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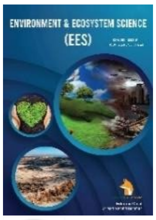

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REVIEW ARTICLE

PHOTOGRAPHIC CLIMATIC CHANGES AS A VISUAL APPROACH TO UNDERSTANDING SHELFORD'S LAW OF TOLERANCE: A CASE STUDY FROM URBAN KUALA LUMPUR

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ABSTRACT

Shelford's Law of Tolerance provides a foundational ecological framework explaining how organisms respond to environmental gradients. This study employed a photographic documentation approach to interpret climatic variability and its impact on human activities, particularly schoolchildren's outdoor behavior, in an urban setting in Kuala Lumpur, Malaysia. A sequence of photographs was analyzed to represent a range of climatic conditions, progressing from clear skies to heavy haze. The images serve as a proxy to visualize the zones described by Shelford's Law: optimum, stress, and intolerance. By integrating the concepts of stenotopic and eurytopic responses, this article illustrated how narrow and broad tolerance species (and individuals) vary in response to environmental changes. The findings highlighted the relevance of visual, pragmatic learning to deepen ecological understanding in urban education and planning.

KEYWORDS

Tolerance limits, photographic documentation, stenotopic, eurytopic, urban ecology, Kuala Lumpur

1. INTRODUCTION

Understanding the principles of ecology is difficult without looking and relating to our surroundings. The Shelford's Law of Tolerance asserts that the survival and distribution of organisms are governed by the range of environmental conditions within which they can persist (Krebs, 2008). This principle is especially pertinent in urban ecology, where microclimatic fluctuations—such as changes in temperature, humidity, air quality, and light—significantly influence species presence, behavior, and overall biodiversity (Figure 1). In the context of increasing climate instability and rapid urbanization, innovative pedagogical tools and observational methods are essential to foster environmental literacy. This paper presents a visual methodology that employs photographic evidence to engage learners with ecological theory, emphasizing the interaction between environmental change and behavioral response.

Understanding species distribution and resilience amid environmental variability requires an integrative approach rooted in both ecological theory and empirical evidence. Habitat suitability models have emerged as effective educational tools for predicting potential species distribution, thereby promoting ecological awareness and informing conservation efforts (Carrasco-Hernandez, 2020). Shelford's Law continues to be validated across diverse domains, including energy systems and aquatic ecology, where experimental studies have demonstrated how variables such as pH and conductivity affect amphipod survival (Day and Saive, 2009; Shapovalov et al., 2022). The physiological mechanisms underlying environmental tolerance are further explored in biogeographic and thermal studies, which reveal how organisms respond to temperature changes at systemic and molecular levels (Pörtner, 2002). Additionally, classical ecological frameworks have highlighted the evolutionary and ecological significance of tolerance limits, while geographic ecology offers broader insights into the spatial distribution of species under environmental constraints (Krebs, 2008; Lynch and Gabriel, 1987). Collectively, these studies illustrate the critical role of tolerance-based modeling in addressing ecological complexity and advancing sustainability science.

The notion of tolerance has also been explored extensively across other scientific fields, revealing its broad implications for human health, ecological sustainability, and urban resilience. In the field of toxicology, advocated for zero-tolerance policies in drug-impaired driving, citing the inconsistencies of drug concentration thresholds as reliable indicators of impairment (Reisfield et al., 2012). In plant physiology, examined the adaptive root responses of rice varieties subjected to low-temperature and gleization stress, whilerevisited Shelford's law through the concept of plant hormesis, illustrating how organisms perform optimally within specific environmental boundaries (Erofeeva, 2021; Wang et al., 2016). From a public health perspective, assessed the risks of heat-related

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mortality in urban areas, identifying critical thermal thresholds for human tolerance (Harlan et al., 2014). Complementing this, studied the heat tolerance of urban tree species during extreme temperature events, highlighting the importance of green infrastructure in climate adaptation (Esperon-Rodriguez et al., 2021). Together, these multidisciplinary investigations reinforce the relevance of tolerance as a framework for understanding biological responses and guiding policy decisions in the face of environmental and societal pressures.

