Marcin Sikora, Aneta Sikora, Iwona Lis, Paweł Michołap, Tomasz Strojny

The reclaimed sites of "Górażdże" Limestone Quarry as a potential habitat for wild bees occurrence

ABSTRACT

The objective of the studies on Górażdże limestone quarry area, managed by members of NiC Association was to indicate and catalog the bees species and their food plants, together with habitat description.

The surveys were conducted during March-August 2014 period. On the Quarry area four experimental quarters were selected: two restored xerothermic meadows,"Kamień Śląski" Reserve and the Reserve surrounding. The apifauna monitoring was carried out using linear transect method. Bee fauna monitoring was conducted using linear transects and observation time within 30 minutes. Bees and their foodplants were catalogued by macro photography methods.

At the Górażdże Limestone Quarry the occurrence of 22 wild bees species belonging to five families was recorded. Bees visited 39 species of plants from which the most attractive were birdsfoot trefoil *Lotus corniculatus*, kidneyvetch *Anthyllis vulneralia*, Cicer milkvetch *Astragalus cicer* and Viper's bugloss *Echium vulgare*. Element to ensure adequate bee development were plants blooming in spring and suitable places for nesting.

In order to optimize the conditions for wild pollinators existence additional plantings of food plants and appropriate treatments were proposed.

INTRODUCTION

In our climate zone, most ecosystems are rich in entomophilus plants, therefore their survival and proper functioning is highly dependent on the pollinators presence , amongst which the most important are bees. Out of 469 species of bees (Hymenoptera, Apoidea) (Banaszak, 2000) occurring in Poland, relatively well documented group are bumblebees. In addition to the honey bee only bumblebees are social insects and their life cycle allows for all-season observations. For such a large and diverse group of insects like bees, it is necessary to select the indicator species, wchich have various habitat requirements and characteristics that allow easy identification. Therefore, the indicator species for surveyed quarters in Górażdże Limestone Quarry were representatives of genus *Bombus*.

Since the mid 50's adverse disappearance of species richness and the decline of bees is observed . The reason lies in reducing the area of habitats and foodplants, mainly due to the intensification and chemicals usage in agriculture. Therefore, now more than half of Polish bees species appear on the Red List of Threatened Animals in Poland (Banaszak 2002). Their active protection is a necessity, and the exploration and creation of alternative refuge sites should be a priority. Conducted in 2012, reclamation work at the Górażdże Limestone Quarry

to restore xerothermic meadows, seems to perfectly fit into the framework of the active protection of wild and endangered bees. Xerothermic meadows are characterized by a relatively high floristic diversity, which attracts oppulence of useful entomofauna.

OBJECTIVES

The aim of the conducted studies was to list the bees species (Hymenoptera, Apoidea) existing in Górażdże Limestone Quarry and to determine the available food base in form of flowering plants and suitable nesting sites. In order to assess habitats quality bumblebees were selected as "umbrella species".

Studies were also undertaken to supplement the Quarry Inventory of Flora and Fauna from year 2005, in which bees were not included. Determining the condition of wild bees population and their foodplants spectrum makes possible to create basis for such ways of reclamation, which embrace environmental needs of these exceedingly important insects.

METHODS

In order to survey wild bees in Górażdże limestone quarry four research quartes were designated, including two restoring xerothermic meadows, "Kamień Śląski" Reserve and the Reserve Roadside. The primar factor to select research quarters was the congeries of flowering plants (Fig.1).

Field studies were carried out in March-August 2014 period. In order to determine the species composition and bees abundance in particular habitats the linear transects method and 30 minutes time observations were used (Banaszak 1980). Remarks were performed between 10 am - 4 pm in flights favourable weather conditions: during sunny and not windy weather and temperature above 22^{o}C (Banaszak 1991). During observations specimens were counted, identified to species range and their foodplants written down (Fig.2.). The quarters were surveyed once a month, except July and August when studied twice. For that period the highest peek of development for majority of bees species is exposed.

