



RESEARCH ARTICLE - WASPS

Nesting Ecology of *Polistes* Species (Hymenoptera, Vespidae) in Urban Areas of South-western Iberian Peninsula

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Abstract

Urbanization is increasing across the globe and it is recognized as a major factor affecting species, populations and assemblages. Although urbanization is recognized as a major threat to biodiversity, there is increasing evidence that urban habitats may play a role in conservation. The objective of this work was to verify the occurrence of *Polistes* species (Vespidae) and the substrates used for nesting in urban areas in south-western Iberian Peninsula. The study was carried out from March to August of 2018 in three small towns in the Llanos de Olivenza region (SW Spain). Active searching was conducted for colonies of social wasps along and for each colony that was found we identified the species, type of substrate used for nesting, height of the colony in relation to the ground level and orientation. 753 colonies of social wasps were found belonging to two species: *Polistes dominula* and *P. gallicus*. The most used nesting substrate was clay roof tile followed by metals. The height of the nests was related to the height of the buildings on which they were built. In all the tree towns nests exposure were oriented to the SE with mean angle values oscillating between 127.42° and 140.68°. In addition, our results confirm the prediction that wasps are more abundant in less or non-urbanized areas even if they are small urban areas such as those studied in our case.

Introduction

Urbanization is increasing across the globe and it is recognized as a major factor affecting species, populations and assemblages (Turner et al., 2004; Grimm et al., 2008). Although urbanization is recognized as a major threat to biodiversity, there is increasing evidence that urban habitats may play a role in conservation (Evans et al., 2009). However, the general belief is that more natural environments, such as rural areas, provide a more suitable habitat for most species and thus for their conservation (Turner et al., 2004; Evans et al., 2009). Indeed, human settlements in rural and urban areas differ in many structural and biotic components and even in human attitudes concerning wildlife (Lepczyk et al., 2004). In urban landscapes, the presence of wildlife is limited by the availability of habitats, human disturbance, collisions with vehicles and behavioral shyness (Ditchkoff et al., 2006).

Previous studies on insects have demonstrated that urban habitats may not be as restrictive as expected (Owen & Owen, 1975; Zapparoli, 1997). In addition, it has been observed that species richness and abundance can greatly vary within each city, indicating that different levels of urbanization have distinct effects on the local insect fauna (Owen & Owen, 1975; Frankie & Koehler, 1978; Zapparoli, 1997; McIntyre, 2000; McIntyre et al., 2001).

Information about the responses of wasps to urbanization is important for a number of reasons. Many wasp species, especially the eusocial ones, are key predators ecosystems (LaSalle & Gauld, 1993). Wasps are sensitive to variations in abiotic conditions (e.g. temperature, luminosity and moisture), which may be related to changes in the urbanization level (Morgan & Jeanne, 1992). In addition, wasps are frequently found in urban environments, efficiently occupying different microhabitats (Saure, 1996; Raw, 1998).



In the south of the Iberian Peninsula, *Polistes* species are widespread both in natural landscapes and in anthropogenic habitats, where the presence of the wasps usually alarm people living near the nests. Numerous media campaigns have increased interest in this issue and have heightened the concerns of city inhabitants. This fear, which is not always fully justified, causes that people massively inform municipal services about practically all of the observed colonies of wasps. Despite their ecological importance and their potential as indicators of environmental conditions (Brown, 1991), few authors have analyzed the effects of urbanization on wasp assemblages in the Iberian Peninsula. In 1985 a study was conducted to analyze the influence of urban conditions on wasps and bees in the city of Salamanca (Gayubo & Torres, 1990). These authors found that urbanization do not affect the populations of *Polistes dominula* (Christ, 1791) and *Polistes gallicus* (L., 1767). In addition Casamitjana (1989) studied some aspects related with the nesting of a small semiurban population of *P. dominula* located inside a brick-structure in an open space in the city of Barcelona. In Europe, the most complete study about nesting habits of *P. dominula* in urban areas was the conducted by Höcherl and Tautz (2015) in Würzburg (Germany). These authors concluded that *P. dominula* wasps are very flexible in their nesting behavior and that nesting itself is strongly linked to temperature conditions. Outside its natural range only Downing (2012) provides information about nest parameters of *P. dominula*, concluding that this species uses a wide range of nesting spots, some of which provided little shelter for the nest and were not locations that either of the native species would be found using.

