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Aquatic insect diversity and spatial distribution in a tropical reservoir ecosystem of Kedungombo, Central Java, Indonesia

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Abstract. *Taqwim MHA, Mardiyanto MB, Wijayanti M, Wardha'adhlina WA, Putra YM, Mahajoeno E, Indrawan M, Yap CK, Setyawan AD. 2025. Aquatic insect diversity and spatial distribution in a tropical reservoir ecosystem of Kedungombo, Central Java, Indonesia. Intl J Bonorowo Wetlands 15: 40-48.* Aquatic insects are essential components of freshwater ecosystems, functioning as bioindicators and key players in trophic interactions. This study evaluated the species richness, spatial distribution, and ecological roles of aquatic and semi-aquatic insects across three distinct habitat types—forested margins, rice field edges, and open unvegetated shores—within the Kedungombo Reservoir, Central Java, Indonesia. Sampling was carried out during the dry season (September–October 2024) using purposive random sampling and hand net techniques. A total of 16 species representing 4 insect orders and 13 families were identified, with dominant taxa including *Culex tritaeniorhynchus*, *Diplonychus rusticus*, *Paederus fuscipes*, and *Chironomus striatipennis*. Species richness and diversity indices (Shannon–Wiener, Pielou's evenness, and Margalef's richness) varied significantly across habitats, with the rice field edge (Station 2) exhibiting the highest diversity. Predatory insects were the most prevalent functional group, followed by detritivores and generalist omnivores. Several species showed station-specific occurrence, suggesting narrow habitat preferences and potential as ecological indicators. The open shoreline habitat had the lowest richness and was dominated by disturbance-tolerant taxa, while shaded and vegetated zones supported more diverse and specialized assemblages. These findings underscore the ecological significance of microhabitat heterogeneity in maintaining aquatic insect communities within artificial lentic systems. Conservation and management strategies for tropical reservoirs should prioritize habitat complexity and buffer zones to sustain insect-mediated ecosystem functions under increasing anthropogenic pressures.

Keywords: Aquatic insects, biodiversity, functional groups, habitat heterogeneity, Kedungombo, tropical reservoir

INTRODUCTION

Aquatic insects represent a significant component of freshwater biodiversity and are widely recognized for their ecological roles in trophic dynamics, organic matter decomposition, and water quality monitoring (Williams and Williams 2017; Parr et al. 2019). They occupy diverse niches across aquatic habitats, from temporary puddles to large reservoirs, and display varying degrees of tolerance to environmental changes (Choudhury and Gupta 2017; Zhao et al. 2021). Because of their sensitivity to habitat alteration, aquatic insects are often used as bioindicators to assess ecological integrity in both lotic and lentic systems (Mahmoud et al. 2022). Understanding the structure and distribution of aquatic insect communities is crucial for tracking ecosystem health and detecting anthropogenic pressures in tropical freshwater environments.

Reservoirs in Southeast Asia, particularly those embedded in rural or semi-urban landscapes, serve as multifunctional ecosystems that support fisheries, agriculture, tourism, and water supply. In Indonesia, large man-made reservoirs such as Kedungombo represent vital resources for regional development, yet are often subjected to multiple stressors including land-use changes, eutrophication, and pollutant inputs (Makmur et al. 2017). While reservoir-based aquatic ecology has gained increasing attention, the insect communities in such systems remain underrepresented in ecological assessments. Aquatic insects in reservoirs may differ markedly in diversity and distribution compared to rivers or ponds due to spatial heterogeneity in hydrology, vegetation, and human activity (Zheng et al. 2021).

Located in Central Java, Indonesia, Kedungombo Reservoir spans approximately 6,576 hectares and intersects three administrative regions—Boyolali, Sragen, and Grobogan (Ariyani et al. 2020). It comprises varied microhabitats including forested edges, agricultural runoff zones, and unvegetated margins that influence aquatic insect assemblages through nutrient input, substrate complexity, and vegetation cover (Popoola and Otalekor 2011). Such environmental variability presents an opportunity to examine how aquatic insect diversity responds to contrasting habitat conditions within a single lentic system. Yet, baseline data on the entomofauna of Kedungombo is scarce, limiting its use for long-term ecological monitoring or reservoir management planning.

Recent studies from tropical Asia have shown that orders such as Odonata, Hemiptera, and Coleoptera are dominant in freshwater ecosystems and display habitat-specific patterns (Letsch et al. 2016). Odonates, in particular, are known for their dual life cycle and sensitivity to water quality and vegetation structure, making them effective indicators of semi-natural aquatic habitats (Ihamdi et al. 2021). Hemipterans such as *Limnogonus fossarum* and coreids are common in slow-moving or still waters, while coleopterans like *Paederus* spp. are adapted to humid microhabitats and often function as predators (Li et al. 2017). Incorporating multiple insect orders enhances the representativeness of aquatic surveys and allows for more nuanced ecological interpretation.

Despite the ecological and bioindicator value of aquatic insects, their assemblages in Indonesian reservoirs remain poorly documented. Most entomological studies have concentrated on rivers (Atmowidi et al. 2022) or rice field agroecosystems (Wakhid et al. 2020), leaving large impoundments relatively unexplored. This gap hampers the development of regionally tailored biodiversity indices and undermines the integration of insect-based monitoring into freshwater management. Assessing aquatic insect diversity in reservoirs is particularly relevant under the current pressures of climate change, hydrological alteration, and agricultural intensification in Java.

This study aims to assess the species richness, taxonomic composition, and spatial distribution of aquatic insects in Kedungombo Reservoir by comparing three contrasting habitat types: forested margins, rice-field interfaces, and unvegetated open water zones. Using standard sampling techniques and diversity indices, this study provides a foundational dataset on aquatic entomofauna in one of Central Java's largest reservoirs. The findings are expected to inform conservation planning, ecological monitoring, and future studies on freshwater biodiversity in tropical lentic environments. Additionally, the study contributes to the broader goal of enhancing insect-based indicators for water quality assessment in Indonesia's rapidly changing inland aquatic ecosystems.

