

Distribution and Structure of Mammal Communities within Unclassified Forest Areas in the Province of Tshopo (DR Congo)

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ABSTRACT

The study on the distribution and structure of mammal communities within unclassified forest areas in the province of Tshopo (DR Congo) focuses on how medium to large sized mammal communities are organized. We seek to understand how wildlife is distributed in these areas, which are not officially protected and are subject to various human pressures. We have implemented an inventory protocol based on a reconnaissance method. To ensure the reliability of our data, the sampling effort was validated by calculating the completeness of the inventories, demonstrating capture rates of over 90% at all three sites, which guarantees the scientific representativeness of the data collected.

The structure of communities was analyzed using multivariate methods, including nonmetric multidimensional scaling (NMDS) to compare similarity between sites, and the calculation of specialization residuals helped identify the ecological preferences of each species. The spatial architecture of mammalian biodiversity reveals a biological organization of striking regularity. Ten species form the common base, representing 43% of the overall assemblage. The three sites share a core of generalist species and a major ecological gradient, with each site presenting signature and specialist species. Beta diversity ensures regional gamma richness, and species dominance differs according to local ecological constraints.

In conclusion, this study shows that despite the proximity of National Road No. 4, these forest areas still harbor structured and diverse animal communities. This highlights how crucial these areas, although unclassified, are for the preservation of biodiversity in the Democratic Republic of Congo.

Key words: Spatial structure, unclassified forests, mammals, specialist species

INTRODUCTION

Background and Rationale

The Congo Basin is the second largest tropical forest area in the world after the Amazon. These ecosystems cover approximately two million square kilometers and are home to remarkable biodiversity, including several hundred species of mammals, birds, amphibians, and reptiles (Mayaux et al., 1998). This biological richness gives the region a major role in the conservation of global biodiversity.

The Democratic Republic of Congo plays a central role in the conservation of African tropical forests. It is home to nearly half of the forests in the Congo Basin and hosts several iconic and endemic species such as the okapi and Grauer's gorilla. (De Wasseige, et al., 2012).

These permanent production areas do not benefit from any strict legal protection status or rigorous state supervision. They serve as transition zones between exploited areas and

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protected sanctuaries. The absence of institutional controls encourages informal exploitation, combining shifting agriculture, illegal logging, and rampant urbanization (Code forestier, 2002). This reflects precarious land management, where the survival of living organisms is negotiated daily in the face of economic necessities.

Problematic

Africa's wildlife and more specifically that of the Democratic Republic of the Congo represents a resource whose depletion is accelerating even before we have fully grasped its complexity. These ecosystems are home to communities of large mammals whose diversity field surveys describe as unique (Gaidet et Le Doze, 2004; Nobimé et al., 2008; Dibloni et al., 2011). However, there is a glaring disparity in biological monitoring, as monitoring efforts are limited solely to Protected Areas, which cover only about 15% of the national territory. The remainder of the forest cover nearly 40% of the country's total area is located in rural areas where local communities harvest resources without government oversight or prior ecological assessment. Almost all of the large mammals that depend on tropical forests still thrive there. Their survival, however, remains dependent on human pressures whose intensity threatens to disrupt the balance necessary for sustainable conservation. Our approach is driven by the urgent need to conduct a survey of large wildlife in the unclassified mountain ranges bordering National Road 4. Our work focused on Tshopo Province, specifically on the Kisangani-Ituri road in the village of Bafwakondima and the Kisangani-Buta road in the villages of Dikwa, Baboro/Libombo (Kühl, et al., 2009).

The constant traffic on the RN4 has a profound impact on the exploitation of biological resources. The ease of travel along this trans-African highway fuels the illegal bushmeat trade by directly linking poaching hotspots to urban consumption center. We have chosen to focus our attention on medium and large-sized mammals because of their role as sentinels. Their vulnerability to hunting makes them excellent indicators of the overall health of a habitat. Furthermore, this group includes taxa of high conservation value such as the okapi, the chimpanzee, and the elephant, whose detection through signs of presence facilitates monitoring in the field. One of the key objectives of our analysis is to examine and compare the spatial patterns of mammalian communities across sites by assessing species overlap, ecological gradients, dominance, and species specialization.

