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Morphometric Description of *Polistes tepidus* from Ternate Island and Obi Island (Wallacea, Indonesia)

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Abstract: This study aimed to descriptively compare the morphometric measurements of two *Polistes tepidus* specimens from Ternate Island and Obi Island preserved in the Museum Zoologicum Bogoriense. The research was conducted by measuring morphometric characters using a Leica Z6 APO microscope and L.A.S. 4.13 software. The observed characters included the head, thorax, wings, and metasoma, which were measured from three viewing angles: frontal, lateral, and dorsal. A total of 33 morphometric characters of the paper wasp were examined, and the mean measurements were analyzed using Microsoft Excel. The results showed that the morphometric measurements of *P. tepidus* from the two different locations, Ternate Island and Obi Island, exhibited size variation in several body characters. In general, *P. tepidus* individuals from Ternate Island had larger body sizes than those from Obi Island for most morphometric characters. Habitats with abundant food resources may allow individuals to develop larger body sizes. The morphometric differences between *P. tepidus* from Ternate and Obi Islands may also be explained by the effects of geographic isolation and the differing ecological conditions of the two islands. The islands of the Wallacea region are known for their high environmental heterogeneity, and insect populations therefore often exhibit morphological differences among regions. These findings highlight the need for broader sampling to further test geographic differentiation.
Keywords: Morphometrics; Ternate Island; Obi Island; *Polistes tepidus*, Wallacea

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INTRODUCTION

Paper wasps (Hymenoptera: Vespidae) are eusocial insects widely distributed in tropical and subtropical regions and play important ecological roles in both natural and human-modified habitats. They construct characteristic paper-like nests from chewed plant fibers mixed with saliva (Lyon & Wegner, 1991; Carpenter, 1996). Among them, *Polistes tepidus* is commonly reported from Southeast Asia, including the Wallacea region of Indonesia (Handru et al., 2020; Stabentheiner et al., 2022). As in other *Polistes* species, its ecological importance is linked to trophic interactions and habitat use. Paper wasps prey on various insects, especially caterpillars, and may therefore contribute to the natural suppression of herbivorous pests in agricultural systems (Beggs et al., 2011). Some species also visit flowers for nectar and may contribute to pollination (Borchardt et al., 2024). These roles highlight the relevance of paper wasps as beneficial insects in both ecological and applied contexts.

Polistes tepidus is characterized by a slender body, brown to reddish coloration, yellow abdominal markings, elongated legs, and narrow wings folded longitudinally at rest (Carpenter, 1996). It builds open-comb nests on tree branches, building walls, and other artificial substrates, indicating considerable ecological flexibility (Budiarsa et al., 2022). Its occurrence across forest margins, rural habitats, and urban environments suggests that this species can persist under contrasting environmental conditions

(Budiarsa et al., 2022). Such ecological breadth makes *P. tepidus* a relevant model for examining whether habitat and geographic context are associated with variation in body size and form.

Intraspecific morphological variation may arise from genetic divergence, phenotypic plasticity, environmental heterogeneity, and geographic isolation. These processes are especially relevant in insular systems, where marine barriers can restrict dispersal and gene flow, thereby promoting population differentiation (Mapel et al., 2021). This perspective is particularly important in Wallacea, a biogeographically complex transition zone characterized by fragmented island geography, high endemism, and distinctive faunal assemblages. Under island biogeography theory, island area, isolation, and habitat heterogeneity may influence population structure and morphological traits (Dudaniec et al., 2011). Consequently, populations of the same species occurring on different islands may exhibit measurable morphometric differences.

Morphometric analysis has long been recognized as an effective approach for assessing population-level variation in Vespidae and for identifying subtle differences that are not easily detected through qualitative observation. In paper wasps, such variation may reflect ecological conditions influencing development, survival, and colony performance. Environmental factors including temperature, vegetation composition, food availability, and anthropogenic disturbance have been associated with body size and morphometric variation in wasp populations (Nugroho et al., 2015; Nokelainen et al., 2022). Morphometric analysis therefore provides a useful framework for evaluating how environmental and geographic factors shape phenotypic variation within widely distributed species.