MATERIALS AND METHODS

Study area

The study was conducted at Kedungombo Reservoir, a large artificial reservoir located in Central Java, Indonesia (Figure 1). It spans the administrative regions of Boyolali, Sragen, and Grobogan Districts. The reservoir covers a total area of approximately 6,576 hectares, consisting of 2,830 hectares of open water and the remainder being terrestrial zones. Kedungombo plays a multifunctional role, including water storage for irrigation, flood control, aquaculture, and domestic use. It also serves as an important artificial freshwater ecosystem supporting a wide range of aquatic biodiversity.

Three distinct habitat types were selected for this study to represent different environmental conditions and land-use interfaces (Table 1). Station 1 was located along a forested margin with dense riparian vegetation and partial canopy cover, providing a shaded and relatively stable microhabitat. Station 2 bordered active rice fields and was characterized by semi-aquatic vegetation and seasonal agricultural runoff. Station 3 was an open, unvegetated shoreline exposed to direct sunlight and fluctuating water levels, typical of disturbed littoral zones.

The ecological differences among these stations allowed the researchers to evaluate the influence of habitat heterogeneity on the composition and distribution of aquatic and semi-aquatic insect communities. Site selection was also influenced by accessibility and safety during the sampling period.

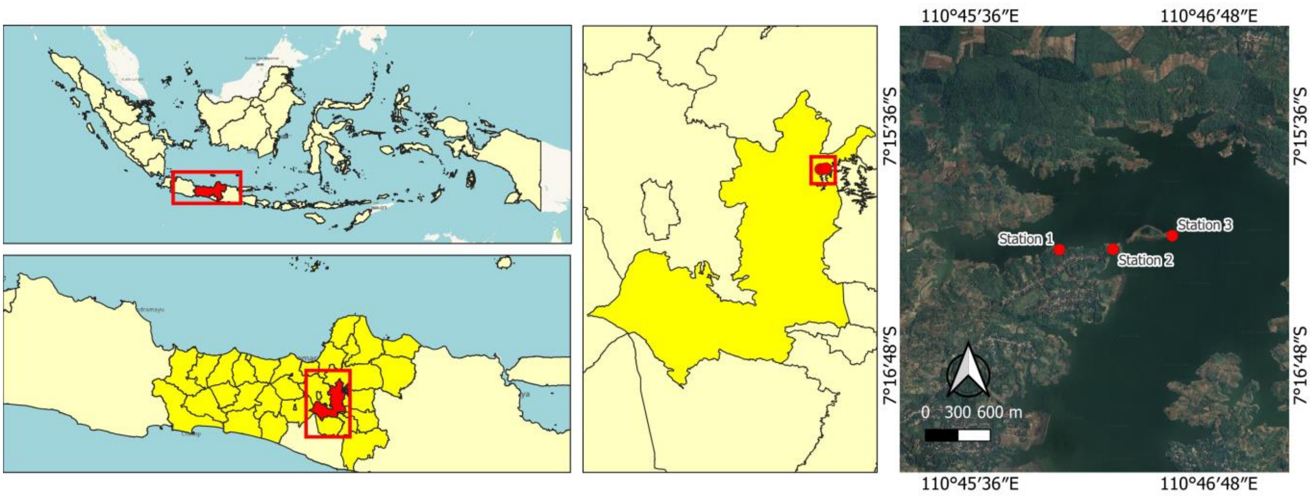

Figure 1. Map of the study area at Kedungombo Reservoir, Boyolali District, Central Java, Indonesia

Sampling design

A purposive random sampling approach was employed to capture aquatic insect diversity across distinct habitat types within the reservoir. The method allowed for targeted site selection based on ecological characteristics while maintaining unbiased insect collection within each station. Sampling was conducted three times during the dry season (September to October 2024), with an interval of approximately 10-15 days between each sampling event, to account for short-term variability and improve the representativeness of insect community data across habitat types.

At each station, three plots of approximately 50 m² were established as active observation areas, each spaced 50-100 meters apart to capture spatial heterogeneity within the habitat. Insects were collected using hand nets (sweep nets) and, where appropriate, with the aid of small aspirator bottles for smaller or surface-dwelling individuals. Each plot was observed for approximately 30 minutes during two time windows—morning (07:00-10:00) and late afternoon (15:30-17:30)—to account for diel variation in insect presence and behavior (Table 2).

All collected specimens were handled carefully to preserve morphological features crucial for taxonomic identification. Each insect was placed in a labeled plastic vial and photographed on-site using a high-resolution digital camera. Specimens were temporarily preserved in 70% ethanol for subsequent laboratory identification and documentation.

Specimen collection and identification

All insect specimens observed or captured during field sampling were documented systematically for taxonomic identification. Collection included both aquatic and semi-aquatic forms that interacted directly with the reservoir environment, such as those found on the water surface, among vegetation, or along the margins. Photographic documentation was performed in situ using a digital camera equipped with macro settings to capture detailed images of critical morphological traits such as antennae, wings, and body segmentation.

Specimens that could not be identified in the field were preserved in labeled vials containing 70% ethanol and brought to the laboratory for further examination. Taxonomic identification was conducted using standard morphological keys and field guides, including Merritt et al. (1996), Borror et al. (2005), and Abowei and Ukoroije (2012). For species-level identification, only individuals with complete and intact diagnostic features were considered. Some taxa were identified only to the genus level due to incomplete morphological characteristics or the lack of comprehensive regional keys, particularly for small or cryptic taxa.

Scientific names were cross-checked for validity and accuracy using international taxonomic databases, namely the Global Biodiversity Information Facility (GBIF, https://www.gbif.org), Catalogue of Life (https://www.catalogueoflife.org), and Integrated Taxonomic Information System (ITIS, https://www.itis.gov). These databases ensured consistency in nomenclature and distributional data.

Data analysis

Data collected from each station were analyzed to assess aquatic insect community structure based on species richness, diversity, and evenness (Table 3). Three ecological indices were employed: the Shannon–Wiener diversity index (H′), Pielou’s evenness index (J′), and Margalef’s species richness index (Dmg). These indices were selected for their relevance in measuring species composition and ecological balance in freshwater systems.

