POLISH ACADEMY OF SCIENCES • MUSEUM AND INSTITUTE OF ZOOLOGY
MEMORABILIA ZOOLOGICA

MEMORABILIA ZOOL.	48	171–179	1994

Joanna PĘTAL

Reaction of ant communities to degradation of forest habitats in the Karkonosze Mountains

Abstract. The studies were conducted along the gradient of degraded forest habitats of the Mumlawski Wierch in the western part of the Karkonosze Mts. Comparisons were performed between well preserved forests, damaged tree stands and a regenerating spruce forest. Ant communities in degraded habitats tended to become more alike to the ant communities of open areas (a mountain pasture of the Hala Izerska). The observed changes consisted in: a) an increase in the number of species, density and frequency of nests, b) a greater society size, c) a larger body size of individuals of dominating species, d) a decrease in turnover of society biomass, i.e. ecologically longer lifetime of ants. The recorded changes were the effect not only of improvement of life conditions for ants but also of the age of habitats.

INTRODUCTION

Many ant species do not leave man-transformed habitats, such as urbanized areas, drained peatlands, intensively fertilized meadows, derilict industrial lands. None the less ants react to habitat changes by mobilizing habitat-modifying behavioral defensive reactions and altering certain parameters of their societies and populations. Studies conducted so far have revealed that at early stages of habitat transformations there have been recorded changes in the number of ant species, density of their nests and the size of ant societies. All these have been accompanied by a more rapid development of larvae, decrease in an average weight of mature individual and increase in society biomass turnover, evidencing a decreased survival rate of ants (PĘTAL 1977, 1978, 1980, 1991, KRZYSZTOFIAK 1991). In the effect of these changes the contribution of ants to total predation pressure of transformed habitats diminishes.

Ecological effects of forest decline are one of the main issues in studies on anthropogenic transformations of Karkonosze landscapes. The research on ant reactions to degradation of forest habitats comes within the scope of these studies. The aim of the present work was to determine how transformations of plant communities affect societies and populations of various ant species.

STUDY AREA

The studies were carried out in 1992 on the south-western slope of the Mumlawski Wierch in the western part of Karkonosze as well as on a mountain pasture of the Hala Izerska. Habitats on the Mumlawski Wierch were situated in the upper forest zone of Sudeten spruce-trees, *Piceetum hercynicum* (MATUSZKIEWICZ 1967).

The study area exemplified typical transformations of spruce ecosystems in Karkonosze. Industrial effluents windblown from over the territory of Germany. Czech and southern Poland have caused a strip decline of trees on the slope since the mid-seventies. For the last 20 years new forest plantings and spontaneous renewal of a spruce forest have created several habitats characterized by a various degree of transformation of forest vegetation. There occur habitats with the preserved tree stand, habitats where the tree stand was totally devastated and the herb layer was noted for a vehement development of grasses and decline of coniferous forest plants as well as habitats of the renewed spruce forest (WASIŁOWSKA 1992, FABISZEWSKI et al. 1992).

According to WASIŁOWSKA 1992, in habitats of the died out forest, a natural transformation of plants communities proceeds. It was reflected in the values of coefficient of coverage with species dominating in the two communities, namely, with *Calamagrostis villosa* (CHAIX) GMEL. dominating in the grassy community and *Vaccinium myrtillus* L. – in the forest community (Table 1).

Table 1. Values of coefficient of coverage with dominating species in different habitats (acc. WASIŁOWSKA 1992)

Habitat / Species	Dead forest (1)	New forest plantings and self-sown wood (2)	15 years old young forest with vast glades (3)	Live forest (6)
Calamagrostis villosa	3973	1893	1465	1180
Vaccinium myrtillus	110	822	1337	1647

According to a preliminary analysis the study site ranked among areas of low dust level, a distinctly acid rain water and an avarage inflow of nitrogen and sulphur compounds (STACHURSKI et al. 1992). Pollutant deposition was uneven, its higher values being noted on the forest edge except for nitrogen compound fall, which was greater on open areas (KMIEĆ et al. 1992).

Soil in most of the examined habitats was of podzolic or podzolic-peattype of a shallow, skeleton profile and high acidity (pH in H_20 = 3.6–4.0) (SKIBA, DREWNIK 1992). It was marked for a restrained rate of organic substance degradation, a property likely to affect immobilization of nutrients and restrict their accessibility to plants (PIETR et al. 1992).

