Review Article

Urban Entomology: Navigating the Intersection of Pests and Human Environments

ABSTRACT

Urban entomology, a distinct discipline within entomology, focuses on pests in human environments, addressing a wide range of species from insects to vertebrates. First coined by A.H. Waters in 1884 and popularized by W. Ebeling's 1975 book, urban entomology gives an idea about arthropods' interactions with humans, pets and structures. As urbanization accelerates, with a projected 68% of the global population living in cities by 2050, understanding pest dynamics becomes increasingly critical. Factors like invasive species, pesticide resistance and public health concerns underscore the need for effective pest management strategies, emphasizing Integrated Pest Management (IPM) approaches. This review explores urban entomology's history, key pest groups and modern management challenges, while highlighting the industry's evolution in response to urbanization. It also discusses the roles of various stakeholders, including researchers, pest management professionals and regulatory bodies, in addressing urban pest issues. Ultimately, the review calls for collaborative efforts to enhance pest control practices, leveraging biological control methods and sustainable strategies to mitigate the impacts of urban pests on public health and infrastructure.

Keywords: [Integrated Pest Management (IPM), Invasive Species, Pest Management, Public Health and Sustainability, Urban Entomology]

1. INTRODUCTION

Urban entomology is a recognized discipline within entomology that focuses on household and structural pests, distinct from traditional economic and medical entomology. Embraced by researchers, academia, cooperative extension specialists and pest management professionals (PMPs), this field addresses pests such as spiders, mites and vertebrates like rodents and bats (Waters, 1884; Ebeling, 1975).

The term "urban entomology" first appeared in an entomological note by A.H. Waters in 1884, but it gained broader acceptance with W. Ebeling's seminal book, "Urban Entomology," published in 1975. Ebeling highlighted five key research areas,including insect pests of humans in urban settings, which remain central to urban entomology today (Ebeling, 1975).

Robinson (2005) described urban entomology as the study of arthropods interacting with humans, pets and plants, while Zungoli (1996) defined it as the study of arthropods associated with human structures. Unlike other entomological fields funded by government grants, urban entomology emerged in response to urbanization, invasive pests, and public awareness of pest management needs (USDA). Entomology departments and research organizations provide essential scientific support, while the pest control industry contributes economically to the discipline's growth (Ebeling, 1975; Robinson, 2005). This review aims to

give a broad Definition: urban entomology is the study of arthropods and pests in the human environment and overview of urban entomology's history and the factors influencing its evolution.

Urban entomology has evolved significantly through numerous publications, initially focusing on pests in the United States, the United Kingdom, and Europe, and more recently extending to Northeast and Southeast Asia. Early influential works include "Common Household Pests of North America" (1939) and "Insect Pests" (1941), which highlighted various pests like rats, cockroaches and bed bugs, emphasizing their damage and control measures (Hartnack, 1939; Harvey & Hill, 1941).

Human activities significantly influence urban landscapes through land cover changes, land use conversion and altering the processes. These transformations become the blunder in the boundaries between urban and natural ecosystems. Urban area exploitation exacerbates the risk of pest infestations and the diseases they carry (Morzillo& Schwartz, 2011). Globalization and improved transportation have further facilitated the spread of invasive pest species (Meyerson & Mooney, 2007; Hulme, 2009). The global pest management market, valued at approximately US$16 billion, is projected to grow to US$21 billion by 2021, with a compound annual growth rate (CAGR) of 5.67% (Technavio, 2018).

Urban expansion is projected to increase by 1.2 million km² in the coming decades (Seto*et al*., 2012), significantly impacting landscapes and ecosystems through habitat fragmentation and vegetation degradation (Grimm *et al*., 2008). Arthropods, due to their rapid generation times and diverse ecological roles, are valuable indicators of anthropogenic change (McIntyre, 2000). Consequently, research on how urban landscapes affect arthropods has surged, revealing inconsistent effects on herbivore populations and their natural enemies (Bergerot*et al*., 2010; Dale and Frank, 2014; Liu *et al*., 2016). These varied responses may stem from differences in feeding guilds, taxonomic groups, and sensitivities to urban conditions like heat islands and pollution (Fenoglio*et al*., 2020). Additionally, urbanization influences competition for resources, leading to different outcomes at community levels (Shochat*et al*., 2010).

Urban pests can be categorized based on their interactions with humans. The most notable groups include:

1. Blood-Feeding Pests: Insects such as mosquitoes and bed bugs directly feed on human blood, causing injuries and transmitting diseases. Ecto-parasites like lice and fleas are also significant; ticks, for instance, can transmit Lyme disease and other illnesses.

