

Composition and abundance of cockroaches in traditional markets of Purwokerto City, Indonesia

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Abstract. *Ambarningrum TB, Widhiono I, Kusmintarsih ES, Pratiknyo H, Haryanto T, Hasyifah FN. 2024. Composition and abundance of cockroaches in traditional markets of Purwokerto City, Indonesia. Biodiversitas 25: 2773-2779.* Markets with high human activity and abundant food are ideal conditions for cockroaches. This study aimed to investigate the composition and abundance of cockroaches infesting three markets in Purwokerto City, Banyumas District, Central Java, Indonesia. To achieve this objective a survey method with random sampling used baiting traps and hand collection. The analysis used the Shannon-Wiener index (H'), Evenness index, relative abundance, and density index. The results showed that three cockroach families were identified, namely Blattellidae, Blattidae, and Blaberidae. The cockroaches found in markets 1 and 3 consisted of five species, namely *Blattella germanica* (Linnaeus, 1767), *Periplaneta americana* (Linnaeus, 1758), *Blatta lateralis* (Serville, 1838), *Nauphoeta cinerea* (Olivier, 1789), and *Pycnoscelus surinamensis* (Linnaeus, 1758), while in Market 2 there were only three species, namely *B. germanica*, *P. americana*, and *N. cinerea*. The total population were 2467, 81, and 3627 individuals in Market 1, 2, and 3 respectively. The *B. germanica* predominated in Markets 1 and 2, while *N. cinerea* dominated in Market 3. Furthermore, density levels varied across markets, showing differing infestation intensities. The study explained the importance of integrated pest management strategies and regular monitoring to control cockroaches population effectively. These results provide valuable insights for local pest control efforts aimed at maintaining hygiene and health standards in market environments.

Keywords: Abundance, infestation, monitoring, pest management, population density

INTRODUCTION

Cockroaches are ubiquitous insects capable of thriving in diverse environments, ranging from forests and farms to densely populated urban areas. Cockroaches play an important ecological role as detritivores. Approximately 5,000 species of cockroaches exist, and only around 40 species are considered significant pests that commonly infest human settlements (Tang et al. 2018). Due to the habit of harboring and spreading disease-causing microorganisms, cockroaches pose serious health and economic concerns, particularly in tropical regions (Memona et al. 2017; Sosan et al. 2019). Studies have shown the insects' ability to carry and transmit various pathogens, including antibiotic-resistant bacteria, which pose a significant public health risk (Ademolu et al. 2020). Cockroaches collected from environments like landfills have been found to harbor high levels of bacteria and fungi, including antibiotic-resistant strains of *Staphylococcus aureus* Rosenbach, 1884 and *Bacillus subtilis* G (Ademolu et al. 2020; Molewa et al. 2022). Furthermore, the insects can host protozoa and parasitic worms, contributing to the spread of infectious diseases (Siagian et al. 2017). Their role as disease vectors, cockroaches trigger allergic reactions in humans, particularly among asthmatics, through allergen proteins present in the bodies and feces (Gautier and Charpin 2017; Kleine-Tebbe et al. 2019). These allergens are well-documented and contribute to

respiratory problems in sensitive individuals (Wangorsch et al. 2021).

In human settlements, several species of cockroaches commonly infest residential and commercial spaces. These include the American (*Periplaneta americana* (Linnaeus, 1758)), Australian (*Periplaneta australasiae* (Fabricius, 1775)), German (*Blattella germanica* (Linnaeus, 1767)), and Oriental Cockroaches (*Blatta orientalis* Linnaeus, 1758) (Yagci et al. 2016). Other cockroach species include the Turkestan Cockroach (*Blatta lateralis* Serville, 1838) and the Brown Ribbon Cockroach (*Supella longipalpa* (Fabricius, 1798)) which infested 39.3% of the 573 housing units in the Iranian city of Yasuj. The prevalence of cockroach infestations can vary significantly across different regions and types of buildings, influenced by factors like sanitation practices and building maintenance (Shahraki et al. 2013). Marketplaces, with a high density of human activity and food sources, are particularly susceptible to cockroach infestations. Poor sanitation and inadequate maintenance of market structures often create ideal conditions for cockroaches to thrive (Sosan et al. 2019). Their presence in markets not only poses health risks to vendors and visitors but also facilitates the transmission of diseases.

Studies specifically focusing on cockroach infestations in the city of Purwokerto identified several key species inhabiting local markets. Ambarningrum et al. (2022) explored the prevalence and composition of cockroaches in

three markets within Purwokerto. The results showed the presence of German cockroaches, among others, with initial reports suggesting susceptibility to fipronil, an insecticide commonly used for pest control. Understanding the specific species composition infesting Purwokerto markets is crucial for effective pest management strategies. Different species may require tailored approaches for control and eradication. Moreover, ongoing surveillance and monitoring are essential to prevent reinfestation and mitigate potential health risks associated with cockroach presence. Given the dynamic nature of urban environments and global trade, the spread of cockroaches is likely to increase alongside human mobility and the transportation of goods (Nasirian 2017). The ability to adapt to various conditions and the association with human settlements make cockroaches challenging to manage effectively.

