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Comparative feeding strategies of two Neotropical cervids (Artiodactyla: Cervidae) from Costa Rica based on dental wear proxies

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ABSTRACT

Introduction: Dental mesowear and microwear analyses provide complementary proxies for reconstructing herbivore feeding ecology at different temporal scales. While mesowear reflects long-term dietary abrasion, microwear captures short-term feeding behavior, allowing evaluation of dietary stability and variability in seasonally dynamic tropical environments.

Objectives: To assess short- and long-term dietary patterns in two Neotropical cervids, the white-tailed deer (*Odocoileus virginianus*) and the Central American red brocket deer (*Mazama temama*), and to evaluate the ecological significance of microwear variability in relation to habitat, seasonality, and foraging behavior.

Methods: Dental mesowear and low magnification microwear analyses were conducted on lower molars of modern cervid specimens from Costa Rica. Microwear variables, including pits, scratches, and scratch texture, were recorded within standardized enamel areas. Scratch variability was assessed using standard deviation and coefficient of variation, and results were interpreted through comparative and descriptive approaches.

Results: *Odocoileus virginianus* exhibited moderate mesowear values combined with low microwear dispersion, indicating a stable feeding strategy. In contrast, *M. temama* showed greater variability in microwear features, particularly in scratch counts, showing a broader diet.

Conclusions: Tropical cervids may maintain consistent long-term feeding strategies while exhibiting variable short-term dietary responses driven by ecological context and resource availability. Integrating mesowear, microwear, and microwear variability provides a robust framework for interpreting cervid feeding ecology in both modern and archaeological contexts, with implications for future comparative studies across tropical environments.

Key words: dental mesowear; dental microwear; *Odocoileus virginianus*; *Mazama temama*; feeding ecology.

RESUMEN

Estrategias tróficas de dos cérvidos neotropicales (Artiodactyla: Cervidae) de Costa Rica a partir de indicadores de desgaste dental

Introducción: El mesodesgaste y microdesgaste dental son enfoques complementarios que permiten reconstruir la ecología trófica de herbívoros en escalas temporales diferentes. El mesodesgaste refleja una temporalidad larga mientras que el microdesgaste presenta el comportamiento alimenticio del animal antes de morir. Estos dos enfoques permiten conocer la estabilidad o la variabilidad de la dieta de los animales en ambientes tropicales.



Objetivos: Estudiar los patrones dietarios a corto y largo plazo en dos especies de venados neotropicales: el venado de cola blanca (*Odocoileus virginianus*) y el temazate rojo (*Mazama temama*) y evaluar el significado ecológico de la variabilidad del microdesgaste en relación con el hábitat, la estacionalidad y los comportamientos de forrajeo.

Métodos: El mesodesgaste y el microdesgaste dental de baja magnificación fueron realizados en molares actuales de individuos de Costa Rica. Las variables del microdesgaste, incluyendo hoyos, estrías y texturas de estrías fueron estudiadas en áreas estandarizadas del esmalte. La variabilidad de las estrías se obtuvo usando la desviación estándar y los coeficientes de variación. Los resultados se interpretaron mediante un enfoque comparativo y descriptivo.

Resultados: *Odocoileus virginianus* presenta valores de mesodesgaste moderados con una dispersión baja en las variables del microdesgaste, indicando una estrategia de alimentación estable. En el caso de *M. temama* se evidencia una mayor variabilidad en los rasgos de microdesgaste, particularmente en número de estrías, mostrando una dieta más amplia.

Conclusiones: Los venados tropicales mantienen unas estrategias tróficas estables a largo plazo, aunque pueden ser variables como una respuesta al contexto ecológico y a la disponibilidad de los recursos. Integrar el mesodesgaste, el microdesgaste y la variabilidad del microdesgaste provee un contexto potente para interpretar la ecología trófica tanto en venados actuales como arqueológicos y paleontológicos, brindando una base para estudios futuros en distintos ambientes tropicales.

Palabras clave: mesodesgaste dental; microdesgaste dental; *Odocoileus virginianus*; *Mazama temama*; ecología trófica.

INTRODUCTION

Understanding how closely related species exploit food resources is central to the study of herbivore ecology and niche differentiation. In ungulates, dietary strategies are commonly structured along a continuum ranging from browsing to grazing, with intermediate mixed-feeding behaviors reflecting varying degrees of dietary flexibility (Hofmann & Stewart, 1972). Dental wear analyses have become a widely used approach for reconstructing feeding strategies in both extant and fossil herbivores, as they provide direct evidence of food properties and ingestion-related abrasives (Semprebon et al., 2016).

