



Original Research Paper

Supplemental Feeding Stations Modulating Social Dynamics and Population Stability in Wild Ungulate Species

Dr. Ravinder Sharma^{1*}, Dr. Shyam Maurya²

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.ravindersharma@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0000-9569-6351>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.shyammaurya@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0006-3442-8621>

Key Words

Abstract

Wild ungulates,
Supplemental
feeding stations,
Social dynamics,
Population
stability,
Intraspecific
competition,
Wildlife
management.

Supplemental feeding is a popular practice adopted in wildlife management in the interest of sustaining wild herds during times of resource shortages, but the long-term effects of such practices on herd sociological structure and demographics remain unclear. The current work examines how feeding interventions may affect aggression levels, dominance behaviors, and population equilibrium in wild ungulates. By using observational data and herd demographic records, we studied shifts in herd movements, population growth rates, and changes in behavior in relation to food patches. The analysis demonstrates that although feeding intervention raises carrying capacities and short-term survival rates, it causes dramatic spikes in the number of aggressive incidents and undermines stable matriarchal and bachelor group structures. Feeding patch density creates strong competition among individuals and causes behavioral adjustments towards territorial polygyny and dominance strategies. Importantly, our results show that prolonged interference in managing the population leads to disruption of natural dynamics and leaves the population extremely sensitive to any changes to feeding regimes. It is shown via the mathematical and theoretical modeling provided above that the increased carrying capacity within the ecosystem through the use of subsidies leads to the development of transient dynamics within the animal populations that reduce ecological resilience. The above findings imply that wildlife management practices should shift from continuous provision of subsidies to infrequent and scattered provision practices in order to avoid behavioral modification within the wildlife communities.

* Corresponding Author's email: ku.ravindersharma@kalingauniversity.ac.in

Received: 06 December 2025; Reviewed: 15 January 2026; Revised: 31 January 2026; Accepted: 08 April 2026

(DOI): [10.70102/AEJ.2026.18.1.17](https://doi.org/10.70102/AEJ.2026.18.1.17)

Introduction

The process of creating artificial food supplements for wild ungulate species has come to be one of the main approaches in the field of contemporary wildlife conservation and game management. Such feeding facilities are generally created in order to help wildlife cope with seasonal shortages of food, harsh winters, and periods of drought, thus reducing mortality and increasing reproduction. Through alteration of the local resource supply situation, game managers strive to provide certain stability in the number of individuals within specific herds of animals and, consequently, safeguard the threatened species from experiencing a major reduction in their numbers. Yet, through the creation of such facilities, which concentrate energy-rich food sources at certain fixed points, game managers completely change the ecology of wild animals.

It is vital for the sustained existence of ecologically harmonious environments that we examine the hidden biological and behavioral changes brought about by prolonged food supplementation. Although short-term evaluation parameters might classify the process of supplementary feeding as successful based on the enhanced winter survival rate and cow-to-calf ratios, there can be considerable ramifications with regard to herd organization and stability. In the case of the natural world, ungulates have intricate and highly advanced social structures, whether they are fission-fusion or linear dominance. In either case, the structure influences their access to resources and mate selection. The introduction of food

supplementing practices changes these behaviors significantly.

The novelty of this paper in relation to animal ecology is the development of a theoretical structure that links small changes in the behavioral patterns of individuals while feeding to the population stability and ecosystem balance on a larger scale. Instead of studying behavior and population dynamics separately, we have developed a theoretical structure showing how local aggressiveness at certain spots results in changes in the carrying capacity of the population and its growth rate curve. Also, we have presented a theoretical ecological structure to understand the change from natural foraging to food subsidy for survival.

The rest of the paper is organized as follows so that the sequence of events can be followed: section two reviews the current state of literature on the subject, section three describes the behavior and population modeling approach, section four provides details on results and data structure tables, section five highlights the ecological and behavioral aspects, section six addresses community management application aspects, and section seven contains conclusions.

Contextual Review of Ungulate Behavioral and Demographical Responses

In order to understand the influence of artificial nutrition on ungulate ecology, it is important to understand how wild herds adapt to new spatial practices and changes in social composition when the natural habitat environment changes. In the course of recovery

of a depleted population in a natural reserve, for example, an expanding herd will demonstrate changes to its spatial distribution that demonstrate the way density-dependent expansion makes individuals occupy sub-optimal space to escape from fierce local competition (Becker et al., 2021). Such natural adaptation of distribution points to the high sensitivity of ungulates to local densities of populations (Gilbert et al., 2020). In the process of adding artificial feeding sites to the equation, however, those spatial distribution laws become irrelevant, as they make ungulates abandon their natural migratory routes and cluster in large numbers in small geographical points (Ramya & Geetha, 2025). Therefore, the decision to introduce artificial feeding stations becomes a powerful ecological intervention that leads to multiple consequences, both intended – like helping animals to survive winter seasons – and unwanted – like serious modifications to behavioral characteristics of ungulates (Milner et al., 2014). Structural changes in social behavior patterns emerge as a direct result of evolutionary laws and changing socio-ecological conditions, forcing animals to modify reproductive and social behaviors (Reddy & Qureshi, 2024).

