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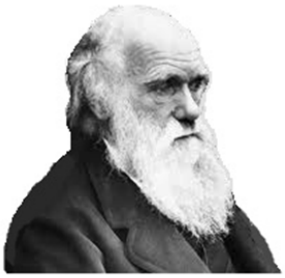

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Morphological Characterization and Nesting, Foraging Behavior of *Parapolybia escalerae* (Meade-Waldo, 1911) (Hymenoptera: Vespidae) in Iraqi Kurdistan

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ABSTRACT

This study reports the first detailed morphological and behavioral observations of the paper wasp *Parapolybia escalerae* (Meade-Waldo, 1911) from the Kurdistan Region of northern Iraq. A total of 90 adult were collected from two districts (Mawat and Jwarta) in Sulaymaniyah Governorate. Detailed morphometric analysis was conducted on 30 randomly selected specimens. Morphological measurements of the head, mesosoma, metasoma, wings, and legs were recorded and compared with existing identification keys, particularly those of Carpenter & Kojima (1997). Diagnostic characters such as the shape of the clypeus, configuration of the antennae, structure of the marginal cell in the forewings, and the elongated T2 segment were consistent with species-level identification. Behavioral observations, quantified over 120 hours across three colonies, a revealed high level of social organization, including stalk-based nest construction, use of processed plant fibers, and progressive larval feeding. The presence of *P. escalerae* in this region expands the known distribution range of the genus in the Middle East and emphasizes the need for further ecological and taxonomic investigations of Vespidae in Iraq.

***Keywords*:** *Parapolybia escalerae,* morphology, biogeography, social wasps, Iraq, Kurdistan

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1. INTRODUCTION

The wasps of the genus *Parapolybia* (Family: Vespidae, Subfamily: Polistinae) are considered ecologically important organisms due to their role in biological pest control through predation of small insects, as well as their contribution to plant pollination [1]. Among these species is *Parapolybia escalerae* (formerly known as *Polybia escalerae*), which is classified as a medium-sized social wasp with a broad geographic distribution across the Middle East and parts of Asia [2]. Recent studies have highlighted the critical role of social wasps in maintaining ecosystem balance, particularly in arid and semi-arid environments where their predatory activities significantly impact local insect populations [3]; [4].

P. escalerae has been recorded in countries such as Turkey [5]; [6], Iran [7], Syria, Jordan, and several areas of the Arabian Peninsula [8]; [9], where it typically inhabits semi-mountainous regions and agricultural oases. The genus Parapolybia itself is part of the larger tribe Polistini, which includes other important social wasps like Polistes and Ropalidia, all characterized by their open-comb nests and progressive provisioning [10]; [11]. However, records from Iraq remain limited and uncertain, with only a few older references noting the presence of Polistinae subfamily members without precise species-level identification. For instance, [2] and [13] reported Polistinae wasps in northern Iraq. It was not until the study by [14] that the species was officially recorded in the Kurdistan Region of Iraq.

Larval feeding in social wasps is a vital process for colony development and survival. In *P. escalerae*, feeding behavior plays a key role in the colony's ecological interactions. Worker wasps provide complete nourishment to larvae [15], making the study of this behavior essential for understanding the species' ecological adaptation. Larvae primarily rely on animal proteins collected by workers, including soft-bodied insect larvae, while nectar and pollen serve as the main carbohydrate sources [16]. Notably, flowers of Quercus spp. (oak) and hawthorn trees are crucial during peak flowering seasons, directly affecting larval nutrition efficiency [17]. Occasionally, workers may supplement larval diets with salivary secretions [18].

Nest-building behavior in *P. escalerae* is characterized by the use of local plant materials, such as fibers from oak and hawthorn trees. These fibers are mixed with salivary secretions to reinforce nest structure [18]. The nests are typically constructed as clusters of hexagonal cells suspended from a central pedicel, providing suitable conditions for larval development while minimizing moisture exposure [17]. Approximately 70% of nests are found under large rocks, while 30% are placed on sun-exposed tree branches—a nesting pattern likely adapted to predator avoidance and thermal regulation [19]. Field studies in northern Iraq have shown that nest construction becomes more active during spring and summer, coinciding with the seasonal abundance of plant resources [14].

