P O L I S H J O U R N A L O F E N T O M O L O G Y
P O L S K I E P I S M O E N T O M O L O G I C Z N E

VOL. **79**: 291-305 Bydgoszcz 30 September 2010

High number of cuckoo wasps (Hymenoptera: Chrysididae) in areas directly affected by lime and sodium industry

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ABSTRACT. Preliminary field research was conducted in 2007-2009 in areas directly affected by lime industry and sodium industry in the region of Kujawy (Kuyavia) in northern Poland. A surprisingly high number of cuckoo wasps (Chrysididae) were caught there: 2683 individuals of 26 species. These taxa account for about 34% of the total number of chrysidid species in Poland. The studied chrysidid communities were dominated by *Hedychrum gerstaeckeri*, which make up more than a half of the total catch. Results of this study imply that industry does not always have a negative effect on the local fauna or flora.

KEY WORDS: Hymenoptera, Chrysididae, industrial areas, lime industry, sodium industry, Kujawy, Poland, Correspondence Analysis.

INTRODUCTION

Currently it is estimated that the family Chrysididae (cuckoo wasps) includes about 5000 species, mostly found in tropical and oriental regions (STRUMIA 2009). In Poland this group of insects was rarely a subject of separate studies. Information about them was collected mostly during studies of other aculeates.

Based on published data, it can be concluded that till the 1980s, 62 species were recorded in Poland (BANASZAK 1980), but currently 77 species of hymenopterans of the family Chrysididae are reported in our country (CELARY 2004, WIŚNIOWSKI & SZCZEPKO 2009, 2010). Data about cuckoo wasps of the Wielkopolska-Kujawy Lowland, where our study area is located, were mostly collected in the 1950s and 1970s. Research in this region was conducted primarily by TORKA (1910, 1917), SZULCZEWSKI (1917, 1922, 1950), BANASZAK (1970, 1972), and WÓJTOWSKI & SZYMAŚ (1973). However, most of the studies in

the Wielkopolska region covered natural habitats, while no data were available from industrial areas. So far, such habitats, as potentially less attractive for cuckoo wasps, have not been studied in Poland and worldwide.

This study is the first attempt to describe chrysidid communities exposed to strong human pressure in areas transformed by lime and sodium-salt industry.

Acknowledgements

We sincerely thank Mr Jacek KACZMAREK (Director of Zakład Kujawy, TRZUSKAWICA S.A.) and Mr Jan SZCZEPAŃSKI (President of the Board of Soda Polska CIECH Ltd.) for permission to conduct our research. We are also grateful to the workers who personally helped us to carry out this study.

STUDY AREA

Our study area (Fig. 1) includes plots directly influenced by lime industry (TRZUSKAWICA S.A.: Zakład Kujawy in Bielawy near Pakość) and sodium-salt industry (Soda Polska CIECH Ltd.: SODA MĄTWY in Inowrocław, and JANIKOSODA in Janikowo near Inowrocław). Field research was conducted in 6 plots:
(1) within the grounds of TRZUSKAWICA: plot Bielawy (in square YU05 on the Polish UTM grid),
(2) near sedimentation ponds with salted lime silt in JANIKOSODA: plot Giebnia (in square CD05),
(3,4) near sedimentation ponds with salted lime silt in SODA MĄTWY: plots Mątwy-2 and Mątwy-3 (both in square CD14),
(5,6) in the area of sedimentation ponds in SODA MĄTWY and JANIKOSODA: plots Mątwy-4 and Janikowo (both in square CD14).
According to their environmental policies, a major objective of those industrial works is to limit their negative effect on the environment by reducing the emission of particulate pollution into the air, protection of surface waters and groundwater, limitation of noise and its effect on the environment (TRZUSKAWICA), and limited production of silt sediments (SODA MĄTWY and JANIKOSODA). The sediments contain mostly CaCO3, CaSO4, Ca(OH)2, Fe(OH)3, silicates and aluminosilicates, while the supernatant is a solution of NaCl, KCl, NH4OH, Na2SO4, NaOH, MgCl2, and $CaCl_2$ (ABRAMSKI & SOBOLEWSKI 1977). They are collected in sedimentation ponds, so-called "white seas".

