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Diversity of Social Wasp Communities (Hymenoptera: Polistinae and Vespinae) in the Agricultural Landscape of Central Poland

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Abstract: Social wasps are perceived as a functionally homogeneous, predatory community in the agricultural environment. This study examined the structure of social wasp communities in relation to deforestation rates in agricultural landscapes. Species richness of social wasps was highest in areas with a low and average (up to 50%) deforestation rate. A high deforestation rate (90%) of the agricultural landscape reduced the species inventory by half, mainly due to the lack of *Dolichovespula species.* The *Polistes nimpha*, *Vespa crabro*, *Vespula germanica* and *Vespula vulgaris* were constant in the agricultural landscape. There was a very strong negative correlation ($r > -0.9$, $p \leq 0.05$) between deforestation and species diversity of social wasp.

Key words: Hymenoptera, Polistinae, Vespinae, social wasps, community diversity, agricultural landscape, deforestation, Poland

Introduction

Social wasps (Vespidae: Polistinae and Vespinae) can be described as a distinguishable, interactive community, especially at the local scale (Morin 2011). There have been several studies of social wasp community structure in the dynamically transformed cultural environments that dominate much of the European landscapes (Akre et al. 1980, Archer 1998, Dvořák & Roberts 2006, Dvořák 2007).

Agricultural lands are very attractive habitats for social wasps (Archer 2012) but resource requirements, including availability of nest sites, vary considerably between vespid species. Furthermore, changes of abundance of different species depend on deforestation rate. The main objective of this study was to describe the structure of social wasp communities in agricultural environments that have experienced different deforestation rates, monitoring wasp abundance using yellow pan traps (Japoshvili & Karaca 2010).

Material and Methods

Study area and wasp collection

The wasps were collected from Central Poland in the surroundings of Poznań (Wielkopolska Region) from April to October, 2006-2009. Five locations were chosen to represent different types of agricultural landscapes with different levels of forest cover: Trzebaw (52.16ºN, 16.46ºE, deforestation 10%) in 2006, Biedrusko (52.33ºN, 16.60ºE, deforestation 25%) in 2006, Wiry (52.19ºN, 16.50ºE, deforestation 55%) in 2006, Gorzyczki (52.05ºN, 16.81ºE, deforestation 90%) in 2008-2009, and Głuchowo (52.17ºN, 16.41ºE, deforestation 95%) in 2008. Vespid nests in forest areas were found in rodent nests, old bird nests, bird boxes and hanging from small branches of shrubs and trees. Nesting sites in rural areas were observed in rodent and common mole (*Talpa europaea*) burrows, and also in dry grass or herbs. Pine marten (*Martes martes*) and badger (*Meles meles*) are important pred-

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ators of Vespinae in forest areas, and the honey buzzard (*Pernis apivorus*) – in open rural areas, although these predators are not frequent in the region (Pucek & Raczyński 1983, Sikora et al. 2007).

Landscape types were determined following Forman & Godron (1986). Assessment of the deforestation rate in the study areas was performed using topographic maps with scale 1:10000. For this purpose, an area with a radius of 2.5 km was selected from the sites where social wasps were collected (A_s). The deforestation rate (df) was determined: $\mathbf{df = 100A_f / A_s}$, where A_f – forested area in A_s.

During the vegetation seasons of 2006-2009 at each selected site, wasps and other Aculeata were collected using 20 yellow pan traps (Moericke 1953). These traps caught 60-80% of the aculeates known in the area: social wasps, bees (Apoidea) and apoid wasps (especially Crabronidae) in the ratio 2 : 1 : 2. This was the more effective method of trapping social wasps. Yellow pan traps were placed 1-1.5 m above the soil surface at intervals of 10 m in fields, orchards and roadside swards. A trap consisted of a yellow plastic vessel, 18 cm in diameter and 11 cm deep, filled with water, glycol and surfactant. Wasps were caught mostly in even-numbered years. Based on the seasonal cycle of Vespinae colony development (Archer 1998, 2012), the largest number of social wasps is expected in even years. It was found that their peaks in abundance were in even-numbered years for 80-90% of the cases in the agricultural landscape of central Poland (Pawlikowski & Pawlikowski 2006). A sample consisted of wasps caught in all traps at a given site during 10 days. Wasps were identified using Archer (2012), Dvořák & Roberts (2006) and Castro & Dvořák (2009).