Bumblebee species were identified by life, based on the key field (Celary 2001; Dylewska Flag; 2000; Pawlikowski 1999). Uncertain specimens were caught using entomological nets, later released after identification. Other bees species were photographed, and their systematic affiliation were consulted in the Apiculture Division in Pulawy (Fig.2)

RESULTS

During the researches on the Quarry area 885 bees individuals, belonging to 10 genra and 22 species were recorded. Amongst the collected data the majority species belonged to *Apidae* family, which includes honeybee *Apis mellifera* L, bumblebees and cuckoo bumblebees *Bombus spp*. Amidst bumblebees 7 species were stated: Buff-tailed bumblebee *Bombus terrestris* L., White-tailed bumblebee *B. lucorum* L., Red-tailed bumblebee *B lapidarius* L.,

Early bumblebee *B. pratorum* L, Common carder bee *B. pascuorum* Scop., Red-shanked bumblebee *B. ruderarius* Müll., Small garden bumblebee *B. hortorum* L. Cuckoo bumblebees were represented by 4 species: : Red-tailed cuckoo bumblebee *B. (Psithyrus) rupestris* F., Gypsy cuckoo bumblebee *B. (Psithyrus) bohemicus* Seidl, Southern cuckoo bumblebee *B. (Psithyrus) vestalis* Geoff. and Field cuckoo bumblebee *B. (Psithyrus) campestris* Panzer (Fig. 3).

The quarter, where the highest number of bees species (14) and specimens (439) were observed was the West Meadow. On the Reserve Roadside also 14 species were recorded and 254 individuals. At the same time, only on Reserve Roadside all 11 representatives of Bombus spp were present, in addition to other bees. On the Reserve area the least number of Apoidea representatives were noticed- only 8 individuals, all of them were bumblebees. Considering the general diversity Shanon index the highest biodiversity was on East Meadow (H '= 1.88), and lowest on Western Meadow (H' = 1.35). However, the Pielou's evenness index shows that the domination structure was the most aligned in Kamień Śląski Reserve (P=0,86) and the least on West Meadow (Fig. 3).

In the general Apoidea structure Bombus spp preveailed-77%. Honeybee A. mellifera contribution was on 18% level. The rest of bee species of Antophora, Eucera, Andrena, Halictus, Lassioglosum, Anthidium, Osmia and Hoplitis genus had a small share in a grouping (5%) (Fig. 4).

The number structure of honeybee A. mellifera and bumblebees Bombus spp indicates that dominating species on xerothermic meadows was Red-tailed bumblebee *Bombus lapidarius*. However, in the Reserve the most abundant was Common carder bee *B. pascuorum* and on the Roadside- honeybee *A. mellifera* (Fig.5.)

On the West Meadw the eudominant species were Buff-tailed bumblebee *B.terrestris* and Red-tailed bumblebee *Bombus lapidarius*. Similarly, on the Reserve Roadside eudominants were these two bumblebees species and honeybee *A. mellifera.* On East Meadow the eudominant species were Buff-tailed bumblebee *B.terrestris,* Red-tailed bumblebee *Bombus lapidarius* and was Common carder bee *B. pascuorum.* On the other hand in the Reserve all recorded bumblebee species were eudominants in the grouping (Fig. 4).

Within the food line of Apoidea bees from the Quarry 39 plant host species were enclosed (Fig. 6). The big gest number of visited plant species were observed on the West Meadow-22, the least in the Reserve-only 4 (Fig.3) Plant species, chich was the most attractive to the biigest number of bees was Viper's bugloss *Echium vulgare*. Similarly, the high turnout of visits (more than 10% of the total abundance and at least 5 species of bees) reported on plant speciesbelonging to the Fabaceae family - birdsfoot trefoil *Lotus corniculatus* L., common kidneyvetch *Anthyllis vulneralia* L. and cicer milkvetch *Astragalus cicer*. Kidneyvetch and cicer milkvetch were only reported from the West Meadow. A special role is played here by the plants blooming in spring (March-April), which provide food for bees in this crucial period. Especially valuable plants were coltsfoot Tussilago farfara L., blue bugle Ajuga reptans L. and willows Salix spp. blooming at this time of a year (Fig. 6).