The objective of this work was to verify the occurrence of *Polistes* species and the substrates used for nesting in urban areas in south-western Iberian Peninsula. We also took into account the height at which the nest was located and its orientation in relation to the north (azimuth).

Materials and Methods

From March to August of 2018, *Polistes* nests were surveyed in three small towns in the Llanos de Olivenza region (SW Spain): Olivenza (OL; 12,008 inhabitants; urban area: 1,358,300 m²; 38° 41' 8.03''N, 7° 6' 3.24''W; alt., 265 m a.s.l.), San Francisco (SF; 466 inhabitants; urban area: 112,300 m²; 38° 44' 47.37''N, 7° 6' 18.81''W; 264 m a.s.l.) and San Benito (SB, 575 inhabitants; urban area: 166,200 m²; 38° 37' 55.99''N, 7° 9' 28.67''W; 223 m a.s.l.). In the Llanos de Olivenza region the climate is typically Continental-Mediterranean with relatively cold wet winters and dry hot summers (mean temperature: 16.3 °C, rainfall: 432 mm yr⁻¹). Its flat to gently undulating landscape is dominated by a mosaic of dry winter cereal crops, olive groves, and vineyards.

Nest abundance was estimated along line transects of 100 m in each town. For each nest the species and the status: active, abandoned or old was recorded. We consider a nest as active when we detect the presence of wasps on the nest. In this

case, the number of foundresses was recorded after detection of the respective nest and verified during the following weeks, until the first workers emerged. Abandoned nests have the same structure and color as an occupied nest, they are usually gray-white nests with well-defined and undamaged edges. Abandoned nests were visited for three consecutive days at different times to verify the absence of wasps. Old nests are nests from previous years, they are generally darker in color than occupied nests, and their edges are irregular and their structure is damaged. In many occasions they appear broken or partially sagged. Binoculars were used to observe and identify the species on high nests. Active nests were left in place after species identification was noted for each nest. For species identification keys Schmid-Egger et al. (2017) were used. Collected nests and wasps were deposited as voucher specimens in the Zoology Department insect collection (University of Extremadura, Badajoz, Spain).

The next features were estimated for each nest: height (using a laser distance meter), orientation (using a digital compass), and substrate (clay roof tile, CRT; corrugated asbestos, CA; direct on wall, DW; metal tubes, MT; non-cylindrical metallic structures, NCM; plant material, PM; others, OT). Localization, height and orientation were estimated just above the nest, and in the case of the height from the soil to the nest.

Differences in height of the nests between species were tested with the Mann-Whitney U test. The preferences between substrates were tested by χ^2 tests. We used Program ORIANA (Kovach, 2011) to calculate circular statistics for nest orientation: mean angle and circular standard deviation (c.s.d). Rayleigh's test of uniformity was used to test mean exposures for nonrandom orientations (Batschelet, 1981). Concentration (r) or length of the mean vector was calculated by circular methods, ranges from 0 to 1 and is affected by variation in circular data, sample size, and grouping. Values of r near 1 indicate data points closely concentrated near the mean angle or, in our case, nest-sites with a preferred directional orientation. Differences in mean direction between years were analyzed using the parametric Watson-Williams F-test in the cases where the assumptions underlying this test were fulfilled (Batschelet, 1981).