Urban environments offer a dynamic setting to observe real-time behavioral adaptations to environmental stressors. Short-term and spatial fluctuations in factors such as temperature, humidity, and air quality create conditions that can be used to illustrate Shelford's Law in action. School children, as a particularly sensitive and observant demographic, display visible behavioral changes in response to these shifts. By analyzing photographic sequences taken from consistent locations, this study explores the relationship between environmental variables and human activity patterns, aiming to delineate ecological zones of tolerance and stress. Through this approach, learners are encouraged to connect abstract ecological concepts with everyday experiences, enhancing both understanding and engagement.

The objective of this study is to demonstrate how photographic documentation of environmental changes in an urban setting can serve as an effective educational and analytical tool for understanding ecological principles. By examining behavioral responses under varying conditions and applying the concepts of stenotopic (narrow tolerance) and eurytopic (broad tolerance) organisms, this study provides a relatable and visual interpretation of ecological tolerance. It aims to enhance environmental awareness, promote experiential learning, and support planning efforts that consider biological sensitivity to climatic variability.

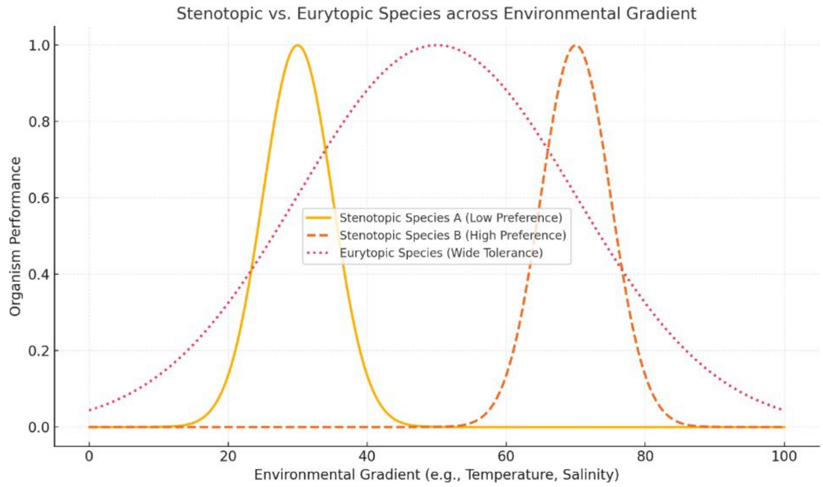

Figure 1: The Shelford Law of Tolerance with the stenotopic (narrow habitat) and eurytopic (broad habitat) across the environmental gradient.

2. Materials and Methods

A series of photographs were captured in Kuala Lumpur showing the same school and urban background under different weather conditions across time. The photos were taken using a Huawei Y-9 smartphone between May and November 2024, from a fixed vantage point on the second floor of the MABA parking place. The photos were interpreted from left to right (top row to bottom row), progressing through clear, hazy, overcast, and highly polluted conditions. Two sets of images were analyzed: one showing a school field with children, and another showing surrounding buildings under varying sky conditions. Human activity, environmental clarity, and visibility of landmarks (e.g., KL Tower) were used as markers to classify conditions according to Shelford's Law. Interpretations were made using ecological principles and supported by classifications of stenotopic (narrow tolerance) and eurytopic (broad tolerance) responses.

3. Results and Discussion

From Figure 2, in the top left photograph, the environment is characterized by bright sunlight, clear air, and excellent visibility. This corresponds to the optimum zone of Shelford's Law. No children are present on the field, possibly because it was taken before recess or a class period. From a stenotopic perspective, individuals or species would only be active under such ideal conditions. Sensitive children, such as those with asthma or low heat tolerance, would find these conditions comfortable. From a eurytopic perspective, these individuals would also thrive but are not limited to this specific range. They can remain active even if slight changes in temperature, light, or dust occur.

