SUSTAINABLE MANAGEMENT PRACTICES AND THEIR IMPACT ON THE BEHAVIOUR OF GAME SPECIES

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Abstract

The aim of this paper was to assess the impact of sustainable management practices on the ethology of game fauna, by analyzing the specialized literature. The method used consisted of reviewing relevant studies, selected from international scientific sources, that addressed the concepts of game resource management, sustainability principles and associated effects on the behaviour of species of interest. The results of the analysis highlighted the fact that the applied management practices, such as food management, habitat management, species management and predator control, have a direct impact on the behaviour of game fauna, influencing distribution, feeding behaviour, reproductive strategies and social interactions. Also, numerical fluctuations of populations, determined by natural or anthropogenic factors, can be balanced by applying sustainable measures, focused on the precautionary principle and habitat conservation. The analysis showed that habitat loss and fragmentation, pollution and illegal trade remain major risk factors, requiring adapted interventions.

Key words: *game species, ethology, sustainable management, habitat management*

INTRODUCTION

Sustainable game management practices are generally grounded in development principles that encompass criteria such as species conservation, the impact of applied management measures on target species, the involvement of stakeholders interested in their preservation, and the implementation of measures proportionate to the anticipated risks to the species [1]. The best-known concept in this context is the precautionary principle [2].

Numerical fluctuations in wild populations, resulting from hunting, accidents, predation, starvation, or disease, represent some of the most significant challenges in wildlife management, for which sustainable solutions must be identified [3]. If the number of animals leaving a hunting area were balanced by the recruitment of new individuals, the population could remain stable over the long term [4]. However, such fluctuations are not always driven by increased mortality; they may also be caused by habitat loss and fragmentation, pollution, or other anthropogenic pressures [5].

In terms of anthropogenic influences, a considerable proportion of hunting resources can be affected by trade, which may negatively impact game species — from reducing their chances of survival in the wild to increasing their risk of extinction when specific criteria are met.

Over recent decades, human pressure on natural habitats has intensified significantly, disrupting biodiversity and ecological balance. Within this context, sustainable hunting management has become essential for the conservation of game species and the maintenance of ecosystem functionality [6].

Ethology is the study of animal behavior and plays an important role in evaluating the

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welfare of game species. Behavioral studies provide valuable insights into the adaptability and health of populations, thereby supporting the implementation of more effective management strategies [6].

The main objective of this paper is to analyze sustainable hunting management practices and evaluate their impact on the behavior of game species. This approach aims to identify best practices that promote species conservation and the protection of their natural habitats.

MATERIAL AND METHOD

This paper is theoretical in nature and is based on the analysis and synthesis of existing literature on sustainable hunting management practices and their impact on the behavior of game species.

To develop the study, scientific articles, specialized books, and technical reports published between 1990 and 2024 were consulted, drawing on major international databases such as ScienceDirect, SpringerLink, Web of Science, and Google Scholar. The selected sources were chosen based on their relevance to the topic of this paper, with particular emphasis on studies addressing: (1) the principles of sustainable management within hunting ecosystems; (2) behavioral patterns of wildlife (feeding, social, reproductive, and territorial behaviors); (3) the effects of anthropogenic interventions on population behavior and dynamics; (4) the application of modern technologies (GPS monitoring, drones, motion-sensor cameras) in the study of animal behavior.

The analysis was conducted using a comparative and synthetic approach to existing studies, with the aim of identifying differences among the results reported in the specialized literature. Examples of best practices in the sustainable management of game populations were examined, along with the potential positive or negative effects of these interventions on species behavior.

The paper focuses on:

(1) the relationship between sustainability and ethology as an indicator of fauna welfare;

(2) the impact of management practices (supplementary feeding, density control, habitat restoration) on the social and spatial behavior of species;

(3) the limits of current studies and future research directions, in the context of environmental changes and technological progress.

The data and conclusions were interpreted based on scientific reference sources.

RESULTS AND DISCUSSIONS

Sustainable hunting management encompasses the set of measures planned and implemented to ensure the rational use of game fauna resources, while conserving them in the long term, maintaining ecosystem balance, and addressing socio-economic needs [7,8]. Examples of sustainable management practices are described in Table 1.

The fundamental principles include [2]:

I. Biodiversity conservation – safeguarding the diversity of game species and their habitats, preventing genetic loss and local extinction. This entails monitoring populations and implementing measures to protect vulnerable species.

II. Food balance – maintaining natural predator–prey relationships to prevent ecological imbalances, such as overpopulation of certain species or the local extinction of others.

III. Responsible use of resources – game exploitation should be planned and adapted according to population density, the breeding season, and the regenerative capacity of the habitat.

