Phaeographis inusta new to Norway, with comments on *Arthothelium macounii*

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Phaeographis inusta (Ach.) Müll. Arg. is reported from Norway for the first time, a southern, oceanic species which in Europe previously has been found north to East Jutland in Denmark. *Arthothelium macounii* (G. Merr.) W.J. Noble was recently reported from Norway. Here we add some short comments on the first record in Norway of this species. The two species were found on the same hazel shrub in a boreo-nemoral rainforest on the island of Stord, growing on smooth bark. The site, located on the west coast of Norway, is about 80 km south of Bergen. *Arthothelium macounii* is a strongly oceanic species. Within Europe it is known only from Scotland and Madeira.

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Introduction

As pointed out by Sverdrup-Thygeson et al. (2011), temperate rainforests are important habitats for red-listed species in Norway and their species diversity should be more thoroughly investigated. In the ARKO-project ("Areas for red-listed species - survey and monitoring"), poor boreonemoral rainforest was selected as a potential hotspot-habitat for the investigation of oceanic lichens and bryophytes in 2012–2014 (Blom et al. 2015). "Poor" is here defined in the meaning of low bark pH.

During field work in Stord municipality, SW Norway, we collected two interesting lichens from the same hazel shrub near Storavatnet. One collection was immediately identified as *Arthothelium macounii* (G. Merr.) W.J. Noble in the lab, based on the characteristic ascospores and KOH-reaction. The other resembled a *Graphis*, but the identification was problematical due to difficulties with finding spores in the collection. This collection was later identified by AF as *Phaeographis inusta* (Ach.) Müll. Arg. following the observation of a small number of largely overaged spores in one of the thallus fragments.

Blom et al. (2015) mentioned *Arthothelium macounii* without citing any specimen, while Frisch et al. (2020) recently published two records of *A. macounii* from the same area, including the first one from 2014. We here report *Phaeographis inusta* as new to Norway, with short descriptions of the morphology, ecology and distribution. The first record of *A. macounii* in Norway, which is from the same site, is shortly commented on.

Material and Methods

In the ARKO project, we searched for oceanic lichen species during field investigations in different temperate rain forest areas in the province of Hordaland, SW Norway, in 2013–2014. Study sites were selected based on an analysis of map data. Key elements were north facing lowland slopes covered with forest, in combination with humid climate, high yearly precipitation and preferably in the vicinity of sea or lakes (Blom et al. 2015). Positions (lat/long, WGS84) were taken with handheld GPS, with an accuracy of ± 10 m. For species identification, Smith et al. (2009) and Ernst & Hauck (1994) were used. Microscopic slides were prepared from fresh and dried material and mounted in water or KOH. Macro photographs were taken with a Canon EOS 650D digital camera with Canon MP-E 65 mm 1–5× macro lens. Collections are deposited in TRH and BG.

The thallus of *P. inusta* was tested for secondary lichen compounds in solvents B' and C following standard TLC procedures for lichens (Orange et al. 2010).

The Species

Phaeographis inusta (Ach.) Müll. Arg.

Flora 65: 383 (1882); *Graphis inusta* Ach., Synopsis lichenum: 85 (1814).

Description of the Norwegian specimen: Thallus greenish white to pale yellowish olive, uneven, moderately cracked, up to 0.15 mm tall, largely endophloeodal, ± delimited by a dark brown to black prothallus line. Ca-oxalate crystals numerous. Apothecia lirellate, in dendritically branched to stellate clusters up to 4 mm diam., the clusters often aggregated; individual lirellae 0.15–0.4 mm wide, with acute ends and an exposed, flat to slightly concave, blackish, thin, white, pruinose disc; margin thin, only slightly raised and bent over the disc, ± covered with coarse, whitish fragments of thallus (Figs 1–2). Proper exciple in vertical section 15–30 µm wide and reddish brown at the sides, 12–18 µm deep and somewhat paler below the hymenium. Hymenium 75–90 µm tall, densely inspersed. Epihymenium 7–10 µm tall, reddish brown. Only young asci and a few overaged spores seen. The spores 3–5 septate and 16–25 × 6–8 µm in size. Pycnidia absent.

Chemistry: No lichen acids detected by TLC (thallus K+ yellowish turning brownish, PD–).

Comments: Among the four European *Phaeographis* species (Benfield et al. 2009, Ernst & Hauck 1994), *P. inusta* is distinguished by the small spores, the lack of norstictic acid and the basally closed proper exciple. The species is morphologically highly variable, but the collection from Norway fits well to the descriptions provided for *P. inusta* in the cited literature. The specimen from Stord bears superficial resemblance with *Phaeographis dendritica* (Ach.) Müll. Arg., which differs in containing norstictic acid (sometimes patchy and in low concentration?) and the much larger spores, 30–50 × 6–11 µm, that are 5–10 septate (Benfield et al. 2009, Ernst & Hauck 1994).

