Factors restricting the abundance of wasp colonies of the European hornet *Vespa crabro* and the Saxon wasp *Dolichovespula saxonica* (Hymenoptera: Vespidae) in an urban area in Poland

Jerzy Nadolski

Nadolski, J. 2013: Factors restricting the abundance of wasp colonies of the European hornet *Vespa crabro* and the Saxon wasp *Dolichovespula saxonica* (Hymenoptera: Vespidae) in an urban area in Poland. — Entomol. Fennica 24: 204–215.

Various factors affecting the reproductive success of *Vespa crabro* and *Dolichovespula saxonica* (Vespinae), including their parasitoids, parasites, pathogens and other microorganisms accompanying their nests in the city of Łódź in Poland were investigated. *Sphecophaga vesparum*, *Aphomia sociella* and especially *Quedius brevicornis*, whose larvae cause destruction of wasp nests, were recorded. Totally 19 species or groups of bacteria, including pathogens like *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Staphylococcus aureus* and *Enterococcus faecalis*, and 5 species of fungi were identified. Cities create very good conditions for wasp societies. Unfortunately, their presence can cause specific but important risks to humans, which lead to massive destruction of wasp nests. However, this does not cause considerable decrease in the number of colonies of common wasp species but less abundant species may be endangered in cities by this practice. It is thus recommended to limit the number of all wasp nests destroyed and to discriminate between the species.

J. Nadolski, Faculty of Biology and Environmental Protection, Natural History Museum, University of Łódź, Kilińskiego 101, 90–011 Łódź, Poland; E-mail: nadolski@biol.uni.lodz.pl

Received 12 February 2013, accepted 22 May 2013

1. Introduction

The presence of wasps (Vespinae) in cities is well known. As a result of numerous and extensive studies, the current species composition and population dynamics of this group of insects are known in many urbanized areas (Haeseler 1982, Skibińska 1987, Kowalczyk 1991, Pawlikowski & Osmański 1998, Nadolski 2004, Pawlikowski *et al.* 2005, Ahrné 2008). However, it is still difficult to determine which factors have important impacts on the effective colonization of cities by many species of social wasps. The most characteristic features of these areas are a warmer and more stable microclimate than in other environments, varied and abundant food resources and a large variety of niches to be used (Christie & Hochuli 2008).

Different activities and methods aimed at reducing the presence of social wasps in cities has increased in recent years. In Poland, different municipal departments, including the Fire Brigade

and disinfestation companies, are hired to eliminate nests of bees and wasps. What is the real extent of these events? Do people and natural enemies of wasps, i.e. predators, parasites and parasitoids, have an important impact on the existence of social wasps in cities?

Studies of accompanying fauna of social Hymenoptera have been conducted for the nests of Apidae (Banaszak 1980, Schmid-Hempel 1998), Formicidae (Staniec & Zagaja 2008) as well as various groups of Vespidae (Nadolski 2004). However, only those organisms can be a threat to societies of wasps, which limit development of colonies or can destroy them. These are parasitoids, parasites and pathogens (Schmid-Hempel 1998, Rose *et al.* 1999). In addition, the presence of different microorganisms in nests of social Hymenoptera can be a potential threat to humans due to human-related pathogenity, especially when nests of wasps are established in the immediate vicinity of human's premises.

The purpose of this study was to assess the extent and impact of the above described phenomena and their importance for the life and development of the urban colonies of two species of Vespinae wasps, *Vespa crabro* (Linnaeus, 1758) and *Dolichovespula saxonica* (Fabricius, 1793), as well as to qualitatively characterize the parasitoids and parasites as well as pathogens and other microorganisms in their nests. These issues are certainly relevant for the safety of the urban human population, but the assessment of these risks is beyond the scope of this study.

2. Material and methods

2.1. Study area

Colonies of two species of wasps (Vespinae), the European hornet (*Vespa crabro*) and Saxon wasp (*Dolichovespula saxonica*), were studied in 2000–2009 within the administrative area of the city of Łódź, covering 294.4 km^2 of land. Łódź has a characteristic structure with the buildings of the city connected by the concentric location of streets and houses. The town centre is an area of dense development with the old buildings originating from the turn of the 19th and 20th centuries. This area is poorly differentiated biologically and only the few old city parks can create specific living conditions for different species of wild fauna. The centre of the city is surrounded by residential zone with housing estates, modern blocks and skyscrapers as well as by industrial areas. Despite the presence of a large number of young trees and green areas, this zone is rather poor and monotonous. The large forest in the north of the city (Łagiewniki forest) and areas of detached houses, old farms and wastelands surround the whole town and have a direct contact with woods and agricultural lands located outside the city.

2.2. Data collection

When young queens of wasps begin the building of nests in the spring, they choose different places which are characteristic for a particular species. Based on studies in the years 2000–2009 the preferred nest sites of the both studied species of wasps were examined. Every place was classified as belonging to one of the two categories, natural or buildings. Places classified in the first category were 'natural' ones, which were not inhabited by humans or associated with their activity, such as different types of buildings and equipment of the city infrastructure. The only exception were breeding boxes for birds, which, because of their construction resembling hollows of trees, were also categorized as 'natural'. To the second category, 'buildings', belonged places directly related to the structure of the urbanization of the city: residential buildings and outbuildings with the associated infrastructure were included.

