The Journal of Archaeology and Heritage Studies (JAHS) 2024: 11 (I) 35-53 pp

The Journal of ARCHAEOLOGY & HERITAGE STUDIES

Journal Home page http://fssh.rjt.ac.lk/index.php/jahs/

Review/Theory/Policy Paper

Prehistoric Subsistence Strategies in Sri Lanka: The Need for Methodological Reconsideration

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ABSTRACT

This paper underscores the need for a critical reassessment of the methodological approaches adopted in prehistoric subsistence studies in Sri Lanka, advocating for the integration of recent methodological advances in ecological archaeology and enhanced interdisciplinary collaboration. Inspired by Siran Deraniyagala's pioneering work, which emphasised the importance of periodic re-evaluations of the island's prehistory, this study draws attention to the significant theoretical and methodological progress made over the past two decades. Despite commendable but fragmented research efforts, a comprehensive re-examination of prehistoric subsistence strategies—ranging from hunting and gathering to early agriculture—remains long overdue. The paper reviews key methodological approaches, including archaeozoology, archaeobotany, isotopic analysis, and ethnoarchaeology, demonstrating their potential to elucidate the dynamic relationship between ancient populations and their environments. It critiques the limitations of conventional methods and advocates for innovative techniques such as Zooarchaeology by Mass Spectrometry (ZooMS) to overcome challenges posed by poor organic preservation in tropical conditions. The potential of ethnoarchaeological analogies and Site Catchment Analysis is also emphasised for reconstructing the complex interactions between ancient populations and their environments. Drawing on global and regional case studies, alongside site-specific insights from locations such as Batadomba-lena and Bellanbendipelessa, the paper proposes a holistic, interdisciplinary framework tailored to the Sri Lankan context. Such an approach not only enriches archaeological understanding but also offers archaeological insights into broader discussions on human resilience and adaptation to environmental changes, with increasing relevance for contemporary climate action initiatives. The paper concludes with a call to embrace emerging technologies while fostering meaningful interdisciplinary collaboration and context-driven methodologies to advance the dynamic and nuanced exploration of Sri Lanka's prehistoric landscape. Beyond enhancing archaeological interpretations, the findings have wider relevance for understanding human resilience and adaptation—offering critical insights for contemporary climate challenges.

ARTICLE INFO

Article history:
Article Received: 26 Feb. 2025
Revision Received: 21 May 2025
Accepted: 30 May 2025
Available online: 08 June 2025

Keywords: Prehistoric subsistence research in Sri Lanka, Ecological archaeology, ZooMS, Ethnoarchaeology, Site catchment analysis, interdisciplinary collaboration

1. Introduction

This paper is inspired by Siran Deraniyagala's monumental work entitled 'The Prehistory of Sri Lanka: An Ecological Perspective', where he insisted on re-evaluating the prehistory of Sri Lanka every ten years or so in light of theoretical and methodological advancements and new archaeological findings on the island and from around the

world (S.U. Deraniyagala, 2004). He provided a comprehensive and critical evaluation of the prehistoric investigations undertaken on the island from circa 1885 to the 1960s, before assuming the responsibility of the Excavation Branch of the Department of Archaeology and commencing his own investigations. He placed prehistoric research in Sri Lanka in the wider context of South Asia (S.U. Deraniyagala, 1972) in light of methodological and theoretical developments, ecological perspectives in particular, at the global level. This was termed Stage I of the research strategy he proposed for Sri Lanka. After the conclusion of his rigorous research on the prehistory of Sri Lanka, which was submitted to the University of Harvard for his doctoral research, he made the recommendation cited above. Under the guidance of Deraniyagala himself, Nimal Perera (2010) undertook this work as Stage VI of the scheme proposed by S.U. Deraniyagala. Nearly two decades have passed since Perera's work, and considerable advances have been made in the theoretical and methodological aspects of prehistory, and a wealth of new evidence has emerged. While a number of commendable but isolated studies (Roberts et al., 2015; 2017b; 2018; Wedage et al., 2019; 2020; Langley et al., 2020; Martinón-Torres et al., 2021; Picin et al., 2022; Stock et al., 2022; Amano et al., 2023; 2024) have been undertaken, thus far, no comprehensive re-evaluation of the prehistory of Sri Lanka has been carried out in light of the developments cited above. This article does not attempt such a comprehensive review; rather, it modestly aims to highlight the need to revisit and re-evaluate the prehistory of Sri Lanka, particularly from an ecological perspective, which S.U. Deraniyagala introduced nearly a quarter of a century ago.

The integration of environmental sciences into archaeological research has undergone significant transformations since the mid-twentieth century, primarily driven by the need to contextualise human behaviours within broader ecological frameworks. Early attempts to understand the interaction between humans and their environment emerged through the work of geographers and natural scientists collaborating with archaeologists. Foundational contributions came from Carl O. Sauer (1925) and later Carl Butzer, whose Environment and Archaeology (1964) emphasised the critical roles of geomorphology, palaeobotany, and climatology in archaeological interpretation. Butzer's subsequent work laid a systematic foundation for 'geoarchaeology' incorporating environmental processes in site formation and landscape evolution (Butzer, 1982).

In the British context, the excavation of Star Carr in the 1950s marked a turning point in the development of ecological archaeology. The site's exceptional organic material preservation enabled an interdisciplinary approach, incorporating palynology, faunal analysis, and sedimentology. Subsequent reflections, notably in Renfrew and Bhan's Archaeology: The Widening Debate underscore how Star Carr's served as a model for integrating scientific techniques with cultural archaeology, demonstrating it as a model for integrating scientific methodologies with cultural archaeology to meaningfully reconstruct Mesolithic lifeways through environmental data (Renfrew and Bhan, 2012).

It was, however, the processual archaeology that emphasised a systemic approach and environmental adaptation as key determinants of culture change that had lasting impact on the ecological approaches to archaeology (for e.g., Binford 1962). It was in fact, these theoretical and methodological perspectives that significantly influenced south Asian scholarship, notably S.U. Deraniyagala whose doctoral research at Harvard University provided an ecological orientation in understanding Sri Lanka's Pre-history.

In the South Asian context, environmental archaeology developed on different trajectories. As outlined in K. Paddayya's seminal review in Man and Environment (1994), early research was dominated by cultural-historical paradigms, with paradigm shift towards multidisciplinary methodologies emerging in the 1970s and 1980s (see also Mishra 2004). This period witnessed the rise of multidisciplinary fieldwork, notably in the Deccan and Rajasthan, where geomorphological and palaeobotanical studies were used to prehistoric sites.