Dental micro- and mesowear proxies capture dietary signals at different temporal scales. Dental microwear reflects short-term feeding behavior by recording the physical properties of foods consumed during the days or weeks prior to death, whereas dental mesowear integrates longer-term dietary patterns over months or years by documenting cumulative tooth wear related to food abrasiveness and toughness (Ackermans et al., 2020; DeSantis, 2016; Fortelius & Solounias, 2000; Solounias &

Semprebon, 2002). Mesowear analysis is based on the macroscopic examination of molar cusp morphology, particularly cusp relief and occlusal sharpness, which reflect the balance between attrition and abrasion during mastication. Following the general framework proposed by Hofmann and Stewart (1972), these wear patterns allow herbivorous mammals to be broadly classified into browsing, grazing, or mixed-feeding dietary categories. Animals dominated by attrition typically retain sharper cusps, characteristic of browsers consuming softer vegetation, whereas grazers feeding on more abrasive resources tend to exhibit more rounded or blunted cusps due to higher levels of abrasion (Fortelius & Solounias, 2000). The combined application of mesowear and microwear proxies therefore provides a more robust framework for reconstructing feeding strategies by integrating both long-term dietary trends and short-term feeding signals (Davis & Pineda-Munoz, 2016).

In paleontological and archaeological research, comparisons of dental wear patterns in extant species with well-documented diets with those in fossil or archaeological teeth remains are widely used to infer the feeding

habits of past mammal populations (Faith & Lyman, 2019). For this reason, establishing reliable reference datasets based on modern taxa is essential for the accurate interpretation of dental wear signals in deep-time and archaeological contexts.

The taxonomy of Neotropical cervids is currently under reevaluation. Recent genetic analyses indicate that the traditionally recognized *Mazama temama* represents a complex of at least three species: *M. temama* (Mexico–Honduras), *Mazama reperticia* (Nicaragua–Panama), and *Mazama zetta* (Colombia–Ecuador) (Escobedo-Morales et al., 2025). Taxonomic relationships within the widely distributed white-tailed deer, *Odocoileus virginianus*, are also the subject of ongoing discussion, given its broad geographic range and ecological variability across the Americas (López-Arévalo et al., 2020).

To provide ecological context for the interpretation of dental wear proxies, it is important to briefly consider the feeding ecology of the two species examined in this study. The white-tailed deer (*O. virginianus*) is generally characterized as a highly plastic and opportunistic species, capable of exploiting a wide spectrum of plant resources across open and heterogeneous landscapes throughout the Americas (Eisenberg, 1989; Emmons, 1999; Gallina-Tessaro et al., 2010). In contrast, Central American red brocket (*M. reperticia*) is typically associated with forested environments and has been described as a more selective feeder with a stronger reliance on browse (Bello-Gutiérrez et al., 2010; Eisenberg, 1989; Gallina-Tessaro et al., 2019; Sarria-Perea, 2012). Although these ecological differences are well documented, direct comparisons of dietary strategies between these taxa, based on dental wear proxies, remain limited, particularly in Central America (Martínez-Polanco & Rivals, 2023).

Accordingly, the aim of this study is to compare the dietary strategies of 16 modern deer specimens—including 10 white-tailed deer (*O. virginianus*) and six Central American red brocket deer (*M. reperticia*)—from two localities in Costa Rica: Guanacaste Province

and Volcán Irazú, using dental micro- and mesowear analyses. By integrating dietary proxies that operate at complementary temporal scales, this study evaluates patterns of ecological niche differentiation across environmentally contrasting settings and provides new insights into feeding specialization and ecological flexibility in tropical cervids, contributing to a better understanding of resource partitioning and dietary adaptation in both modern and archaeological contexts.

MATERIALS AND METHODS

Specimen selection and provenance: The cervid specimens analyzed in this study are housed in the Natural History Museum of Vienna and were collected during the Austrian scientific expedition to Costa Rica in 1930. The expedition was organized by the mammalogist Otto Porsch, and the specimens examined here were collected by Otto Koller during systematic mammal surveys conducted in different regions of the country (Díaz-Bolaños, 2008; Weber, 2008).

In this study, a total of 16 deer specimens were analyzed, including 10 individuals of *O. virginianus* and six individuals of *M. reperticia*. Only adult individuals with fully erupted permanent dentition were included in the present analysis. Of seven *O. virginianus* adult males, six were collected in the vicinity of Bebedero, Guanacaste Province, and one was collected in Carrillo, within the primary forests of Santa Clara. All adult females were collected in Bebedero (Koller, 1934) (Fig. 1).

According to Koller's original field notes, all white-tailed deer specimens were personally collected within the same general area over a period of approximately three weeks between June and July (Koller, 1934). Because the specimens derive from a geographically restricted locality and a very short collection interval, environmental variation among individuals is expected to be minimal. Moreover, dental microwear reflects short-term dietary signals, typically representing the foods consumed during the last days or weeks prior

