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Family-Level Diversity and Dominance of Arthropod Natural Enemies in Maize in Eastern Indonesia

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Abstract: Natural enemies are important components of maize agroecosystems because they help regulate insect pests naturally and support ecologically based integrated pest management. This study evaluated the family-level diversity and dominance of arthropod natural enemies associated with maize (Zea mays L.) in Laha Village, Teluk Ambon District, Maluku, eastern Indonesia. Field sampling was conducted during October-November 2025 using pitfall traps, yellow sticky traps, and sweep nets over 12 observation periods. Community structure was evaluated using the Shannon-Wiener diversity index (H') and Simpson dominance index (D). A total of 570 natural-enemy individuals representing nine taxonomic families from six orders were included in the community analysis. Tachinidae was the most abundant family, comprising 312 individuals (54.74% of the total collection). The Shannon-Wiener diversity index was H' = 1.36427, indicating moderate family-level diversity according to the classification adopted in the study. The Simpson dominance index was D = 0.36076, indicating an uneven distribution of individuals among families, primarily associated with the numerical predominance of Tachinidae. The simultaneous occurrence of parasitoid and predatory arthropods demonstrates that the maize agroecosystem supports multiple functional groups of natural enemies. However, numerical abundance alone does not demonstrate actual pest suppression. These findings provide baseline information on natural-enemy community structure in maize agroecosystems of Maluku and emphasize the importance of further species-level identification and direct assessment of predation and parasitism to determine their contribution to biological control.

Keywords: biological control; community structure; conservation; parasitoids; predators; tropical agroecosystems.

1. Introduction

Maize (*Zea mays* L.) is an important cereal crop cultivated extensively in tropical agricultural regions. However, its productivity can be constrained by various insect pests that attack plants from the vegetative to reproductive stages. The occurrence of invasive and economically important pests such as the fall armyworm, *Spodoptera frugiperda* (J.E. Smith), has further increased the need for effective and sustainable pest-management strategies in maize production systems.

Chemical insecticides remain an important component of pest management. However, excessive or inappropriate insecticide application can cause adverse ecological effects, including mortality of non-target organisms, disruption of natural-enemy communities, pest resurgence, and the development of insecticide resistance. Integrated pest management (IPM) therefore emphasizes combining compatible pest-management approaches with the conservation of naturally occurring biological-control agents.

Natural enemies, particularly predators and parasitoids, constitute an important ecological component of agricultural ecosystems. Predators consume one or more prey individuals during their development, whereas parasitoids develop in or on their hosts and ultimately cause host mortality. The occurrence and persistence of these organisms can contribute to the natural regulation of herbivorous arthropod populations.

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Conservation biological control seeks to enhance the survival, reproduction, and effectiveness of naturally occurring enemies by maintaining or manipulating ecological resources within agricultural landscapes. Habitat management can provide food, alternative prey or hosts, refuges, and suitable microhabitats for beneficial arthropods (Landis et al., 2000; Gurr et al., 2017).

The ecological condition of a natural-enemy community can be evaluated using quantitative measures of diversity and dominance. The Shannon-Wiener diversity index (H') combines information on taxonomic richness and the proportional distribution of individuals. In contrast, the Simpson dominance index (D) measures the degree to which the community is numerically concentrated in one or several taxa (Magurran, 2004). These indices describe community structure and identify taxa that make disproportionately large numerical contributions.

Crop characteristics, surrounding vegetation, microclimatic conditions, agricultural management, pesticide application, availability of prey and hosts, and landscape complexity may influence natural-enemy community structure. Vegetation surrounding agricultural fields can potentially provide nectar, pollen, alternative hosts or prey, shelter, and suitable microhabitats for predators and parasitoids. Consequently, diversified agricultural habitats may contribute to the persistence of beneficial arthropods.

In Indonesia, natural enemies associated with maize have received increasing attention, particularly following the invasion of *S. frugiperda*. Recent investigations have demonstrated that Indonesian maize agroecosystems support several parasitoid groups associated with this pest. For example, parasitoids in Tachinidae and Braconidae have been reported from S. frugiperda in Indonesia, indicating potentially important indigenous biological-control resources.

Despite these developments, information concerning the community structure of natural enemies in maize agroecosystems of Maluku remains limited. Maluku represents an island-based tropical agricultural environment in eastern Indonesia, and baseline ecological information from this region is important for developing locally appropriate conservation-based pest-management strategies.