This contextual, multidisciplinary and paradigmatic shift in South Asian archaeology is best exemplified through broader regional studies undertaken in India. Long-term investigations led by Paddayya in the Hunsgi-Baichbal basin of Karnataka serve as a vital contribution in this regard (Paddayya, 1982; 2007; Paddayya et al., 2002). Through geomorphological surveys, actualistic studies, and lithic distribution analysis (Paddayya and Petraglia, 1997), his research reconceptualised Lower Palaeolithic settlements, not as isolated occurrences but as interconnected elements within the broader cultural landscape in the prehistoric period. This basin-wide approach underscored the importance of ecological variables which were influential Acheulean hominin land-use strategies—such as the availability of raw materials, perennial water sources, and terrace formations (Paddayya and Petraglia, 1997; Petraglia, LaPorta and Paddayya, 1999; Paddayya, Jhaldiyal and Petraglia, 2000; Paddayya et al., 2002; Paddayya, 2007). Importantly, Paddayya's integration of ethnographic analogues, including those undertaken on contemporary pastoral and foraging communities, enhanced the interpretation of site function and tool use interpretations, illustrating later developments in actualistic and ethnoarchaeological methodologies in India (Paddayya, 1991; Paddayya, 1995).

In contrast, archaeological investigations carried out by the Deccan College at Inamgaon, a Late Jorwe Chalcolithic site in Maharashtra, further established the extensive application of environmental archaeology in a different temporal and cultural setting (Sankhalia et al. 1973, 1984).

Excavations, led by H.D. Sankhalia and later M.K. Dhavalikar and collaborators, combined archaeobotanical, zooarchaeological, and geomorphological data for reconstructing subsistence patterns and agricultural practices (Rajaguru, 1977). Pollen and phytolith studies undertaken here provided vital evidence of drought-resistant crops and changing hydrological schemes, although faunal remains advocated for a mixed economy with cattle herding (Vishnu-Mittre and Gupta, 1974). These findings went beyond descriptive reconstruction, offering vital insights into the continuity of settlements, their resilience, and subsequent abandonment in response to environmental shifts during the second millennium BCE.

The growth of environmental archaeology in South Asia as a whole, from initial geomorphological mapping to more advanced landscape studies and actualistic studies, illustrates broader developments that took place within the parent discipline. These developments, indeed, served as a groundwork for the integration of experimental and ethnographic analogues, which interconnect methodologically, environmental reconstruction and drawing behavioural inferences. Studies such as Paddayya's use of ethnographic parallels in Hunsgi, or ethnoarchaeobotanical insights from Inamgaon, highlight the radical conceptual transformations in perceiving the environment not merely as a passive context but an active agent in archaeological reasoning. Therefore, this groundbreaking early research in environmental studies continues to inform South Asian archaeology. This is particularly true for those researchers undertaking experimental approaches, forager analogues, and community use of landscapes, which are being extensively researched at present in actualistic studies.

2. Theoretical Background

The environmental or ecological history approach to prehistoric studies has long been a sub-discipline of archaeology from its inception, with archaeologists exploring the intricate dynamic relationships human groups maintained with their surrounding environments. This perspective recognises that past human societies were neither isolated nor static entities; they were indeed dynamic systems that co-evolved with the changing physical world around them. Understanding the complex human-environment interactions inevitably requires an interdisciplinary approach involving archaeology, zoology, ecology, anthropology, and paleoethnobotany. The potential for paleoethnobotany, still present in Sri Lanka, affords a great deal of insight into prehistoric subsistence strategies by way of studying archaeological remnants of ancient plant resources used for food, medicine, and other purposes. Multi-proxy evidence, on the other hand, can be analysed archaeologically within the broad environmental and cultural context to grasp how societies of the past coped with, and exploited, the resources offered to them by their natural landscapes. Such understanding can contribute to climate action wherein the foregoing analyses could project backward into the history of human-environmental interactions for developing the key to a sustainable future.

Understanding the prehistoric subsistence strategies of ancient populations in Sri Lanka is fundamental for understanding the sophisticated tapestry of human adaptation in a rainforest ecological setting. Given its wide-ranging landscapes, from coastal regions to the highlands, the island appears to have sustained a diversity of practices of subsistence over millennia. This complexity calls for the development and subsequent application of innovative methodological approaches to provide possible perspectives concerning the lifestyles, behaviours, and interactions of these prehistoric populations.

The prehistoric record of Sri Lanka exhibit a series of subsistence strategies a ranging from hunting and gathering (Roberts and Petraglia, 2015; Roberts, Boivin and Petraglia, 2015; Perera, Roberts and Petraglia, 2016; Roberts et al., 2017b; Langley et al., 2020; Picin et al., 2022; Amano et al., 2023; 2024) to advanced agricultural practices (Premathilake, Epitawatta and Nilsson, 1999; Premathilake, 2006; Somadeva, 2014; Premathilake and Seneviratne, 2015; Somadeva et al., 2017; 2018; Premathilake and Hunt, 2018). While the methodologies adopted by previous researchers are useful in identifying the types of resources that were used, these methods, for the most part, cannot inform us about how important and interactive these food sources were, or about larger environmental and sociocultural parameters that impinged upon subsistence strategies in the first place.

This study underscores the need for an innovative methodological approach to the study of prehistoric subsistence in Sri Lanka. The approach that we propose should be able to accommodate a variety of subsistence strategies across different ecological regions, which might involve coastal and in land agricultural resources exploited by prehistoric man, and therefore it is necessary to use a fusion of methods. Additionally, it becomes the responsibility of the archaeologists, anthropologists, ethnologists, ecologists, and environmental scientists to collaborate in the pursuit of a holistic understanding of prehistoric subsistence strategies. The integration of diverse data and methodologies can hence offer a window into complex relationships between humans and their environments. Moreover, investigating how ancient communities managed climatic upheavals can impart learning to modern societies dealing with environmental issues, currently a major concern, from a historical perspective. The proposed approach will broaden archaeological understanding of the prehistoric subsistence strategies, while also cultivating an appreciation for the remarkable human ingenuity and resilience displayed by prehistoric communities in overcoming ecological challenges.

