

The role of *Paranectria oropensis* in community dynamics of epiphyte synusia on roadside trees

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Abstract: HAFELLNER, J. & OBERMAYER, W. 2009. The role of *Paranectria oropensis* in community dynamics of epiphyte synusia on roadside trees. – Herzogia 22: 177–190.

It is documented from a study site in the city of Graz (Austria, Styria) that beside the corticioid basidiomycete *Athelia arachnoidea*, the lichenicolous hypocrealean pyrenomycete *Paranectria oropensis* can play a comparably important role in opening lichen synusia on bark. Shortly after the death and the splitting off of the remnants of lichen thalli caused by an invasion with *Paranectria oropensis*, a recolonisation of the bare bark areas can be observed.

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In einer in Graz (Österreich, Steiermark) durchgeführten Studie wird gezeigt, dass der hypocreale Pyrenomyzete *Paranectria oropensis* bei der Öffnung von borkenbewohnenden Flechtensynusien eine ähnlich bedeutende Rolle spielen kann wie der corticioide Basidiomyzete *Athelia arachnoidea*. Kurz nach dem Absterben und Ablösen der Thallusreste der Flechten in Folge eines Befalls mit *Paranectria oropensis* ist schon eine Neubesiedlung der entblößten Borkenflächen zu beobachten.

Kew words: *Athelia arachnoidea*, Austria, climate change, Graz, lichen, lichenicolous fungi, pathogenic fungi, Styria.

Introduction

Lichen synusia on bark dominated by foliose species are relatively stable but show increasing dynamics in case of changes in habitat conditions or are connected to certain bark characteristics, such as smooth bark versus scaling bark (WIRTH et al. 1999). An additional cause for increasing dynamics is seen in the activity of lichenicolous fungi.

In general, lichenicolous fungi are much more common and their diversity is much higher in ecosystems with low anthropogenic influence (e.g., HAFELLNER & KOMPOSCH 2007). For the fungus-host system *Abrothallus suecicus* – *Ramalina sinensis* an increase of disease incidence with increasing forest stand age has been observed (HEDENÅS et al. 2006). Only very few lichenicolous fungi are not significantly rarer in synusia with short ecological continuity and therefore are regularly found also in towns, the best documented of which is *Athelia arachnoidea* (Berk.) Jülich (ARVIDSSON 1976, 1979, GILBERT 1988, PARMASTO 1998). As *A. arachnoidea* is a strong pathogen on a wide range of epiphytic lichens (JÜLICH 1972), it plays an important role in the process of opening of more or less closed lichen communities, leaving back bare areas on the bark surface followed by recolonisation (LIŠKA 1993, MOTIEJŪNAITĖ 2004, 2005, MOTIEJŪNAITĖ & JUCEVICIENE 2003, YURCHENKO & GOLUBKOV 2003).



Fig. 1: **A** – Overview of study site. **B** – Infections of *Phaeophyscia orbicularis* with *Athelia arachnoidea*. Note the growing edge of the infection being more webby than in the case of *Paranectria oropensis*. (photo A by W. Obermayer, 3 June 2009, photo B by W. Obermayer, 15 May 2006).

We here document a further case of a lichenicolous species with similar behaviour and ecological importance, *Paranectria oropensis* (Ces.) D.Hawksw. & Piroz., not observed to occur in cities



Fig. 2: **A** – Overall view of epiphytic lichen synusia severely attacked by lichenicolous fungi, predominantly *Paranectria oropensis*. **B** – Fusing infections with *P. oropensis* causing a severe disease of *Phaeophyscia orbicularis*. **C** – Infections of *Ph. orbicularis* with *P. oropensis* spreading into neighbouring thalli of *Candelariella efflorescens* auct. (photos W. Obermayer, 15 May 2006).

in large quantities or at least not published in an accessible journal so far. Furthermore we add some data on lichenicolous species invading lichens on canopy branches at the same locality.

Material and Methods

Field work has been performed in the city of Graz in spring 2006, in the street in front of the Botanical Garden of the Karl-Franzens-University, named Schubertstraße. There, rows of roadside trees form a picturesque avenue. The trees, predominantly of *Aesculus hippocastanum*, but also including *Fraxinus excelsior*, *Tilia cordata*, and *Sophora japonica* are planted on a meadow stripe in between the road and the paved footpath (Fig. 1A).

The locality data are: Austria, province of Styria, Graz, avenue “Schubertstraße” near junction with “Holteigasse”, 47°04'55"/15°27'30"E, elev. c. 375 m, GF 8958/2, roadside trees, 15 May 2006.

Community composition on bark of selected trunks of *Aesculus hippocastanum* was analyzed on squares of 400 cm² by application of the Braun-Blanquet approach. The selection of the squares was subjective in that we tried to place the grid on areas with a lichen cover representative for the trunk in the chosen exposition. The overall aspect of the epiphyte synusia and close-ups of infested thalli were documented by digital photographs. Dead branches fallen off the trees during a thunderstorm the day before with a minimum diameter of 3 cm at the thicker end were randomly collected and investigated with emphasis on detecting as many species of lichenicolous fungi as possible.

The lichenicolous fungi were investigated in the laboratory by mycological routine methods, especially light microscopy. For good sketches of perithecia depth of field was extended. For this purpose series of photographs were processed with the public domain software “CombineZM” developed by A. Hadley.

Voucher specimens of the mentioned taxa are preserved in GZU. Duplicates of *Paranectria oropensis* and *Athelia arachnoidea* will be distributed in the exsiccata “Lichenicolous Biota”.