Table 1. Geographic coordinates and habitat descriptions of each sampling station

Station	Coordinates	Habitat type	Habitat description
Station 1	7°16'13.10" S, 110°46'2.95" E	Forested margin	Vegetated shoreline with dense riparian vegetation and partial canopy cover, providing shade and stable microclimate.
Station 2	7°16'12.93" S, 110°46'19.09" E	Rice field edge	Interface between reservoir and rice paddies, characterized by semi-aquatic vegetation and influenced by agricultural runoff.
Station 3	7°16'8.89" S, 110°46'36.98" E	Open unvegetated zone	Bare shoreline with minimal vegetation, exposed to direct sunlight and fluctuating water levels.

Table 2. Sampling time and collection methods at each observation station

Station	Observation time (hr)	Methods used	Notes
1	3 (morning and afternoon)	Hand net sweep, direct pick	Shaded, rich vegetation cover
2	3 (morning and afternoon)	Sweep net, aspirator	Edge of rice fields, dense herbaceous cover
3	3 (morning and afternoon)	Hand net, surface collection	Open, unshaded, minimal vegetation

Table 3. Formulas and ecological interpretation of biodiversity indices used

Index	Formula	Ecological meaning
Shannon–Wiener (H′)	$H' = -\sum(pi \times \ln pi)$	Species diversity considering abundance and dominance
Pielou’s Evenness (J′)	$J' = H' / \ln S$	Uniformity of individual distribution across species
Margalef Richness (Dmg)	$Dmg = (S - 1)/\ln N$	Species richness relative to sample size

The Shannon–Wiener index (H′) was calculated using the formula H′ = −∑(pi × ln pi), where pi represents the proportion of individuals belonging to the i-th species. Higher H′ values indicate greater diversity and lower dominance by a single species. Pielou's evenness index (J′) was computed as J′ = H′ / ln S, where S is the total number of species, reflecting how evenly individuals are distributed across taxa. Margalef's richness index (Dmg) was calculated using Dmg = (S − 1)/ln N, where S is the number of species and N is the total number of individuals observed.

Values from the three indices were compared across stations to evaluate the ecological variability of each habitat. Graphical visualizations and summary tables were generated to highlight trends in diversity and to support the interpretation of spatial patterns.

RESULTS AND DISCUSSION

Species richness and composition

A total of 16 species of aquatic and semi-aquatic insects were recorded from three stations within the Kedungombo Reservoir ecosystem (Table 4). These species belong to four insect orders and 13 families, reflecting a moderate level of taxonomic diversity (Figure 2). The highest species richness was observed at Station 2 (rice field edge), followed by Station 1 (forested margin), while Station 3 (open zone) had the lowest richness (Figure 3). This pattern suggests that habitat complexity and vegetation cover may influence the availability of microhabitats for different taxa (Figure 4).

The species overlap among the three stations is illustrated in the Venn diagram (Figure 4). Five species were shared among at least two stations, while only two species—*Culex tritaeniorhynchus* and *Paederus fuscipes*—occurred in all three stations, indicating their broad ecological tolerance. Station 2 shared more species with Station 1 (four species) than with Station 3 (three species), suggesting greater ecological similarity between the forested margin and rice field edge compared to the open zone. Several taxa, such as *Diplonychus rusticus*, *Hydrophilus* sp., and *Notonecta glauca*, were exclusive to Station 2, reinforcing the distinctiveness of this habitat. These patterns of overlap highlight the role of habitat complexity and vegetative cover in structuring aquatic insect communities.

Across all stations, the most frequently encountered species included *C. tritaeniorhynchus*, *D. rusticus*, *P. fuscipes*, and *Chironomus striatipennis*. These taxa were widely distributed and tolerant of a variety of environmental conditions. Conversely, certain species such as *Hydrophilus* sp., *Laccotrephes robustus*, *N. glauca*, *Coccinella transversalis*, and *Ranatra linearis* were found exclusively in a single station, indicating habitat specificity or restricted range.

In terms of functional roles, the recorded insects included predators (e.g., *D. rusticus*, *L. robustus*), detritivores (e.g., *C. striatipennis*), herbivores, and generalist scavengers. This functional diversity suggests the presence of multiple trophic interactions within the reservoir ecosystem. Additionally, several taxa, such as *P. fuscipes* and *Gerris* sp., are known bioindicators of environmental change and may serve as sentinel species for monitoring reservoir health.

Distribution patterns across habitats

The distribution of aquatic and semi-aquatic insect species varied markedly among the three habitat types studied. Station 1, situated in a forested margin, supported 10 species and showed moderate levels of diversity. The presence of shade-tolerant taxa such as *Sceliphron caementarium* and *Rhynocoris* sp. suggests that certain species are adapted to microclimatic stability and protected edge zones. The combination of riparian vegetation and canopy cover likely buffers environmental fluctuations, supporting insects that rely on cooler, more humid conditions and detrital inputs.

Station 2, located at the interface of the reservoir and adjacent rice fields, exhibited the highest species richness and abundance, with 12 of the 16 recorded species found in this habitat. The structurally complex environment—comprising dense semi-aquatic vegetation, shallow stagnant waters, and nutrient input from agricultural runoff—provides a mosaic of microhabitats that support a wide range of aquatic and semi-aquatic insect taxa. Several species showed strong habitat specificity in this site, including *D. rusticus*, *Hydrophilus* sp., *N. glauca*, *C. transversalis*, and *R. linearis*, which were not detected elsewhere. These taxa likely depend on vegetated, low-flow conditions and organic enrichment typical of agro-reservoir margins. In contrast, widely distributed generalist species such as *C. tritaeniorhynchus* and *P. fuscipes* were present across all three stations, reflecting their ecological plasticity and tolerance to a range of environmental conditions.