Description of research plots

1. Bielawy (studied in 2007-2009) – wooded wasteland covering a total area of about 3 ha, within the industrial grounds. Some parts of this plot are not wooded (in total about 0.8 ha). This plot lies close to a limestone quarry. The dominant plant species include

Populus nigra L., *Betula pendula* ROTH., *Salix* sp., *Robinia pseudoacacia* L., *Padus serotina* EHRH., *Prunus domestica* L. and *Malus domestica* BORKH. Herbaceous vegetation is dominated mostly by grasses: *Calamagrostis epigeyos* (L.) ROTH, *Arrhenatherum elatius* L., *Poa pratensis* L., but also *Lotus corniculatus* L., *Eryngium campestre* L., *Melilotus alba* MED., and *Echium vulgare* L.

2. Giebnia (studied in 2007-2009) – sunny, dry grassland covering about 5 ha, near sedimentation ponds. Near the grassland, an area of 2 ha is covered by self-sown *Salix* sp., *Ulmus* sp., *Sambucus nigra* L., fruit trees, and salt-marsh (covering about 1 ha) with *Salicornia europaea* L. and *Aster tripolium* L. The grassland is dominated by *Taraxacum officinalle* (WEBER s.l.), *Vicia cracca* L., *Achillea millefolium* L., *Berteroa incana* (L.) DC., *Solidago canadensis* L., *Tanacetum vulgare* L., *Conium maculatum* L., and the grasses *Calamagrostis epigeios* (L.) ROTH, *Arrhenatherum elatius* L., and *Poa pratensis* L.

3. Mątwy-2 (studied in 2007-2009) – plot located within the administrative borders of Inowrocław town. It is a sunny, dry grassland covering about 3 ha. It is part of a mosaic of arable fields, hay meadows, and the immediate vicinity of the chemical works. This plot is characterized by a high degree of human disturbance due to continuous earthworks. The plot is dominated by *Lotus siliquosus* L., *L. corniculatus* L., *Tanacetum vulgare* L., *Achillea millefolium*, *Echium vulgare* L., *Melilotus alba* MED., *Sonchus arvensis* L., *Cerastium fontanum* FRIES em. HYL., and *M. officinallis* (L.) PALLAS. In the immediate neighbourhood there are self-sown patches of *Populus alba* L., *Betula pendula* ROTH., and *Salix* sp. These patches cover about 2 ha. The grassland lies close to a salt-marsh covering about 3.5 ha, dominated by *Salicornia europaea* L., *Aster tripolium* L., and *Triglochin maritima* L. The major grass species include *Calamagrostis epigeyos* (L.) ROTH, *Arrhenatherum elatius* L., and *Poa pratensis* L.

4. Mątwy-3 (studied in 2007-2009) – plot covering about 2.5 ha, situated within the administrative borders of Inowrocław town. It is a dry grassland located beside sedimentation ponds of the chemical works. The ponds have been partly transformed into a municipal rubbish dump. The dominant plant species include *Coronilla varia* L., *Echium vulgare* L., *Tanacetum vulgare* L., *Euphorbia cyparissias* L., *Euphorbia esula* L., *Papaver rhoeas* L., and *Eupatorium cannabinum* L. The grassland is bordered by a ditch with saline water. Its edges are overgrown by *Salicornia europaea* L., *Spergularia salina*, *Atriplex nitens* SCHKUHR. In wet parts of the grassland also some other halophytes are found, e.g. *Lotus siliquosus* L., *Triglochin maritima* L., and *Aster tripolium* L. The major grass species are *Calamagrostis epigejos* (L.) ROTH and *Poa pratensis* L.
In this plot, pheasants (*Phasianus colchicus*) were once observed to eat out of the traps some of the caught insects, which probably affected the final results.

5. Mątwy-4 (studied in 2009) – plot located covering about 7.5 ha, within the administrative borders of Inowrocław town. It includes the area of non-rehabilitated sedimentation ponds jointly covering about 90 ha. The plot is characterized by permeable substrate (lime sediments, i.e. industrial waste) and lack of woody vegetation. The plot is dominated by *Reseda lutea* L., *Sisymbrium Loesella* L., *Echium vulgare* L., *Tanacetum vulgare* L., *Eupa-*

torium cannabinum L., *Cerastium fontanum* FRIES em. HYL., *Cerastium semidecandrum* L., *Myosotis arvensis* (L.) HILL, *Lappula squarrosa* (RETZ.) DUM., and the grass species *Calamagrostis epigeyos* (L.) ROTH, *Arrhenatherum elatius* L., *Dactylis glomerata* L., *Poa pratensis* L., and *Poa compressa*.