Managing infestations in markets and other human settlements requires a multifaceted approach that includes sanitation improvements, structural maintenance, targeted insecticide application, and ongoing surveillance. Collaborative efforts between public health authorities, pest control professionals, and community members are also essential to minimize the health risks and economic impacts associated with the infestations. By understanding the composition of local species and implementing proactive control measures, it is possible to create safer and healthier environments for residents, workers, and visitors in Purwokerto and other cities.

MATERIALS AND METHODS

Study period and area

Sampling was carried out at three markets in Purwokerto City, Banyumas District, Central Java, Indonesia, from March to June 2022. Purwokerto City is an aggregate of 10 sub-districts in Banyumas District which were once proposed to become a separate city. The markets are located at coordinates L: -70 25'35.91", B: 109014'59.53" (Market 1), L: -70 25' 8.23", B: 109013'39.35" (Market 2), and L: -70 23' 49.41", B: 109013' 55.69" (Market 3), as shown in Figure 1. The first

market is situated in North Puwokerto Village, East Purwokerto Sub-district. It is the oldest and largest market in Purwokerto, covering one hectare and approximately 1,700 registered vendors, both outdoor and indoor, with 24-hour trading activities. Market 2 is located in Kedungwuluh Village, West Purwokerto Sub-district. This semi-modern market spans about 1,500 square meters, has around 550 traders, and operates from 06:00 to 21:00. Market 3 is in Purwosari Village, Baturaden Sub-district. This village market spans approximately 1,000 square meters in size, has about 300 vendors, and operates from 06:00 to 14:00.

All stalls in the sampling area in the three markets are indoors. Stalls sampled at Markets 1, 2 and 3 were 85, 70, and 70, respectively, with merchandise including basic necessities, kitchen spices, food and vegetables. The selection of stalls is based on the permits of each stall owner and the initial inspection. This research is in collaboration with the Regional Technical Implementation Unit for Market Regions 1 and 2 of Purwokerto City; based on interviews with market heads, so far, no efforts have been made to control cockroaches in the market area.

Field survey

This study used a survey method with random sampling, incorporating both hand-collecting and baiting traps. A total of three baiting traps were installed at 85 stalls at Market 1 and 70 stalls each in Markets 2 and 3. The traps were left at each location for 3 x 24 hours between March and June 2022 and involved eight people field workers. Three baiting traps were installed in each of the 10 stalls in each market for three days, except for installation in the last three days at 15 stalls in Market 1, resulting in 255 baiting traps installed in Market 1 and 210 baiting traps each in Market 2 and 3. Baiting traps were placed under food storage cupboards, drawers, and in-room corners and set up the afternoon before the market closure. Hand collecting was performed immediately in suspected cockroach hiding places, such as scattered used cardboard, cracks in wood and walls, and temporary rubbish storage areas within the market premises. Captured cockroaches were transferred to a killing jar containing 10% chloroform and subsequently preserved in 70% alcohol.

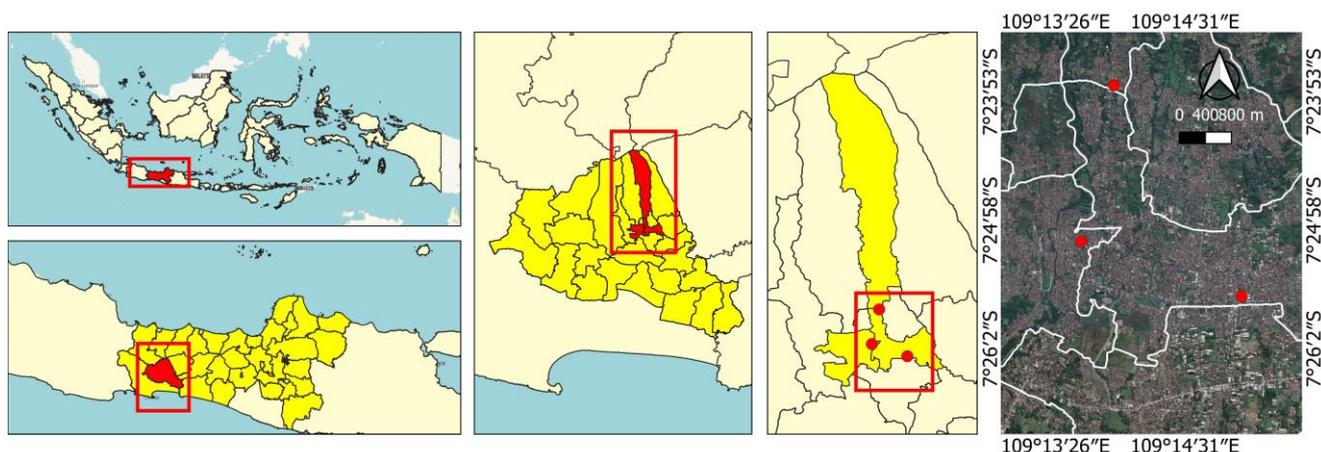


Figure 1. Location of Purwokerto City, Banyumas District, Central Java, Indonesia