Information about the locations of wasp colonies were obtained from the municipal and forest services as well as from the telephone notification and survey data from citizens of Łódź and as the author's own observations (Nadolski 2012). Empty nests in the stage of initiation were not included. After verified, data were entered into a specially created database in Access (Microsoft Inc. 1997, 2000).

Colonies of the two studied species were found from different places of the city. The European hornet is a large wasp and finding and identification of its nests are very easy. However, all received information was checked. While being

Table 1. Success of *Vespa crabro* and *Dolichovespula saxonica* colonies established in natural places and buildings in the city of Łódź in 2000–2009.

a. Nests destroyed by humans

	Vespa crabro					*Dolichovespula saxonica*				
	Destr.		Not		Total	Destr.		Not		Total
	N	%	N	%	N	N	%	N	%	N
Natural places	4	11	34	89	38	8	7	106	93	114
Buildings	265	81	62	19	327	232	75	77	25	309
χ^2	83.7, p<0.001					154.4, p<0.001				

b. Nests with reproductive castes present vs. not; nests without reproductive castes became extinct or abandoned

	Vespa crabro					*Dolichovespula saxonica*				
	Present		Not		Total	Present		Not		Total
	N	%	N	%	N	N	%	N	%	N
Natural places	12	35	22	65	34	17	16	89	84	106
Buildings	59	95	3	5	62	76	99	1	1	77
χ^2	37.8, p<0.001					101.2, p<0.001				

aware of possible defects of these methods of collecting data about nest locations, only these were feasible in practice, and made it necessary to estimate the possible error in the assessment of nest numbers. Note that the city of Łódź is large (almost 300 km^2) with a dense urban structure and multiple industrial and agricultural areas as well as forests and parks. Therefore, a detailed inventory of all hornet nests was carried out in randomly selected 10 squares, each with an area of 1 km^2 (Nadolski 2012). Effort was made in these squares to record all nests of Vespinae, particularly colonies of *V. crabro* and compare the data obtained in this way with the number of colonies from the same squares noted as a result of notifications, surveys, and data obtained from all of the municipal services. It turned out that in the case of *V. crabro* only few nests established on the premises of abandoned factories and fallow lands were not included in the notifications. These studies showed very high, over 90% effective registration of the colonies of the hornet in the city.

To locate and recognize nests of the Saxon wasp is much more difficult, and hence the above described method can be unreliable. Therefore, the total number of colonies of this species in the city of Łódź, in particular years, could not be determined. Some nests could not be examined in detail because they were in inaccessible places. Other nests, both active and empty, were subjected to a thorough examination. Thus, the real total number of colonies of this species in the city of Łódź may have been up to several dozen percent higher in each year than shown in this study. However, the proportions in the location of the nest (natural and buildings) are rather constant.

Active colonies of wasps were removed by enclosing each nest as a whole into a plastic bag and cutting it from the place of suspension. Sometimes, in the case of large societies, the fire extinguisher with carbon dioxide to freeze or insecticides to kill the wasps in nests was used. After removal of the nests, the whole colonies were kept at –18°C. Because of the need to collect all individuals of the societies, the sampling of the nests was carried out at nights. Besed on detailed studies of the nests, the degree of development of the

Table 2. Causes of natural death of societies of *Vespa crabro* and *Dolichovespula saxonica* in the city of Łódź in 2000–2009.

	V. crabro	*D. saxonica*
Weather	3	16
Parasitoids, parasites and predators		
Sphecophaga vesparum	0	23
Aphomia sociella	0	24
S. vesparum + *A. sociella*	0	4
Quedius brevicornis	3	0
Mammals	3	4
Queen failure		
Death	7	11
Usurper	2	2*
Broken nests or nest boxes	3	2
Cause unknown	1	3
Total	22	89

* *Dolichovespula adulterine*

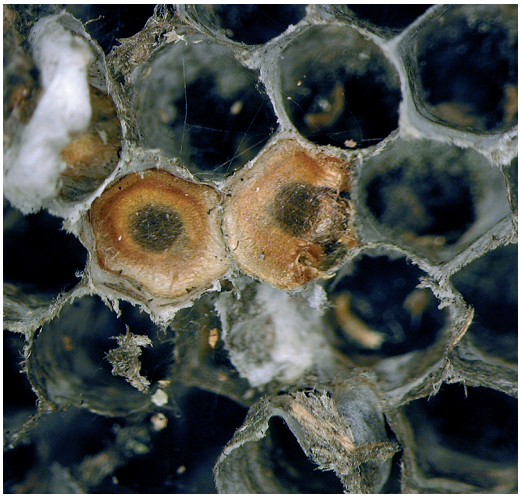

Fig. 1. Cells from a nest of *Dolichovespula saxonica* attacked by *Sphecophaga vesparum*.

colonies (the presence or absence of reproductive castes) as well as their condition (presence or absence of the queen, presence of parasitoids, physical destruction of the nest by predators or municipal services etc.) were determined. A total of 365 nests of the European hornet and 423 nests of Saxon wasps were examined (Table 1). A detailed description of the methods of the analysis of the nests of wasps is presented by Nadolski (2012).