METHODOLOGICAL APPROACH

Study Area

Our study focused on unprotected forest areas along National Highway 4 in Tshopo Province, Democratic Republic of the Congo. This strategic selection of our study sites was driven by the predominant influence of National Highway 4. This major trans-African corridor has emerged as the primary route for wildlife movement. Our fieldwork was therefore conducted in three distinct locations spread along this key highway.

a. Kisangani-Ituri Axis

The village of Bafwakondima is located 172 kilometers from the city of Kisangani, on the Ituri Road. Survey data indicate its exact coordinates as 0°48' north latitude and 24°29' east longitude, at an elevation of 505 meters. This area lies entirely within the northern equatorial climate zone of the Democratic Republic of the Congo, between 0 and 2° north latitude. Our investigations focused on the forest massif located on the right side of National Highway 4 coming from Kisangani, extending into the vegetation for a distance of approximately 12 kilometers as the crow flies from the center of Bafwakondima.

b. Kisangani-Buta Axis

Our second site, located in Baboro/Libombo within the Banalia territory in Tshopo Province, is home to the village of Libombo (N01.71244°; E025.33563°; Alt: 424 m). The surrounding forest is characterized by an evergreen tree layer, maintaining an evergreen canopy.

Finally, our third site, the town of Dikwa, is located about 175 kilometers from Kisangani on the road leading to Buta (01°91'62.1" N, 025°40'06.0" E, at an elevation of 459 meters).

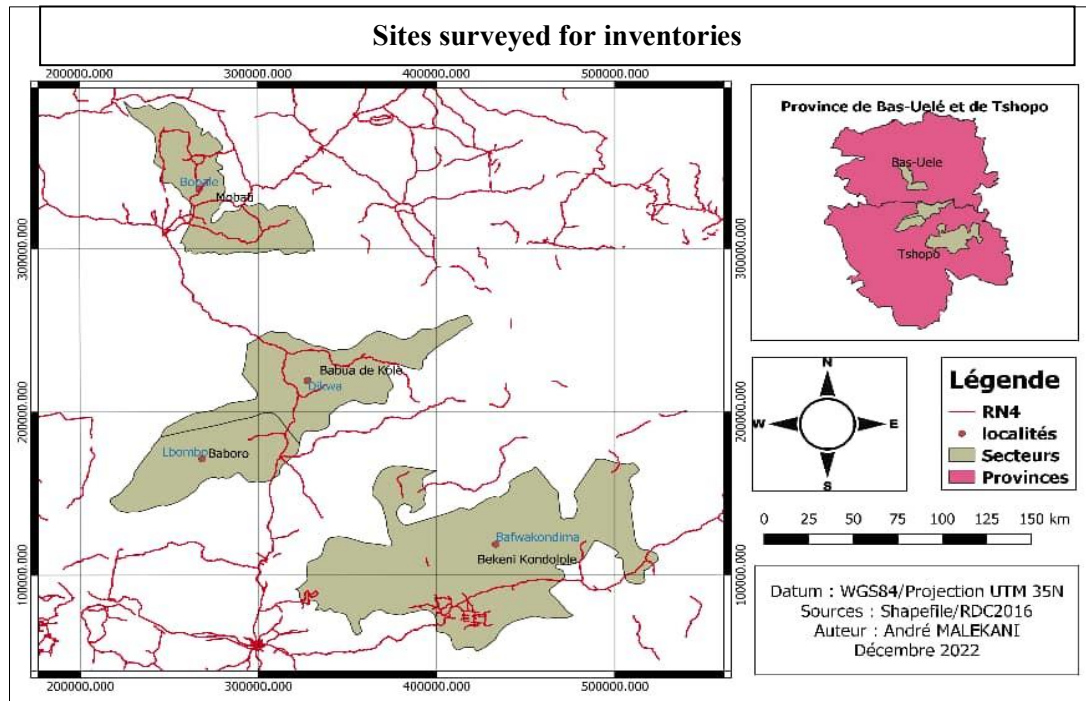


Figure 1. Map showing the locations of three surveyed sites

Sampling

Methodology of the fauna and flora study

To document the presence of wildlife, we opted for the “guided recce” method. Our approach was to move through the forest along a specific azimuth determined by compass, striving to maintain a straight path while taking the “paths of least resistance” to avoid disturbing the vegetation. This strategy, validated by Walsh et al. (2001), makes it possible to quickly assess animal populations and map habitats in remote and vast areas where establishing traditional transects would be too costly.

