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THE FIRST REPORT OF A DATABASE ON EDIBLE INSECT CONSUMPTION BASED ON EXPLORATION AND SURVEY IN TERNATE ISLAND AS A WALLACE LINE AREA

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ABSTRACT

Edible insects are gaining attention as sustainable, nutrient-dense alternative sources of protein, particularly in biodiverse regions where local food systems and ecological knowledge remain closely intertwined. This study investigated the potential of edible insects on Ternate Island, Indonesia, a small island in the Wallacean biogeographical area, through a combination of a field-based insect inventory and a survey of community perceptions of entomophagy. A quantitative cross-sectional study was conducted in August–September 2025 in five administrative regions of Ternate Island, including home gardens, agricultural land, plantation areas, and sago-associated habitats. Field exploration recorded edible and potentially edible insects, primarily from the orders Orthoptera, Hymenoptera, Lepidoptera, and Coleoptera. We found 20 records of edible insects, including grasshoppers, crickets, bee and wasp brood, lepidopteran larvae or pupae, and coleopteran larvae such as sago-associated Rhynchophorus spp. Five more records were classified as non-edible or not commonly eaten and were predominantly associated with pest monitoring. A community survey was conducted, and 51 responses were considered valid. The majority of respondents were aware of entomophagy (82.35%); however, knowledge of its health benefits was nearly equal between yes and no responses (50.98 vs. 49.02%), and only 31.37% had previously consumed insects. The most frequently recognized edible insects were grasshoppers/locusts and sago larvae, and the main barriers to acceptance were disgust, low willingness to try, safety uncertainty, and limited market availability. While nearly half of the respondents considered insects an important source of protein, willingness to consume processed insect-based foods remained low. These findings indicate that edible insects on Ternate Island are viable as supplementary local protein sources, especially sago larvae and grasshoppers/locusts. However, further taxonomic validation, nutritional profiling, food safety assessment, allergen evaluation, studies on sustainable harvesting, and sensory-based consumer research are necessary for their wider application in food systems.

Keywords: Edible insects, Entomophagy, Alternative protein, Ternate Island, Wallacea, Sago larvae, Community acceptance.

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1. INTRODUCTION

Malnutrition remains a major public health concern in Indonesia, affecting multiple demographic groups, particularly children and adolescent girls (Rah et al., 2021; Andriani et al., 2023). Approximately one in three children under five is stunted, one in ten is wasted, and one in four adolescent girls is anemic. Low protein consumption in Indonesia is mostly due to socioeconomic inequality and limited access to healthy food (Moruzzo et al., 2021; Purnami et al., 2023; Setyawati & Magfirah, 2024). To promote the community's nutrition and food security, the government developed the Free Nutritious Meal (MBG) program (Hidayah et al., 2025; Shiddiq & Effendi, 2025; Andini, 2025). Economic development in Southeast Asian countries has been associated with the transition in food consumption from traditional plant-based diets to increased use of animal protein sources (Khusun et al., 2022; Tjahyo et al., 2024; Ueda, 2026). The FAO balance sheet analysis highlights the importance of animal-based foods in meeting protein needs, particularly in low- and middle-income countries (Paulin & Purwanto, 2020; Al Hasan et al., 2022;

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Tacon, 2023). Animal protein consumption in Indonesia remains uneven and accounts for only a tiny proportion of overall food intake (Khusun et al., 2022; Khoiriyah et al., 2025). The lack of animal protein intake may lead to nutritional deficiencies, including stunting, anemia, and wasting (Biró et al., 2020; Angelica et al., 2023; Hermawan et al., 2023). Food security programs should improve food availability, diet quality, and nutritional adequacy (Rah et al., 2021; Angelica et al., 2023; Hermawan et al., 2023).

Meat is a rich source of protein and easy to digest (Zeng et al., 2022; Xie et al., 2022). Conventional beef cattle ranching has been linked to environmental problems, including greenhouse gas emissions and the overexploitation of water resources (Naranjo et al., 2020; Heinke et al., 2020; Biró et al., 2020; Cheng et al., 2022). These challenges have increased the demand for novel protein sources, both nutritionally and environmentally. Edible insects are among the sustainable protein sources to be researched. Edible insects are defined as species of bugs that can be eaten safely without any harmful health consequences when taken in the appropriate amounts (Mézes & Erdélyi, 2020; Giampieri et al., 2022; Aguilar-Toalá et al., 2022; Van Itterbeeck & Pelozuelo, 2022). Entomophagy is believed to be universal across taxa and geographies, with 2,205 insect species consumed as food in 128 countries worldwide (Omuse et al., 2024). Insects are increasingly recognized as important components of sustainable and circular agricultural systems due to their potential to close the loop of nutrients and energy, improve food security and offer solutions to issues related to climate change and loss of biodiversity (Madau et al., 2020; Sokame et al., 2024; Barragán-Fonseca et al., 2025). Thus, edible insects can directly help achieve the SDGs, in particular SDG 2, which aims to end hunger, ensure food security and improved nutrition, and promote sustainable agriculture.

Insects are a source of high-quality protein, necessary amino acids, unsaturated fatty acids, vitamins and minerals (Orkusz, 2021; Weru et al., 2021; Zhou et al., 2022; Nowakowski et al., 2022). Edible insects have been shown to contain protein content comparable to or higher than that of normal beef products, with substantial variation depending on the species (Liceaga, 2022; Shah et al., 2022). Internationally, insects eaten include sago worms, beetles, bees, grasshoppers, crickets, and dragonflies (Van Huis, 2020; Van Itterbeeck & Pelozuelo, 2022; Omuse et al., 2024). Some are high in protein, fat, and calories. According to Orkusz (2021), 100 g of various edible insects, such as Acheta domesticus, *Gryllus bimaculatus, Tenebrio molitor, Zophobas morio, Gonimbrasia belina, Bombyx mori*, and species of Pyralidae, contain an average energy of 120–274.7 kcal and a protein content of 15.5%–35%. Other traditional meats such as goat, beef, horse, pork, chicken, bluefin tuna and turkey, in comparison, have lower to similar energy and protein content of about 13.2 to 125 kcal and 15.1% to 21.5% protein per 100 g (Köhler et al., 2020; Soren & Biswas, 2020; Cusimano et al., 2024; Li et al., 2025; Tan et al., 2025). The results suggest that edible insects can serve as an alternative food source with excellent nutritional value. In several nations, insects have been consumed as larvae and adults, e.g., in Indonesia (Adegboye et al., 2021; Tuhumury, 2021; Salgado-Ramos et al., 2024; Khoiriyah et al., 2025; Jankowski et al., 2025).