6. Janikowo (studied in 2007-2009) – a plot in the area of rehabilitated sedimentation ponds, jointly covering about 7 ha. Their rehabilitation consisted in filling them with earth and sowing of grass. Single clumps of trees are formed mostly by *Salix* sp. The total area of the ponds is about 210 ha (area of rehabilitated about 107 ha). The plot is dominated by the grasses *Arrhenatherum elatius* L., *Dactylis glomerata* L., *Poa pratensis* L., *Poa compressa*, as well as *Sonchus arvensis* L., *Sisymbrium loeselli* L., *Reseda lutea* L., *Achillea millefolium* L., *Taraxacum officinale* WEB., *Echium vulgare* L., and *Senecio sylvaticus* L.

Fig. 1. Location of study plots. A - TRZUSKAWICA S.A. - Zakład Kujawy; B - SODA MĄTWY in Inowrocław. (Photo by J. TWERD).

METHODS

Field research was conducted in growing seasons of 2007-2009 (April to September). Insects were caught in Moericke traps (white pans) filled with a mixture of water (94.2%), ethyl glycol (5.6%), and detergent (0.2%). The traps were emptied every 10 days. In each plot, 6 traps were placed (each on a metal rod, 60 cm above ground).

The structure of chrysidid communities in all plots was characterized on the basis of the Shannon index of diversity *H'* (SHANNON & WEAVER 1963) and species evenness *J'* (PIELOU 1977).

Cluster analysis was based on numerical methods. As probability measures in the calculations, we used Euclidean distance and Jaccard's coefficient. The dendrogram was constructed using the UPGMA method. The calculations were made by MVSP software (demo) (CA. 1986-1999).

In the indirect gradient analysis (ordination), Correspondence Analysis (CA) was used. The choice of this method was associated with the earlier Detrended Correspondence Analysis (DCA), which showed unimodality of the data. The analysis did not take into account the species that were recorded only once during this study. The calculations were made by MVSP software (KOVACH 1986-1999).

RESULTS

Species diversity

During this study, we caught 2683 cuckoo wasps of 26 species. They account for 33.77% of the total number of chrysidid species in Poland and belong to 6 genera: *Hedychrum* (89.64% of the total catch), *Chrisis* (4.44%), *Hedychrydium* (2.42%), *Holopyga* (2.31%), *Euchroeus* (1.11%), and *Omalus* (0.08%).

Relative abundance of the recorded species is presented in Table 1. Species diversity and abundance of cuckoo wasps in individual plots (Table 2) varied greatly between years. This is probably due to changes in the environment, both natural ones and those caused by human disturbance (plant succession, deforestation, stealing of traps).

Cuckoo wasps of the genus *Hedychrum*

Chrysidids of the genus *Hedychrum* were the most common in all the plots. In total, 2412 individuals of 4 species of this genus were recorded.

Table 1. Abundance classes of individual species of Chrysididae in the analysed study period.

