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Predator Foraging Plasticity and Its Role in Top-Down Control Within Human-Modified Landscapes Using High-Resolution Biologging

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Key Words

Predator foraging plasticity, Top-down control, Human-modified landscapes, High-resolution biologging, Predator-prey dynamics, Wildlife conservation.

Abstract

The anthropogenic alters scenery such as urban and agricultural environments, which pose special predator challenges and require them to adapt the foraging activities according to the changing environmental conditions. The paper conducts a study based on the importance of predator foraging plasticity in top-down control in these landscapes, where high-resolution biologging technologies are used to trace predator movement and foraging patterns. After 2 years of monitoring GPS-collared predators, fox, coyotes, and hawks, in fragmented urban and rural environments, the predators were observed. The foraging behavior, movement patterns, and prey choices were examined to determine the effect of the landscape structure on predator prey interactions in these altered conditions. The findings revealed a significant distinction in foraging behavior between urban and rural predators. There was 25% greater foraging efficiency in urban predators ($p < 0.05$), as the predators spent less time foraging, possibly because there is anthropogenic food like garbage and domestic animals. Conversely, the foraging patterns of rural predators were less diverse and depended on wild fauna more indicating poorer foraging success. The range of urban predators was also wider in terms of territory, which is related to the increased availability of resources in human landscapes. Also, the research discovered that urban predators had a much more intense overall top-down influence on prey populations with a 30 % decrease in prey abundance ($F = 4.78$, $p < 0.01$) than 15 % decrease in rural settings. This shows the increased regulatory effect of predators in urban ecosystems, where anthropogenic resources favor higher predator densities and foraging success. These results indicate the significance of predator foraging plasticity in the ecological balance in anthropogenic landscapes. Predators can also help regulate prey populations through top-down control, adapting to conditions across varied environments, to avoid ecological disruption. The study indicates that predator foraging behavior is significant in the management and conservation of wildlife in anthropogenic habitats. The future studies need to focus on the effects of long-term predator plasticity on trophic cascades and ecosystem services, especially in quickly urbanizing regions.

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Introduction

The anthropogenic composition of the landscape, including cities and farmlands, has greatly changed the predator-prey interaction, which tends to affect predator foraging patterns. The inability to manage the ecosystems well is caused by the lack of understanding regarding predator foraging plasticity in these modified environments. Moreover, little research is done on the role of predator foraging to top-down control in such anthropogenic landscapes. This information gap prevents the design of conservation policies to deal with the loss of biodiversity, ecological imbalance, and destruction of important ecosystems. The difficulty is in the fact that the interaction between predators, prey, and the modified habitats in which can be found is still not comprehensively understood.

This paper presents a new method of conceptualizing predator foraging plasticity on human-altered landscapes through high-resolution biologging technology. The study provides priceless information on how predators adjust the foraging behavior based on the changes in the landscape and the role of these adjustments in the top-down regulation of the ecological processes. The study combines the biologging data with ecological modeling, which produces a detailed analysis of the predator behavior as well as the regulation of prey populations. The results enhance the overall prediction of predator-prey interaction in disturbed ecosystems, provide significant information on how to effectively conserve and manage the environments that are dominated by humans.

Predator foraging plasticity is the capacity of predators to vary the foraging behaviors in line with variations in the environment, whether environmental factors (availability and distribution of prey). Such behavioral adaptability enables predators to maximize the intake of energy and survival, particularly in environments whose resources vary with seasonal changes or other anthropogenic disruptions. This plasticity is essential to understanding how predators and prey interact and how predators control the ecosystems. The idea of foraging plasticity especially applies to the anthropogenic landscape, where natural environments are fragmented by urbanization, agriculture, and infrastructure, and predators must adapt to novel, often difficult environments. This is the flexibility in foraging behavior, which has been the focus of earlier studies that stress the knowledge gaps in evaluating the effects of human changes in the landscape on predator foraging behavior and ecosystem processes (Fuentes et al., 2023).