DISCUSSION

It is difficult to find any data about bees occurrence in mining or post-mining areas. In 50's the only grassland position created at a limestone quarry site of Mount Wapienna near Stolec was inventoried in terms of flora and fauna (Macko, Noskiewicz, 1954). Due to presence of rare Mason-bee of the Pebbles (*Chalicodomia parietina* Fourcroy) the only reserve protecting Hymenoptera insects was created –„Skałki Stoleckie".

Areas of Opole voivoidship in terms of a bumblebee fauna were studied in the early twentieth century by German authors (Dittrich 1903, Scholz 1912, Tork 1927). Studies indicated the presence of seven bumblebee species: Buff-tailed bumblebee *Bombus terrestris*, White-tailed bumblebee *B. lucorum*, Heath bumblebee *B. jonellus*, Moss carder bee *B. muscorum*, Shrill carder bee *B. sylvarum*,. *B. veteranus*, *B . confusus*. Such a composition of bumble bee fauna indicates a rich flora of this period with a predominance of forests and scrubs.

Bilinski and Ruszkowski (1990) performed in the 70's an accurate inventory of bumblebees visiting red clover throughout the country including the Opole region. Across the whole region 17 bumblebee species were recorded. The village closest to Górażdże ie. Dobra 4 common species of bumblebees were observed AT this time. Dominant in the population, as well as at the Quarry in 2014, was the Buff-tailed bumblebee *B. terrestris* and White-tailed bumblebee *B. lucorum* with the subdominants of Red-tailed bumblebee *B. lapidarius*, and Common carder bee *B. pascuorum*. In addition, our studies have found less frequently occurring three specialized species: Early bumblebee *B. pratorum*, Red-shanked bumblebee *B. ruderarius*, Small garden bumblebee *B. hortorum* and 4 cuckoo bumblebees: Red-tailed cuckoo bumblebee *B. (Psithyrus) rupestris*, Gypsy cuckoo bumblebee B. (Psithyrus) bohemicus, Southern Cuckoo bumblebees *B. (Psithyrus) vestalis* Geoff. and Field Cuckoo bumblebee *B. (Psithyrus) campestris*. Therefore, their presence at the Quarry indicates that their hosts – bumblebees had adequate conditions for stabilized existence.

The wild bees inventory were performed in the country with regard to areas under legal protection, in the agricultural landscapes and in the cities or the Botanical Gardens. Most of these studies are based on a different methodology, the bees were catched in the colour traps, and then identified. Our studies were based on the method of noninvasive observation in afield, therefore the number of species recorded at the mine may be lower, than it is actually.

On the Reserve Roadside rich set of host plants affect the high apifauna diversity. Honeybee were dominating species, and constant species in this grouping were bumblebees - *B. terrestris* and *B. lapidarius*. A similar scheme was observed on the rural enviroment roadside (Banaszak, 1985).

The East and West Meadow had a similar arrangement of Apoidae grouping. The dominance of *B. lapidarius* with various contribution of the other bumblebees was associated with specific composition of Fabaceae species plants. Red-tailed bumbblebee prefers plants with yellow-colored floral and butterfly structure (Sikora, Kelm 2012), and those were *Lotus corniculatus L., Anthyllis vulneralia L. Astragalus cicer L*. In addition, the presence of numerous piles of stones near grasslands created suitable places for nesting. Moreover, willow trees blooming during spring period near the West Meadow were valuable Skurce of pollen for freshly merged bumblebee queens and solitary bees. In addition, the presence of numerous piles of stones near Meadows created suitable nesting sites for bees.

The Reserve is located in close vicinity of the Quarry and plays a vital role as a place where the bees can find food during spring. Plants with long floral crown were visited mainly by young mothers of medium-tongued bumblebees - *B. pascuorum*. In the later months due to poor fleece Reserve was not attractive to bumblebees, which occured in the Quarry.

