Spatial distribution of *Vespa affinis* based on land use and population density in Bojonegoro District, East Java Province, Indonesia

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Abstract. *Rahmawati LA, Hidayati D, Saptarini D, Rendra MI, Al Zakina BL. 2023. Spatial distribution of* Vespa affinis *based on land use and population density in Bojonegoro District, East Java Province, Indonesia. Biodiversitas 24: 861-868.* Cases of *Vespa affinis* (Lesser banded hornet) attacks significantly increased last three years in several regions in Indonesia, including Bojonegoro District, East Java Province. Based on the Evacuation Report data from the Fire Department of Bojonegoro District, the number of Nest Evacuations increased nine times from 2019 to 2021. Even the *Vespa* Wasp attack caused one person to die. This study's purpose is to analyze the distribution and habitat characteristics of *Vespa* Wasps in Bojonegoro based on land use and population density. The method used a survey of *Vespa* wasp evacuation points to see the distribution in each area, the results were covered on the land use map and population density map in Bojonegoro in 2021. The results showed that the distribution of *V. affinis* wasps based on land use has an 83% tendency to be in residential areas, while based on population density, it shows that 87% of the nests are in areas with high population density. The tendency of the wasps to inhabit residential areas with high population density is likely to be an adaptive form of wasp in response to forest destruction as its natural habitat, so they seek more abundant food sources and safer nesting locations in new places.

Keywords: Settlement, *Vespa* wasp, *Vespa* nest, wasp distribution pattern

INTRODUCTION

Vespa affinis is a type of wasp with a dangerous sting capable of causing acute kidney injury (Kularatne et al. 2014; Ullah et al. 2016; Schmidt 2018; Ambarsari et al. 2019), pulmonary edema (Kularatne et al. 2014) and even death (Rungsa et al. 2016; Gunasekara et al. 2019), as occurs in several regions in Indonesia, including in Bojonegoro District (Nugroho 2019). The aggressive nature of *V. affinis* should be watched out for, especially if it attacks its colonies in large numbers. *Vespa affinis*, as a social insect, will release pheromones to attract its colonies when threatened as a self-defense mechanism (Claudia et al. 2010; Nugroho 2019).

The wasp species *V. affinis* is a common insect found in the tropics and subtropics (Diaz 2016; Sultana and Akter al. 2022; Yudha et al. 2022). The natural habitat of Wasp *V. affinis* is generally in lowland forests (Diaz 2016; Yudha et al. 2022) and also in rice fields (Martin 1992), including in Indonesia. However, recently there have been many research results that say that the wasp nests of *V. affinis* have begun to shift to residential areas, especially urban areas with a high density of settlement (Ruiz-Cristi et al. 2020; Choi et al. 2012a). Whereas usually, *Vespa* type wasps have a tendency to live in rural areas with low density of settlements to reduce the risk of conflict with humans (Choi et al. 2012a, 2012b). Given that the sting of this wasp is very dangerous, then its presence in densely populated residential areas is very necessary to be aware of.

This study took the case of a *V. affinis* wasp attack that occurred in Bojonegoro District, East Java Province, Indonesia, which caused one critical person and one person to die. The handling of *V. affinis* wasps in this region is within the authority of the Fire Department of Bojonegoro District. Based on the data we collected from the agency, it was reported that there was a significant increase in the number of evacuations of *V. affinis* Wasps in the last 3 years, namely 2019-2022. In 2019, the number of cases reported by the community amounted to 47 cases, then increased in 2020 to 177 cases, and increased again in 2021 to 450 cases (Fire Department of Bojonegoro District 2021, unpublished data).