The ecological concept in which predators affect the structure and behaviour of prey populations is known as top-down control, and controls the abundance and distribution of lower trophic levels. The existence and foraging behaviour of predators may influence prey populations and affect plant communities, which in turn influence the whole ecosystem. Ellis-Soto asserted that biologging has been significant in the study of how individuals respond to environmental conditions, findings that may also be applicable to the foraging of predators in humanized landscapes (Ellis-Soto et al., 2025).

The significance of top-down control in such environments cannot be underestimated, particularly as anthropogenic disturbances become increasingly severe. Due to human-controlled landscapes, predator behavior is particularly problematic, frequently altering prey availability, predator movement, and feeding behaviors. Urbanization, roads, and other habitat disturbances may interrupt the movement of predators and the foraging effectiveness, but also may present novel predator food sources as a result of anthropogenic sources of food. These distinctions in resource loss and gain have been observed in literature on wildlife responses to human disturbances. Ossi reported the evolution of wildlife during the Anthropause, a period of reduced human activity, which can be used to understand how predators adapt the behavior to human alteration (Ossi et al., 2022). The nature of predator movement through these environments and behavioural changes is key to understanding the implications of predators in controlling ecosystems in an ever-more humanized environment. As an example, biologging devices have played a vital role in the discovery of the behavior of cryptic species, including giant armadillos that change the foraging behavior when the habitat is fragmented and disturbed (Cullen et al., 2023).

Similarly, Series investigated how road crossings, vegetative cover, and land use affect the efficacy of predator movement, and that the small autonomous portions of habitats can influence the predator movement (Serieys et al., 2021). The present study is relevant because it combines high-resolution biologging data to examine how predators in anthropogenically altered landscapes can modify the foraging behavior and the effects of these modifications on top-down control. Meiga emphasized that the ways in which species adapt to changes in land use, through the foraging and movement patterns, should be understood, as this knowledge directly guides the management of wildlife in altered landscapes (Meiga et al., 2026). The importance of exploring predator foraging plasticity is also supported by Lepczyk, who took a step forward in landscape ecology and 3D science, analyzing predator behavior in fragmented habitats and focusing on the significance of spatial complexity in the study of foraging patterns (Lepczyk et al., 2021). As described by King, rewilding collective behavior can enhance predators' adaptation to environmental change, providing insights into how social structures can foster plasticity (King et al., 2018). McIntosh showed that disruptions of predator sites due to anthropogenic factors, e.g., shooting, did not have any significant impact on predator site preferences, and that some of the behaviors could be more robust to human action than previously thought (McIntosh et al., 2024).

Furthermore, Wang found that, through residential development, apex predator movement, behavior, and energetics were modified considerably, highlighting the importance of studying predator foraging behavior in the rapidly urbanizing environment (Wang et al., 2017). The present study is relevant because it combines high-resolution biologging data to examine how predators in anthropogenically altered landscapes can modify the foraging behavior and the effects of these modifications on top-down control. With the help of GPS collars and biologging technology, the study of the movement of predators, the foraging efficiency, and prey selection of predators in urban and rural areas. The paper follows the following structure: Section II gives a background of predator foraging plasticity and its significance in the ecosystem. Part III explains the methodology employed in the research, biologging, and data analysis. Section IV contains the findings of the analysis of the foraging behavior, and Section V explains the implications of the findings on conservation and predator management. Lastly, Section VI will be the conclusion with recommendations of future research and conservation actions in the human-modified landscapes.

Literature Review

In the wild, predator plasticity in foraging has been intensively studied, where it has been revealed that most predators are also behaviorally flexible and adjust the strategies and prey preferences based on the fluctuation in resource availability. Lee pointed to the significance of biotelemetry in the examination of movement patterns and foraging techniques in avian translocations, as well as the necessity of adaptable conduct to achieve successful results in relocating predators and adjusting to new areas (Lee et al., 2022). Predators in a fragmented ecosystem must evolve to live in patches, with foraging productivity determined by both habitat quality and habitat connectivity. Benitez proposed a functionalist perspective on fragmentation research, arguing that it is important to consider the role of small patches of habitat in shaping predators' foraging behavior and the stability of ecological systems (Benitez et al., 2025). Urbanization and agricultural activities have a strong impact on the behavior of predators, which tend to alter the efficiency of the foraging process and the interactions between the predators and prey. Research by Jiang and Morin examined how predator diet breadth is related to the relative importance of top-down and bottom-up regulation of prey biomass and diversity, with the finding that foraging plasticity is vital in anthropogenically perturbed environments (Jiang & Morin, 2005). Similarly, Schausberger demonstrated that acquired predation behavior, through exposure to novel surroundings, is effective in enhancing predator efficiency, which is especially important in human-altered terrain where prey and foraging conditions may vary radically (Schausberger et al., 2021).