In the studies of microorganisms of the nests of Vespinae, both the colonies of *D. saxonica* and *V. crabro* were used. These studies were carried out during the years 2000–2003, 2007 and 2008. Altogether, 22 nests of *V. crabro* and 20 nests of *D. saxonica* from different areas of the city were studied. They were located in residential and utility buildings as well as in nesting boxes for birds and different natural places (branches and hollows of the trees, holes in the ground). For qualitative microbiological tests, swabs were collected from both the empty and active nests. The swabs were taken from the outlets of the nests, from the surface of the workers returning to the nests, as well as from the detritus accumulated below the nests, and in the case of empty nests, from the surface of the combs and interior of cells.

For the culture of microorganisms, the solid substrates of the company Bio Merieux were used: Columbia Agar with 5% Sheep Blood (a general purpose culture medium used for the growth and recovery of fastidious microbial species including *Streptococcus pneumonia*, *Staphylococcus aureus* and *Escherichia coli*), Mannitol salt agar (MSA, containing pancreatic digest of casein, peptic digest of animal tissue and beef extract) for the isolation and enumeration of pathogenic staphylococci, MacConkey's Agar (a special bacterial growth medium that is selective for Gram-bacteria and can differentiate those bacteria that are able to ferment lactose) and D-coccosel agar (for selective isolation and differentiation of enterococci and group D streptococci).

In addition, substrates of the company Emapol were used: Mannitol Salt Agar (MSA) (a commonly used growth medium in microbiology) and Sabouraud Dextrose Agar (a type of agar containing peptones, used to cultivate dermatophytes and other types of fungi). For isolating and marking of the bacteria of Enterobacteriaceae family, substrates of tryptone-tryptophan from the company Graso and identification tests EPL – 21 from the company HTL were used.

Statistical analyses were conducted using STATISTICA 9 package (StatSoft, Inc. 2010). The chi-squared tests were performed using Yates correction.

Fig. 2. A nest of *Dolichovespula saxonica* destroyed by larvae of *Aphomia sociella*.

3. Results

The number and percentage of nests of both *V. crabro* and *D. saxonica* destroyed by humans depended on their location (Table 1a). Colonies established in buildings were destroyed more frequently than the ones in natural places. However, the number and percentage of nests which were not destroyed and completed their development and obtained reproductive castes was also significantly higher in buildings than in natural places (Table 1b).

In Table 2, the causes of natural dying out of the societies of *D. saxonica* and *V. crabro* in the city of Łódź are presented. In Saxon wasp's nests the following parasitoids, parasites and predators were found in Łódź: the parasitic wasp *Spheco-phaga vesparum* (Curtis 1836) (Hymenoptera, Ichneumonidae) (Fig. 1), bee moth, *Aphomia sociella* (Linnaeus 1758) (Lepidoptera, Pyralidae) (Fig. 2) and parasitic yellow-jacket, *Dolicho-vespula adulterina* (du Buysson 1905) (Hymenoptera, Vespinae).

In the nests of the European hornet, larvae of

Fig. 3. A comb from a nest of *Vespa crabro* destroyed by larvae of *Quedius brevicornis*.

Table 3. Microorganisms isolated from colonies of *Vespa crabro* and *Dolichovespula saxonica* in the city of Łódź.

	Vespa crabro				*Dolichovespula saxonica*			
	Natural places		Buildings		Natural places		Buildings	
	Nests	Detritus	Nests	Detritus	Nests	Detritus	Nests	Detritus
Pseudomonas aeruginosa				x				
Escherichia coli		x	x	x			x	x
E.blattae			x	x	x			
Citrobacter freundii		x						
C. diversus		x	x					
Klebsiella pneumoniae			x					
K. oxytoca		x		x				x
Enterobacter cloacae		x	x	x				
Proteus mirabilis				x				
P. vulgaris		x		x				
Pantoea agglomerans		x		x		x		x
Staphylococcus aureus			x	x				x
S. epidermidis	x		x	x	x	x		x
S. saprophyticus			x	x			x	x
Enterococcus faecalis		x	x	x			x	x
Enterococcus sp.	x	x	x	x				
Gram-positive bacilli				x				
Gram-negative bacilli				x				
Gram-positive rods		x						
Aspergillus niger	x	x	x	x	x	x	x	x
Penicillium sp.	x	x	x	x	x	x		x
Candida krusei			x	x				
C. glabrata							x	x
C. albicans			x	x			x	