The significant increase in the number of community reports for the evacuation of *V. affinis* wasps to the Fire Department of Bojonegoro District of East Java Province, Indonesia, is an interesting phenomenon to study, especially since it has resulted in casualties. Therefore, the study aims to analyze the spatial distribution patterns of *V. affinis* wasps in Bojonegoro in the past two years based on land use patterns and population density. The previous study, using a remote sensing approach, said that there had been a change in land use from green open space to other land use covering an area of 12,679.7 Ha in 2015-2018 (Dianovita and Sukentyas 2018), or about 5% of the total

area of Bojonegoro. The areas that experienced the most decline in the area of green open space were mainly in the northeastern, central, and southern parts, which were originally forest areas (Dianovita and Sukentyas 2018). This condition is likely to affect the distribution of *V. affinis* wasps in Bojonegoro, considering that the forest is the original habitat of wasps that have been damaged, so the possibility of wasps moving to other locations is very large (Yudha et al. 2022). In addition, researchers also made population density one of the basis for looking at the pattern of distribution of *V. affinis* wasps, considering that in similar cases that occurred in South Korea, it was found that the distribution of wasps for the *V. velutina* type has a tendency to spread to urban areas, especially in residential areas with a high population density (Choi et al. 2012b).

MATERIALS AND METHODS

Study area

This research was conducted in Bojonegoro District, East Java Province, Indonesia. Based on data from the Fire Department of Bojonegoro District, East Java Province, Indonesia, the evacuation of *Vespa* wasps in the last 2 years has increased from 177 in 2020 to 450 in 2021, with a total number of 627 *Vespa* wasp evacuation points. This is the basis for this study to survey the location of the distribution of *V. affinis* wasps as preliminary data in looking at the spatial distribution of the territory. The data used by the initial survey of the location point of the *V. affinis* wasp based on residents' reports to the Fire Department includes name, address and type of report. The data is spread across 28 areas in Bojonegoro. The number of cases of *V. affinis* wasps in each sub-district in Bojonegoro District can be seen in Figure 1. The limitations of this study only show an overview of the distribution of *V. affinis* based on community reports to the Fire Department, while the possibility of other nests in locations that are not reported by the community is not included in this research study

Procedures

The data used as a reference for the beginning of this study is the Evacuation Report *V. affinis* wasps in Bojonegoro by the Fire Department of Bojonegoro District for the period 2020-2021. The data is in the form of a list of the incident report based on the name and address that has been evacuated. Furthermore, survey and distribution mapping *V. affinis* wasps by plotting the coordinates of the evacuation location tawon *V. affinis* based on the address obtained using Handheld GPS. The points to be mapped totaled 177 points for 2020 and 450 points for 2021, bringing the total to 627 points. The coordinate points that have been collected will be mapped in each sub-district (28 sub-districts) as distribution points for the Habitat of the *Vespa* Wasp. Furthermore, the distribution point has been overlayed with the Land Use Map of Bojonegoro District, East Java Province, Indonesia, sourced from the Technical Document of the 2021 Bojonegoro District Spatial and Regional Planning Plan, and also covered with a population density map based on population data from the Population and Civil Registry Office of Bojonegoro District in each sub-district in 2021, so that 2 maps were generated, namely: *V. affinis* wasp distribution map based on land use and *V. affinis* wasps distribution map based on population density. Furthermore, the distribution pattern of the *V. affinis* wasps was analyzed descriptively based on the results of the two maps.
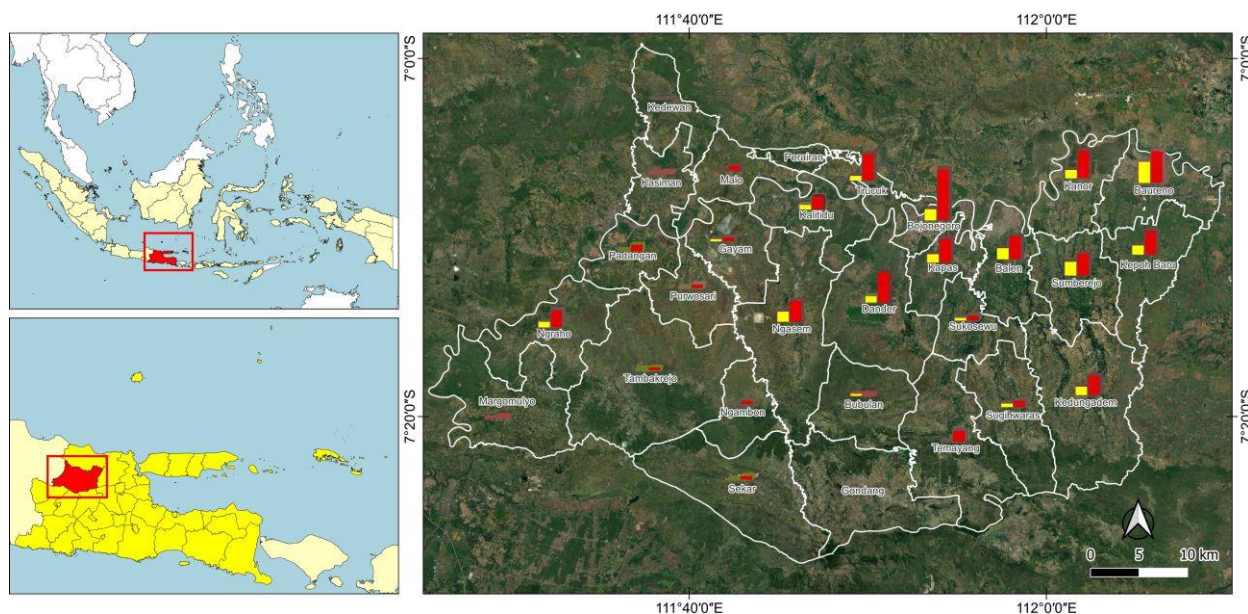