Therefore, this study aimed to evaluate the family-level diversity and dominance of arthropod natural enemies associated with maize in Laha Village, Maluku, eastern Indonesia, using the Shannon-Wiener diversity and Simpson dominance indices. The study also discusses the potential implications of the observed community structure for conservation biological control and integrated pest management.

2. Materials and Methods

2.1. Study Area and Research Period

The study was conducted in maize fields located in Laha Village, Teluk Ambon District, Ambon City, Maluku Province, Indonesia. The study area is located at approximately 3.7388° S and 128.0935° E. Field sampling was conducted during October-November 2025. The study area consisted of maize fields surrounded by cultivated and non-crop vegetation typical of smallholder agricultural landscapes in the region. Collected arthropod specimens were subsequently sorted and identified in the laboratory at the Faculty of Agriculture, Pattimura University, Ambon, Indonesia.

2.2. Research Design

The research used a descriptive quantitative field-survey approach. Three observation plots were purposively selected within the maize-growing area based on crop condition and suitability for sampling. Each observation plot measured approximately 20 × 30 m. Natural enemies were sampled during 12 observation periods using three complementary collection methods: pitfall traps, yellow sticky traps, and sweep nets. These sampling methods were combined to collect arthropods occupying different strata of the maize agroecosystem.

2.3. Pitfall-Trap Sampling

Pitfall traps were used primarily to sample ground-active arthropods. Each trap consisted of an approximately 220-mL plastic cup installed with its upper edge near the soil surface. The cups contained a water-detergent solution to approximately three-quarters of their capacity. A protective cover was positioned above the trap to reduce interference from rainfall and debris. Captured specimens were collected, sorted, and prepared for subsequent identification.

2.4. Yellow Sticky Traps

Yellow sticky traps were used to sample flying arthropods associated with the maize canopy. Four traps were positioned within each observation plot, primarily at the plot corners. Each trap consisted of yellow material measuring approximately 20 × 25 cm covered with transparent adhesive material. Traps were positioned approximately 20-30 cm above the maize canopy and adjusted according to plant growth when necessary.

2.5. Sweep-Net Sampling

Sweep nets were used to sample arthropods occurring within and around the maize canopy. Ten double sweeps were conducted within each observation plot during each sampling occasion. Collected specimens were transferred to appropriate containers for subsequent sorting and identification. Sampling was conducted at approximately two-day intervals, three times per week for four weeks, resulting in 12 observation periods. Wet specimens were preserved in 70% ethanol when appropriate, while selected specimens were maintained as dry collections for morphological examination.

2.6. Arthropod Identification

Collected arthropods were sorted and identified based on morphological characteristics using available taxonomic references. The natural-enemy community included in the diversity and dominance analyses consisted of nine families belonging to six orders: Coccinellidae, Cicindelidae/Cicindelinae, Tachinidae, Mantidae, Gryllidae, Lycosidae, Braconidae, Vespidae, and Formicidae. Because most specimens were identified at family rather than species level, diversity in this study is explicitly interpreted as family-level taxonomic diversity. Tachinidae and Braconidae were principally treated as parasitoid groups, whereas the remaining groups were discussed cautiously as potential predatory components according to the original study and available ecological literature.

2.7. Shannon-Wiener Diversity Index

The Shannon-Wiener diversity index was calculated as $H' = -\Sigma\, p_i \ln p_i$, where $p_i = n_i/N$, n_i is the number of individuals belonging to family i, and N is the total number of individuals. According to the classification adopted in the original study, $H' < 1$ represents low diversity, $1 \leq H' \leq 3$ moderate diversity, and $H' > 3$ high diversity.

2.8. Simpson Dominance Index

Family-level dominance was calculated as $D = \Sigma\, p_i^2$. A larger D value indicates greater numerical concentration of the community in one or a few taxonomic groups. The term Simpson dominance index is used because the calculated statistic was $D = \Sigma p_i^2$ rather than the alternative Simpson diversity expression $1 - D$.

2.9. Data Analysis

The abundance of each natural-enemy family was pooled across the 12 sampling periods to describe overall community structure. Data were analyzed descriptively using total abundance, proportional abundance, Shannon-Wiener diversity, and Simpson dominance. Because the research was an observational community survey rather than a controlled treatment experiment, the analysis focused on ecological description and did not use inferential tests for treatment comparisons.