It should be emphasized that apart of foodplants, Górażdże limestone quarry creates favorable conditions for nesting by wild Apoidea, being also refugee environment in which the full development and lifecycle of these insects might be possible. Such places were mostly sunny rocky slopes with scattered stones, sand and clay escarpment edge of the forest and the place of the dried, former-year grass (Fig.7). Such areas are particularly important for the presence of wild bees (Ruszkowski et al, 1998) and are abundant in the studied areas of the Quarry. Most of th solitary bees (Andrena types, Eucera, Halictus), found at the mine build their nests in sandy soils or clay (Celary 2001).

An important factor influencing the existence of many bee species is the presence of suitable host plants, especially of the Fabaceae family. In Poland cultivations of plants like clover *Trifolium spp*., and alfalfa *Medicago spp*. collapsed (Dylewska 1996). Growing legumes were popular in most of European countries and provided food not only to farm animals, but also werea food base for bumblebees and other bees. After the introduction of low-cost fertilizers crop rotation with legumes was ceased (Edwards, 1999).). There was also a regress in terms of legume meadows (Goulson, 2010). In UK between 1932 and 1984 90% of lowland meadows disappeared, and with them the whole potential of legumes. Two plants *Trifolium pratense* and *Lotus corniculatus* provided almost 40% of pollen for collecting it bumblebees (Goulson et al. 2005). Their presence was found at three surveyed sites, and the most abundant species, birdsfoot trefoil was also one of the main host plants for bees (Celary 2001) in the Quarry.

SUMMARY

1. Amongst 22 species of bees observed in the limestone mine Górażdże the greatest abundance and contribution in a grouping were bumblebees Bombus spp., and honeybee *Apis mellifera*.

2. The photographic documentation included the Quarry Apoidea bees from genus, Antophoridae, Andrenidae, Halictidae and Megachilidae (Fig. 8)

3. West Meadow and the Reserve Roadside were places abound in the greatest number of bees species, while the reserve was the least.

4. The Reserve Roadside was the only quarter where all of recorded bumblebees and cuckoo bumblebees were present

5. The most frequently visited plants by bees in Górażdże Limestone Quarry were birdsfoot trefoil *L. corniculatus*, kidneyvetch *A. vulneralia*, Cicer milkvetch *A. cicer* and Viper's bugloss *E. vulgare* (Fig. 9).

CONCLUSIONS AND RECOMENDATIONS

The highest quality surveyed quarter for inhabiting bees was the Reserve Roadside , where real and cuckoo bumblebees as indicator species, had the most appropriate conditions for existence.

In Górażdże Limestone Quarry there is suitable base of food plants providing food existing bees here throughout the growing season. However, due to their uneven distribution the additional foodplants should be plantem. We propose bees active protection treatments including adequate plant species for individual quarry quarters (Figure 10).

A large amount of legumes indicates poor soil quality and initial phase of reclamationon areas where they occur. At the same time their condition and spreading depends on the polinators, which exist and forage on these plants. .

In order to avoid overgrowing meadows, and loss of biodiversity appropriate treatments should be executed at such time and in such a way to ensure food base for p[olinators, which exist here. It is therefore proposed sheep grazing xerothermic meadows or mowing after seeding in order to later self-recovery and cessation of unwanted plants succession. Appropriate month for such treatments will be in September, and the resulting mass of cut plants dishould be disposed to prevent excessive accumulation of nitrogen in the soil.

At the Górażdże Limestone Quarry a large number of places for nesting bees were observed, in particular clay and sandy slope and piles of stones. However, some bees use plant material to build their nests, That is why in the planting proposals (Figure 8) plants supplying building material are included. In addition, it is proposed to set artificial nest sites in the form of insects cottages (Figure 11).