A schematic illustrating the principles and reference elements can be found in Fig. 1.

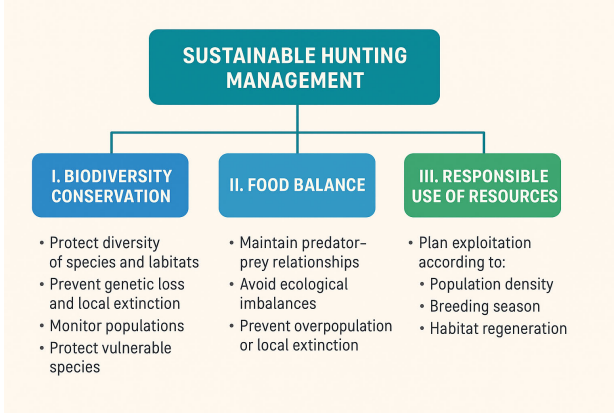

Fig. 1 Fundamental principles of sustainable hunting management

Table 1 Examples of sustainable management practices

Management measures	Implementation conditions
Population density control	This is achieved by planning the hunting season and establishing harvest quotas, thereby avoiding overcrowding and habitat degradation.
	Continuous monitoring of population density allows management measures to be adapted in response to ecological changes.
Development of ecological corridors	Ecological corridors connect different habitats, facilitating migration and genetic exchange between populations, and thereby reducing species isolation; examples include protective forests between agricultural lands and pastures, as well as green belts along watercourses.
Habitat restoration	Restoration of degraded areas involves planting native vegetation, controlling soil erosion, and rehabilitating wetland or forest ecosystems.
	This ensures the availability of adequate food and shelter resources for game species.
Controlled supplementary feeding	It is applied during critical periods (e.g., winter or drought) to prevent excessive mortality, while avoiding alterations to natural foraging behavior.
	It is important to monitor both the quantity and quality of food provided to prevent health problems and dependency on supplementary feeding.

The care and sustainable management of game involves a set of practical principles and guidelines aimed at maintaining balance at the habitat level, both in terms of wildlife population development and applied management practices. Some principles of sustainable management focus on hunting activities, while others address administrative and legislative aspects (Table 2).

In accordance with these principles, the most common management practices in hunting include: (1) feed management, (2) habitat management, (3) species management and (4) predator control.

Sustainable management of existing food resources involves the monitoring of pastures, crops, and forest stands, which constitute the main food sources for game species [9].

Regarding stand management, the most important considerations include controlling the use of fertilizers and biocides, as these can have harmful effects on wildlife. Grazing management is implemented by regulating the number and grazing patterns of domestic animals within hunting grounds. Low grazing pressure generally benefits most game species, as it reduces the risk of local extinction of

various plant species. Conversely, excessive grazing due to poor management can reduce plant diversity, particularly in mountain ecosystems, by favoring coarse grass species [10].

To mitigate these effects, grazing areas are typically managed using a rotational system that allows rest periods and avoids disturbances during critical stages of the life cycle of game species [11,12]. The most adverse impacts on pastures, which in turn affect game populations, are usually associated with intensive land use, leading to food scarcity and a general reduction in habitat diversity.

To meet the nutritional requirements of game during critical seasons, such as post-reproduction periods or hunting seasons, sustainable hunting management recommends planting specialized agricultural crops, including cereals or perennial legumes. Similar to arboretums, the use of agrochemicals around these crops is strictly prohibited, especially during breeding periods [13].

Habitat management aims to maintain natural areas adapted to the needs of wildlife, providing optimal food resources and protection from natural predators. This practice benefits most game species by diversifying habitats and attracting a variety of other species. Many species avoid open, short-grass areas because they offer little cover from predators, highlighting the need for habitat management measures to maintain the desired habitat mosaic [14].

Hedgerows have been identified as particularly important for wildlife in agricultural landscapes. Hunting management can contribute positively by promoting the creation and maintenance of hedgerows, thereby enhancing habitat quality. Additionally, the management of herbaceous plant resources is a key component of game management, as it can mitigate the negative effects of agricultural operations, such as pesticide application, while improving habitat suitability for breeding and wintering [15].

Species Management. Two key practices associated with the sustainable management of game species are disease and parasite control, and the provision of supplementary feed, water, and mineral salts. Disease and parasite control is essential for maintaining the balance of wildlife populations, as the risk of transmission is often higher than in domestic animals. Preventive medications or protective substances are generally administered at feeding sites to maximize the likelihood of effective treatment [11].

The provision of supplementary feed is a common management practice in many hunting areas, particularly near agricultural landscapes. Its primary purposes are to reduce the damage caused to crops and to maintain the body condition and proper development of game animals until the hunting season.