a) Initiations of ecological perspectives in Sri Lankan prehistoric studies

One of the most influential studies in prehistoric archaeology in Sri Lanka was undertaken by Siran Deraniyagala, who integrated for the interpretation and synthesis of the island's prehistory. His work was significantly influenced by scholarly advancements in New Archaeology, primarily initiated by Gordon Willey, Graham Clarke, Gordon Childe and Lewis R. Binford. Processual archaeologists argue that reconstructing human prehistory requires a comprehensive approach that considers not only the individual but also the entire environment in which they lived (Binford 2001). Contemporary advancements, particularly the advent of Cultural Ecology as introduced by Leslie White (1959), underscore the critical importance of understanding the interplay between humans and their environment. White's approach emphasises that human cultures are intricately linked to their surroundings. This perspective highlights that the environment's form and characteristics are influenced by cultural, historical, and geological factors. Consequently, the interactions between humans and their environment are complex and multifaceted (Butzer, 1972; 1975), necessitating a highly interdisciplinary ecological approach to fully comprehend these dynamics. Furthermore, diverging from the artefact-focused culture-historical approach, Graham Clarke emphasised the importance of understanding how ancient populations adapted to their environments to gain deeper insights into prehistoric societies. Clarke (1936, 1961) advocated for the collaboration of a diverse range of specialists—including zoologists, geologists, botanists, and ethnographers—as essential for this endeavour. He exemplified this interdisciplinary approach through his Star Carr excavation in northeast Britain, where he successfully integrated these specialists to enhance the comprehensive analysis of the site.

Parallel to these theoretical developments in Europe, Sri Lankan prehistory was significantly influenced by concurrent advancements in neighbouring India. The discovery of the first hand-axe at Pallavaram (Madras), South India, in 1863 (Foote, 1916), mirrored European finds such as those near the Somme Valley gravel bed by Jacques Boucher de Perthes and Joseph Prestwich (Renfrew and Bhan, 2012). These findings established the antiquity of human presence in the Indian subcontinent and lent support to Darwin's theory of human evolution (Foote, 1916). This shift introduced a scientific approach towards Palaeolithic archaeology in the region (Chakrabarti, 1979). Scientists, including those from geology, anthropology and archaeology, such as Charles Lyell (1797-1875), James Hutton (1726-1797), Jacques Boucher de Perthes (1788-1868) John Evans (1823-1908), and Joseph Prestwich (1812-1896), had already laid the groundwork for this new scientific paradigm for the antiquity of man in Europe (see for e.g., Renfrew and Bhan 2004;26). In India, this was left to H.D. Sankhalia – in Archaeology- , whose monumental discoveries, formed a descriptive phase of Indian prehistory. These discoveries and holistic view of archaeology paved the way for systematic excavation and environmental reconstruction. This period witnessed transformational changes in the approaches to the study of man and environment, including in the collection of artifacts wherein the surface surveys started incorporating excavation at primary sites; interdisciplinary collaborations becoming a common practice; the onset of reconstructing the paleo-environment to infer prehistoric modes of life; and the evolution of absolute dating methods, which threw light on various aspects of climate and cultural events (Sankhalia 1956, 1962, 1969, 1971).

Additionally, this period witnessed the development of ethnoarchaeology in India (Sankhalia 1949). This involved comparing prehistoric instigation results with ethnographic analogies from indigenous societies, as well as rock art studies. Early contributions by De Terra and Paterson established the necessary framework for understanding stratigraphy and Palaeolithic cultural progression. A significant development during this period was the incorporation of environmental and scientific perceptions into archaeological research, and interpretations spearhead by scholars such as F.E. Zeuner (1950, 1951, 1963). He was among the first to stress the position of environmental archaeology in reconstructing past human ecologies in India. Building on such foundations, the work of scholars such as V.N. Misra (Misra 2004, 1997, 1971, 1990, Misra et al. 1986), M.K. Dhavalikar (1973, 1984, 1989), Vishnu-Mittre (Vishnu-Mittre, 1967; 1990; Vishnu-Mittre and Gupta, 1974), A.R. Sankhyan (Sankhyan, 1997; 2016; 2020; Badam and Sankhyan, 2009), S.N. Rajaguru (Rajaguru, 1969; 1977; 1983; Misra et al., 1982; Misra and Rajaguru, 1986), G.L. Badam (Badam, 1979; 2007; Badam and Sankhyan, 2009), P.K. Thomas (Thomas, 1974; 1977), Joglekar (Joglekar & Thomas 1992, 1991, 1990a, 1990b, Joglekar 2015) , Sheela Mishra (Mishra, 1992; 1994; 1995; 2008; Mishra, Chauhan and Singhvi, 2013), M.D. Kajale (1989, 1990, 2013), and S. Pappu (Pappu, 2001; Pappu et al., 2011; Akhilesh et al., 2018) significantly expanded the scope of prehistoric research through studies on palaeoanthropology, geomorphology, archaeobotany, zooarchaeology, and lithic technology.

This global synthesis was initially introduced to Sri Lanka by S.U. Deraniyagala, the pioneering prehistorian of the island. He integrated ecological and geological perspectives into Sri Lankan prehistory, effectively merging previous isolated geological, anthropological, and paleontological studies. His capability to integrate such contextually isolated scholarly works needed a considerable precision and a deep knowledge of contemporary developments in global archaeology, particularly related to environmental archaeology. S.U. Deraniyagala holistically placed these fragmented geological, anthropological and paleontological studies to introduce an ecological perspective to the Island's Prehistory for the first time.

b) Before S.U. Deraniyagala

S.U. Deraniyagala was significantly influenced by Edward James Wayland, a geologist with a keen interest in Sri Lanka's prehistory and geology. Prior to Wayland's contributions, the island's prehistory had begun to stem under the work of E.E. Green (1855) and John Pole (1907, 1913). They discovered prehistoric sites and chert stone tools in the upcountry regions of the Island. Following their works, anthropologists F. Sarasin and P. Sarasin undertook research across various parts of the island, investigating the cultural continuity of Sri Lankan Palaeolithic populations and the indigenous Vadda communities. Their excavations yielded stone tools analogous to those of the European Upper Palaeolithic Magdalenian culture. Charles Hartley (1913, 1914) further contributed by uncovering additional stone tools, supporting the Sarasins' findings.