2. Injury-Inflicting Pests: Insects like bees, ants, and wasps can cause severe allergic reactions or even fatalities through envenomation.

3. Allergen and Contamination Sources: Some pests contribute to food contamination and trigger allergies, impacting human health significantly.

4. Stored Product Pests: These pests, including various insects and rodents, infest stored food, clothing, and artefacts, leading to economic losses and health risks.

5. Structural Pests: Termites, powder-post beetles and rodents compromise the integrity of buildings, causing physical damage and spreading diseases.

Historically, human efforts to manage pests date back to the dawn of civilization. The Romans, for example, drained marshes to combat malaria. By the 18th and 19th centuries,

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specialized rat trapping emerged in Europe, with knowledge of pest control techniques carried by immigrants to the United States, laying the groundwork for the American pest control industry.
The development of DDT in the 20th century marked a turning point in pest management, becomes a new era with synthetic pesticides that effectively reduced vector-borne diseases. However, the widespread use of such chemicals led to significant environmental concerns, particularly highlighted in Rachel Carson's "Silent Spring." This awareness triggered the establishment of regulatory bodies and the promotion of Integrated Pest Management (IPM), which combines various control methods, including biochemicals and behavioral modifiers.
W. Ebeling's work at UCLA laid the groundwork for urban entomology research in the western U.S., leading to the influential book "Urban Entomology" (1975) (Ebeling, 1975). In Australia, P. Hadlington published "Urban Pest Control in Australia," advocating for professionalism in the industry (Hadlington&Gerozisis, 1985). Research on urban pests in Asia, notably cockroaches and termites, began gaining traction in the 1960s and expanded in the 1990s following pesticide bans (Lee, 1999).

The focus on pests associated with human habitats broadened economic entomology's scope, leading to new sections in journals dedicated to household and structural insects (Journal of Economic Entomology, 1992; Journal of Agricultural and Urban Entomology, 1999).
Urban entomology has gained significance due to several key factors. First, the global trend of urbanization is shifting populations from rural to urban areas, with an estimated 4.5 billion people currently living in cities. By 2050, this figure is projected to rise to 68% of the world's population (United Nations, 2018). This rapid increase in urbanization creates conditions favorable for pests, as inadequate housing and infrastructure provide harborage for vectors of communicable diseases.

Secondly, Invasive pests are another critical factor. Increased international trade has led to the global spread and dispersal of household pests, including ants and cockroaches. The number of invasive termite species has risen from 17 in 1969 to 28 in 2013, highlighting the escalating threat they pose to both health and economy.

Additionally, pest resurgence, particularly among species like bed bugs, causes significant problem. High levels of resistance to insecticides have led to their increased prevalence, prompting intensified research and development in pest management strategies. These factors underscore the growing importance of urban entomology in addressing pest-related challenges in increasingly populated urban environments.

2. Several key factors contribute to the rapid expansion of the pest management industry in Asia:

Urban Population Growth: Asia is the main center of global urbanization, expected to host 22 mega cities by 2030 (UNESCAP, 2017). The increasing urban population attracts demand for pest management services, especially as new urban developments with landscaped gardens create ideal pest habitat conditions.

Improved Socio-Economic Status: By 2030, 66% of the global middle-class population will reside in Asia (Pezzini, 2012). As this huge demographic shift from relying on ineffective government pest control to seeking private pest management services, awareness of pest issues is growing due to education and social media.

Regulatory Requirements: Many Asian countries are introducing strict hygiene and food safety rules and regulations, necessitates effective pest management services. For instance,

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China's Food Safety Law (2015) prohibits the production or distribution of contaminated food, driving food facilities to adopt international pest management standards.

Increased Global Travel: The rise of budget airlines has boosted travel within Asia, leading to an increase in hotels and restaurants. Consequently, the demand for pest management services has surged, particularly in the food and beverage sector, where compliance with food safety legislation is mandatory (Tomiyama, 2015).

3. Management:

Modern urban pest management dependent on chemical methods, incorporating exclusion devices, engineering solutions, pest-proofing materials and traps into IPM programs. This comprehensive approach aims for sustainable pest control.

Today, the urban pest management industry faces multiple challenges: increasing pesticide resistance, rising bed bug populations, emerging research on chemical toxicity, stricter regulations and growing public concern over environmental impacts. Moreover, urban pests can lead to legal disputes as they infiltrate even the most secure environments. Experts in pest behavior and biology are essential for resolving these conflicts and implementing effective management strategies.