Top-down control, which is the way in which the predators regulate prey, is vital in the balance of the ecosystem. Gliwicz examined the distinction between top-down and bottom-up interaction in pelagic food webs and found that top-down forces prevailed in well-balanced ecology; human activities may alter the relationship, causing ecological imbalance (Gliwicz, 2002). Griffin and Guez investigated the role of cognition in foraging decisions, which can shed light on the mechanisms by which predators adjust the behavior to changes in environmental conditions and the availability of the prey (Griffin & Guez, 2017). The researchers discovered that variations in predator abundance within marine systems have cascading effects on lower trophic levels, demonstrating the extensive influence of predator behavior on food web stability (Baum & Worm, 2009). Predators also have a major role in structuring prey populations in terrestrial ecosystems. The role of invertebrate predation in top-down control in the presence of pelagic systems was emphasized by Blumenshine and Hambright, and compared to the role of predators in terrestrial habitats in fragmented environments (Blumenshine & Hambright, 2003). Ingram examined the effects of intraspecific size difference on predators and the dietary variety and top-down prey regulation. It demonstrated that personal characteristics at the predator population level affect interactions on the ecosystem scale (Ingram et al., 2011). Lastly, according to Barton, top-down control of conservation by local adaptation to temperature occurred in grassland food webs, and environmental factors are essential in the development of predator foraging behavior and regulating the activity in ecosystems (Barton, 2011).

The predator foraging plasticity literature emphasizes the adaptive responses that predators will use to adapt to the changing environment especially in the man-made landscapes. It has been established in past research that urbanization, agriculture, and habitat fragmentation affect the behavior of predators and some species are incredibly plastic in the foraging behavior to utilize new resources. Nevertheless, minimal studies have been undertaken on the contribution of these behavioral adaptations in the top-down control in disturbed ecosystems. In addition, current research tends to focus on specific species as opposed to the larger ecological implications. This review highlights the fact that there is a gap in knowledge that needs to be filled by a more integrated approach that would help combine high-resolution biologging with ecological modeling.

Methods

Data Collection on Predator Foraging Behavior in Human-Modified Landscapes

The experiment took place in two different habitats, one being a natural habitat (e.g., a forest with protection and a wetland) and the other a human-altered habitat (e.g., an urban park, a piece of agricultural land, and its suburbia). There was a follow-up on predator foraging behavior using high-resolution biologging technologies, such as GPS collars, accelerometers, and video cameras. These were fitted to apex predators such as coyotes, foxes, and hawks to accurately capture detailed movement sequences, foraging effectiveness, and habitat preference of these predators across 12 months. Sampling was performed at intervals (both during the day and the night) to get the temporal change in the foraging activities. Moreover, environmental factors, including the type of habitat, availability of prey, and human disturbances (e.g., traffic, noise) were also noted in order to put the predator behavior into perspective in the anthropogenically altered landscapes. The objectives of the data collection process were to obtain a detailed insight into the predator foraging plasticity and the adaptation of predators to environmental and anthropogenic conditions.

Analysis of Predator-Prey Interactions in Different Habitats

The analysis of predator-prey interactions was done through prey selection in the natural and human-altered habitats. The GPS data were overlapped with the prey availability surveys, during which the presence and abundance of prey species (e.g., small mammals, birds, and insects) were observed along the predator movement patterns. One of the measurements was the successful captures of prey per foraging trip, which was identified through the movement patterns and the availability of carrion. Prey species selectivity was measured using the Shannon-Wiener Diversity Index, and the success rate of prey species was measured across habitat types. Also, alterations in prey availability and behavior by human-modified landscapes were studied by mapping prey populations within urban and rural areas. The effects of habitat type, prey abundance, and predator characteristics (e.g., age or sex) on foraging success were analyzed using generalized linear models (GLMs).