Figure 1. Map of the number of evacuations of *Vespa affinis* wasp cases handled by the Fire Department of Bojonegoro District, East Java Province, Indonesia, 2020-2021

Data analysis

The analysis used in this study was spatial analysis using data from plotting the location of the discovery of the *V. affinis* wasp nest, which was then overlayed to a land use map sourced from the Technical Document of the Spatial and Regional Plan of Bojonegoro District, in 2021 and a population density map. The population density map is made using those sourced from the Population and Civil Registry Office of Bojonegoro in each sub-district in 2021.

Based on the Land Use Map in the Technical Document of the Spatial and Regional Plan of Bojonegoro in 2021, the land in Bojonegoro is mostly in the form of forests, rice fields, and settlements. The area of each type of land use in Bojonegoro is stated in Table 1. The density of settlements is assumed to be proportional to the density of households living in a sub-district. Household Density uses data on the population of each sub-district in 2021. Household density is calculated based on a comparison of the total number of households in a sub-district area compared to the area of the sub-district. The results obtained were categorized into 3 groups as per Table 2. After obtaining the distribution map of *V. affinis* wasps based on Land Use and the Distribution Map of *V. affinis* wasps based on settlement density, a descriptive analysis will be carried out by referring to the results with previous studies.

RESULTS AND DISCUSSION

Based on the results of a field survey for mapping the distribution of *V. affinis* wasps, from the total initial data of 627 points, only 615 points were found. A total of 12 points were not found on the grounds survey because, 1) the address and name did not match the evacuation data reported to the Fire Department of Bojonegoro District; 2) locations reported to have undergone changes from their original conditions; 3) information reported to the Fire Department are incomplete. The survey results obtained are in the form of coordinate points displayed in the form of a distribution map of *V. affinis* wasps in Bojonegoro, as shown in Figure 2. It can be seen that the distribution of *V. affinis* wasps in Bojonegoro is mostly in the northern part, especially in the city center of Bojonegoro. The next largest distribution towards the east includes the Sub-districts of Kapas, Balen, Sumberrejo, Kanor and Baureno. Meanwhile, in southern and western Bojonegoro, there are not many cases of *V. affinis* wasps reported, so the distribution of wasps at these locations is seen very rarely.