Results

A total of 744 wasp nests were found in the surveys, of which 583 were not active and 161 were active. Of the active nests 106 were occupied by *P. dominula* and 55 by *P. gallicus* (Table 1). The nests of *P. dominula* were significantly more abundant in Olivenza ($\chi^2 = 13.16$, $p < 0.001$) and San Benito ($\chi^2 = 17.00$, $p < 0.001$), while the nests of *P. gallicus* were more abundant in San Francisco, but the differences were not significant ($\chi^2 = 0.51$, $p = 0.5102$). Overall, nests of *P. dominula* were significantly more abundant than nests of *P. gallicus* ($\chi^2 = 16.5$, $p < 0.001$). In the case of *P. dominula* the number of foundresses per nest ranged between one and

four (1.9230 ± 0.7344), whereas in the case of *P. gallicus* the number of foundresses per nest ranged between one and tree (1.1750 ± 0.4464). Thus, we determined a ratio of 29.79% single-versus 70.51% multiple- foundress colonies for *P. dominula*, and a ratio of 84.62% single-versus 15.38% multiple- foundress colonies for *P. gallicus*. The multiple foundation was significantly higher in *P. dominula* than in *P. gallicus* ($\chi^2 = 39.36$, $p < 0.001$).

The mean number of active nests per transect was higher in San Francisco than in San Benito and Olivenza (Table 2). The same occurred with the mean number of non-active nests and the mean number of total nests. Similarly, the number of active nests per 100 m was greater in San Francisco (4.60) than in San Benito (3.48) and Olivenza (1.68, Table 2).

Among the 753 colonies registered, the most used nesting substrate was clay roof tile in 60.02% ($\chi^2 = 30.28$,

Table 1. Number of nests in each of the sampled localities.

Town	Active nests		Non active nests	Total
	<i>P. dominula</i>	<i>P. gallicus</i>		
Olivenza	52	21	382	455
San Benito	32	7	95	134
San Francisco	22	27	106	155

$p < 0.0001$) of the records (Fig 1). Secondly, nests build directly on walls represented with 10.09%, followed by metals with 9.63% of nest found; the fourth position was occupied by plant material with 6.64%, followed by glass corrugated asbestos with 4.78%. The others categories include nests found on glass, plastic, and wood (in door, windows). In the case of the species, both *P. dominula* and *P. gallicus* preferred the clay roof tile as a material to build their nests.

Table 2. Average abundance of active and non-active nests in the localities studied and relative abundance of nests with respect to the urban area and the number of inhabitants.

Town	Active nests	Non active nests	Total	Active nest/100 m	Non active nest/100 m	An active nest for each...	An active nest by
Olivenza	0.55 ± 0.94	2.80 ± 3.28	3.40 ± 3.81	1.68	0.29	15344 m ²	148 inhabitants
San Benito	2.38 ± 1.53	5.04 ± 2.29	7.42 ± 2.83	3.48	1.10	2825 m ²	15 inhabitants
San Francisco	2.60 ± 2.06	6.33 ± 3.64	8.93 ± 3.91	4.60	1.48	1986 m ²	9 inhabitants

The height of nests was 4.88 ± 1.59 m (range: 0.15-14 m) in Olivenza, 3.28 ± 1.14 m (range: 1.3-7.0 m) in San Benito, and 3.35 ± 1.04 m (range: 1.6-7.0 m) in San Francisco. Mean overall height of nests was 4.23 ± 1.57 m (range: 0.15-14 m). The height of the nests did differed between the three towns (Kruskal-Wallis test, $H = 164.54$, $p < 0.001$).