Pest management has become essential as urban pests not only spread diseases but also elicit strong negative emotions, prompting reactions ranging from disgust to the use of toxic chemical sprays. The nature of pest control services often varies based on the environment; for instance, an ant infestation in a home may be a mere nuisance, while a single ant in a hospital could pose serious health risks. Therefore, institutional settings like healthcare facilities require meticulous design and planning to prevent pest incursions.

Biological control, a crucial ecosystem service provided by arthropods, is especially relevant in urban areas where chemical pest control poses risks to health and the environment (Lowe *et al.*, 2019).

Integrated Pest Management (IPM) is a promising approach among many pest management companies in Asia, yet its adoption is lacking. Factors contributing to this reluctance include clients' price sensitivity and the perception of IPM as costly compared to conventional methods (Dhang, 2014). The rise of eco-friendly designs, such as landscaped gardens and green buildings, inadvertently creates congenial habitats for pests, further complicating pest management efforts (Robinson, 1996).

Recent years have seen the introduction of invasive pest species and the emergence of diseases like dengue and Zika, increased by climate change and urbanization (Kraemer *et al*., 2019). Additionally, resistance to insecticides in urban pests poses a significant challenge (Moyes *et al*., 2017).

To address these challenges, pest management companies should collaborate and adopt the Blue Ocean strategies (Kim & Mauborgne, 2005). Stakeholders must focus on promoting IPM principles, acoustic pest management,leveraging technology and fostering partnerships to develop pest-resistant environmental conditions. Collaborative training initiatives and awareness campaigns can strengthen the efficacy in managing pest populations (Mauborgne & Kim, 2017).

Monitoring collected insects is crucial for identifying pest species and assessing their numbers, which aids in selecting appropriate control methods. Sticky traps, such as glue boards, are effective for monitoring cockroaches; they should be strategically placed along travel ways, particularly near intersections of walls and floors, as well as in cabinets and near major appliances in kitchens.

Pest control decisions depends on several factors, including health and safety threats, legal regulations and public tolerance of pests. Health and safety thresholds necessitate rapid

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response when pests pose potential harm, such as mosquitoes or rodents, which can transmit diseases or cause structural damage. If there's a risk of severe injury or property damage, the control threshold should be very low; for instance, a single rat can compromise electrical wiring, leading to fire hazards.

Legal thresholds fixed by public safety codes shows necessary pest control actions in public spaces, including commercial and residential buildings. Even when pest-related issues do not pose immediate health risks, compliance with these regulations is mandatory.
Individuals have varying difference of pest acceptance, which is mainly influenced by cultural beliefs and perceived risks associated with control methods. Understanding these thresholds can helps to build pest management strategies. Lastly, economic thresholds involve assessing whether the cost of control measures justifies potential losses from pest damage. Effective pest management typically employs a combination of prevention, trapping and when necessary, pesticides or biological controls to minimize infestations in structures.

Sanitation and habitat modification are essential strategies for pest management. Habitats provide the necessary resources for pests to survive and disperse and each habitat has a maximum population limit, known as carrying capacity. High carrying capacity occurs where food and shelter are abundant, while limited capacity helps maintain population size. Removing food, water, and breeding sites can significantly reduce pest populations.
Effective sanitation involves practices such as clearing dense vegetation, collecting trash in closed containers, managing standing water and eliminating attractants. Inside buildings, proper food storage, regular cleaning and thorough vacuuming are vital. A well-maintained environment aids in pest detection and cleaning effectiveness. Additionally, removing debris that can harbour pests, like wood or cellulose materials, helps to prevent infestations.

Exclusion is another most important method for keeping pests out. Building design should incorporate pest-proof features. Check for gaps in doors, windows and vents and use weather stripping and screens to block entry points. Inspect chimneys and ensure any openings for pipes or wires are sealed. Resources like "Pest Prevention by Design" provide guidelines on pest-resistant building strategies.
Biological control is a gaining tactic, with methods like introducing parasitic wasps to manage pest populations. While pesticides are commonly used for pest control in buildings, their application must consider the specific pest habits and environments. Various formulations-baits, powders, liquids and gases-are available, allowing for targeted pest management. Combining these methods enhances overall effectiveness and reduces pest populations sustainably.