Despite this relevance, information on intraspecific morphometric variation in *P. tepidus* in Indonesia remains scarce. Previous studies have mainly addressed taxonomy, distribution, or general ecology, whereas comparative morphometric data from geographically separated island populations are still limited. In particular, it remains unclear whether *P. tepidus* populations from different islands in Wallacea show measurable morphological differences associated with insular separation and environmental variation. Addressing this gap is important not only for improving baseline knowledge of the species in eastern Indonesia, but also for supporting future taxonomic, ecological, and conservation research.

This study addresses that gap by comparing the morphometric characteristics of *P. tepidus* specimens from Ternate Island and Obi Island, North Maluku, based on museum collections deposited in the Museum Zoologicum Bogoriense. By focusing on specimens from two geographically separated islands within Wallacea, this study provides preliminary evidence of population-level morphological variation in *P. tepidus* in Indonesia. The findings are expected to contribute to biodiversity documentation and to provide a basis for further investigation of geographic differentiation, ecological adaptation, and possible taxonomic implications in *Polistes* wasps.

METHOD

Study Location and Period

This study was conducted at the Zoology Laboratory, Research Center for Biosystematics and Evolution, Life and Environmental Sciences Research Organization, BRIN (National Research and Innovation Agency), Cibinong Science Center, Bogor, West Java, Indonesia. The study was carried out from August to October 2025. Subsequent data processing was conducted at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, University of Jember.

Research Instruments and Materials

The instruments used in this study included a Leica WILD M3B stereo microscope, Leica Microsystems (Switzerland) Ltd or Leica DM5400, a Leica Z6 APO microscope camera, L.A.S version 4.13 software, a Dell laptop computer, insect storage boxes, and entomological forceps. The materials consisted of dry wasp specimens of *Polistes tepidus* originating from Ternate Island and Obi Island. All specimens were morphologically intact and suitable for morphometric measurement.

Wasp Morphometric Measurements

This study was a descriptive-comparative morphometric investigation based on specimens from the Museum Zoologicum Bogoriense collection. The approach was used to describe and compare the morphological dimensions of *P. tepidus*, although the analysis was necessarily limited by the small sample size.

Morphometric measurements were conducted directly on the external morphological characters of the specimens. Visual documentation was first obtained using a digital microscope, after which measurements were performed based on the resulting images. A total of six specimens were measured, and all measurement data were recorded directly (Table 1). Each sample was measured only once. This approach was applied to ensure that each dataset directly represented the original specimen. It also minimized data modification or aggregation, so that the raw data accurately reflected the original measurement conditions.

Table 1. Morphometric characters measured in each body segment

View orientation	Body segment measured	
Frons (frontal view)	Mandible length and width	
	Clypeus height and width	
	Eye height and width	
	Antennal socket diameter and width	
	Head length and width	
Lateral view	Head length and width	
	Thorax length and width	
	Midleg length	
	Hind leg length	
	Forewing and hindwing length and width	when wings were open and visible in lateral view
	Metasomal tergum 1–2 length and width	
Dorsal view	Head length and width	
	Thorax length and width	
	Forewing and hindwing length and width	when wings were open and visible in dorsal view
	Metasomal tergum 1–2 length and width	

Visual Documentation

Visual documentation was carried out under a Leica Microsystems (Switzerland) Ltd or Leica DM5400 microscope, using a Leica Z6 APO microscope camera and L.A.S version 4.13 software. Imaging was performed consistently from two principal angles, namely dorsal and lateral views. These images were used as visual complements and

as reference archives for morphological identification and classification, including the head, thorax, and abdomen. The resulting images also served as one of the benchmarks for validating the morphometric measurements.

RESULTS AND DISCUSSION

Morphometric Measurements of *Polistes tepidus*

Morphometric measurements of the paper wasp *P. tepidus* from two different locations, Ternate Island and Obi Island, revealed variation in several body characters. The observed characters included the head, thorax, wings, and metasoma, which were measured from three viewing angles: frontal, lateral, and dorsal. In general, *P. tepidus* individuals from Ternate Island exhibited larger body size than those from Obi Island for most morphometric characters (Figure 1).