Indonesia has a significant opportunity to explore the potential of edible insects, given its wide insect diversity (Palupi et al., 2020; Campera et al., 2022; Ferdian et al., 2023; Syabana et al., 2025). Some intensive entomological studies on the diversity and distribution of insects in North Maluku, especially on Ternate Island, have been carried out, especially on insects such as butterflies (Mas'ud et al., 2020; Tamnge & Nurdin, 2021; Mas'ud et al., 2021; 2024) and beetles (Nurdin & Saelan, 2020; Matalin, 2025). However, no study has documented the inventory, distribution, and nutritional content of edible insects on Ternate Island. There is scant evidence that the indigenous people find eating insects acceptable. Identifying suitable edible bug species from the locality and assessing community acceptability are important for developing edible insects as an alternative source of animal protein. The gap in information is large. This study aimed to estimate the potential of edible insects on Ternate Island based on abundance data and to evaluate the acceptability of entomophagy among the local population using a cultural survey. The research will generate baseline data on creating locally available, sustainable, and culturally relevant alternative protein sources using an integrated ecological and sociocultural approach. The results of this study can bring new insights into the Free Nutritious Meal Program, especially in increasing the availability of low-cost and environmentally sustainable animal protein sources in the biodiversity of Ternate Island.

2. MATERIALS AND METHODS

2.1. Study Area

This research was conducted on Ternate Island, Indonesia, which is divided into five administrative regions, namely North Ternate, South Ternate, Central Ternate, West Ternate and Ternate Island District The geographical distribution of the study sites is shown in Fig. 1.

2.2. Study Period and Design

The present study was carried out using a quantitative cross-sectional approach which consisted of two parts: (1) field exploration and inventory of insect diversity in various habitats on Ternate Island, and (2) a mini-survey on the community to assess public perception and acceptance of edible insects. The field inventory documented the presence

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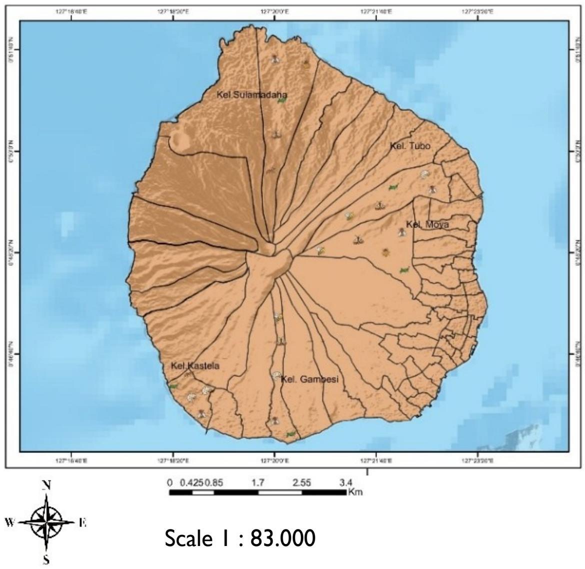
and diversity of insect species on Ternate Island, while the survey captured community views on entomophagy and the potential use of insects as alternative food sources. Data collection was conducted over a period of one month (August - September 2025).



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Note:

Icon	Family	Morphospecies	Consumed part/life stage	Utilization notes
	Tephritidae	Fruit fly	Not commonly consumed	Used mainly for pest-control relevance
	Carabidae	Ground beetle larva	Larva/pupa	Protein-rich food source
	Curculionidae	Sago larva	Larva	Fat-rich food source
	Formicidae	Weaver ant	Eggs, larvae, adults	Consumed in Southeast Asia
	Gryllidae	Grasshopper/cricket	Whole body	High-protein food source
	Noctuidae	Noctuid moth	Larva/pupa	Protein source

Map information

Grid system	:	UTM Zone 52N; geographic coordinates
Geodetic datum	:	WGS 1984
Local projection	:	World Mercator
Data sources	:	DEM Nasional, BIG; topographic base map; bathymetry data; field survey data.

Map Insert:

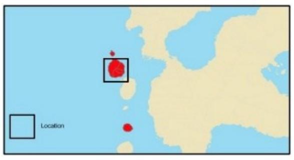

Fig. 1: Map of the study area on Ternate Island.

2.3. Insect Inventory

Field exploration and insect inventory were conducted across various habitat types at five study sites on Ternate Island using purposive sampling. The inventory procedure was adapted, with contextual modifications, from the regional insect-fauna survey approach described by Egorov et al. (2024), which emphasizes field-based documentation of insect diversity, species richness, and habitat-associated occurrence. All insect taxa observed or collected during the study period were recorded and identified to the lowest possible taxonomic level, with particular attention to species potentially relevant as edible insects. The data were summarized descriptively by occurrence across the study areas and used to update knowledge of insect species richness on Ternate Island and to identify locally available insect taxa with potential value as edible food resources.

2.4. Survey of Community Perceptions

A structured cross-sectional mini-survey was conducted to assess residents' perceptions, prior experiences, and acceptance of insects as food on Ternate Island. The survey was adapted, with contextual modifications, from the consumer acceptance framework of Bae et al. (2021). Data were collected through direct distribution and an online Google Forms questionnaire, involving 51 respondents. The questionnaire included closed-ended items and short explanatory responses. Respondents rated their interest in consuming insects on a numerical scale and provided reasons for their interest or reluctance. The survey also explored prior insect consumption, types of insects consumed, sensory perceptions among previous consumers (taste, texture, and aroma), and respondents' views on insects' potential as an alternative food source in Indonesia.

2.5. Data Analytics

The insect inventory data were analyzed descriptively to summarize the occurrence and richness of insect species found in the study areas. Descriptive analyses of the survey data were also conducted to describe the distribution of respondents' answers regarding interest in consuming insects, previous consumption experience, perceived sensory characteristics, and acceptance of insects as future alternative foods. Open-ended item responses were coded by common reasons and interpreted to support the quantitative results.