the beetle *Quedius brevicornis* (Thomson, 1860) (Coleoptera, Staphylinidae) were found (Table 2) (Fig. 3) in nests which were located in nesting boxes for birds in the Łagiewniki Forest and Botanic Garden in the Łódź. For the purpose of proper taxonomic designation, larvae of rove-beetles from hornet nests were bred. The larvae of *Q. brevicornis* were found both in the detritus beneath the hornet's nest and in lower combs which adjoined to the bottom of the nesting box. In these combs, the cells were used for larvae of the reproductive castes – gynes (young queens) and drones. Due to aggressive foraging by the larvae of *Q. brevicornis*, the combs placed the lowest were severely damaged and the hornet's larvae and pupae in them were completely destroyed (Fig. 3). Moreover, because workers of *V. crabro* cut off access to the affected combs, those could not be cleaned. In these parts of the nests there was a serious secondary infection by fungi, which further increased the loss of these colonies. It was found that larvae of *Q. brevicornis* produced a very specific odeur in nests of *V. crabro*.These are the first described cases of predation by larvae *Q. brevicornis* on larvae and pupae of *V. crabro*.

The last group of animals which can be 'blamed' for destroying wasps' nests are mammals. In Łódź, two nests of *V. crabro* located underground that were destroyed by foxes (*Vulpes vulpes* L.) or badgers (*Meles meles* L.) were found, and five nests of both species of wasps in buildings or tree hollows probably destroyed by martens (*Martes* sp.) were observed (Table 2).

A total of 19 species or groups of bacteria including pathogens like *Pseudomonas aeruginosa*, Klebsiella pneumoniae, Enterobacter cloacae *Staphylococcus aureus* and *Enterococcus faecalis* and 5 species of fungi were identified in nests and in detritus in colonies of the European hornet and Saxon wasp (Table 3). Especially detritus located directly under the nests was contaminated with microorganisms.

4. Discussion

4.1. Urban areas as nesting habitats for social wasps

Large cities provide an environment in which habitat types are dependent on the degree of urbanization. For many species of social wasps the fundamental feature of this environment is unlimited number of sites to establish colonies and a wealth of food availability which is also often unlimited (garbage, food warehouses). This seemingly idyllic picture of the city as an ideal place for the existence of colonies of wasps is disturbed by people living there, who in most cases are reluctant and hostile towards such neighbours. The European hornet and the Saxon wasp most often establish their colonies in forests (Pawlikowski 2009). However, in urban areas their nests can often be found inside residential and utility buildings. Accordingly, the studies by Nadolski (2012) demonstrated that urban populations of both *V. crabro* and *D. saxonica* prefer places in residential and utility buildings and other accompanying urban infrastructures to more natural places. Buildings and the entire infrastructure as places for wasp nests allow the formation of larger colonies and create better conditions for the development of their societies. Therefore, colonies of wasps established in these places are larger and more numerous than those outside the urban areas (Nadolski 2012). It seems that the key element conditioning reproductive success of Vespinae is the choice of place to build a nest, made in the spring by the young queen.

The preference for buildings and other constructions as nest sites in urban areas is understandable, because the number of natural places is limited there, while in buildings there are plenty of them. However, sometimes there are situations in which the number of natural places for nests is sufficient. This applies especially to both studied species which, according to their biology, usually build their nests on the branches of trees (Saxon wasp) or in the hollows of trees (both species) as well as in underground burrows (the European hornet). Why then these 'tree hollow' wasps prefer attics of buildings and sheds for their nesting, although many wooden nest boxes were suspended nearby? The cause of the observed trends can therefore not only be explained by a limited number of available natural places for the nests, but probably also by their quality. Places in buildings provide a relatively stable temperature, protection from precipitation, predators and also probably against the different parasitoids as they were not observed in the wasp nests located in buildings. Anyway, the lack of parasitoids in the buildings is to some extent consistent with results of other studies (Kowalczyk 1991), in which a smaller number of parasitic species was recorded in the centre of Łódź than in non-urban areas. Colonies of wasps in buildings may also reach much larger sizes than those in natural places, and they can achieve higher reproductive success, because the number of all individuals of a particular society, including sexual castes, is closely correlated with the nest size (Jeanne & Bouwma 2002) which has been confirmed also in studies by Nadolski (2012).

As shown in the present study, one of the causes limiting wasp colonies is weather conditions, which may sometimes contribute to premature death of the whole society of wasps. According to the present study and the author's other observations, long-lasting and heavy rain and strong winds can cause the destruction of nests and eliminate colonies completely, especially those which were created in underground burrows or on branches of trees and bushes. Nests which are located on branches of trees are often washed away by rain or damaged by the wind, and those located underground are flooded by water. Low rainfall does not pose direct threat to a colony, but long-lasting and high humidity leads to proliferation of pathogenic fungi (Table 3), which destroy both the structure of a nest made of a delicate material resembling paper, as well as larvae and pupae within it.

