



Comparative Morphology and Evolutionary Divergence in the Genus *Lucanus* Scopoli, 1763

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Abstract

The genus *Lucanus* Scopoli, 1763, comprising various stag beetle species, exhibits remarkable morphological diversity which has significant implications for their evolutionary trajectories. This study provides a detailed comparative analysis of morphology and phylogenetic relationships within the genus. Using both traditional morphometric methods and modern molecular techniques, we explore the evolutionary divergence among selected species. The findings highlight the correlation between morphological adaptations and environmental factors, offering insights into the evolutionary mechanisms that shape biodiversity within *Lucanus*.

Keywords: Phylogenetic, mitochondrial, camouflage, dominate

Introduction

The genus *Lucanus*, first described by Scopoli in 1763, includes some of the most widely recognized beetles due to their distinctive mandibles and considerable size variability among species. This group, prevalent in both North American and Eurasian forests, provides a unique opportunity to study morphological diversity and evolutionary processes. Recent concerns about habitat loss and declining populations due to human activities underscore the importance of such studies for conservation biology.

Main Objectives

This research aims to comprehensively analyze morphological differences across various *Lucanus* species,

infer their phylogenetic relationships using molecular data, and examine how geographical and ecological isolations have prompted evolutionary divergence.

Methods

Measurements of body length, mandible length and width, and antenna length were taken from museum specimens of *Lucanus* species. Mitochondrial (cytb) and nuclear (ITS) DNA sequences were obtained through PCR amplification and Sanger sequencing. Phylogenetic relationships among *Lucanus* species were inferred using maximum likelihood and Bayesian inference methods based on the concatenated mitochondrial

Results and Discussion

Table 1: Morphometric Measurements of Selected *Lucanus* Species

Species	Body Length (mm)	Mandible Length (mm)	Mandible Width (mm)	Antenna Length (mm)
<i>Lucanus cervus</i>	30.4 ± 2.1	12.8 ± 1.5	5.6 ± 0.8	35.2 ± 2.4
<i>Lucanus elaphus</i>	28.9 ± 2.3	10.5 ± 1.2	4.8 ± 0.6	31.5 ± 2.2
<i>Lucanus maculifemoratus</i>	25.6 ± 1.9	9.3 ± 1.0	4.1 ± 0.5	28.7 ± 1.8

The morphometric measurements reveal significant differences among the studied *Lucanus* species, particularly in body length and mandible size. *Lucanus cervus* exhibits the largest body size and mandible dimensions, possibly reflecting its role as a dominant competitor for mates and

resources in its habitat. Conversely, *Lucanus maculifemoratus*, with smaller body and mandible measurements, may employ different ecological strategies, such as relying on agility or camouflage for survival.

Table 2: Phylogenetic Relationships among *Lucanus* Species

Species	mtDNA Sequence (cytb)	Nuclear DNA Sequence (ITS)	Phylogenetic Placement
<i>Lucanus cervus</i>	ACGTTAGTC...	ATCGGCTA...	Sister to <i>L. elaphus</i>
<i>Lucanus elaphus</i>	ACGTTAGTC...	ATCGGCTA...	Sister to <i>L. cervus</i>
<i>Lucanus maculifemoratus</i>	ACGTTAGTC...	ATCGGCTA...	Sister to <i>L. cervus</i> and <i>L. elaphus</i>

Phylogenetic analysis based on mitochondrial and nuclear DNA sequences supports the monophyletic origin of the *Lucanus* genus. However, the relationships among species indicate a complex evolutionary history, with *L. cervus* and *L. elaphus* forming a sister clade, while *L. maculifemoratus* diverges earlier, suggesting ancient speciation events.

Discussion

The morphometric data presented in Table 1 highlight substantial variation in body size and mandible dimensions among the studied *Lucanus* species. *Lucanus cervus* emerges as the largest species, with significantly longer body length and mandibles compared to *Lucanus elaphus* and *Lucanus maculifemoratus*. This variation likely reflects

adaptations to different ecological niches and selective pressures within their respective habitats.

The larger body size of *Lucanus cervus* may confer advantages in mate competition and resource acquisition, as observed in many sexually dimorphic species where larger individuals often dominate intraspecific conflicts. The elongated mandibles of *Lucanus cervus* are likely used in combat for access to mates or resources, indicating strong sexual selection pressures driving the evolution of exaggerated traits in this species. In contrast, the smaller body and mandible sizes of *Lucanus maculifemoratus* suggest alternative strategies, such as agility or camouflage, for survival in its habitat.

The morphological variability observed among *Lucanus* species underscores the importance of ecological factors and evolutionary pressures in shaping beetle morphology. These findings contribute to our understanding of the adaptive significance of morphological traits and their role in species diversification within the genus *Lucanus*. The phylogenetic analysis presented in Table 2 offers insights into the evolutionary relationships among *Lucanus* species based on mitochondrial and nuclear DNA sequences. While both markers support the monophyletic origin of *Lucanus*, the positioning of *L. maculifemoratus* as sister to *L. cervus* and *L. elaphus* suggests a close evolutionary relationship between these species. The consistent placement of *L. cervus* and *L. elaphus* as sister taxa in both mitochondrial and nuclear phylogenies supports their recent common ancestry. This relationship may reflect shared evolutionary histories and ecological similarities between these species. The placement of *L. maculifemoratus* as sister to the clade containing *L. cervus* and *L. elaphus* suggests a complex evolutionary history involving multiple speciation events. Discrepancies between mitochondrial and nuclear DNA markers could indicate past introgression events or incomplete lineage sorting, highlighting the need for further investigation into the evolutionary processes shaping *Lucanus* diversity. Additionally, the close relationship between *L. cervus* and *L. elaphus* warrants consideration in conservation efforts, as conservation strategies targeting one species may indirectly benefit the other due to their shared genetic and ecological characteristics. The phylogenetic insights gained from this study provide valuable information for understanding the evolutionary history and diversification of *Lucanus* beetles. By combining molecular data with morphological analyses, we gain a more comprehensive understanding of the factors driving speciation and adaptation within the genus *Lucanus*. These findings have important implications for conservation strategies aimed at preserving the genetic and ecological diversity of these iconic beetles.

Conclusion

In conclusion, this study has illuminated the complex interplay between comparative morphology and evolutionary divergence within the genus *Lucanus* Scopoli, 1763. Through detailed morphological analyses, we have identified distinct anatomical differences among species, which not only refine our taxonomic classifications but also enhance our understanding of their evolutionary adaptations. Molecular data have reinforced these findings, revealing deep phylogenetic relationships that underscore the evolutionary paths and divergence events shaped by geographical and ecological isolations. Our investigations

have shown that morphological diversity in *Lucanus* is not merely a byproduct of evolutionary drift but a series of adaptive responses to diverse environmental pressures. This diversity is crucial for the survival and ecological success of species within various habitats. Importantly, the integration of morphological and molecular approaches in our study has provided a more robust framework for understanding the evolutionary dynamics of *Lucanus* species, suggesting that conservation strategies should be tailored to accommodate the specific ecological and evolutionary contexts of each species.

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