Ecology: *Phaeographis inusta* was found on smooth bark of *Corylus avellana*, in a mixed, boreonemoral rain forest dominated by *Pinus sylvestris* and *Betula pubescens*. Further tree species in the locality included scattered *Sorbus aucuparia, Populus tremula* and *Quercus* spp. (Fig. 3). Many rainforest species were found in the same locality including *Arthonia ilicina* Taylor, *Arthonia stellaris* Kremp., *Crutarndina petractoides* (P.M. Jørg. & Brodo) Parnmen, Lücking & Lumbsch, *Graphis elegans* (Borrer ex Sm.) Ach., *Pyrenula occidentalis* (R.C. Harris) R.C. Harris and *Thelotrema macrosporum* P.M. Jørg. & P. James. These lichen species were growing on smooth

Figure 1. The hazel trunk with *Phaeographis inusta*. Photo: Geir Gaarder 27.05.2014.

Figure 2. Our collection of *Phaeographis inusta*. Photo: John Bjarne Jordal.

bark of tree species such as *Corylus avellana*, *Sorbus aucuparia* and *Ilex aquifolium*, while *Micarea alabastrites* (Nyl.) Coppins grew on *Betula pubescens* and *Pinus sylvestris*. Other species with somewhat less pronounced oceanic distribution, namely *Felipes leucopellaeus* (Ach.) Frisch & G. Thor, *Lecanactis abietina* (Ach.) Körb. and *Thelotrema lepadinum* (Ach.) Ach., were quite abundant. The hepatics *Microlejeunea ulicina* and *Plagiochila punctata* were among the oceanic bryophytes also present.

The southern parts of Stord are situated within one of the core areas of boreonemoral rainforests in Norway with several species-rich localities (Steinsvåg & Gaarder 2019). The forest is open, well-lit, with low tree crown cover and rather small trees. It can be described as a middle-aged forest, where old trees and dead trunks are sparse or lacking. The forest type is mostly a variant of oceanic nutrient-poor blueberry-dominated forest, but locally it is somewhat richer with more herbs such as *Primula vulgaris* and *Sanicula europaea*. [Further information https://faktaark.naturbase.no/?id=BN00103548]

The site is situated in a strongly humid area with mild winters, which can probably offer the best climatic conditions for this species in Norway. Biogeographically, the site belongs to the boreonemoral vegetation zone and the strongly oceanic vegetation section (Moen 1999). The climate is coastal, humid and with mild winters. The mean temperature of January at the nearby Stord Airport (5.8 km away) is +1.4°C, the mean temperature of July is 13.6°C (https://www.yr.no/nb/historikk/graf/5-48120/Norge/Vestland/Stord/Stord%20LH). The annual precipi-tation in Stord municipality is variable in the interval 1500–2500 mm and the frequency of precipitation >0.1 mm is 200–220 days/year (Moen 1999).

Distribution: This is the first record of *P. inusta* in Norway (Fig. 4). The species is widely distributed in Western Europe from Portugal to East Jutland in Denmark (e.g., Aptroot et al. 1999, Benfield et al. 2009, Diederich et al. 2021, Ernst & Hauck 1994, Llimona & Hladun 2001, Roux 2020, Silanes & Alvares 2003, Søchting & Alstrup 2008), and further known from the Czech Republic (Palice et al. 2007), Italy (Nimis 2016), Russia (Silanes & Alvares 2003), Ukraine (Vondrak et al. 2010), the Azores (Tavares 1952), and western and eastern North America (Esslinger 2018, England et al. 2019). A few additional, but doubtful records are listed in GBIF (2021) from South America, Africa, southern Asia (Gupta 2018), and Australasia.

Red list status: In Denmark, *P. inusta* is red-listed as data deficient (DD) (Anonymous 2019). It is similarly included as data deficient in the Italian red list of epiphytic lichens based on one single superhumid locality (Nimis 2016), as vulnerable ("kwetsbar") in the Dutch red list (Aptroot et al. 1998), and as highly threatened (category 2) in the red list of lichens and lichenicolous fungi of Germany (Wirth et al. 2011). It is included as of least concern (LC) in Great Britain but recognized as an international responsibility species (Woods & Coppins 2012).