Examinations of ant communities were made along the north-western slope of the Mumlawski Wierch from its foot to the top, enlosing all the characteristic habitats, namely habitats differing image of phytosociological succesion as well as an old living forest and a glade:

1) dead forest above habitat 2;
2) new forest plantings on the foot of the slope;
3) young spruce tree forest, ca 15 years old, at the level of habitat 2, light-penetrated, enclosing large areas grown with lush grassy vegetation;
4) woodland glade in live forest (5), above habitat 3;
5) live forest at the level of habitats 1, 2, 3;
6) live forest right below the top of the Mumlawski Wierch.

Ants communities of forest and deforested habitats of the Mumlawski Wierch were compared to ants of a typically montane grassy habitat of the Hala Izerska (habitat 7).

METHODS

Spatial distribution of ant-hills, the size of societies and their age structure and the size of individuals have been examined. The methods employed were described in earlier papers (PĘTAL 1972, PĘTAL, PISARSKI 1993).

The examinations were made in the latter part of June 1992, i.e. in the mid-period of ant seasonal activity. Examinations of species composition and spatial distribution of ant-hills were carried out along 10 m long and 1 m wide transects. In each habitat 10–36 samples were taken. The size of societies was estimated by means of digging out ant nests and extracting all the specimens: imagines, pupae and larvae of various size classes. A total of 3–11 samples of this kind was taken from each habitat.

Dry mass of larvae, pupae one-year old and older imagines was measured in order to estimate society mass and production. Calculation of production was the basis for determining turnover of society biomass and consumption.

RESULTS

Characteristic of ant communities (Table 2)

A total of 11 ant species was recorded in all the examined habitats, each habitat being populated by 1–8 species. Live forests were the poorest in species due to their dimness and shadow, which did not offer propitious conditions for ants to settle (habitat populated by 1 and 2 ant species at nest density of $0.10 \times 10\ m^{-2}$ and 10% frequency). The greatest number – 5 ant species – were found, in the woodland glade (habitats 4), their nest density amounting to $3.3 \times 10\ m^{-2}$ and frequency reaching 100%.

In the deforested habitats there was observed succession of ant communities related to the age of plant community transformation. Density and frequency of nests were the lowest in the dead forest (habitat 1) and greater in the new forest plantings (habitat 2) as well as on the open areas of a young spruce forest (habitat 3). Besides species recorded to occur in other habitats, also typical forest species were found in the latter habitat (*Leptothorax acervorum, Formica sanguinea, Camponotus herculeanus*).

Table 2. Ants of the forest habitats on the north-western slope of the Mumląwski Wierch (1 – dead forest above 2; 2 – new forest plantings, foot of the slope; 3 – young spruce forest, ca 15 years, above 1 and 2; 4 – woodland glade; 5 – live forest at the level of 1, 2 and 3; 6 – live forest below the top; 7 – the Hala Izerska)

Habitat / Parameter	Successional gradient			Not degraded habitats			
	1	2	3	4	5	6	7
Number of species	5	5	8	5	1	2	4
Density of ant-hills ($N \times 10\ m^{-2}$)	0.85±0.23	1.7±0.22	1.75±0.31	3.33±0.21	0.10±0.10	0.10±0.07	1.97±0.28
Frequency of ant-hills (%)	55	90	80	100	10	10	78
Contribution of species: dominance (%)/frequency (%)							
Manica rubida LATR.	–/–	–/–	–/–	30/83	–/–	–/–	–/–
Myrmica ruginodis NYL.	17.6/20	44.1/55	40/50	10/33	–/–	50/5	52.3/64
Myrmica jacobsoni KUTT.	11.8/10	20.6/35	17.1/30	5.1/17	–/–	50/5	35/33
Myrmica rugulosa NYL.	–/–	–/–	11.4/20	–/–	–/–	–/–	–/–
Myrmica scabrinodis NYL.	–/–	–/–	–/–	–/–	–/–	–/–	8.6/17
Leptothorax acervorum F.	–/–	–/–	5.7/10	–/–	–/–	–/–	–/–
Lasius niger L.	35.3/25	5.9/10	–/–	–/–	–/–	–/–	–/–
Formica fusca L.	11.8/10	–/–	11.4/10	15/50	–/–	–/–	–/–
Formica lemani BONDR.	17.6/15	23.5/30	5.7/10	39.9/100	–/–	–/–	4.1/5
Formica sanguinea LATR.	–/–	5.9/10	2.8/5	–/–	–/–	–/–	–/–
Camponotus herculeanus L.	–/–	–/–	5.7/5	–/–	100/5	–/–	–/–
Diversity of species (H')	1.52	1.32	1.76	1.39	0	0.69	1.05
Eveness (J)	0.94	0.84	0.94	0.87		1.0	0.76

Density and frequency of ant-hills in the two older deforested habitats did not statistically differ from the values estimated for the ant community on the Hala Izerska. In all the examined habitats (except the for live forests 5 and 6) the same species dominated, namely, *Myrmica ruginodis* and *M. jacobsoni*.