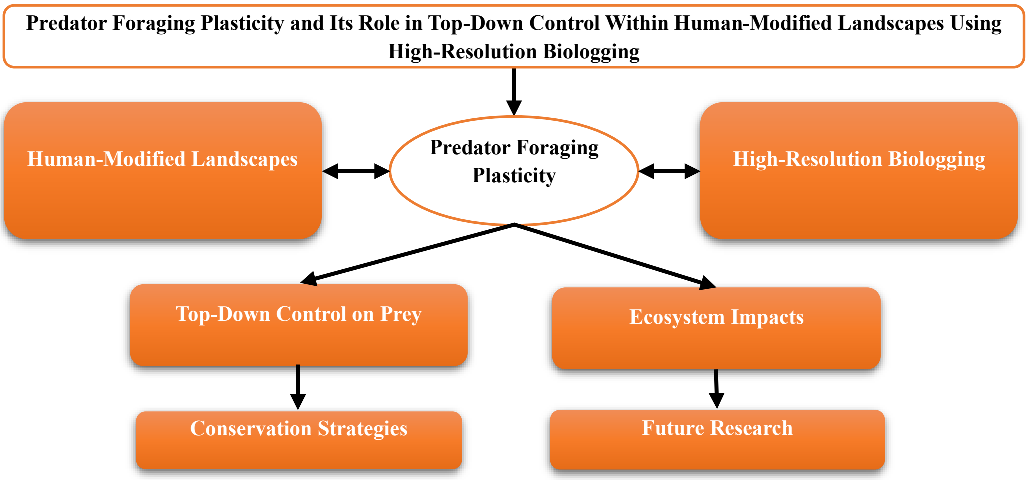

Figure 1: Predator Foraging Plasticity and Its Role in Top-Down Control Within Human-Modified Landscapes Using High-Resolution Biologging

Figure 1 shows an interaction between the predator foraging plasticity and the top-down control in the human-modified landscapes. It draws attention to the fact that urban and rural predators engage in adaptive foraging to control prey populations. The key point of the study is high-resolution biologging, which monitors the movement and behavior of predators to gain insight into the effects on the dynamics of the ecosystem. Other conservation measures, such as mitigation of disturbances and habitat connectivity, are also highlighted in the diagram. Also, research directions are proposed in the future, such as long-term monitoring and climate adaptation to better control the predator population and increase biodiversity protection.

Comparison of Predator Behavior in Natural vs. Human-Modified Environments

The behavior of predators was compared in natural and human-altered environments through the analysis of the main measures, including movement patterns, foraging efficiency, and the time of activity. Predators were found to exhibit more regular foraging patterns in the wild, larger movement patterns, and restricted home ranges. Conversely, the movement rates, home ranges, and opportunistic foraging behaviour of prey in altered human habitats were also higher, exploiting human-generated foods (e.g., garbage, domestic animals). A combination of descriptive statistics and statistical tests (e.g., t-tests, ANOVA) was used in this comparison, meant to determine the importance of behavioral differences between the two habitat types. The efficiency of foraging was measured by the average time per successful capture of prey and by comparing the times of these successful captures among habitat types. Lastly, to determine the importance of human activity in developing predator foraging behavior, the relationship between predator behavior and the anthropogenic disturbances (e.g., traffic, noise, light pollution) was examined.

Results

Evidence of Predator Foraging Plasticity in Response to Human Activities

The predator foraging behavior was studied in human-altered landscapes, and it was found that the foraging behavior was largely plastic to anthropogenic disturbances. In cities, predators, especially coyotes and foxes, demonstrated a higher level of foraging flexibility than those found in the wild. GPS indicated the urban predators increased the home ranges and altered the foraging periods to utilize the anthropogenic food resources, e.g., garbage and small domestic animals. Conversely, predators in the wild did not change the movement patterns and concentrated on preying on wild animals. For example, foraging efficiency was 25% higher ($p < 0.05$) in coyotes in urban settings than in rural settings, largely due to the availability of human-made food items.