Community structure and statistical analysis

The following formula was applied to calculate species diversity: $\mathbf{H' = -\sum p_i \log_2 p_i}$, where $p_i = n_i / N_t$, gives the dominant fraction of the i^{th} species in a community consisting of S species, with N_t being the mean number of specimens per trap over 10 days (Shannon & Weaver 1963). In order to define evenness of the communities, Pielou's (1966) index was applied: $\mathbf{J' = H'/H'_{max}}$, where value $H'_{max} = \log_2 S$. The index J' has values within the range of $0 < J' < 1$, with a decreasing value approaching 0 corresponding to an increasing tendency for s super-dominance, and an increasing value approaching 1 corresponding to an increasing tendency towards co-dominance.

Community diversity measured by the H' index depends on the number of species and the evenness J' (quantitative contribution of species). The higher the value of J', the more species in the community have similar quantitative contribution. If a high value of the J' index refers to a community with many species, then the H' index of this community reaches the highest value.

All statistical analyses were conducted using STATISTICA v.6 software. Analysis of variance was applied with $p \leq 0.05$ for significance testing according to Hutcheson (1970).

Results

We found only ten species of typical social wasps (Table 1). A very rare paper wasp *Polistes biglumis* (L.) and three equally rare cleptoparasites (*Dolichovespula adulterina* (du Buysson), *D. omissa* (Bischoff) and *Vespula austriaca* (Panzer)) were not found although these are known to be present in Central Poland.

The number of species in a population decreased along with a decrease in the area of woodland at a site. It was owing mainly to the loss of individuals of *Dolichovespula* spp. and *Vespula rufa*. The specimens of *P. nimpha*, *Vespa crabro*, *Vespula germanica* and *Vespula vulgaris* were recorded from all the study sites in the agricultural landscape.

The species composition of the communities in the rural areas with a lower deforestation rate (up to 55%) clearly differed from the ones from more deforested areas. In areas with a lower deforestation rate, *Vespula vulgaris* and *Vespula germanica* dominated (38-68% and 16-40% of the total individuals, respectively), and *Vespa crabro* was subdominant (6-17%). *Dolichovespula media* (1-5%) and *P. nimpha* (3-8%) were the next most common species. *Vespula vulgaris* (53-74%) and *Vespula germanica* (13-35%) dominated also in more deforested areas, although with a higher contribution, and *Vespa crabro* (6-9%) subdominated to a lesser extent. *Dolichovespula media* (1-5%) and *P. nimpha* (less than 2%) were the next most common species in these areas (Table 1).

We recorded a significant decrease ($p \leq 0.05$) in diversity from the years with the maximum development of colonies with increased deforestation rates of 25-90% (Table 1). Values of J' had the most significant effect ($p \leq 0.05$) on the increase in the values of H' at the sites with the lowest (Trzebaw and Biedrusko) and the highest deforestation rates (Głuchowo). We recorded significantly lower H' index ($p \leq 0.05$) for the season of minimum development (Gorzyczki 2009) as compared to the H' index for populations from other sites. Consequently, there was a significant negative, very strong correlation between H' values and deforestation of sites ($r = -0.951$, $p < 0.05$: Fig. 1).

Table 1. Species composition and parameters of social wasp communities in agricultural landscapes during 2006-2009; df – deforestation; n – number of samples (over 10 days) of 20 traps in the study area during the vegetation season; n_i – number of specimens; %N – domination ($100n_i / N$); N_t – mean number of specimens per trap during 10 days; superscripts$^{abc...k}$ – significance level $p \leq 0.05$

Species	Trzebaw df = 10%		Biedrusko df = 25%		Wiry df = 55%		Gorzyczki df = 90%		Gorzyczki df = 90%		Głuchowo df = 95%	
	2006 n = 13		2006 n = 14		2006 n = 19		2008 n = 12		2009 n = 10		2008 n = 14	
	n_i	%N	n_i	%N	n_i	%N	n_i	%N	n_i	%N	n_i	%N
Polistes dominula (Christ)	1	0.13	-	-	-	-	1	0.21	1	0.70	1	0.62
Polistes nimpha (Christ)	43	5.71	59	8.05	32	2.76	4	0.85	1	0.70	3	1.87
Vespa crabro L.	130	17.26	69	9.41	73	6.30	28	5.97	12	8.39	15	9.38
Dolichovespula media (Ret.)	36	4.78	5	0.68	28	2.41	4	0.85	4	2.80	-	-
Dolichovespula norwegica (F.)	1	0.13	-	-	3	0.26	-	-	-	-	-	-
Dolichovespula saxonica (F.)	1	0.13	8	1.09	23	1.98	-	-	-	-	-	-
Dolichovespula sylvestris (Sc.)	1	0.13	2	0.27	3	0.26	-	-	-	-	-	-
Vespula germanica (F.)	239	31.74	288	39.29	185	15.96	143	30.49	19	13.28	56	35.00
Vespula rufa (L.)	18	2.39	7	0.95	25	2.15	-	-	-	-	-	-
Vespula vulgaris (L.)	283	37.58	295	40.25	787	67.90	289	61.62	106	74.12	85	53.13
Total number of specimens [N]	**753**		**733**		**1159**		**469**		**143**		**160**	
Density [N_t]	**11,58** ^{afgh}		**26,18** ^{abcde}		**12,20** ^{bijk}		**3,91** ^{cgjm}		**1,43** ^{ehklm}		**5,71** ^{dfil}	
Diversity [H']	**0.64** ^{efgh}		**0.57** ^{abcd}		**0.48** ^{aeij}		**0.40** ^{cgi}		**0.38** ^{dhjk}		**0.45** ^{bfk}	
Evenness [J']	**0.64**		**0.63**		**0.51**		**0.51**		**0.48**		**0.64**	