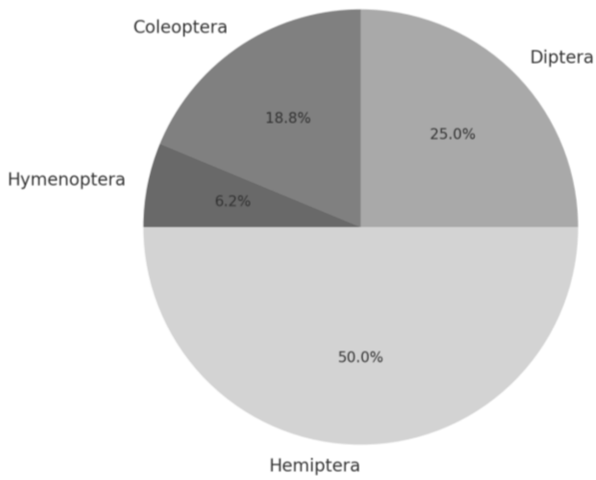

Figure 2. Proportional representation of insect orders across all stations (n = 16 species)

Table 4. Summary of aquatic and semi-aquatic insect specimens collected from each station

Order	Family	Species name	Station 1	Station 2	Station 3	Total
Diptera	Culicidae	*Culex tritaeniorhynchus* (Giles, 1901)	4	8	5	17
Hemiptera	Belostomatidae	*Diplonychus rusticus* (Fabricius, 1871)	0	6	0	6
Coleoptera	Staphylinidae	*Paederus fuscipes* (Curtis, 1826)	2	4	2	8
Diptera	Chironomidae	*Chironomus striatipennis* (Kieffer, 1910)	3	5	1	9
Hemiptera	Gerridae	*Gerris* sp.	2	2	0	4
Hemiptera	Notonectidae	*Notonecta glauca* (Linnaeus, 1758)	0	3	0	3
Coleoptera	Hydrophilidae	*Hydrophilus* sp.	0	2	0	2
Hemiptera	Nepidae	*Laccotrephes robustus* (Stål, 1871)	1	0	0	1
Diptera	Chironomidae	*Polypedilum* sp.	0	1	1	2
Diptera	Culicidae	*Anopheles vagus* (Dönitz, 1902)	1	0	2	3
Hymenoptera	Sphecidae	*Sceliphron caementarium* (Drury, 1773)	1	1	1	3
Coleoptera	Coccinellidae	*Coccinella transversalis* (Fabricius, 1781)	0	1	0	1
Hemiptera	Pyrrhocoridae	*Dysdercus cingulatus* (Fabricius, 1775)	1	0	0	1
Hemiptera	Corixidae	*Micronecta* sp.	1	0	1	2
Hemiptera	Nepidae	*Ranatra linearis* (Linnaeus, 1758)	0	1	0	1
Hemiptera	Reduviidae	*Rhynocoris* sp.	1	1	0	2
		Total	17	45	13	75

Note: Station 1: Forested margin, Station 2: Rice field edge, Station 3: Open unvegetated zone

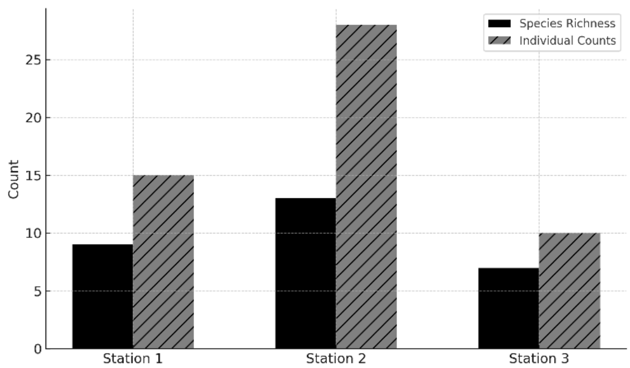

Figure 3. Bar chart showing species richness and individual counts per station

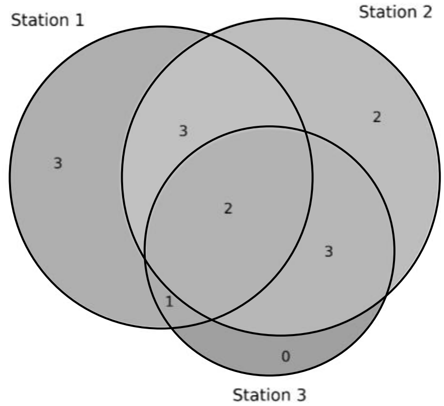

Figure 4. Venn diagram illustrating species overlap among the three sampling stations

Station 3, located along the open, unvegetated shoreline, exhibited the lowest species richness, with only 7 of the 16 recorded species present. The exposed nature of this habitat—characterized by direct sunlight, minimal vegetation, and fluctuating water levels—creates harsh abiotic conditions that limit aquatic insect diversity. Species encountered at this site, such as *Anopheles vagus*, *Polypedilum* sp., and *Micronecta* sp., are generally recognized for their tolerance to disturbed, low-cover environments. The absence of shade and submerged structures reduces available refugia and breeding substrates, favoring generalist or stress-tolerant taxa over habitat specialists. These findings suggest that shoreline simplification may reduce ecological complexity and affect trophic dynamics at the reservoir margin.

Diversity indices

Diversity analysis using three ecological indices—Shannon–Wiener (H′), Pielou's Evenness (J′), and Margalef's Richness (Dmg)—revealed distinct patterns among the three habitat types in Kedungombo Reservoir (Table 5, Figure 5). Station 2 consistently showed the highest values across all indices, reflecting its complex habitat structure and diverse microenvironments.

The Shannon–Wiener index (H′) was highest at Station 2 (2.42), followed by Station 1 (2.13), and lowest at Station 3 (1.78). This indicates that species diversity was greatest where environmental conditions were moderate and heterogeneous. Pielou's evenness (J′) showed similar trends, with Station 2 reaching 0.91, suggesting a relatively balanced distribution of individuals across species. The lowest evenness value (0.75) was recorded at Station 3, where a few species dominated the community.

