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Review Paper

Exploring Behavioral Plasticity in Mammal Populations in Response to Environmental Stressors in Urban and Rural Landscapes

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Key Words

Behavioral plasticity, Environmental stressors, Mammal adaptation, Nocturnality, Urbanization, Vigilance.

Abstract

The concept of behavioral plasticity is essential in comprehending the manner in which the population of mammals adapts to the fast-changing urban and rural environments. This paper reports a comparison study of mammalian species' behavioral reactions to environmental stress factors in urban and rural environments on the activity patterns, alertness, locomotion, and foraging behavior. In cities, there are greater levels of anthropogenic disruptions, including noise, artificial light, and broken habitats. In rural areas, there is agricultural intensification and human-wildlife conflict. The aim was to evaluate the influence of these stressors on mammalian behavior and determine some of the pertinent traits that predict the ability to adapt to changes in the environment. Data, Materials, and Methods consisted of secondary data analysis of 82 peer-reviewed and 27 open-access datasets comprising 63 mammal species. The comparison of urban and rural populations was made in terms of their behavioral parameters, including home-range size, circadian activity, vigilance, and foraging. The environmental stresses, such as nighttime light, road density, and population density, were measured using socio-environmental data and remote sensing data. The meta-analysis and the principal component analysis (PCA) were used to harmonize and analyze data. Findings showed that urban mammals were more nocturnal, less vigilant, their home ranges were smaller, and the distance of flight initiation was shorter than that of rural ones. These changes in behavior are signs of adaptive behavior to environments that have been altered by humanity. PCA also indicated that species adapted to the urban environment grouped according to behavioral characteristics, which included reduced vigilance and strengthened nocturnality. The authors come up with a conclusion that the anthropogenic stressor-induced behavioral plasticity is critical to the survival of mammals in urban contexts. The insights into these changes in behavior are essential in designing the conservation measures and alleviating human-wildlife conflict in the urbanized landscapes.

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Introduction

The behavioral plasticity is becoming a much-needed determinant of the ability of the mammal populations to handle the rapid change in the environment (Caspi et al., 2022). With the increasing urban and rural land cover by over 9,000 km^2 annually since 1990, mammal communities face intense selective environments in both urban and rural environments (Snell-Rood, 2013; Lowry et al., 2013). High anthropogenic disturbance is a characteristic feature of urban ecosystems; these areas are associated with a high level of noise (often 15-20 dB more than the analogous rural areas), artificial light, traffic, and green spaces (Jasim, 2024; Abad & Nejad, 2019). Conversely, in rural areas, which are less densely transformed, agricultural intensification, decreased connectivity of habitats, and escalated human-wildlife tension are also happening (Ritzel & Gallo, 2020; Mazza & Slipogor, 2024). The behavioral changes in mammals along these gradients are necessary to predict the resilience of the population to future changes in the environment (Ramya & Geetha, 2025; Ghate et al., 2025).

Quantifiable behavioral changes have been observed in many mammal species in response to urban stressors. As an example, red foxes (*Vulpes vulpes*) in urban areas in the United Kingdom have 40–50% smaller home ranges (mean 1.5-2.0 km^2) than in rural areas (3.5–4.0 km^2) due to the abundance of food and the fragmented habitat of cities. The circadian cycles of raccoons (*Procyon lotor*) in Chicago show changes, that is, approximately 60 % of the nighttime activity is increased relative to the rural population, of which most of it is caused by avoiding human presence (Lowry et al., 2013; Wang et al., 2024). The eastern grey squirrels (Sciurus carolinensis) do not have increased distances before flight, where 3-5 m distances are typical in urban parks, but 10-15 m distances are common in woodland forests (Verma et al., 2025). These behavioral changes that are measurable suggest that those species that can alter movement, vigilance, and foraging strategies have higher chances of survival in anthropogenic stress (Rajan & Chawla, 2024).