We used a “Garmin 64” GPS device for navigation and positioning and “Sunto” compasses for bearing in the forest. We selected a 40° angle, which is parallel to the eastern and western boundaries and perpendicular to the north-south axes of the study areas. The survey effort resulted in 25.82 km covered in Bafwakondima across 13 transects, compared to 23 km across 12 transects in Libombo-Baboro and 25.1 km across 12 transects in Dikwa.

Using cameras allowed us to document our observations, and Jonathan Kingdon’s field guides ‘African Mammals’, (2015) were indispensable for resolving taxonomic uncertainties.

Data Analysis

Statistical environment and Software

For data processing and analysis, we used software from the R computing environment. Our consistent use of the tidyverse meta-package allowed us to structure our datasets with a level of rigor that ensures the complete reproducibility of each step.

RESULTS

Sampling Efficiency (Estimate S)

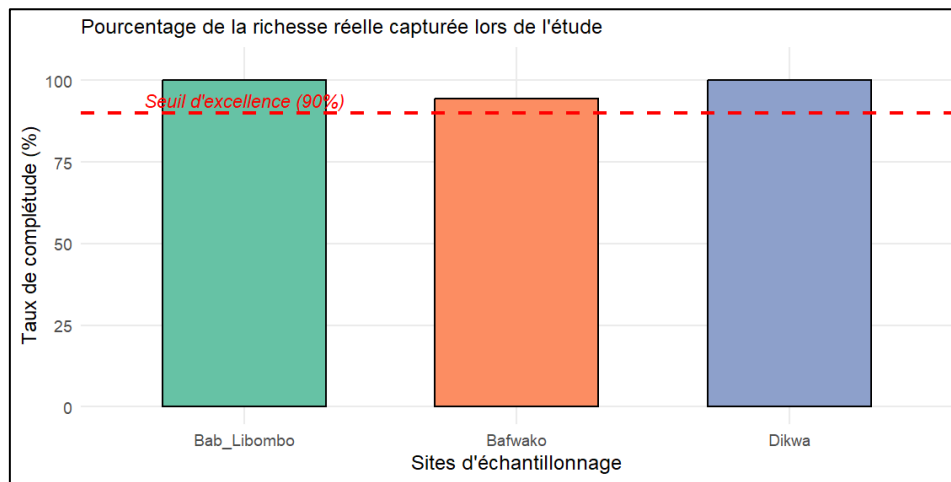


Figure 2. Sampling efficiency and percentage of actual species richness captured during the study

Figure 2 provides an overview of the mammal communities with high sampling completeness, with Chao1 values exceeding 90% at all sites and 100% saturation at Dikwa.

Species Distribution across Sites

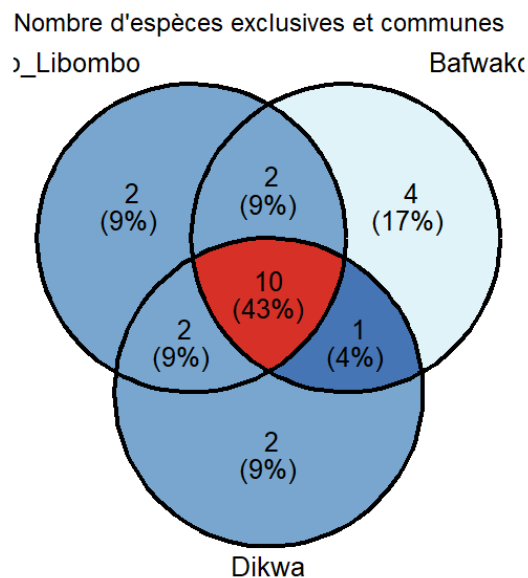


Figure 3. Venn diagram illustrating the overlap in specific richness and the number of exclusive species among the three sites

The spatial architecture of mammalian biodiversity, outlined in Figure 3, reveals a biological organization characterized by striking regularity. Ten species form the common core. Representing 43% of the total species pool, these taxa exhibit an ubiquity that reflects an ecological plasticity enabling them to occupy every segment of the forest gradient, regardless of site conditions. Bafwakondima stands out, however, due to a contrast justified by its mosaic

landscape of forest and savanna, as it is home to four species found exclusively within its boundaries. This exclusive group accounts for 17% of the sample, which is more than double the frequencies recorded at Dikwa or Baboro/Libombo. Binary exchanges between pairs of sites are dwindling. Ranging from 4% to 9%, these low rates of sharing confirm a sharp partitioning of ecological niches as soon as one moves away from the central core. Regional richness thus stems from the sum of local identities, with each locality enriching the overall diversity through its own unique contributions of fauna.

