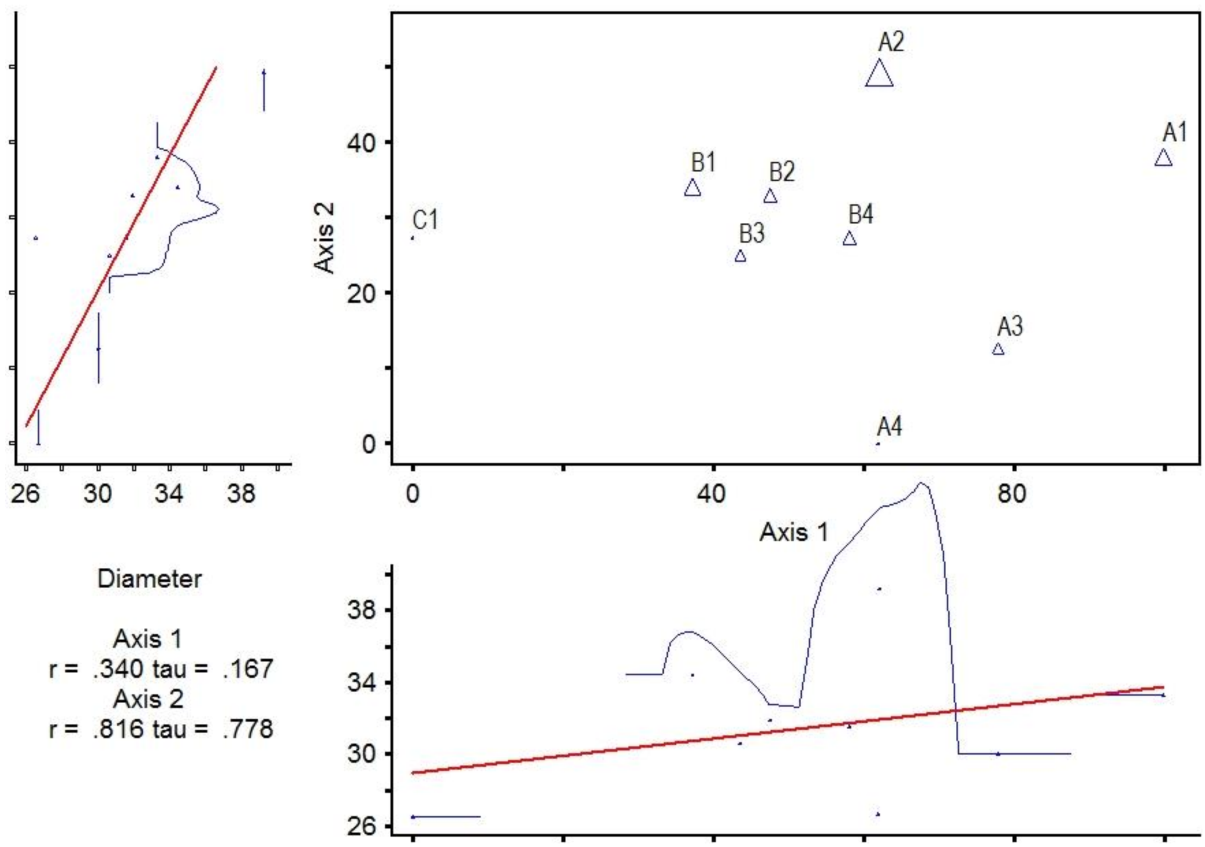

Figure 6c. Ordination living/sub-fossil Acavidae species overlaid by diameter of mouth to show their correlation along ordination axes.