Results

a) Community composition on trunks of *Aesculus hippocastanum*

The lichen dominated community of epiphytic cryptogams on the study site shows a rather high coverage of the bark surface (83–95 % of the study squares), but is composed of relatively few species (study squares with 6–10 species, excluding the lichenicolous fungi) (Tab. 1). The composition of the synusia in terms of participating species indicates the presence of a depauperate Physcietum adscendentis (BARKMAN 1958, WILMANN 1962), although out of the set of characteristic species only *Phaeophyscia nigricans* is present with low steadiness, and the species ought to be present with high steadiness, *Physconia distorta*, is lacking.

b) Abundance of selected lichenicolous fungi and observed host spectra of *Athelia arachnoidea* and *Paranectria oropensis*

According to our quantitative analysis on about 20–40 % of the area of the study squares, the lichens were attacked by one of the destructive lichenicolous fungi (Tab. 1, Fig. 2A, 2B).

Paranectria oropensis in general is significantly more abundant and is more regularly present in the lichen-dominated epiphyte community than *Athelia arachnoidea* (Tab. 1), both with comparable aggressivity assessed by comparable effects on host thalli. For both species *Phaeophyscia orbicularis* is the main host lichen. Whereas *Athelia arachnoidea* was also observed destroying adjacent cushions of bryophytes (*Orthotrichum* spec. div.), subicular hyphae and ascomata of *Paranectria oropensis* were additionally demonstrated on neighbouring thalli of *Physcia adscendens*, *Phaeophyscia chloantha*, *Candelariella efflorescens* s. auct. medio-europ. (Fig. 2C), and *Melanelixia subaurifera*, but did not infest the mosses. Both fungi cause complete bleaching and the death of the host thalli resulting in a splitting off of the lichen thalli

Tab. 1: Epiphyte community composition on study site and proportion infested by lichenicolous fungi, predominant host species of which is *Phaeophyscia orbicularis*. Abundance-dominance values according to REICHELT & WILMANN (1973) modified (r = 1 small thallus, + = -1 %, 1 = 1-5 %, 2a = 5-12,5 %, 2b = 12,5-25 %, 3 = 25-50 %, 4 = 50-75 %, 5 = 75-100 %). Values of the lichenicolous fungi followed by percent values of area in brackets (investigated squares = 400 cm²).

No. of releve	1	2	3	4	5	Steadiness
Distance above the ground in cm	150	100	180	140	160	
Exposition	E	E	E	SE	SE	
Total cover of bark epiphytes in %	92	94	83	86	95	
Total portion of infested area in %	38	23	23	21	23	
<i>Phaeophyscia orbicularis</i>	4	3	4	4	4	V
<i>Physcia adscendens</i>	2a	1	1	1	1	V
<i>Candelariella efflorescens</i> s. auct.	1	2b	1	1	+	V
<i>Candelariella reflexa</i>	+	+	r	.	.	III
<i>Amandinea punctata</i>	+	.	+	.	+	III
<i>Xanthoria parietina</i>	1	.	.	+	.	II
<i>Phaeophyscia chloantha</i>	.	1	+	.	.	II
<i>Phaeophyscia nigricans</i>	r	+	.	.	.	II
<i>Candelaria concolor</i>	.	+	.	.	r	II
<i>Parmelia sulcata</i>	.	.	.	1	.	I
<i>Xanthoria polycarpa</i>	.	r	.	.	.	I
<i>Melanelixia subaurifera</i>	.	.	r	.	.	I
<i>Physcia tenella</i>	.	.	.	.	r	I
corticolous bryophytes*	1	1 (2 spec.)	2a	2a	1	V
<i>Paranectria oropensis</i>	3 (36)	2b (23)	2a (10)	2b (21)	2b (17)	V
<i>Athelia arachnoidea</i>	1 (2)	.	2b (13)	.	2a (6)	III
Number of species excl. lichenicolous fungi	8	10	8	6	7	

*The corticolous bryophytes mentioned in the table include *Orthotrichum affine* Brid., *O. pallens* Brid., *O. patens* Bruch ex Brid., *O. obtusifolium* Brid., *O. diaphanum* Brid., and *Tortula papillosa* Wils. (det. C. Berg, 2009.)

and an exposure of the naked bark surface, a process usually starting in the centre of the patchy infested areas (Fig. 3A, 3B, 4B). Bare bark areas are then recolonized by juvenile lichen thalli or outgrowth of surviving lobes (Fig. 4A). To determine the time needed for complete recolonisation was not among the aims of this study.

Although the overall aspect of infections by either *Paranectria oropensis* or *Athelia arachnoidea* from larger distance is rather similar (compare Fig. 3A, 1B); a distinction between the two fungi is simple under a hand lens, especially as soon as ascomata are developed on thalli of *Paranectria oropensis*. But also prior to the presence of fruiting bodies a distinction between thalli of the two fungi is normally unproblematic as in the case of *Athelia arachnoidea* a webby growing edge is much more prominent (Fig. 1B, compare also YURCHENKO & GOLUBKOV 2003).

c) Lichenicolous fungi on canopy branches of *Fraxinus excelsior* at the same study site

The incidentally easy access to canopy branches was used to check if *Paranectria oropensis* plays a similar role in lichen communities on branches. The lichenicolous fungi detected on



Fig. 3: Single infections of *Phaeophyscia orbicularis* with *Paranectria oropensis* **A** – Killed lobes of the host starting to split off. **B** – Advanced stage of A. (photos W. Obermayer, 15 May 2006).

canopy branches included *Arthonia phaeophysciae* Grube & Matzer and *Lichenochora obscurioides* (Linds.) Triebel & Rambold, both with mature ascomata developed upon *Phaeophyscia orbicularis*, which under the influence of these lichenicolous fungi does not show any severe symptom of disease. However, neither *Paranectria oropensis* nor *Athelia arachnoidea* were seen on the investigated branches, indicating that on canopy branches these fungi must be at



Fig. 4: Infections of *Phaeophyscia orbicularis* with *Paranectria oropensis*, the lichenicolous fungus showing abundant ascoma production, in **A** recolonisation of a bare bark area with young lobes of *Ph. orbicularis* (photos W. Obermayer, 15 May 2006).

least much rarer than on the bark of the trunk. As the predominant host lichen *Phaeophyscia orbicularis* in both habitats looks quite healthy and did not show significant damage that might be caused by air pollution, we conclude that the site characteristics (e.g., microclimate, inclination of site surface, age of substrate) are responsible for the different set of lichenicolous fungi.