Diversity of ant species in the deforested habitats, the woodland glade and on the Hala Izerska was much alike (Shannon-Wiener's $H' = 1.05–1.76$), yet differed significantly from the values estimated for the forest habitats ($H' = 0$ and $H' = 0.69$, respectively).

The size of society (Table 3)

The dominants in the deforested habitats and on the Hala Izerska (*Myrmica ruginodis, M. jacobsoni*) were not noted to reveal any statistically significant differences in their society sizes in one and the same habitat. However, society sizes differed significantly when particular habitats were compared.

Also age structure of societies of these species varied in different habitats. Differentiation of the number of larvae, pupae and one-year old and older worker ants in the examined habitats amounted to Friedman's $\chi^2 = 5.1$; $p = 0.19$ for *M. ruginodis* and $\chi^2 = 6.0$; $p = 0.07$ for *M. jacobsoni*. It pointed to differentiation of the examined habitats in regard to living requirements of ants.

Table 3. The size and composition of ant societies (for denotations of habitats see Table 2)

Species	Stage \ Habitat	1	2	3	7
M. ruginodis	larvae	154.0 ± 38.2	238.8 ± 47.3	220.3 ± 15.4	105.2 ± 51.3
	pupae	63.3 ± 15.6	11.9 ± 3.9	45.3 ± 36.2	79.7 ± 6.2
	young imagines	42.7 ± 21.4	148.0 ± 32.1	216.3 ± 84.6	108.2 ± 56.4
	old imagines	34.3 ± 5.9	140.8 ± 43.5	213.0 ± 23.1	108.2 ± 50.4
	Total	294.3 ± 43.8	539.5 ± 101.9	694.9 ± 274.1	401.3 ± 177.7
M. jacobsoni	larvae	–	243.7 ± 42.0	357.7 ± 59.3	317.6 ± 72.2
	pupae	–	9.2 ± 3.8	70.0 ± 39.3	107.4 ± 48.6
	young imagines	–	123.5 ± 4.9	523.7 ± 12.8	218.2 ± 71.3
	old imagines	–	95.2 ± 34.4	169.7 ± 66.6	225.8 ± 82.1
	Total	–	471.6 ± 70.5	1121.1 ± 166.2	869.0 ± 197.7
M. scabrinodis	larvae	–	–	–	237.0 ± 106.8
	pupae	–	–	–	70.0 ± 17.0
	young imagines	–	–	–	123.2 ± 25.1
	old imagines	–	–	–	300.0 ± 77.2
	Total	–	–	–	730.2 ± 176.0

In the young spruce forest (habitat 3) at the furthest stage of phytosociological transformations, societies of dominants (*Myrmica ruginodis*, *M. jacobsoni*) were the largest and were marked for a more advanced development of young generation than in the other deforested habitats. Pupae and young, one-year old worker ants were more abundant in these societies, which proved that also in the previous year these habitats offered better conditions for ant development. As compared to the habitats discussed above, societies of dominants on the Hala Izerska found there better living conditions, as attested by a greater abundance of pupae and one-year old worker ants.

The size of individuals (Table 4)

The dominating species *Myrmica ruginodis* and *M. jacobsoni* did not differ in respect to the mass of pupae, adult workers (one-year old and older) and queens in the same habitat. However, differences were recorded in the mass of individuals of the same species in different habitats. It concerned mainly one-year old and older worker ants, whose mass was smaller in habitats at the earlier stage of phytosociological transformations (1 and 2) than in the young spruce forest (3) and on the Hala Izerska (7). The mass of pupae was less diversified (statistically significant in the habitat 1 and 2, 2 and 7, 3 and 7 in the case of *M. ruginodis*, and in the habitat 2 and 3 in the case of *M. jacobsoni*). The size of mature individuals formed an increasing series in the habitats:

$$1 < 2 > 7 < 3.$$

The recorded pattern indicated that ants found better living conditions and more food in the deforested habitat at an advanced stage of succession and in the woodless natural habitat than in habitats at an earlier stage of phytosociological transformations.