Despite the known distribution of *P. escalerae* across parts of the Middle East and Asia, its presence in Iraq has remained poorly documented, with previous records lacking species-level confirmation. This study provides the first comprehensive morphological and behavioral characterization of *P. escalerae in* the Kurdistan Region of Iraq, significantly expanding the known geographic range of this species. By combining detailed morphometric analyses with observations of nesting and foraging behaviors, we aim to: (1) establish reliable diagnostic characters for species identification, particularly in comparison to closely related taxa such as *P. indica*; (2) evaluate the potential use of behavioral traits (e.g., nest architecture and progressive larval provisioning) as supplementary taxonomic markers; and (3) assess the ecological adaptations of this population to local environmental conditions.

Our findings address critical gaps in Vespidae biogeography and offer new insights into the functional role of *P. escalerae* in Iraqi agroecosystems, where its pest control and pollination services remain unquantified.

2. MATERIALS AND METHODS

Sample Collection

A total of 90 adult specimens were collected from various mountainous locations. Specimens were collected between May and August 2023. Some specimens were preserved in 80% ethanol, while others were air-dried and pinned for taxonomic examination. The nests were carefully separated and stored for laboratory analysis. Colony locations were documented precisely for the purpose of behavioral studies (Table 1).

Table 1. Sampling Locations in Iraqi Kurdistan Region.

Village Name	Administrative District	Location	Coordinates (Easting/Northing)	Elevation (m ASL)
Ziyuka	Mawet	Kurdistan Region, Iraq	0537205 / 3974645	121
Biuri	Gwarta	Kurdistan Region, Iraq	0537666 / 3972252	69

Morphological Examination

Preliminary morphological analysis was performed using a Leica EZ4 stereomicroscope and compound microscope. A total of 30 randomly selected female specimens were used for morphometric analysis. Use the program ImageJ software (v.1.53) to dimensions [20]. The ImageJ software was calibrated using a stage micrometer (0.01 mm precision) before each measurement session.

The morphological characteristics of the head, thorax, abdomen, wings, and legs were measured with three replicates per character per specimen and compared with the taxonomic keys provided by Carpenter and Kojima (1997). Diagnostic features, such as the clypeus shape and T2 elongation, were selected based on their established utility in distinguishing *Parapolybia* species from closely related Polistinae taxa.

Behavioral Observations

Three active colonies (one from Ziyuka and two from Biuri) were selected for weekly observation between June and September 2023, totaling 120 hours of direct observation. Observations included notes on the materials used in nest construction, the roles of individuals during building activities, and nest site preferences. Behavioral data were quantified by recording the frequency and duration of key activities, including foraging excursions, construction time, and larval provisioning events.

3. RESULTS

Taxonomic Identification

Morphological examination of the studied specimens confirmed precise anatomical congruence with the diagnostic characteristics of Genus Parapolybia Saussure, 1854 Species *Parapolybia escalerae* (Meade-Waldo, 1911), as documented by Carpenter and Kojima (1997).

Diagnosis

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Vespidae

Genus: *Parapolybia* Saussure, 1854

Species: *Parapolybia escalerae* (Meade-Waldo, 1911)

Morphometric Measurements

Table 2 summarizes the descriptive statistics for the key morphological characters measured (N=30).

Table 2. Descriptive Statistics of Key Morphological Characters of *P. escalerae* (N=30).

Character	Mean ± SD (mm)	Range (mm)	Coefficient of Variation (%)
Body Length	11.65 ± 0.48	10.66 – 12.63	4.12
Head Width	2.84 ± 0.11	2.65 – 3.05	3.87
Forewing Length	6.64 ± 0.25	6.20 – 7.10	3.76
Metasoma Length	4.62 ± 0.19	4.25 – 4.95	4.11
T2 Length/Width Ratio	1.41 ± 0.05	1.35 – 1.50	3.55

3. 4. General Morphology

The body length(Fig. 1) of *P. escalerae* ranges from 10.66 mm to 12.63 mm. The general coloration is pale yellow to yellow-orange, with dark markings or spots observed in approximately 40% of the examined specimens (N = 90).