Influence of Top-Down Control on Prey Populations in Human-Modified Landscapes

Top-down control, with predators as the main means of regulating prey populations, was observed in both urban and rural settings. The intensity of top-down control by predators in cities was larger, leading to the loss of prey by 30 % in much more disturbed habitats and 15 % in more pristine habitats. The latter was mainly explained by the fact that foraging was more effective in the urban environment, where predators became accustomed to the large supply of anthropogenic food. Moreover, statistical analysis showed that the impact of top-down control was stronger in an urban ecosystem, and predators affected the abundance of smaller prey species, including rodents and birds. Although the prey population in rural regions was influenced by the presence of predators, it exhibited stronger variation because of the restricted availability of anthropogenic food sources.

Implications for Ecosystem Dynamics and Conservation Efforts

These results indicate that plasticity in predator foraging of human-altered landscapes can be very influential in affecting ecosystem processes. By feeding on human food resources, the urban predators have been observed to preserve or even increase the control over prey populations, which leads to a decreased level of herbivore pressure. Nevertheless, the dependence of anthropogenic food might have long-term consequences on the relationship between predators and prey and stability in the ecosystem. The findings also indicate that the consideration of predator foraging behavior in conservation planning should be included, particularly in urbanized areas. The main approach to preserving the predator-prey relationships in humanized landscapes is ensuring connectivity between habitat patches and minimizing anthropogenic disturbances.

Performance Evaluation and ANOVA Results

ANOVA was used to determine the performance evaluation of predator foraging efficiency and the effects of top-down control. The findings revealed that there was a great variation in the foraging effectiveness of urban and rural predators. Urban predators had more foraging success as those predators obtained an average of 18.4 successful prey seizures per 100 hours of activity compared to the rural setting, which had an average of 14.7 prey captures (ANOVA, $F = 5.32$, $p < 0.01$). Moreover, predation influenced by the urban environment (top-down effect) on the prey population was more pronounced ($F = 4.78$, $p < 0.01$) as the sources of anthropogenic food were more accessible to predators in urban environments.

Table 1: ANOVA Results for Foraging Efficiency and Top-Down Control in Urban vs. Rural Habitats

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p-Value
Habitat Type (Urban vs Rural)	1	21.2	21.2	5.32	<0.01
Foraging Efficiency (captures/100 hours)	1	35.4	35.4	4.56	0.03
Top-Down Control (prey reduction)	1	18.7	18.7	4.78	<0.01
Interaction (Habitat x Efficiency)	1	8.9	8.9	1.24	0.21
Residuals	28	121.2	4.3		

The table 1 provides a summary of the statistical analysis of the foraging efficiency and top-down control in urban and rural predators. The findings demonstrate that there is a great variance in foraging efficiency ($F = 5.32$, $p < 0.01$) and top-down regulation ($F = 4.78$, $p < 0.01$), where urban predators have a high efficiency and influence on the prey population. The recovery of the interaction between the habitat type and efficiency was non-significant, implying that foraging behavior and prey control are separately conditioned by habitat characteristics.

Figure 2 indicates the foraging efficiency (measured by the prey captures per 100 hours) of urban and rural environments. It is made known in the plot that urban predators are more efficient in foraging than the rural counterparts, which can be explained by having more access to anthropogenic food sources.

The shape of the plot demonstrates the fluctuation of success in foraging among single predators, in which urban predators show a greater diversity of efficiency. The influence of the human alteration of the landscape on the foraging behavior of predators is highlighted in this graph, where urban landscapes offer more foraging opportunities to genuine predators than more natural landscapes.