4.2. Accompanying fauna of wasp nests

Apart from the weather, parasitoids can be an equally important factor limiting the number of Vespinae nests. Species of parasitoids which were found in nests of *D. saxonica* in the city of Łódź are well known (Schmid-Hempel, 1998). Some of them, especially the parasitic wasp *Sphecophaga vesparum*, of which a few subspe-

cies are known (Berry *et al.* 1997), have been successfully used against species of wasps, which are considered as invasive species, especially German wasp (*Vespula germanica*) and the common wasp (*V. vulgaris*), and the presence of which has become a serious problem for the residents in New Zealand (Barlow *et al.* 1996, Harris & Read 1999). This ichneumonid has been recorded in Poland in the nests of *D. saxonica* in some areas, for example Borecka Primeval Forest (Pawlikowski & Pawlikowski 2003), Kampinoska Primeval Forest (Sawoniewicz & Wiśniowski 2007) and in the city of Łódź (Nadolski 2004). The effectiveness of this ichneumonid in destroying wasp colonies is moderate and depends primarily on the degree of development of the infected insect societies. The earlier the infection happens, the more effective and dangerous this action is to the host.

The situation is different, when a wasp colony is attacked by the moth parasite *Aphomia sociella* (Pyralidae), which has often been recorded in Poland (Pałka 2000). Its effectiveness in destroying wasp nests is 100%. Caterpillars of this moth totally destroy the nest structure, including combs and envelopes (Fig. 2). Thus, the level of destruction is high enough to cause complete annihilation of the society at any stage of its development. Its presence absolutely disorganizes the work of the whole wasp colony and causes various kinds of anomalies in the constructions of combs. The destructive activity of this parasite eventually leads to the physical destruction of the nest. The presence of *A. sociella* in nests of the Saxon wasps in the Łódź has always resulted in total destruction of the whole colony.

The abundances of *S. vesparum* or *A. sociella* in Łódź have not yet been carefully determined. According to the author's observations it can be concluded that both species are rather common within the administrative boundaries of the city, although they are not easy to find.

In contrast to the two species above, the parasite found in this study, *Dolichovespula adulterina*, is a rare species of wasp in Łódź. It is a well-known social parasite of *D. saxonica* and *Dolichovespula norwegica* (Fabricius 1781) (Dvořák 2007). In this study, two colonies of *D. saxonica* parasitized by *D. adulterina* were found. This species is not a threat to the population of *D. saxonica*, but the presence of *D. adulterina* in Łódź may be threatened by the massive destruction of nests of their hosts.

In studies of *V. crabro* nests, its accompanying fauna has rarely been investigated. However, the presence of many representatives of different animal groups, especially insects, has been shown in its nests (Schmid-Hempel 1998, Papp 2000), among others, numerous larvae of dipterans (Diptera) and beetles (Coleoptera) feeding on detritus located directly under the nest, as well as predatory species which hunt on them. Some rove-beetle species (Staphylinidae), first of all known from underground burrows of mammals (Nowosad 1990) and nests of birds (Majka *et al.* 2006), have been found in nests of social wasps (Staniec & Zagaja 2008).

The beetle *Quedius brevicornis* (Thomson, 1860) was found in the nests of hornets in the area of Łódź. It is an uncommon species in Europe, in Poland known from a dozen locations (Staniec 2003). Larvae of this species were known as commensals which feed on the detritus in wasp nests, but detailed biology of the species is not yet fully known. It is interesting that in certain cases it may also be a predator whose larvae feed on larvae and pupae of *V. crabro*. Because they can gnaw the walls of cells and combs in hornets' nests (Fig. 3) and they can move quickly, larvae of this beetle are not attacked by workers of hornets. The destruction of hornet's nest by larvae of *Q. brevicornis* were observed only in boxes for birds, in which, due to the limited space, larvae of the beetle were able to attack low-positioned combs that were located directly above the bottom of boxes. Because larvae and pupae of gynes and drones were placed in these cells, the destruction caused by the larvae of the beetle was so huge that it led to the total extinction of the colonies. Workers tried to save the hornet nest by isolating the threatened area of the nest and by building additional envelopes which limited the area occupied by larvae of *Q. brevicornis*. These actions caused the death of all isolated larvae, which ceased to be fed as well. In all cases of the presence of the larvae of this beetle in a hornet nest, all wasp larvae and pupae of the reproductive castes were eaten by larvae of the rove-beetles in the end. Based on these observations it may be assumed, that *Q. brevicornis* can be a dangerous beetle to hornet

only in nests located in spaces, where sizes and development of colonies are limited by the volume of these places (in this case these were the breeding boxes for birds). In a large tree hollow or in the attic of a building, where combs of the nest have no contact with the place on which the detritus is gathered, the larvae of *Q. brevicornis* probably do not attack the larvae and pupae of hornets.

Plundering of nests of wasps by mammals were limited to only few cases where the colonies were destroyed by martens (*Martes* sp.) and probably foxes (*Vulpes vulpes*) and badgers (*Meles meles*) (Table 3). Accordingly, it can be assumed that these predators do not have a substantial impact on the size of populations of Vespinae in Łódź.