Distribution of *Vespa affinis* wasps by land use

Land use is one of the indicators to see the characteristics of the distribution of the territory of the *V. affinis* wasps. The results showed that the distribution of *V. affinis* wasps was highest in the type of land use of settlements, which amounted to 510 points. In addition, *V. affinis* wasps are also distributed in rice fields totaling 83 points, plantations totaling 18 points, forests totaling 3 points, and shrubs totaling 1 point. The distribution pattern of *V. affinis* wasps based on land use can be seen in Figure 3, and the number of *V. affinis* wasps distributed in each land use is in Table 3.
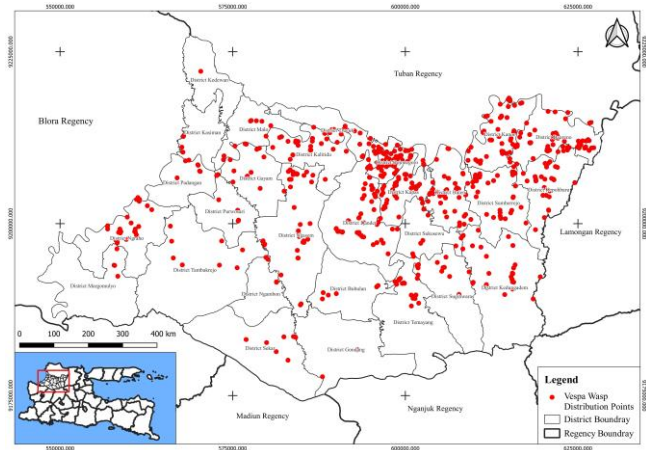

Figure 2. Distribution of *Vespa affinis* wasps in Bojonegoro District, East Java Province, Indonesia, 2020-2021
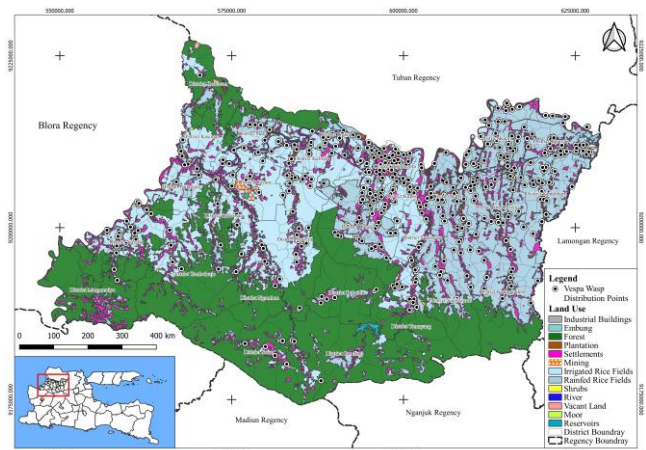

Figure 3. Distribution of *Vespa affinis* wasps based on land use in Bojonegoro District, East Java Province, Indonesia, 2021

Table 1. Types and areas of land use in Bojonegoro District in 2021

Land use	Area (Ha)
Industrial Buildings	1.444
Water Reservoir	2.505
Forest	871.709
Plantation	21.410
Settlements	274.228
Mining	4.753
Irrigated Rice Fields	554.999
Rainfed Rice Fields	547.676
Shrubs	3.704
River	21.243
Vacant Land	3.143
Moor	0.144
Reservoirs	3.588
Total	2310.546

Source: Bojonegoro District Spatial and Regional Planning Technical Plan Technical Document, East Java Province, Indonesia in 2021

Table 2. Population density categories

Category	Description
Low	If the population density in the subdistrict area is lower compared to the density in the distric area
Medium	If the population density in the subdistrict area is equal to density on the territory of the district
High	If the population density in the subdistrict area is higher compared to the density in the county area

When viewed from the percentage of evacuation points of *V. affinis* wasps based on land use, the value is highest on residential land use with a percentage of 83%. Then the next biggest percentage is the use of total paddy fields of 14%, with details of irrigated rice fields as much as 7% and rainfed rice fields as much as 7%. Then for the use of plantation land, it only has a percentage of 3%, and the lowest is the distribution on forest and shrub land use. The percentage of evacuation points of *Vespa* wasps in each type of land use can be seen in Figure 4.

Distribution of *Vespa affinis* wasps by population density

The distribution of *V. affinis* wasps based on population density is obtained by dividing the total number of residents in each sub-district by the area of each sub-district. The results then been categorized based on the criteria listed in Table 3. The density value in each sub-district is spatially mapped to see the distribution of *V. affinis* wasps in each sub-district which is distinguished into 3 categories, namely: sub-districts with high, medium, or low population density categories. However, based on the results of categorizing population density in each sub-district in Bojonegoro, it is only included in 2 categories, namely high and low. This is due to the absence of a population density value in the same sub-district as the population density value in the total area of Bojonegoro.