Predator control is a traditional practice in game management, implemented in many countries, and involves managing a wide variety of predators, including raptors, foxes, and jackals [16].

In general, predator management should prioritize habitat management to minimize the risk of predation. This can include modifying predator habitats, enhancing cover, increasing the size and density of habitat areas, and reducing the isolation of cohabitation zones. In practice, direct predator control is commonly applied [17, 18], while an “integrated pest management” approach has also been proposed for the strategic regulation of different natural predators [19, 20] (Rollins & Carroll, 2001).

However, predator control remains a controversial practice. It can potentially destabilize game populations and negatively affect biodiversity conservation by influencing the abundance and distribution of legally protected species.

Table 2 Applied hunting management practices and their effects

Applied practices		Effects	Refs
Impact of artificial feeding on feeding patterns	Changing natural feeding patterns	Animals tend to concentrate around feeding points, which reduces the time and energy spent foraging naturally. For example, deer and elk provided with supplementary feed often decrease their daytime activity and alter their movement routes.	[7]
	Effects on spatial distribution	Concentrated feeding can result in the aggregation of certain species in specific areas, increasing the risk of intra- and interspecific competition, as well as the transmission of diseases.	[8]
		Field studies have shown that artificially fed areas exhibit higher population densities compared to unfed areas, which may affect the local trophic balance.	
	Influence on social and reproductive behavior	Concentrations of artificial food can promote dominance of certain individuals over subordinates, thereby altering social interactions and potentially affecting the reproductive success of some animals.	[21]
		Altering the feeding routine may result in a closer synchronization of nocturnal activity in response to human presence or other disturbances.	
Population density control	Impact on social behavior	Reducing density through controlled harvest or other management measures reduces competition for resources and intra-specific stress; e.g. in deer or fallow deer populations, decreasing density leads to reduced aggression between males and a better distribution of females across the territory, favoring reproductive success.	[8]
	Modifying group interactions	High population density promotes the formation of large groups and increases social conflicts, which can negatively impact the health and growth of juvenile individuals.	[7]
		Population control contributes to the formation of more balanced social groups, with stable hierarchies and the preservation of natural vigilance and foraging behaviors.	
	Indirect effects on feeding and movement behavior	In overcrowded populations, individuals need to travel greater distances to locate food, which can increase energy expenditure and their vulnerability to predators or extreme environmental conditions.	
		By maintaining population density at optimal levels, animals are better able to follow their natural feeding, migration, and reproductive patterns.	
Habitat restoration and provision	Migration routes and habitat connectivity	Restoring degraded areas and creating ecological corridors facilitates seasonal migrations of game species, such as deer or roe deer, and reduces population fragmentation; e.g. restoring protective forests between agricultural lands or reconnecting wetlands allows individuals to move safely for feeding and reproduction.	[8]
	Territorial behavior	Well-structured habitats and sufficient resources allow for the establishment of more balanced territories, reducing conflicts between individuals and promoting stable social hierarchies.	
		In degraded or fragmented habitats, animals tend to concentrate in small areas, which increases aggression and stress, affecting reproduction and survival of young.	
	Adaptation to anthropogenic pressure	Habitat restoration can reduce disturbances caused by human activities by providing safe refuges and feeding areas.	[21]
		Animals can maintain their natural feeding and migration patterns, and population density is distributed more evenly across the available territory.	

Artificial feeding of game species is a common practice in sustainable management, particularly in areas affected by severe winters, droughts, or high population densities. It has significant effects on animal behavior and must be carefully planned and monitored to prevent dependence on human-provided food, overcrowding, and adverse impacts on the health and natural behavior of the species. In this context, sustainable management practices include rotating feeding points and maintaining controlled feeding periods.

Population density control is not limited to achieving quantitative harvest objectives; it also directly influences the social behavior of individuals and the overall health of the population. Sustainable management involves assessing population densities in the field and applying adaptive measures to maintain a balance between natural behaviors and anthropogenic pressures [22].

Habitat restoration and provision are essential components of sustainable management, directly influencing the distribution and behavior of game species. By restoring and maintaining suitable habitats, managers can positively affect migration patterns and territorial behavior. Practices that enhance habitat connectivity and the availability of natural resources help reduce stress, stabilize social hierarchies, and support long-term population conservation [13].

While sustainable management practices can provide significant benefits to the behavior and health of game, they must be implemented carefully to avoid negative consequences such as dependence on artificial feeding, overcrowding, and disruption of natural behaviors (Table 3).