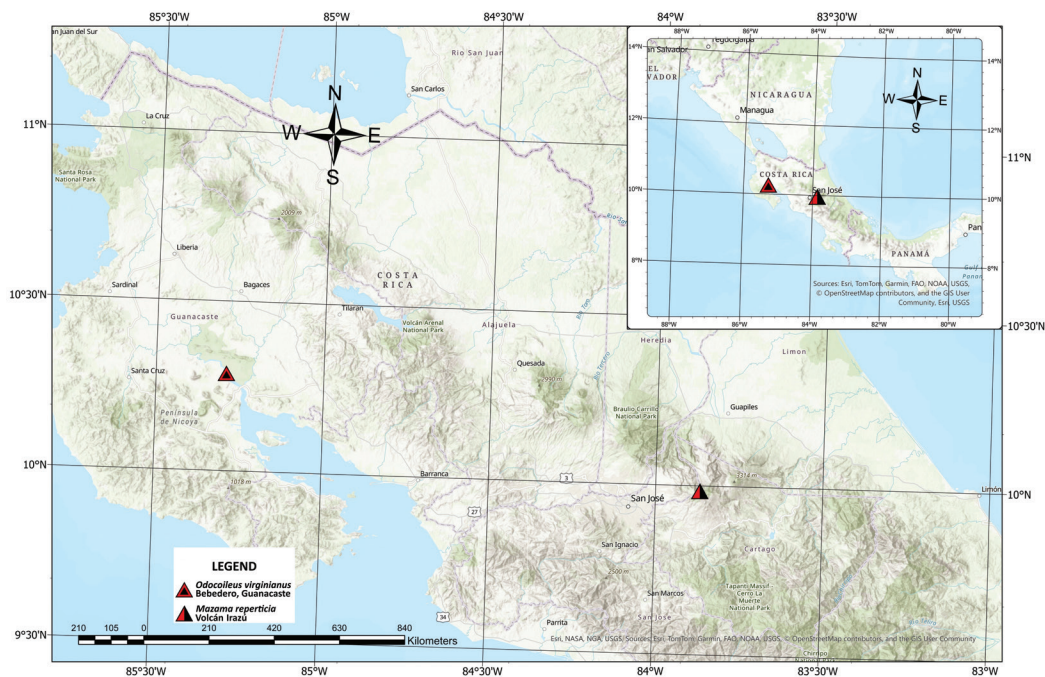


Fig. 1. Map of Costa Rica indicating the sampling localities of the studied specimens. Symbols represent the collection sites of white-tailed deer (*Odocoileus virginianus*) and Central American red brocket deer (*Mazama reperticia*) from Guanacaste Province and Volcán Irazú.

to death. Therefore, seasonal dietary differences within this sample are likely limited. This tightly constrained temporal and spatial framework provides a rare opportunity to examine intra-population variability in dental wear patterns under broadly comparable environmental conditions.

The Central American red brocket deer series consists of six skulls without associated postcranial material, all collected in the forested areas of Volcán Irazú (Koller, 1934) (Fig. 1). All individuals in this sample are adult males. Although the Central American red brocket deer sample is limited in size and derives from a different locality, the uniformity in sex reduces intra-sample variability and strengthens the comparison of dietary strategies inferred from dental micro- and mesowear proxies.

Mesowear is inherently a population-based proxy, and the original framework proposed by Mikael Fortelius and Daniel Solounias recommended sample sizes of 20-30 individuals,

although reliable approximations can be obtained from smaller samples of around 10 specimens (Fortelius & Solounias, 2000). While larger datasets are desirable, assembling extensive modern comparative samples is often limited by the availability of curated skeletal material from wild populations (Patterson, 2002). In the present study, the sample includes 10 individuals of *O. virginianus* and six of *M. reperticia*. Although relatively modest, these sample sizes are comparable to those reported in several mesowear studies of both modern and fossil ungulates and still provide meaningful ecological information when interpreted cautiously (Ackermans et al., 2020; Wilson et al., 2025). Furthermore, the integration of mesowear with dental microwear analysis strengthens dietary interpretations by combining proxies that operate at different temporal scales, thereby improving the robustness of the ecological inferences derived from the available material.

Age and sex considerations: Due to the limited availability of detailed age-at-death data and well-established wear sequences for cryptic Neotropical deer species such as *M. reperticia*, individuals could not be assigned to discrete chronological age classes. To minimize potential age-related bias, only adult specimens were included in the analyses, defined as individuals with complete eruption of the third molar (m3). Juvenile specimens were excluded because dental microwear patterns in young individuals may reflect transient dietary signals associated with nursing, weaning, or incomplete dental eruption and occlusal function.

Dental wear stages were evaluated using qualitative morphological criteria based on the functional condition of the occlusal surface. Teeth exhibiting advanced stages of wear—characterized by substantial cusp obliteration, strongly reduced occlusal relief, and extensive dentine exposure—were excluded to avoid distortions associated with senescent wear surfaces (Severinghaus, 1949). Restricting the sample to adult individuals with functional occlusal surfaces ensures comparability with previously published microwear datasets and provides a more reliable representation of typical feeding ecology. In contrast, mesowear has been shown to be less sensitive to age effects and more strongly related to long-term dietary patterns, particularly in intermediate age groups that commonly dominate fossil assemblages (Rivals et al., 2007).

Both male and female individuals were pooled in the analyses, as previous studies have demonstrated that dental wear patterns do not differ significantly between sexes (Martínez-Polanco et al., 2023; Martínez-Polanco & Rivals, 2023). Microwear observations were therefore interpreted as reflecting species-level dietary strategies rather than sex-specific feeding behavior.

Tooth selection and dental wear analysis: The dental wear analysis focused exclusively on lower second molars (m2), all of which correspond to left elements. No other molar positions were considered in the present study.