Cockroaches identification

The specimens were examined in the Entomology and Parasitology Laboratory, Faculty of Biology, Universitas Jenderal Soedirman, Indonesia, using an identification key (Beccaloni 2014; Bugguide 2024).

Data analysis

Diversity, evenness, relative abundance, and cockroach density index were calculated using the following formula:

Shannon - Wiener Diversity Index (H’):

$$H' = - \sum_{i=1}^n pi \ln pi$$

- H' : Diversity index
- Pi : ni / N
- Ni : Number of type i
- N : Total number of species

Criteria:

- H>3 : high diversity index
- 1<H<3 : medium diversity index
- H<1 : low diversity index

Evenness index (E):

$$E = H' / \ln S$$

- E : Evenness index
- H' : Diversity index
- S : Number of types

Criteria = Evenness has an indicator value of E = 1. E = 1 means that the habitat does not exist for the dominating species

Relative abundance = $\frac{\text{The total number of species in an area} \times 100}{\text{The total sum of all populations of species in an area}}$

$$\text{Density Index} = \frac{\text{Number of cockroaches caught}}{\text{Number of traps}}$$

Cockroach density index criteria:

- 0-1 : Clean
- 1-3 : Low
- 3-8 : Moderate
- 8-26 : High
- 26-50 : Very high
- >50 : Considerably high

RESULTS AND DISCUSSION

Abundance of cockroaches in three markets in Purwokerto City

The results showed that three families of cockroaches infested three markets in Purwokerto City, namely Blattellidae, Blattidae, and Blaberidae. Markets 1 and 3 were infested by five species, namely German (*B. germanica*), American (*P. americana*), Turkestan (*B. lateralis*), Lobster (*Nauphoeta cinerea* (Olivier, 1789)), and Surinamese cockroaches (*Pycnoscelus surinamensis* (Linnaeus, 1758)). In contrast, Market 2 was only infested by three species, namely German (*B. germanica*), American (*P. americana*), and Lobster cockroaches (*N. cinerea*).

Market 3 had the highest number of cockroaches with a total of 3627, followed by Market 1 with 2467 and Market 2 with 81. German cockroaches were the most common in Markets 1 and 2, with a total of 1690 and 59, respectively, while Lobster cockroaches predominantly infested Market 3. The fewest American cockroaches were found in Market 1 (8), while Market 2 had only 3 Lobster cockroaches, and Market 3 had 35 Turkestan cockroaches. The diversity indices (H') for Markets 1, 2, and 3 were 0.84, 0.69, and 0.9, respectively. The evenness indices (E) for Markets 1, 2, and 3 were 0.46, 0.67, and 0.49 respectively (Table 1).

Table 1. Number of families, individuals, diversity index (H'), and evenness index (E) of cockroaches on three traditional markets in Purwokerto City, Indonesia

Family	Species	Location								
		Market 1			Market 2			Market 3		
		Trap (ind.)	HC (ind.)	Number of Individuals	Trap (ind.)	HC (ind.)	Number of individuals	Trap (ind.)	HC (ind.)	Number of individuals
Blattellidae	<i>B. germanica</i>	689	1001	1690	11	48	59	405	1190	1595
Blattidae	<i>P. americana</i>	6	2	8	13	6	19	41	15	56
	<i>B.lateralis</i>	35	62	97	0	0	0	9	26	35
Blaberidae	<i>N. cinerea</i>	146	468	614	3	0	3	951	909	1860
	<i>P. surinamensis</i>	3	55	58	0	0	0	68	13	81
Number of Individual		2467			81			3627		
Number of Families		3			3			3		
H'		0.84			0.69			0.9		
E		0.46			0.67			0.49		

Note: Ind: individuals, HC: Hand Collection, H: Shannon Weiner diversity index, E: Similarity index

The diversity index (H') of cockroaches in the three markets of Purwokerto City ranged between 0.49-0.9 ($H' < 1$), showing low cockroach diversity. A low diversity index showed only a few species were dominating with a significant number than others. This was evidenced by the uniformity index (E) for the three markets, ranging between 0.46 and 0.67 ($E < 1$). Therefore, the distribution of cockroaches between species was uneven, and some species were more dominant (Magguran 2004). According to Leksono (2007), diversity measures community structure. When there are several species with almost the same population, heterogeneity is high. Conversely, heterogeneity is low when there are few species with significant differences in population.