4.3. Accompanying microorganisms in wasp nests

It is common knowledge that colonies of wasps can cause serious problems for people, the main residents of the city. Apart from venom poisoning, colonies of wasps in urban areas can cause other serious problems. The present study demonstrated the presence of many pathogens in the nests of wasps, especially in the detritus accumulated under the nest. Very often, the presence of colonies of wasps in a house is ascertained by detection of stinking stains on the ceilings and walls, over or near the location of the nest. Microorganisms, which were found in the nests (Table 3), can be a real threat not only for the wasps themselves (Schmid-Hempel 1998, Rose *et al.* 1999), but also for the people. The presence of numerous pathogens in the wasp nests were found, including *Pseudomonas aeruginosa* which can be an important cause of infection of the people, *Staphylococcus aureus*, a dangerous bacterial purulent, *Escherichia coli*, *Klebsiella pneumoniae* and *Klebsiella oxytoca* which often cause urinary tract infections, faecal bacteria *Enterobacter cloacae* and *Enterococcus faecalis*, and various species of fungi, including *Aspergillus niger* which produce aflatoxins causing respiratory diseases and candidiasis, as well as *Candida krusei*, *C. glabrata* and *C. albicans* which may be sources of many different infections and allergy.

The above pieces of information should be important for guiding epidemiological prevention. It is hard to directly blame wasps for the situation, because, as have been shown, the cause of the problem rather lies in the fauna accompanying the colonies of these insects. On the other hand, without wasp colonies there would not be the accompanying fauna either and thus no microorganisms. The nests of the studied species of Vespinae, especially when established in natural places are bacteriologically cleaner. This indicates that the sources of infection does not need to be the wasps, but could be other saprophytic insects, which eat excrements of wasps. The fauna accompanying nests of social wasps is rich, as discussed in the previous section, and except for parasite species, most of them feed on detritus.

As mentioned, active nests are bacteriologically rather clean but in the empty nests, more types of microorganisms were found. Very strong fungal growths on empty nests were often observed by the author of this study. It can be assumed that the purity of active nests is maintained through the intense work of the workers that probably clean the combs and cells in their nests from microorganisms through using the venom. The toxin of *V. crabro* demonstrates bacteriostatic properties, especially the mastoparan contained in their venom. These properties have been found in toxins of many species of insects (Stocker & Traynor 1986, Yibin *et al.* 2005, Xu *et al.* 2006, Chen *et al.* 2008).

Interesting examples of bacteria are the species of the genus *Enterococcus* (Enterococcaceae), which were always present in cultures of microorganisms from nests and individuals of the European hornets. It can be argued that they are symbiotic bacteria always present in the gastrointestinal tract of the hornet, similarly as they can be in other species, such as the Asian hornet, *Vespa orientalis* (Linnaeus, 1771), for example (Ishay *et al.* 2003). It is possible, that these symbiotic bacteria protect larvae of wasps from fungal infestation (Kaltenpoth *et al.* 2005).

4.4. Conflict between wasps nesting in buildings and humans

The presence of social aculeates in urban areas has many consequences, some of which are still underestimated, and others that can cause excessive concern among people, disproportionate to the real threats. The scale of these phenomena is so serious that in Poland the Fire Brigade Headquarters had to develop special procedures to be used for these types of threats (Łyszkiewicz & Nadolski 2009). These rules are intended in a logical way to limit the scope of intervention carried out by the fire brigades, to the cases important for social reasons. However, the question arises, whether this threat is so great that it is necessary to use municipal services? Studies on honeybee (*Apis mellifera* Linnaeus) in Łódź (Nadolski 2008) showed the acceptance of the presence of bee colonies by people, although their colonies are more dangerous than those of wasps, because honeybee venom is stronger and more often causes allergy than toxins of wasps (Habermann 1972, Banks & Shipolini 1986, Schmidt 1986, Antonicelli *et al.* 2003).

In the present study, the percentage of societies in which the reproductive castes appeared was small, only about 20%. Moreover, these societies of wasps, in the majority of cases, were not established in natural places but in buildings where colonies of *V. crabro* were destroyed in over 80% of the cases and those of *D. saxonica* in about 75% (Table 1). Given that approximately 60–70% of all colonies of both studied species of wasps were destroyed by municipal services or the owners of buildings, the real picture that emerges from this study indicates the scale of the problem concerning the survival of urban populations of wasps. In all Polish cities in 2009 only, there were almost 80 thousand interventions of the Fire Brigade in relation to the risks arising from the presence of nests and swarms of social insects. It must be remembered that each of these interventions meant destruction of an insect colony, including also societies of honey bees nests which are more and more often recorded in urban structures (Nadolski 2008).