Discussion

a) Species composition of epiphytic lichen synusia

As pointed out above, species diversity in the study squares was rather low. At the same time the total cover of bark epiphytes was found to be rather high with *Phaeophyscia orbicularis* being the constantly dominating species. Low diversity and the recorded species composition may be caused by a short period of time available for colonisation after the concentrations of acid air pollutants have dropped down in the city of Graz in the 1980ies (e.g., GRILL et al. 1988) and a more or less simultaneous increase of nitrogen-containing pollutants and dust resulting from an increase of traffic. Increase of nitrogen emissions, for instance by traffic, is discussed as one possible factor favouring nitrophytic species such as *Phaeophyscia orbicularis* (JANSSEN et al. 2007).

b) Notes on *Paranectria oropensis* and its host spectrum

The hypocrealean genus *Paranectria* is mainly characterized by its peculiar shape of ascospores, i. e. the long attenuated ends (ROSSMAN et al. 1999, Fig. 6C). Whereas ascospores of the type species *P. affinis* are 3-septate, those of the other species including *P. oropensis* are muriform (Fig. 6), for which previously the generic name *Ciliomyces* was in use but then reduced under the synonymy of *Paranectria* (HAWKSWORTH & PIROZYNSKI 1977). *Paranectria oropensis* was treated in detail by SAMUELS (1976, sub *Ciliomyces o.*) and HAWKSWORTH (1982) and the population studied by us perfectly fits the species concept as applied there.

Furthermore it was stressed by various authors that *P. oropensis* is able to attack a wide range of lichens (ROSSMAN et al. 1999, CEZANNE et al. 2008a). This capability is well demonstrated by the specimens originating from Austria preserved at GZU on the labels of which the following host species are mentioned: *Bacidia rubella*, *Biatora pontica*, *Buellia griseovirens*, *Candelaria concolor*, *Candelariella efflorescens* auct., *Lecanora allophana*, *L. chlarotera*, *Lepraria* spec., *Melanelixia fuliginosa* var. *glabrata*, *M. subargentifera*, *Normandina acroglypta*, *Parmeliella triptophylla*, *Parmelina pastillifera*, *P. tiliacea*, *Phaeophyscia chloantha*, *P. endophoenicea*, *P. orbicularis*, *Phlyctis argena*, *Physcia adscendens*, *Physconia distorta*, *Xanthomendoza fallax*, and some sterile crustose species.

Further recorded host lichens in Europe include *Agonimia tristicula* (HITCH 2001), *Agonimia* spec. (ETAYO 1998), *Amandinea punctata* (SÉRUSIAUX et al. 1999), *Bacidina* spec. (VAN DEN BOOM & VAN DEN BOOM 2006), *Candelariella reflexa* (VAN DEN BOOM 2002, 2004, VAN DEN BOOM & VAN DEN BOOM 2006, SPARRIUS et al. 2002), *Cladonia* spec. (type, according to HAWKSWORTH 1982), *Chrysothrix candelaris* (ETAYO 1998), *Degelia atlantica* (HAWKSWORTH 1982), *Fellhanera viridisorediata* (VAN DEN BOOM 2004), *Hypotrachyna revoluta* (VAN DEN BOOM 2004), *Lecidella elaeochroma* (KEISSLER 1930), *Lepraria incana* (HITCH 2000, 2005), *L. lobificans* (SÉRUSIAUX et al. 2003), *L. membranacea* (CZARNOTA & KUKWA 2001), *Leprocaulon microscopicum* (HERNÁNDEZ PADRÓN et al. 2004), *Massalongia carnosa* (DIEDERICH 2003), *Melanelixia subaurifera* (HAFELLNER 2008b), *Megalospora tuberculosa* (ETAYO 1998, 2002, VAN DEN BOOM & ETAYO 2000), *Melanohalea exasperatula* (VAN DEN BOOM 2004), *Normandina pulchella* (ETAYO 1998, VAN DEN BOOM & VAN DEN BOOM 2006), *Physcia tenella* (BERGER & TÜRK 1993, VAN DEN BOOM 2004, ERTZ & DUVIVIER 2006, HITCH 2005), *Physconia enteroxantha* (ETAYO 1998, HITCH 2001), *P. perisidiosa* (ETAYO 1998), *P. subpulverulenta* (HERNÁNDEZ PADRÓN et al. 2004), *P. venusta* (BRACKEL 2008), *Pleurosticta acetabulum* (BRACKEL 2008), *Strigula stigmatella* (ETAYO 1998), and *Xanthoria candelaria* (SÉRUSIAUX et al. 1999).

c) Distribution and frequency of *Paranectria oropensis* in Central Europe

Paranectria oropensis is widely distributed in Europe. Beside Austria it is reported from Belgium (VAN DEN BOOM & VAN DEN BOOM 2006, ERTZ & DUVIVIER 2006, VAN DEN BROECK et al. 2006), France (VOUAUX 1912, sub *Pleonectria appendiculata*, ROUX et al. 2006), Germany (BRACKEL 2005, KOCOURKOVÁ & BRACKEL 2005, CEZANNE et al. 2008a), Italy (for type see e.g. TRIEBEL 1989; TRETIAH 1993, BRACKEL 2008), Great Britain (HAWKSWORTH 1982, HITCH 2000, 2001, 2005), Luxembourg (SÉRUSIAUX et al. 1999, 2003), the Netherlands (e.g., VAN DEN BOOM 2002, 2004, APTROOT & SPARRIUS 2004, SPARRIUS et al. 2002), Poland (CZARNOTA & KUKWA 2001), Portugal (VAN DEN BOOM & ETAYO 2000), Slovenia (HAFELLNER 2008b), Spain (ETAYO 1998, 2002, LONGÁN & GÓMEZ-BOLEA 1999), Sweden (KEISSLER 1923, SANTESSON et al. 2004), and Ukraine (COPPINS et al. 1998).