L.	Species	**Abundance class (no. of individuals)**				
		≤10	11-50	51-250	250-1000	> 1000
1.	*Omalus bidentulus* (LEPELETIER, 1805)	+				
2.	*O. pusillus* (FABRICIUS, 1804)	+				
3.	*O. auratus* (LINNAEUS, 1761)					
4.	*Holopyga fastuosa generosa* FOERSTER, 1853			+		
5.	*H. gloriosa* (FABRICIUS, 1793)	+				
6.	*Hedychridium roseum* (ROSSI, 1790)	+	+			
7.	*H. ardens* (COQUEBERT, 1801)					
8.	*H. coriaceum* (DAHLBOM, 1854)		+			
9.	*Hedychrum nobile* (SCOPOLI, 1763)			+		
10.	*H. micans* LUCAS, 1849				+	
11.	*H. intermedium rutilans* DAHLBOM, 1854			+		
12.	*H. gerstaeckeri* CHEVRIER, 1869					+
13.	*Euchroeus neglecta* (SHUCKARD, 1837)		+			
14.	*Chrysis trimaculata* FOERSTER, 1853	+				
15.	*C. gracillima* FOERSTER, 1853	+				
16.	*C. bicolor* LEPELETIER, 1806		+			
17.	*C. cyanea* LINNAEUS, 1761		+			
18.	*C. calimorpha* MOCSARY, 1882	+				
19.	*C. iris* CHRIST, 1791	+				
20.	*C. inaequalis* DAHLBOM, 1845	+				
21.	*C. viridula* LINNAEUS, 1761	+				
22.	*C. rutilans* OLIVIER, 1790	+				
23.	*C. splendidula* ROSSI, 1790	+				
24.	*C. graelsii sybarita* FOERSTER, 1853	+				
25.	*C. obtusidens* DUFOUR et PERRIS, 1840		+			
26.	*C. ignita* (LINNAEUS, 1758)		+			

Table 2. Species richness and abundance of Chrysididae in individual plots.

Plot	Number of species/number of individualsin study years				
	2007	2008	2009	Total no. of individuals	Mean no. of individuals
Bielawy	-	18/119	7/13	132	66.0
Giebnia	11/20	14/36	5/ 11	67	22.3
Mątwy-2	10/381	9/ 714	13/190	1285	428.3
Mątwy-3	-	-	5/46	46	-
Mątwy-4	-	-	12/ 958	958	-
Janikowo	8/32	12/ 71	14/92	195	11.33

Hedychrum gerstaeckeri CHEVRIER, 1869

Widespread in the Palaearctic (LINSENMAIER 1997), including Poland. It is a parasitoid of sand wasps (Bembicini) of the genera *Cerceris* LATR., *Philanthus* FABR., and *Oxybelus* LATR., as well as bees of the subfamily Halictinae and *Osmia* (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980, LINSENMAIER 1997). The highest percentage contribution (Fig. 2) of individuals of this species was recorded in plots Mątwy-2 (66.38%), Mątwy-4 (51.15%), and Mątwy-3 (45.65%), while the lowest in Giebnia (17.91%), Janikowo (20.00%), and Bielawy (33.33%).

Hedychrum intermedium rutilans DAHLBOM, 1854

Distributed in Europe, western Asia, and North Africa (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980). Common in Poland, It is a parasitoid of sand wasps (Bembicini) of the genus *Philanthus* FABR., and bees of the subfamily Halictinae (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980). Found most often on sandy and sunny sites (BANASZAK 1980).

The percentage contribution of this species to the total catch did not exceed 20% in any plot: Mątwy-4 (17.43%), Giebnia (4.48%), Bielawy (3.03%). Its lowest contributions were recorded in Janikowo (1.02%) and Mątwy-2 (1.48%). In Mątwy-3 this species was not noted in 2009.

Hedychrum micans LUCAS, 1849

Distributed probably in most of the Palaearctic region (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980). Common in Poland, it is a parasitoid of sand wasps (Bembicini) of the genera *Cerceris* LATR. and *Philanthus* FABR., but also of bees of the subfamily Halictinae as well as the Vespidae (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980).

Percentage contributions of this species were the highest in Mątwy-2 (22.96%), Mątwy-4 (22.55%), and Janikowo (19.27%), while the lowest in Mątwy-3 (2.17%), Bielawy (9.85%), and Giebnia (12.48%).

Hedychrum nobile (SCOPOLI, 1763)

Palaearctic (KIMSEY & BOHART 1990), found in open, sunny habitats. Common in Poland, it is a parasitoid of sand wasps (Bembicini) of the genera *Cerceris* LATR. and *Philanthus* FABR., but also of bees of the subfamily Halictinae and of the vespid *Odynerus parietum* (NOSKIEWICZ & PUŁAWSKI 1958, BANASZAK 1980). The percentage contribution of this species to the total catch did not exceed 15% in any plot: Giebnia (11.92%), Janikowo (6.15%), Mątwy-2 (6.07%). Its lowest contributions were recorded in Bielawy (0.15%), Mątwy-3 (2.17%), and Mątwy-4 (4.59).