Figure 2: A sequence of four photographs capturing the school field with the KL Tower in the background. Note: The photos were taken from the second floor of the MABA parking place and represent environmental transitions from optimum to intolerance zones. The top left image (**A**) shows a clear sky and empty field; the top right (**B**) shows active children under clear skies; the bottom left (**C**) shows a gloomy, overcast sky with an empty field; and the bottom right (**D**) captures a haze-covered landscape with poor visibility.

Each condition reflects varying responses based on Shelford's Law of Tolerance, as well as stenotopic and eurytopic behavioral responses. The top right image maintains similar clear conditions but now shows children playing actively. This still falls within the optimum zone. From the stenotopic view, this represents the ideal moment for activity; however, these individuals are highly dependent on such narrow environmental bands and would not function well if the conditions changed. Eurytopic individuals, on the other hand, continue to thrive and could sustain activity across a broader range of environmental variation, including rising temperatures or slight haze.

The bottom left image presents a darker sky with stormy clouds, a pre-rain atmosphere, and no children on the field. This reflects the zone of physiological stress. Stenotopic individuals might perceive this as discomfort or a threat and withdraw from outdoor activity. Organisms sensitive to light or wind would reduce their activity or seek shelter. Eurytopic individuals may still function, albeit at a lower level, and would adapt their behavior accordingly, such as delaying play or waiting for conditions to improve.

In the bottom right image, dense haze has settled over the city, with low visibility and KL Tower barely discernible. This environment marks the zone of intolerance. Stenotopic individuals are completely unable to cope in these conditions, potentially experiencing health risks such as respiratory distress. Highly sensitive organisms would avoid the area or not survive. Eurytopic individuals, though stressed, may continue to endure or adapt temporarily by limiting activity or moving indoors. Resilient urban species may persist in such conditions, although not at optimal performance.

This series of images, therefore, demonstrates the applicability of Shelford's Law of Tolerance to real-life urban settings, offering a visual narrative that distinguishes the responses of organisms based on their ecological tolerance breadth. It highlights how environmental quality directly affects activity levels and presence, particularly in sensitive populations like children.

From Figure 3, in the top left photograph, the urban landscape is bathed in bright sunlight with clean air and sharp visibility. This reflects the optimum zone in Shelford's Law, where environmental conditions are at their peak. Stenotopic species thrive under these precise circumstances. Sensitive organisms, such as certain bird species or flowering plants, require such ideal conditions to maintain function. In contrast, eurytopic species, while also benefiting from these conditions, are not restricted to them. These generalists—like pigeons, urban cockroaches, and humans—can remain active across a broad environmental gradient.

Figure 3: A sequence of four photographs documenting changes in the urban skyline featuring church and city buildings under progressively deteriorating atmospheric conditions. Note: The images illustrate the ecological implications of air clarity, light levels, and pollution through the framework of Shelford's Law of Tolerance and the ecological concepts of stenotopic and eurytopic species. The top left image (**A**)represents clear, optimal conditions; the top right (**B**) shows mild haze; the bottom left (**C**)reveals stormy skies; and the bottom right (**D**) captures heavy smog and low visibility, correlating to the tolerance spectrum from optimum to intolerance.

The top right image presents slightly overcast or hazy skies, with visibility still relatively good. This represents a transition zone, straddling the line between optimum and early stress. Stenotopic organisms begin to experience physiological stress, and their activity may decline or shift, such as migrating insects responding to light intensity changes. Eurytopic organisms, however, continue to operate normally, demonstrating tolerance to minor shifts in visibility and air quality.