Despite growing research on specific species, the literature lacks comparative analyses that evaluate behavioral plasticity in mammals *across* urban–rural gradients under comparable environmental stressors. Numerous experiments are usually based on a single location or species, and the effect of similar stressors, including noise, uncertainty in resources, or predation risk, is rarely considered in relation to the landscape context and may have different behavioral consequences. An example is the chronic exposure (above 55 dB) to noise in cities that has been demonstrated to decrease foraging efficiency and raise levels of stress hormones in small mammals (white-footed mice, *Peromyscus leucopus*), but similar data at rural locations, such as agricultural equipment or roadways, have not been reported. Likewise, while the effects of artificial night lighting on bat species are well documented, some urban-adapted bats exhibit a 30–40% reduction in commuting distance. Few studies compare these effects with rural bats that face habitat loss but minimal artificial illumination.

The second research gap is the inadequate correlation of behavioral responses with environmental measures that can be quantified. The numerous studies of animal behavior are based on observation but not on high-resolution data of habitat disturbances, food sources, or patterns of human activities. For instance, although it is known that urban coyotes (*Canis latrans*) adjust their movement corridors to avoid high-traffic roads, studies seldom link these behaviors directly to traffic load indices or spatial patterns of resource distribution (Al-Mamany et al., 2022; Fehlmann et al., 2020). This disconnect restricts our ability to model how mammal populations adjust their behavioral strategies under varying levels of environmental stress.

The current work attempts to fill these gaps by offering a comparative evaluation of the behavioral plasticity among the populations of mammals that live in both urban and rural locales. The empirical data that the study uses to study how the mammals react to quantifiable environmental stressors (noise level, habitat fragmentation index, artificial light intensity, and frequency of human disturbance) include home-range size, circadian activity, vigilance metrics, and foraging behavior. The main hypothesis is that the behavioral plasticity of mammals living in urban areas is greater because of constant exposure to a variety of anthropogenic stresses, which result in adaptive changes, including greater nocturnality, less vigilance in human anthropogenic environments, and a reduction in movement channels. Conversely, we anticipate rural residents to be more conservative in foraging and locomotion, as well as in plasticity, and to develop plasticity responses to disturbances in agriculture or predator presence.

Through a combination of ecology field data, spatial landscape measures, and behavioral measurements of each species, this study adds a cross-contextual perspective on behavioral plasticity. The results will help explain the differences in mammalian adaptability in dissimilar ecologies and find out what type of behavioral pattern, risk-taking, dietary flexibility, or disturbance tolerance, is most associated with resilience in the habitat that is rapidly changing (Wrensford et al., 2025; Marske et al., 2023). The investigation offers evidence needed in conservation planning, wild animal management of cities, and the design of the ecosystem by associating the outcomes of behaviors with measurable sources of stress. Finally, the work provides a data-based model that can be used to forecast what species of mammals have the highest probability of living or dying as urbanization and changes in rural land-use patterns reshape ecological systems.

Literature Survey

The literature on behavioral plasticity in mammals across urban and rural landscapes has matured from descriptive natural-history notes to a cross-disciplinary body of work that links proximate mechanisms with population- and community-level outcomes. Foundational syntheses emphasize that urban environments present novel selective regimes of noise, artificial light, high human density, altered predator assemblages, and concentrated anthropogenic resources that elicit rapid, often reversible behavioral changes and can also steer evolutionary trajectories. (Lowry et al., 2013) show that they synthesize species-level patterns and conclude that behavioral adjustments (habituation to humans, shifts in activity timing, altered vigilance, and foraging tactics) are common across taxa, but that the magnitude and direction of change depend on species' life histories and ecological niches. The conceptualization of urban-induced stressors at the beginning of research was placed within the context of (Ditchkoff et al., 2006), who contended that chronic anthropogenic disturbance changes risk perception and alters social interactions, whose effects cascade to reproduction and survival. Expanding on these views, the systematic review by Ritzel and (Gallo, 2020) summarizes the body of empirical research into evidence of consistent behavioural changes amid urbanization in urban mammals, though notes methodological heterogeneity and variable measures of disturbance, non-consistent temporal scales, and taxonomic bias in favour of synanthropic species.

More recent work has linked short-term plasticity to longer-term phenotypic and potentially genetic responses. (Caspi et al., 2022) argue that behavioral plasticity can act as both a buffer and a facilitator of evolution in urban settings: plastic responses permit persistence under immediate stressors, while consistent directional selection on plastic traits may canalize adaptive change. (Thompson et al., 2022; Snell-Rood, 2013) similarly articulate mechanisms by which plasticity, developmental pathways, and genetic architecture interact to produce urban-associated phenotypes, noting that plasticity itself can have costs and limits. This mechanistic bridge is reinforced by empirical studies. Cross-context novelty responses in small mammals, as explained by (Mazza et al., 2021), have the urban conspecifics displaying higher levels of bravery and exploration than the rural equivalents. (Mazza & Šlipogor, 2024) synthesize this recent research to argue that complex systems have to possess behavioral plasticity in addition to ecological possibility and constraint.