The island's geology was initially explored through administrative records compiled by British civil servants, which later evolved into academic publications on certain aspects of its geological history. E.J. Wayland, the government's Mineral Resources Officer, paid particular attention to the influence of geological and climatic conditions on Sri Lankan prehistory. His surveys of the semi-arid regions demonstrated that the deep gravel layers in these areas dated to the Pleistocene glacial period, while the surface red sands indicated a dry climatic condition. Wayland was the first to investigate the Iranamadu Formation (IFm) from an archaeological perspective, establishing the existence of the Sri Lanka's Miocene period (Wayland, 1914; 1919; 1920; 1925; 1926). Additionally, in 1923, Wayland and Davies were the first to record a lithological profile and make an initial effort to date terrestrial gastropod fossils found within the sandstone pinnacles. S.U. Deraniyagala used maps based on ecological and vegetational perspectives to create a complete ecological map of the island, dividing it into separate ecozones categorised by distinctive vegetation categories (Gaussen et al., 1968; Mueller-Dombois, 1968). This approach assisted a more nuanced understanding of the prehistoric ecosystem of the island and its impact on past human activities, particularly emphasising the unique subsistence strategies developed by the Mesolithic population. This ecological mapping allowed S.U. Deraniyagala to contextualise how these ancient populations adapted to and interacted with their environment.

Despite S.U. Deraniyagala's foundational work, methodological approaches in Sri Lankan prehistoric studies have often remained derivative, relying heavily on typological comparisons rather than localised, context-driven analyses. This overreliance on external frameworks has at times obscured the island's unique subsistence adaptations and environmental interactions. A critical reassessment of research methodologies is essential to better reflect the distinctiveness of Sri Lanka's prehistoric trajectories and advance the field.

c) An Overview of Methodological Approaches

Lately, archaeologists have been using diverse methodologies, including archaeobotany, archaeozoology, and isotopic analysis to understand the complex connections between past societies and their surrounding environments. By analysing stable isotopes, genetic markers, ancient plant remains, and osteological markers, bioarchaeologists dig beyond mere diet reconstruction, exposing the complicated relationships between past human societies and their subsistence strategies. Thus, this section is an introductory overview of the diverse archaeological and scientific methodological approaches on how archaeologists reconstruct the ways in which past people satisfied their basic needs for survival, i.e., attainment of nutrition, water, and shelter (Haviland et al., 1996), using archaeozoology, archaeobotany, isotope and DNA studies.

Archaeozoology

Archaeozoology serves as an important perspective for understanding subsistence practices in the past. Scientists use archaeozoology as one of the principal methods to reconstruct paleodiet, which refers to habitual dietary patterns and the regular consumption of specific food types. Analysing bone assemblages permits archaeozoologists for identifying exploited species, recognise hunting strategies, and understand the rise of domesticated species. This methodology reveals not just what ancient societies consumed but also exemplifies the way they hunted, herded, and processed animal resources, using various indices as the butchery index, meat utility index, or seasonality index to quantify and interpret specific aspects of animal exploitation. Moreover, this discipline adds to environmental reconstruction, interpreting changes in ecosystems and human interactions with their local surroundings.

Quantification of archaeozoological data is a multi-dimensional method which employs various statistical techniques to analyse and interpret data extracted from animal remains from archaeological excavations. Researchers use standard measures such as the Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI) to measure abundance and approximate the minimum number of animals represented in an archaeological assemblage (Bökönyi, 1970; Grayson, 1984; Lyman, 2008). Techniques for age and sex determination (Reitz and Wing, 2008), including age profiles and sex identification depicts, human-animal interactions and subsistence strategies. Biometric analyses, involving metric measurements and tooth wear assessments (Driesch, 1976; Hillson, 2005), contribute to statistical analyses when taphonomic analyses brought light into postmortem processes that form the assemblage (Efremov, 1940; Brain, 1981; Lyman, 1984; 2014; Bartosiewicz, 2008; Fernandez-

Jalvo and Andrews, 2016). Spatial analyses expose patterns in the spread of animal remains within a site, demonstrating past human activities in a given temporal space. Statistical tests and zooarchaeological indices further enhance the quantitative analysis (Grayson, 1984; Lyman, 2008; Rodrigo and Bohingamuwa, 2025), aiding in the identification of patterns and differences in the data. Comparative studies across sites or regions contribute to a broader understanding of regional variations in human-animal interactions, developing our understanding of past human communities. In essence, the quantification of archaeozoological data holds a widespread approach, using diverse methodologies in reconstructing sophisticated relationships between ancient humans and animals.

In Sri Lanka, Archaeozoological and Palaeoanthropological studies are rather frequent. Sri Lanka provides the earliest definitive evidence for the presence of Homo sapiens in tropical rainforest environments, particularly in the southern region (S.U. Deraniyagala, 1992; S.U. Deraniyagala & Kennedy, 1989; Kennedy et al., 1987) as well as evidence for heavy reliance on rainforest resources (Roberts, Boivin and Petraglia, 2015; Roberts et al., 2015; 2017a; Wedage et al., 2019b; 2020), supported by microlithic and osseous technologies (S.U. Deraniyagala, 1992; Langley et al., 2020; Perera et al., 2011; Wedage et al., 2019; Wijeyapala, 1997). Wedage et al. (2020) exposed archaeological evidence of early humans using tropical rainforest environments, including specialised hunting of arboreal and semi-arboreal fauna from ~45,000 years ago.

Even before this 'scientific reconnaissance', there were several attempts to explore the ecological relationships between humans and their environment using archaeozoology as the preliminary methodological approach. The genesis of interest in zooarchaeological studies in Sri Lanka owes itself to P.E.P. Deraniyagala, who remains the most distinguished palaeontologist to have conducted substantial research so far on the island. He published extensively prehistory and palaeontology demonstrating and broad and eclectic range of interests. Prior to P.E.P. Deraniyagala, one of the most enigmatic Archaeozoological personalities in the colonial period were the cousins, Paul and Fritz Sarasin. Between 1884 and 1886, the Sarasins conducted multidisciplinary research in Sri Lanka, exploring various aspects of zoology, archaeology and anthropology. Their work yielded the first comprehensive account of Sri Lanka's Stone Age, including significant insights into the use of mollusc-based ornaments and bone tools (Sarasin and Sarasin, 1908). Building on this legacy and drawing from postcolonial archaeological perspectives Bohingamuwa et al. (2024) critically re-evaluate longstanding assumptions about the Vadda, Sri Lanka's indigenous community, by interrogating both archaeological and ethnographic data. Their study highlights the limitations of previous interpretations, which relied on serious misconceptions about the Vadda people as well as fragmentary skeletal remains and under representative modern samples, while also challenging reductive narratives of cultural and biological continuity from the Mesolithic 'Balangoda Man' to present-day Vadda groups and sometimes to Sinhalese. Drawing on fresh ethnoarchaeological insights, the authors underscore the need for more nuanced, interdisciplinary approaches to better understand the complex socio-cultural and evolutionary trajectories of the island's indigenous populations.