Ecological Gradient between Sites

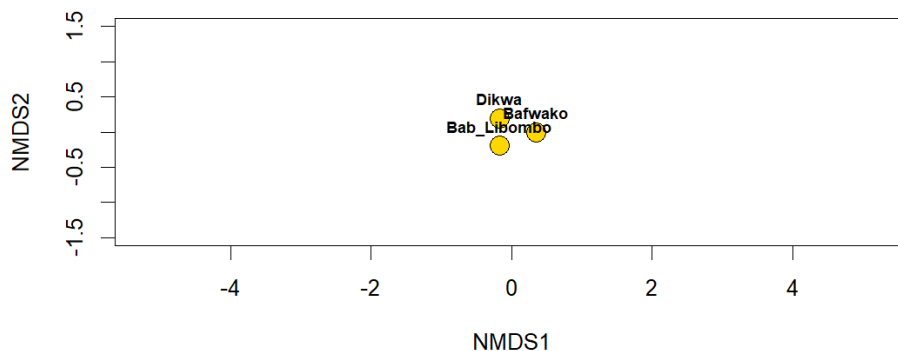


Figure 4. Non-metric multidimensional scaling (NMDS) of the similarity of mammal communities across sites

The ordination resulting from the non-metric multidimensional analysis, shown in Figure 4, places our three study sites in close proximity to the origin of the plot. This spatial convergence reflects low beta diversity (the sites have nearly identical species) along the RN4 highway. The presence of a specific dominant plant community shared by Dikwa, Bafwakondima, and Baboro/Libombo confirms the unity of a single regional ecological complex, whose structural homogeneity is striking. This lack of structural variation suggests a low ecological gradient and a dominance of generalist species capable of adapting to a wide range of environmental conditions.

Beta Diversity Heatmap

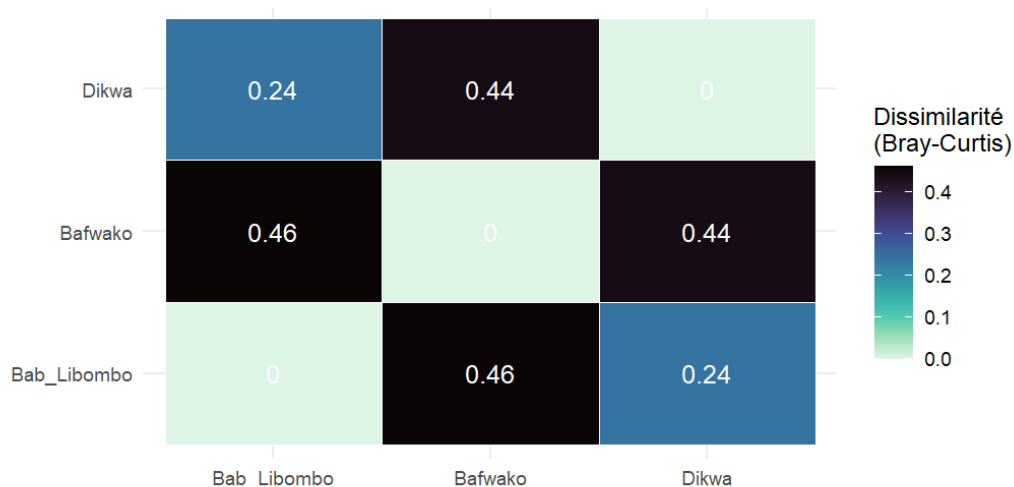


Figure 5. Similarity in composition between sites (0=identical, 1=different)

The Bray-Curtis dissimilarity analysis reveals a moderate spatial pattern in mammal communities across the study sites. Baboro/Libombo and Dikwa show a higher similarity (0.24), suggesting comparable ecological conditions, while Bafwakondima stands out clearly (0.44 and 0.46), reflecting a distinct species composition and possibly an increased influence of anthropogenic environmental factors.