The second molar was selected because of its intermediate position in the tooth row, which makes it less susceptible to extreme wear than the first or third molars, while still providing a reliable signal of dietary abrasion (Fortelius & Solounias, 2000). The use of a single side was intended to maintain methodological consistency and to minimize potential sampling bias. Restricting the analysis to a single side is a common strategy in dental wear studies to ensure comparability among specimens when sample sizes are limited (Martínez-Polanco et al., 2022). Lower second molars were analyzed because mandibular elements are more frequently preserved in archaeological assemblages from the study area, and the present dataset was designed to provide a comparative framework applicable to such materials (Martínez-Polanco et al., 2019).

Tooth mesowear analysis: Dental mesowear analysis was used to infer long-term dietary strategies from macroscopic wear patterns on molar crowns. Following the mesowear ruler method originally proposed by Fortelius and Solounias (2000), mesowear reflects the balance between attrition (tooth-to-tooth contact) and abrasion (food-to-tooth contact) accumulated over extended periods, providing an estimate of average dietary abrasiveness (Ackermans et al., 2020; Fortelius & Solounias, 2000).

Mesowear was assessed by visual inspection of cusp morphology, with emphasis on cusp relief and occlusal sharpness. These features were combined into an ordinal mesowear score ranging from low values, indicative of sharp cusps and high relief typically associated with browsing diets, to high values reflecting rounded or blunt cusps, characteristic of more abrasive feeding strategies. In this scale, these features are scored on a scale from zero (sharp and high relief) to six (very blunt), and an average mesowear score (MWS) is calculated for each taxon (Mihlbachler et al., 2011; Rivals et al., 2013; Rivals et al., 2017).

To aid interpretation, mesowear scores obtained for *O. virginianus* and *M. reperticia*



were compared with published reference values for extant ungulates representing browsing, mixed-feeding, and grazing dietary guilds, generated using comparable scoring protocols (Fortelius & Solounias, 2000; Rivals et al., 2011; Rivals et al., 2013; Rivals et al., 2017). These reference data were used exclusively as a descriptive framework and were not included in statistical analyses.

Tooth microwear analysis: Dental microwear was analyzed using the traditional low-magnification microwear method based on the counting of pits and scratches on the occlusal enamel surface under stereomicroscopy. This approach follows the protocol widely applied in ungulate dietary reconstructions (Solounias & Semprebon, 2002; Semprebon et al., 2004). Dental microwear analysis was used to reconstruct short-term dietary behavior based on microscopic wear features formed on the enamel surface during feeding (Fortelius & Solounias, 2000). Microwear patterns consist primarily of pits and scratches generated by the interaction between food items, exogenous abrasives, and tooth enamel. Because these features form rapidly and are continuously overwritten, they reflect dietary intake during the last days or weeks prior to death and provide a snapshot of recent feeding behavior (Davis & Pineda-Munoz, 2016; DeSantis, 2016; Solounias & Semprebon, 2002; Xafis et al., 2017).

Prior to analysis, all teeth were examined under a stereomicroscope to evaluate surface preservation. Specimens showing post-mortem damage, surface alteration, contamination, or conservation-related modifications that could obscure or mimic dietary wear were excluded. Experimental studies have shown that taphonomic processes such as trampling, sediment pressure, or thermal alteration can modify enamel surfaces and potentially produce features resembling dietary microwear (Micó, Blasco, Muñoz del Pozo et al., 2024; Micó et al., 2024). Only molars with well-preserved occlusal surfaces allowing clear identification of primary microwear features were retained for analysis.

Microwear analysis followed established low-magnification protocols widely applied to ungulates. High-resolution dental impressions were obtained using light-body polyvinylsiloxane, and epoxy resin casts were produced for observation. Microwear features were examined under a stereomicroscope at 35X magnification using transmitted light. Counts of pits and scratches were recorded within a standardized 0.4×0.4 mm area located on the enamel band of the protoconid of the lower second molar (m2). The number of scratches allows dietary categorization: browsers (0-17 scratches), grazers (17.5-29.5 scratches), and mixed feeders, which fall in the overlapping range (Fortelius & Solounias, 2000). Bivariate plots were generated using R code following Rivals (2019), with packages including readxl, ggrepel, plyr, lattice, Rmisc, and ggplot2 (RStudio Team, 2022).

In addition to the total counts of pits and scratches, supplementary microwear variables were recorded to refine dietary interpretation, including the presence of cross scratches (% XS), large pits (% LP), and gouges (% G). Scratch texture was assessed using a scratch width score (SWS), ranging from fine to coarse scratches, with average values calculated per species (Solounias & Semprebon, 2002; Semprebon et al., 2011). Microwear variables were interpreted using published reference frameworks for browsing, mixed-feeding, and grazing strategies, which were applied solely for descriptive purposes.

All microwear observations were made by a single trained observer following standardized protocols. Scoring was done with awareness of species identity but without considering geographic origin, which was only included during the analysis.