The species appears to have become more frequent in Central Europe in recent times. Also CEZANNE et al. (2008a) discuss shortly, based on data from Germany, that the species may be in process of spreading out in recent years.

In Austria the species was recorded for the first time by KEISSLER (1930) but no further record could be traced until the late 1980s when J. Poelt and others deposited their first collections of the species in GZU. In more recent times it turns up quite regularly in investigations of regional lichen diversity (e.g., BERGER & TÜRK 1995, HAFELLNER 1999, 2002, 2003, HAFELLNER et al. 2005a, b, 2008, HAFELLNER & OBERMAYER 2001, 2007, NEUWIRTH 2005) and collections are often abundant indicated by the fact that the species was repeatedly distributed in exsiccata (e.g., SANTESSON 1994, 2008, HAFELLNER 2007, 2008a). Meanwhile its frequency and the severeness of the attacks show features of an epidemic disease.

Whether the obvious increase of frequency of this lichenicolous hypocrealean fungus has something to do with climatic change is up for discussion. Principally a series of milder winters may well have an effect on the survival rate of mycelia or diaspores available for infection in the following vegetation period. Indications for an influence of climatic changes (mainly raise of temperature and change of relative humidity) on the lichen vegetation of the lowlands and the distribution patterns of selected lichen species in Europe during the past two decades are already documented (e.g., POELT & TÜRK 1994, VAN HERK et al. 2002, INSAROV & SCHROETER 2002, CEZANNE et al. 2008b).

Another hypothesis, why *Paranectria oropensis* might have become more frequent was raised by CEZANNE et al. (2008a). They argue that the circumstance of the most frequent host lichens (nitrophytic epiphytes) being in process of spreading might at the same time favour the spreading of the lichenicolous fungus. The development should be observed for a longer period of time.

d) *Paranectria oropensis* and other lichenicolous fungi as succession factor

Most of the lichenicolous fungi have little impact on the succession dynamics of their host lichens because they coexist with their hosts over months and years without showing any severe disease symptom. However, some of them, including *Athelia arachnoidea* (compare ARVIDSSON 1976, 1979, GILBERT 1988, PARMASTO 1998), *Marchandiomyces corallinus* (Roberge) Diederich & D.Hawksw. (see e.g., HAWKSWORTH 1979), *Marchandiobasidium aurantiacum* Diederich & Schultheis (see e.g., DIEDERICH et al. 2003), and *Paranectria oropensis* behave very differently. They are highly aggressive and can invade large surface areas in relatively short periods of time. In the terminology of LAWREY & DIEDERICH (2003) they represent pathogens, and they occur mainly in depauperate lichen communities, often under