REFERENCES

1. Banaszak J. 1980. Studies on methods of censuing the numbers of bees (Hymenoptera, Apoidea). Pol. Ecol. Stud., 6, 2: 355–266.
2. Banaszak J. 1985. Zgrupowania pszczół (Apoidea) w środowisku wiejskim. Pol. Pism. Ent. 55: 115–133.
3. Banaszak J. 1991. Metody określania liczebności pszczół (Hymenoptera, Apoidea). Wiad. Entom., 10(2): 113–118.
4. Banaszak J. 2000. A checklist of the bee species (Hymenoptera, Apoidea) of Poland, with remarks on their taxonomy and zoogeography: revised version. Fragm. faun., 43, 14: 135–193.
5. Banaszak J. 2002. Apoidea Pszczoły. Czerwona lista zwierząt ginących i zagrożonych w Polsce, Polska Akademia Nauk Instytut Ochrony Przyrody red. Głowaciński Z., Kraków: 69–75.
6. Biliński M. Ruszkowski A., Kosior A. 1990. Trzmiele Śląska Górnego i Opolskiego. Pszczel. Zesz. Nauk. 34(1): 93–100.
7. Celary W. 2001. Dzikie pszczoły (Hymenoptera, Apoidea) w Polsce Klucz do oznaczania rodzin i rodzajów. Diagnostyka szkodników roślin i ich wrogów naturalnych, SGGW, Warszawa. tom IV: 137–194.

8. Dittrich R. 1903. Verzeichnis der bisher In Schlesien aufgefunden Hymenopteren. I. Apidae. Jahresheft des Vereins für schlesische Insektenkunde zu Breslau, 28: 19–54.
9. Dylewska M. 1996. Nasze trzmiele. Ośrodek Doradztwa Rolniczego APW Karniowice, Karniowice, 172ss.
10. Dylewska M. Flaga S. 2000. Barwny klucz do rozpoznawania w warunkach polowych krajowych gatunków trzmieli. Polski Klub Ekologiczny, Kraków, 80ss.
11. Edwards M. 1999. U. K. Biodiversity Action Plan Bumblebee Working Group Report, Midhurst, UK.
12. Goulson D., Hanley M.E., Darvill B., Ellis J.S., Knight M.E. 2005. Causes of rarity in bumblebees. Biol. Conserv. 122:1–8.
13. Goulson D. 2010. Bumblebees. Behaviour, Ecology and Conservation, Oxford University Press, Second Edition, 317 ss.
14. Kasprzak K., Niedbała W. 1981. Wskaźniki biocenotyczne stosowane przy porządkowaniu i analizie danych w badaniach ilościowych. W: Górny M., Grum L. (red.) Metody stosowane w zoologii gleby. Wyd. Naukowe PWN, Warszawa: 397–416.
15. Macko S., Noskiewicz J. 1954. Stanowisko rozchodnika białego (Sedum album L.) na Górze Wapiennej koło Stolca pod Ząbkowicami. Próba charakterystyki florystycznej i faunistycznej. Ochr. Przyr. 22: 167–194.
16. Pawlikowski T. 1999. Przewodnik terenowy do oznaczania trzmieli i Trzmielów Polski. Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń.
17. Ruszkowski A., Jabłoński B., Biliński M., Gosek J., Kuna K., Cybula A., Kaczmarska K. 1998. Wybór miejsc gniazdowania przez niektóre gatunki ziemnych pszczół samotnic (Hymenoptera, Apoidea). Pszczel. Zesz. Nauk. 42(1) : 273–280.
18. Scholz E. J. R. 1912. Hymenoptera aculeate. Seltenere schlesische Vorkommnisse, Jahresh. D. Ver. F. Schles. Insektenkunde zu Breslau, E. V.
19. Sikora A. Kelm M. 2012. Flower preferences of the Wrocław Botanical Garden Bumblebees (Bombus spp.). J. Apic. Sci, 56(2): 27–36.
20. Torka V. 1927. Zur Bienenfauna Oberschlesiens. Int. Ent. Z., Guben, 20: 125–130.