Following the approach proposed by Rivals et al. (2015), the standard deviation (SD) and coefficient of variation (CV) were assessed (Rivals et al., 2015). These metrics provide insights into short-term dietary heterogeneity within taxa and allow evaluation of the degree of dietary consistency or flexibility reflected in the microwear signal. Variability in scratch counts was examined exclusively for

O. virginianus. This approach was adopted because previous microwear studies on white-tailed deer provide a well-established comparative framework for interpreting dispersion metrics such as standard deviation and coefficient of variation (Martínez-Polanco et al., 2019; Martínez-Polanco et al., 2023). In addition, the precise collection dates available for the Costa Rican white-tailed deer specimens allow the microwear signal to be evaluated within a well-constrained temporal context, facilitating direct comparison with previously published datasets.

Recent studies have successfully applied combined dental wear approaches to *M. temama* and *M. reperticia* (Martínez-Polanco, 2022; Martínez-Polanco & Rivals, 2023; Martínez-Polanco, 2026); however, interpreting scratch variability remains challenging, particularly in the absence of detailed chronological information for all specimens. As a result, dispersion metrics for this taxon were not evaluated within the same analytical framework used for white-tailed deer. Instead, microwear data for *M. reperticia* are discussed primarily in descriptive terms, emphasizing general patterns of dental wear rather than formal assessments of short-term dietary variability.

RESULTS

Tooth mesowear results: Mesowear scores differed between the two cervid species analyzed (Table 1). *M. reperticia* (n = 6) displayed low average mesowear values (mean MWS = 0.17, SD = 0.41), indicating predominantly sharp cusps and high occlusal relief across the sample. In contrast, *O. virginianus* (n = 10) exhibited higher mesowear scores (mean MWS = 0.70, SD = 0.67), reflecting a greater degree of cusp rounding and reduced occlusal relief. *M. reperticia* shows relatively low variability, as indicated by the standard deviation of scratch counts. *O. virginianus* presents more homogeneous distribution of mesowear scores within the sample.

Mesowear analysis reveals clear differences in dental wear patterns between the two cervid species. *M. reperticia* consistently displays low MWS, with values clustering near zero and showing minimal variability, indicating limited exposure to abrasive dietary components. In contrast, *O. virginianus* exhibits higher and more variable MWS values, falling within the lower-to-intermediate range of the dietary reference framework. When compared with extant dietary categories, *M. reperticia* overlaps

Table 1

Mesowear and microwear data of *Mazama reperticia* (red brocket deer) and *Odocoileus virginianus* (white-tailed deer) from Costa Rica.

		Mesowear		Microwear						
		n	MWS	n	NP	NS	% LP	% G	% XS	SWS
<i>M. reperticia</i>	M		0.17		9.25	10.50	0	0	10	0
	SD	6	0.41	6	5.05	5.73	0	0	10	0
	CV		-		0.55	0.55				
<i>O. virginianus</i>	M		0.70		8.10	9.90	0	0	0	0.1
	SD	10	0.67	10	2.32	2.13	0	0	0	0.1
	CV		-		0.29	0.22				

Abbreviations: n: sample size, MWS: mesowear score, NS: number of scratches, NP: number of pits, % LP: percentage of specimens with large pits, % G: percentage of specimens with gouges, % XS: percentage of specimens with cross scratches, SWS: scratches width score (from zero: fine scratches only to two: coarse scratches only), M: mean, SD: standard deviation, CV: coefficient of variation.

closely with leaf browsers, whereas *O. virginianus* shows partial overlap with both leaf browsers and mixed feeders. These patterns suggest a more specialized browsing strategy in *M. reperticia* and a broader dietary niche in *O. virginianus*, consistent with greater trophic flexibility across different environmental settings in Costa Rica (Fig. 2) (Tab. 1).

Tooth microwear results: Microwear variables showed moderate differences between the two cervid species analyzed (Table 1). *M. reperticia* ($n = 6$) presented an average of 9.25 number of pits (NP) and 10.50 number of scratches (NS), with relatively high standard deviations ($SD = 5.05$ for pits; $SD = 5.73$ for scratches), indicating substantial inter-individual variability. The coefficients of variation were similar for pits and scratches ($CV = 0.55$ for both variables). Large pits and gouges were absent in this sample, while cross scratches were recorded in 10 % of the observations. The average scratch width score (SWS) was zero, indicating predominantly fine scratches.

O. virginianus ($n = 10$) exhibited slightly lower mean values for pits ($NP = 8.10$) and

scratches ($NS = 9.90$), with smaller standard deviations ($SD = 2.32$ for pits; $SD = 2.13$ for scratches) and lower coefficients of variation ($CV = 0.29$ for pits; $CV = 0.22$ for scratches). No large pits, gouges, or cross scratches were observed in this sample. The average scratch width score was low ($SWS = 0.1$), reflecting mainly fine scratches with occasional coarser features.