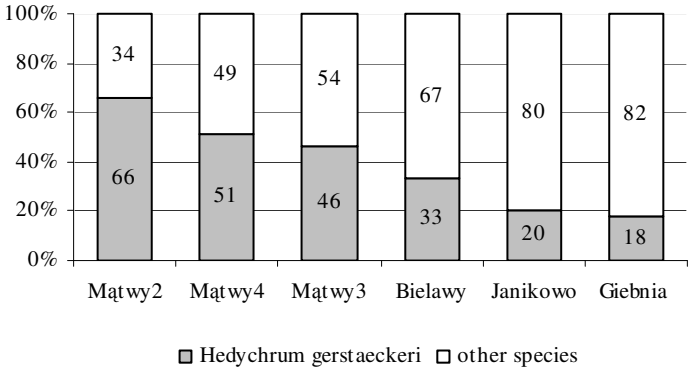

Fig. 2. Percentage contribution of *Hedychrum gerstackeri* to the total catch of Chrysididae.

Diversity index and species evenness

The Shannon index of species diversity *H'* in chrysidid communities in the study area ranged from 0.89 to 2.27, while species evenness *J'* from 0.43 (Mątwy-2) to 0.96 (Giebnia) (Fig. 3).

The lowest value of diversity index (0.89) was recorded in Mątwy-3, whereas the highest in Bielawy (2.27), where as many as 18 chrysidid species were recorded. A high diversity was also observed in Giebnia (2.20), where species evenness J' reached 0.96. Species diversity index was low in Mątwy-2 (0.99), Mątwy-3 (0.89), and Mątwy-4 (1.31). In Mątwy-2 and Mątwy-4, because of the dominance of *Hedychrum gerstackeri*, also species evenness was low: 0.43 in Mątwy-2 and 0.54 in Mątwy-4. By contrast, in Mątwy-3, species

evenness reached 0.64. In this plot, the lowest number of species was recorded, i.e. only 5 taxa (Fig. 3). It can be concluded that areas exposed to strong human pressure (permeable substrate in Mątwy-4, earthworks in Mątwy-2) or the impact of wildfowl (in Mątwy-3) were characterized by a lower species diversity.

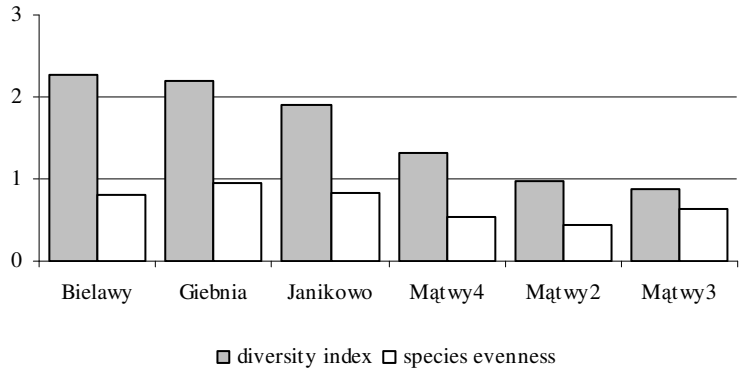

Fig.3. Species diversity and evenness of chrysidid communities in individual plots.

Similarity of chrysidid communities

Cluster analysis, taking into account both qualitative and quantitative aspects of community structure, allowed grouping of similar communities (Figs 4-5).

The most distinct group, in respect of both species diversity and abundance, was constituted by the chrysidid community in Mątwy-3. This plot is characterized by the lowest species richness and diversity (Figs 3-5). This is probably associated with the impact of wildfowl observed in this plot. In the qualitative analysis, the second group is divided into several subgroups. Among them, the most similar are the communities of Mątwy-4 (the area of non-rehabilitated sedimentation ponds with permeable substrate) and Mątwy-2 (grassland subject to repeated earthworks, located close to sedimentation ponds). The most similar is the chrysidid community in Janikowo (area of rehabilitated sedimentation ponds). Somewhat different are the communities in Bielawy and Giebnia: in wooded habitats and grassland, which are less exposed to human pressure (Fig. 4).