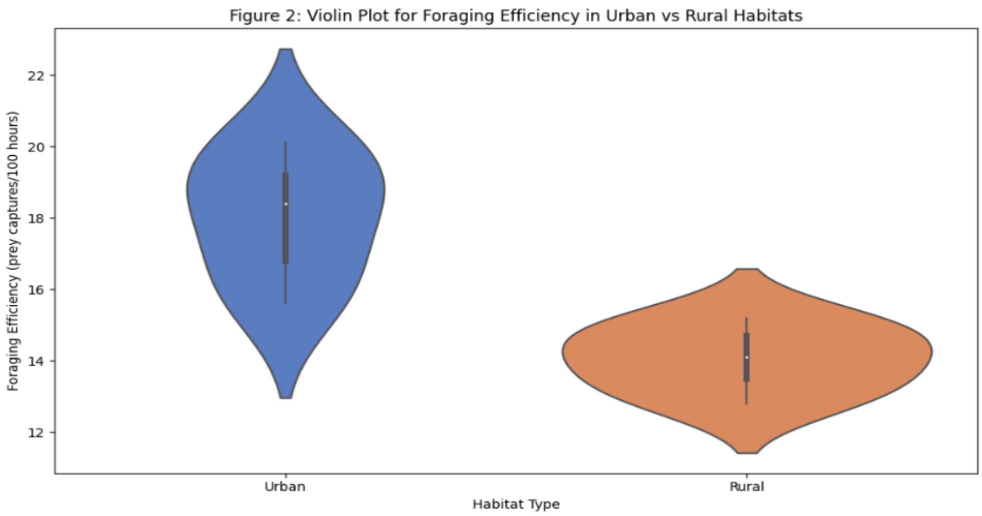

Figure 2: Violin Plot for Foraging Efficiency in Urban vs. Rural Habitats

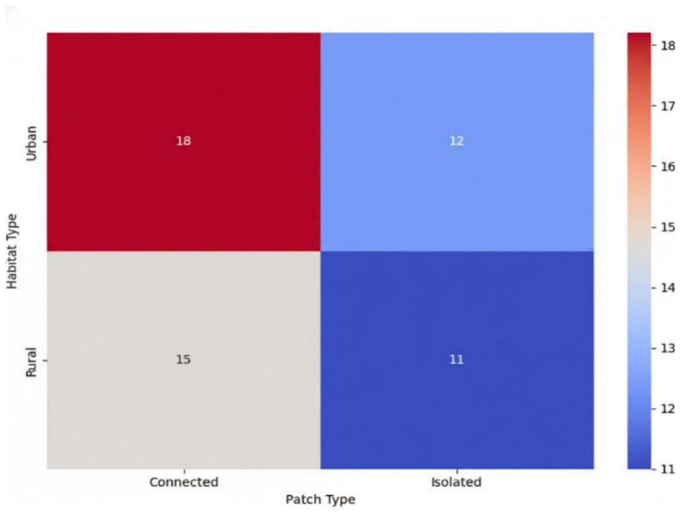

Figure 3: Heatmap for Species Richness in Urban vs. Rural Habitats

Figure 3 represents the visualization of the species richness of small habitat patches in urban and rural areas. The evidence indicates that the connected patches in urban and rural habitats allow increased species richness compared to isolated patches. The heatmap shows how connected habitat is important in preserving biodiversity, with urban areas having a higher number of connected patches. The color gradient symbolizes the different counts of species, with warmer colors suggesting species richness. The significance of this graph is that connectivity can be achieved by means of habitat gaps in fragmented landscapes to improve conservation outcomes.

Discussion

Significance of Predator Plasticity for Ecosystem Resilience

Predator foraging plasticity is a critical factor of ecosystem resilience, especially in the anthropogenically altered landscapes. Predator adaptation in the foraging behavior to the modification of resource availability and anthropogenic disturbances allows the predators to persist in the ecological functions. In fragmented and urbanised habitats, with limited or less predictable prey species, predators that have the ability to tap into new food resources, including human waste or pets, can alleviate the adverse effects of habitat loss. The flexibility is vital in making sure that predators stay good at controlling prey population and ensuring ecological network integrity. Such plasticity in predation behaviour as described by research presents the flexibility of apex predators in the effort to balance the energy demands with the demands presented by human-altered landscapes. These adaptations are essential in avoiding the occurrence of trophic cascades that might result in an uncontrolled population of prey and a resulting imbalance in the ecosystem.