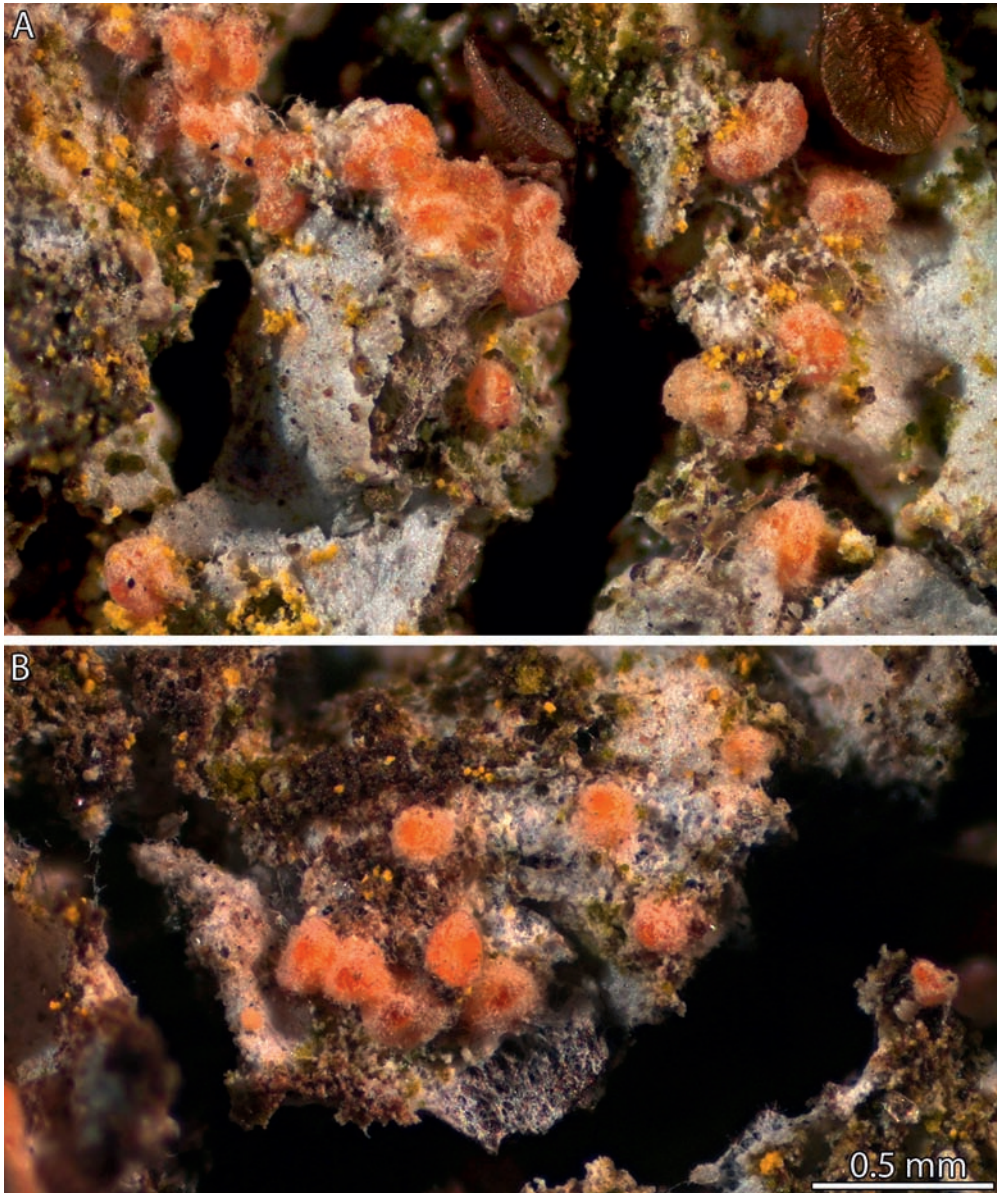


Fig. 5: *Paranectria oropensis*, mature ascomata showing their typical webby surface and the darker orange ostiolar region (photo W. Obermayer, 10 Feb. 2009).

the influence of air pollution. For *Paranectria oropensis* this is only partly true as this fungus is able to infest also lichens in habitats with little human impact and under clean air conditions. In this respect it is biologically similar to *Trichonectria hirta* (Bloxam) Petch, for which DIEDERICH (1989) reported that it can destroy the epiphytic lichen vegetation in the forest interior. Interestingly none of these pathogenic fungi is host specific. As they kill the host thalli

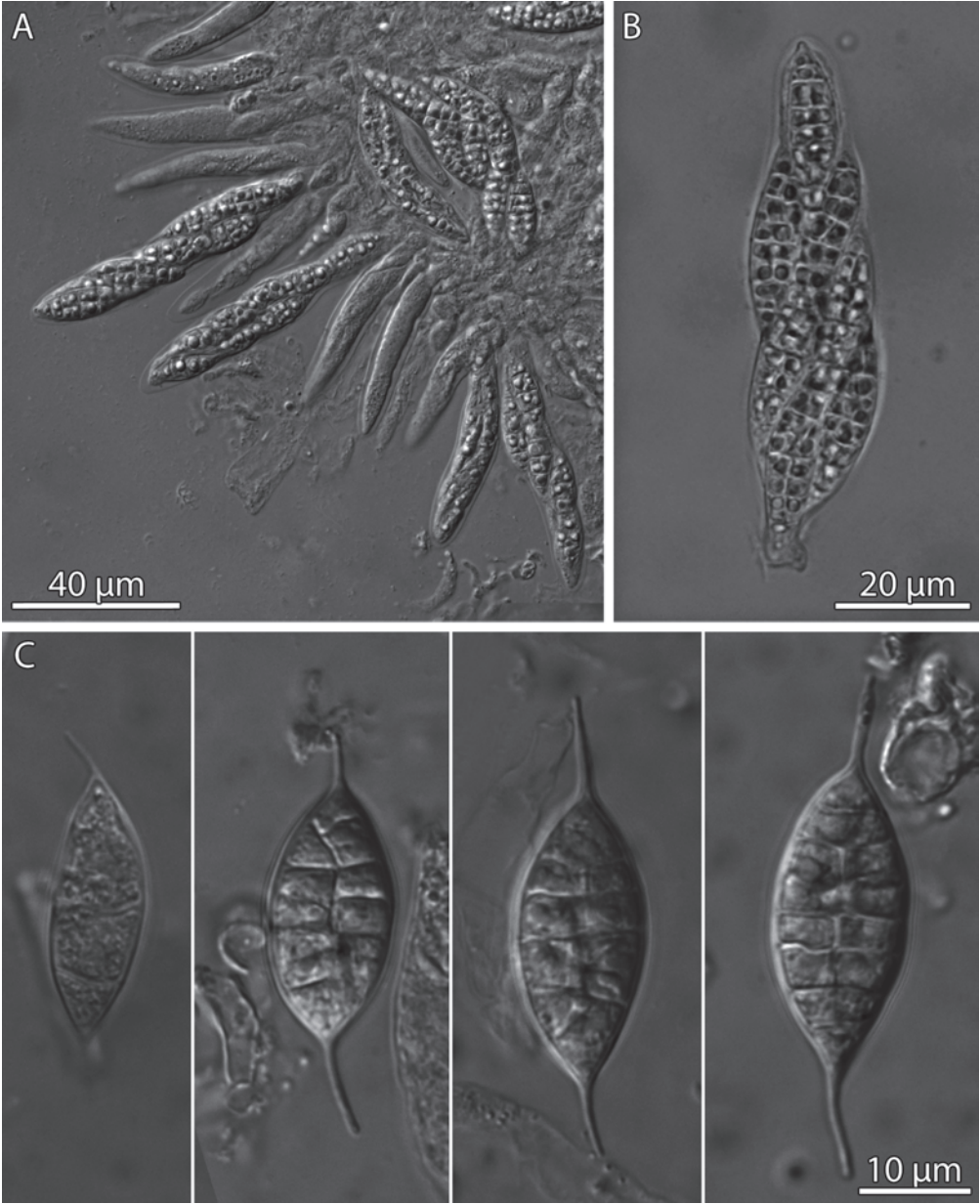


Fig. 6: *Paranectria oropensis*. **A** – Hymenium in squash preparation. **B** – Mature ascus. **C** – Immature and mature ascospores (photos W. Obermayer, 10 Feb. 2009).

shortly after invasion, large patches of surface area become exposed for recolonisation. In rural environments and forested landscapes at low to mid elevations *Paranectria oropensis* might be of considerable importance in the community dynamics and can play a similar role as the nowadays rarely occurring peaks in concentration of air pollutants.