German cockroaches belong to the Blattellidae family member and were the most prevalent species in Market 1, followed by lobster cockroaches. In Market 2, American cockroaches ranked second after German cockroaches. The German cockroaches are typically found in grocery store stalls, dry foods, cardboard boxes, wall cracks, wood crevices, storage cabinets, and drawers. The body length ranges from 1 to 2 cm. Adult males are light brown, females are dark brown, and both have two black stripes on the pronotum (Figure 2.A). Although the wings are not used for flight, they can help when gliding from heights (Apple 1995; Ross and Mullins 1995). Female German cockroaches can produce 4-8 oothecae in a lifetime, each containing 35-48 eggs. The ootheca is attached to the subgenital region and is carried until just before the hatching of the eggs (Robinson 2005).

In several developing nations, German cockroaches pose a serious problem as a common indoor pest in low-income housing. These species thrive indoors and are rarely found in natural habitats, spreading widely due to human mobility, transportation, and distribution of goods (Beccaloni 2014; Tang et al. 2018; Lee and Wang 2021). Cahyani et al. (2018) reported that German cockroaches were the most frequently encountered species in the Semarang city market, accounting for 80.09% of all cockroaches found. According to Hidayati (2020), the population of American and German cockroaches was high in the Harjodaksino and Gede markets in Surakarta. German cockroaches were absent in Padang City but prevalent in two hospitals (Mairawita et al. 2014). The species also dominated commercial kitchens in hotels, restaurants, apartments, and transportation modes such as ships. Furthermore, Alias et al. (2018) documented high infestations of German and American cockroaches on passenger and cargo ships at the port of Baubau, Indonesia.

Lobster cockroaches were most prevalent in Market 3, followed by German cockroaches. In Market 3, Lobster cockroaches were commonly found on the floor, specifically around meat stalls and under storage cupboards. These cockroaches belong to the Blaberidae family, have a body length of 2-3 cm, and are light gray. The wings do not cover the entire body and feature brown spots in adults. These cockroaches are outdoor insects but can infest animal feed processing factories (Figure 2.B) (Bugguide 2024).

American cockroaches belong to the Blattidae family and have a body length of 3-5 cm. The imago is characterized by a reddish-brown body with a light-colored

pronotum edge and a dark-colored two-circle pattern in the center (Figure 2.C). Males are light-colored with a sharp tip of the abdomen, while females have a dark color with a round tip of the abdomen. The wings are quite well developed, facilitating flight for short periods. However, the wings are rarely used except to reach inaccessible areas or, to avoid danger, or to intimidate predators in urgent situations. Females can produce 11-17 oothecae in a lifetime, each containing 14-15 eggs/oothecae, which are typically deposited in a safe place or near food sources (Borah and Hazarika 2019).

American cockroaches are a globally widespread pest species (Bell et al. 2007). Amalia and Harahap (2010) conducted a study in the Babakan Lebak area, Dramaga, Bogor, Indonesia, testing cockroach bait in 30 houses. The results showed that 8 American cockroaches and 1 Australian cockroach were found, with imago comprising 87.5% and nymphs 12.5%. American cockroaches are commonly found in toilets frequently used by Australian cockroaches. In Vietnam, out of the 187 houses, condominiums and shops surveyed, 44.9% were infested, with the composition being American (72.1%), German (14.8%), Surinamese (7.3%), Australian (*P. australasiae*) (2.9%), *P. fuliginosa* Serville, 1838 (1.9%), and *S. longipalpa* (1.0%) (Trinh et al. 2016). Another study conducted in low-cost and mid-range apartments in Lagos, Nigeria, showed that American cockroaches were the most dominant species (68%), followed by German Cockroaches (32%) (Adenusi et al. 2018). Supryatno et al. (2018) reported high infestations (3196 cockroaches) in 24 passenger and cargo ships at Baubau Port, Indonesia, specifically American (69.5%) and German (29.6%). Furthermore, a survey in 2015 found German and American Cockroaches infesting motorboats docked at Surabaya's Perak Harbor. It was reported that out of the 30 sample ships, 63.3% had low cockroach densities, while 36.7% had high densities.

Surinamese cockroaches belong to the Blaberidae family. At the study location, these cockroaches were found in piles of litter at vegetable stalls. Their presence in the market could be attributed to the transportation of vegetables from planting fields. The Surinamese cockroaches are dark brown with a blackish brown pronotum and pale brown wings, with a body length ranging from 1.8 to 2.5 cm (Figure 2.D). In their natural habitat, these cockroaches hide under rocks and feed on plants, including vegetable plantations. In urban environments, the insects are common around buildings, feeding on the surrounding plants. These cockroaches can reproduce by parthenogenesis (Robinson 2005).