Margalef's richness index (Dmg) followed the same order, with Station 2 (3.14) outperforming Station 1 (2.47) and Station 3 (1.86). These results further emphasize the ecological advantage provided by semi-natural agricultural interfaces, which appear to support higher insect richness compared to both forested and barren littoral zones.

Dominant and indicator species

Analysis of species abundance revealed a small subset of taxa that were dominant across multiple habitats. The most abundant species overall was *C. tritaeniorhynchus*, contributing 17 individuals and appearing in all three stations, confirming its status as a generalist mosquito with high ecological tolerance. Other widespread and relatively abundant species included *C. striatipennis* (9 individuals) and *P. fuscipes* (8 individuals), both of which are known to thrive in nutrient-rich and disturbed aquatic environments (Figure 6).

Station-specific dominance was also evident. At Station 2, *D. rusticus* showed a notably high abundance (6 individuals), reflecting its affinity for shallow, vegetated waters adjacent to agricultural fields. Several other species, such as *Hydrophilus* sp., *N. glauca*, *C. transversalis*, and *R. linearis*, were also restricted to Station 2, albeit in low numbers, indicating narrower ecological niches. Meanwhile, *L. robustus* was found only in Station 1, suggesting a preference for shaded, forested margins. This pattern of occurrence underscores the role of habitat heterogeneity in shaping insect distribution within the reservoir.

Several taxa showed potential as indicator species for specific habitat conditions. For example, *N. glauca*, a backswimmer typically associated with calm and vegetated waters, was found only in Station 2, aligning with its known habitat preferences. Similarly, *S. caementarium*, a mud-dauber wasp, occurred in all stations but only in low numbers, suggesting a broader but low-density distribution potentially linked to nesting substrate availability rather than water quality.

The presence of *Rhynocoris* sp. and *D. cingulatus* in shaded, less disturbed zones further support their value as indicators of low-disturbance or edge habitats. These patterns of dominance and specificity enhance the understanding of how insect assemblages respond to microhabitat features within reservoir ecosystems.

Ecological roles and functional group composition

The aquatic and semi-aquatic insect community recorded from the Kedungombo Reservoir consisted of taxa occupying diverse ecological roles, including predators, detritivores, herbivores, and omnivores (Figure 7). Predators were the most dominant functional group, accounting for approximately 50% of the total species recorded. Representative taxa include *D. rusticus*, *N. glauca*, *L. robustus*, and *Rhynocoris* sp., all of which are active hunters of aquatic larvae, small insects, or zooplankton.

Detritivorous species such as *C. striatipennis* and *Polypedilum* sp. were also frequently encountered, particularly in Stations 2 and 3, where organic matter tends to accumulate. Their presence reflects the productivity of these habitats and the availability of sediment-based resources. Herbivores and generalist feeders were less common but included taxa such as *Gerris* sp. and *D. cingulatus*, which may exploit periphyton or decaying plant material along the water margin.

Omnivorous or facultatively scavenging species—such as *P. fuscipes* and *C. tritaeniorhynchus*—were widespread across habitats, demonstrating their adaptability and tolerance to environmental fluctuations. The presence of these functionally diverse groups suggests that the reservoir supports a relatively complex trophic structure, even in its simplified artificial state.

Table 5. Diversity indices (Shannon–Wiener, Pielou's Evenness, and Margalef's Richness) for each sampling station

Station	Shannon–Wiener (H′)	Pielou's Evenness (J′)	Margalef's Richness (Dmg)
Station 1	2.13	0.84	2.47
Station 2	2.42	0.91	3.14
Station 3	1.78	0.75	1.86

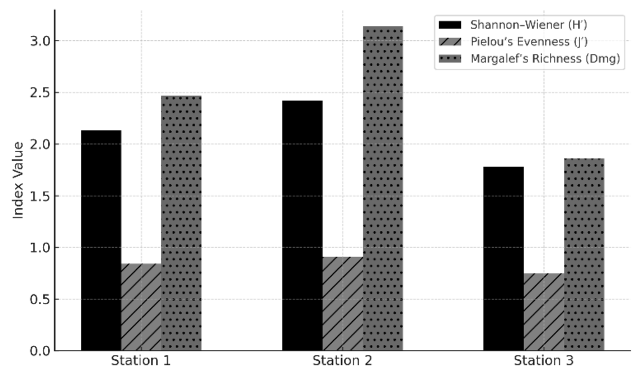

Figure 5. Bar chart comparing H′, J′, and Dmg values across the three sampling stations

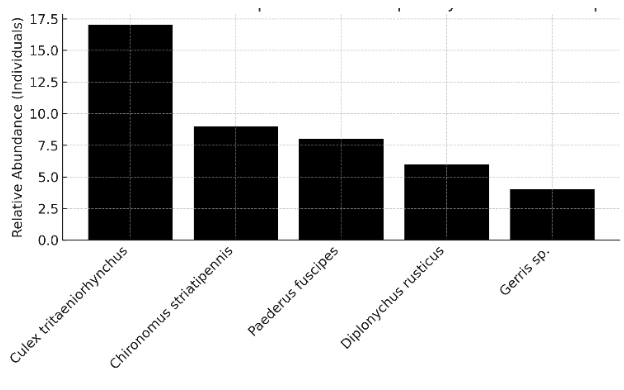

Figure 6. Relative abundance of the top five most frequently encountered species across all stations

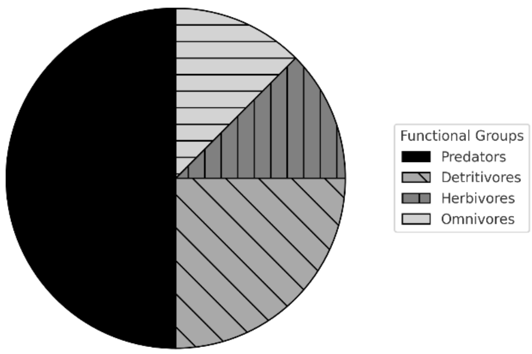

Figure 7. Functional group composition of aquatic and semi-aquatic insect species recorded from all sampling stations

Discussion

Aquatic insect diversity in a tropical reservoir context

The recorded diversity of 16 aquatic and semi-aquatic insect species across three habitat types in Kedungombo Reservoir provides a valuable insight into the ecological dynamics of tropical man-made freshwater ecosystems. Although this number may seem modest compared to natural riverine systems or wetlands, it aligns with diversity levels reported in other tropical reservoir studies, where environmental stability, water chemistry, and habitat complexity often constrain community richness (Nguyen et al. 2021).