Analysis of the Spatial Segregation of Niches

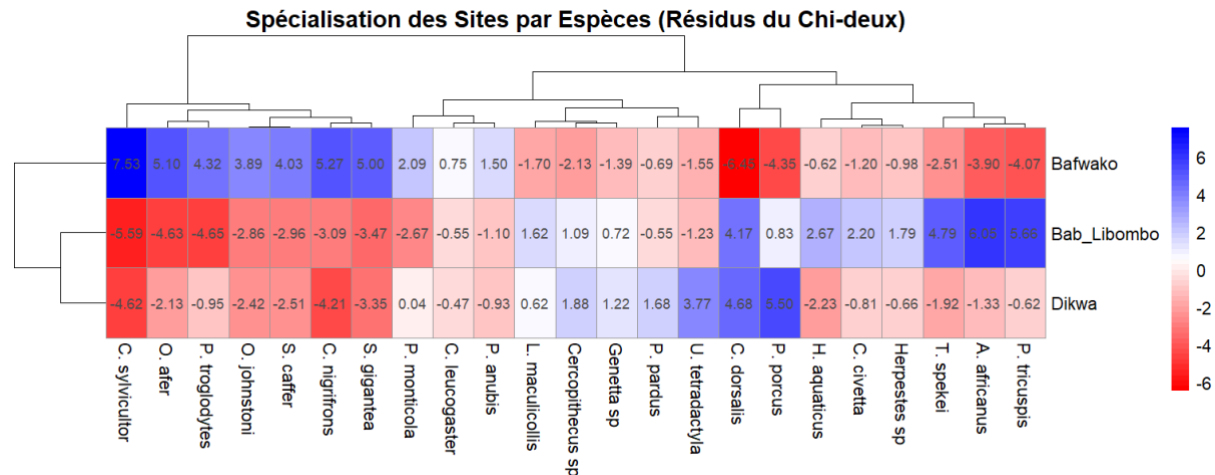


Figure 6. Heat map based on chi square residuals

The heat map derived from the residuals of the Chi-squared test, whose gradients are shown in Figure 6, illustrates for each taxon the difference between the actual abundance and a theoretical stochastic distribution. Blue indicates areas of overrepresentation. Bafwakondima is characterized by a close association between mosaic land cover and a core of specialist species, as evidenced by the high residual values measured for *C. sylvicultor* (7.53), *C. nigrifrons* (5.27), and *Orycteropus afer* (5.10), whereas the near-total exclusion of *C. dorsalis* (-6.45) and *Potamochoerus porcus* (-4.35) drives these usual inhabitants of dense woody cover away. Baboro/Libombo shows a strong affinity for *A. africanus* (6.05), *Phataginus tricuspis* (5.66), and *Tragelaphus spekei* (4.79), while Dikwa predominantly hosts *P. porcus* (5.50) and *C. dorsalis* (4.68). Because of its unique characteristics, each site serves as a refuge for an irreplaceable subset of the region’s wildlife. This mutual dependence between species and their habitats precludes any fragmented management approach. Only a multi-site conservation strategy will ensure the integrity of mammalian diversity at the landscape level.

Analysis of Wildlife Habitat Zoning and Conservation Issues

Bafwakondima is teeming with wildlife along its edges; this area is home to a variety of large ungulates, including duikers, buffalo, the Okapi (*Okapia johnstoni*), and the aardvark (*Orycteropus afer*), whose recorded sightings in Table 1 reflect a wildlife distribution pattern closely tied to ecotones. The woody layer becomes denser in Baboro/Libombo. Within a humid forest block with a continuous canopy, rodents such as the African ground squirrel (*A. africanus*) coexist with strictly forest-dwelling species such as the pangolin, the sitatunga, and the waterbuck. Dikwa branches off into other ecological niches. The inventory reveals a predominance of suids and carnivores, with the river hog and the black-striped duiker sharing the habitat with the leopard (*Panthera pardus*), the otter, and the genet species whose presence indicates a niche oriented toward semi-aquatic environments and predation. Each land unit ensures the sustainability of an irreplaceable component of overall gamma diversity.