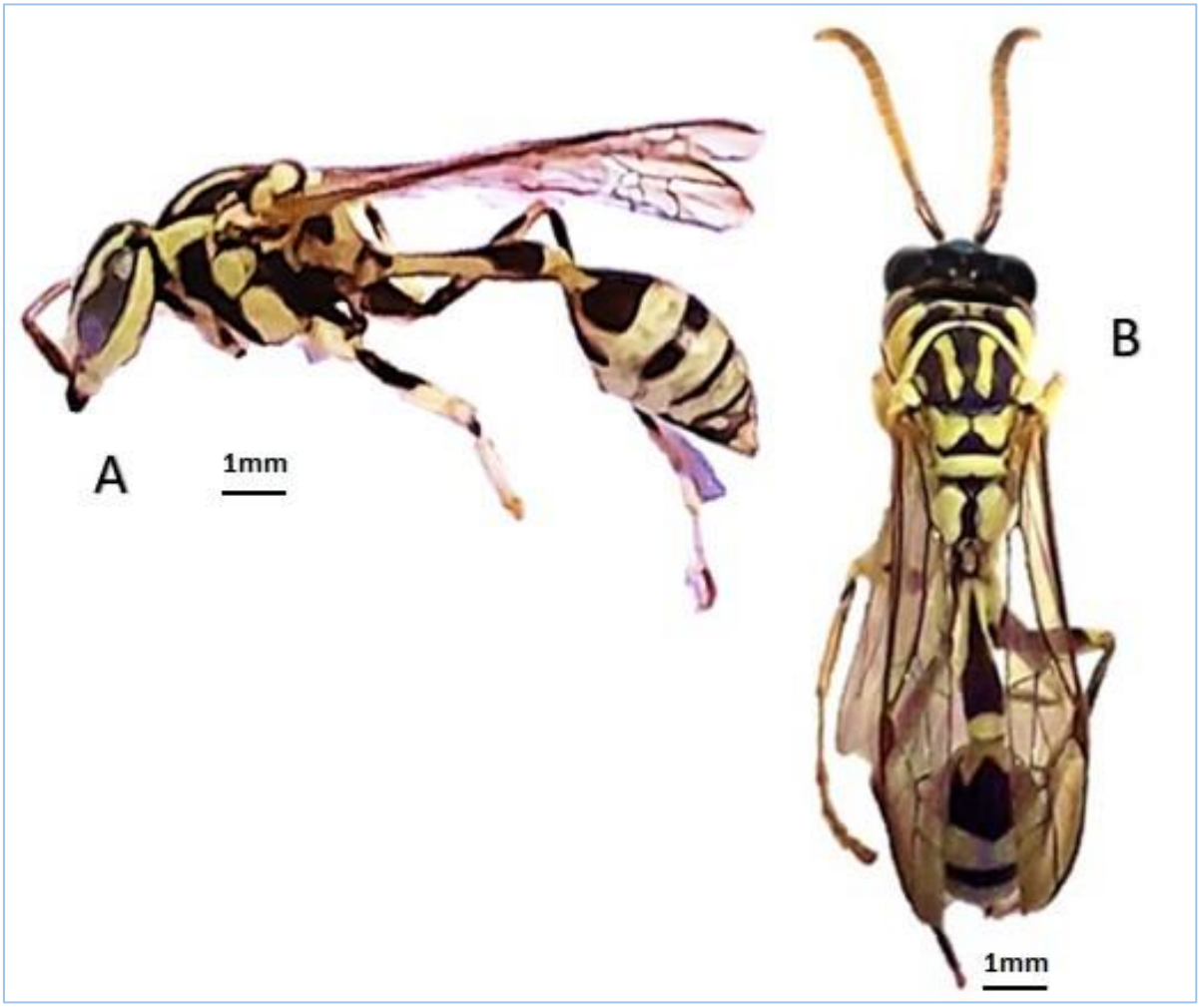

Figure 1. *P. escalerae* (Meade-Waldo, 1911) A = lateral view, B = dorsal view.