The dominance of Diptera and Hemiptera, particularly members of Culicidae, Chironomidae, and Nepidae, is consistent with patterns observed in tropical standing waters. Such taxa are typically adapted to lentic conditions, high organic content, and shallow, sunlit environments that are common in reservoir littoral zones (Yule and Yong 2004). Moreover, the co-occurrence of both predators (e.g., *D. rusticus*) and detritivores (e.g., *C. striatipennis*) indicates a structured trophic web supported by diverse resource inputs, particularly from shoreline vegetation and agricultural runoff.

While some species like *C. tritaeniorhynchus* and *P. fuscipes* showed wide distribution and numerical dominance, the detection of rare or habitat-restricted taxa such as *L. robustus* and *D. cingulatus* highlights the importance of microhabitat variability within the reservoir system. The presence of such taxa may be underreported in large-scale surveys and points to the value of site-specific sampling approaches for biodiversity assessment (Harvey and Altermatt 2019).

In a broader ecological context, the species richness observed here underscores the role of artificial reservoirs as secondary refuges for insect biodiversity in increasingly modified tropical landscapes. Although they cannot replace the ecological functions of natural freshwater systems, reservoirs like Kedungombo may provide essential habitats—especially when managed with attention to edge vegetation and pollutant control (Dias-Silva et al. 2021). Thus, even low richness may still signify stable trophic interactions under constrained conditions.

Habitat-specific patterns and environmental drivers

The contrasting species compositions observed among the three stations reflect how microhabitat features influence aquatic insect distribution within a reservoir system. Station 2, which bordered rice fields, had the highest species richness and diversity, likely due to a combination of shallow water, abundant macrophytes, and nutrient influx from agricultural runoff. These conditions are known to support higher insect productivity by increasing food availability and structural habitat complexity (Merritt et al. 1996; Hoang et al. 2022).

In comparison, Station 1—situated along a forested margin—supported moderately high diversity, dominated by taxa that favor shaded and stable shoreline conditions, such as *S. caementarium* and *Rhynocoris* sp. The presence of canopy cover likely contributes to more stable thermal and humidity conditions, while detritus input from forest litter may enrich benthic substrates for detritivores. Such interfaces between terrestrial vegetation and reservoir water bodies act as critical transition zones that buffer environmental extremes (Callisto et al. 2014).

Station 3, the open and unvegetated shoreline, showed the lowest richness and functional diversity. Harsh abiotic factors such as direct sunlight, fluctuating water levels, and a lack of refugia likely limit insect colonization. This habitat type appears to favor a few tolerant taxa such as *A. vagus* and *Polypedilum* sp., both known to thrive in disturbed, low-cover environments with minimal competition or predation pressure (Benetti and Hamada 2003).

The spatial segregation of taxa also suggests varying sensitivity to habitat degradation. Species restricted to vegetated or shaded zones may serve as early indicators of habitat disturbance or shoreline alteration. In contrast, widespread generalists may persist under a range of environmental pressures but are less informative for ecosystem health assessments.

Functional roles and trophic implications

The functional diversity observed among the aquatic insect assemblages in Kedungombo Reservoir highlights the complexity of trophic interactions even within an artificial lentic system. Predatory taxa, including species such as *D. rusticus*, *N. glauca*, and *Rhynocoris* sp., comprised approximately half of the total species recorded, underscoring their role in regulating prey populations and maintaining ecological balance (Dudgeon et al. 2006). These predators exert top-down control, potentially influencing the abundance of mosquito larvae and other invertebrates, which is significant for ecosystem health and vector management.

Detritivores, particularly dipterans like *C. striatipennis* and *Polypedilum* sp., play a crucial role in the decomposition of organic matter, facilitating nutrient cycling within the reservoir. Their presence correlates with organic-rich sediments and contributes to energy transfer from detritus to higher trophic levels, including fish and amphibians (Wallace and Webster 1996). Herbivorous and omnivorous species, though less abundant, contribute to the regulation of primary production and scavenging activities, supporting overall ecosystem resilience.

The coexistence of these functional groups reflects a relatively balanced food web structure in Kedungombo Reservoir despite anthropogenic pressures. However, fluctuations in habitat conditions—such as nutrient loading from agricultural runoff or physical disturbance of shoreline vegetation—may disrupt these trophic interactions, leading to shifts in community composition and potential declines in biodiversity (Allan et al. 1997).

Understanding the functional roles of aquatic insects in reservoirs provides insight into ecosystem processes that underpin water quality, nutrient dynamics, and biological control. Future management efforts should prioritize the maintenance of habitat heterogeneity to support diverse functional groups, thereby enhancing ecosystem services and resilience.

Comparison with other tropical freshwater systems

The aquatic insect diversity and community patterns observed in Kedungombo Reservoir are comparable to those reported in other tropical freshwater ecosystems, including natural lakes, wetlands, and reservoirs across Southeast Asia. For instance, studies in reservoirs of Malaysia and Thailand have documented similar dominance of Diptera and Hemiptera, with species richness ranging between 15 to 25 taxa per site (Yule and Yong 2004; Prommi et al. 2024). However, the total of 16 species recorded in Kedungombo can be considered relatively modest. Several factors may explain this. First, Kedungombo is an artificial reservoir with dynamic water level fluctuations, sparse submerged vegetation, and significant human activity along its margins, all of which can reduce habitat stability and limit the presence of specialist taxa. Second, sedimentation and agricultural runoff may lead to eutrophication and habitat homogenization, favoring generalist and pollution-tolerant species but suppressing sensitive groups (Benetti and Hamada 2003; Dias-Silva et al. 2021).