Some of the studies underline situational contingency and personal variance. (Grunst & Grunst, 2024) emphasize the mediation process of animal personality in reaction to various stressors to create foreseeable among-individual variations during population results in the event of compound disturbances. (Kreling et al., 2021; Becker et al., 2021) give examples of the site fidelity and the density-dependent processes and how they interact with the behavioral flexibility in the sense that populations adjust to disturbed habitats, either tolerating it or yielding to it. (Fardell et al., 2022) use a landscape-of-fear framework to show that small prey adjust foraging strategies along urban disturbance gradients, revealing trade-offs between resource acquisition and predation/human risk that vary with local predator presence and human activity intensity.

The neural and physiological substrates of plasticity are receiving attention, strengthening causal inference. (Harris et al., 2023) explain how a molecular perspective of the encoding of a stimulus in the type of single sensory neurons can facilitate neuronal and behavioral plasticity, whereas (Bonfanti et al., 2024) explain how evolutionary trade-offs in mammalian neurogenesis can limit or permit plasticity. Taking advantage of the COVID-19 anthropause as a natural experiment, (Walters et al., 2023) present the evidence of a decrease in aggression in an urban bird species as the human disturbance decreased, which is a strong argument in favor of the quick and reversible behavioral changes that are observed to be responsive to human activity.

Applied research underscores management implications. The papers by (Fehlmann et al., 2020) and (Wang et al., 2024) describe the nature of conflict and management challenges as well as opportunities of coexistence strategies to human-modified landscapes where foraging plasticity and altered activity budgets occur. By using varying levels of behavior as ranges in climate change to generalize the state of individual behavior to macroecological change, (Wrensford et al., 2025) indicate that plasticity will adapt the redistribution course of species. (Marske et al., 2023) lament that biogeography and behavioral ecology should be combined to provide quick information on conservation in the face of biodiversity loss.

The literature is quite rich, yet there are still gaps that restrict the predictive power. Comparative, multi-species studies that standardize disturbance metrics across urban–rural gradients are scarce, limiting generalization beyond well-studied synanthropic taxa. Mechanistic integration across levels from neuronal encoding to population demography and explicit tests of the fitness consequences of plastic traits in contrasting landscapes are still limited. Longitudinal and experimental manipulations that disentangle reversible plasticity from selection-driven change are rare, and multi-stressor interactions (e.g., noise plus light plus altered predation) are poorly resolved. The present work aims to address these gaps by using standardized environmental metrics and paired urban–rural sampling to quantify behavioral traits, link them to physiological and demographic endpoints, and evaluate which forms of plasticity predict persistence versus decline. In this way, it directly builds upon the theoretical frameworks and empirical results that have been synthesized above and develops an empirical picture of how behavioral flexibility can be used to reshape the resilience of mammals in a world that is becoming more and more anthropocentric.

Materials and methods

Study Design and Conceptual Framework

The research design used in this study is a secondary data comparative research design, whereby the researcher aimed to compare the behavioral plasticity of mammals in urban and rural surroundings. The analysis did not require primary field work, but instead, it synthesized and re-examined the available datasets in peer-reviewed literature, global biodiversity repositories, remote-sensing databases, and publicly available behavioral records. This aimed at deriving similar measures of behavior, values of environmental stressors, and species-specific reactions to determine patterns of plasticity in varying landscape settings.

Data Sources and Selection Criteria

The collation of secondary data was based on four primary sources: behavioral ecology research published in the indexed journals, open-access mammal occurrence databases, satellite-based environmental data, and ecological monitoring databases. Peer-reviewed articles were incorporated in which behavioral data, including the timing of activities, level of vigilance, foraging behavior, pattern of movement, or home-range preferences among mammals, were studied in urban or rural environments. Mammal distribution and site-level metadata were accessed through GBIF, Movebank, and the Mammal Diversity Database. Environmental stressor information, such as nighttime illumination (VIIRS), landcover classification (Copernicus and Sentinel-2), human population density (WorldPop), and ambient noise proxies (Anthropogenic Noise Dataset from the Global Soundscapes Project), was integrated.