In all the tree towns nests exposure were oriented to the southeast (SE) with mean angle values oscillating between 127.42° and 140.68° (Table 3). The length of the mean vector oscillated between 0.477 and 0.748. In all cases nests were significantly oriented on SE direction (Raleigh's Z test). Differences in nest orientations were only significantly

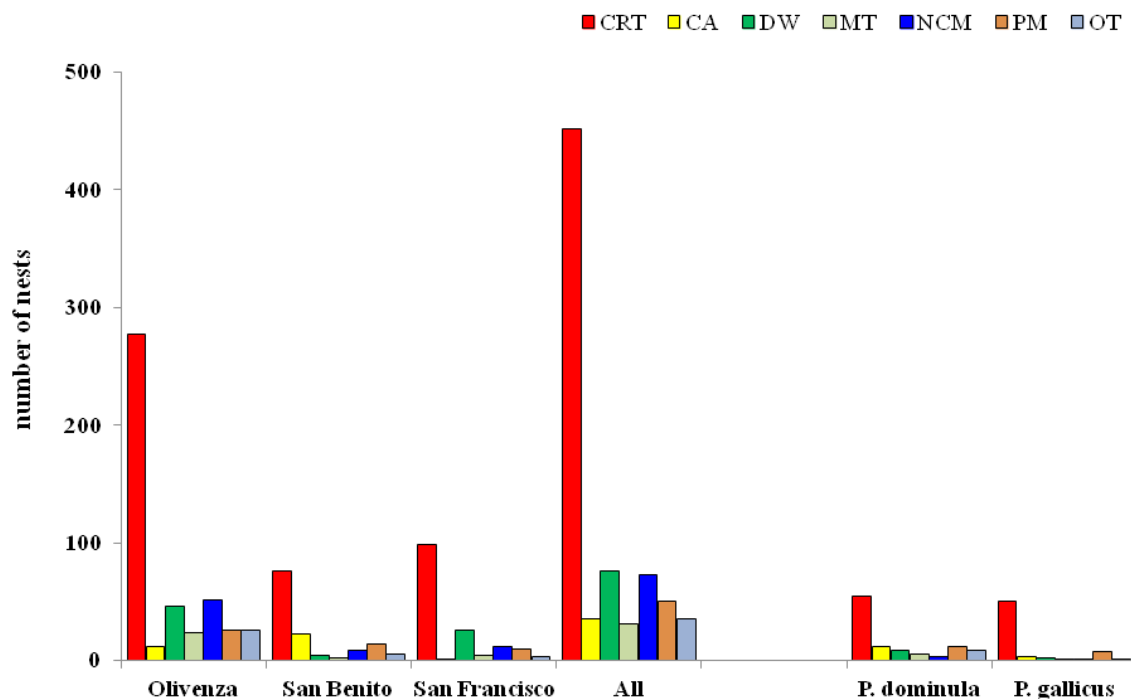


Fig 1. Type of substrate selected by wasps in each city and by species (clay roof tile, CRT; corrugated asbestos, CA; direct on wall, DW; metal tubes, MT; non-cylindrical metallic structures, NCM; plant material, PM; others, OT).

between San Francisco and San Benito (Watson-Williams F-test, $F = 4.3946$, $p = 0.036$). Overall, nests were oriented to the SE with a mean vector of 131.94° and a length of mean vector of 0.474 (Table 3). Nests were significantly oriented to

the SE (Raleigh's $Z = 163.746$, $p < 0.0001$). The analysis by species showed that nests of *P. dominula* and *P. gallicus* were significantly oriented to the SE (Table 3) and their orientations did not differ (Watson-Williams F-test, $F = 0.8199$, $p = 0.368$).

Table 3. Nest orientations in the three sampled localities and by species.