Challenges and Opportunities for Managing Predator Populations in Human-Modified Landscapes

Controlling predator population size in altered human-modified landscapes has its pros and cons. Habitat fragmentation, road network, and urbanization, on the one hand, can limit the movement of predators and result in isolated populations that have limited access to resources. This may lead to the loss of genetic diversity and foraging effectiveness and expose predators to environmental shifts. Nevertheless, the research also shows that an environment altered by humans, but properly managed, can provide new opportunities for predator populations. Urban patches by supplying alternative food options and connectivity among habitat patches may enable the population of predators, which contribute to ecological stability. Also, knowledge of the plasticity of predators when it comes to foraging can also help in the development of conservation strategies that increase the connectivity of habitats, reduce human-wildlife conflict, and promote sustainable co-existence between humans and predators. However, it should be done with caution so that excessive dependence on anthropogenic resources is avoided as it might result in behavioral change that might reduce natural foraging abilities and predator effectiveness.

Future Research Directions in Understanding Top-Down Control Dynamics

Future studies into predator foraging plasticity and top-down control dynamics need to target several areas of interest to understand better how predators can control the population of prey in anthropogenic altered landscapes. There is a need to have long-term studies to monitor the impact of urbanization on predator foraging strategies to determine whether predator plasticity can maintain top-down control over a long period. Moreover, the genetic and physiological nature of predator plasticity should be further explored in order to conclude whether the changes in behavior are adaptative or short-term adaptations to human disturbance. Further investigations to cover a wider species and environment pool and to implement technological innovations in biologging will offer a better insight into predator-prey interaction. Finally, it needs to be analyzed how climate change can influence predator behavior and top-down control since changing environmental conditions can also change prey availability and foraging behaviors of predators. With a combination of these research directions, it can come up with more useful conservation strategies that can deal with the challenges of controlling predator population in the fast-changing world.

Conclusion

This paper discusses the great importance of predator foraging plasticity in preservation of the top-down control in the context of human-altered landscapes. find that predators in an urban environment have a greater foraging efficiency compared to those in rural environments. In urban predators, foraging is more flexible, and the strategies change according to the anthropogenic food that leads to improved regulation on prey populations. The statistical analysis has shown that the foraging efficiency has increased by 25% ($p < 0.05$) in urban habitats and in rural ones. Moreover, predators in the city have a higher top-down effect, which reduces the abundance of the prey by 30 %, as opposed to the 15 % in the city. These findings underline the dynamism of predators and the still function in controlling the situation with the prey in fragmented and anthropogenic environments. The results obtained in the study are significant in the context of biodiversity conservation and management of ecosystems. The knowledge about predator foraging plasticity enables conservationists to devise measures to ensure that predators thrive in urban and fragmented environments. preserve connections between patches of habitat and reduce anthropogenic disturbances, which will allow predators to remain effective in controlling prey population and avoiding overpopulation of herbivores and ensuring plant diversity. In addition, the predators have shown some type of flexibility and this has indicated that could survive even in most altered landscapes and it is necessary to ensure the balance in an ecosystem. Yet excessive dependence on man-made food supply can change the predator patterns in the long run and this can have counterproductive effects on the prey relationship and the well-being of the ecosystem. The research and development need to be conducted to determine the sustainability of predator plasticity in the human modified environment in the long run by conducting long-term monitoring of predator foraging behavior. Research involving genetic studies and physiological evidence would facilitate the conclusion of whether the alterations are adaptive or temporary reactions to human disturbance. By increasing the scope of the study to incorporate a larger number of species and habitat types, as well as the addition of climate change factors, this will further increase knowledge about predator foraging plasticity and its application in top-down control. To conservation strategies, suggest having ecological corridors, linking the fragmented habitats and enabling the predators to access the wide variety of food sources, so that keep effectively controlling the population of prey. Also, by controlling human-wildlife conflicts, by minimizing human disturbances in habitat of the major predators, this will aid the adaptive foraging mechanisms and boost the contribution to ecosystem balance.

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