P.E.P. Deraniyagala conducted extensive excavations at several sites, including Bellanbendipelessa open-air site (P.E.P. Deraniyagala 1958a, 1963a), Batadomba-lena at Kuruvita, Ravana-ella cave at Wellavaya and many other prehistoric sites (P.E.P. Deraniyagala 1944, 1946, 1960a; b) and protohistoric sites (P.E.P. Deraniyagala 1972). The animal remains unearthed by P.E.P Deraniyagala were described in his scientific papers, many of which are published in Spolia Zeylanica. Taking it a step further, he reconstructed animal species using osteological characters (P.E.P Deraniyagala, 1958b, 1963b, 1969) and he even attempted cross-check between two species (P.E.P. Deraniyagala, 1961). In his masterpiece, The Pleistocene of Ceylon (P.E.P. Deraniyagala, 1958c), he describes approximately 20 species of vertebrates belonging to the Rathnapura fauna. Similarly, he conducted extensive research on the Tertiary Period in Sri Lanka.

In the late twentieth century, excavations carried out by Durham University, U.K., in collaboration with Sri Lankan scholars, placed Anuradhapura within a wider archaeological context (Coningham, 1991). When analysing faunal materials unearthed, special attention was given to teeth (Young et al., 1999). They specifically applied 'Grant Dental Attrition Age Estimated Method' to assess the recovered teeth. Various zooarchaeological methods have also been applied to identify faunal remains, Chandraratne, for example used quantitative methods and computer applications to determine faunal remains from the 1985 Gedige Excavation (Chandraratne, 2015).

Novel Proteomic Approaches in Tropical Archaeozoology: Integrating ZooMS and SPIN for Enhanced Taxonomic Resolution

The analysis of fragmented and taxonomically ambiguous faunal assemblages in tropical regions has long posed significant challenges for archaeozoologists. Traditional morphological methods often prove inadequate in contexts where bone preservation is poor due to taphonomic processes such as soil acidity, microbial action, and climatic degradation, which limits diagnostic features. Recent advances in biomolecular techniques, particularly those leveraging protein preservation, have opened new avenues for species identification.

Among these, Zooarchaeology by Mass Spectrometry (ZooMS) and Species by Proteome INvestigation (SPIN)

have emerged as powerful tools for taxonomic discrimination, even in highly degraded samples. ZooMs employ peptide mass fingerprinting of type I collagen, the most abundant protein in bone, to generate taxon-specific spectral profiles. By targeting conserved yet variable collagen sequences, ZooMS can distinguish between species, often to the genus or family level, with minimal sample destruction. Its taxonomic resolution, however, is occasionally limited for closely related taxa (e.g., domestic vs. wild bovids) due to collagen sequence homology. To address this, SPIN (Species by Proteome INvestigation) offers a complementary approach by extending proteomic analysis beyond collagen to include other bone proteins (e.g., osteocalcin, albumin). SPIN leverages high-resolution mass spectrometry (LC-MS/MS) to sequence multiple protein markers, thereby increasing discriminatory power. For example, SPIN has successfully resolved ambiguities within Southeast Asian rodent assemblages in cases where ZooMS alone was insufficient to differentiate between morphologically similar species (Hendy, 2021).

By using the development in ZooMS, archaeologists can overcome the limitations presented by traditional morphological and morphometrical identification methods, particularly in regions where the climate and taphonomic conditions pose significant hinderance to preservation. In tropical regions with high temperatures, humidity, and acidic soils often expedite the decaying process of organic materials. Furthermore, paleogenetic and ZooMS offer robust alternatives to traditional archaeozoological identification methods. These advanced techniques assist the species identification from small bone fragments by analysing the unique peptide sequences stored in bone collagen, thereby bypassing the need for well-preserved diagnostic features.

The implementation of such methodologies is timely and important in regions such as Sri Lanka. The adverse climatic conditions that affect faunal materials preservation need advanced means to extract biological information and analyse them. Using ZooMS, upgrading taxonomic-level identifications could offer not only more conclusive identifications but even further incisions into ancient ecosystems, human diet, and hunting patterns. An amalgamation of ZooMS with traditional and molecular techniques will offer a holistic approach to tackling issues faced by archaeozoologists in tropical environments towards a comprehensive understanding of historic biodiversity and human-animal relations.

Archaeobotany

The study of archaeobotany, being a particular branch of bioarchaeology, is extremely useful in studying the relationship between ancient human societies and plant resources. This bioarchaeological approach provides insights into the diets, farming, and environmental interactions of the bygone societies, providing perspective on the adaptations and resilience of such communities in the face of landscape changes. Hence, archaeo-botanical studies could assist with:

Recovery and Identification of Plant Remains: Archaeobotanical studies involve the recovery of preserved plant materials from archaeological sites. Raw data types include seeds, fruits, pollen, wood, and phytoliths. These materials can be identified through microscopy, isotopic analysis, and other scientific techniques. In 2024, Diffey and colleagues used primary archaeobotanical analysis, including crop stable isotope determinations, to reveal on cultivation strategies and water management of Tell Brak farmers in upper Mesopotamia during the mid-3rd millennium BCE.

Cultural and Economic Significance: Plant remains analyses facilitates the reconstruction of agricultural practices, dietary preferences, and economic methods of past societies. The presence of specific crops or the absence of certain plants can indicate cultural preferences or environmental constraints.

Technological Aspects: Studying plant-processing tools, grinding stones, and other artefacts related to plant use offers awareness into the technological advancements of past societies in terms of ancient food preparation, storage, and craft activities. For example, the identification of grinding stones and plant processing tools emphasised the technological aspects of subsistence practices during the Jomon period in Japan. These tools were likely used for the preparation and processing of plant-based foods, stressing the integration of plant resources into the Jomon diet (Yasui, 2022).

The Holocene encompass an important milestone of transition, evidenced by the terminal Pleistocene, and the transition from foraging to food production. Therefore, archaeobotany plays a fundamental role in interpreting how these shifts established in the course of exploitation of plant resources. Consequently, archaeobotany can offer insights into:

Transition to Agriculture: Archaeobotanical evidence is a vital to understand the shift from hunting-gathering to farming. Identifying domesticated plant species and cultivations would establish a timeline for this transformative period. For example, throughout the occupation, archaeobotanical evidence from Asikli Höyük, Türkiye, suggests a wild-domesticated mixture (Ergun et al., 2018).