Town	Mean angle \pm c.s.d	Length of the mean vector (r)	Raleigh's Z	p value
Town				
Olivenza	$128.55^\circ \pm 69.76^\circ$	0.477	109.903	< 0.0001
San Benito	$140.68^\circ \pm 62.14^\circ$	0.555	41.326	< 0.0001
San Francisco	$127.42^\circ \pm 43.62^\circ$	0.748	91.847	< 0.0001
All towns	$131.94^\circ \pm 70.01^\circ$	0.474	163.746	< 0.0001
Species				
<i>P. dominula</i>	$142.79^\circ \pm 36.99^\circ$	0.812	35.593	< 0.0001
<i>P. gallicus</i>	$149.76^\circ \pm 51.61^\circ$	0.667	47.089	< 0.0001

Discussion

It is generally assumed that urbanization reduces habitat complexity, mostly by reducing natural vegetation cover. Consequently, it may be predicted that less urbanized areas are structurally more complex. For these reasons, it can also be predicted that less urbanized areas support a greater abundance and species richness of wasps and bees (Zanette et al., 2005). Previous works (Torres & Gayubo, 1989; Zanette et al., 2005) have demonstrated that wasps were more abundant in the less or non-urbanized areas of cities. Our results seem to confirm these predictions, as we have shown that in both species the number of nests decreases with increasing levels of urbanization (square meters built, number of inhabitants). According to Zanette et al. (2005) the reduction in prey availability caused by the loss of vegetation may be one of the factors responsible for these results. In addition, the increase of pavements and buildings coupled with the reduction of vegetation cover increases the exposure of wasp colonies to possible predators and particularly to humans, which are the major cause of colony mortality in urban environments (Fowler, 1983).

One of the advantages of built nests in urban environments is the reduction of the competence for nesting sites (da Silva et al., 2019). *P. dominula* and *P. gallicus* are the only synanthropic wasps species in the Iberian Peninsula (Gayubo & Torres, 1990) and the observed differences in nest abundance between these species in this study may be related with their biological traits. As a primitively eusocial wasp, the cooperation of queens in nest building and brood care of *Polistes* species is common (Reeve, 1991). We detected maximal four foundresses (in *P. dominula*) per nest during the study period. This number of foundresses is in contrast with observations made in other studies. For instance, Zanette and Field (2009) recorded nest buildings of *P. dominula* wasps by 1–10 foundresses in southern Spain. The colonies of *P. gallicus* are founded by a single foundress in open locations

(Cervo & Turillazzi, 1985). In our study it became apparent that *P. gallicus* preferred single over multiple foundation of colonies contrary to *P. dominula*. For this species Turillazzi et al. (1982) determined a ratio of 36 % single-versus 64 % multiple- foundress colonies and Zanette and Field (2011) described a ratio of 7 % single versus 93 % multiple-founded nests. However, in Germany (Höcherl & Tautz, 2015) the hibernating queens of *P. dominula* neither preferred multiple nor single founding (46 % and 54 %, respectively). One of the advantages of multiple founding is that the survival of nests increases in relation to single founding. Another benefit of multiple-foundress nests is an increased productivity as measured by the number of cells per nest (Queller et al., 2000; Tibbetts & Reeve, 2003). In addition, we have observed at our three study sites that *P. dominula* hibernating foundress emerges before and produces its first workers earlier than *P. gallicus*. According to Gamboa et al. (2002) early worker production enhances productivity.

Polistes dominula may have other advantages over *P. gallicus* in addition to those we have considered. For example, *P. dominula* is less demanding than *P. gallicus* in relation to the selection of the nesting sites. Downing (2012) demonstrated in the United States (where *P. dominula* is an invasive species), that *P. dominula* used a wide range of nesting spots, some of which provided little shelter for the nest and were not locations that either of the native species would be found using. In this way, Gamboa et al. (2002) suggested that nesting sites may be a limiting resource, and its use of a wider diversity of nesting locations may provide some competitive advantages.