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3. RESULTS

3.1. Field Exploration and Habitat Distribution of Insect Taxa on Ternate Island

The field exploration was carried out in five administrative areas of Ternate Island, namely Central Ternate, North Ternate, West Ternate, South Ternate, and Ternate Island District. The habitats surveyed were home gardens, agricultural lands, plantation areas, and sago-associated habitats, and field temperatures ranged from 28 to 33°C. Preliminary exploration showed several dominant insect groups in the sampling sites, such as Orthoptera, Coleoptera, Lepidoptera, Hymenoptera, Diptera, Hemiptera, Phasmatodea, Blattodea, and Gryllidae-associated taxa (Table 1). The results suggest that the insect assemblage of Ternate Island is heterogeneous among anthropogenic and semi-natural habitats, with some taxa that could be relevant as edible insect resources.

Table 1: Preliminary exploration and collection results of dominant insect families on Ternate Island

No	Location (District/Subdistrict)	Habitat	Temperature (°C)	Order/Family Recorded
1	Central Ternate / Tabahawa	Yard Agricultural plantation	28	Orthoptera Hemiptera Hymenoptera
2	North Ternate / Tubo	Agricultural plantation Plantation land	33	Coleoptera Phasmatodea Lepidoptera
3	West Ternate / Sulamadaha	Agricultural plantation	32	Curculionidae Hemiptera
4	South Ternate / Gambesi	Plantation land Plantation land	30	Homoptera / Diptera Hymenoptera
5	Ternate Island / Kastela	Sago land Agricultural plantation	29	Coleoptera Orthoptera Blattodea Gryllidae

Orthoptera, Hemiptera, and Hymenoptera were characteristic of Central Ternate/Tabahawa at the site level in garden and agricultural plantation habitats. Coleoptera, Phasmatodea and Lepidoptera were found in the agricultural and plantation areas of North Ternate/Tubo, while Curculionidae and Hemiptera dominated the agricultural plantation habitat of West Ternate/Sulamadaha. Homoptera/Diptera and Hymenoptera were recorded in the plantation land in South Ternate/Gambesi, while Coleoptera, Orthoptera, Blattodea and Gryllidae-related insects were recorded in the sago land and agricultural plantation areas in Ternate Island/Kastela. The overall distribution of these taxa reflects the habitat diversity on Ternate Island and underscores the relevance of multi-habitat sampling for documenting edible and potentially edible insect resources.

3.2. Taxonomic Composition and Edible-use Categories of Recorded Insects

A total of 20 edible insect records belonging to four principal orders (Orthoptera, Hymenoptera, Lepidoptera and Coleoptera) were recorded across the five sampling locations in the edible insect inventory (Table 2). Furthermore, five records were classified as non-edible or not regularly consumed, mostly comprising taxa more important for pest monitoring or ecological observation than for direct food use. The edible insects recorded were from the taxa Formicidae, Apidae, Vespidae, Noctuidae, Dryophthoridae/Curculionidae, Scarabaeidae, Carabidae, Acrididae and Gryllidae. The taxa were collected using several field methods, i.e., hand collection, sweep nets, light traps, colour traps, pit traps, and pheromone traps.

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Patterns of edible use varied by insect order and developmental stage. In general, hymenopteran taxa, e.g., *Oecophylla smaragdina, Tetramorium bicarinatum, Polistes stigma,* and *Apis sp.*, were found mainly in relation to the consumption of eggs, larvae, pupae, adults, or brood. Lepidopteran taxa were predominantly recorded as edible at the larval and pupal stages, particularly *Spodoptera sp.* and *Spodoptera litura*. Orthopteran insects, such as *Locusta migratoria*, *Valanga nigricornis* and *Gryllus bimaculatus*, were generally found to be associated with whole-body consumption, especially in the adult stage. The larval stages of coleopteran taxa such as *Rhynchophorus bilineatus*, Rhynchophorus ferrugineus, *Oryctes sp.* and *Carabus sp.* were mainly consumed and frequently described as good

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sources of protein or lipids.

Table 2: Preliminary records of insect taxa collected across sampling sites on Ternate Island and their potential edible use

Site	Collection method	Order	Family	Morphospecies	Edible part	Reported use/remarks
Kastela	Light trap	Hymenoptera	Formicidae	*Oecophylla smaragdina*	Eggs, larvae, adults	Consumed in Southeast Asia
		Lepidoptera	Noctuidae	*Spodoptera* sp.	Larvae/pupae	Rich in protein
	Hand collection	Coleoptera	Dryophthoridae	*Rhynchophorus bilineatus*	Sago larvae	Rich in lipids
			Scarabaeidae	*Oryctes* sp.	Oryctes larvae	
	Sweep net	Orthoptera	Acrididae	*Locusta migratoria*	Whole body	Rich in protein
			Gryllidae	*Gryllus bimaculatus*		
	Petrogenol trap	Diptera	Tephritidae	*Bactrocera dorsalis*	Not commonly eaten	Target for pest monitoring/control
Sulamadaha	Sweep net	Hymenoptera	Formicidae	*Tetramorium bicarinatum*	Eggs, larvae	Locally used
			Vespidae	*Polistes stigma*		
		Lepidoptera	Noctuidae	*Spodoptera litura*	Larvae/pupae	Protein source
		Orthoptera	Acrididae	*Valanga nigricornis*	Whole body	High in protein
			Gryllidae	*Gryllus bimaculatus*		
	Hand collection	Coleoptera	Carabidae	*Carabus* sp.	Larvae	Fat source
		Lepidoptera	Noctuidae	*Helicoverpa armigera*	Not commonly eaten	Not commonly eaten
Moya	Sweep net	Hymenoptera	Apidae	*Apis* sp.	Larvae/pupae	Bee larvae consumed
		Diptera	Tephritidae	*Bactrocera dorsalis*	Not commonly eaten	Major fruit pest; commonly targeted in pest monitoring/control
	Hand collection	Lepidoptera	Noctuidae	*Spodoptera litura*	Larvae/pupae	High in protein
		Coleoptera	Carabidae	*Carabus* sp.	Larvae	Larvae used as an alternative food
		Orthoptera	Acrididae	*Locusta migratoria*	Whole body	Not commonly eaten; high in protein
Tubo	Hand collection	Lepidoptera	Noctuidae	*Spodoptera litura*	Larvae/pupae	High in protein
		Coleoptera	Curculionidae	*Rhynchophorus ferrugineus*	Coconut beetle larvae	Lipid source
	Sweep net	Hymenoptera	Apidae	*Apis* sp.	Larvae/pupae	Bee larvae consumed
		Coleoptera	Coccinellidae	*Coccinella septempunctata*		Locally used
		Hemiptera	Pentatomidae	*Pentatomid* sp.	Whole body	Local protein source; not commonly eaten
		Orthoptera	Acrididae	*Locusta migratoria*,		
		Diptera	Tephritidae	*Bactrocera dorsalis*	Not commonly eaten	Fruit fly monitoring
Gambesi	Color trap	Hymenoptera	Apidae	*Apis* sp.	Larvae/pupae	Bee larvae consumed
		Coleoptera	Carabidae	*Carabus* sp.	Larvae	Larvae are utilized
	Pitfall trap	Lepidoptera	Noctuidae	*Spodoptera litura*	Larvae/pupae	High in protein
		Orthoptera	Acrididae	*Valanga nigricornis*	Whole body	Not commonly eaten; high in protein
			Gryllidae	*Gryllus bimaculatus*		
	Sweep net	Diptera	Tephritidae	*Bactrocera dorsalis*	Not commonly eaten	Fruit fly monitoring