In the quantitative analysis, the second group is divided into 2 subgroups. Among them, the chrysidid community in Bielawy is the most distinct from the others. The cuckoo wasps found in this plot are characterized by the highest species richness (18 species), diversity (2.27), and relatively high species evenness (0.80). Another subgroup of communities very similar in respect of abundance is composed of communities from plots Mątwy-4 and Mątwy-2 (the area of non-rehabilitated sedimentation ponds with salted lime silt, and

grassland near sedimentation ponds). The chrysidid communities in Janikowo and Giebnia are somewhat different. (Fig. 5). The results to a large extent are consistent with the qualitative analysis.

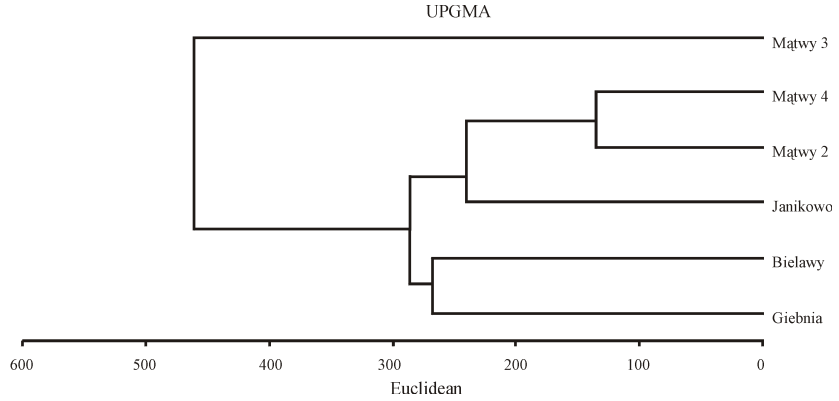

Fig. 4. Qualitative similarity of chrysidid communities in all study plots.

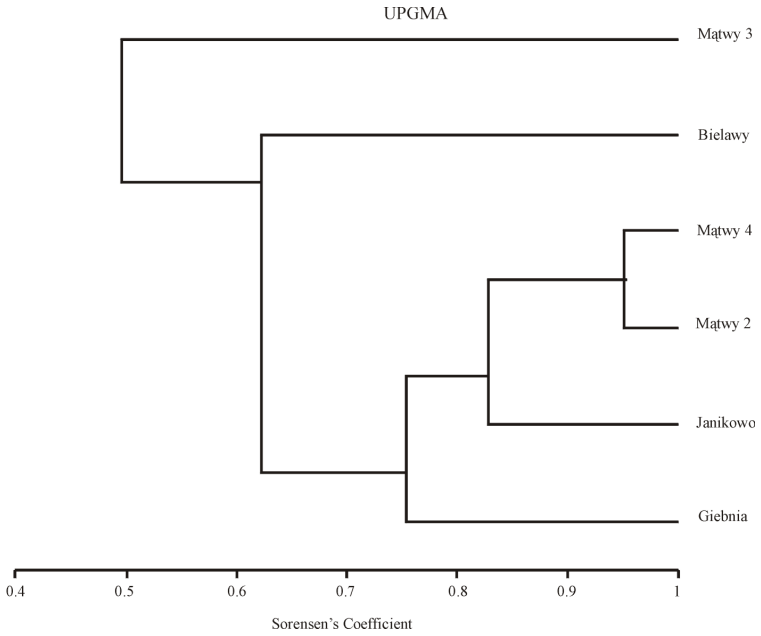

Fig. 5. Quantitative similarity of chrysidid communities in all study plots.

Gradient analysis

In this set of data, the first and second ordination axis explain 43.83% and 25.68% of the variation in community structure, respectively. The central part of the ordination diagram (Fig. 6) is occupied by the first group of species: *Hedychrum nobile* (SCOPOLI, 1763), *H. micans* LUCAS, 1849, *H. intermedium rutilans* DAHLBOM, 1854, *H. gerstaeckeri* CHEVRIER, 1869. They were most abundant in Mątwy-4 (area of non-rehabilitated wastewater ponds) and Mątwy-2 (grassland near sedimentation ponds). The areas are exposed to strong human pressure. This group includes also *Chrysis rutilans* OLIVIER, 1790, and *C. splendidula* ROSSI, 1790. The analysis showed that they too are associated with such habitats (Fig. 6).