Figure 1. Specimens of *Polistes tepidus* from Ternate Island (a, b, c, d, e) and Obi Island (a', b', c', d', e') in North Maluku (a. Head, frontal view; b. head and thorax, lateral view; c. thorax, wings, and abdomen, lateral view; d. dorsal view; e. wings and abdomen, dorsal view)

Table 2. Morphometric characters of *Polistes tepidus* from Ternate Island (n = 4) and Obi Island (n = 2) in the Maluku Archipelago

View Orientation	Body Segment	Measurement Value (mm)	
		Ternate	Obi Island
Frontal	Mandible length	2.137	1.593
	Mandible width	0.817	0.948
	Clypeus height	2.194	2.018
	Clypeus width	2.233	1.779
	Eye height	3.031	2.746
	Eye width	1.320	1.356
	Antennal socket width	0.525	0.461
	Antennal socket diameter	0.521	0.461
	Pedicel length	1.760	1.569
	Head length	3.967	3.624
	Head width	4.880	4.359
Lateral	Head length	4.208	3.971
	Head width	2.512	2.175
	Thorax length	8.636	7.064
	Thorax width	5.639	4.546
	Mid femur length	14.432	13.132
	Hind femur length	19.578	16.562
	Forewing length	17.346	15.132
	Forewing width	4.985	4.624
	Hindwing length	12.194	10.188
	Hindwing width	2.162	1.964
	Metasomal tergite 1 length	2.393	1.915
	Metasomal tergite 1 width	2.540	2.208
	Metasomal tergite 2 length	3.369	2.847
	Metasomal tergite 2 width	4.106	3.734
Dorsal	Head length	4.888	4.307
	Head width	1.932	1.813
	Thorax length	8.167	6.157
	Thorax width	5.080	4.105
	Metasomal tergite 1 length	2.888	1.356
	Metasomal tergite 1 width	3.464	2.652
	Metasomal tergite 2 length	3.881	3.180
	Metasomal tergite 2 width	4.755	3.777

Based on measurements taken from the frontal, lateral, and dorsal views, several characters showed substantial size differences between the two populations (Table 2). In the frontal view of the head, mandibular length in specimens from Ternate (2.137 mm) was greater than that in specimens from Obi (1.593 mm). A similar pattern was observed for clypeus height (2.194 mm in Ternate; 2.018 mm in Obi) and clypeus width (2.233 mm in Ternate; 1.779 mm in Obi). Eye size also varied, with eye height being greater in Ternate specimens (3.031 mm) than in Obi specimens (2.746 mm). However, eye width was relatively similar between the two populations, measuring 1.320 mm in Ternate and 1.356 mm in Obi. Antennal characters, such as antennal socket width and antennal socket diameter, showed the same values in both locations,

indicating that these traits were relatively stable and exhibited little variation between populations.

In the lateral view, size differences became more evident, particularly in the thorax and wings. Thorax length in wasps from Ternate reached 8.636 mm, which was greater than that of specimens from Obi (7.064 mm). Thorax width showed the same pattern, with values of 5.639 mm in Ternate and 4.546 mm in Obi. Leg measurements also varied, as the length of the midleg femur in Ternate specimens (14.432 mm) exceeded that in Obi specimens (13.132 mm). Likewise, the hind femur was longer in Ternate (19.578 mm) than in Obi (16.562 mm). Forewing characters also showed clear differences. The forewing length of individuals from Ternate (17.346 mm) was greater than that of individuals from Obi Island (15.132 mm), whereas forewing width was relatively similar in both populations. In the metasoma, the length of metasomal tergite 2 was greater in Ternate (3.369 mm) than in Obi (2.847 mm).

In the dorsal view, the head size of wasps from Ternate was also generally larger, as shown by head length, which reached 4.888 mm compared with 4.307 mm in Obi. Thorax length in Ternate (8.167 mm) was also greater than that in Obi (6.157 mm). In addition, metasomal tergite characters showed variation, with the length of metasomal tergite 2 being greater in Ternate (3.881 mm) than in Obi (3.180 mm). Overall, the dorsal-view characters further support the pattern that the Ternate population tends to have a larger body size.

The morphometric data indicate a consistent tendency for *Polistes tepidus* specimens from Ternate Island to be larger than those from Obi Island across multiple body regions, particularly the head, thorax, wings, and metasoma. This pattern is visible in measurements from the frontal, lateral, and dorsal views, suggesting that the observed difference is not restricted to a single trait but reflects a broader size-related trend. Because the largest differences were recorded in structures associated with feeding, locomotion, and flight, the results may indicate variation in overall body development rather than isolated character divergence. However, given the limited number of examined specimens, these findings should be interpreted as preliminary descriptive evidence rather than as conclusive proof of population-level differentiation.