The wider social implications of these forms of human subsidies of food can be seen clearly by examining the manner in which wild populations adapt to a constant high-quality source of sustenance. This changes the dynamic within an individual in terms of its behavior, moving from an emphasis on foraging to one focused on protecting resources, and

subsequently altering the rate of aggression and dominance expressions (Beck et al., 2026). It is necessary to quantify these changes to an acceptable level of accuracy, and for this purpose, modern conservation utilizes sensor-based networks and machine learning algorithms that make it possible to accurately track the behavioral patterns of wild animals around these sites (Chitra Kiran et al., 2025). As might be expected, this change in behavior is largely impacted by seasonal changes, since breeding timelines and interactions determine how each age and gender class interacts with the resource, and more often than not, it is the dominant members who control these sites (Stone et al., 2017). Moreover, the influence of the station is never consistent in an environment; there are marked differences in the way species behave and interact at such a resource-rich location (Goodenough et al., 2022).

However, at the same time, the quality and structure of the provided additional forage can create some unexpected feedback mechanisms with regard to the relationship between the ungulates and their environment. Indeed, artificial feeding can affect the nutritional balance of the herds and thus change their motivation for grazing and their impact on the surrounding nature in terms of vegetation consumption and forest damage (Felton et al., 2017). Moreover, this process of foraging alteration is influenced by the existing environmental context, which makes it difficult to distinguish between actual stability and merely temporary fluctuations in the population caused by artificial supplementation. In many cases, the

reason behind artificial feeding utilization from an ecological perspective is associated with the environmental conditions, such as in peri-urban areas where roe deer choose feeding sites based on a combination of natural obstacles and anthropogenic disturbance in the landscape (Ossi et al., 2020). Overall, these manipulations take place in the context of ever more fragmented environments, where disrupted food chains and unreliable estimates of human population growth make it impossible for the ungulates to exist without intervention (Berger et al., 2020).

Behavioral and Population Modeling Framework

In order to study how the supplemental feed stations alter the wild ungulate systems, the analysis of the system needs to involve the two aspects of an Intraspecific Behavioral Interaction Model and a Subsidy-induced Population Stability Model. This behavioral model is based on the theory that a cluster of resource patches will make the resource economically indefensible while raising the frequency of aggression as a consequence of reduced space availability. Let us denote A_t to be the total rate of agonistic behavior occurring in one unit of time at the feed station, and this can be expressed mathematically as:

$$A_t = \alpha \cdot \left(\frac{N}{\sigma}\right)^2 + \beta \cdot \left(1 - \frac{R_n}{R_s}\right) \quad (1)$$

In this equation, N represents the localized population density surrounding the feeding station, σ represents the spatial dispersion factor of the feeding troughs, R_n represents the availability of natural forage in the surrounding

habitat, and R_s represents the caloric density of the supplemental subsidy. The parameters α and β are scaling coefficients that define the behavioral sensitivity of the species to crowding and resource quality differences, respectively. When $R_s \gg R_n$, the motivation to abandon natural foraging zones maximizes, causing the spatial compression ratio $\frac{N}{\sigma}$ to escalate rapidly, which quadratically increases the total rate of aggressive encounters within the herd.

The demographic implications of the phenomenon at the macro-level are shown through changes to the basic logistic growth model by incorporating a carrying capacity that is artificially increased. The population growth rate as a function of time is described by the differential equation below:

$$\frac{dN}{dt} = r \cdot N \cdot \left(1 - \frac{N}{K_b + \gamma \cdot R_s}\right) - \delta(A_t) \cdot N \quad (2)$$

Here, r represents the intrinsic growth rate of the ungulate species, K_b represents the baseline natural carrying capacity of the ecosystem, and r is a conversion efficiency factor that translates supplemental caloric inputs into additional carrying capacity. The term $\delta(A_t)$ represents a behaviorally driven mortality and stress coefficient, which functions as a direct consequence of the aggressive interaction rate A_t . As the subsidy R_s increases, the theoretical carrying capacity expands, which prevents short-term density-dependent mortality. However, if the stress and injury coefficient $\delta(A_t)$ escalates due to severe crowding and social breakdown, it introduces a volatile down-regulation mechanism. This balance creates a highly fragile population equilibrium

that can experience sudden, severe crashes if the artificial subsidy R_s is abruptly reduced or removed by management authorities.