Dietary Analysis: Micro and macro archaeobotanical analyses, coupled with dental calculus and coprolite studies, would aid in reconstructing dietary habits and preferences, suggesting insights into staple crops, their seasonal variations, and plant diversity. Analysing charred plant remains, Ohalo II, Israel, provides a thorough understanding

of Epipalaeolithic dietary habits and their seasonality (19,000 BP). Staple crop consumption has been emphasised through the identification of wild barley and other edible plants (Kislev, Nadel and Carmi, 1992). Additionally, new investigated ingesta samples from the 'Ötzi' the Iceman confirm a varied diet that included a mix of wild and cultivated plants, along with game animals (Oeggl, Kofler and Schmidl, 1970).

Seasonal Harvesting and Adaptations: Archaeobotanical data help deduce seasonal plant exploitation to adapt environmental changes which is, crucial for understanding the timing and seasonality of agricultural activities. For instance, at mid-late Holocene settlements in the Aegean region of western Türkiye, findings of cereal grains and legumes like einkorn wheat and lentils reflect adaptive agricultural strategies for coping with a drying climate. These strategies included cultivating drought-tolerant cereals on drier fields with water management tactics redirected towards pulses (Maltas, Şahoğlu and Erkanal, 2023). This highlights the community's ability to adapt their agricultural practices to seasonal changes and optimise resource utilisation.

A special sub-discipline within archaeobotany is Anthracology, perhaps the least studied among the applied environmental archaeological fields, especially in tropical regions. It focuses on the analysis of charcoal and wood found in archaeological and palaeoecological contexts, providing insights into past vegetation and human activities related to wood use (Western, 1963). The examination of charcoal remains in sambaquis and Tupi-Guarani sites in Southern and Southeastern Brazil has provided insights into the environmental resources, site catchment areas, the economy of fuel, and the utilisation of wood (Scheel-Ybert, Beauclair and Buarque, 2014). The combined use of anthracology and dendrology proved effective in reconstructing the timber selection and their catchment areas of fuel used in Neolithic domestic fireplaces in northwestern France (Marguerie and Hunot, 2007).

Until now, limited archaeobotanical investigations have been conducted in Sri Lanka, hindering a comprehensive grasp of the ecological setting and subsistence approaches intertwined with the growth of urbanisation and trade (Kajale, 1989; 1990; 2013; Premathilake, Epitawatta and Nilsson, 1999; Premathilake, 2006; Premathilake and Seneviratne, 2015; Kingwell-Banham et al., 2018; De Langhe et al., 2019). In 2021, Allué et al. (2021), conducted the first anthracological study of the early historic sites of Kirinda and Kantharodai in Sri Lanka, providing evidence of direct and active fuel management by human groups. These highlight the effects of new management practices on landscapes and the earliest signs of sustainable forest exploitation.

Isotope and DNA studies

The combination of isotope studies and DNA analyses has emerged as a powerful and multifaceted approach for reconstructing past subsistence strategies. Isotope studies, focusing on stable isotopes of elements like carbon, nitrogen, oxygen, and strontium, provide insights into dietary patterns, migration histories, and environmental adaptations of ancient populations (Ambrose, 1993). Such an analysis enables researchers to reconstruct the long-term dietary patterns, thereby providing insights into the average environmental conditions encountered by animals throughout their lives. For example, consumption of both animal protein (meat or milk) and manured cereal crops may raise δ15N values (Bogaard et al., 2007). Simultaneously, DNA studies, in the sense of subsistence studies, offer a genetic lens of the presence of specific domesticated plants and animals.

The Cheia, Romania, case study explores cattle, caprine, and pig husbandry practices through isotopic analysis of an archaeozoological assemblage from the mid-fifth millennium BCE. It examines the relative importance of domestic stock, providing insights into animal diet management, birth seasonality, and demographic practices during that period (Balasse et al., 2014). Balasse and colleagues (2016) offer a unique glimpse into small-scale pig husbandry within Romania's Gumelnița culture in the fifth millennium BCE. Bone collagen analysis reveals that the wild boars were likely not forest-dwelling but instead consumed human leftovers or by-products. Geometric morphometric and stable isotope analyses indicate that pigs with enlarged molars may not have been part of the domestic stock.

Balasse and colleagues (2021) explore the impact of animal domestication on Neolithic Europe's subsistence patterns using stable oxygen isotope ratios in cattle teeth enamel from 18 European sites. Findings indicate that agropastoral systems were influenced by environmental conditions, particularly forage availability, shaping variations in milk supply. This likely prompted the development of cheese-making practices for storing milk over longer periods. Vaiglova and colleagues (2014) utilise isotope studies in archaeozoology and archaeobotany to reconstruct early farming practices at Kouphovouno, a middle-late Neolithic village in southern Greece. The findings underscore the close integration of crop cultivation and animal husbandry, showcasing the broader significance of stable isotope analysis in understanding human-plant-animal subsistence relationships that are beyond dietary reconstruction.

In Sri Lanka, stable carbon and oxygen isotope analysis of the Sri Lankan Vadda population reveals that many groups, once considered isolated 'forest' foragers, were in fact deeply integrated into networks with local agricultural communities or diverse environments by the nineteenth and twentieth centuries. The incorporation of C4 resources, likely in human diets in the Wet Zone of Sri Lanka during the

Iron Age (c. 3 ka) may be evidence for trade with agricultural populations in other environmental zones (Roberts et al., 2018).

Additionally, ancient DNA studies would contribute to:

I. Identifying the wild ancestors of domestic species
II. Establishing phylogenetic relationships between species
III. Estimating the chronology of diversification
IV. Determining the monophyletic or polyphyletic origin of the domestication process.

Çatalhöyük, a Middle East Neolithic site, offers a compelling case study integrating archaeobotanical and genetic approaches to unveil early agricultural practices, revealing charred seeds and grains in excavations (Hastrof, 2005). Çatalhöyük's plant remains underwent modern genetic analysis (Malhi et al., 2005), revealing specific genetic changes associated with domestication. Researchers targeted specific genetic markers associated with domestication traits, such as changes in seed morphology and reproductive strategies which provide molecular evidence of selection pressures applied by early farmers to crops (Bilgic et al., 2016). In animal domestication studies, recent advances, like enhanced ancient DNA extraction and next-gen sequencing are being used to reconstruct the process by which animals entered domestic relationships with humans (Frantz et al., 2020).