The nesting sites chosen by wasps are strongly influenced by predation and the weather (Jeanne, 1970). Nesting on man-made substrates, in addition to natural ones, may be a useful strategy for wasp populations since their colonies may have higher developmental success as these locations may allow them to avoid their natural predators and take shelter from harsh weather conditions (Alvarenga et al., 2010). *Polistes*

species may build their nest in man-made structures, such as eaves (Cervo & Turillazzi 1985) or attics (Rusina et al., 2007), where metal, concrete, ceramic, stone, plastic, porcelain, asbestos, synthetic materials, and wood are highlighted as the substrates chosen by wasps in urban areas (Lima et al., 2000; Detoni et al., 2018). The apparent preference of the wasp for nesting under clay roof tiles (or Arabian tile) might be related to the greater offer of this substrate in comparison to the others. Probably in the Iberian Peninsula the tile is the material most used to cover the houses, especially in small towns and cities where buildings do not predominate. Tiles are made of clay, are curved and protrude about 10-20 cm. With a thickness of 10-15 mm they provide excellent protection against cold and rain. The second category most used by wasps was metal tubes. Some authors (Lola et al., 2013; Virginio et al., 2016) have suggested that this preference was probably related with a phenomenon known as “heat islands”; the accumulated heat over the metallic superficies provides suitable conditions for the colonies to develop. We cannot rule out this fact, but in the south of the Iberian Peninsula very high temperatures are recorded in July and August, which can cause the death of the colony. In fact, most of the nests built on metallic tubes were located during the warmest months. According with da Silva et al. (2019) the results might have been affected by each nesting substrate type availability rate in the area rather than preference.

In this study nest height above ground (0.15 – 12 m) is greater than the reported for European species of *Polistes* in natural habitats (15-25 cm, Kozyra et al., 2016; 4-60 cm, Cervo & Turillazzi, 1985). This is no surprise, as wasps take advantage of the height of human structures to build their nests. In a similar study conducted in Brazil (Virgilio et al., 2016) nest were located at 2-4 m above ground. We are agreeing with Kozyra et al. (2016) that nest height plays an important role in protecting the nest from predators. In this way we suppose, as occurs in birds (Mainwaring et al., 2014), that wasps vary the height at which they build their nests in response to predators, as they build their nests higher from the ground in response to mammalian and ant predators and lower in response to avian predators.

In many social insects, such as ants and termites, the geographic orientation of nests is not accidental and is of great significance for their thermoregulation (Jones & Oldroyd, 2006). Nest orientation often influences the amount of solar radiation absorbed by a nest and the time of day that the highest radiation is received. Many species orientate their nests so that it is warmed by solar radiation in the cool of the morning (Jones & Oldroyd, 2006). The orientation of nests of *Polistes* in our study (131.94°) is very similar to those reported for *P. nimpha* in Poland (110°, Kozyra et al., 2016), and in Italy (162°, Cervo & Turillazzi, 1985) and agree with orientations reports by Yamane (1996) for *P. snelli* and *P. biglumis* (southern and southeastern slopes). Although the above examples are for non-urban populations, the trend appears to be the same. In tropical areas the situation seems

to be quite different, as occurs in Brazil for example with other vespids. In the State of Minas Gerais most colonies of *Mischocyttarus cassununga* (Vespidae, Mischocyttarini) were north-oriented, between northwest and northeast, 271° to 90° (de Castro et al., 2014). In the Lower Amazon, colonies of *M. drewseni* were mainly oriented to the west (Jeanne, 1972). In the State São Paulo nests of *M. cerberus styx* were oriented to the east (Giannotti, 1999), and in the State of Mato Grosso do Sul Montagna et al. (2010) did not find a preference for a particular nest orientation in *Mischocyttarus consimilli*. However, for *P. canadiensis* Virgilio et al. (2016) have pointed out that most of nests were oriented to the East. These results confirm that at least in temperate areas nest orientation is not accidental.

According to Sumner et al. (2018) scientists may provide robust evidence on the ecological and economic value of wasps to convince the public to view these insects favourably. An overall increase of scientific understanding could, in turn, help to improve the public’s perception of wasps. If this were achieved, we expect that the public would be more accommodating of wasps and more inclined to tolerate wasp nests in their local environment, rather than have them removed. Increased tolerance will benefit the conservation of these important insects even in urban environments.

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