The microwear bivariate plot shows the position of the analyzed cervid samples relative to reference dietary envelopes defined by extant browsers and grazers. The Costa Rican specimens cluster in the low-to-moderate scratch range and intermediate pit frequencies, plotting close to the browser dietary space and clearly outside the grazer envelope. Mean values for *O. virginianus* and *M. reperticia* overlap broadly, with both taxa characterized by relatively low scratch counts and moderate pit frequencies. This pattern indicates limited consumption of abrasive grasses and suggests a diet dominated by browse or soft vegetation shortly before death. The proximity of the samples to the browser reference ellipse supports a predominantly browsing feeding signal,

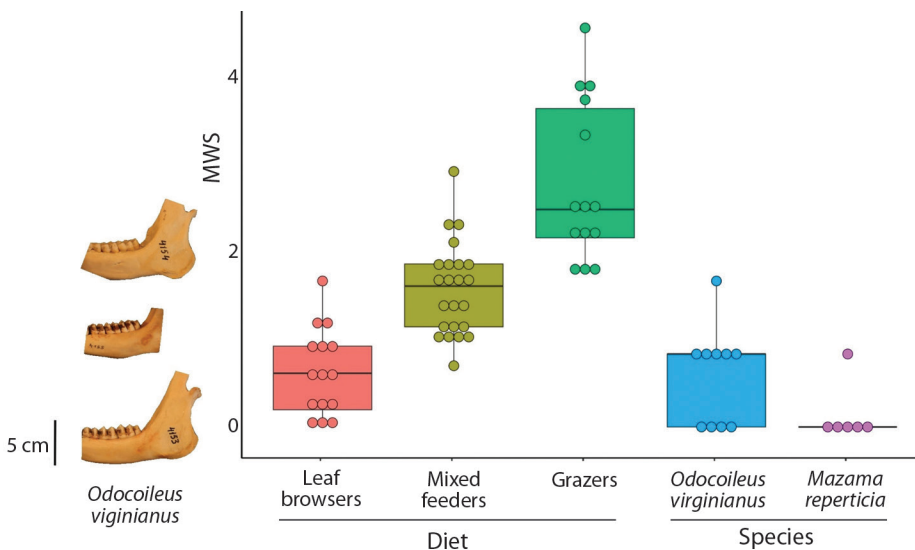


Fig. 2. Mesowear results for the Central American red brocket deer (*Mazama reperticia*) and white-tailed deer (*Odocoileus virginianus*) from Costa Rica in comparison with data on ungulates with known diets: Data from Fortelius and Solounias (2000), Rivals et al. (2011), Rivals et al. (2013), Rivals et al. (2017). Error bars correspond to the standard error of the mean (± 1 SEM).