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References

- APTROOT, A. & SPARRIUS, L. B. 2004. De korstmossen van het najaarsweekend 2003 in oostelijk Noord-Brabant. – *Buxbaumiella* **66**: 40–43.
- ARVIDSSON, L. 1976. *Athelia arachnoidea* (Berk.) Jül. and its influence on epiphytic cryptogams in urban areas. – Göteborgs Svampklubbs Årsskrift **1975–1976**: 4–10.
- ARVIDSSON, L. 1979. Svampangrepp på lavar - en orsak till lavoken. Fungus attacks on lichens and lichen deserts in cities. – Svensk Bot. Tidskr. **72**: 285–292.
- BARKMAN, J. J. 1958. Phytosociology and ecology of cryptogamic epiphytes including a taxonomic survey and description of their vegetation units in Europe. – Assen: Van Gorcum & Co. N. V. - G. A. Hak & Dr. H. J. Prakke.
- BERGER, F. & TÜRK, R. 1993. Neue und seltene Flechten und lichenicole Pilze aus Oberösterreich, Österreich. – Linzer Biol. Beitr. **25**: 167–204.
- BERGER, F. & TÜRK, R. 1995. Die Flechtenflora im unteren Rannatal (Mühlviertel, Oberösterreich, Österreich). – Beitr. Naturk. Oberösterreichs **3**: 147–216.
- VAN DEN BOOM, P. P. G., 2002. Some interesting records of lichens and lichenicolous fungi from The Netherlands V. – Österr. Z. Pilzk. **11**: 153–157.
- VAN DEN BOOM, P. P. G., 2004. A long-term inventory of lichens and lichenicolous fungi of the Strabrechtse Heide and Lieropse Heide in Noord-Brabant, The Netherlands. – Österr. Z. Pilzk. **13**: 131–151.
- VAN DEN BOOM, P. P. G. & VAN DEN BOOM, B. 2006. An inventory of lichens and lichenicolous fungi in northern Belgium (area of Stramprooierbroek). – Bull. Soc. Nat. Luxemb. **106**: 39–52.
- VAN DEN BOOM, P. P. G. & ETAYO, J. 2000. Contribution to the knowledge of lichenicolous fungi from Portugal and Spain. – Österr. Z. Pilzk. **9**: 151–162.
- BRACKEL, W. v. 2005. Flechten, flechtenbewohnende Pilze und Moose im NSG Sandgrasheide Pettstadt. – In: NEZADAL, W. (Hrsg.): Flora und Vegetation im östlichen Franken. – Veröffentl. Berufsverband Ökologen Bayerns **9**: 85–97.
- BRACKEL, W. v. 2008. *Zwackhiomyces echinulatus* sp. nov. and other lichenicolous fungi from Sicily, Italy. – Herzogia **21**: 181–198.
- VAN DEN BROECK, D., APTROOT, A. & JORDAENS, D. 2006. Een lichenologisch verslag van het voorjaarsweekend 2006 naar Zeeuws-Vlaanderen en aangrenzend België. – *Buxbaumiella* **75**: 16–25.
- CEZANNE, R., EICHLER, M., HOHMANN, M.-L. & WIRTH, V. 2008a. Die Flechten des Odenwaldes. – Andrias **17**: 1–520.
- CEZANNE, R., EICHLER, M., KIRSCHBAUM, U. & WINDISCH, U. 2008b. Flechten als Anzeiger des Klimawandels. Lichens as indicators of climate change. – In: Facetten der Flechtenforschung. Festschrift zu Ehren von Volkmar Wirth. – Sauteria **15**: 159–174.
- COPPINS, B. J., KONDRATYUK, S. Y., KHODOSOVTSSEV, A. Y., ZELENKO, S. D., COPPINS, A. M., WOLSELEY, P. A. & VIRCHENKO, V. M. 1998. Diversity of lichens and bryophytes in regional landscape park „Stuzhytzia“ (Ukrainian part of the international biosphere reserve „Eastern Carpathians“). – In: KONDRATYUK, S. Y. & COPPINS, B. J., Lobarion lichens as indicators of the primeval forests of the Eastern Carpathians, pp. 139–161. – Kiev: M. H. Kholodny Institute of Botany, Ukrainian Phytosociological Centre.
- CZARNOTA, P. & KUKWA, M. 2001. Lichens of the genera *Lepraria* and *Leproloma* from the Gorce Mts (Western Carpathians, Poland) and note on lichenicolous fungus *Paranectria oropensis* found on *Leproloma membranaceum*. – Polish Bot. J. **46**: 199–206.
- DIEDERICH, P. 1989. Les lichens épiphytiques et leurs champignons lichénicoles (macrolichens exceptés) du Luxembourg. – Trav. Sci. Mus. Natl. Hist. Nat. Luxembourg **14**: 1–268.
- DIEDERICH, P. 2003. New species and new records of American lichenicolous fungi. – Herzogia **16**: 41–90.
- DIEDERICH, P., SCHULTHEIS, B. & BLACKWELL, M. 2003. *Marchandiobasidium aurantiacum* gen. sp. nov., the teleomorph of *Marchandiomyces aurantiacus* (Basidiomycota, Ceratobasidiales). – Mycol. Res. **107**: 523–527.
- ERTZ, D. & DUVIVIER, J.-P. 2006. Les lichens du bassin hydrographique de l'Hermeton (Belgique): flore et mesures de conservation. – Bull. Soc. Nat. Luxemb. **107**: 39–62.
- ETAYO, J. 1998. Some hypocrealean lichenicolous fungi from Southwest Europe. – Nova Hedwigia **67**: 499–509.
- ETAYO, J. 2002. Catálogo de líquenes y hongos liquenícolas del Parque Natural de Bértiz (Navarra, España). – Bull. Soc. Linnéenne Provence **53**: 155–170.
- GILBERT, O. L. 1988. Studies on the destruction of *Lecanora conizaeoides* by the lichenicolous fungus *Athelia arachnoidea*. – Lichenologist **20**: 183–190.
- GRILL, D., HAFELLNER, J., KASCHNITZ, A. & PONGRATZ, W. 1988. Neuerliche Erhebung der epiphytischen Flechtenvegetation in Graz. – Mitt. Naturwiss. Vereines Steiermark **118**: 145–155.