Body size variation in paper wasps is biologically plausible because developmental traits in *Polistes* are known to be sensitive to nutritional conditions during the larval stage. Experimental studies on *Polistes metricus* showed that restricted larval nourishment resulted in smaller emerging females, whereas better-fed individuals displayed larger body dimensions and improved condition-related traits (Karsai & Hunt, 2002; Judd et al., 2015). In this context, the larger measurements observed in the Ternate specimens may reflect more favorable developmental conditions, including better larval nutrition or greater access to prey resources during colony growth. This interpretation should nevertheless be treated cautiously, because food availability was not measured directly in the present study.

Environmental conditions may also contribute to the observed morphometric differences. Comparative work on *Polistes* has shown that body size can vary geographically in association with latitude, elevation, and broad-scale climatic variation, although the direction and magnitude of these relationships may differ among species (Miller & Sheehan, 2021). In addition, studies on paper wasps have demonstrated that local climate and microclimatic conditions influence nest temperature regulation, brood development, and nesting behavior, all of which may indirectly affect adult morphology (Stabentheiner et al., 2022; Kovac et al., 2023). Therefore, even though Ternate and Obi are both located in a tropical region, differences in local habitat structure, vegetation, nesting substrates, prey availability,

or microclimate may have contributed to the size variation observed in the examined specimens.

The geographic separation of Ternate and Obi may provide an additional explanation for the pattern recorded here. In island systems, population isolation can reduce exchange among local populations and increase the opportunity for phenotypic divergence over time. For insects, such divergence may arise through a combination of environmental effects, developmental plasticity, and restricted gene flow rather than through any single mechanism alone. In vespid wasps more broadly, habitat conditions have been shown to shape species assemblages and abundance, indicating that these insects respond strongly to local ecological settings (Molski et al., 2020). Accordingly, the larger body dimensions of the Ternate specimens may represent a localized phenotypic response to island-specific ecological conditions, although this possibility remains to be tested with broader sampling and complementary genetic or environmental data.

The present findings are also relevant from a taxonomic and ecological perspective. In Vespidae, morphometric characters are useful for documenting intraspecific variation and can provide baseline information for recognizing geographically structured forms. For *P. tepidus* in Indonesia, such baseline data remain limited. The current study therefore contributes an initial comparison between two island populations and shows that measurable differences can be detected even from a small museum-based sample. Nevertheless, the biological meaning of these differences should not be overstated. Because the sample size was very small and no statistical test of population differentiation was performed, the results are best interpreted as evidence of observable morphometric variation rather than definitive separation between the Ternate and Obi populations.

Several limitations should be acknowledged. First, the small sample size restricts statistical inference and makes it difficult to distinguish consistent population patterns from individual-level variation. Second, the study did not measure ecological variables such as prey availability, habitat complexity, temperature, humidity, or vegetation structure, so the mechanisms underlying the observed size differences cannot be evaluated directly. Third, because the material was based on museum specimens, the study is highly valuable for baseline documentation but remains limited in its capacity to link morphology with current environmental conditions. Future research should therefore include larger sample sizes, multivariate morphometric analyses, environmental measurements, and, where possible, molecular data to test whether the size differences observed here are associated with geographic isolation, habitat-related developmental plasticity, or incipient population divergence.

CONCLUSION

The present study shows that *Polistes tepidus* specimens from Ternate generally possess larger morphometric dimensions than those from Obi Island, particularly in the head, thorax, wings, and metasoma. These observed differences suggest possible influences of local environmental conditions and habitat characteristics on body size variation between the two island populations. Nevertheless, because the sample size was limited, the results should be interpreted as preliminary and descriptive rather than as definitive evidence of population differentiation. Further research based on larger sample sizes and supported by statistical as well as ecological analyses is necessary to confirm the observed pattern and to clarify the factors underlying morphometric variation in this species.

RECOMMENDATION

Further studies are recommended to examine color variation in *Polistes tepidus* in order to complement the present morphometric findings.

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