In contrast, aquatic insect assemblages in Indonesian natural lakes such as Rawa Pening and Lake Toba tend to be richer, likely due to more stable hydrological regimes, greater macrophyte diversity, and reduced physical disturbance (Sinambela et al. 2023; Sutrisno and Handoko 2024). This aligns with broader ecological theory suggesting that man-made impoundments often reduce niche availability, trophic stratification, and spatial complexity (Faghihinia et al. 2021).

Nevertheless, the functional composition observed in Kedungombo—predator dominance alongside detritivore presence—is consistent with patterns seen in tropical lentic systems subject to moderate eutrophication and nutrient influx. These functional groups may sustain simplified but still ecologically meaningful food webs, even in disturbed conditions (Dias-Silva et al. 2021). Comparative analyses highlight the importance of habitat heterogeneity and water quality management to conserve aquatic insect biodiversity in tropical reservoirs. Conservation strategies implemented in other Southeast Asian reservoirs, such as riparian buffer restoration, macrophyte replanting, and agrochemical input reduction, are equally applicable to Kedungombo.

Limitations and recommendations for future research

This study has several limitations that should be addressed in future research. Firstly, the data were collected during a single sampling event in the dry season, limiting the ability to assess seasonal dynamics and temporal variability of aquatic insect communities. Seasonal fluctuations can significantly influence species composition and abundance, especially in tropical ecosystems with distinct wet and dry periods (Ramírez et al. 2018). Secondly, the reliance on morphological identification without molecular confirmation could lead to taxonomic uncertainties, particularly for cryptic or closely related species. Incorporating DNA barcoding and molecular tools would enhance accuracy and allow for the detection of hidden diversity.

Furthermore, abiotic parameters such as water temperature, pH, dissolved oxygen, and nutrient concentrations were not systematically measured during sampling, restricting the ability to correlate environmental variables with insect community patterns. Future studies should integrate physicochemical assessments to better understand habitat drivers. Expanding sampling frequency to cover multiple seasons and including additional microhabitats would provide a more comprehensive picture of biodiversity and ecosystem health.

Lastly, despite the study’s focus on biodiversity assessment, there is a need to link insect community data with ecosystem services such as water purification, pest regulation, and fisheries productivity. Such integrative approaches will support reservoir management policies that balance human use and conservation goals. The study highlights the need to integrate aquatic insect indicators into reservoir management plans, emphasizing the conservation of vegetated shorelines to sustain biodiversity and ecosystem function.

In conclusion, the present study provides a baseline assessment of aquatic and semi-aquatic insect diversity and distribution within the Kedungombo Reservoir, Central Java, Indonesia. Our findings reveal that habitat heterogeneity across forested margins, agricultural edges, and open littoral zones significantly influences species richness, community composition, and functional group dynamics. The reservoir supports a moderate but ecologically important assemblage dominated by Diptera, Hemiptera, and Coleoptera, with a balance of predators, detritivores, and generalists that contribute to ecosystem functioning. The rice field interface habitat exhibited the highest diversity and evenness, highlighting the role of agricultural landscapes as transitional zones that can sustain aquatic biodiversity when managed sustainably. Conversely, unvegetated open shores displayed lower diversity and were dominated by a few tolerant species, underscoring the importance of vegetation structure in maintaining healthy insect communities. This study underscores the value of tropical reservoirs as supplementary habitats for freshwater biodiversity in human-modified landscapes. Continued monitoring and integrated management practices that preserve habitat complexity and water quality are critical to sustaining these insect communities and their associated ecological services. These findings provide a basis for incorporating insect-based indicators in reservoir biodiversity monitoring and habitat management policies in tropical Southeast Asia.

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REFERENCES

Abowei JFN, Ukoroije BR. 2012. The identification, types, taxonomic orders, biodiversity and importance of aquatic insects. Br J Pharmacol Toxicol 3 (5): 218-229.

Allan JD, Erickson DL, Fay J. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshw Biol 37 (1): 149-161. DOI: 10.1046/j.1365-2427.1997.00134.x.

Ariyani N, Fauzi A, Umar F. 2020. Faktor-faktor yang mempengaruhi partisipasi pemangku kepentingan pada pengembangan kawasan wisata Kedung Ombo. Jurnal Pariwisata Terapan 4 (2): 147-162. DOI: 10.22146/jpt.60678. [Indonesian]

Atmowidi T, Setiawan B, Sulistijorini S. 2022. Kemelimpahan anggang-anggang *Ptilomera dromas* Breddin (Hemiptera: Gerridae) di Sungai Ciliwung dalam kaitannya dengan kualitas air. Jurnal Entomologi Indonesia 19 (1): 1-8. DOI: 10.5994/jei.19.1.1. [Indonesian]

Benetti CJ, Hamada N. 2003. Fauna de coleópteros aquáticos (insect: coleoptera) na Amazônia central, Brasil. Acta Amaz 33: 701-710. DOI: 10.1590/S0044-59672003000400015.

Borror DJ, Triplehorn CA, Johnson NF. 2005. An Introduction to the Study of Insects. 7th ed. Brooks/Cole, Thomson Learning, Belmont, CA.

Callisto M, Molozzi J, Barbosa J. 2014. Eutrophication of lakes. In: Ansari A, Gill S (eds). Eutrophication: Causes, Consequences and Control. Springer, Dordrecht. DOI: 10.1007/978-94-007-7814-6_5.

Choudhury D, Gupta S. 2017. Impact of waste dump on surface water quality and aquatic insect diversity of Deepor Beel (Ramsar site), Assam, North-east India. Environ Monit Assess 189 (11): 540. DOI: 10.1007/s10661-017-6233-7.

Dias-Silva K, Vieira TB, de Matos TP, Juen L, Simião-Ferreira J, Hughes RM, Júnior PDM. 2021. Measuring stream habitat conditions: Can remote sensing substitute for field data? Sci Total Environ 788: 147617. DOI: 10.1016/j.scitotenv.2021.147617.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA. 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. Biol Rev 81: 163-182. DOI: 10.1017/S1464793105006950.