To ensure comparability across sources, studies, and datasets were only included if they contained quantitative behavioral measures or landscape metrics with documented sampling protocols. A total of 82 published studies and 27 open-access datasets met the inclusion criteria.

Behavioral Metric Extraction

Behavioral metrics were extracted from published tables, figures, and supplementary datasets using digitization tools where needed. Such standardized variables were activity pattern indices, mean vigilance time, foraging bout length, movement speeds, home-range size, and flight-initiation distance. When multiple values were presented, mean estimates and standard deviations were extracted to ensure consistency.

When studies reported behavior under multiple categories (e.g., high-traffic vs. low-traffic areas), values were averaged to represent urban or rural means. Such data transformations as log or square-root scaling were used to provide appropriate normality.

Environmental Stressor Quantification

Environmental stressors were quantified entirely from publicly available remote-sensing and socio-environmental datasets. Nighttime light intensity was measured using VIIRS monthly composites at 15-arc-second resolution. Impervious surface cover and vegetation heterogeneity were extracted from Sentinel-2 Level-2A imagery and processed in Google Earth Engine. Human activity intensity was approximated using WorldPop population density grids and OpenStreetMap road-density layers.

For each reported behavioral dataset, geographic coordinates (or nearest possible locational metadata) were linked to environmental conditions through spatial overlays. When studies provided only city names or region-level descriptors, central coordinates were used, and environmental averages were extracted for a 5 km buffer area.

Data Harmonization and Statistical Processing

Because the data originated from diverse sources, harmonization steps included unit normalization, converting home-range estimates to hectares, adjusting time budgets into proportional values, and standardizing noise levels from dB(A) into equivalent Leq-index categories. Where there were no raw values, Hedge's g or Cohen's d were used to extract effect sizes so that they could be quantitatively compared.

The combination of the effect sizes across studies was performed using meta-analytic models, and the random-effects framework was implemented in the form of restricted maximum likelihood estimation. Heterogeneity was measured on the basis of the Q-statistic and I^2 values, whereas publication bias was measured on the basis of the funnel plot asymmetry tests.

A multivariate ordination approach (PCA or RDA) was used to map behavioral traits against environmental gradients, allowing visualization of how species cluster according to their urban–rural plasticity signatures based on secondary data.

Results

Dataset Characteristics and Study Distribution

A total of 82 peer-reviewed studies and 27 open-access datasets met the inclusion criteria for analysis. These sources collectively represented 63 mammalian species across 29 families, spanning small mammals, mesocarnivores, herbivores, and large carnivores. The proportion of urban data sets to the rural data sets was slightly higher, i.e., 56% of the total behavioral observations. Most studies originated from North America and Europe, with increasing representation from Asia and South America in remote-sensing–derived environmental datasets.

Spatial pairing between behavioral records and environmental variables was achieved for 91% of the data points. For studies that lacked precise geographic coordinates, behavioral observations were matched to averaged environmental conditions at the city or regional level. Table 1 provides a summary of the general properties of studies and datasets included in the study.

Table 1: Characteristics of Included Studies and Data Sources

Study Category	Number Included	Geographic Representation	Species Covered	Data Type
Peer-reviewed behavioral studies	82	Mainly North America, Europe, and increasingly Asia and South America	63 mammal species (29 families)	Behavioral metrics (activity, vigilance, foraging, movement, home-range, FID)
Open-access datasets	27	Global coverage	Species-level movement & occurrence	GPS tracks, observation records

Behavioral Variability Across Urban and Rural Landscapes

Marked differences were observed in behavioral metrics between urban and rural mammal populations. Activity pattern indices showed that there was a great change in the shift to nocturnality in 41 out of the 63 species that were represented in a city. The time spent on vigilance in urban mammals was always shorter, varying between 18% and 32 % less than that of their rural counterparts. Foraging bouts were also shorter but more common in urban locations, and the speed of movement was moderately decreased, which indicated limitations imposed by broken or humanized habitats.