The relationship between sustainability and ethology is one of mutual interdependence. Sustainable management practices cannot be effective without a thorough understanding of the behavior of game species, while ethology provides essential indicators for assessing the success of these measures.

Table 3 Positive and negative effects of management practices on game behavior

POSITIVE	NEGATIVE
Mitigation of Human–Wildlife Conflicts	**Dependence on artificial feeding**
Through controlled supplementary feeding and habitat restoration, animals are able to access the necessary resources within protected or specially managed areas, thereby avoiding agricultural lands and human settlements. Population density control further helps reduce overcrowding and the damage caused by game species to crops and property.	Excessive or uncontrolled use of supplementary feeding can disrupt natural foraging patterns and reduce the mobility of species, thereby affecting their adaptive behavior. For example, animals may become concentrated around feeding points and lose the ability to forage naturally.
Maintenance of Stable Social and Territorial Behaviors	**Crowding and disease transmission**
Populations inhabiting well-structured habitats tend to maintain more stable social hierarchies, which reduces aggression and intraspecific stress. Seasonal migration patterns and natural feeding routines are preserved, supporting the overall health and reproductive success of the species.	Artificial feeding and high population density in certain areas can facilitate the spread of diseases and parasites. Crowding often leads to increased social conflicts and stress, negatively affecting the health and reproductive success of juveniles.
Long-term conservation of populations and biodiversity	**Alteration of migration patterns and territoriality**
Sustainable practices help maintain a balance between population density, available resources, and trophic relationships within the ecosystem.	The creation of ecological corridors or restored habitats, if not properly planned, may alter natural movement routes, leading individuals to avoid important areas or to concentrate excessively within limited territories.

Behavioral patterns related to feeding, migration, reproduction, and social interactions directly reflect the well-being of populations and the overall balance of ecosystems [8].

Thus, sustainable management requires adapting human interventions to the ethological needs of wildlife — for example, respecting breeding periods, maintaining migration routes, and ensuring the availability of natural food resources. Without these considerations, management practices risk becoming counterproductive, generating stress, dependency, or abnormal behaviors in animals [7,21].

Most studies examining the relationship between management and the behavior of game fauna reveal several limitations. Firstly, the lack of long-term monitoring hinders the evaluation of cumulative effects arising from management interventions such as artificial feeding or habitat modification. Secondly, ethological differences between species limit the generalization of results; for instance, the adaptive behaviors of cervids differ significantly from those of suids or lagomorphs.

Moreover, local factors – anthropogenic pressure, climate, and vegetation structure – significantly influence behavioral responses, highlighting the need for a contextualized and adaptive approach to wildlife management. Modern perspectives in ethological research and sustainable management increasingly emphasize the integration of digital monitoring technologies.

GPS telemetry systems attached to individuals enable the tracking of migration routes and territorial dynamics, providing accurate data on space use and behavioral responses to habitat changes [23]. Drones can be employed for discreet population monitoring and for identifying stress zones or high-density areas without inducing disturbance. Likewise, motion-sensor cameras generate valuable ethological data on nocturnal activity, social interactions, and behavioral reactions to environmental factors.

The integration of these tools into sustainable management programs offers a more comprehensive understanding of the relationship between anthropogenic interventions and the natural behavior of game fauna, thereby supporting adaptive and evidence-based conservation strategies.

CONCLUSIONS

The analysis of the relationship between sustainable management practices and the behavior of game fauna underscores the necessity of integrating ecological and ethological principles into a unified conservation framework. Ethology, through its role as an indicator of species' well-being, adaptability, and social stability, provides a robust foundation for assessing the effectiveness of management strategies.

Sustainable management measures - such as population density regulation, controlled supplementary feeding, habitat restoration, and the creation of ecological corridors - can generate significant ecological and behavioral benefits, contributing to the reduction of human–wildlife conflicts, the maintenance of trophic balance, and the preservation of biodiversity. However, when applied inappropriately, these interventions may lead to unintended consequences, including dependence on artificial feeding, disruption of migration routes, or increased intra- and interspecific competition.

Overall, the reviewed studies indicate that genuine sustainability in game management cannot be achieved solely through technical interventions, but requires an adaptive approach grounded in behavioral monitoring, ecological understanding, and long-term observation of wildlife populations.

In this regard, the integration of modern technologies - GPS tracking, drones, and motion-sensor cameras - provides innovative perspectives for assessing the impact of management practices and for optimizing decision-making based on

concrete ethological data. In conclusion, achieving a balance between conservation objectives and resource utilization must rely on understanding animal behavior as a central component of sustainability. Only through a careful correlation between management practices, ethological knowledge, and ecosystem dynamics can effective and ethical management of game fauna be ensured, in alignment with the principles of sustainable development.

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