- HAFELLNER, J. 1999. Einige Flechtenfunde in den Mürztaler Alpen (Steiermark, Österreich). – *Fritschiana* **21**: 31–35.
- HAFELLNER, J. 2002. Ein Beitrag zur Diversität von lichenisierten und lichenicolen Pilzen im Gebiet der Geinalpe (Steiermark, Österreich). – *Fritschiana* **33**: 33–51.
- HAFELLNER, J. 2007. Lichenicolous Biota (Nos 1–20). – *Fritschiana* **60**: 35–49.
- HAFELLNER, J. 2008a. Lichenicolous Biota (Nos 21–60). – *Fritschiana* **61**: 1–28.
- HAFELLNER, J. 2008b. Zur Diversität lichenisierter und lichenicoler Pilze im Gebiet der Koralpe (Österreich: Kärnten und Steiermark, Slowenien). – *Mitt. Naturwiss. Vereines Steiermark* **138**: 29–112.
- HAFELLNER, J. & KOMPOSCH, H. 2007. Diversität epiphytischer Flechten und lichenicoler Pilze in einem mitteleuropäischen Urwaldrest und einem angrenzenden Forst. – *Herzogia* **20**: 87–113.
- HAFELLNER, J. & OBERMAYER, W. 2001. Ein Beitrag zur Flechtenflora der Murberge (Steiermark, Österreich). – *Fritschiana* (Graz) **25**: 19–32.
- HAFELLNER, J. & OBERMAYER, W. 2007. Flechten und lichenicole Pilze im Gebiet der Stubalpe (Österreich: Steiermark und Kärnten). – *Mitt. Naturwiss. Vereines Steiermark* **136**: 5–59.
- HAFELLNER, J., OBERMAYER, S. & OBERMAYER, W. 2005a. Zur Diversität der Flechten und lichenicolen Pilze im Hochschwab-Massiv (Nordalpen, Steiermark). – *Mitt. Naturwiss. Vereines Steiermark* **134**: 57–103.
- HAFELLNER, J., PETUTSCHNIG, W., TAURER-ZEINER, C. & MAYRHOFER, H. 2005b. Zur Flechtendiversität in den Gurktaler Alpen (Kärnten, Steiermark, Salzburg). – *Herzogia* **18**: 79–138.
- HAWKSWORTH, D. L. 1979. The lichenicolous Hyphomycetes. – *Bull. Brit. Mus. (Nat. Hist.), Bot. ser.* **6**(3): 183–300.
- HAWKSWORTH, D. L. 1982. Notes on British lichenicolous fungi: IV. – *Notes R. Bot. Garden Edinburgh* **40**: 375–397.
- HAWKSWORTH, D. L. & PIROZYNSKI, K. A. 1977. The generic names *Paranectria* and *Paranectriella* and their synonyms. – *Can. J. Bot.* **55**: 2555–2557.
- HEDENÅS, H., LUNDIN, K. & ERICSON, L. 2006. Interaction between a lichen and a fungal parasite in a successional community: implications for conservation. – *J. Veget. Sci.* **17**: 207–216.
- VAN HERK, C. M., APTROOT, A., VAN DOBBEN, H. F. 2002. Long-term monitoring in the Netherlands suggests that lichens respond to global warming. – *Lichenologist* **34**: 141–154.
- HERNÁNDEZ PADRÓN, C. E., SICILIA MARTÍN, D., PÉREZ VARGAS, I., PÉREZ DE PAZ, P. L. & ETAYO SALAZAR, J. 2004. Líquenes y hongos liquenícolas. – In: BELTRÁN TEJERA, E. (ed.), *Hongos, líquenes y briófitos del Parque Nacional de la Caldera de Taburiente*, pp. 233–350. – Madrid: Organismo Autónomo de Parque Nacionales. Ministerio de Medio Ambiente.
- HITCH, C. (ed.) 2000. New, rare and interesting British lichen and lichenicolous fungus records. – *Brit. Lich. Soc. Bull.* **86**: 42–56.
- HITCH, C. (ed.) 2001. New, rare and interesting lichens. – *Brit. Lich. Soc. Bull.* **89**: 70–81.
- HITCH, C. (ed.) 2005. New, rare and interesting lichens. – *Brit. Lich. Soc. Bull.* **97**: 69–79.
- INSAROV, G. & SCHROETER, B. 2002. Lichen monitoring and climate change. – In: NIMIS, P. L., SCHEIDEGGER, C. & WOLSELEY, P. A. (eds.), *Monitoring with lichens - monitoring lichens*. – NATO Science Series IV. Earth and Environmental Sciences **7**: 183–201. – Dordrecht, Boston, London: Kluwer Academic Publishers.
- JANSSEN, A.-M., FRAHM, J.-P. & HEIDELBACH, B. 2007. Die Entwicklung der Flechtenvegetation in Bonn 2003–2006. The development of lichen vegetation in Bonn, FRG, between 2003 and 2006. – *Decheniana* **160**: 157–165.
- JÜLICH, W. 1972. Monographie der Atheliae (Corticaceae, Basidiomycetes). – In: Willdenowia Beih. **7**: 3–283.
- KEISSLER, K. v. 1930. Die Flechtenparasiten. – In: Dr. L. Rabenhorst's *Kryptogamen-Flora von Deutschland, Österreich und der Schweiz*, 2. Aufl., **8**: I–XI, 1–712. – Leipzig: Akademische Verlagsgesellschaft.
- KOCOURKOVÁ, J. & BRACKEL, W. v. 2005. Einige für Bayern neue flechtenbewohnende Pilze – Beitrag zu einer Checkliste I. – *Ber. Bayer. Bot. Ges.* **75**: 3–10.
- LAWREY, J. D. & DIEDERICH, P. 2003. Lichenicolous fungi: Interactions, evolution, and biodiversity. – *Bryologist* **106**: 80–120.
- LIŠKA, J. 1993. Příklad parazitizmu jako významného faktoru v sukcesi [The role of parasites in succession.]. – *Bryonora* **12**: 8–9.
- LONGÁN, A. & GÓMEZ-BOLEA, A. 1999. Líquenes y hongos liquenícolas epífitos de *Quercus ilex* L., poco conocidos en encinares de Cataluña (España). – *Cryptogamie, Mycol.* **20**: 49–55.
- MOTIEJUNAITĖ, J. 2004. Observations on epiphytic community dynamics in deciduous forests around a chemical factory in central Lithuania. – In: RANDLANE, T. & Saag, A. (eds.), *Book of Abstracts of the 5th IAL Symposium. Lichens in Focus*, p. 73. – Tartu: Tartu University Press.
- MOTIEJUNAITĖ, J. 2005. Epidemiology of the fungus *Athelia arachnoidea* in epiphytic communities of broadleaved forests under strong anthropogenic impact. – *Ekologiya* **2005**: 28–34.
- MOTIEJUNAITĖ, J. & JUCEVICIENE, N. 2003. Influence of *Athelia arachnoidea* on epiphytic communities growing in broad-leaved forests under strong anthropogenic impact [*Athelia arachnoidea* itaka labai antropogenizuotu placi-alapiu misku epifuitu bendrijoms]. – *Bot. Lithuanica* **9**: 253–258.
- NEUWIRTH, G. 2005. Die Flechtenflora des Kobernaufewaldes (Oberösterreich, Österreich). – *Beitr. Naturk. Oberösterreichs* **14**: 361–396.