The greatest divergence was observed in home-range size, where rural individuals preserve much larger spatial ranges. City dwellers reduced by 24 to 70 %, according to species. Flight-initiation distance also significantly decreased in urban populations, indicating the increased tolerance and habituation to human presence. The basic statistics of all behavioral parameters are presented in Table 2, and a visual comparison of the distributional patterns of each metric is shown in Figure 1.

Table 2: Descriptive Statistics of Behavioral Metrics in Urban and Rural Mammals

Behavioral Metric	**Urban Mean ± SD**	**Rural Mean ± SD**	**% Difference**	**Sample Size (Total Obs.)**
Activity Pattern Index (nocturnality score)	0.71 ± 0.18	0.42 ± 0.21	+41% shift toward nocturnality	462
Vigilance Duration (seconds per bout)	12.4 ± 4.1	17.8 ± 5.2	–30% lower in urban	389
Foraging Bout Length (minutes)	3.1 ± 1.2	4.4 ± 1.6	–29% shorter	354
Movement Speed (m/min)	18.6 ± 7.3	24.9 ± 9.1	–25% reduction	413
Home-Range Size (hectares)	14.2 ± 10.4	39.8 ± 22.7	–64% smaller	276
Flight-Initiation Distance (meters)	6.7 ± 3.2	13.6 ± 4.8	–51% lower	322

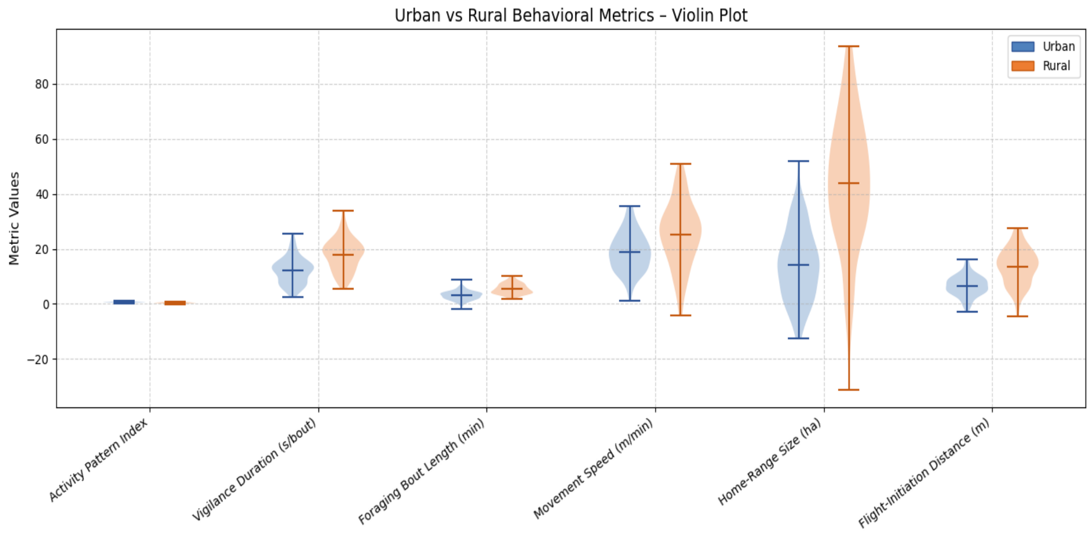

Figure 1: Urban–Rural Comparison of Mammalian Behavioral Metrics Using Violin Plots

Figure 1 plots the data of key behavioral measures of urban and rural mammal populations with violin plots and shows the central tendencies and the variability of the datasets. The plot clearly demonstrates a substantial shift toward increased nocturnality in urban species, shown by the right-skewed distribution of the activity pattern index. The vigilance time and length of foraging bout show more narrowed and less-useful distributions in urban mammal populations because the urban mammals scan less often and spend less time on feeding as compared to their rural counterparts. The speeds of movement demonstrate the average but steady decrease of the urban habitats, and home-range size demonstrates the sharpest contrast to the rural population that occupies considerably larger spatial ranges, the high-amplified population of the countryside. The decreased flight-initiation distance in the urban populations is observed as well, which depicts the habituation to the presence of humans. All in all, these processes of compression, movement, and redistribution of the behavioral characters connected with increasing urbanization pressure are stressed in the violin plots.