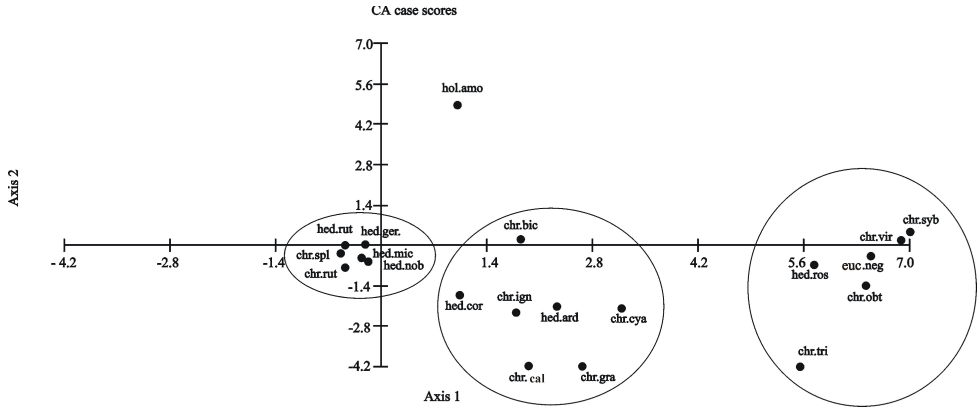

Fig. 6. Ordination diagram (results of Correspondence Analysis, CA) of species distribution in relation to canonical axes 1 and 2. **Group I**: chr.rut = *Chrysis rutilans*; chr.spl = *Chrysis splendidula*. hed.ger = *Hedychrum gerstaeckeri*; hed.mic = *Hedychrum micans*; hed.nob = *Hedychrum nobile*; hed.rut = *Hedychru intermedium rutilans*; **Group II**: chr.bic = *Chrysis bicolor*; chr.cya = *Chrysis cyanea*; chr.gra = *Chrysis gracillima*; chr.ign = *Chrysis ignita*. chr.pul = *Chrysis calimorpha*; hed.ard = *Hedychridium ardens*; hed.cor = *Hedychridium coriaceum*; **Group III**: chr.obt = *Chrysis* obtusidens; chr.vir = *Chrysis viridula*; chr.syb = *Chrysis graelsii sybarita*; hed.ros = *Hedychridium roseum*; euc.neg = *Euchroeus neglecta*.

The second group is composed of *Hedychridium ardens* (COQUEBERT, 1801), *H. coriaceum* (DAHLBOM, 1854), *Chrysis gracillima* FOERSTER, 1853, *C. bicolor* LEPELETIER, 1805, *C. cyanea* LINNAEUS, 1761, *C. calimorpha* MOCSARY, 1882, and *C. ignita* (LINNAEUS, 1758). These species were most abundant in the area of rehabilitated sedimentation ponds (Janikowo), as well as in Mątwy-3 and Giebnia.

The last group consists of taxa recorded mostly in Bielawy: *Hedychridium roseum* (ROSSI, 1790), *Euchroeus neglecta* (SHUCKARD, 1837), *Chrysis viridula* LINNAEUS, 1761, *C. graelsii sybarita* FOERSTER, 1853 and *Chrysis obtusidens* DUFOUR et PERRIS, 1840 (Fig. 6).

The observed distribution of species in various habitats seems to be mostly shaped by two factors. The first ordination axis may be interpreted as the degree of human pressure. The second axis, at the current stage of research, is difficult to interpret. The degree of human pressure is affected by environmental conditions. The less stable they are, the greater is the pressure that may determine species distribution.

The results will be subject to further verification. In the near future, we plan to continue research in the Inowrocław Region of Environmental Threat.

DISCUSSION

Results of this study show that areas transformed by human activity may be exceptionally valuable sites of occurrence of interesting species of Aculeata, including Chrysididae. This was earlier noticed also by KOWALCZYK and NADOLSKI (2007), who found 20 species of Chrysididae near railway stations and sidings in Łódź city (central Poland). Unfortunately, so far, there have been no published data on the occurrence of this interesting group of insects in industrial areas, both in Poland and worldwide. Earlier reports of entomologists have focussed on natural habitats, which are not exposed to strong human pressure and in urban areas.