Among the documented groups of edible insects, coleopteran larvae are especially notable for their well-known association with local food practices, particularly sago larvae. Orthopteran insects were also frequently observed at sites and are commonly associated with high-protein food use. In contrast, Diptera, especially Bactrocera dorsalis, were predominantly reported for pest monitoring and control rather than direct consumption. Fig. 2 shows the representative insect taxa recorded during the survey.

3.4. Awareness, Knowledge and Previous Experience of Entomophagy

The final descriptive analysis consisted of 51 valid survey responses. Most respondents had heard of insect consumption, or entomophagy. 42 respondents (82.35%) answered: “Yes,” while 9 respondents (17.65%) answered “No” (Fig. 3). The awareness of the health benefits of eating insects was more evenly spread, with 26 respondents (50.98%) saying they knew the health benefits and 25 respondents (49.02%) saying they did not. Awareness of entomophagy was relatively high compared with prior consumption experience. Only 16 respondents (31.37%) had an experience of consuming insects, while 35 respondents (68.63%) had never consumed insects.

This pattern reveals a clear gap between awareness and actual consumption experience. Most respondents were aware of entomophagy, but their own experience eating insects was limited. Fig. 4 also shows that awareness of entomophagy did not necessarily imply knowledge of its health benefits or willingness to consume insect-based foods.

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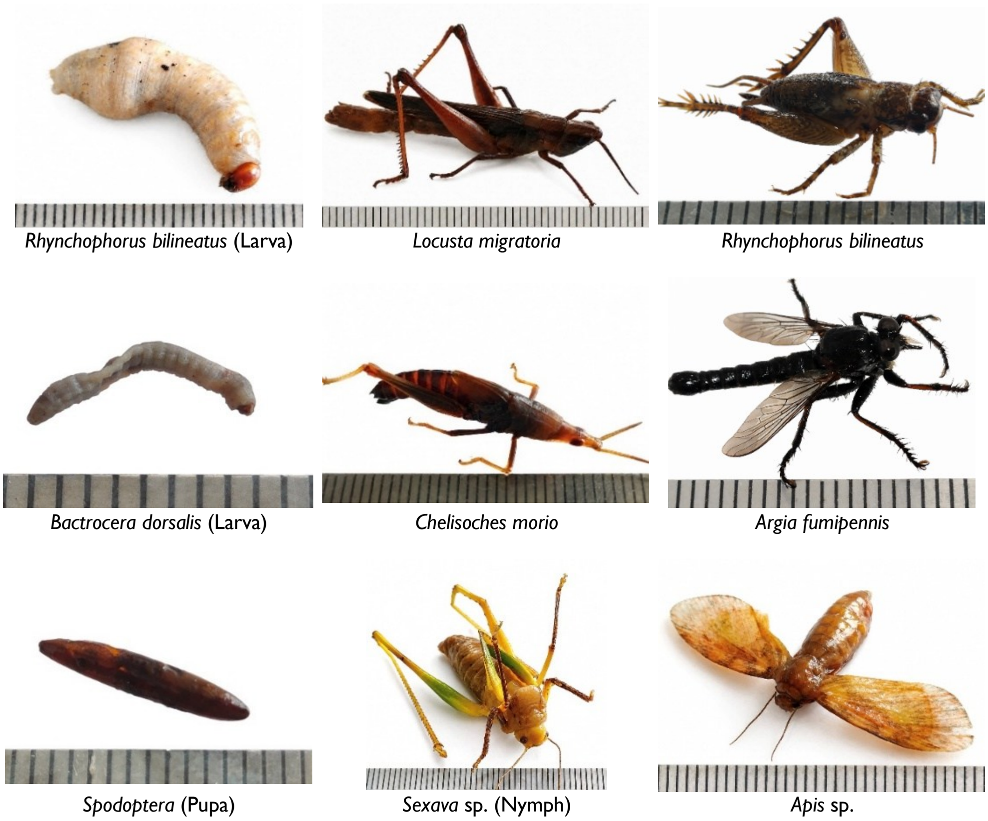

Fig. 2: Representative edible insect species documented and consumed on Ternate Island.