3. Results

3.1. Composition of the Natural-Enemy Community

We recorded a total of 570 natural-enemy individuals during the study. The community analyzed for diversity and dominance consisted of nine families representing six arthropod orders.

Table 1. Family-level composition of arthropod natural enemies recorded in the maize agroecosystem of Laha Village, Maluku.

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Order	Family	Number of individuals (n)	Proportion
Coleoptera	Coccinellidae	116	0.2035
Coleoptera	Cicindelidae/Cicindelinae	10	0.0175
Diptera	Tachinidae	312	0.5474
Mantodea	Mantidae	8	0.0140
Orthoptera	Gryllidae	15	0.0263
Araneae	Lycosidae	1	0.0018
Hymenoptera	Braconidae	24	0.0421
Hymenoptera	Vespidae	11	0.0193
Hymenoptera	Formicidae	73	0.1281
Total		**570**	**1.0000**

Tachinidae was the numerically dominant family, accounting for 312 individuals or 54.74% of the total collection. Coccinellidae was the second most abundant family, with 116 individuals (20.35%), followed by Formicidae with 73 individuals (12.81%). The remaining families individually represented less than 5% of the total community. Only one individual represented Lycosidae.

3.2. Shannon-Wiener Diversity

The calculated Shannon-Wiener diversity index was H' = 1.36427. According to the classification adopted in this study, the natural-enemy community exhibited moderate family-level diversity. Although nine families were represented, their numerical distribution was uneven. The high proportional contribution of Tachinidae reduced community evenness and strongly influenced the overall diversity value.

3.3. Simpson Dominance

The Simpson dominance index was D = 0.36076. The original classification used in the study categorized this value as moderate dominance. Tachinidae had a proportional abundance of approximately 0.5474; consequently, its individual contribution to Simpson dominance was approximately $(0.5474)^2 = 0.2996$. Thus, Tachinidae alone contributed approximately 83% of the total Simpson dominance value, showing that the overall dominance pattern was primarily driven by the numerical predominance of this family.

3.4. Relationship Between Diversity and Dominance

The simultaneous values of H' = 1.36427 and D = 0.36076 indicate that the maize agroecosystem supported several natural-enemy families while showing substantial numerical concentration in one taxonomic group. Therefore, moderate diversity should not be interpreted as complete community evenness. Instead, the community can be characterized as taxonomically heterogeneous but numerically uneven.

4. Discussion

4.1. Family-Level Diversity of Natural Enemies

The Shannon-Wiener diversity index of H' = 1.36427 indicates moderate family-level diversity according to the classification adopted in the study. This result demonstrates that the maize agroecosystem in Laha supported several taxonomically different natural-enemy groups, including predators and parasitoids. However, individuals were not evenly distributed among these groups.

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The occurrence of several natural-enemy families may be associated with the structural characteristics of the maize agroecosystem and surrounding vegetation. Habitat management is recognized as an important component of conservation biological control because vegetation can provide natural enemies with shelter, alternative hosts or prey, nectar, pollen, and other food resources (Landis et al., 2000; Gurr et al., 2017). However, the present study did not experimentally manipulate vegetation or quantitatively test relationships between plant diversity and natural-enemy abundance. Consequently, surrounding vegetation should be considered a plausible ecological factor rather than a demonstrated cause of the observed diversity.

4.2. Dominance Structure of the Natural-Enemy Community

The Simpson dominance index of D = 0.36076 indicates that the community was numerically concentrated in a relatively small number of families. This pattern was primarily attributable to Tachinidae, which accounted for 54.74% of all individuals collected. The strong numerical contribution of Tachinidae explains why the community could simultaneously exhibit moderate family-level diversity and substantial dominance. Therefore, interpreting H' and D together provides a more complete representation of community structure than either index alone. The present findings should not be interpreted as evidence that the ecosystem was necessarily stable, because ecological stability involves temporal persistence, resistance, resilience, and functional interactions that cannot be determined from diversity and dominance indices alone.

4.3. Ecological Importance of Tachinidae

Tachinidae was the most abundant family recorded in the study. Tachinid flies are among the most diverse groups of dipteran parasitoids and are important natural enemies of many terrestrial arthropods. Lepidopteran larvae represent particularly important hosts for many tachinid species (Stireman et al., 2006). The high abundance of Tachinidae in Laha is therefore ecologically noteworthy, especially in maize ecosystems where lepidopteran pests may occur. Nevertheless, the present study did not rear parasitoids directly from *Spodoptera frugiperda* larvae or identify the collected Tachinidae to species level. Accordingly, the 312 Tachinidae individuals recorded in Laha cannot be assumed to have parasitized *S. frugiperda*. Future research should combine field collection with host rearing and, where possible, molecular identification to establish host-parasitoid relationships and determine actual parasitism rates.