Faghihinia M, Xu Y, Liu D, Wu N. 2021. Freshwater biodiversity at different habitats: Research hotspots with persistent and emerging themes. Ecol Indic 129: 107926. DOI: 10.1016/j.ecolind.2021.107926.

Harvey E, Altermatt F. 2019. Regulation of the functional structure of aquatic communities across spatial scales in a major river network. Ecology 100 (4): e02633. DOI: 10.1002/ecy.2633.

Hoang T, Foquet B, Rana S, Little DW, Woller DA, Sword GA, Song H. 2022. Development of RNAi methods for the Mormon cricket, *Anabrus simplex* (Orthoptera: Tettigoniidae). Insects 13 (8): 739. DOI: 10.3390/insects13080739.

Ihamdi ML, Idrus AA, Santoso D, Hadiprayitno G, Syazali M. 2021. The species richness and conservation priority of dragonflies in the Suranadi Ecotourism Area, Lombok, Indonesia. Biodiversitas 22 (4): 1846-1852. DOI: 10.13057/biodiv/d220430.

Letsch H, Gottsberger B, Ware JL. 2016. Not going with the flow: A comprehensive time-calibrated phylogeny of dragonflies (Anisoptera: Odonata: Insecta) provides evidence for the role of lentic habitats on diversification. Mol Ecol 25 (6): 1340-1353. DOI: 10.1111/mec.13562.

Li H, Leavengood JM, Chapman EG, Burkhardt D, Song F, Jiang P, Liu J, Zhou X, Cai W. 2017. Mitochondrial phylogenomics of Hemiptera reveals adaptive innovations driving the diversification of true bugs. Proc R Soc B: Biol Sci 284 (1862): 20171223. DOI: 10.1098/rspb.2017.1223.

Mahmoud AM, El-Naggar HA, Hasaballah AI, Haggag AA, Selim TA. 2022. Aquatic insects as a biomonitoring and bioindicators for trace metals in the contaminated Al-Mahmoudia Canal, River Nile, Egypt. Egypt J Aquat Biol Fish 26: 365-386. DOI: 10.21608/ejabf.2022.217582.

Makmur S, Rahardjo M, Sukimin S. 2017. Biologi reproduksi ikan gabus (*Channel striata* Bloch) di daerah banjiran Sungai Musi Sumatera Selatan. Jurnal Iktiologi Indonesia 3 (2): 57-62. DOI: 10.32491/jii.v3i2.258. [Indonesian]

Merritt RW, Cummins KW, Berg MB. 1996. An Introduction to the Aquatic Insects of North America (4th ed.). Kendall/Hunt Publishing, Dubuque.

Nguyen TN, Nguyen TX, Pham TV, Nguyen DT. 2021. Applying the soil and water assessment tool model for integrated lake basin management in northern Vietnam: case study of the Thac Ba Reservoir Basin. Environ Eng Sci 38 (11): 1027-1035. DOI: 10.1089/ees.2020.0378.

Parr TB, Capps KA, Inamdar SP, Metcalf KA. 2019. Animal-mediated organic matter transformation: Aquatic insects as a source of microbially bioavailable organic nutrients and energy. Funct Ecol 33 (3): 524-535. DOI: 10.1111/1365-2435.13242.

Popoola KOK, Otalekor A. 2011. Analysis of aquatic insects' communities of Awba Reservoir and its physico-chemical properties. Res J Environ Earth Sci 3: 422-428.

Prommi TO, Khamboonruang P, Klorvuttimontara S. 2024. Diversity and structure of aquatic insect communities in relation to water quality parameters in The Kasetsart University Drainage Ditches, Central Thailand. J Food Health Bioenviron Sci 17 (1): 11-22.

Ramírez A, Gutiérrez-Fonseca PE, Kelly SP, Engman AC, Wagner K, Rosas KG, Rodríguez N. 2018. Drought facilitates species invasions in an urban stream: results from a long-term study of tropical island fish assemblage structure. Front Ecol Evol 6: 115. DOI: 10.3389/fevo.2018.00115.

Sinambela M, Simangunsong M, Simorangkir A, Harahap A. 2023. Correlation of macrozoobenthos diversity index with physico-chemical factors in Lake Toba, Toba Samosir Regency. Intl J Sci Technol Manag 4 (3): 575-581. DOI: 10.46729/ijstm.v4i3.829.

Sutrisno AJ, Handoko M. 2024. Spatial distribution of water quality classes of Rawa Pening Lake. IOP Conf Ser: Earth Environ Sci 1384 (1): 012013. DOI: 10.1088/1755-1315/1384/1/012013.

Wakhid, Rauf A, Krisanti M, Sumertajaya IM, Maryana N. 2020. Species richness and diversity of aquatic insects inhabiting rice fields in Bogor, West Java, Indonesia. Biodiversitas 21 (1): 34-42. DOI: 10.13057/biodiv/d210106.

Wallace JB, Webster JR. 1996. The role of macroinvertebrates in stream ecosystem function. Ann Rev Entomol 41 (1): 115-139. DOI: 10.1146/annurev.en.41.010196.000555.

Williams DD, Williams SS. 2017. Aquatic insects and their potential to contribute to the diet of the globally expanding human population. Insects 8 (3): 72. DOI: 10.3390/insects8030072.

Yule CM, Yong HS. 2004. Freshwater Invertebrates of the Malaysian Region. Academy of Sciences Malaysia, Kuala Lumpur.

Zhao CS, Pan X, Yang ST, Xiang H, Zhao J, Gan XJ, Ding SY, Yu Q. 2021. Effects and prediction of nonpoint source pollution on the structure of aquatic food webs. Ecohydrology 14 (1): e2257. DOI: 10.1002/eco.2257.

Zheng L, Wang X, Li D, Xu G, Guo Y. 2021. Spatial heterogeneity of vegetation extent and the response to water level fluctuations and micro-topography in Poyang Lake, China. Ecol Indic 124: 107420. DOI: 10.1016/j.ecolind.2021.107420.