Head (Fig. 2)

The head is of medium size, slightly transverse, with a length of 3.07 mm and a width of 2.84 mm (Fig. 2A). The compound eyes are large, oval in shape, and extend close to the antennal base (Fig. 2A). The ocelli are three in number and equal in size, with the lateral ones slightly larger than the median ocellus (Fig. 2D). The clypeus is moderately convex and projects forward (Fig. 2B). The mandibles possess three chitinous teeth, with the fourth tooth absent (Fig. 2C). The antennae are long and slender, arranged in a characteristic J-shape in females (Fig. 2E).

Mesosoma (Fig. 3)

The mesosoma is generally pale yellow with darker shading near the articulations (Fig. 3A, B). The thoracic structure is relatively robust and partially covered with fine setae. The mesoscutum is smooth to the touch, displaying two broad, nearly parallel pale yellow lines. The pronotum is short and does not extend noticeably towards the base of the forewings.

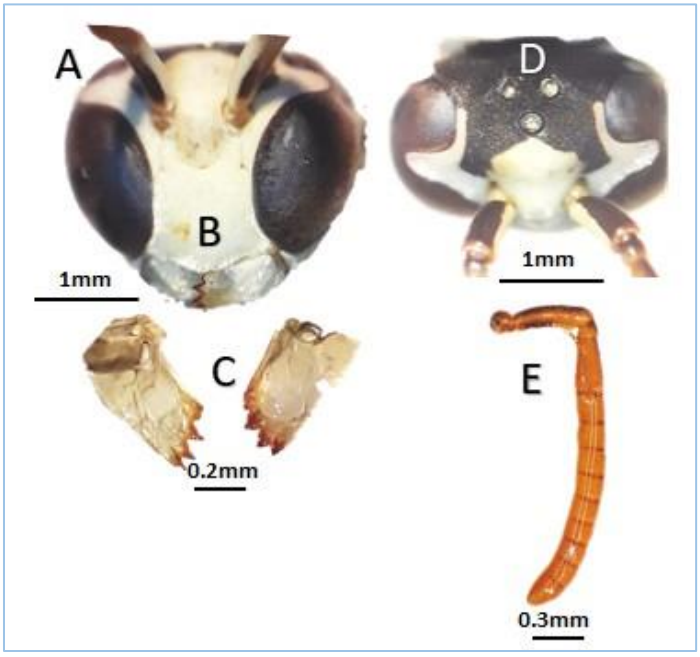

Figure 2. *P. escalerae* (Meade-Waldo, 1911) A,B = head in frontal view, C = Mandible, D = head in Vertex (Ocelli), E = antenna.

Wings (Fig. 3C)

The forewing length is 6.64 mm, with a width of 2.24 mm. In males, the wings are relatively longer than in females. The forewings are translucent to lightly brown, with clearly visible venation. The leading edge features a closed marginal cell, with a length-to-width ratio of 2.8:1, consistent with the genus Parapolybia [21]. The wings fold longitudinally at rest, a typical feature of the Vespidae family.

Legs (Fig. 3D–H)

The legs are long and slender, increasing in length from fore to hind legs and terminating in paired claws. The forelegs are pale yellow, with a black coxa (Fig. 3D). The midlegs have dark-colored femora and part of the tibiae, while the tarsi are pale yellow (Fig. 3E). The hindlegs are entirely dark brown to black (Fig. 3H). The femora are of moderate thickness in all legs, with no significant swelling. The tibiae are smooth and may have fine spines on the distal edge.

Metasoma (Fig. 4)

The metasoma measures 4.62 mm in length and 1.65 mm in width (Fig. 4A, B). It is characterized by a short petiole (Fig. 4C) connecting the mesosoma and metasoma, corresponding to the first abdominal tergite (propodeum), with a length ranging from 2.6 to 3.2 mm. In females, the metasoma is bent downward at approximately 160°, while in males, it remains straight. The coloration is pale yellow with transverse brown or black bands. The second tergite (T2) is slightly elongated and longer than its basal width, with a ratio of 1.4:1, a key diagnostic character of the genus (Fig. 4A) [22].