Table 4. Dry mass (mg/individual) of pupae and adults of dominating ant species in the degraded forest habitats on the slope of the Mumlawski Wierch and on the Hala Izerska (for denotations of habitat see Table 2)

Species	Stage \ Habitat	1	2	3	7
M. ruginodis	worker pupae	0.43 ± 0.00	0.48 ± 0.02	–	0.35 ± 0.12
	sexual pupae	–	1.27 ± 0.14	1.08 ± 0.08	0.80 ± 0.06
	young worker imagines	0.86 ± 0.07	0.88 ± 0.01	1.16 ± 0.03	1.07 ± 0.03
	old worker imagines	0.89 ± 0.09	0.90 ± 0.05	1.15 ± 0.04	1.06 ± 0.06
	old queens	–	1.14 ± 0.96	–	–
M. jacobsoni	worker pupae	–	0.42 ± 0.03	–	0.44 ± 0.05
	sexual pupae	–	1.49 ± 0.00	0.95 ± 0.10	0.85 ± 0.03
	young worker imagines	–	0.89 ± 0.01	1.03 ± 0.11	1.02 ± 0.07
	old worker imagines	–	0.89 ± 0.04	1.08 ± 0.08	1.03 ± 0.04
	old queens	–	1.80 ± 0.10	1.57 ± 0.73	–

Ant society development index (Table 5)

Mean biomass of ant societies as well as ant production formed an increasing series paralleling the progressing stage of phytosociological transformations. However, the estimated values were lower for the Hala Izerska than for the open woodland glades of a young spruce forest, namely,

$$1 < 2 < 7 < 3.$$

Turnover of society biomass revealed a contrary tendency, i.e.

$$3 < 7 < 2 < 1.$$

The acquired data proved that better conditions for society development and lower mortality rate were characteristic of more stabilized habitats on Hala Izerska and in a young spruce forest as compared to habitats at earlier stages of phytosociological succession. A several times higher consumption recorded in the former habitats was also indicative of a more profuse food (mainly of small invertebrates) found there.

Table 5. Production, turnover of biomass and consumption of societies of *Myrmica* spp. in the degraded forest habitats on the Mumlawski Wierch and on the Hala Izerska (for denotations of habitats see Table 2). (Consumption calculated on the basis of $^{P}/_{C}$ = 0.026 index (PĘTAL 1977)

Value \ Habitat	1	2	3	7
Production (*P*) (mg d.wt.)	74.8 ± 24.8	145.8 ± 1.6	242.4 ± 78.6	167.7 ± 36.6
Society mass (*B*) (mg d.wt.)	125.7 ± 39.5	382.8 ± 64.5	848.4 ± 168.2	503.2 ± 104,2
$^{P}/_{B}$	0.59	0.38	0.28	0.33
Consumption (C) till mid-vegetation season:				
mg d.wt. per society	2876.9	5607.7	9307.7	6450.0
mg d.wt.× $m^{-2)}$	71.92	616.85	1116.92	1219.05

CONCLUSIONS

Changes in ant communites as observed in the degraded forest of Karkonosze should be related to formation of open, insolated areas, always preferred by ants, as well as to succession of grassy vegetation.

These areas are most likely populated by species occurring on woodland glades and nearby mountain pastures. Along with progressing habitat changes and plant succession the number of ant species as well as density and frequency of their nests increased, assuming values approximate to those recorded on the Hala Izerska.

In most of the examined habitats the same species dominated, namely, *Myrmica ruginodis* and *M. jacobsoni*. The mass of adult worker ants, the size of societies and their production tended to increase along with advancing stage of phytosociological habitat changes. On the other hand, turnover of society biomass decreased, which was indicative of a higher survival rate of ants. The recorded data attest to the fact that habitats at advanced stages of phytosociological transformations offer better conditions for ant development. Ants may find there not only better conditions for nesting but also greater food resources as evidenced by a several times greater consumption. This, in turn, points to an increasing contribution of ants to trophic network and nutrient cycling in habitat as well as evidences capabilities of ants in regulating abundance of other invertebrates.

Abundant populations of ants and good condition of ant societies in the deforested habitats were also determined by the age of these habitats. Significance of time factor lies in the fact that only after several years a proper size of ant societies may be attained and ants become capable of expansion (UCHMAŃSKI, PĘTAL 1982).

A noteworty fact is that an opposite tendency of changes, i.e. a decrease in the number of species and density indices, dwindling society size and production, diminishing size of individuals and an increase in biomass turnover, was observed in a series of habitats under augmenting effect of such factors as intensive organic and mineral fertilization (PĘTAL 1974, 1976), industrial and transport pollution (PĘTAL 1980, KRZYSZTOFIAK 1991), peatland drainage (PĘTAL 1991).