The main enemy of wasp societies in the city are people who in most cases do not even try to tolerate a colony of insects in their neighbourhood. Still, as shown above, wasps prefer objects created by people for their nest sites. The conflict of the interests is obvious, and the insects are most at risk. The numerous and common species of Vespinae can cope quite well in these conditions, and as it seems, a quite large number of their colonies remains in relatively similar numbers from year to year. As an evidence of this there are similar numbers of interventions of municipal services each year (Nadolski, unpubl.). A more important problem may be to keep other, less numerous species of social wasps in the city, which are recorded in Łódź only occasionally and sporadically. These are the median wasp, *Dolichovespula media* (Retzius, 1793), the tree wasp, *D. sylvestris* (Scopoli, 1763) and the red wasp, *Vespula rufa* (Linnaeus 1758), as well as the species classified as social parasites of yellow-jackets: *Dolichovespula omissa* (Bischoff, 1931) and *D. adulterina* (du Buysson, 1905) (Nadolski, unpubl.).

It is difficult to take a stand on what should be done with colonies of wasps in urban areas. They are, unfortunately, the neighbors that cause so many problems for people but the mass extermination of their nests can lead to the total elimination of some of the species of social wasps from urban areas. It seems that the most appropriate approach would be to limit the extermination of the nests only to the cases of their presence in the immediate vicinity of people, especially where there are many people (schools, hospitals). Maybe it would be worthwhile to consider installing in the future special large nesting boxes for wasps in places where they would not be dangerous to humans.

Acknowledgements. The author thanks prof. Bernard Staniec for valuable tips on breeding and identification of larvae and adults of the beetle *Quedius brevicornis*, the team of the Laboratory of Microbiology Department of Laboratory Diagnostics ZOZ Łódź-Śródmieście and a Medical Diagnostic Laboratory "Analityk" for help in the implementation of microbiological studies as well as thanks the municipal and forest services and especially the Regional Fire Brigade Headquarters for the long-term cooperation.

References

Ahrné, K. 2008: Local Management and Landscape Effects on Diversity of Bees, Wasps and Birds in Urban Green Areas. — Doctoral Thesis, Swedish University of Agricultural Sciences.

Antonicelli, L., Bilo, M. B., Napoli, G., Farabollini, B. & Bonifazi, F. 2003: European hornet (*Vespa crabro*) sting: a new risk factor for life-threatening reaction in hymenoptera allergic patients? — European Annals of Allergy and Clinical Immunology 35(6): 199–203.

Banaszak, J. 1980: Investigations of the fauna associated in bee-hives. — Fragmenta Faunistica 10: 1–175. [In Polish.]

Banks, B. E. C. & Shipolini, R. A. 1986: Chemistry and pharmacology of honey-bee venom. — In: Piek, T. (ed.), Venoms of the Hymenoptera: 329–416. Academic Press, London. 570 pp.

Barlow, N. D., Moller, H. & Beggs, J. R. 1996: A model for the effect of *Sphecophaga vesparum* vesparum as a biological control agent of the common wasp in New Zealand. — Journal of Applied Ecology 33: 31–34.

Berry, J. A., Harris, R. J., Read, P. E. C. & Donovan, B. A. 1997: Morphological and colour differences between subspecies of *Specophaga vesparum* (Hymenoptera: Ichneumonidae). — New Zealand Journal of Zoology 24: 35–46.

Chen, W., Yang, X., Yang, X., Zhai, L., Lu, Z., Liu, J. & Yu, H. 2008: Antimicrobial peptides from the venoms of *Vespa bicolor* Fabricius. — Peptides 29:1887–1892.

Christie, F. J. & Hochuli, D. F. 2008: Responses of wasp communities to urbanization: effects on community resilience and species diversity. — Journal of Insect Conservation 13(2): 213–221.

Dvořák, L. 2007: Parasitism of *Dolichovespula norvegica* by *D. adulterina* (Hymenoptera: Vespidae). — Silva Gabreta 13(1): 65–67.

Habermann, E. 1972: Bee and wasp venoms. —Science 177: 314–322.

Haeseler, V. 1982: Amaisen, Wespen und Bienen als Bewohner gepflasterter Bürgersteige, Parkplätze und Straben (Hymenoptera: Aculeata). — Drosera 82(1): 17–32.

Harris, R. J. & Read, P. E. C. 1999: Enhanced biological control of wasps. — Science for conservation 115:1–39.

Ishay, J. S., Raibinin, K. & Pertsin, V. 2003: Symbiotic bacteria in hornet pupal silk. —Naturwissenschaftem 90(2): 72–75.

Jeanne, R. L. & Bouwma, A. N. 2002: Scaling in nests of a social wasp: a property of the social group. — The Biological Bulletin 202: 289–295.

Kaltenpoth, M., Göttler, W., Herzner, G. & Strohm, E. 2005: Symbiotic bacteria protect wasp larvae from fungal infestation. — Current Biology 15(9): 475–479.

Kowalczyk, J. K. 1991: Materials to the knowledge of Aculeata (Hymenoptera) in Łódź. — Acta Universitatis Lodziensis, Folia zoologica et anthropologica 7: 67–114. [In Polish.]

Łyszkiewicz, Z. & Nadolski, J. 2009: Principles of actions with hymenopterans. — Kurier Strażacki 111–112: 4–5. [In Polish.]

Majka, C. G., Klimaszewski, J. & Lauff, R. 2006: New Coleoptera records from owl nests in Nova Scotia, Canada. — Zootaxa 1194: 33–47.