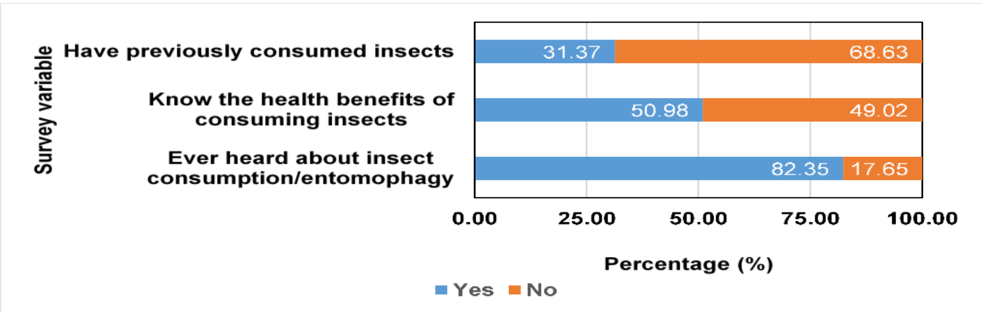

Fig. 3: Awareness, knowledge, and previous consumption of insects (n=51).

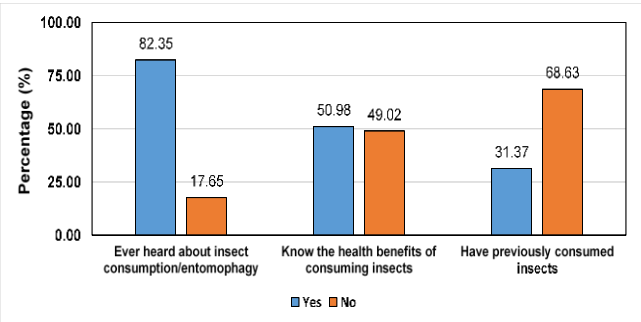

Fig. 4: Distribution of respondents (%) according to awareness of entomophagy, knowledge of its health benefits, and previous consumption experience.

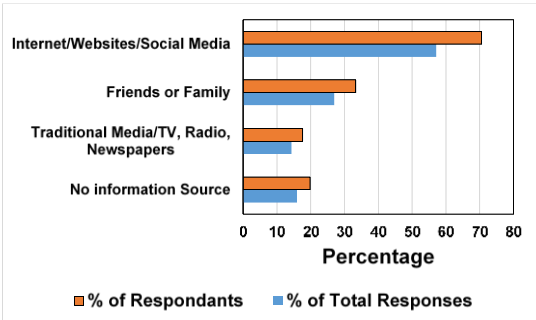

Fig. 5: Multiple-response distribution of respondents' sources of information about entomophagy (n=51 respondents; 63 total responses).

3.5. Sources of Information about Entomophagy

Respondents obtained information on entomophagy from multiple sources, with 51 respondents providing 63 valid source mentions (Fig. 5). Websites and social media were the most common sources, accounting for 36 responses and 57.14% of all source mentions. Friends or family was the next most common source, cited by 17

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respondents and accounting for 26.98% of all mentions. Traditional media (television, radio, newspapers) accounted for 9 mentions (14.29%). Also, 10 respondents reported having no source of information on entomophagy.

These results show that digital media played the most influential role in shaping respondent's exposure to information about edible insects. However, the presence of respondents with no information source also indicates that public dissemination of entomophagy-related knowledge remains incomplete within the study population.

3.6. Edible Insects Recognized by Respondents

Respondents mentioned 86 valid records of edible insects, which were subsequently grouped into 14 categories (Fig. 6). The grasshoppers and locusts category was the most mentioned one with 27 mentions (31.40%). The second most frequently mentioned group was sago larvae or sabeta (14 mentions, 16.28%), followed by crickets (10 mentions, 11.63%) and beetles or beetle larvae (9 mentions, 10.47%). Other categories included ants and bee/wasp brood (5 mentions, 5.81%); silkworms or silkworm pupae (4 mentions, 4.65%); and unspecified larvae or caterpillars (3 mentions, 3.49%). Mealworms, termites and winged termites, and dragonflies were mentioned twice (2.33%), and moths, flies and bed bugs were mentioned once (1.16%). The prevalence of grasshopper/locust and sago larvae/sabeta suggests that the respondents' knowledge of edible insects was limited to taxa that were visually familiar, locally available, or culturally recognised as food. The relatively low frequency of other categories suggests that the community is less familiar with the wider diversity of edible insects.

3.7. Perceived Importance of Insects as a Protein Source and Willingness to Try Processed Insect-based Foods

Respondents perceived the importance of insects as a protein source differently (Fig. 7a). 15 respondents (29.41%) stated that consuming insects was important as a protein source, and 10 (19.61%) stated that it was very important. On the other hand, 11 respondents (21.57%) chose neutral, 10 (19.60%) chose unimportant, and 5 (9.80%) chose very unimportant. Overall, 25 respondents (49.02%) had a positive perception of insects as a source of protein, while 15 respondents (29.40%) had a negative perception.

However, the willingness to try processed insect-based foods was lower than perceived nutritional importance (Fig. 7b). Thirteen respondents (25.49%) were very unwilling to try processed insect-based foods, while 10 (19.61%) were unwilling. Eleven respondents (21.57%) gave a neutral response, 8 respondents (15.69%) were willing, and 9 respondents (17.65%) were very willing to try processed insect-based foods. Thus, only 17 respondents (33.34%) were positively willing, and 23 respondents (45.10%) were reluctant. This shows that mere awareness of insects as a potential protein source does not translate into a readiness to consume insect-derived products.

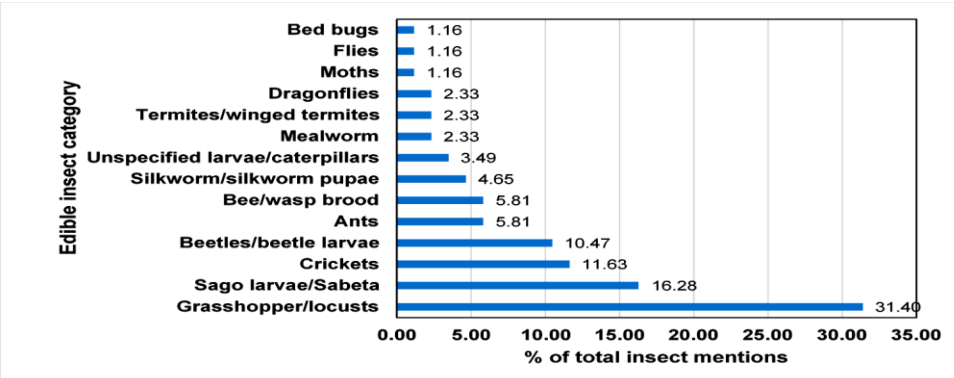

Fig. 6: Distribution of edible insects mentioned by respondents based on total valid insect mentions (n=51 respondents; 86 valid insect mentions).

