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POPULATION DYNAMICS, PHYSIOLOGICAL ADAPTATIONS AND BEHAVIORAL RESPONSES OF GAME SPECIES IN SUBMONTANE ECOSYSTEMS: A MINI REVIEW

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Abstract

Understanding the interactions between physiological processes, population structure, and behavioral responses is essential for the sustainable management of game species in submontane ecosystems, especially under increasing environmental and anthropogenic pressures. This review aims to synthesize current knowledge on population dynamics and physiological adaptations of game species, with a particular focus on cervids and wild boar. The study is based on a comprehensive analysis of recent scientific literature, integrating data on population structure parameters (density, demographic composition) and key physiological mechanisms underlying behavior, including metabolism, thermoregulation, reproduction, and stress response. The results indicate that species-specific physiological adaptations influence survival, reproductive success, and spatial distribution, leading to distinct population patterns in submontane habitats. Overall, the results show that effective game management should take into account the ecological context, physiological constraints, and behavioral patterns of species.

Key words*: behavioral responses, game species, physiological adaptations, population dynamics.*

INTRODUCTION

Game species comprise a diverse group of terrestrial mammals and birds that live in the wild and are not classified as domestic animals. From a hunting perspective, these species are commonly categorized according to body size and management relevance, including large game species such as bear, deer, roe deer, and wild boar, as well as small game species such as hare, fox, lynx, marten, and various bird species, including pheasant, wild ducks, and quail. The composition and diversity of game species vary across geographical regions, being strongly influenced by ecological factors such as climate, habitat characteristics, and food availability, as well as by local traditions and wildlife management practices (Sălăjan, 2017).

Populations are subject to self-regulation mechanisms, such as migration, territorial behavior, and physiological responses to stress, which contribute to maintaining numerical equilibrium. In this context, population dynamics describe temporal variations in these parameters, typically manifested as seasonal, irregular, or cyclic fluctuations (Fryxell et al., 2014).

Research conducted over time on the behavior, ecology, ethology, and physiology of game species has an important role in supporting the development of effective conservation and management strategies (Matei et al., 2024; Vedel et al., 2024; Newman et al., 2024). Ethology, defined as the biological study of behavior and social organization, represents a central field within modern behavioral sciences. Ethological observation and analysis traditionally require considerable effort due to the inherent complexity and variability of behavioral patterns. Nonetheless, a range of methodological approaches has been developed to facilitate the identification, characterization, and classification of species-specific behavioral patterns (Datta et al., 2019; Goodwin et al., 2022).

Within natural ecosystems, wildlife resources have traditionally represented an essential component in meeting human food requirements, being among the most accessible sources of animal-derived food (Boișteanu et al., 2024; Ciobanu et al., 2020). Moreover, the quality and biological characteristics of game products are closely related to the physiological

status, feeding behavior, and environmental adaptability of wild species (Flocea et al., 2024; Gucianu et al., 2023). Beyond their primary role as a direct food source, game species are increasingly recognized for their potential in the development of value-added meat products (Anchidin et al., 2024; Manoliu et al., 2025).

The study of game species in submontane ecosystems represents a complex and interdisciplinary field at the interface of ecology, ethology, and physiology, with scientific and practical important. In the current context, characterized by accelerated climate change and increasing anthropogenic pressure on natural ecosystems, understanding the physiological mechanisms underlying animal behavior becomes essential for the development of effective and sustainable wildlife management strategies.

Game mammals, including especially cervids and suids, exhibit a range of specific physiological adaptations that enable survival and reproduction under the variable environmental conditions typical of submontane areas. These adaptations include seasonal modulation of energy metabolism, efficient thermoregulatory mechanisms, reproductive strategies synchronized with environmental conditions, and complex responses to stress factors. Such physiological processes are directly reflected in behavioral patterns, influencing population structure, spatial distribution, and overall population dynamics (Vilela ș.a., 2020). From an ethological perspective, the behavior of game species results from the dynamic interaction between intrinsic factors (physiological and endocrine) and extrinsic factors (climatic, trophic, and anthropogenic). Therefore, an integrated analysis of these components is essential for improving our understanding of how species respond to environmental changes and wildlife management interventions.