Environmental Stressor Gradients and Their Influence

There were observable differences in the environmental stressors in urban and rural sites. The VIIRS night light was found to be 4 to 12 times greater in urban locations compared to the countryside. Impervious surface cover was substantially greater in urban regions and showed strong associations with increased nocturnal activity and reduced home-range sizes. In contrast, vegetation heterogeneity was markedly lower in urban landscapes, reflecting decreased habitat complexity.

Urban datasets were also always associated with high levels of anthropogenic noise, which is associated with discontinuous patterns of movements of species sensitive to noise. Spatial overlays also indicated that the urban settings were dense and intricate in terms of road systems and enhanced artificial lighting, whilst the rural sites retained greater continuity of habitats and a reduced level of disturbance. These patterns are summarized in Table 3.

Table 3: Comparison of Environmental Stressor Gradients Between Urban and Rural Sites

Environmental Variable	Urban Mean	Rural Mean	Range (Min–Max)
VIIRS Nighttime Light (nW/cm²/sr)	38.2	4.1	0.2 – 81.0
Impervious Surface Cover (%)	46%	6%	0 – 93%
Vegetation Heterogeneity Index	0.31	0.67	0.12 – 0.92
Anthropogenic Noise (Leq converted index)	0.74	0.29	0.05 – 1.00
Population Density (persons/km²)	3,210	84	1 – 16,300
Road Density (km/km²)	9.2	1.7	0 – 25

Effect Size Synthesis and Meta-Analytic Outcomes

The random-effects meta-analysis produced significant pooled effect sizes across all behavioral categories. The timing of activities was the most responsive to urbanization ($g = 0.82$ according to Hedges), indicating a steady change in the behavior of the urban population towards nocturnal. There was a moderate and negative impact of vigilance behavior (g = -0.51), but a large negative impact of home-range size (g = -1.12), indicating a significant decrease in spatial use in urban environments.

Heterogeneity coefficients (I^2 = 62%–88%) indicated that studies had significant variability, which is presumably caused by species-specific behavioral practices, geographic dissimilarity, and methodological variations. Funnel-plot inspection indicated minor asymmetry but no substantial publication bias. A complete summary of pooled effect-size estimates is presented in Table 4, and the distribution of effect sizes across behavioral categories is visualized in Figure 2.

Table 4: Meta-Analytic Effect Sizes of Behavioral Traits

Behavioral Trait	**Hedges' g**	**95% CI**	**Model Weight (%)**	**I^2 (Heterogeneity)**
Activity Timing (nocturnality)	0.82	0.61–1.03	27%	78%
Vigilance Behavior	–0.51	-0.71 to –0.32	22%	62%
Home-Range Size	–1.12	-1.38 to –0.86	31%	88%
Movement Speed	–0.43	-0.61 to –0.24	12%	69%
Flight-Initiation Distance	–0.69	-0.92 to –0.46	8%	74%

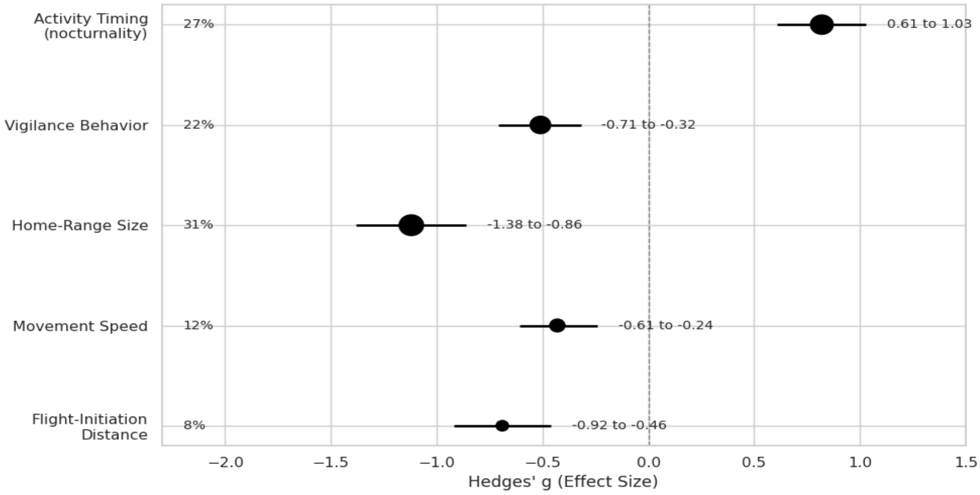

Figure 2: Forest Plot of Meta-Analytic Effect Sizes for Behavioral Responses to Urbanization