- PARMASTO, E. 1998. *Athelia arachnoidea*, a lichenicolous basidiomycete in Estonia [Parasiitnahkis (*Athelia arachnoidea*), samblikel kasvav kandseen Eestis]. – Folia Cryptog. Estonica **32**: 63–66.
- POELT, J. & TÜRK, R. 1994. *Anisomeridium nyssaegenum*, ein Neophyt unter den Flechten, in Österreich und Süddeutschland. – Herzogia **10**: 75–81.
- REICHELT, G. & WILMANN, O. 1973. Vegetationsgeographie. – Braunschweig: Georg Westermann Verlag.
- ROSSMAN, A. Y., SAMUELS, G. J., ROGERSON, C. T. & LOWEN, R. 1999. Genera of Bionectriaceae, Hypocreaceae and Nectriaceae (Hypocreales, Ascomycetes). – Stud. Mycol. **42**: 1–248.
- ROUX, C., COSTE, C., BRICAUD, O. & MASSON, D. 2006. Catalogue des lichens et des champignons lichénicoles de la région Languedoc-Roussillon (France méridionale). – Bull. Soc. Linn. Provence **57**: 85–200.
- SAMUELS, G. J. 1976. A revision of the fungi formerly classified as *Nectria* subgenus *Hyphomycetia*. – Mem. New York Bot. Garden **26**(3): 1–126.
- SANTESSON, R. 1994. Fungi lichenicoli exsiccati. Fasc. 9 & 10 (Nos 201–250). – Thunbergia **22**: 1–24.
- SANTESSON, R. 2008. Fungi lichenicoli exsiccati. Fascicles 15 & 16 (Nos 351–400). – Thunbergia **36**: 1–28.
- SÉRUSIAUX, E., DIEDERICH, P., BRAND, A. M. & VAN DEN BOOM, P. 1999. New or interesting lichens and lichenicolous fungi from Belgium and Luxembourg. VIII. – Lejeunia, Nouv. Sér. **162**: 1–95.
- SÉRUSIAUX, E., DIEDERICH, P., ERTZ, D. & VAN DEN BOOM, P. 2003. New or interesting lichens and lichenicolous fungi from Belgium, Luxembourg and northern France. IX. – Lejeunia, Nouv. Sér. **173**: 1–48.
- SPARRIUS, L. B., APTROOT, A., VAN HERK, C. M. & BRAND, A. M. 2002. Nieuwe en interessante korstmossen en korstmosparasieten in Nederland met aanvullingen en wijzigingen op de checklist. – Buxbaumiella **59**: 26–46.
- TRETIACH, M. 1993 (“1992”). Lichenological studies in NE-Italy. V: New records from Friuli – Venezia Giulia. – Stud. Geobot. **12**: 3–60.
- TRIEBEL, D. 1989. Lecideicole Ascomyceten. Eine Revision der obligat lichenicolen Ascomyceten auf lecideoiden Flechten. – Biblioth. Lichenol. **35**: 1–278.
- WILLMANN, O. 1962. Rindenbewohnende Epiphytengemeinschaften in Südwestdeutschland. – Beitr. Naturkundl. Forsch. SW-Deutschl. **21**: 87–164.
- WIRTH, V., CEZANNE, R. & EICHLER, M. 1999. Beitrag zur Kenntnis der Dynamik epiphytischer Flechtenbestände. [Contribution to the knowledge of dynamics of epiphytic lichens]. – Stuttgarter Beitr. Naturk., Serie A **595**: 1–17.
- YURCHENKO, E. O. & GOLUBKOV, V. V. 2003. The morphology, biology, and geography of a necrotrophic basidiomycete *Athelia arachnoidea* in Belarus. – Mycol. Progr. **2**: 275–284.

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