In this context, the present review aims to synthesize current knowledge on population dynamics, physiological adaptations, and behavioral responses of game species in submontane ecosystems, providing a conceptual framework to support sustainable management practices.

This paper aims to review the specialized literature on the physiological characterization of game mammals, with a particular emphasis on the relationships between bioecological, ethological, and physiological foundations and the behavioral manifestations observed under the specific conditions of submontane areas. To provide a clearer overview of the study direction and structure, the main objectives and their interconnections are illustrated in Figure 1.

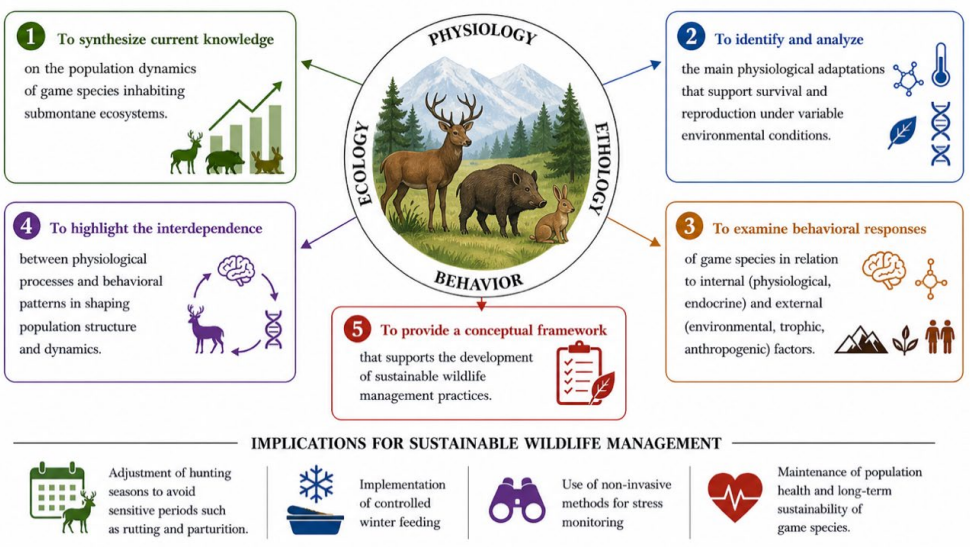

Figure 1. Representation of the study objectives (own elaboration, generated with AI support)

MATERIALS AND METHODS

The present study is based on a review of the scientific literature addressing population dynamics, physiological adaptations, and behavioral responses of game species, with a particular focus on submontane ecosystems. The literature search was conducted using major international scientific databases, including Web of Science, Scopus, PubMed, ScienceDirect, and Google Scholar. Additional sources were identified through institutional resources. The search process focused primarily on studies published between 2010 and 2025, while selected earlier references were included when considered essential for the scientific background of the topic.

The selection of sources was guided by their relevance to the topic, scientific quality, and recency, with priority given to seminal works in the field. Keywords such as "game species", "population dynamics", "physiological adaptations", "behavioral responses", and "submontane ecosystems" were used to identify these studies.

The inclusion criteria considered scientific reports and authoritative publications focusing on the ecological, physiological, ethological, and management-related aspects of European game species. In addition, because the evidence from the literature highlights the need for adaptive management strategies, this review is structured to synthesize the fundamental physiological mechanisms underlying behavior in European game species, within an ethological and wildlife management context.

Four major domains are addressed: energy metabolism, thermoregulation, reproductive physiology, and stress response. These are analyzed in relation to seasonal, age-specific, and sex-related behavioral patterns, as well as to the main ecological drivers influencing species adaptation.

RESULTS AND DISCUSSIONS

Behavioral determinants and ethological context

Understanding the determinants of animal behavior represents a key aspect in the study of game species, particularly in relation to their adaptation to dynamic environmental conditions. The available literature consistently indicates that animal behavior is fundamentally shaped by the interaction between genetic factors, specific to each individual, and environmental influences. Genetic inheritance has different roles in defining metabolic, hormonal, and neurosensory characteristics, thereby influencing how organisms respond to external stimuli and contributing to the development of species-specific behavioral patterns.