The results showed that 16 of the 28 sub-districts in Bojonegoro had high population density criteria, and the other 12 sub-districts were categorized in the low criteria. As for the distribution of *V. affinis* wasps is mostly directly proportional to the territory of high population density. In other words, areas with high population density tend to be found in many nests of *V. affinis* wasps. The categorization of population density in each sub-district in Bojonegoro is stated in Table 4.

If followed up from the results of the overlay of the evacuation point of the *V. affinis* wasp against the population density (Figure 5), it shows that the evacuation points are at most 541 points with high-density criteria. As for the criteria for low population density, it is only 74 evacuation points. For evacuation points with high population density criteria with a percentage of 87%, then for low population density criteria, it only has a percentage of 12%. The results of the overlay of the evacuation point of the *Vespa* wasp against the population density can be seen densely table 5.

Discussion

There are several important facts from the results of the study that should be discussed further. The first important fact is that 510 nest points of *V. affinis* wasps found during the survey were in settlements or about 83% of the total points surveyed. This indicates the tendency of *V. affinis* wasps to stay, make nests, and form their colonies in residential areas. This is in accordance with the results of previous studies (Choi et al. 2012b; Ruiz-Cristi et al. 2020), which said that the distribution pattern of *Vespa* type wasps today has a tendency to spread towards settlements, especially in urban. This is inversely proportional to the distribution of *V. affinis* wasps in the type of land use in the form of forests, which is only 3 points. In fact, the forest is the natural habitat of the *V. affinis* wasps, especially in lowland areas (Yudha et al. 2022). Besides to settlements and forests, the wasp nests of *V. affinis* are also quite widely distributed in the type of rice field use, which amounts to 83 points, and plantations, which amounts to 18 points. The interesting finding is that the use of land in the form of rice fields and gardens, which are the distribution sites of the *V. affinis* wasps in this study, are all close to residential areas. Based on these data, it can be said that the distribution of *V. affinis* wasps in Bojonegoro has a tendency of almost 99% to be in residential areas. This fact is related to data community reports from the Fire Department regarding requests for the evacuation of wasp nests around their residential locations. They frequently report the *V. affinis* nests near their home to the Fire Department for evacuation because the existence of wasp nests in communities is thought to pose a threat to the safety of the populace.

Table 3. Distribution of *Vespa affinis* excavated nests on each type of land use

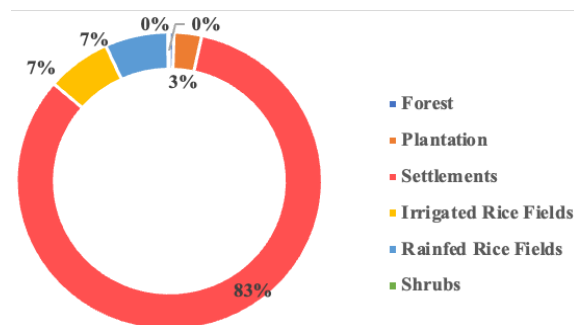| Land use	Area (Ha)
Forest	3
Plantation	18
Settlements	510
Irrigated Rice Fields	42
Rainfed Rice Fields	41
Shrubs	1
Total	**615**

Figure 4. Percentage of distribution of *Vespa affinis* wasps observation location based on land use in Bojonegoro District, East Java Province, Indonesia, in 2021

Table 4. Distribution of *Vespa affinis* wasps based on the population density of each sub-district in Bojonegoro District, Indonesia in 2021