ATTACHMENTS

Fig.1 Map of surveyed sites in Górażdże Limestone Quarry

Legend:

-the area of studied quarter

1-The West Meadow

2-The East Meadow

3-The Kamień Śląski Reserve

4-The Reserve Roadside

Fig.2. Photographic documentation from conducted studies

Fig. 3. The structure of bees (Hymenoptera, Apoidea) grouping on surveyed quarters in Górażdże Limestone Quarry

Family	Genus	Species	Quarter								∑n
			1		2		3		4		
			n	D	n	D	n	D	n	D	**885**
Apidae	*Bombus*	*Bombus terrestris* L.	146	D5	17	D5	1	D5	46	D5	210
		B. lucorum L.	4	D1	3	D2			16	D4	23
		B lapidarius L.	214	D5	57	D5	1	D5	40	D5	312
		B. pratorum L.	3	D1			1	D5	1	D1	5
		B. pascuorum Scop.	31	D4	28	D5	4	D5	4	D2	67
		B. ruderarius Müll.	3	D1	10	D4					13
		B. hortorum L.	17	D3			1	D5	2	D1	20
		B. (Psithyrus) rupestris F.	1	D1					3	D2	4
		B. (Psithyrus) bohemicus Seidl	1	D1					3	D2	4
		B. (Psithyrus) vestalis Geoff.							6	D2	6
		B. (Psithyrus) campestris Pancer							1	D1	1
	Apis	*Apis melifera* L.	13	D3	18	D5			115	D5	146
Anthophoridae	*Anthophora*	*Antophora plumipes* Pallas			3	D2					3
	Eucera	*Eucera sp*	1	D1							1
Andrenidae	*Andrena*	*Andrena assimilis* Radoszkowski	2	D1							2
		Andrena sp	1	D1	7	D3					8
Halictidae	*Halictus*	*Halictus subauratus*							1	D1	1
	Lassioglosum	*Lassioglossum sp*							5	D2	5
Megachilidae	*Anthidium*	*Anthidium manicatum* L.			8	D4					8
	Osmia	*Osmia sp*	1	D1	1	D1					2
		Osmia sp	1	D1	1	D1					2
	Hoplitis	*Hoplitis sp*							2	D1	2
Number of species [S]			**14**		**11**		**14**		**14**		
Number of individuals[n]			**439**		**153**		**439**		**245**		
Number of visited hostplants			**22**		**15**		**22**		**19**		
General diversity Shanon index [H']			**1,35**		**1,88**		**1,35**		**1,63**		
The Pielou's evenness index [P']			**0,51**		**0,78**		**0,51**		**0,62**		

Explanation: n-the number of individuals; : D domination class: D5 - eudominant, D4 - dominant, D3 - subdominant, D2 - recedent, D1 - subrecedent (by Kasprzak, Niedbała 198 1).

Fig. 4. The structure of numerical amount bees (Hymenoptera, Apoidea) in Górażdże Limestone Quarry

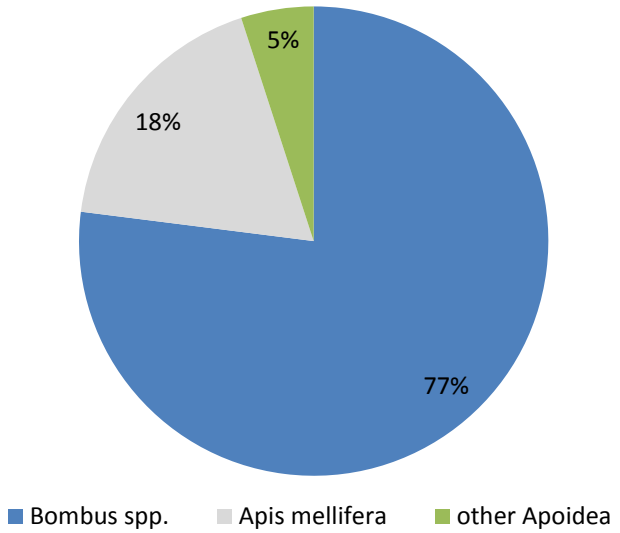

Fig. 5. The structure of numerical amount honeybee *Apis mellifera* and bumblebees *Bombus* spp. in Górażdże Limestone Quarry