Innate behavior, resulting from these genetic determinants, tends to be relatively consistent among individuals of the same species, although individual variability may occur due to genetic differences. In parallel, acquired behavior develops through individual experience, complementing and refining innate responses. The relative contribution of innate and learned behavior varies depending on species and developmental stage, with learned components becoming more prominent in adult individuals and in more evolutionarily advanced species.

Environmental factors, both biotic and abiotic, exert a strong influence on behavioral expression by imposing adaptive pressures that shape species responses over time. In this context, the literature emphasizes that ethological studies cannot be dissociated from ecological approaches, as these disciplines are closely interconnected in understanding the relationships between organisms and their environment (Alanis-Hernandez et al., 2023).

Global anthropogenic changes are increasingly recognized as major threats to animal survival and reproduction, primarily through their effects on behavioral patterns. The literature highlights that migratory species are particularly vulnerable, as they depend on a well-coordinated spatio-temporal sequence of habitats and resources; consequently, even minor disruptions within this chain can lead to some consequences for their development and survival (Vickery et al., 2014; Mizrahi & Peters, 2009).

In addition, climate change has been shown to generate phenological mismatches between species and their trophic resources, with negative implications for population dynamics (Both et al., 2009; Visser & Gienapp, 2019). Several studies emphasize that such disruptions can alter feeding behavior, reproductive timing,

and overall fitness, ultimately affecting species persistence.

From an ethological perspective, research provides valuable insights into how global changes influence animal welfare, performance, and reproductive success. At the same time, the literature underscores the important role of ethology in identifying, understanding, and, in some cases, mitigating human-induced impacts. Within the context of game management, sustained hunting pressure that does not lead to population collapse may still act as a selective force, promoting evolutionary adaptations at both behavioral and morphological levels. The literature suggests that such adaptations arise as a result of natural selection, enabling species to adjust to persistent anthropogenic pressures (Matei et al., 2025). These changes can, in turn, generate cascading effects on interspecific interactions and overall ecosystem functioning (Potratz et al., 2024).

Human hunting activity has been widely reported to induce alterations in the activity patterns of wildlife with broader implications for ecological communities and ecosystem processes (Werner et al., 2003; Schmitz et al., 2004). These behavioral modifications may trigger behaviorally mediated trophic cascades, influencing predator-prey relationships as well as population structure and stability.

For instance, the reduction of age structure within populations due to human-induced mortality has been associated with increased vulnerability to additional environmental disturbances (Audzijonyte et al., 2013). Furthermore, the indirect effects on non-target species represent an often underestimated, yet important component in understanding ecosystem dynamics, highlighting the complex and far-reaching consequences of hunting practices.

Population dynamics of game species in submontane ecosystems

A population represents the fundamental organizational form of a species within a given habitat, functioning as a dynamic and self-regulating system. The principal parameters that characterize populations include population size, density, natality, mortality, and age and sex structure. Population structure is determined by the sex ratio and the distribution of individuals across age classes (juveniles, adults, and senescent individuals), these indicators reflecting both the growth potential and the overall stability of the population.

Individual variability contributes to the adaptability and evolutionary potential of populations under changing environmental conditions. Population size results from the balance between birth and death rates and is influenced by both intrinsic factors, such as longevity and genetic structure, and extrinsic factors, including environmental conditions, resource availability, competition, predation, and anthropogenic pressure. Population density expresses the number of individuals per unit area, with optimal values ensuring efficient resource use without generating ecological imbalances (Fryxell et al., 2014).

The analysis of population dynamics represents a key component in understanding the adaptive responses of game species to both environmental and anthropogenic pressures. The available literature indicates a general increasing trend in ungulate populations, particularly in wild boar and deer, over recent decades, largely attributed to their high ecological adaptability and the reduction of natural predator pressure (Abrantes & Vieira-Pinto, 2023).