Polish data on the distribution of cuckoo wasps, starting from the 1970s, can be found, e.g., in reports of KOWALCZYK (1988a, 1990, 1991, 1994, 1995 1998), KOWALCZYK & ŚLIWIŃSKI (1996), KOWALCZYK & SZCZEPKO (2001), KOWALCZYK & KURZAC (2003), and KOWALCZYK & NADOLSKI (2007). There are also monographs written by BANASZAK (1970, 1972, 1975, 1980), BANASZAK & KOCHANOWSKI (1994), and WIŚNIOWSKI & SZCZEPKO (2009). The last work is the most informative review of data on the occurrence of Chrysididae in protected areas in Poland. Those authors list 46 species of cuckoo wasps from the Kampinos National Park, supplemented with two additional species reported in 2010 (WIŚNIOWSKI & SZCZEPKO 2009, 2010).

The areas directly affected by lime and sodium industry in northern Poland are, surprisingly, refuges of xerothermic vegetation and halophytes (WAROT et al. 2003), and create favourable conditions for some insect species, including aculeates (L. TWERD, unpubl. data). It could be expected that in areas exposed to strong disturbances, particularly intensive in the Inowrocław region, chrysidid communities should be poor in species. However, in this study we recorded a total of 26 chrysidid species, represented by as many as 2683 individuals! Our total study area was only about 0.3 km^2. In comparison to the area of, e.g., the Kampinos National Park (385.44 km^2), where 48 chrysidid species were recorded and their abundance was much lower, our results seem to be particularly interesting.

The dominant chrysidid genus in our study area was *Hedychrum*, as it accounted for 89.64% of the total catch. The dominant species was *Hedychrum gerstaeckeri* CHEVRIER, 1869, which made up 54.38% of the total. This and other *Hedychrum* species are associated with dry habitats (BANASZAK & KOCHANOWSKI 1994). In the analysed period, great variation was observed in the abundance of cuckoo wasps. Most probably, these differences are due to changes in environmental conditions.

Both qualitatively and quantitatively, the most similar are the chrysidid communities of Mątwy-2 and Mątwy-4. These plots are specific, unstable habitats where unfavourable conditions slow down plant succession towards grassland. These areas are characterized by relatively permeable substrates and partly lack the plant cover because of continuous earthworks. They are associated mostly with *Hedychrum* species. The most distinct was plot Mątwy-3, where plant diversity was high but chrysidid diversity was the lowest. This, however, may be due to the impact of wildfowl (i.e. mostly pheasants, which ate out of the traps some of the insects caught in this plot).

When analysing species distribution in various habitats, we distinguished 3 groups of species with similar habitat preferences. The first group is composed mostly of *Hedychrum* species, which are found in habitats greatly transformed by human activity. These plots, because of the high abundance of dominant species, are characterized by low values of diversity index.

The second group includes *Chrysis bicolor* LEPELETIER, 1806, *C. ignita* (LINNAEUS, 1758), *C. cyanea* LINNAEUS, 1761, *C. calimorpha* MOCSARY, 1882, *C. gracillima* FOERSTER, 1853, *Hedychridium ardens* (COQUEBERT, 1801), and *H. coriaceum* (DAHLBOM, 1854). Their habitat is a typical meadow. In Janikowo (rehabilitated wastewater pond), the meadow is managed conventionally.

It also seems interesting that the chrysidid community found in Bielawy (group III) in wastelands of TRZUSKAWICA, is the richest in species. Most probably, this is associated with the close location of a limestone quarry owned by Lafarge Poland Ltd. That quarry may be a natural refuge of interesting insect species. Such habitats are typically colonized by *Hedychridium roseum* (ROSSI, 1790), *Euchroeus neglecta* (SHUCKARD, 1837), *Chrysis viridula* LINNAEUS, 1761, *C. graelsii sybarita* FOERSTER, 1853, and *C. obtusidens* DUFOUR et PERRIS, 1840.

Our results on species diversity of cuckoo wasps in areas affected by lime and sodium industry seem to be highly valuable not only for scientists. They confirm that industrial plants, such as those described in this study, may have a positive effect on species diversity. This may be particularly valuable for preservation and migration of taxa in the agricultural and industrial landscape.

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Received: April 10, 2010
Accepted: August 16, 2010