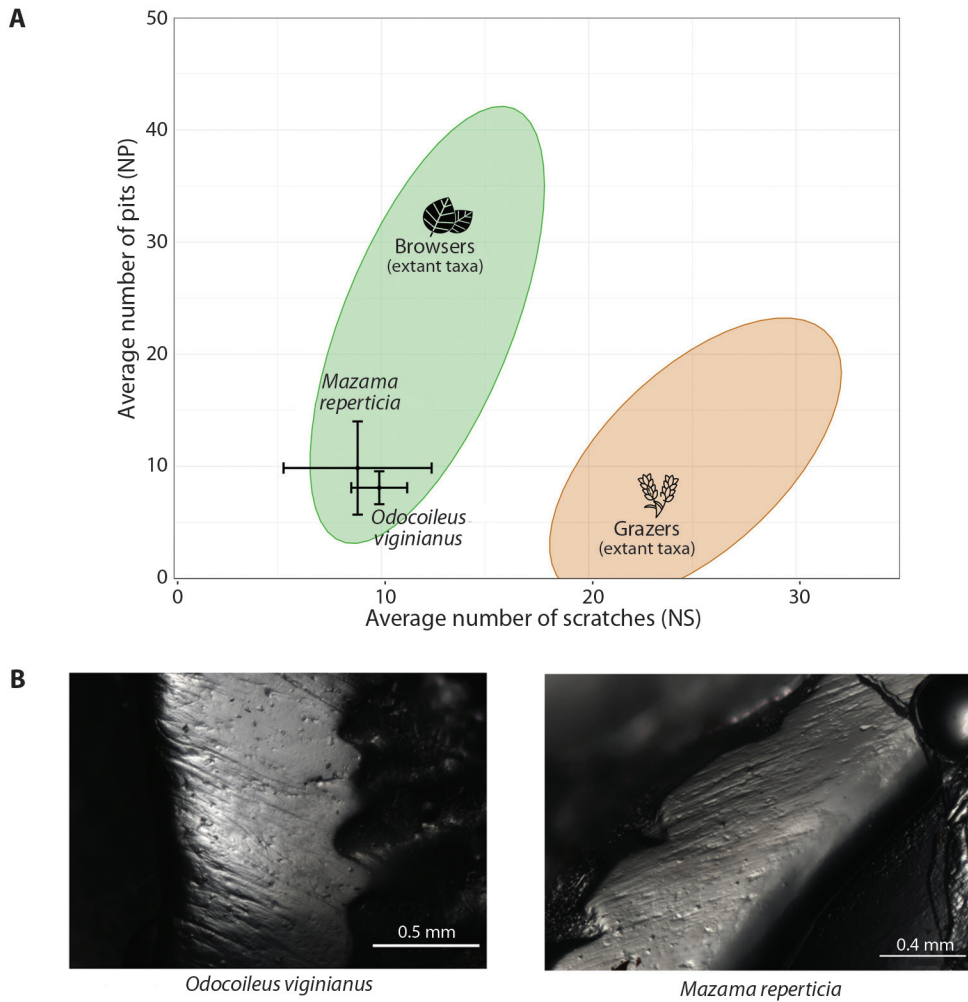


Fig. 3. A. Bivariate plot of the average numbers of pits and scratches of Central American red brocket deer (*Mazama reperticia*) and white-tailed deer (*Odocoileus virginianus*) from Costa Rica. Error bars correspond to the standard error of the mean (± 1 SEM). Ellipses correspond to the Gaussian confidence ellipses ($p = 0.95$) on the centroid for the extant leaf browsers and grazers from Solounias and Semprebon (2002) White-tailed deer (*Odocoileus virginianus*): fine and coarse scratches (specimen NMW-4154), collected during the rainy season. **B.** Examples of microwear features on the enamel bands of the occlusal surface of the lower second molar (m_2). Central American red brocket deer (*Mazama reperticia*): fine and coarse scratches (specimen NMW-4178).

with no evidence of a strong grazing component (Fig. 3A). Fig. 3B illustrates representative microwear features on the enamel bands of the lower second molar (m_2) of *M. reperticia* and *O. virginianus*, highlighting the fine and coarse scratches recorded during analysis.

Scratch variation, quantified using the standard deviation ($SD = 2.13$) and coefficient of variation ($CV = 0.22$), shows low dispersion. The white-tailed deer sample from Guanacaste plots within area A of the heat map (Fig. 4) shows a consistent microwear signal

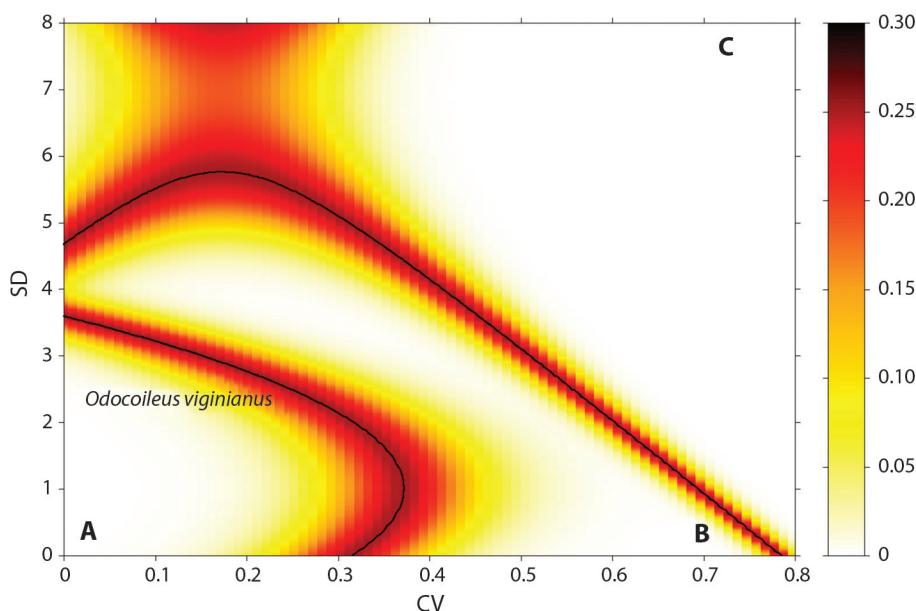


Fig. 4. Heat map (boundary lines of the three regions with the error probability) and the sample of white-tailed deer (*Odocoileus virginianus*) from Guanacaste, Costa Rica. **A.** Seasonal or shorter events. **B.** Longer than a season events. **C.** Separate events (data from Rivals et al., 2015).

suggesting multiple individuals experienced similar short-term dietary conditions during the same season.

DISCUSSION

The combined analysis of mesowear and microwear provides complementary insights into the feeding ecology of *M. reperticia* and *O. virginianus* from Costa Rica, revealing clear interspecific differences structured across temporal scales. Mesowear results indicate low to moderate tooth abrasion in both taxa, consistent with diets dominated by relatively soft vegetation. However, *M. reperticia* exhibits consistently lower mesowear values, supporting a predominantly browsing strategy over the long term, whereas *O. virginianus* shows higher average mesowear scores, indicating a greater contribution of moderately abrasive food resources. In contrast, microwear patterns show substantial overlap between the two species. Although *M. temama* displays slightly

greater dispersion in microwear variables and *O. virginianus* shows a somewhat more clustered signal, these differences are subtle and should be interpreted cautiously.