Table 1. Specialist and common species at the study sites

Site	Dominant and specialist species	Secondary or common species
Bafwakondima	<i>C. sylvicultor</i> , <i>O. afer</i> , <i>O. johnstoni</i> , <i>S. caffer</i> , <i>C. nigrifrons</i> .	<i>P. troglodytes</i> , <i>S. gigantea</i> , <i>P. anubis</i> .
Baboro_Libombo	<i>A. africanus</i> , <i>P. tricuspis</i> , <i>T. spekei</i> , <i>H. aquaticus</i> .	<i>C. dorsalis</i> , <i>P. monticola</i> , <i>Cercopithecus sp.</i>
Dikwa	<i>P. porcus</i> , <i>C. dorsalis</i> , <i>P. pardus</i> , <i>L. maculicollis</i> , <i>Genetta sp.</i>	<i>P. monticola</i> , <i>U. tetradactyla</i> , <i>C. civetta</i> .

DISCUSSION

Species Distribution across Sites Partage

The Venn diagram reveals the presence of ten species that form the core group, accounting for 43% of the total species list, along with species found exclusively in Bafwakondima. This configuration corresponds to the classic model of regional structuring described by Robert H. Whittaker (1965), according to which gamma diversity results from the combination of local diversity (alpha) and site-specific species turnover (beta). This significant proportion of common species reflects the presence of a regional core of generalist species capable of tolerating a range of ecological conditions (Magurran, 2004), while exclusive species indicate “ecological turnover” linked to landscape heterogeneity (Fahrig, 2003).

Ecological Gradient between Sites

The ordering resulting from the non-metric multidimensional positioning places our three study sites in close proximity to the origin of the plane. Correspondence analysis confirms that axis 1 accounts for the majority of the inertia, indicating a structuring ecological gradient.

This NMDS ordination reveals a high degree of similarity among the study sites, indicating homogeneity in the mammal communities. This lack of structure suggests a weak ecological gradient and a predominance of generalist species capable of adapting to a wide range of environmental conditions. These results are fully consistent with the work of Magurran (op. cit.), which indicates that low spatial dispersion in the ordination space reflects low ecological differentiation. Furthermore, the absence of distinct clusters suggests a low presence of signature species, which could be explained by habitat homogenization, possibly linked to anthropogenic pressures, as described by Walsh et al. (op.cit).

Analysis of the Spatial Segregation of Niches

The heat map derived from the residuals of the Chi-squared test illustrates the gradients, showing for each taxon the difference between actual abundance and a theoretical stochastic distribution. This residual heat map highlights significant over or under-representation of species across sites. The high positive residuals at Bafwakondima for *Cephalophus sylvicultor* and *Orycteropus afer* confirm their local specialization. At Baboro/Libombo, the overrepresentation of *Phataginus tricuspis* indicates a strong affinity for dense forest cover. The reciprocal negative residuals indicate ecological exclusion, reflecting niche partitioning. This phenomenon is consistent with the theory of niche differentiation, which stems from the work of G. Evelyn Hutchinson (1957), according to which species coexist by occupying distinct niches or resources.

Analysis of Wildlife Habitat Zoning and Conservation Issues

Table (1) in the results section clearly shows that each site has common dominant structural species and secondary species. At Bafwakondima, the dominance of ungulates

indicates a significant biomass associated with ecotones. At Boboro/Libombo, there is a dominance of specialized forest species. Meanwhile, at Dikwa, there is a combination of suids and carnivores, suggesting a more complex trophic structure. This organization corresponds to the community assembly model based on environmental filtering and trophic interactions (Weiher and Keddy, 1995). This variation in dominance across sites confirms a strong ecological complementarity among the three sites.

CONCLUSION AND SUGGESTIONS

An analysis of mammalian community structure across study sites by assessing species overlap, ecological gradients, dominance, and species specialization shows that the sites share : a core of generalist species, a major ecological gradient; each site features signature and specialist species; beta diversity ensures regional gamma diversity, and species dominance varies according to local ecological constraints.

In conclusion, this study shows that despite the proximity of National Road No. 4, these forest areas still harbor structured and diverse animal communities. This highlights how crucial these areas, although unclassified, are for the preservation of biodiversity in the Democratic Republic of Congo.

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