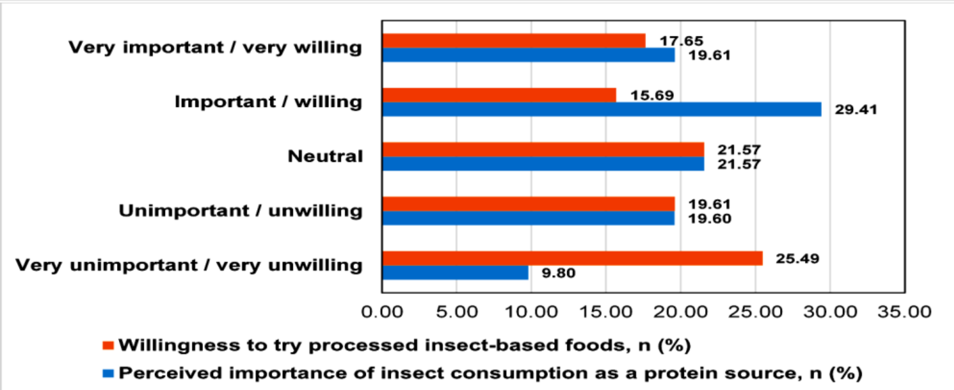

Fig. 7: Distribution of Likert-scale responses for perceived importance and willingness to try processed insect-based foods among respondents (n=51).

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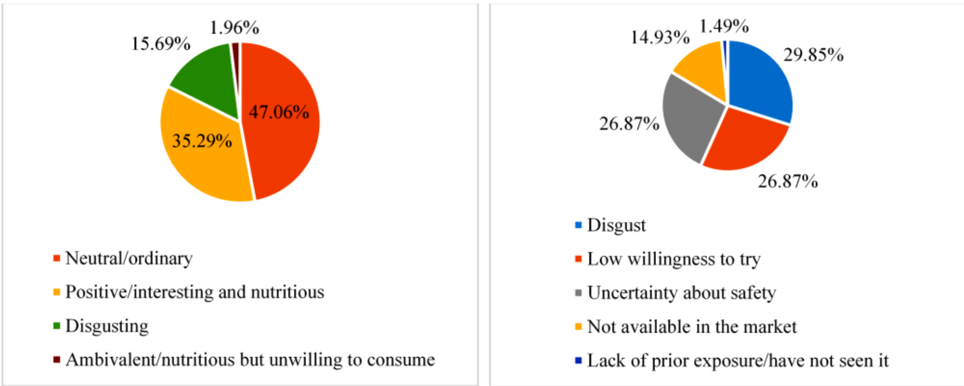
3.8. General Perceptions and Barriers to Insect Consumption

Respondents' general perceptions of insect consumption were dominated by neutral or ordinary views, reported by 24 respondents (47.06%) (Fig. 8a). Positive perceptions were reported by 18 respondents (35.29%), including that insects are interesting and nutritious. 8 respondents (15.69%) reported negative perceptions of disgust, and 1 respondent (1.96%) expressed ambivalence, recognizing the nutritional value of insects but unwilling to consume them.

Barriers to insect consumption were analyzed as multiple-response data, yielding 67 valid barrier selections (Fig. 8b). Disgust was the most common barrier, with 20 selections (29.85%). Low willingness to try and uncertainty about safety were equally important barriers, with 18 selections each (26.87%). Ten selections (14.93%) were due to limited market availability, and a lack of prior exposure or having never seen edible insects was reported once (1.49%). The findings suggest that the primary barriers to adopting edible insects as food are psychological acceptance, food safety concerns, and limited accessibility.



(a) (b)

Fig. 8: Distribution of respondent's perceptions toward insect consumption and the reported barriers to insect consumption. (a) Respondent's perceptions toward insect consumption (n=51). (b) Barriers to consuming insects based on total barrier selections (n=51 respondents; 67 valid barrier selections).

3.9. Reported Modes of Insect Consumption

The insect consumption modes were coded based on the respondent's answers and 54 valid coded selections were obtained (Fig. 9). The most prevalent category was no prior consumption or never consumed insects, with 20 responses coded (37.04%). Of those respondents who reported consumption-related practices, the most common mode was incorporating insects into dishes, such as stir-fried preparations, with 14 selections (25.93%). Processing insects for eating as snacks (e.g., chips) accounted for 12 selections (22.22%), and direct eating accounted for 6 selections (11.11%). Other methods of preparation were insects on skewers (satay) and roasted or grilled insects, each with 1 selection (1.85%). These results imply that insect consumption on Ternate Island is not solely direct but may also involve culinary processing that transforms insects into familiar foods. Thus, processed formats, particularly stir-fried dishes and snack-like products, may be more acceptable entry points for developing insect-based foods in the local context.

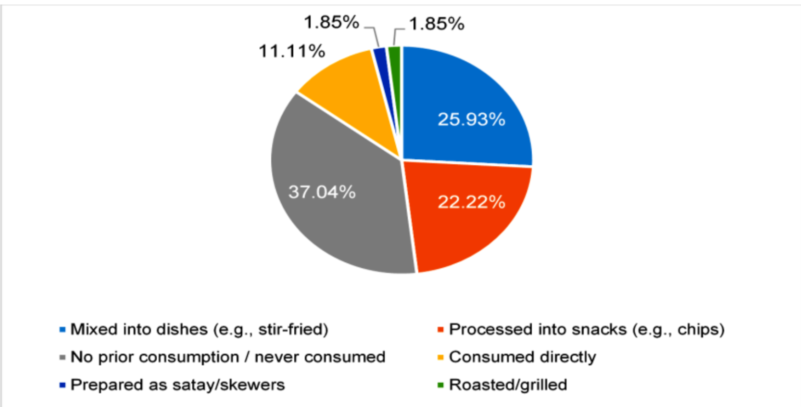


Fig. 9: Reported modes of insect consumption among respondents based on coded responses (n=51 respondents; 54 valid coded selections).