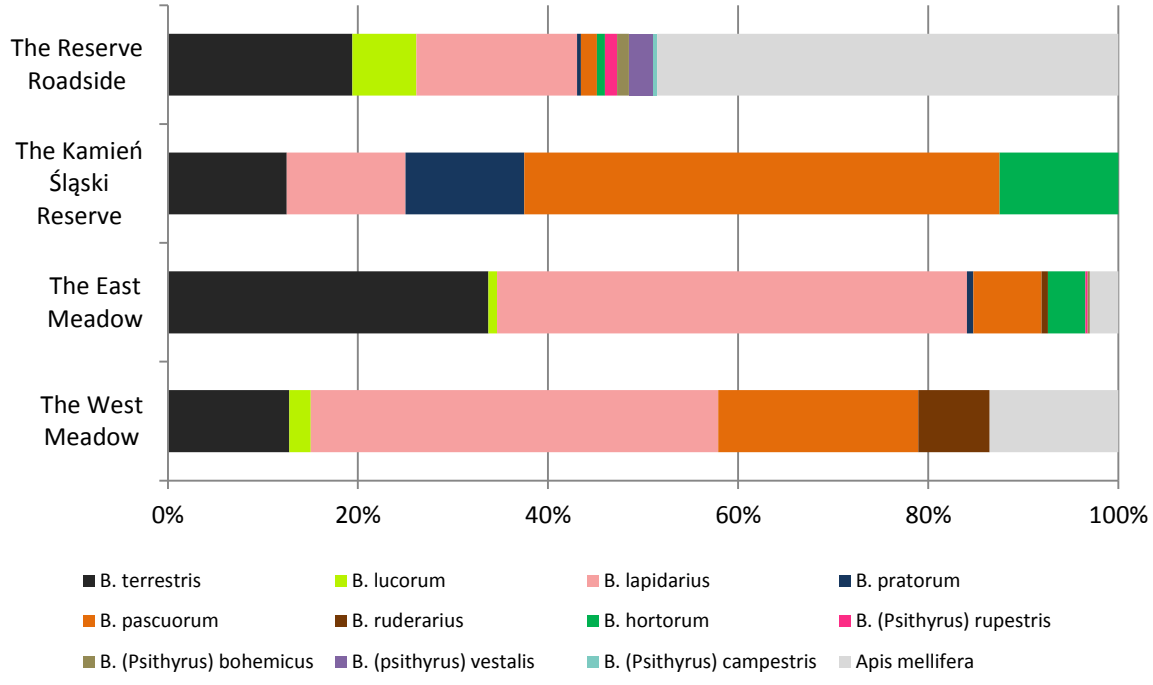

Fig. 6. Food line of bees (Hymenoptera, Apoidea) in Górażdże Limestone Quarry

Plant species	S	n [%]	Surveyed quarter				Period of flights					
			1	**2**	**3**	**4**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Tussilago farfara L.	3	0,5	**x**	x			■	■				
Salix spp.	4	1,5	x				■					
Viola reichenbachiana Boreau	2	0,3			x			■				
Glechoma hederacea L.	3	0,6		x				■				
Ajuga reptans L.	5	3,5	x	x	x			■			■	
Lathyrus vernus L.	1	0,1			x			■				
Galeobdolon luteum Huds.	3	0,3			x			■				
Taraxacum officinale WEBB.	1	0,1	x					■				
Trifolium repens L.	3	0,7	x			x			■		■	
Trifolium pratense L.	5	2,4	x	x		x			■	■	■	■
Lotus corniculatus L.	7	12,1	x	x		x			■	■	■	■
Stachys sylvatica L.	5	2,4		x					■	■	■	
Rubus sp.	4	1,0	x	x		x			■	■	■	
Ranunculus repens L.	1	0,1				x			■			
Galium verum L.	1	0,2				x			■			
Echium vulgare L.	10	23,8	x	x		x			■	■	■	
Hypericum perforatum L.	4	2,3	x	x		x			■	■	■	■
Vicia sp.	2	0,2	x						■		■	
Anthyllis vulneraria L.	8	17,5	x						■	■	■	
Geranium sp.	1	0,1		x						■		
Coronilla varia L.	2	0,7	x	x						■	■	
Trifolium dubium Sibth.	2	0,2	x							■		
Trifolium arvense L.	1	0,2	x							■	■	
Salvia pratensis L.	2	0,3	x							■	■	
Melilotus alba Medik.	6	1,5	x	x		x				■	■	■
Prunella vulgaris L.	1	0,1		x						■		
Astragalus cicer L.	5	13,3	x							■	■	■
Eupatorium cannabinum L.	2	1,2				x					■	■
Medicago lupulina L.	1	0,1	x								■	
Cirsium vulgare SAVI	7	3,5	x			x					■	■
Centaurea stoebe L.	2	4,1	x			x					■	■
Senecio sp.	2	0,5				x					■	
Solidago canadensis L.	1	1,9				x					■	
Cirisium sp.	1	0,5		x							■	
Lathyrus sylvestris L.	1	0,1				x						■
Solidago graminifolia L	1	0,1				x						■
Leontodon hispidus L.	2	1,9	x			x						■
Carlina vulgaris L.	1	0,1				x						■