Unfortunately, Sri Lankan prehistoric caves are consistent with a global pattern of poor DNA preservation in the tropics as revealed by Reed et al. (2003) and Chandimal et al. (2021). Recently, Fernando et al. (2023) published the first complete mitochondrial sequences for Mesolithic hunter-gatherers from two cave sites in Sri Lanka. However, there has been no effort to establish correlations with subsistence or to extract ancient DNA (aDNA) from archaeological animal or plant remains up to this point.

Ethnoarchaeological studies

Given the sparse molecular preservation of archaeological plant and animal remains in Sri Lanka, a compelling need arises for an innovative methodological approach to address ongoing inquiries related to subsistence. One promising avenue is the incorporation of 'ethnozooarchaeology' and 'ethnobotany', well-established methodologies in Europe and Asia, which hold potential for valuable insights in this context.

As David and Kramer (2001: 2) point out 'ethnoarchaeology is neither a theory nor a method, but a research strategy' which is an important concept to bear in mind, as it explains the great and healthy diversity of theoretical and methodological approaches that ethnoarchaeology may take to study contemporary societies to gain insights into past human behaviours and practices. Thus, it belongs to the more general category of 'actualistic studies' to understand how past societies utilised resources, adapted to their environments, and engaged in various economic activities (David and Kramer, 2001: 13). Doubts have often been raised about the use of ethnographic analogy as a useful heuristic tool (Holtrof, 2000; Tilley, 1999; Gosselain, 2016). But at the same time emphasis has been placed on the fact that "archaeologists draw upon their lives and upon everything they have read, heard about or seen in the search for possible analogies to the fragmentary remains they seek to interpret" (David and Kramer 2001: 1), and Mathew Johnson (1999) argues 'all archaeologists of whatever theoretical stripe make a link between present and past by using analogies', either intentionally or unintentionally. Criticisms were made accusing ethnoarchaeology of limiting archaeological interpretation of past models of behaviour to known analogues (Binford, 1968; Freeman, 1968). Albarella (2011) claims that 'we interpret the world through our own experience and no individual can experience the full range of human behaviours'. Hence, Hodder (1982: 9) claims that "all archaeology is based on analogy".

Ethnographic models generally combine many complex relationships among various elements of human society as well as different components of the human ecosystem. Binford (1978) provided a classic example of how ethnozooarchaeology can be used in ancient subsistence studies. He observed Inuit populations in Alaska and their material remains generated through their everyday subsistence activities. He analysed these remains simultaneously from both behavioural and archaeological perspectives, in order to interpret the periglacial environment that Mousterian hominins occupied, and to see how hunter-gatherer behaviour is reflected in material remains. Moreover, Brain (1981) used ethnozooarchaeology as a taphonomic perspective.

However, the extent to which ethnographic data from such societies can be used to interpret hunters and gatherers remains questionable (McGranaghan 2017; Gould et al. 1982; Binford 1968). As Hodder (1982) suggested, analogies should never be transported wholesale. Similarities and differences should be assessed. Then, in determining whether the similarities allow the analogy to be applied, one should refer to the cultural links between the different aspects of the model (Ascher, 1961: 319).

The use of analogy in archaeology has attracted sustained, if not widespread, criticism. Gould & Watson (1982) argue that the essence of ethnoarchaeology rests not with the collection of scientific data by analogies, hypothesis and models, because human behaviours vary and changes according to time and space, perhaps ecological provinces too. Therefore, key to this kind of reasoning in ethnoarchaeology is the concept of uniformitarianism. To use the principle of uniformitarianism effectively, ethnoarchaeologists tend to ask a specific set of questions,

in a particular order: procure, transport, consume and discard meat products in hunter-gatherer societies. This uniformitarianism is thus a bridge between past and present. It furnishes assumptions about those relationships in nature that hold true in both the past and present, and it permits us to test these assumptions in cases of human behaviour to see how much of the behaviour we observe in human societies today must also have occurred in past human societies living under similar conditions.

The concept of uniformitarianism emerged as a significant theoretical approach in archaeology during the twentieth century, drawing from principles rooted in geology. Most of them emphasised the 'ecological similarities between the archaeological ad ethnographic cultures. Binford (1968, 1978, 1983, 2001) and Julian Steward (1955), advocated for its application in interpreting prehistoric lifeways. Binford, in particular, emphasised the use of ethnoarchaeology and actualistic studies to bridge the gap between past and present behaviours, arguing that present-day foraging societies could offer valuable analogies for understanding the archaeological record. Similarly, Steward's cultural ecology highlighted the adaptive relationship between human societies and their environments, reinforcing the idea that ecological and cultural processes observable today operated in similar ways in the past. Central to this approach was the assumption that the ecological and behavioural patterns of ethnographic groups could be used to infer the functions and meanings behind archaeological materials. This perspective provided a robust framework for interpreting subsistence strategies, settlement systems, and social structures in prehistoric contexts.

By way of illustration, Graham Clark (1953: 355), stated that 'archaeologists should use analogies from societies at a common level of subsistence' and should 'attach greater significance to analogies drawn from societies under ecological conditions' which are approximately reconstructed for the prehistoric culture under investigation than those adapted to markedly different environs. At the same time Wylie (1982, 1985) would advise on 'the same general level of technical development, perhaps existing under similar environmental situations', whereas Childe (1956: 51) would select the analogies 'drawn from the same region or ecological province' because of the high reliability of clues they provide. The canon is to seek analogies in cultures which manipulate similar environments in similar ways (Ascher, 1961).

Being particular

Contrary to what Martin Wobst (1978) argued, ethnoarchaeology is not entirely 'ethnology with a shovel'. Analogies are being built using explicit archaeological ethnography, which provides the most detailed and useful information, not obtainable from literature, material culture or experimental studies. Therefore, specific problems are being investigated. For example, Peterson (1971) believes that sites should be studied because variation in artefacts results from broad ecological, rather than specific cultural causes. Gould (1974: 41-42) emphasises 'sites first and then areas', in the sense of insufficiency of particular archaeological details in the light of cultural patterning.