4.4. Contribution of Other Natural-Enemy Groups

In addition to Tachinidae, several predator and parasitoid groups were present in the maize agroecosystem. Coccinellidae was the second most abundant family. Predatory coccinellids are well recognized as biological-control agents, particularly against aphids and other soft-bodied arthropods (Obrycki & Kring, 1998; Obrycki et al., 2009). Formicidae was also relatively abundant. Ants can function as generalist predators in agricultural systems, although their ecological effects vary among species and contexts. Braconidae represented an additional parasitoid component. Lycosidae represented the spider component; wolf spiders are active hunters and can contribute to predation of insect pests in agricultural habitats (Nyffeler & Sunderland, 2003). The simultaneous occurrence of several natural-enemy groups may increase the range of potential prey and hosts affected by biological control, but greater natural-enemy diversity does not automatically translate into greater pest suppression because competition, intraguild predation, and differences in prey preference may influence outcomes.

4.5. Habitat Heterogeneity and Conservation Biological Control

The vegetation observed around the maize fields included crop and non-crop plants that could potentially contribute to habitat heterogeneity. Non-crop vegetation can provide food resources for adult parasitoids and predators and can offer shelter and alternative hosts or prey. Landis et al. (2000) emphasized that habitat management for natural enemies should provide ecological resources in appropriate spatial and temporal configurations. Similarly, Gurr et al. (2017) described shelter, nectar, alternative prey or hosts, and pollen as important components of habitat-management strategies for pest suppression. These concepts have practical implications for maize production in Maluku. Maintaining selected flowering vegetation and refuges around crop fields may help conserve natural enemies. Nevertheless, vegetation management should be implemented carefully because some non-crop plants may also harbor pests or plant pathogens.

4.6. Implications for Integrated Pest Management

The occurrence of parasitoids and predators in the maize agroecosystem provides an ecological foundation for conservation-based IPM. Pest-management strategies should therefore consider practices that minimize unnecessary disruption of natural-enemy populations, including avoiding unnecessary broad-spectrum insecticide applications, using selective insecticides when chemical intervention is required, and maintaining suitable refuges where agronomically appropriate. However, the present study provides evidence primarily for community occurrence, diversity, and numerical dominance; it does not directly quantify biological-control effectiveness. The results should consequently be regarded as baseline ecological information that can guide more targeted biological-control studies in Maluku.

4.7. Study Limitations and Future Research

Several limitations should be considered. The study was conducted at a single locality during a relatively short sampling period. Natural-enemy populations may vary by season, crop-development stage, and year. Taxonomic identification was predominantly conducted at family level, which may mask ecological differences among species. Pitfall traps, yellow sticky traps, and sweep nets differ in capture efficiency and target different arthropod guilds; observed abundance therefore represents sampling-based abundance rather than absolute field population density. The study also did not directly measure predation, parasitism, or pest mortality. Future investigations should incorporate species-level identification, molecular identification where required, direct host-parasitoid rearing, measurements of predation and parasitism, simultaneous monitoring of pest populations, quantitative characterization of surrounding vegetation, and replicated observations across seasons and maize-development stages.

5. Conclusion

The maize agroecosystem of Laha Village, Maluku, eastern Indonesia, supported a family-level assemblage of arthropod natural enemies from nine families across six orders. We recorded a total of 570 individuals. Tachinidae was the most abundant family, with 312 individuals, representing 54.74% of the total natural-enemy community. The Shannon-Wiener diversity index was $H' = 1.36427$, indicating moderate family-level diversity according to the classification adopted in this study. The Simpson dominance index was $D = 0.36076$, demonstrating an uneven distribution of individuals among families. Tachinidae contributed most to community dominance, while the presence of several additional predator and parasitoid groups indicated broader taxonomic heterogeneity. These findings provide baseline information on natural-enemy community structure in maize production systems of Maluku. Conservation of beneficial arthropods and appropriate habitat management may contribute to ecologically based IPM; however, the actual contribution of the recorded natural enemies to pest suppression requires confirmation through species-level identification and direct measurements of predation and parasitism.

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