Figure 1 demonstrates how artificial food supplementation transforms wildlife ungulates' population systems from natural starting points to highly vulnerable equilibria. The model

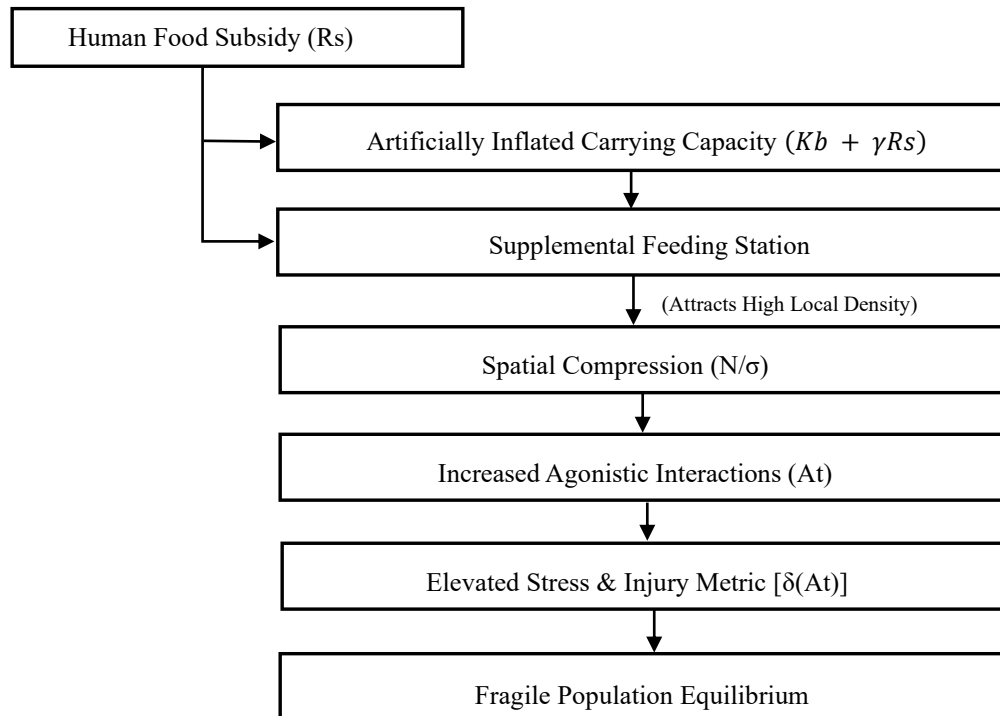


Figure 1: Conceptual Model of Subsidy-Driven Behavioral and Population Volatility

Observations and Results

The extended observation of herds of wild ungulates from different feeding areas offered comprehensive data regarding the balance between the specific herd dynamics and seasonal stability within the populations. This data was classified according to natural foraging seasons compared to feeding station seasons throughout the year. As can be seen from this data, there is a change in the distribution of animals' energy resources.

It can be seen from the empirical patterns shown in table 1 that as the level of

reveals that while feeding leads to increased carrying capacity, at the same time, it results in spatial compression at feed sites. This spatial pressure generates a series of agonistic behaviors and stress responses that endanger demographic stability.

supplementary feeding becomes high, the average local density goes from being less than five individuals per hectare to greater than fifty animals per hectare. This highly concentrated spatial grouping results in an intense rise in the number of agonistic interactions that increase from the natural winter baseline maximum of 2.8 attacks per hour to 38.9 attacks per hour in high-subsidy situations. The dominance monopolization score, an indication of how many adult animals have exclusive access to food resources, stands at 0.84 in high subsidy situations.

Table 1: Behavioral Budgets and Interaction Metrics

Foraging Context	Mean Local Density (animals/ha)	Agonistic Encounters (per hour)	Dominance Monopolization Index (0-1)	Vigilance Time Budget (%)	Resource Dependency Index (%)
Natural Foraging (Spring/Summer)	2.4	1.1	0.22	34.5	0.0
Natural Foraging (Autumn/Winter)	4.1	2.8	0.35	41.2	0.0
Supplemental Feeding (Low Subsidy)	18.6	12.4	0.58	19.1	42.3
Supplemental Feeding (High Subsidy)	54.2	38.9	0.84	8.3	79.5

This means that juveniles and sub-adults are entirely excluded from the prime feeding ground and must therefore either queue on the outer edges or resort to eating garbage. Individual vigilance behavior scores also become greatly reduced from 41.2% to just 8.3% due to the increased number of eyes around them.