These contrasting signals emphasize the importance of integrating dental proxies with different temporal resolutions. The combination of low mesowear values and variable microwear patterns in *M. reperticia* suggests long-term dietary stability, recorded over the extended functional lifespan of the tooth, coupled with short-term flexibility reflected in microwear signatures that capture dietary behavior during the last days or weeks prior to death. As a forest-dwelling species foraging primarily in the understory, *M. reperticia* consumes plant items whose abrasiveness varies with species, phenology, and proximity to the ground (Flores-Vázquez, 2021). Occasional intake of more abrasive items, such as fallen fruits or low vegetation, may increase scratch counts without producing sustained tooth abrasion detectable in mesowear. Although, the

species remains strongly browse-oriented, the specific plant taxa consumed may vary seasonally and across habitats. As noted by Martínez-Polanco (2026), the fruits consumed by *M. temama* may be relatively soft and therefore unlikely to produce conspicuous microwear features such as pits or gouges, a pattern also observed in other Neotropical cervids. In addition, fruit consumption may be highly seasonal; if most dental wear is generated while animals feed on leaves, buds, and stems, the frugivorous component of the diet may be weakly expressed in the dental record. Although ecological studies report the consumption of fruits and flowers, particularly in montane cloud forests of Mexico (Villarreal-Espino-Barros et al., 2008), dental wear patterns remain dominated by features associated with soft browse. This suggests that the mechanical properties and seasonal availability of fruits may lead to an underrepresentation of frugivory in microwear signatures (Martínez-Polanco & Rivals, 2023), highlighting the need to consider food properties and seasonal dietary contributions when interpreting dental wear patterns.

In contrast, the dental wear patterns of *O. virginianus* indicate a relatively stable feeding strategy across both short- and long-term temporal scales. The Guanacaste specimens originate from a highly seasonal tropical dry forest environment (Jiménez et al., 2016), yet they display moderate mesowear values combined with low microwear dispersion. All individuals were collected during the early rainy season, a period characterized by increased food availability and the selective consumption of young, nutritionally rich leaves (Arceo et al., 2005; Bello et al., 2001; Sánchez-Rojas et al., 1997). Such selective foraging behavior likely reduces short-term dietary heterogeneity and contributes to the relatively homogeneous microwear signal observed (Martínez-Polanco et al., 2023). These patterns are consistent with the well-known ecological flexibility of *O. virginianus*, which combines broad dietary potential with selective feeding when preferred resources are abundant (Granados et al., 2014).

Similar patterns have been documented in other dietary studies from tropical dry forest systems. Microhistological analyses of fecal samples from white-tailed deer at the Chamela Biological Station in Mexico have documented marked seasonal variation in diet composition (Arceo et al., 2005). During the rainy season, deer tend to consume a smaller number of plant species but rely heavily on young leaves, which offer higher nutritional quality and lower concentrations of secondary compounds. In contrast, dietary diversity increases during the dry season, when fruits become a more important resource. Experimental and comparative studies of dental microwear further indicate that fruit consumption may produce distinctive features such as increased pit frequencies, large pits, or gouges in some taxa (Semperebon et al., 2011). However, these signals may vary depending on the mechanical properties of consumed fruits and the degree of environmental contamination by exogenous particles. The absence of these distinctive microwear features in the sample analyzed suggests that fruit consumption was probably limited during the period when the animals were collected.

Finally, although the present study focuses on modern ecological contexts, the low microwear variability observed in *O. virginianus* has important implications for archaeological research. Previous studies have shown that variation in scratch dispersion can inform on the temporal clustering of hunting events when collection dates are well constrained (Martínez-Polanco et al., 2019; Martínez-Polanco et al., 2023). The consistency of the microwear signal documented here therefore provides a valuable modern analogue for future archaeological and palaeoecological studies investigating seasonal patterns of deer exploitation across different environments.

This study provides new insights into short-term dietary variability in Central American cervids by integrating dental microwear and mesowear analyses in extant populations of *O. virginianus* and *M. reperticia*. The results reveal clear interspecific differences in the interpretative resolution of microwear proxies,



closely linked to ecological niche, foraging behavior, and the availability of comparative reference data.

In white-tailed deer, low scratch variability and the clustering of individuals within a single microwear area indicate repeated feeding events concentrated within the same season. Because the exact collection dates of these specimens are known and comparable datasets are available, microwear variability in *O. virginianus* can be robustly interpreted and directly compared with both modern and archaeological populations. These results reinforce the value of white-tailed deer as a reliable reference taxon for evaluating short-term dietary patterns and temporal aspects of resource use in paleoecological and archaeological contexts. However, the limited number of specimens and the restricted representation of seasonal and ontogenetic variation should be considered when extrapolating these patterns to broader populations.

In contrast, *M. reperticia* exhibits pronounced variability in microwear features, particularly in scratch counts, despite consistently low mesowear values indicative of a long-term browsing strategy. This pattern likely reflects short-term dietary flexibility within forested environments, where the abrasiveness of consumed plant items may vary due to plant part selection, phenology, or exogenous contamination, rather than sustained shifts in trophic strategy. While recent studies have successfully applied combined dental wear approaches to *M. reperticia*, the present results underscore the need for careful ecological contextualization when interpreting microwear dispersion in this taxon.

Overall, this study highlights the importance of interpreting microwear variability within a species-specific ecological framework and of grounding such interpretations in well-constrained modern reference datasets. White-tailed deer emerge as a particularly robust model for future comparative and archaeological applications, while expanded regional and seasonal datasets for Central American red brocket deer will further refine the use of dental

wear proxies for reconstructing cervid ecology and human–environment interactions in tropical settings.

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