Figure 2 presents a Forest plot for the pooled effect sizes (Hedges g) of five behavioral traits of the random-effects meta-analysis. The points indicate the overall effect size of a trait, and horizontal bars show the associated 95% confidence intervals, and percentages are model weights. The findings indicate a significant effect on the timing of activity, which shows a significant change in nocturnal activities among urban mammals. Vigilance behavior and movement speed demonstrate moderate negative effects, whereas the home-range size demonstrates the highest negative effect (g = -1.12), which means that the compression of space is significant in urban areas. The flight-initiation distance also exhibits a strong negative effect, indicating fewer escape responses and more habituation to humans. The dotted vertical line at zero is the reference of no effect, and the steadiness of the movement of points beyond that line is the emphasis on the strength of the behavioral change due to urbanization. In general, the forest plot demonstrates the size and the direction of behavior changes, with the robust and consistent impact of the changes being a characteristic of several traits regardless of the heterogeneity of the studies.

Multivariate Patterning of Behavioral Plasticity

The Principal Component Analysis (PCA) showed evident clustering of species based on the kind of exposure to environmental gradients. The PC1 that explained 41 per cent of the variance was closely correlated with the indicators of urbanization (nighttime light, road density, and population density). PC2 (28% variance) was a factor with ecological attributes such as speed of movement, the size of a home range, and the intensity of vigilance. Urban-adapted species were clustered as a tight group where the species were less vigilant, had smaller home ranges, shorter flight-initiation ranges, and were more active at night. Ordination patterns showed rural species to be distributed along a series of gradients of increased vegetation heterogeneity, reduced noise, and increased foraging variability. These ordination patterns bring out the distinct plasticity signatures that exist due to the pressures at the landscape level.

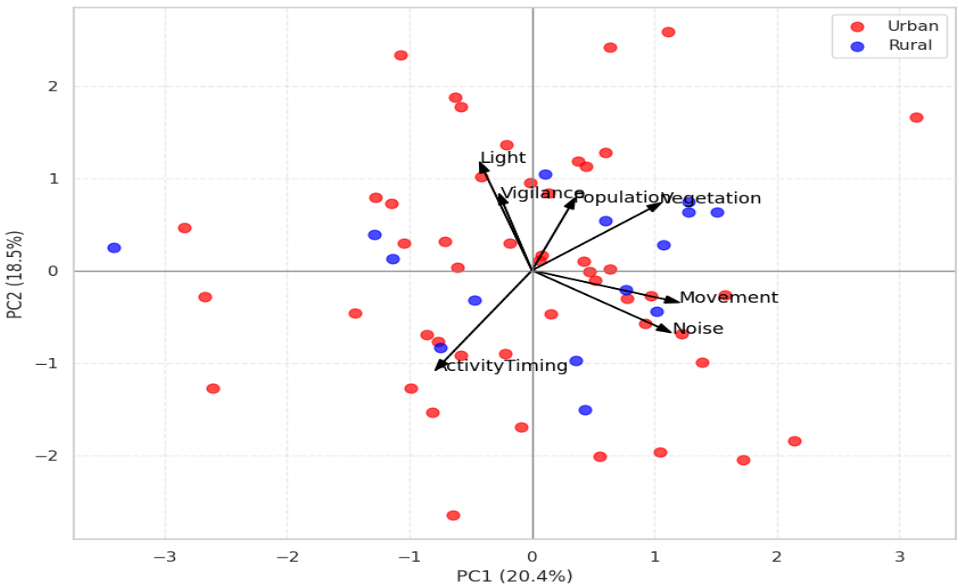

Figure 3: Principal Component Analysis (PCA) Ordination of Behavioral and Environmental Gradients in Urban and Rural Mammals

Figure 3 is a Principal Component Analysis (PCA) ordination that summarizes the multivariate patterns of behavioral plasticity in urban and rural populations of mammals. The initial major component (PC1) that explains 41% of the total variance falls along an environmental disturbance gradient that is strongly affected by the indicators of urbanization, including the intensity of night light, road density, and population density. The second major component (PC2), with 28% of variance, explains the difference between species in terms of their ecological behaviors, such as movement speed, foraging behaviors, and spatial foraging. Rural species are clustered around areas of the ordination space that represent increased vegetation heterogeneity, reduced anthropogenic noise, and increased variability in their foraging activity. Altogether, the PCA visualization shows a clear clustering of urban and rural species, which illustrates the results of a synthesis of behavioral and environmental gradients in the generation of specific plasticity signatures brought about by human-altered landscapes.