Therefore, there are three general categories for conducting ethnological studies, which tend to answer various types of questions and build analogies for several purposes (Stiles, 1977):

I. Study of activities at occupied sites
II. Involvement within living communities
III. Studies of historically abandoned settlement sites

The first category falls under several objectives such as observe relationship between cultural and natural in order to understand refuse patterning, observe the life of artefacts to understand better aspects of variation in what's left on occupation sites and observe man-land-artefact relationship for creating analogies of settlements and subsistence behaviour (Stiles, 1977). In this matter of sense, Gosselain (2016: 217) argues that analogies would not penetrate 'how the object was used in practice'. He furthermore returns to the analogy of 'stone knife', then presents how do we know if this stone knife was used in 'in cutting' or 'for cutting'? A fine reply to Gosselain received from Lyons & David (2019: 14), stating that archaeologist's task is to match the least improbable interpretation from data that are decontextualised, fragmentary and in other ways unrepresentative or imperfect, instead of applying everything 'without borders' gathered from ethnographic parallels. In Sri Lanka, S.U. Deraniyagala (2004:25-27), who identified himself as a 'cultural paleo-ecologists' while emphasising the significance of ethnographic analogy for archaeological interpretation, insisted that 'the ethnographic data should refer to a society which is at a level oof technological development similar to that estimated for the archaeological community.'

The second category involves engagement within living communities, focusing on the relationship between populations of artefacts and the sociology of the people who produce. A wide range of reputed authors have dealt with this approach. For example, Binford (1978) conducts an extensive analysis of the relationship between the behaviour involved in the harvest of caribou and mountain sheep and the archaeological manifestations of that behaviour, whereas Hodder (1982) and Henrietta (1985) analyse gender roles from ethnologic parallels. Gould (1969) presents more holistic view of Aboriginal life from time to time. It has been compared with the wealth of information on bushman subsistence available from Lee (1991). This kind of studies can be extended to which artefact patterns may provide information on kinship, residence patterns and enculturation systems.

The third category of studies can elucidate archaeological objects and features from an archaeological standpoint, validating inferences against ethnological knowledge (Stiles, 1977). The three methods of using ethnographic data can be and often are used together. Unlike 'ethnology with a shovel', the 'rationale and methodology' of using ethnographic analogies in ethnoarchaeological studies is essential.

Behavioural archaeology expands this analogical framework by incorporating non-cultural processes that influence the formation of the archaeological record. It posits that a comprehensive understanding of both depositional and post-depositional processes is essential for refining analogical reasoning, thereby strengthening the interpretive links between past and present behaviours as inferred from archaeological contexts (Schiffer, 1995). While experimental archaeology can produce robust analogies—often with improved control over variables (Outram, 2008) — its scope remains limited. It typically addresses only low levels of inference and often lacks the cultural context necessary to fully interpret the outcomes. In contrast, despite ongoing epistemological critiques and certain methodological limitations, ethnoarchaeology remains one of the most significant and systematically applied sources of analogy in archaeological interpretation. And this is ethnoarchaeology's strength.

Site Catchment Analysis

Being a geographic approach in archaeology, Site Catchment Analysis studies the spatial organisation of human activities and resource utilisation within a specific adjacent area within an archaeological site (Vita-Finzi and Higgs, 1970). It helps archaeologists to understand how past human societies exploited and managed resources in their immediate vicinity. Researchers also compare the site catchment analyses results across different sites, regions, or chronologies to identify cohesions or contrasts in respective subsistence strategies. This comparative approach improves the understanding of regional variability in past subsistence practices. For example, an archaeobotanical study of Neolithic settlements in the Valais, compared to the Northern French Alps, revealed that the Valais Neolithic communities had a different plant economy (Martin, 2015). This is an indication of plant resource utilisation in a mountainous context and outlines settlement catchment areas in early agro-pastoral communities in the Swiss Alps.

Binford (1978) has demonstrated the way how archaeologists identify whether groups in the past had maximised their use of meat resources from a study of animal bones. It could be said that site catchment analysis, when used to compare on-site evidence of how the environment was used with the evidence for the potential resources in that environment, provides a measure of maximisation.

3. Conclusions

In conclusion, reconstructing subsistence practices is a multidisciplinary endeavour which requires a diverse range of methodological approaches and analytical techniques. Integrating archaeobotany, archaeozoology, isotopic analysis, and ethnoarchaeological studies, researchers can gain a substantial understanding of how past societies secured their essential needs for survival. These methods reveal the complexities in reconstructing ancient subsistence strategies, explaining past dietary habits, farming practices, and human-environmental interactions. As technology and methodologies continue to advance, the holistic exploration of subsistence practices remains essential, contributing not only to our understanding of the past but also to the broader narrative of human history and adaptation by way of:

I. Moving beyond the mere construction of site-specific and regional cultural sequences, reorienting the discipline's objectives toward recognising and explaining cultural similarities and differences across temporal and spatial scales
II. Replacing overarching, generalized treatments of the archaeological record with regionally focused approaches that emphasise contextual specificity
III. Shifting from traditional classificatory frameworks to interpretive analyses, wherein artefacts are understood as tangible expressions of past human behaviour
IV. Redefining the discipline's own concepts of site, artefact, type, culture, assemblages etc in terms of human behaviour
V. Conceptualising cultures as systemic entities composed of interrelated components, the interactions of which constitute cultural processes
VI. Viewing cultures as adaptive mechanisms through which human groups negotiate their environmental—both natural and social—contexts
VII. Use of hypothesis-driven methodologies to address questions of causality, specifically the 'how' and 'why' behind cultural phenomena
VIII. Study of formation processes of the archaeological record, through the application of ethnoarchaeological, ethological, and experimental analogies
IX. Final reconstruction of past cultures as settlement systems
X. Identifying of common cultural patterns of the past appearing from synchronic and long-term studies of archaeological record.

Integration of these advanced methodologies and analytical techniques with traditional methods would represent a necessary step forward in addressing the challenges faced by archaeologists in tropical environmental contexts. It allows for a more detailed and reliable reconstruction of

past human-animal interactions and subsistence strategies, contributing to a more refined understanding of historical biodiversity and human adaptation to environmental changes. Overall, the adoption of these innovative approaches is essential for advancing the field of prehistoric subsistence studies in Sri Lanka. As technology and methodologies continue to evolve, ongoing interdisciplinary collaboration and methodological innovation will remain vital for uncovering the complexities of ancient subsistence strategies and their implications for understanding human history and adaptation.

Acknowledgement

We thank Mr. Chandula Arsakulasuriya and Mr. R. M. Wijayawardhana (Department of English and Linguistics, Faculty of Humanities and Social Sciences, University of Ruhuna) for the assistance in language editing of the manuscript.

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