Game populations in submontane areas are characterized by a dynamic and adaptive structure, reflected in the expansion of large ungulate populations, high variability among small game species, moderate genetic differentiation between populations, and a strong influence of both ecological and anthropogenic factors. These patterns are closely linked to the physiological foundations of behavior, particularly energy metabolism, reproductive strategies, and stress responses, which collectively shape population resilience and adaptability.

The analysis of population densities of the main game species in submontane ecosystems reveals important interspecific differences, primarily determined by their ecological and physiological traits (Table 1).

The analysis of population densities further highlights species-specific differences in adaptive strategies among game species. Roe deer (*Capreolus capreolus* L.) exhibit relatively high population densities (5–40

individuals/km²), reflecting a high adaptive capacity associated with efficient energy metabolism and considerable trophic plasticity. In contrast, red deer (*Cervus elaphus* L.) typically occur at lower densities (2-10 individuals/km²), which can be explained by their higher energetic requirements and pronounced territorial behavior.

Table 1. Average population densities of game species in temperate and submontane regions of Europe

Species	Density (individuals/km²)	Source	References
Roebuck (*Capreolus capreolus*)	**5-40**	ecological modeling studies (Germany)	Benjamin et al. (2022)
Deer (*Cervus elaphus*)	**2-10**	forestry studies Central Europe	Ionescu et al. (2025)
Wild boar (*Sus scrofa*)	**1-15**	European level estimates	Smith et al. (2026)
Fox (*Vulpes vulpes*)	**0.5-3**	general ecological studies	Benjamin et al. (2022)
Rabbit (*Lepus europaeus*)	**10-60**	European agro-ecosystem studies	

Wild boar (*Sus scrofa*) display a wide range of population densities (1-15 individuals/km²), a pattern closely linked to their high reproductive rate and remarkable ability to exploit diverse food resources. These traits make the species highly responsive to environmental changes. Small game species, such as the European hare (*Lepus europaeus*), generally show relatively high but unstable population densities, being strongly influenced by climatic variability and predation pressure.

At the European scale, population size estimates of major game species confirm the trends observed at local levels, particularly the marked increase in ungulate populations, with wild boar showing the most pronounced expansion (Table 2).

Table 2. Estimated population sizes of major game species in Europe

Species	Estimated population
Wild boar	13.5-19.6 million individuals
Deer	several million (wide distribution)
Roebuck	the most abundant ungulate species in Europe
Rabbit	declining in many regions

Smith et al., 2026; Abrantes & Vieira-Pinto, 2023

The available literature indicates that wild boar (*Sus scrofa*) populations in Europe are currently estimated at approximately 13.5-19.6 million individuals, reflecting a marked expansion of the species over recent decades. This trend has been widely associated with a combination of physiological and behavioral traits, including high fecundity, early sexual maturity, and strong metabolic adaptability, which collectively enhance the species' resilience to environmental variability.

Roe deer (*Capreolus capreolus* L.) are considered the most abundant ungulate species in Europe, a pattern that reflects their high ecological efficiency and superior ability to exploit fragmented habitats. In contrast, the European hare (*Lepus europaeus*) has experienced a decline in many regions, a phenomenon frequently linked to increased sensitivity to environmental stress, agricultural intensification, and elevated predation pressure.

Population structure analyses based on genetic studies reveal varying degrees of differentiation among game species, depending on their mobility and the presence of ecological barriers (Table 3). In the case of roe deer, the analysis of 920 individuals across 16 European sites indicates a relatively homogeneous structure at a large spatial scale, with regional differentiation patterns suggesting moderate dispersal capacity and relatively high ecological connectivity.