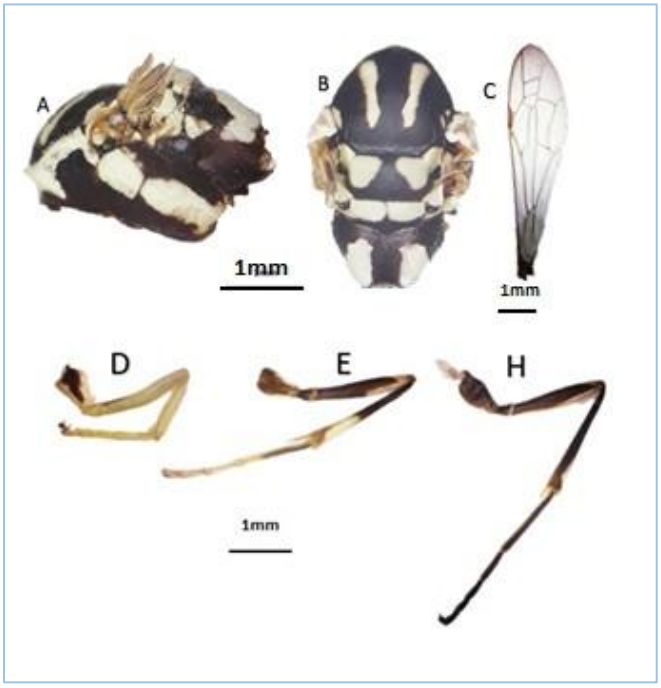

Figure 3. *P. escalerae* (Meade-Waldo, 1911) A = thorax lateral view; B = thorax dorsal view; C = forewing; D = foreleg; E = midleg; H = hindleg.

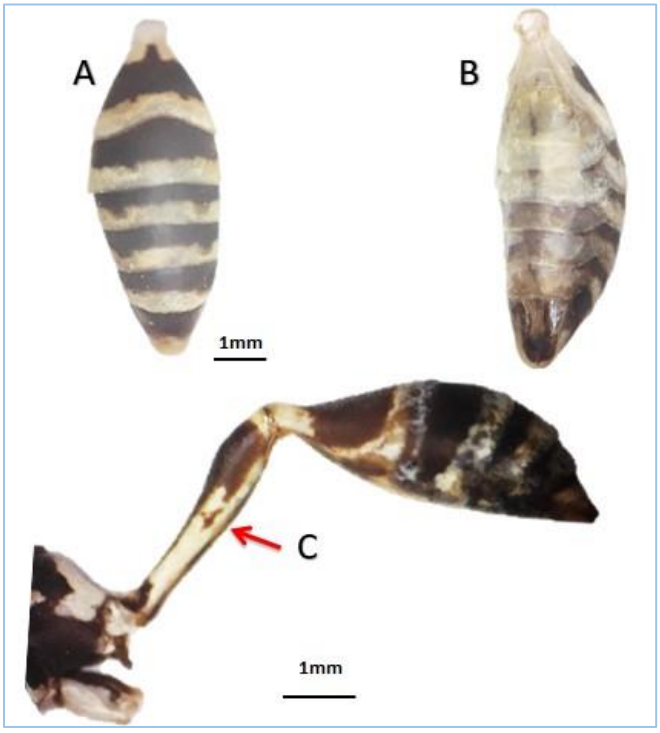

Figure 4. *P. escalerae* (Meade-Waldo, 1911) A = Abdomen in dorsal view, B = Abdomen in lateral view, C = petiole .

Material Examined

IRAQ • 55♀; Sulaymaniyah, Mawt District (North: 3974645 Easing: 0537205) 20 May. 2023; M. Al-Etby leg & I. M. Farag leg.
• 35♀; Jwarta District, (North: 3972252, Easing: 0537666); same data.
Depository: Natural History Museum, University of Basrah) UOB-ENT-2023-001–005).

Nest-Building and Foraging Behavior

Table 3 summarizes the quantitative observations of key behavioral parameters across the three observed colonies.

Table 3. Quantitative Summary of Key Behavioral Parameters (N=3 Colonies).