| Sub-district	Number of survey result points	Population	Area (km²)	Population density (population/km²)	Population density criteria
Bojonegoro	60	97,764	25.71	3802.57	High
Dander	50	92,092	118.36	778.07	High
Baureno	45	87,700	66.37	1321.38	High
Kanor	45	65,943	59.78	1103.09	High
Sumberejo	43	77,944	76.58	1017.81	High
Kapas	42	56,326	46.38	1214.45	High
Balen	36	70,678	60.52	1167.85	High
Ngasem	36	68,284	147.21	463.85	Low
Kepohbaru	35	72,691	79.64	912.74	High
Trucuk	30	44,505	36.71	1212.34	High
Kedungadem	26	91,341	145.15	629.29	High
Ngraho	25	51,512	71.48	720.65	High
Kalitidu	24	55,470	65.95	841.09	High
Temayang	15	40,654	124.67	326.09	Low
Sugihwaras	13	51,453	87.15	590.40	Low
Gayam	12	35,863	50.05	716.54	High
Sukosewu	9	47,165	47.48	993.37	High
Malo	9	35,604	65.41	544.32	Low
Tambakrejo	8	60,755	209.52	289.97	Low
Sekar	7	30,179	130.24	231.72	Low
Padangan	6	50,363	42	1199.12	High
Purwosari	6	33,484	62.32	537.29	Low
Bubulan	6	16,766	84.73	197.88	Low
Kasiman	5	34,855	51.8	672.88	High
Ngambon	4	13,219	48.65	271.72	Low
Margomulyo	4	25,539	139.68	182.84	Low
Gondang	2	28,075	107.01	262.36	Low
Kedewan	1	14,665	56.51	259.51	Low
Total	615	1,450,889	2307.06		
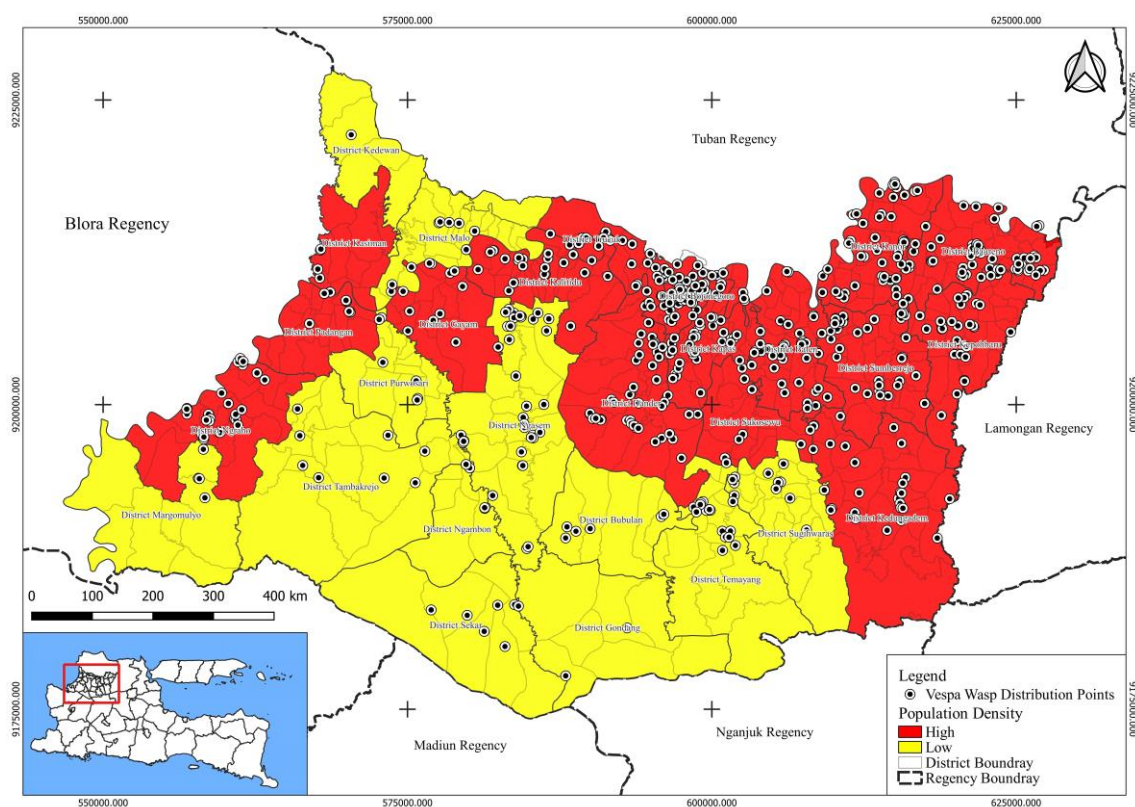
Figure 5. Distribution of *Vespa affinis* wasps based on population density in Bojonegoro District, East Java Province, Indonesia, 2021