Table 3. Population structure of selected game species

Species	No. of individuals analyzed	Population structure
Roebuck	**920 individuals** (16 sites Europe)	relatively homogeneous, but regionally differentiated populations
Wild boar	**486 individuals** (Carpathian Basin)	2 distinct subpopulations (Fst = 0.03)

Niedziałkowska et al., 2024; Mihalik et al., 2020

For wild boar populations in the Carpathian Basin, studies have identified the presence of two distinct subpopulations (Fst = 0.03), indicating a low but important level of genetic differentiation. This structure is influenced by the species' high mobility, social behavior, and elevated reproductive rate. Overall, these findings highlight that population structure is the result of complex interactions between physiological, ethological, and environmental factors, with direct implications for wildlife management strategies.

From a game management perspective, large and productive populations of wild boar and cervids represent valuable resources, providing game meat that is increasingly appreciated in developed countries (Marescotti et al., 2019), as well as generating substantial economic benefits. The literature highlights that recreational hunting contributes positively to rural economies by generating income for landowners, conservation institutions, public authorities, and local communities (Di Minin et al., 2021; Delisle et al., 2024).

In addition, hunting-related services further support economic development at both local and national levels, reinforcing the multifunctional role of wildlife resources within socio-ecological systems (Di Minin et al., 2021; Martín-Delgado et al., 2020).

Physiological adaptations and associated behavioral responses in game species

Seasonal energy metabolism and behavioral adaptations

The literature highlights that seasonal energy metabolism represents a key adaptive mechanism in game species inhabiting temperate and submontane ecosystems. Large mammals typically exhibit pronounced annual metabolic cycles, characterized by increased energy allocation during periods of resource abundance (spring-summer) for growth, reproduction, and fat accumulation, and reduced metabolic activity during winter, when food availability is limited. For example, in red deer (*Cervus elaphus*), basal metabolic rate and heart rate decrease during winter, even in the absence of major changes in body mass or food intake, suggesting the involvement of endogenous biological rhythms and thermoregulatory adjustments (Turbill et al., 2010).

In contrast, wild boar (*Sus scrofa*) display a distinct metabolic pattern, with elevated energy expenditure in early spring (associated with gestation) and late autumn (linked to mating and fat accumulation), and lower metabolic activity during summer. This pattern reflects both the energetic costs of reproduction and the species' omnivorous diet, which supports metabolic flexibility under varying environmental conditions (Ruf et al., 2021).

Reproductive status and age further influence metabolic dynamics. Pregnant and lactating females exhibit increased energy demands, as observed in the European hare (*Lepus europaeus*), where peak energy expenditure occurs during advanced lactation. However, studies suggest that such metabolic limits may be self-regulated to prevent thermal stress, indicating adaptive trade-offs between reproduction and thermoregulation (Valencak et al., 2010). Similarly, in roe deer (*Capreolus capreolus*), metabolic rates increase during late gestation, with important nutritional implications (Mauget et al., 2003).

These physiological processes are closely reflected in behavioral adaptations. During winter, energy conservation strategies include reduced movement, selection of sheltered habitats, and crepuscular feeding patterns, while spring and summer are associated with increased activity levels, driven by reproductive and growth demands. From a management perspective, understanding these metabolic cycles is essential for optimizing hunting practices and habitat management, particularly by avoiding periods of peak physiological stress and ensuring adequate resource availability (Table 4).

Thermoregulation and behavioral adaptations

The literature indicates that thermoregulation in game species is achieved through a combination of physiological and behavioral mechanisms, which are essential for maintaining homeostasis under variable environmental conditions. Physiological adaptations include insulation through seasonal coat changes and peripheral heat exchange, while behavioral strategies are important in modulating thermal stress.

For instance, wild boar (*Sus scrofa*), lacking efficient sweat glands, rely on behavioral thermoregulation such as wallowing in mud and seeking shaded or humid areas to facilitate heat

dissipation. Similarly, cervids adjust their thermal balance through seasonal changes in fur density and by shifting activity patterns, with feeding behavior predominantly occurring during crepuscular periods to avoid thermal extremes. In winter, large mammals may reduce peripheral body temperatures and metabolic activity as part of energy conservation strategies (Turbill et al., 2010).