The bottom left photograph captures a stormy or heavily overcast sky, with a darker atmosphere and likely increased humidity. This corresponds to the zone of stress, where environmental conditions have shifted far enough to impair performance. Stenotopic organisms are likely absent or inactive, as their narrow range of light and pressure tolerance limits survival or normal function. Light-sensitive species may cease photosynthesis. In contrast, eurytopic species may alter their behavior—mammals seeking shelter, for instance—but remain present and functional, though not at peak performance.

In the bottom right image, thick smog dominates the skyline, with buildings fading into the background due to poor air quality and reduced light penetration. This scenario falls within the zone of intolerance. Stenotopic species—especially those sensitive to pollution or requiring high light levels—cannot function and may either relocate or perish. Examples include epiphytic mosses, lichens, and pollution-sensitive human individuals. Eurytopic species, while also affected, can still endure temporarily. Urban survivors such as rats, feral cats, and humans utilizing indoor environments or protective gear may still persist.

Collectively, these images convey a vivid narrative of how changing environmental parameters can selectively affect species based on their ecological tolerance. They offer an accessible and practical application of Shelford's Law and deepen our understanding of urban biodiversity and resilience amidst climatic stressors.

Figure 4: showing Shelford's Law of Tolerance across four environmental conditions—Clear and Sunny, Slightly Hazy, Overcast/Stormy, and Heavy Haze/Smog—linked to their respective ecological zones

Optimum, early stress, stress, and intolerance should be noted as it visualizes how stenotopic species (narrow tolerance) and eurytopic species (broad tolerance) respond to environmental changes. Stenotopic responses range from "Thriving" in the optimum zone to "Absent or Dead" in the zone of intolerance. Eurytopic responses, in contrast, demonstrate broader resilience, ranging from "Thriving" to "Survives with Adaptation." The figure 4 illustrates species-specific tolerances to environmental variability using both color-coded zones and textual cues for behavioral outcomes.

The photographic sequences used in this study offer a compelling and intuitive visualization of Shelford's Law of Tolerance, effectively linking environmental gradients with observable changes in human behavior, particularly among schoolchildren. This method captures behavioral shifts as ambient conditions fluctuate, illustrating the concept of ecological tolerance zones in real time. Under optimal conditions—characterized by clear skies, mild temperatures, and good air quality—children actively occupy outdoor spaces, representing the behavioral analogue of organisms thriving within their optimum tolerance zone. However, as environmental quality deteriorates due to haze, smog, or poor lighting from cloud cover, outdoor activity visibly declines. This behavioral withdrawal reflects movement into zones of stress or intolerance, where conditions exceed comfort or safety thresholds as shown in Figure 4. Such visual data not only reinforce theoretical ecological principles but also resonate with students' lived experiences, making abstract concepts like environmental tolerance limits more tangible and relevant (Carrasco-Hernandez, 2020; Day and Saive, 2009; Erofeeva, 2021).

This visual methodology serves as a powerful educational tool, bridging ecological theory with real-world observation. Unlike traditional textbook approaches, the use of photographic evidence in local urban settings transforms passive learning into active, place-based inquiry (Carrasco-Hernandez, 2020; Krebs, 2008). Students and educators can draw direct parallels between observed human behavior and ecological responses of other organisms. Urban landmarks—such as schoolyards, parks, and sidewalks—become living laboratories for ecological literacy, where everyday experiences become evidence for interpreting environmental effects. This experiential learning fosters deeper environmental awareness and allows for the contextualization of concepts such as tolerance limits, stress zones, and ecological thresholds within familiar, localized environments (Lynch and Gabriel, 1987; Shapovalov et al., 2022).