Table 5. Distribution of *Vespa affinis* wasps based on settlement density

Density criteria	Number of wasp overlay points *Vespa affinis* inhabitant
High	541
Low	74
Total	615

The next important fact is that most of the nest points of the *V. affinis* wasps were found in regions with high-density criteria, which amount 541 points, or about 87% of the total points surveyed. The distribution pattern of *V. affinis* wasp nests shows that the downtown area of Bojonegoro, with the highest population density, which is 3802.57 inhabitants/km^2, is also the location where the most *V. affinis* wasp nests are found, which is 60 nests. Furthermore, the high distribution of *V. affinis* wasps is also found in several districts with high population density, such as Dander, Baureno, Kanor, Sumberrejo, Kapas, Balen, Kepohbaru, Trucuk, Kedungadem, Ngraho and Kalitidu. In the 11 sub-districts, the number of *V. affinis* wasp nest points found is quite large, namely between 50-24 nests, or in other words, 75% of districts with high population density are also the districts with the highest number of wasp distributions. This suggests that there is a tendency for wasps of *V. affinis* to prefer to build nests in residential areas with high population density. The results are in accordance with the research of Choi et al. (2012) and Ruiz-Cristi et al. (2020), who said that there was a shift in the distribution of *V. affinis* wasps to residential areas, especially urban areas with high-density characteristics (Choi et al. 2012; Ruiz-Cristi et al. 2020) as happened in South Korea. Urban areas as insect habitats have local habitat factors as an attraction for the ecological community, especially in relation to sun exposure and leaf litter.

However, there is also one sub-district with a low population density, but the number of *V. affinis* wasp nests found in the region is quite large, namely Ngasem Sub-district, with as many as 36 nests. This is an anomaly when referring to the research of Choi et al. (2012) and Ruiz-Cristi et al. (2020). However, if considering that the natural habitat of the *V. affinis* wasp is forest, then this condition can occur because in part of the Ngasem area is still a forest (Figure 3). In addition, when viewed from the number of residents, Ngasem has a relatively large population compared to other districts, it's just that the area of Ngasem is the third highest in Bojonegoro District, with part of the area in the form of forests. In Figure 2, it appears that the residential area in Ngasem is on the north side with a tight conditions, while in the south, it is dominated by forests.

Furthermore, there are also sub-districts with a high population density, but the number of *V. affinis* wasp nests found in the region is very rare, such as Gayam, Sukosewu, Padangan and Kasiman Sub-districts, of which only 5-12 wasp nest points *of V. affinis* wasps are found. Interestingly, Padangan Sub-district is categorized as the fifth highest population density in Bojonegoro District, but in that area, there are not many locations where *V. affinis* wasp nests are found. Further studies are needed to answer this phenomenon.

The tendency of *V. affinis* wasps to occupy densely populated residential areas rather than their natural habitat in the forest can be caused by several things, some of the possible causes of migration of *V. affinis* wasps include the fragmentation of forests as natural habitats (Torok et al. 2022), efforts to find food sources and nest behavioral adaptation. This is supported by the results of previous research, which states that certain types of wasps have a preference for building nests on certain land covers, such as the invasive Asian paper wasp in New Zealand, which prefers to build nests in herbaceous saline vegetation, built-up land, and shrubs (Ward and Morgan 2014). *Vespa affinis* is one type of wasp that is very adaptive to environmental changes and also a way of predation (Lu et al. 2021). Some wasp populations are as adapted to summer as Taiwan and show changes in prey capture strategies, from group hunting to sitting and waiting. This wasp even shows adaptation by changing the type of prey (Lu et al. 2021).

The fragmentation of forests as natural habitats occurs in almost all parts of Indonesia. According to a report by Global Forest Watch, the destruction of primary forests in Indonesia from 2001-2021 reached 9.95 MHa, while the vegetation cover lost in that period reached 28.6 MHa, partly caused by deforestation (Global Forest Watch 2022). The same condition also occurs in Bojonegoro, in the period 2015-2018, there has been a change in land use from green open space to open land, reaching 12,679.7 Ha (Dianovita and Sukentyas 2018), or about 5% of the total area of Bojonegoro. The areas that experienced the most decline in the area of green open space were mainly in the northeastern, central, and southern parts, which were originally forest areas (Dianovita and Sukentyas 2018). The fragmentation of the forest often affects the decrease in the biodiversity of insects that live in forest areas (Torok et al. 2022).