Turkestan cockroaches belong to the Blattidae family. At the study location, these cockroaches were found in temporary rubbish dumps near vegetable stalls. The males have a body length of 1.9 to 2.3 cm (Figure 2.E), while the females range from 2.2 to 2.5 cm. At first glance, male Turkestan cockroaches resemble male German cockroaches but differ with lighter body color and the absence of two black lines on the pronotum. The females are wingless with a reddish brown pronotum, resembling American cockroach nymphs. When gravid, females carry ootheca until the eggs hatch.

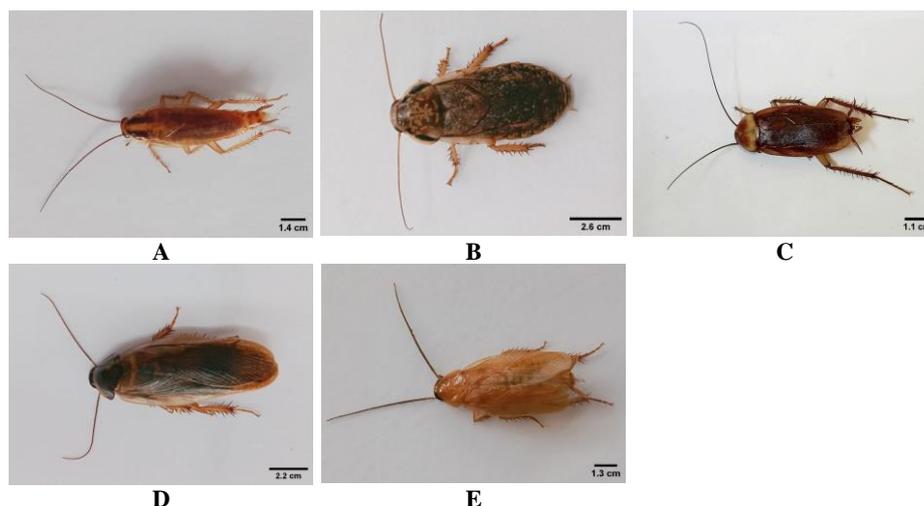


Figure 2. Cockroach species are found in three markets in Purwokerto City, Indonesia. Note: A: *B. germanica*, B: *N. cinerea*, C: *P. americana*, D: *P. surinamensis*, E: *B. lateralis*

Table 2. Cockroaches density index in three markets in Purwokerto City, Indonesia

Location	Number of trap	Number of cockroaches (ind.)	Density index (ind. /trap)
Market 1	255	879	3.45
Market 2	210	27	0.13
Market 3	210	1870	8.90

Market 3 had the highest cockroach density index (8.9 individuals/trap), followed by Market 1 (3.45 individuals/trap), while Market 2 had the lowest (0.13 individuals/trap) (Table 2).

The high cockroach density index in Market 3 (8.90 individual/trap) could be attributed to several factors, including poor sanitation and the old building structure with many cracks on the walls and floors. The market is around 1000 m², with about 120 traders, making it crowded with goods piled up and stalls close to each other. These conditions attract cockroaches, along with the abundant food available. Market 1, the oldest market in Purwokerto, had significant structural damage, and a fire in one of the blocks in 2020 left the area quite dark, providing a hiding place for various species of cockroaches. In contrast, Market 2 had low cockroaches due to better sanitation, lighting, and building conditions. Market 2 also had several trash bins and effective waste management. Only three species of cockroaches were found in this market, namely German, American, and Lobster cockroaches, excluding Turkisan and Surinamese cockroaches. American and Lobster cockroaches were more common in the chicken and fish stalls on the lower floor, while German cockroaches were more common in the canteen. Despite the low cockroach density index in Market 2, regular population monitoring was still necessary. The density of cockroaches at the study location was in accordance with Lee and Heng (2000), stating that the presence of cockroaches depends on environmental conditions and food availability. Poor sanitation, damaged buildings, abundance

of food, and water availability contributed to increased cockroach populations in human habitats (Lamiaa et al. 2007).

Composition of cockroaches in three markets in Purwokerto City

German cockroaches made up 68.5% of the total population in Market 1, followed by Lobster (24.9%), Turkestan (3.9%), Suriname (2.4%), and American (0.3%) (Figure 3.A). The community of cockroaches in Market 2 comprised German (23.5%) and Lobster (3.7%) (Figure 3.B). Lobster cockroaches made up 51.3% of the total population in Market 3, followed by German (44%), Surinamese (2.2%), American (1.5%), and German cockroaches (1%) (Figure 3.C).