Table 4. Overview of physiological mechanisms in major game species

Physiological mechanisms	Red deer (*Cervus elaphus* L.)	Roebuck (*Capreolus capreolus* L.)	Wild boar (*Sus scrofa*)	Rabbit (*Lepus europaeus*)	Game birds (pheasants, quails)
Energy metabolism (seasonality)	Intense in spring–summer; reduced in winter through energy saving	Increased in gestation; reduced in winter, efficient use of resources	Increased during breeding periods; reduced at high temperatures	High, maximum in lactation; low in winter, use of reserves	High; increases in reproduction and raising offspring
Thermoregulation and adaptations	Seasonal fur; crepuscular activity; adaptation to thermal variations	Dense fur in winter; avoids exposure; adapted activity	Behavioral thermoregulation (mud, shade); no sweating	Fur insulation; heat preservation posts	Regulation by plumage; shelter and radiation avoidance
Reproduction (seasonality)	Autumn rut (Sept–Oct); calving in spring; intense hormonal activity in males	Summer mating; delayed implantation; spring calving	Breeds in autumn; gestation ~115 days; calving in spring, possibly 2 series/year	Mating in winter; short gestation; 3-4 litters/year under favorable conditions	Breeding in spring; seasonal egg laying; rapid development of young
Stress response (mechanisms)	HPA activation; increased cortisol; chronic stress reduces immunity	Similar HPA response; increased sensitivity in gestation	Intense HPA response; stress reduces resistance to disease	Rapid increases in cortisol; high sensitivity to manipulation	Increased corticosteron; sensitivity to capture and translocation
Associated behavior and ethological implications	Intense rutting behavior; formation of male groups; seasonal activity; under stress: agitation and dispersal	Solitary behavior; high alertness; avoidance reactions in disturbed conditions	Complex social structure; stable hierarchies; territorial behavior	Solitary behavior; rapid avoidance reactions; chicks use camouflage strategies	Rapid flight reactions; sheltering behavior; sensitivity to disturbances
Management and hunting implications	Avoiding hunting during the rut; protecting pregnant females; monitoring stress	Limiting hunting during the breeding season; trophic management during the cold season	Controlling hunting pressure; avoiding artificial selection; managing resources	Hunting during the breeding season; ensuring refuge habitats	Banning hunting during the nesting period; reducing stress through appropriate handling

Turbill et al. 2010; Mauget et al., 1997; Ruf et al., 2021; Valencak et al., 2010.

Behavioral adjustments also include habitat selection in response to thermal constraints. Species may move to higher altitudes or shaded areas during warm periods, reflecting trade-offs between thermoregulation and foraging efficiency (Mason et al., 2017). In birds of hunting interest, thermoregulation involves sun exposure for warming, feather maintenance behaviors, and group aggregation during colder periods to reduce heat loss.

Seasonal variation strongly influences these responses. During harsh winters, animals adopt strategies to conserve heat, such as reduced movement, use of sheltered microhabitats, and aggregation. Conversely, during heat stress, species seek shade and water sources, and shift activity to cooler periods of the day. These thermoregulatory behaviors directly influence spatial and temporal distribution patterns.

From a management perspective, the literature emphasizes the importance of habitat features that support thermoregulation, including the availability of shelter, vegetation cover, and water resources, particularly under changing climatic conditions.

Reproductive physiology and behavioral manifestations

The literature consistently shows that reproduction in European game species is strongly seasonal, primarily regulated by photoperiod and endocrine mechanisms. In cervids and wild boar, shorter day length during

autumn stimulates melatonin secretion and the activation of the hypothalamic–pituitary-gonadal axis, leading to mating periods typically occurring in early autumn, with births synchronized in spring. In roe deer (*Capreolus capreolus*), delayed implantation represents a key adaptive mechanism, allowing mating in summer while postponing embryo development until winter, thereby ensuring parturition under favorable spring conditions (Asher, 2011).

Reproductive cycles are closely associated with pronounced behavioral changes. During the rutting season, males exhibit increased activity, vocalization, and competitive interactions, driven by elevated testosterone levels, often accompanied by reduced feeding and increased energetic stress. After conception, females display more cryptic behavior, selecting sheltered areas for parturition and offspring rearing, while lactation imposes substantial energetic demands. These physiological and behavioral adjustments ensure reproductive success under variable environmental conditions.