In addition to forest destruction, the migration of *V. affinis* wasps from forests to settlements may also be caused as an attempt to find new sources of food. *Vespa affinis* food types are generally in the form of nectar (Dorji et al. 2017), pollen and also pollinating insects (Keeling et al. 2017), such as *Trigona* spp (Erniwati and Kahono 2012; Kahono et al. 2012; Yin 2020), or in other words, these insects are omnivorous. The loss of the forest as a habitat as well as a place to forage for wasps *V. affinis* made them move to residential areas. Another source states that wasps tend to prefer to forage for food in various types of hedged plants (Akter et al. 2020), that are generally found in residential areas. The presence of flowers in gardens or hedges plants in residential areas is an attraction for *V. affinis* as a new land for finding food. When referring to cases of the spread of invasive wasps in other countries, for example, *V. velutina*, which spreads in Asia and Europe, is considered to threaten the existence of honeybees deliberately cultivated by humans (Choi et al. 2012; Cappa et al. 2021). The *V. velutina* wasps posed the greatest threat

to the survival of European honeybees and commercial apiaries since its first attack in France in 2004 (Villemant et al. 2010; Cappa et al. 2021), then successfully invaded Korea and Japan (Choi et al. 2012; Cappa et al. 2021), and has spread throughout much of Western Europe, including France, Italy, Spain, Portugal, Belgium, Netherlands, United Kingdom, Germany and Switzerland (Cappa et al. 2021). But for the case of *V. affinis*, its threat to honeybees or other types of insects has not been widely studied, so it needs further research.

The presence of *Vespa* wasp nests in residential areas can also be attributed to the nesting behavior *of V. affinis*. Based on previous research, hymenopterans and especially social wasps (Vespinae), often indicate a larger population in urban areas than in non-urban areas (Nadolski 2012). They have a tendency to build nests in buildings, especially in empty attics or basements, roofs, walls, and window edges. Nests found in buildings tend to be larger than nests found elsewhere, which means nests in buildings are reproductively advantageous by producing more wasp populations (Nadolski 2012). Based on cases found in the Ishigaki islands, Japan, *V. affinis* wasp nests tend to occupy open land, for example, forest edges or rice fields, with a position sticking close to the ground (<1 m) to protect the nest from strong winds (Martin 1992). In addition, nests found on higher ground (>1 m) tend to occupy dense thickets to shelter from monsoon rains and typhoons due to strong winds (>25 m/s) and heavy rain (>30 mm /h) easily destroying exposed nests (Martin 1992). The same thing could happen to the nests of *V. affinis* wasps which are found in many residential areas in Bojonegoro. Adaptive behavior of *V. affinis* wasps in nesting may consider that nests built in settlements (houses of residents) are much safer than in trees or open areas. Based on public information during this research survey conducted, it is known that most of the nests of *V. affinis* wasps are on the roof of the house, so they are protected from rain, strong winds, floods, and human disturbances.

The conclusion that can be drawn from this study is that the distribution of *V. affinis* wasps based on land use has an 83% tendency to be in residential areas, the remaining only 14% are in rice fields, and 3% in plantations, forests, and shrubs. Meanwhile, the distribution of *V. affinis* wasps based on population density shows that 87% of *V. affinis* wasps nests are in areas with high population density, and only about 13% of the rest are in areas with low population density. The tendency of *V. affinis* wasps to inhabit residential areas with high population density is likely due to the impact of forest destruction as their natural habitat, so *V. affinis* wasps seek to adapt to the search for more abundant food sources and new, safer nesting sites. In this study, the distribution of *V. affinis* wasp nests was often found in settlements because its presence was considered a threat to human safety, so it was widely reported for evacuation by the Fire Department. On the other hand, the settlements provide a new source of food for the *V. affinis*, such as nectar from the flower and other insects. Besides that, settlements provide new, safer nesting places for *V. affinis*, such as the roof of the building to protect their nests

from natural disturbances (rain, wind and flood) and human disturbance.

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