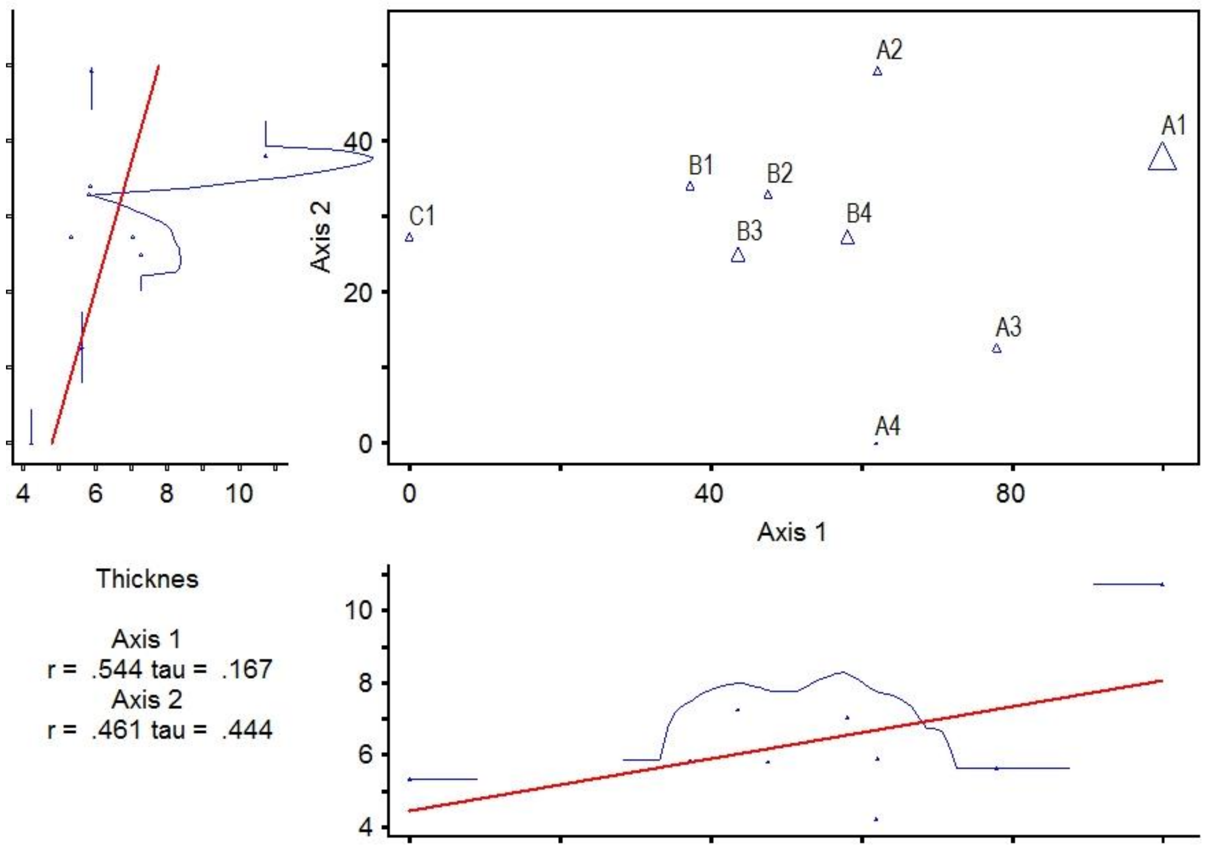

Figure 6d. Ordination living/ sub-fossil Acavidae species overlaid by thickness of lip to show their correlation along ordination axes.

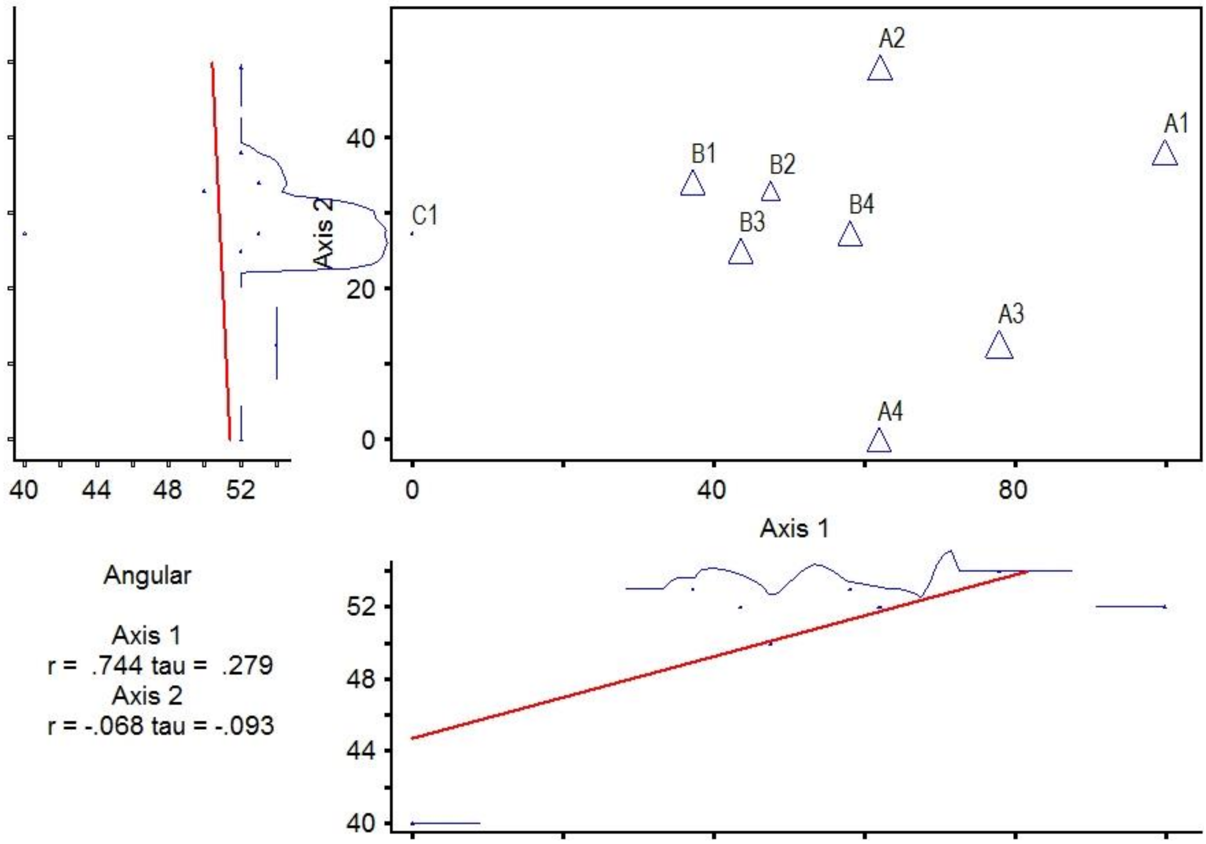

Figure 6e. Ordination living/ sub-fossil Acavidae species overlaid by angular of axis to show their correlation along ordination axes.

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