Nadolski, J. 2004: Nests of social wasps (Hymenoptera: Vespinae) in breeding boxes for birds in the town area of Łódź – preliminary results of investigation. — In: Indykiewicz, P. & Barczak, T. (eds), Urban Fauna of Central Europe in the 21st Century: 83–93. LOGO, Bydgoszcz. 584 pp. [In Polish.]

Nadolski, J. 2008: Occurrence of honey bee *Apis mellifera* in Town area of Łódź. — In: Indykiewicz, P., Jerzak, L. & Barczak, T. (eds), Urban fauna, Protect biotic diversity in cities: 253–259. SAR "Pomorze" Bydgoszcz. 634 pp. [In Polish.]

Nadolski, J. 2012: Structure of Nests and Colony Sizes of the European Hornet (*Vespa crabro*) and Saxon wasp (*Dolichovespula saxonica*) (Hymenoptera: Vespinae) in Urban Conditions. — Sociobiology 59(4): 1075–1120.

Nowosad, A. 1990: [Staphylinidae (Coleoptera) of mole's nests – *Talpa europaea* L. in Poland]. — Wydawnictwo naukowe Uniwersytetu Adama Mickiewicza w Poznaniu, Seria Zoologia nr 15: 1–254. [In Polish.]

Pałka, K. 2000: Pyralidae. — In: Buszko, J. & Nowacki, J. (eds), The Lepidoptera of Poland. A Distributional Checklist: 73–83. Polskie Towarzystwo Entomologiczne Poznań, Toruń. 176 pp.

Papp, L. 2000: Diptera reared from nests of *Vespa crabro* in Hungary. — Folia Entomologica Hungarica 61: 215–218.

Pawlikowski, T. & Osmański, M. 1998: Attractiveness of city environments for social wasps (Hymenoptera: Vespinae) in the area of Toruń. — Wiadomości entomologiczne 17(2): 95–104. [In Polish.]

Pawlikowski, T. & Pawlikowski, K. 2003: Wasp *Dolichovespula saxonica* (Fabr.) (Hymenoptera: Vespidae) settling wooden breeding boxes for birds in the Borecka Forest. — Wiadomości Entomologiczne 22(4): 201–210. [In Polish.]

Pawlikowski, K., Pawlikowski, T. & Szaławicz, E. 2005: Phenology of flight of social wasps (Hymenoptera: Vespidae) in the city of Toruń in the years 1981–2000. — Biblioteka Monitoringu Środowiska, Poznań: 495–500. [In Polish.]

Pawlikowski, T. 2009: Structural dynamic of social wasp communities (Hymenoptera: Vespinae) in forest areas destroyed by acid rains in the Karkonosze Mountains. — Ecological Questions 11: 43–48.

Rose, E. A. F., Harris, R. J. & Glare, T. R. 1999: Possible pathogens of social wasps (Hymenoptera: Vespidae) and their potential as biological control agents. — New Zealand journal of ecology 26: 179–190.

Sawoniewicz, J. & Wiśniowski, B. 2007: Contribution to the knowledge of ichneumonid wasps (Hymenoptera: Ichneumonidae) parasitising Aculeata in Poland. —

Wiadomości entomologiczne 26(1): 27–33. [In Polish.]

Schmid-Hempel, P. 1998: Parasites in social insects. — Princeton University Press, Princeton NewJersey. 392 pp.

Schmidt, J. O. 1986: Allergy to Hymenoptera venoms. — In: Piek, T. (ed.), Venoms of the Hymenoptera: 509–546. — Academic Press, London. 570 pp.

Skibińska, E. 1987: Structure of wasp (Hymenoptera, Vespidae) communities in the Urban Green of Warsaw. — Memorabilia Zoologica 42: 37–54.

Staniec, B. 2003: Morphology of the mature larva and pupa of *Quedius brevicornis* (Thomson, 1860) (Coleoptera: Staphylinidae). — Annales Zoologici 53(4): 673–680.

Staniec, B. & Zagaja, M. 2008: Rove-beetles (Coleoptera: Staphylinidae) of ants nests of the vicinities of Lazajsk. — Annales Universitatis Mariae Curie-Skłodowska Lublin – Polonia, LXIII/1/9: 111–127.

Stocker, J. F. & Traynor, J. R. 1986: The action of various venoms on *Escherichia coli*. — Journal of Applied Bacteriology 61: 383–388.

Xu, X., Li, J., Lu, Q., Yang, H., Zhang, Y. & Lai, R. 2006: Two families of antimicrobial peptides from wasp *Vespa magnifica* venom. — Toxicon 47: 249–253.

Yibin, G. Jiang, Z., Hong, Z., Gengfa, L., Liangxi, W., Guo, W. & Yongling, L. 2005: A synthesized cationic tetradecapeptide from hornet venom kills bacteria and neutralizes lipopolysaccharide in vivo and in vitro. — Biochemical Pharmacology 70(2): 209–219.