4. DISCUSSION

Research shows that using edible insects as a protein source in Ternate Island, Indonesia, is ecologically and socioculturally viable. Many respondents were aware of insect consumption, but few were aware of the health benefits or had tried them. This pattern is consistent with previous consumer studies showing that edible insects may be culturally known or socially recognized, but their acceptance as food is strongly mediated by nutritional knowledge, perceived health benefits, familiarity, and direct eating experience (Bartkowicz, 2020; Reed et al., 2021; Florença et al., 2021). A cross-national survey involving 14 countries (Guiné et al., 2024) reported that consumers often showed neutral or uncertain responses to several statements related to the nutritional value and health effects of edible insects, suggesting that awareness alone is insufficient to generate informed acceptance.

Edible and potentially edible insects are found in yards, agricultural fields and plantations, and in sago-associated landscapes, indicating their integration in productive landscapes. These habitats may also host edible insect diversity, especially on islands where food supply, land use, biodiversity, and local ecological knowledge are interlinked (Girsang et al., 2025; Ochieng & Egonyu, 2025). The most widespread edible insects in the world are Orthoptera, Hymenoptera, Lepidoptera, and Coleoptera, including grasshoppers, crickets, beetle larvae, ants, bees, wasps, and lepidopteran larvae. Results from Ternate Island are locally distinct but are consistent with global data on major taxonomic groups of edible insects (Van Huis, 2020; Van Itterbeeck & Pelozuelo, 2022; Omuse et al., 2024).

Coleopteran larvae are of particular interest due to their association with sago-based environments and cuisine. In eastern Indonesia, where sago ecosystems are natural habitats and culturally important food landscapes, many beetle larvae are important (*Oryctes sp.*, *Rhynchophorus bilineatus*, *Rhynchophorus ferrugineus*) (Leatemia et al., 2021; Rozziansha et al., 2021). In East Indonesia, sago larvae are easier to identify than other insect genera, locally known as sabeta or similar names (Ibrahim & Gunawan, 2015; Aydoğan et al., 2024). Sago larvae are frequently encountered in field inventory and are known by the respondents, probably making them one of the most culturally rooted edible insect candidates of Ternate Island. Unlike foreign insects, which may cause aversion or rejection, Samoa larvae are already eaten locally. Cultural familiarity is important as local innovations are more likely to be adopted than foreign culinary forms (Abbasi, 2024; Ogwu, 2025; Seo, 2025).

Orthopterans like the locust (*Locusta migratoria*), the dark brown locust (*Valanga nigricornis*), and the two-spotted cricket (*Gryllus bimaculatus*) were tasty. These insects were regularly found at the sampling sites and were often eaten whole. In the survey, the most regularly reported edible insects were grasshoppers and locusts. The respondents seem to be intellectually familiar with the subject but have minimal experience with it. The strong public perception, applicability in popular culinary practices, and global nutritional value of orthopterans make them promising alternative sources of protein (Fombong et al., 2021; Magara et al., 2021; Lisboa et al., 2024). When introducing grasshoppers and locusts to agriculture, the points to be considered are seasonality, ecological sustainability, pesticide exposure, microbiological contamination, and post-harvest hygiene (Makkar et al., 2022; Mugo-Kamiri et al., 2024). Therefore, food safety testing needs to be included in large-scale commercialization of these species.h

Hymenopteran taxa (*Oecophylla smaragdina*, *Tetramorium bicarinatum*, *Polistes stigma* and *Apis* sp.) were found most frequently in the form of edible eggs, larvae, pupae, adults and broods. This suggests that edible insects have distinctive sensory and nutritional properties at different stages (Mishyna et al., 2020; Tanga et al., 2023). Many traditional dishes include nutritious bee and wasp larvae. However, the use of Hymenoptera as food should be carefully considered because these insects also play important ecological roles in pollination, predation, and biological control (Dunn et al., 2020; Brock et al., 2021). Prior to recommendations for use as food, the risks of harvesting, stinging, nest availability, and local ecosystem implications need to be considered. Thus, Hymenoptera are to be regarded as consumables and to be sustainably harvested and environmentally conserved.

Spodoptera litura was also identified as a potential edible species, which is notable because lepidopteran larvae are often abundant in agricultural systems and can provide substantial nutritional value. They are agricultural pests and food sources, posing safety and perception risks. The larvae of agricultural pests may be affected by pesticides, secondary plant metabolites, diseases, and other contaminants (Saraswathi et al., 2023; Thakur et al., 2024; Nougadère et al., 2025). Lepidopteran larvae contribute to the species described in this work as edible or potentially edible, but toxicological, microbiological and residual testing is required to approve their use. This distinction preserves the scientific rigour of the work. Ecological availability justifies food development only after proof of safety, sustainability and consumer acceptance.

Instead of a food, *Bactrocera dorsalis* (Diptera) was reported as a pest to watch and control (Heve et al., 2021; Jaffar et al., 2023; Wang et al., 2024). The scientific interest in this difference lies in the fact that not all the collected insects taste good. The inventory should therefore clearly distinguish between locally consumed, edible, potentially edible and not commonly consumed taxa. These species could have nutritional potential but lack cultural acceptance or they are known but need safety validation. This classification must be published in a high-impact publication to avoid overestimation of insect nutrition. The species 'high in protein' and 'not commonly eaten' should be considered potential sources for further validation rather than edible insects.

The community survey revealed a huge gap in awareness, knowledge and practice. Most respondents were familiar with entomophagy, but only half were aware of its health benefits, and fewer than one-third had eaten insects.

It appears that awareness does not necessarily translate into nutritional knowledge and food intake. This gap matters because many food diversification programs fail by assuming that knowledge alone is sufficient to change diets. Current standards indicate that the public is aware of eating insects, but this is not sufficient to support their widespread use (Olivadese & Dindo, 2023; Abbasi, 2024). Thus, future activities in Ternate Island should not only be about awareness. Education in evidence-based nutrition, sensory exposure, food safety assurances, culinary demonstrations, and the development of culturally appropriate products are necessary.