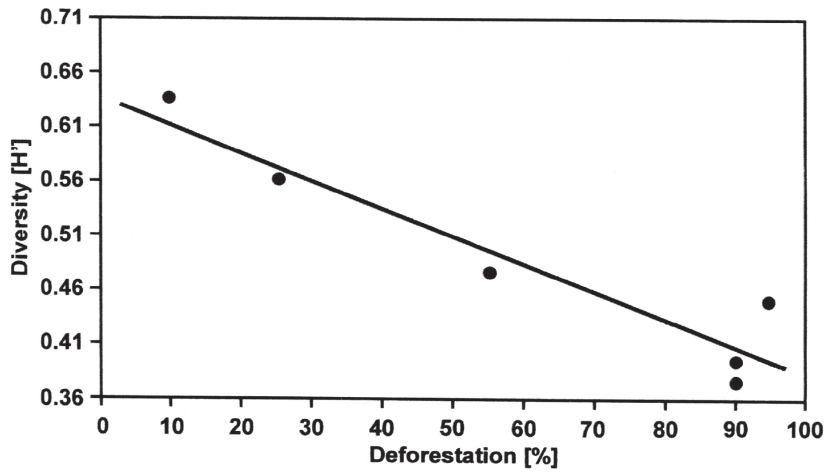

Fig. 1. Relationship between species diversity (y) and deforestation (x): $r = -0.951$, $p < 0.05$; regression line $y = 0.645 - 0.003x$

Discussion

Social wasps are predators connected with forest or forest-like habitats, where they may take advantage of abundant nutritional resources, construction materials for their nests and safe place for nesting (Edwards 1980, Matsura & Yamane 1984). The richest populations of social wasps were found in agricultural areas with a high contribution of forests. The wasp species which were recorded in all types of agricultural landscape, were most abundant in the least deforested areas, i.e. areas with the highest tree cover.

The distribution of several other species was consistent with their preferences for forest or open ecosystems (Archer 2012). In his study of social wasps in European forest ecosystems, Dvořák (2007) found that *Vespula vulgaris* and *Vespa crabro* dominated, whereas *Vespula germanica* was an accessory species. On the other hand, in a study conducted in European open ecosystems (Dvořák et al. 2008), *Vespula germanica* subdominated in addition to the same dominant species as in forest ecosys-

tems. In agricultural areas, forest preferences were reflected by the subdominance of *Vespa crabro* and the highest dominance rates for *D. media* and *P. nimpha* in the most afforested areas.

In this study, the effect of deforestation was characterised primarily by a decrease in the number of *Dolichovespula* species. *Vespula rufa* was not found at sites with deforestation of 90-95%. This species, like *Vespula vulgaris* and *D. media*, is usually reported as a forest species. Pawlikowski (1990) and Pawlikowski & Hirsch (2001) have previously reported that *V. rufa* showed high local variation in presence or absence at sites in the deforested agricultural landscape of Central Poland.

High diversity and developmental success of social wasps in rural-forest areas contribute to the fact that their nests are an important component of food for predatory vertebrates (Jędrzejewska & Jędrzejewski 1998, Jędrzejewski et al. 1993). One avian predator, the honey buzzard feeds mainly on social wasps. A significant number of Vespinae wasps were found in faeces of badgers and pine martens (10-50% samples).

Besides relative availability of food for larvae (which has not been investigated here), the lack of *Dolichovespula* from deforested areas might be owing to the fact that they nest on branches of trees and bushes (Edwards 1980). This has been observed during the long-term study in the city of Toruń (Pawlikowski et al. 2005, Pawlikowski & Przybylska 2001). It has been established that the occurrence of *D. media* in the city is enabled by small greenery enclaves (avenues, parks, gardens, graveyards), where these wasps could build their nests. Furthermore, this indicates high tolerance of the species to the location of nesting sites in extremely transformed cultural areas. In the present study, *D. media* was the only species of *Dolichovespula* recorded in agricultural areas with a small amount of tree cover (deforestation 90%).

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