In general, German cockroaches dominated the three markets in the city of Purwokerto. This dominance could be attributed to environmental factors strongly supporting their life cycle, as shown by Tang et al. (2018). High infestations of German cockroaches in an area were influenced by high reproductive ability, faster life cycle compared to other pest cockroaches, high adaptability, preference for warm temperatures, tendency to find food and shelter in urban environments, aggregation behavior, high mobility facilitated by transportation, and resistance to various classes of insecticides. This research is consistent with the findings of Wang et al. (2019), who determined that 3,342 cockroaches captured in apartments in two New Jersey cities were German cockroaches. In the Turkish province of Van, cockroach infestations are widespread (Oğuz et al. 2017). The species composition of cockroaches in this study differs from the findings of Trinh et al. (2016), who surveyed 187 housing units, condominiums, and shops in Vietnam and discovered that American cockroaches were the most prevalent species in 44.9% of these dwellings. (72.1%), then German cockroaches (14.8%), Surinamese cockroaches (7.3%), Australian cockroaches (2.9%), Serville cockroaches (1.9%), and brown ribbon cockroaches (1%).

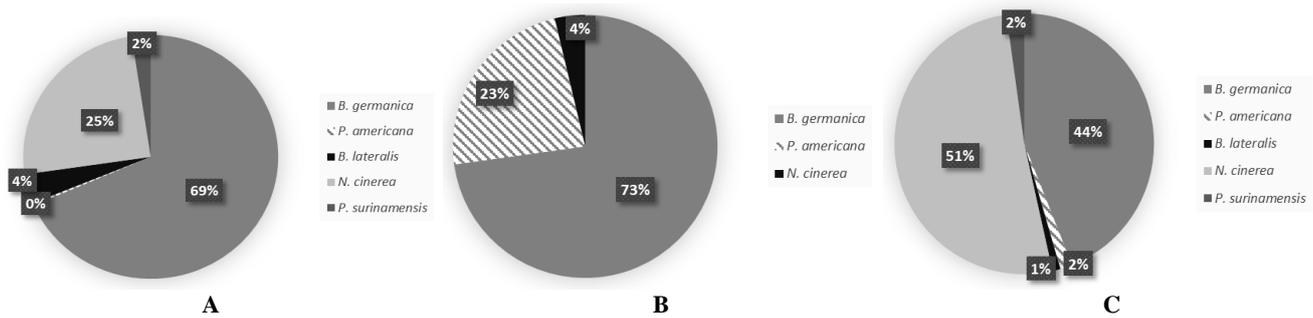


Figure 3. Composition of cockroaches in three markets in the city of Purwokerto City, Indonesia. A. Market 1, B. Market 2, C. Market 3

Each location's composition of cockroach species may exhibit the same or different patterns. It depends on the environmental factors that sustain each species' survival. In urban areas, the German cockroach is the most widespread species of cockroach. This is a result of its small body size, rapid generation rate, and rapid evolution, particularly its resistance to insecticides (Lee and Wang 2021). The German cockroach has also developed behavioral adaptations that allow it to be more flexible in locating and selecting food, which is supported by its capacity to learn and remember, particularly in its food search (Ko et al. 2017).

In conclusion, five species of cockroaches were found in two markets and three species in another market in Purwokerto, with density levels ranging from low to high. The level of infestation varied in each market depending on the availability of food sources, sanitary conditions, and the quality of market building. The results of this research provide important information regarding cockroach infestation in markets, considering the market's function as a distribution center of commodities from producers to consumers, including households, hotels, restaurants, offices, etc. Cockroach infestations in markets can cause the spread of cockroaches to these areas, which in turn can cause various health and hygiene problems. Therefore, integrated pest control (IPM) efforts are needed which combine various actions, including good sanitation, improving facilities and infrastructure, such as closing cracks and repairing leaky pipes, which is very important to reduce hiding places and water sources for cockroaches, as well as educating traders and market staff to understand the importance of cleanliness and ways to prevent cockroach infestation. These efforts should be complemented by regular monitoring of cockroach populations to ensure that control measures implemented are effective and can be adjusted if necessary. In the context of sensitive market areas related to human mobility and food safety from insecticide residues, as well as the association with aggregation behavior in nesting, coprophagy and necrophagy behavior in cockroaches, bait-based control using slow action active ingredients is recommended. This active ingredient works slowly so that it has a domino effect on cockroaches in their nests. When a cockroach consumes bait, the cockroach can return to its nest and die. Its feces and carcasses will be eaten by other cockroaches,

which, in the end, can reduce the cockroach population significantly without causing the risk of insecticide residues in areas frequently visited by humans and used for food storage. Through this comprehensive approach, it is hoped that cockroach infestations in the market can be controlled more effectively, thereby reducing the risk of cockroaches spreading to various places.