Reproductive performance also varies with age and sex. Younger females may delay reproduction until reaching adequate body condition, while adult individuals with established energy reserves are better able to sustain the energetic costs of gestation and lactation. In males, dominance hierarchies during the rut influence reproductive success, and selective pressures, including hunting, may alter population structure and breeding dynamics.

From a management perspective, the literature emphasizes the importance of aligning hunting practices with reproductive cycles. Avoiding the harvest of pregnant females and limiting hunting pressure on dominant males during the rut are key measures for maintaining population stability. Additionally, ensuring adequate nutritional support during critical periods, such as late gestation and lactation, can contribute to improved reproductive outcomes and long-term population sustainability (Matei et al., 2026).

Stress response and associated behavioral manifestations

The literature highlights that the physiological response to stress in game species is primarily mediated by the hypothalamic-pituitary-adrenal (HPA) axis. Exposure to stressors such as predation risk, hunting activities, or extreme climatic conditions triggers the release of glucocorticoids (cortisol in mammals and corticosterone in birds), which mobilize energy reserves and redirect physiological resources toward immediate survival (Vilela et al., 2020; Güldenpfennig et al., 2021). While acute stress responses are adaptive, chronic stress has been associated with suppressed immune function, reduced reproductive performance, and altered population structure.

Behaviorally, stress is reflected in increased vigilance, flight responses, and avoidance strategies, often leading to changes in habitat use and activity patterns. Empirical studies demonstrate that repeated hunting pressure can induce long-term physiological stress. For example, elevated cortisol levels have been recorded in hunted deer populations during hunting seasons, indicating cumulative stress effects (Vilela et al., 2020). Similarly, hunting with dogs has been associated with higher stress responses compared to less intrusive hunting methods (Gentsch et al., 2018). In wild boar, sex-related differences in stress responses have been observed, with females showing higher cortisol levels under hunting pressure (Güldenpfennig et al., 2021).

In birds of hunting interest, repeated exposure to anthropogenic stressors, such as capture and translocation, has been shown to alter baseline corticosterone levels and negatively affect body condition (Dickens et al., 2009), suggesting long-term impacts on physiological regulation. These findings indicate that sustained exposure to stressors may disrupt the HPA axis and compromise species resilience.

From a behavioral and ecological perspective, stress responses can lead to habitat avoidance, increased energy expenditure, and shifts in spatial distribution, particularly in areas subjected to intense anthropogenic pressure. Consequently, the literature emphasizes the importance of monitoring stress levels using non-invasive methods and adopting management strategies that reduce chronic stress exposure. These include adjusting hunting intensity and methods, as well as avoiding hunting during extreme environmental conditions.

CONCLUSIONS

The present review highlights the complex interdependence between population dynamics, physiological adaptations, and behavioral responses in game species inhabiting submontane ecosystems. The available literature indicates that these components are closely interconnected, with physiological mechanisms such as energy metabolism, thermoregulation, reproductive processes, and stress responses has some roles in shaping behavioral patterns and population structure.

The findings emphasize that game species exhibit a high degree of adaptability to both environmental variability and anthropogenic pressures. However, ongoing global changes, including climate variability and intensified hunting activities, may disrupt these adaptive mechanisms, with potential consequences for population stability and ecosystem functioning.

In this context, the integration of physiological and ethological knowledge into wildlife management strategies is essential. Adaptive management approaches, including the alignment of hunting practices with biological cycles, the protection of critical reproductive periods, and the reduction of chronic stressors, are key elements in ensuring the sustainability of game populations.

Furthermore, the literature underscores the importance of continuous monitoring and the use of non-invasive methods to assess population health and stress levels. Such approaches can provide valuable insights for improving management decisions and mitigating the impact of human activities.

Overall, a comprehensive understanding of the interactions between physiological processes, behavior, and environmental factors provides a robust framework for the development of sustainable and scientifically grounded game management practices in submontane ecosystems.

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