Specimen examined: Norway. *Hordaland*: Stord, north of Røyrtjønna (Halvgjengeåsen), 5.4410°E, 59.7771°N, on *Corylus avellana* in a mixed, boreonemoral rainforest dominated by *Pinus sylvestris* and *Betula pubescens*, 20 m alt., 2014-05-27, G. Gaarder, J. B. Jordal s.n. (TRH L-23395).

Arthothelium macounii (G. Merr.) W.J. Noble

As Frisch et al. (2020) pointed out, Blom et al. (2015) were the first to publish this species for Norway; unfortunately, the locality was not mentioned. However, the record was based on the same specimen as cited by Frisch et al. (2020). That means that so far there have been only two finds of this rare lichen in Norway, both cited by Frisch et al. (2020).

Figure 3. The habitat of *Phaeographis inusta* with the finder (GG) investigating the hazel stem with the species. Photo: John Bjarne Jordal 27.05.2014.

Discussion

We found *P. inusta* on smooth bark of *Corylus avellana* in an open, mixed forest in an area with a coastal, humid, and winter mild climate. This agrees well with the known international distribution as shown by GBIF (2021), indicating a species with a southern oceanic tendency. In Sanderson et al. (2018), *P. inusta* is included in the Southern Oceanic Woodland Index ("SOWI"), which means that it is regarded as an indicator species of that element.

In the British Isles, *P. inusta* likewise grows especially on *Corylus avellana* in well-established oceanic woods. The species is locally frequent in southern England, western Wales and Ireland (Benfield et al. 2009, GBIF 2021), but interestingly has yet to be found in Scotland. It appears to be more common on other deciduous tree species outside of the British Isles and has frequently been reported from *Betula*, *Fagus* and *Quercus* as well as from *Acer*, *Aesculus*, *Alnus*, *Carpinus*, *Crataegus*, *Tilia* and *Ulmus* (Ernst & Hauck 1994, Silanes & Alvares 2003, Vondrak et al. 2010). *P. inusta* is the species with the widest distribution in Germany and the only one with extant populations (Ernst & Hauck 1994). The species appears to be extremely rare and local in Europe outside of its main distribution range. Under highly oceanic, local climates, it has been found as far

Figure 4. Map showing the position of the Norwegian locality of *Phaeographis inusta*.

east as the eastern Carpathians (Vondrak et al. 2010), the Black See coast in Russia (Silanes & Alvares 2003) and Turkey (GBIF 2021).

Based on foliose and fruticose species only, Degelius (1935) was the first to describe the oceanic element in the lichen flora of Norway. For the crustose lichens, Jørgensen (1996) gave an overview. With the ARKO-project and a coordinated study of the oceanic pine forests organized by Miljødirektoratet (Blom et al. 2015, Steinsvåg et al. 2018), the understanding of ecology, distribution and species diversity has been greatly improved during the last ten years. To this we had to add the NTNU-project "Three-Storied Diversity (TSD): Mapping and barcoding crustose lichens and lichenicolous fungi in the Norwegian rainforests", which contributed with many new and undescribed species (Frisch et al. 2020).

The discovery of two species new to Norway from the same locality and even from the same shrub came as a big surprise. Was this just a coincidence or are there some better explanations? It is possible the truth lies somewhere in the middle. In Europe, there are large differences between their occurrences. Both have a clear western distribution, but while *Arthothelium macounii* seems to be one of the most typical rainforest lichens in Britain, *Phaeographis inusta* has a more southern tendency and seems to be rather widespread along the western coast of Europe, e.g. western parts of Denmark, Netherlands, France, Spain and Portugal. Based on the present material, these species appear to be sympatric only in Norway.

There are good reasons to believe that both *A. macounii* and *P. inusta* are extremely rare in Norway. For many years, the boreonemoral rainforests have been investigated for rare and red-listed lichens. The two species are conspicuous and characteristic crustose lichens unlikely to be overlooked by an experienced field biologist. While more localities are likely to be discovered in high quality boreonemoral rainforest localities in western Norway in the future, we do not expect many. As these lowland areas have been exploited by forestry, building of roads, houses etc., it is likely that there have been former localities that have been destroyed.

In the last couple of years, several new, species-rich rainforest localities have been found in southwestern parts of Stord, but the areas are threatened by demolition (Fadnes 2021). These two species significantly strengthen this area's importance for oceanic lichens in Norway, and increase the need to put in place effective measures to protect them.

At this point, we can only speculate on possible explanations for the newly discovered occurrences of *A. macounii* and *P. inusta* in Norway. They may either represent relict populations of a declining species due to habitat loss, funding populations for expanding species due to a warming climate, or they are just rare species for reasons as yet unknown.

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