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REFERENCES

- Ademolu KO, Mustapha OY, Idowe AB. 2020. Nutritional and gut microbial analyses of adult male cockroaches (*Periplaneta americana*) (Dictyoptera, Blattodea) from three locations in Abeokuta, Nigeria. *Entomol Rom* 24: 19-23. DOI: 10.24193/entomolrom.24.2.
- Adenusi AA, Akinyemi MI, Akinsanya D. 2018. Domiciliary cockroaches as carriers of human intestinal parasites in Lagos Metropolis, Southwest Nigeria: Implications for public health. *J Arthropod Born Dis* 12 (2): 141-151. DOI: 10.18502/jad.v12i2.40.
- Alias, Hadi UP, Retnani EB. 2018. Diversity and abundance of cockroaches (Insecta: Dictyoptera) in ships at Bau-Bau Port. *J Entomol Zool Stud* 6 (3): 29-34. [Indonesian]
- Amalia H, Harahap IS. 2010. Preference of the American Cockroach *Periplaneta americana* (L.) (Blattaria: Blattellidae) for various bait combinations. *J Entomol Indones* 7 (2): 67-77. DOI: 10.5994/jei.7.2.67. [Indonesian]
- Ambarningrum TB, Kusmintarsih ES, Haryanto T, Basuki E, Rejeki DSS. 2022. Resistance Level of German Cockroaches (*Blattella germanica* L.) origin of three traditional markets in Purwokerto City to fipronil using the contact and bait method. *Aspirator* 1 (1): 1-10. DOI: 10.22435/asp.v14i1.4495. [Indonesian]
- Apple AG. 1995. *Blattella and Related Species, Regulator*. In: Rust M, Owen JM & Reirson DA (eds). *Understanding and Controlling the German Cockroach*. Oxford University Press, New York. DOI: 10.1093/oso/9780195064957.003.0001.
- Beccaloni GW. 2014. Cockroach Species File Online Version 5.0/5.0. <http://Cockroach.SpeciesFile.org>.