REFERENCES

KMIEĆ G., KACPERCZYK J., ZWOŹDZIAK A. 1992. Całkowity opad zanieczyszczeń w wyższych partiach Karkonoszy. In: Karkonoskie Badania Ekologiczne. I Konferencja. Oficyna Wydawn. Inst. Ekol., Dziekanów Leśny, pp. 33–45.

KRZYSZTOFIAK L. 1991. The effect of habitat pollution with heavy metals on ant populations and anthills soil. Ecol. pol., Warszawa, **39**: 181–202.

PĘTAL J. 1972. Methods of investigating the producvity of ants. Ekol. pol., Warszawa, **20**: 9–22.

PĘTAL J. 1974. The effect of pasture management on ant populations. Ekol. pol., Warszawa, **22**: 679–692.

PĘTAL J. 1976. The effect of mineral fertilization on ant populations in meadows. Pol. ecol. Stud., Warszawa, **2**: 209–218.

PĘTAL J. 1977. The role of ants in ecosystem. In: Production Ecology of Ants and Termites (ed. by M. V. BRIAN). IBP. 13, Cambridge Univ. Press, pp. 293–325.

PĘTAL J. 1980a. The effect of industrial pollution of Silesia on populations of ants. Pol. ecol. Stud., Warszawa, **6**: 665–672.

PĘTAL J. 1980b. Ant populations, their regulation and effect on soil in meadows. Ekol. pol., Warszawa, **28**: 297–326.

PĘTAL J. 1991. Diversity of ant communities in peat bogs of various origin and period under management. Pol. ecol. Stud., Warszawa, **17**: 249–265.

PĘTAL J., PISARSKI B. 1993. *Formicidae*. In: Metody Stosowane w Zoologii Gleby (ed. by M. GÓRNY, L. GRÜM). PWN, Warszawa, pp. 253–261.

PIETR S. J., STANKIEWICZ M., LUBCZYSKA J., WĘGRZYN T. 1992. Aktywność mikroflory glebowej wybranych ekosystemów Karkonoszy. In: Karkonoskie Badania Ekologiczne. I Konferencja. Oficyna Wydawn. Inst. Ekol., Dziekanów Leśny, pp. 103–107.

SKIBA S., DREWNIK M. 1992. Gleby zdegradowanych ekosystemów wybranych rejonów Karkonoszy. In: Karkonoskie Badania Ekologiczne. I Konferencja. Oficyna Wydawn. Inst. Ekol., Dziekanów Leśny, pp. 93–102.

STACHURSKI A., ZIMKA J., KWIECIEŃ, WALD M. 1992. Niektóre aspekty krążenia pierwiastków w ekosystemach leśnych na terenie Karkonoszy. In: Karkonoskie Badania Ekologiczne. I Konferencja. Oficyna Wydawn. Inst. Ekol., Dziekanów Leśny, pp. 115–126.

UCHMAŃSKI J., PĘTAL J. 1982. Long term stability of ant colonies – a simulation model. J. Anim. Ecol., Cambridge, **51**: 349–362.

WASIŁOWSKA A. 1992. Przekształcanie się roślinności borów świerkowych w rejonie Mumlawskiego Wierchu (Karkonosze) In: Karkonoskie Badania Ekologiczne. I Konferencja. Oficyna Wydawn. Inst. Ekol., Dziekanów Leśny, pp. 33–45.

Institute of Ecology, PAS
Dziekanów Leśny
05-150 Łomianki, Poland

STRESZCZENIE

Reakcja zespołów mrówek na degradację środowisk leśnych w Karkonoszach

Badania prowadzono w degradujących się środowiskach leśnych w zachodniej części Karkonoszy. Badane środowiska charakteryzują się różnym stopniem przekształcenia roślinności leśnej – od dobrze zachowanych drzewostanów, poprzez drzewostany zniszczone z ustępującymi gatunkami borowymi w runie i gwałtownie rozwijającą się roślinnością trawiastą, po odnowione świerczyny. Wraz ze zmianami sukcesyjnymi roślinności występują zmiany w zespołach mrówek, które upodobniają się do zespołu terenów

otwartych – Hali Izerskiej. Zmiany te polegają na: a) wzroście liczby gatunków oraz zagęszczenia i frekwencji gniazd, b) wzroście wielkości społeczeństw, c) wzroście wielkości dorosłych osobników gatunków dominujących oraz d) spadku rotacji biomasy społeczeństw, t.j. wydłużeniu ekologicznej długości życia mrówek. Zmiany te są związane nie tylko z poprawą warunków życia mrówek, ale i z wiekiem środowisk.