The dominance of digital media as the primary source of knowledge about entomophagy has important implications (Kamenidou et al., 2023). The Internet, including websites and social media, was the most frequently reported source of information, followed by friends or family and traditional media. This suggests that it is digital exposure, not intergenerational culinary traditions, that is moulding public knowledge of edible insects. Digital channels can be a way to introduce edible insects to the younger and more informed population (Jones & Beynon, 2021; Pianella, 2025). Digital exposure without locally relevant scientific facts can fragment, sensationalise or superficialise understanding. Future dissemination should involve social media as well as credible instructional content on edible species, safe preparation, nutritional value, environmental benefits, allergen risks and hygienic processing.

In this study, willingness to try processed insect-based food was not always influenced by perceived nutritional value. Almost half of the participants considered insects to be a vital protein source. One-third were interested in or very willing to try processed insect foods. This difference shows that knowing the importance of nutrition is not sufficient to overcome emotional, sensory, and social constraints (Florença et al., 2021; Abbasi, 2024; Seo, 2025). Food acceptability is influenced by nutrient content, disgust sensitivity, perceived safety, prior exposure, social norms, visual aesthetics, and symbolic meaning (Prinyawiwatkul, 2023). The marketing of edible insects on Ternate Island needs to go beyond the protein content and sustainability. Acceptance of edible insects is more likely when they are presented in familiar meal forms, prepared in an appealing way, with clear safety messages and introduced gradually to the senses (Okaiyeto et al., 2024).

The most common barriers were disgust, lack of motivation, and safety concerns. These are common problems for exotic foods (Seaman et al., 2025; Jaspe Nieto et al., 2026). Repulsion might indicate that whole insects aren't the best way to get consumers to accept them. Whole insects may not be as appealing as insect flour, chips, crackers, stir-fry mixes, satay-style dishes, and local delicacies with added protein (Brynning et al., 2020; Wendin & Nyberg, 2021). Processing should not obscure the insect-based nature of food products but should instead improve hygiene, prolong shelf life, and enhance sensory acceptability and product uniformity. From a food safety perspective, essential information should be clearly disclosed, including species identity, source habitat, hygienic treatment, allergenic potential, microbiological contamination, chemical residues, and cooking or processing procedures.

The consumption patterns identified in this study provide valuable insights and promising opportunities for developing insect-based food products. Direct eating was rare in coded responses, although insects were incorporated into dishes and snacks. These results indicate that using insects in familiar recipes may be more acceptable than promoting them as individual foods. Transitional food formats such as stir-fries, snacks, chips, satay-type preparations, and roasted insects may minimize psychological resistance while maintaining local distinctiveness.

This study reports on entomophagy in Wallacea, a biogeographically isolated region with high biodiversity but lacking systematic evidence of insect consumption. Monitoring the natural insect food resources on Ternate Island is scientifically important due to its Wallacean location. There are many studies on edible insects from mainland locations or from countries with long traditions of entomophagy, but few from small islands. The present results expand the geographical coverage of edible insect research, and point to the need for island-based studies to identify overlooked dietary diversity. The text would be enriched by integrating the Wallacea framework to link the recorded taxa to island biogeography, environmental heterogeneity, local food systems, and conservation challenges.

Several limitations should be acknowledged. The initial field inventory was primarily descriptive and did not include quantitative assessments of abundance, biomass, population density, seasonality, or sustainable harvest potential. Second, the identification of several taxa was restricted to genus, family, or morphospecies level, reducing taxonomic resolution and potentially impacting edibility, safety and conservation significance. The survey has 51 real respondents, which give important exploratory insights, but limit generalisability to Ternate Islanders. Demographic factors, awareness, prior consumption, willingness, and perceived barriers were analyzed descriptively without inferential testing (Florença et al., 2021; Hopkins et al., 2022). The study did not involve laboratory-based nutritional profiling, microbiological testing, toxicological assessment, pesticide residue analysis, heavy metal analysis and allergy evaluation. The data should be viewed as a preliminary baseline, not as conclusive evidence for rapid food evolution.

Future studies should address these limits ecologically, nutritionally, and socioculturally in a holistic way. Taxonomic units must be verified through professional morphological analysis and DNA barcoding. Ecological studies should determine the abundance, biomass, seasonality, habitat specialization, and restrictions of priority taxa for sustainable harvesting (Titus et al., 2021). Nutritional analyses should include protein, amino acids, lipids, fatty acid profiles, minerals, vitamins, and potential antinutritional or hazardous compounds in priority species such as sago larvae, grasshoppers, crickets, and bee brood. Food safety studies should evaluate microbial contamination, pesticide residues, heavy metals, allergenicity, and the effects of processing techniques on safety and nutrition. Beyond descriptive surveys, consumer research should include sensory evaluation, willingness to pay, comparisons of product formats, intervention-based nutrition education, and demographic acceptance factors (Kokkorou et al., 2024; Salam, 2025).

5. CONCLUSION

The present study revealed that Ternate Island may contain edible coleopteran larvae, orthopteran larvae, hymenopteran brood, and lepidopteran larvae or pupae. But the transition from biodiversity inventory to food system innovation needs to be demonstrated. The ideal development plan should be based on species that are ecologically sustainable, culturally relevant, nutritionally valuable, and safe for consumers. The results indicate that sago larvae and grasshoppers/locusts are the most promising, while rare or safety-sensitive taxa need further research. Research, product development and innovation for food security in the Wallacean islands will be based on ecological inventory and community perception data.

Declarations

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Data Availability: All the data generated during the study are available within the article.

Ethics Statement: This study did not involve humans/animals in its experiments; therefore, ethics approval was not required.

Author's Contributions: Abdu Mas'ud: conceptualization, study design, field investigation, data interpretation, supervision, and manuscript preparation. Betty Kadir Lahati: Field investigation, ecological data collection, habitat observation, and manuscript review. Andy Kurniawan: Field exploration, taxonomic observation, ecological interpretation, and manuscript review. Sundari: Survey coordination, data compilation, descriptive analysis, and manuscript review. Aditya Sindu Sakti: Writing original draft, writing review and editing, scientific interpretation, manuscript structuring, and final manuscript refinement. All authors read and approved the final version of the manuscript.

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