- Bell WJ, Roth LM, Nalepa CA. 2007. *Cockroaches: Ecology, Behavior, and Natural History*. The Johns Hopkins University Press, Baltimore.
- Borah N, Hazarika LK. 2019. Biology and morphometrics of *Periplaneta americana*. *J Entomol Zool Stud* 7 (1): 1206-1210.
- Bugguide. 2024. Identification, images, & information for insects, spiders & their kin for the United States & Canada. <https://bugguide.net/node/view/342386>.
- Cahyani LK, Yuliawati S, Martini. 2018. An overview of the factors associated with the density of cockroaches in food stores traditional market of Semarang City. *Jurnal Kesehatan Masyarakat* 6 (5): 295-301. DOI: 10.14710/jkm.v6i5.22027. [Indonesian]
- Gautier C, Charpin D. 2017. Environmental triggers and avoidance in the management of asthma. *J Asthma Allergy* 10: 47-56. DOI: 10.2147/JAA.S121276.
- Hidayati NR. 2020. An Overview of Sanitation and Presence of Vectors, Pest and Nuisance Animals in Traditional Markets of Surakarta City. [Thesis]. Public Health Study Program, Faculty of Health Sciences. Universitas Muhammadiyah, Surakarta. [Indonesian]
- Kleine-Tebe J, Hamilton RG, Goodman RE. 2019. Cockroach allergens: Coping with challenging complexity. *J Allergy Clin Immunol* 143 (4): 1342-1344. DOI: 10.1016/j.jaci.2019.01.028.
- Ko AE, Jensen K, Schal C, Silverman J. 2017. Effects of foraging distance on macronutrient balancing and performance in the German Cockroach *Blattella germanica*. *J Exp Biol* 220: 304-311. DOI: 10.1242/jeb.146829.
- Lamiaa B, Mariam L, Ahmed A. 2007. Bacteriological analysis of *Periplaneta americana* L. (Dictyoptera; Blattellidae) and *Musca domestica* (Diptera; Muscidae) in ten districts of Tangier, Morocco. *Afr J Biotechnol* 6 (17): 2038-2042. DOI: 10.5897/AJB2007.000-2315.
- Lee CY, Heng CY. 2000. Effect of food and water deprivation on nymphal development, adult fecundity, and insecticide susceptibility in German Cockroaches, *Blattella germanica* (L.). *Trop Biomed* 17: 27-34.
- Lee CY, Wang C. 2021. German Cockroach infestation in the World and their social and economic impacts. In: Wang C, Lee CY, Rust MK. (eds). *Biology and Management of the German Cockroach*. CSIRO Publishing, Clayton South VIV 3169. DOI: 10.1071/9781486312078.
- Leksono AS. 2007. *Ecology Descriptive and Quantitative Approach*. Bayumedia Publishing, Malang. [Indonesian]
- Magguran AE. 2004. *Measuring Biological Diversity*. Blackwell Science Ltd, Oxford.
- Mairawita, Rahayu R, Dahelmi, Jannatan R. 2014. Inventory of Cockroaches (*Dictyoptera*) in traditional markets and hospitals in Padang City, West Sumatera. *Bioeti, Padang. BioETI* (2014): 149-153.
- Memona H, Manzoor F, Riaz S. 2017. Species diversity and distributional pattern of cockroaches in Lahore, Pakistan. *J Arthropod Borne Dis* 11 (2): 249-259.
- Molewa ML, Barnard, Naicker N. 2022. A potential role of Cockroaches in the transmission of pathogenic bacteria with antibiotic resistance: A scoping review. *J Infect Dev Ctries* 16 (11): 1671-1678. DOI: 10.3855/jidc.16893.
- Nasirian H. 2017. Infestation of cockroaches (Insecta: Blattaria) in the human dwelling environments: A systematic review and meta-analysis. *Acta Trop* 167: 86-98. DOI: 10.1016/j.actatropica.2016.12.019.
- Oğuz B, Özdal N, Oruç Kilinc O, Değer MS. 2017. First investigation on vectorial potential of *Blattella germanica* in Turkey. *Ankara Univ Vet Fak Derg* 64: 141-144. DOI: 10.1501/Vetfak_0000002788.
- Robinson W. 2005. *Urban Insects and Arachnida*. Cambridge University Press, New York. DOI: 10.1017/CBO9780511542718.
- Ross MH, Mullins DE. 1995. *Biology*. In: Rust MK Owen JM & Reirson DA (eds). *Understanding and Controlling the German Cockroach*: 21-47. Oxford University Press, New York. DOI: 10.1093/oso/9780195064957.003.0002.
- Shahraki GH, Parhizkar S, Nejad ARS. 2013. Cockroach infestation and factors affecting the estimation of cockroach population in urban communities. *Intl J Zool* 2013: 649089. DOI: 10.1155/2013/649089.
- Siagian FE, Livina J, Dana IMBS, Daroedono E, Ronny. 2017. Prevalence of cockroaches in a private faculty building/ its surrounding with emphasize on its vectorial capacity for intestinal parasite, its public health implication and comparison of the performance of several traditional baits. *J Med Sci* 11 (1): 39-46. DOI: 10.26891/JIK.v11i1.2017.39-46.
- Sosan MB, Ajibade RO, Adeley AO. 2019. Survey of the distribution and diversity of cockroaches (Insecta: Blattaria) on the campus of a higher institution in South-Western Nigeria. *Intl J Appl Biol Res* 10 (1): 37-51.
- Supryatno A, Hadi UK, Murtini S. 2018. Potency of Cockroaches (*Periplaneta americana* and *Blattella germanica*) on the ship as vector of Salmonellosis in Bau Bau Port. *J Indones Vet Res* 2 (2): 63-69. DOI: 10.20956/jrvi.v2i2.4515.
- Tang Q, Bourguignon T, Willenmse L, De Coninck E, Evans T. 2018. Global spread of the German Cockroach, *Blattella germanica*. *Biol Invasions* 21: 693-707. DOI: 10.1007/s10530-018-1865-2.
- Trinh VH, Nguyen TH, To TMD, Nguyen TM, Tran TTH, Nguyen, VC. 2016. Species composition and level of infestation of Cockroaches in tree Areas in Hanoi. *Trop Biomed* 33 (3): 500-505.
- Wang C, Bischoff E, Eiden AL, Zha C, Cooper R, Graber JM. 2019. Residents' attitudes and home sanitation predict presence of German Cockroaches (Blattodea: Ectobiidae) in apartments for low-income senior residents. *J Econ Entomol* 112: 284-289. DOI: 10.1093/jee/toy307.
- Wangorsch A, Jamin A, Eichhorn S, Pablos I, Sharma S, Schweidler B, Kastner B, Wildner S, Saloga J, Fuhrer F, Orozco RRR, Sherkat R, Sadeghi S, Teifoori F, Park JW, Briza P, Vieths S, Ferreira F, Arora N, Lidholm J, Gadermaier G, Scheurer S. 2021. Component resolved diagnosis of American Cockroach (*Periplaneta americana*) allergy in patients from different geographical areas. *Front Allergy* 2: 691627. DOI: 10.3389/falgy.2021.691627.
- Yagci M, Sacti Z, Yasarer AH, Simsek M. 2016. Main cockroach species in urban areas in our country and the world, prevention and alternative control methods of these pests. *Turk J Occup Environ Med Saf* 1 (4): 1-6.