3.1 Professional Pest Management Industry

The structural pest control and professional pest management industries in the United States began in the 1930s, with Snetsinger documenting their early development and collaboration with the scientific community (Snetsinger, 1988). By 1965, around 6,000 pest control firms were generating approximately $350 million in revenue, equivalent to about $3.3 billion today. By 2022, the market had surpassed $11 billion, with general pest control services—targeting pests like ants, cockroaches, and termites—accounting for roughly 75% of industry income.

In Asia, urban entomology did not gain significant traction until after the 1960s. Early research was focused on vector-borne diseases such as malaria and dengue due to limited resources. Bed bugs, however, remained a major concern in the region, having plagued populations for centuries. In the 1940s, pest control operators in Tokyo focused on eradicating bed bugs, while China launched a nationwide campaign in 1960 against the

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"Four Pests"—bed bugs, rodents, flies, and mosquitoes. In 1978, China established a National Four-Pest Elimination Research Team to monitor and control these pests.

In the U.S., the Federal Insecticide, Fungicide, and Rodenticide Act of 1947—amended in 1972—shifted regulatory responsibilities to the newly established Environmental Protection Agency (EPA). This legislation mandated certification for private and commercial pesticide applicators, with ongoing training in urban entomology and integrated pest management (IPM) strategies required. Continuing education became essential for maintaining certification, fostering collaboration between the pest management industry and regulatory agencies to create standardized training.

The Cooperative Extension Service, part of the land-grant university system, played a critical role in providing this training, leading to the hiring of additional personnel and faculty across multiple states. A 1977 survey found that 47.6% of pest management professionals (PMPs) relied on extension agencies for technical support.

Despite these advancements, resources for applied entomological research have declined in recent decades. However, the pest management industry has contributed significantly by establishing endowed positions in urban entomology at various universities. These positions, including those at Texas A&M University (1989) and North Carolina State University (1993, 1999), have strengthened the field of urban entomology and supported professional pest management efforts.

3.2 Entomological Organizations

The International Congress of Entomology (ICE) was founded in 1910 and gradually expanded its focus to include various branches of entomology, including economic entomology, which dealt with pests such as stored-product insects. By 1992, a specific section for Urban Entomology was introduced, highlighting the growing significance of the field (International Entomology Congress, 2020).
The Entomological Society of America (ESA), with a membership of over 7,000, has played a key role in promoting urban entomology. In 1986, efforts to recognize the importance of this field led to the creation of a subsection, which eventually became the current Medical, Urban, and Veterinary Entomology section (ESA, 2010). Pi Chi Omega, an organization founded in 1950 at Purdue University, fosters connections between entomologists working in structural pest control. The organization promotes academic engagement through scholarships and leadership initiatives (Pi Chi Omega, 2021). Early partnerships between pest control organizations and land-grant universities led to the establishment of important conferences that have set industry standards for training and ethics. Notable among these are the Purdue Annual Pest Control Conference, which began in 1937, and the North Carolina Pest Management Association's Pest Control Technician School, which started in 1951.

Challenges in the Industry

Despite its growth, the pest management industry in Asia faces significant challenges:

Business Competition: Increasing of local companies by multinational firms, such as Rentokil and Rollins, lead to rapid growth but often at the cost of service quality. After acquisitions, companies may prioritize profit over the training and retention of technical staff, leading to a decline in service standards and employee morale.

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Technical Training: Pest management technicians often receive in adequate training. Larger companies may offer comprehensive programs, but smaller firms usually rely on on-the-job training from experienced employees. The diversity of languages across Asia complicates training efforts. Additionally, licensing requirements vary, with only a few countries mandating pest control technician licenses, while others, like India and Indonesia, do not require any licensing at all.

4. CONCLUSION:

Urban entomology plays a crucial role in understanding and managing pests within increasingly populated environments. Its evolution, influenced by urbanization, invasive species and public health concerns, underscores the need for comprehensive pest management strategies that integrate biological, chemical, and engineering solutions. As urban areas expand and pest challenges escalate, especially in Asia, the demand for professional pest management services will continue to grow. Collaboration between academia, industry and regulatory bodies is essential for advancing research and education in urban entomology. Despite challenges such as competition and training disparities, the industry's commitment to adopting sustainable practices and innovative approaches will be vital in addressing pest-related issues effectively. Ultimately, a focus on Integrated Pest Management (IPM) and community engagement will enhance urban ecosystems and safeguard public health, ensuring a balanced coexistence between humans and the arthropods that inhabit urban landscapes.

ETHICAL APPROVAL: This article does not contain any studies with human participants or animals performed by any of the authors.

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