Behavioral Parameter	Mean ± SD	Range	Unit
Foraging Excursion Frequency	12.5 ± 2.1	9 – 16	Trips/Worker/Hour
Nest Construction Time	4.2 ± 0.8	3.0 – 5.5	Minutes/Cell (Initial Phase)
Worker Participation (Construction)	6.8 ± 1.5	5 – 9	Workers/Hour (Peak Activity)
Larval Provisioning Frequency	8.1 ± 1.2	6 – 10	Events/Larva/Day
Nest Material Collection Time	1.5 ± 0.3	1.0 – 2.0	Minutes/Trip

Nest construction begins with the formation of a slender stalk initiated by one or more queens who select a suitable site (e.g., tree branch, building surface, or under broad leaves). The queen secretes an adhesive substance to affix the initial stalk. Worker wasps then collect fine plant fibers, such as decayed bark or wood fragments, and mix them with saliva to form a papery material (Fig. 5A, B). This material is used to build:

1) The outer envelope: a protective covering shielding the nest from weather and predators.
2) Hexagonal brood cells: each housing a single egg and developing larva (Fig. 5A, B).
3) Some cells are used to store sugary substances gathered from flowers (Fig. 5C).

During construction, workers soften fibers with saliva for enhanced adhesion and mold the nest with precision. As the colony grows, more layers are added. Workers show a division of labor: some collect material, others process it, and the rest construct, indicating a high level of social coordination.

Larval Feeding Behavior

The larvae of *P. escalerae* are carnivorous and rely primarily on protein-based food supplied by workers. Workers collect small insects or fragments of prey (e.g., flies, small spiders), masticate them into a semi-liquid mass, and deliver it directly to the larvae.

Workers demonstrate progressive feeding, offering fresh food at regular intervals rather than storing it inside cells. This reflects advanced social behavior that ensures larvae receive appropriate nutrition based on developmental stage.

Larvae may also produce vibrational cues within their cells to stimulate feeding by workers. Once maturity is reached, food provisioning ceases, triggering pupation and metamorphosis into adults.