Explanations: S- number of bees species visiting plant; n- percent of whole number of individuals visiting plant; x-the plant visited on conducted quarter; ■- the plant visited in particular month

Fig. 7. Nesting sites of wild bees (Hymenoptera, Apoidea) in Górażdże Limestone Quarry

Fig.8 Bees (Hymenoptera, Apoidea) from Górażdże Limestone Quarry

Bombus terrestris

Bombus lucorum

Bombus lapidarius

Bombus pratorum

Bombus pascuorum

Bombus ruderarius

Bombus hortorum

Bombus (Psithyrus) rupestris

Bombus (Psithyrus) bohemicus

Bombus (Psithyrus) vestalis

Bombus (Psithyrus) campestris

Apis mellifera

Anthophora plumpiens

Eucera sp.

Andrena assimiliss

Andrena sp.

Halictus subauratus

Lassioglossum sp

Anthidium manicatum

Osmia sp.

Osmia sp

Hoplitis sp

Fig. 9 The most frequently visited plants by bees (Hymenoptera, Apoidea) in Górażdże Limestone Quarry

Birdsfoot trefoil *Lotus corniculatus*

Kidneyvetch *Anthyllis vulneraria*

Cicer milkvetch *Astragalus cicer*

Viper’s bugloss *Echium vulgare*

Fig.10 The proposals of additional plantings in Górażdże Limestone Quarry

Plant	Kind of source*	Area for planting					
		Rocky slopes	Dry grasslands	Sunny roadsides	Shaded edges	Forest	Water banks
Phragmites australis (Cav.)Trin. ex Steud	2						+
Geum rivale L.	1				+		+
Filipendula ulmaria (L.) MAXIM.	1						+
Veronica longifolia L.	1						+
Onobrychis viciifolia Scop.	1		+	+			
Knautia arvensis (L.) Coult.	1		+				
Origanum vulgare L.	1		+				
Anthriscus sylvestris L.	1, 2				+	+	
Heracleum sphondylium L.	1, 2				+	+	
Carum carvi L.	1, 2				+	+	
Vicia cracca L.	1				+		
Stachys sylvatica L.	1				+		
Primula veris L.	1				+		
Digitalis purpurea L.	1, 2					+	
Arctium tomentosum Mill.	1, 2			+			
Rosa canina L.	1, 2	+			+		
Fragaria vesca L.	1, 2					+	
Anchusa officinalis L.	1	+		+			
Eryngium planum L.	1			+			
Lamium album L.	1				+		
Echinops sphaerocephalus L.	1			+			
Reseda lutea L.	1	+					
Linaria vulgaris Mill.	1	+	+	+			
Sedum album L.	1	+					

*Kind of source:
1 – Source of food
2 – Skurce of building swubstance

Fig.11 Proposals of artificial nesting sites for wild bees (examples)