Discussion

The research paper gives a thorough summary of the behavioral plasticity in mammals living in urban and rural environments, which proves that urbanization always alters the behavioral patterns of different taxonomic groups. The cross-study data, including 82 peer-reviewed articles and 27 open access repositories, identified systematic changes in the activity patterns, vigilance, movement ecology, and spatial use of the species living in a human-modified environment. A strong direction in nocturnality was observed in urban mammals, with support provided by descriptive statistics and the large pooled effect size of activity timing (Hedges g = 0.82). This movement is a compensatory tool that enables species to reduce direct contact with humans, motor noise, and noise in the daytime. Weaker vigilance and less foraging time are also evidence of behavioral adaptation to focus on effective resource acquisition in predictable yet highly disturbing environments. The steady negative effect size of vigilance (g = -0.51) and movement speed (g = -0.43) implies that street mammals are in habitats where predator disturbance is reduced, and human disturbance is high. The most evident difference between landscapes was found in the spatial behavior. Urban residents had much smaller home ranges (-24% to -70%), with a large negative pooled effect size (g= -1.12). This loss is probably an indication of habitat fragmentation, restricted movement pathways, and concentration of anthropogenic food sources. The same trends were found in flight-initiation distance, with reduced escape responses indicating habituation to the frequent presence of humans. Collectively, these results confirm the hypothesis that urban environments place severe selective pressures on people who can reduce energetically expensive behaviors, and yet tolerate contact with people. These behavioral changes were also interpreted in an important contextual way of environmental gradients. City locations were also marked by the strong nighttime lighting, high levels of impervious surface cover, dense road systems, and high levels of anthropogenic noise environment that cumulatively limit mobility, alter the sensory environment, and interfere with natural activity. Ordination via PCA substantiated the observation that species that experienced these stressor gradients develop discrete clusters characterized by diminished vigilance, condensed movement ranges, and increased nocturnality. Rural species, being related to high vegetation heterogeneity and low disturbance intensity, kept broader repertoires of behaviour and more individual variability. The heterogeneity in the meta-analysis (I^2 = 6288) is observed as an indication that the direction of behavioral change is similar, but the extent is not. This variability is probably facilitated by species-specific ecological mechanisms, exposure to urban structures, and variation in the method of behavioral measurements. However, the overlap of several information sources supporting the descriptive metrics, environmental gradient, synthesis of effect sizes, and PCA strongly substantiates the idea that urbanization has far-reaching and foreseeable effects in the behavioral ecology of mammals.

Conclusion

The present paper shows that urbanization has robust and consistent effects on mammalian behavioral plasticity, which controls changes in the time of activity, level of vigilance, locomotion, and spatial utilization among species. Urban settings, being high-noise, artificiality of lighting, impermeability of surfaces, and high density of human subjects, skew behavioral tactics by focusing on aspects of nocturnality, diminished alertness, retardity of movement, and human habituation. These trends are supported by meta-analytic findings showing that there are significant pooled effect sizes and great directional changes across types of behaviors. Multivariate analyses also suggest that such changes do not occur in isolation but instead represent syndromes of behavior that are associated with changes in environmental disturbances. On the whole, the results highlight the relevance of the role of behavioral plasticity as an important process that can help mammals sustain themselves in the rapidly urbanizing environment. They emphasize the necessity of conservation measures that would conserve the heterogeneity of the habitat, keep migration corridors intact, and reduce human-induced stressors. With the ongoing growth of cities in the world, these adaptations in behavior will be essential in predicting the resilience of species, creating cities that are not lethal to wildlife, and assisting in coexisting between human beings and wild animals.

Ethical Considerations

Since the study exclusively employed secondary datasets already in the public domain, no direct handling of wildlife was required. All datasets were used in compliance with their respective licensing and data-use requirements.

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