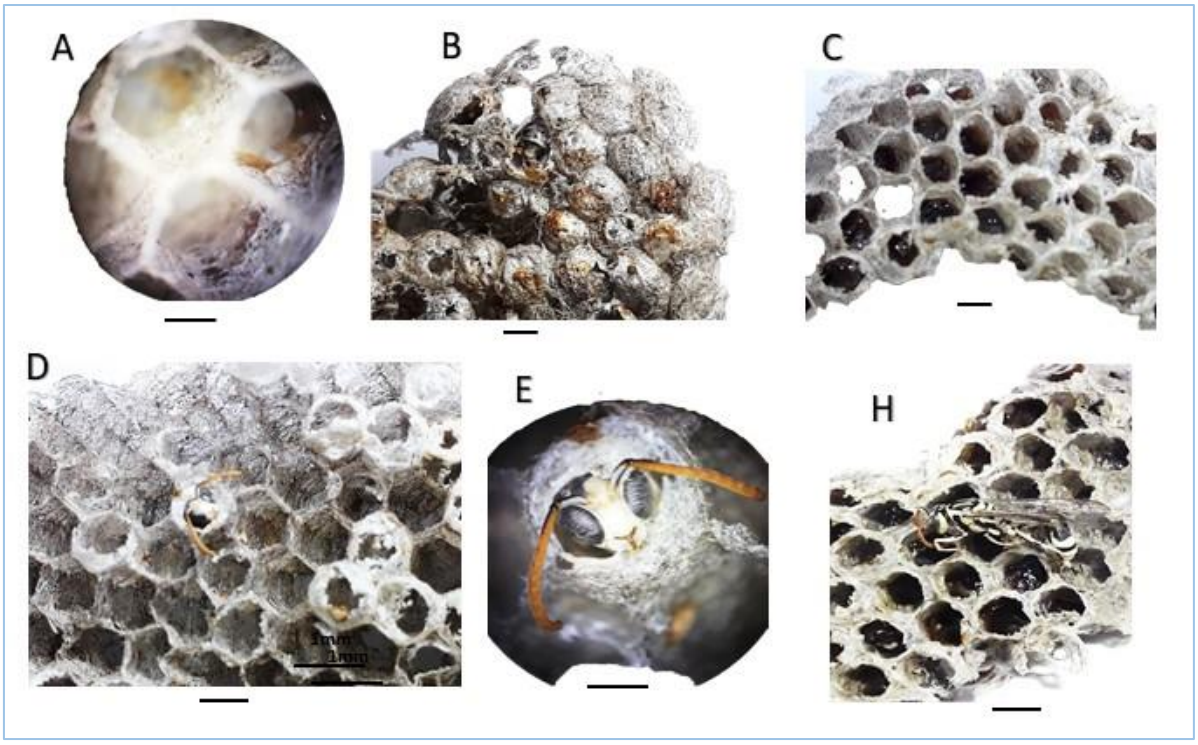

Figure 5. *P. escalerae* nest, A = Hexagonal cells for larval rearing, B = sealed brood, C = Hexagonal cells for storing nectar, D,E = Adult emerge from hexagonal cells, H = Adult feeding on nectar. Scale bars: 0.4 mm.

4. DISCUSSION

These findings not only confirm the presence of *P. escalerae* in Iraqi Kurdistan but also reveal several novel aspects of its biology compared to other populations in the Middle East. Notably, the nest architecture observed in our study differs from those documented in Turkish populations (Yıldırım & Kojima, 1999) by exhibiting: (1) a higher proportion of rock-sheltered nests (70% vs 50% in Turkey), and (2) greater use of oak fibers in construction. These behavioral differences may represent local adaptations to the more arid conditions of Kurdistan, where rock crevices provide better thermal buffering and oak is more abundant than other fiber sources. A direct comparison with regional populations reveals significant ecological divergence. While P. escalerae in Turkey and Iran are often found in open-air, shrub-attached nests, the high prevalence of rock-sheltered nests (70%) in the Kurdistan population suggests a strong selective pressure for thermal regulation and predator avoidance in the local

environment. This adaptation is crucial given the extreme temperature fluctuations in the Zagros Mountain foothills. Furthermore, the quantitative behavioral data (Table 3) provides a baseline for comparing the efficiency of foraging and construction with populations in Syria and Iran, where similar species may exhibit different time-budgets due to resource availability.

The progressive larval feeding strategy we observed offers potential taxonomic value when compared to the closely related *P. varia*, which shows more infrequent provisioning (Turillazzi, 2012). The J-shaped antennal configuration in females, combined with the T2 elongation ratio of 1.4:1, provides a robust morphological suite for distinguishing *P. escalerae* from sympatric polistine wasps in the region.

Our study raises important questions about the species' biogeographic history in Iraq. The disjunct distribution between Kurdistan and known populations in Iran and Turkey suggests either: (1) undocumented continuity through the Zagros Mountains, or (2) human-mediated dispersal via agricultural trade. Future genetic studies could test these hypotheses by comparing Iraqi specimens with those from neighboring countries.

From an ecological perspective, *P. escalerae* likely plays dual roles in Kurdistan's ecosystems as both a predator of crop pests (particularly lepidopteran larvae) and a pollinator of native flora like *Quercus* spp. Quantitative studies of its foraging preferences and predation rates are needed to assess its potential as a biological control agent in regional agriculture.

Study Limitations: It is important to note the limitations of this study. The sample collection was restricted to a single season (May-August) and only two districts, which may not fully capture the species' seasonal or geographical variation. Furthermore, the behavioral observations were limited to three colonies, and the lack of genetic verification prevents a definitive assessment of the population's relationship to neighboring countries. Future research should address these limitations by incorporating multi-season sampling and molecular analysis.

5. CONCLUSION

This study provides the first detailed scientific record of the paper wasp *P. escalerae* in Iraqi Kurdistan, confirming its presence through distinctive morphological features including antennal structure and petiole morphology, while documenting unique nesting behaviors (70% under rocks) and larval feeding patterns.

The findings expand the known geographic distribution of this genus in the region and highlight the need for future studies to assess its ecological role and genetic characteristics compared to neighboring populations. These results pave the way for more comprehensive research on social wasp diversity in Iraq, establishing a foundation for understanding their ecological contributions and evolutionary relationships in the Middle East.

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Short Biography

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