The observed variation in behavioral response among children also serves as a symbolic representation of ecological specialization and generalization. Children who quickly retreat indoors at the onset of environmental discomfort mirror stenotopic organisms—species with narrow environmental tolerances that are sensitive to even minor changes in conditions (Harper et al., 2000; Boag et al., 2018). These behavioral patterns reflect a low resilience to environmental stress, akin to specialized species in nature. On the other hand, children who continue outdoor activities despite mild environmental deterioration exemplify eurytopic organisms—generalist species with broader tolerance ranges, capable of adapting to a wider array of environmental conditions (Davenport and Davenport, 2007; Lema et al., 2016; Lannig et al., 2003). This analogy provides a concrete framework for teaching the concept of ecological niches, species resilience, and adaptive capacity. It also aligns with broader discussions on urban flood resilience and adaptive strategies, as evidenced by research in Ghana, India, and other global urban settings where vulnerability assessments, infrastructure planning, and public-private cooperation have been integral to managing environmental hazards (Ampofo et al., 2025; Shukla et al., 2025; Ambily et al., 2025).

Beyond its educational implications, this photographic approach offers valuable insights for urban planning and public health. Documenting human behavioral responses to changing environmental conditions can help identify thresholds beyond which outdoor activity becomes unsafe or undesirable (Harlan et al., 2014; Esperon-Rodriguez et al., 2021). These insights can inform the design of heat-mitigation strategies, such as shaded areas, green infrastructure, and cooling centers, as well as the implementation of early warning systems for air quality and thermal stress (Shukla et al., 2025; Ambily et al., 2025). By applying ecological principles—specifically Shelford's Law—to urban management, planners and policymakers can develop proactive interventions that enhance community resilience and support well-being in increasingly volatile urban climates. These findings echo ecophysiological studies in aquatic systems, where researchers have long investigated thermal tolerance and metabolic adaptations in eurythermal species like cod and pupfish (Davenport and Davenport, 2007; Lema et al., 2016; Lannig et al., 2003), as well as the role of oxygen and temperature in the evolution and distribution of stenothermal marine species (Boag et al., 2018; Zale, 1987; Harper et al., 2000).

Ultimately, using photography to document and interpret environmental change through the lens of Shelford's Law of Tolerance provides a multifaceted framework for exploring ecological responses. This method integrates behavioral ecology, environmental education, and climate adaptation into a unified, accessible approach. By making ecological theory visible and relatable, it supports both classroom learning and policy innovation. It encourages adaptability, cultivates ecological empathy, and strengthens the public's capacity to respond to environmental stress—an urgent necessity as cities worldwide confront the realities of climate change and urban expansion (Pörtner, 2002; Reisfield et al., 2012).

4. Conclusion

This study demonstrates the value of using photographic evidence to contextualize Shelford's Law of Tolerance within an urban environment, providing a clear and relatable framework for understanding how organisms respond to environmental gradients. By integrating the ecological concepts of stenotopic and eurytopic tolerance, the analysis reveals how varying weather conditions—from optimal to intolerable—affect both human behavior and broader ecological dynamics. This approach not only enhances ecological education through visual and experiential learning but also offers practical insights for public health, environmental planning, and climate resilience. As cities face increasing environmental stressors, such visual tools can foster greater ecological awareness and inform adaptive strategies for sustainable urban living.

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Author contributions

Chee Kong Yap: conceived,and designed the experiments, performed the experiments; analyzed, and wrote the paper, Musefiu Adebisi Tiamiyu: validation, writing-reviewing, and editing, Noraini Abu Bakar: analyzed and interpreted the data, reviewing and editing, Wan Mohd Syazwan: data curation, reviewing, and editing, Wan Mohd Syazwan: validation, writing-reviewing, and editing Ahmad Dwi Setyawan: contributed materials, reviewing, and

editing.: Rosimah Nulit: reviewing and editing, Noor Azrizal-Wahid: reviewing and editing, Chee Seng Leow: reviewing and editing, Mohamad Saupi Ismail: reviewing and editing, Yoshifumi Horie: reviewing and editing, Chee Wah Yap: reviewing and editing and Kennedy Aaron Aguol: reviewing and editing

Ethics approval

There is no ethical approval needed to conduct the present study.

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