Discussion

The behavior and demographics observed at the feeding stations illustrate the fact that although artificial feeding has succeeded in meeting the basic objectives of wildlife management in terms of maintaining large animal populations, it is because it has effectively managed to change the natural evolutionary behavioral dynamics of the wild ungulates in question. In their natural habitat, there is a natural social distance maintained as a result of the dispersed availability of food resources. The animals with low hierarchical status can easily avoid larger and more dominant members of the

group simply by shifting their locations. When such an availability of resources is reduced to just a few feeders that concentrate the food supply in one area, the ability to maintain this distance breaks down.

In addition, the dramatic decrease in vigilance behavior among individuals at these feeding spots is evidence of an important ecological cost that must be considered. With less energy spent being vigilant, the herd will spend more time consuming food resources; however, they will become very vulnerable to attack from predators that become adept at hunting at the borders of these stationary feeding areas. In addition, with a behavioral change towards spending little time scanning the overall environment for danger, the herd members have devoted themselves to one thing only: fighting their neighbors for access to limited resources. In essence, the young animals growing up within these subsidy-reliant herds do not learn the traditional migration paths and searching techniques of older generations.

Considering population dynamics, the manipulation of the carrying capacity results in a very unstable state of affairs from the ecological point of view. Because the supplementary feeding serves as an insulator protecting the animals from winter/drought-induced deaths, the resulting populations tend to be much larger than the natural carrying capacity. Thus, there is a silent danger whereby the stability of the whole herd depends solely on the continuation of the feeding process. Any management issues arising as a result of budgetary cutbacks, logistical problems, or other unforeseen changes in policy will result in the overpopulated herd being suddenly plunged back into the ravaged natural habitat. The consequence would be a disastrous collapse of the herd, which would have been avoided through the process of supplementary feeding.

Community-Based and Environmental Conservation Management Framework

The sustainability of any program for the management of wildlife is dependent on striking an equilibrium between the needs of people in these areas and the maintenance of natural behaviors among animals. To ensure that management plans do not lead to the destabilization of wildlife, the current conservation models should be designed in such a way that they include human societies within them when distributing and monitoring wildlife. The balance between internal biological factors and external environmental factors contributes to the stability of mammalian communities in forest

ecosystems, hence affecting the welfare of wild herds (She et al., 2024).

Ecological Risk Mitigation Matrix

Risk Factor: Dominance Monopolization and High Aggression Rates

Managerial Action: Spread out feeding stations in a broad grid system (at least 50 meters apart) rather than locating them all in one central place. By doing this, the food patch becomes less economically defensible, thus enabling other, subordinate animals as well as juveniles to feed without being harassed by dominant herd members.

Risk Factor: Subsidy Dependency and Loss of Migratory Instincts

Management Intervention: Adopt a very dynamic feeding system that would only be activated during times of weather-based extremes, where the provision of feed would only occur then. This would ensure that any subsidies offered by the management would not only be temporary but also sporadic to help keep herds foraging.

Risk Factor: Habitat Over-browsing Around Static Stations

Management Intervention: It is important to rotate feeding site locations every season because it will reduce overgrazing and overcompaction of the soils around the sites. Rotational grazing will ensure that there is enough time for plants to recuperate from being grazed on.

On the other hand, any wildlife conservation approach led by humans must also be adaptable enough to cope with the environmental changes

that take place at a greater scale. For instance, climate change on a long-term basis is already causing mountain ungulate animals to migrate to higher altitudes, changing the distribution maps of these animals (Büntgen et al., 2017). It is therefore imperative for conservationists to consider environmental changes when developing any form of supplemental feeding program. Through the integration of both local management solutions like dispersed feeding grids and an insight into environmental changes, contemporary conservation efforts can help wild ungulates through times of crises without creating an artificial dependency in them.

Conclusion

Through this study, it is clear that the establishment of supplemental feeding stations causes significant modifications in the short-run social dynamics and the long-run sustainability of the wild ungulate species populations. From the results obtained, one can clearly see that even though concentrated subsidies provide the animals with nutrients to decrease mortality rates in the short run, these subsidies introduce an entirely different set of difficulties for the species. First, concentrating the herd at a fixed feeding location results in increased levels of aggression, unnatural dominance hierarchies, and segregation of more vulnerable groups of individuals outside the feeding ground. Additionally, continued feeding results in artificially increasing the carrying capacity of the system, which is unstable and susceptible to any changes in policy or resource availability. As such, in the development of wildlife management policy, it becomes necessary to abandon static

feeding plans and replace them with dynamic, low-frequency, and geographically widespread provisioning of food. This will significantly decrease the level of aggression within the herds while maintaining foraging abilities and migratory routes. Further studies could also examine the use of automated tracking systems in keeping track of the welfare of animals born in close proximity to feed stations. A better knowledge of how such behavior and genetics affect the animals could provide information for designing management strategies that would help save wild ungulates during environmental disturbances without affecting their natural social structure and survival instincts.

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