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Pyramidula tetragona (Brid.) Brid. rediscovered in Fennoscandia and new to Norway

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The threatened moss *Pyramidula tetragona* is rediscovered in Fennoscandia and found for the first time in Norway. The species has recently been classified as regionally extinct both in Sweden and Finland, and it is thus highly surprising that we can present four new localities from southeast Norway. All localities are or have been influenced by agriculture through grazing or cereal crop production.

The distribution of *Pyramidula tetragona* Brid. (Brid.) is confined to the Western Palearctic and Nearctic ecozones. It seems to avoid the northernmost areas, and in Sweden it has not been recorded north of *Limes norrlandicus* (about 60°N in Uppland), and the distribution is southern to southeastern in Fennoscandia. The distribution in the West Palearctic region is wide, but it seems to avoid the most extreme oceanic areas. In North America it has only been found in more continental areas. (Fig. 1).

The ecology of *Pyramidula tetragona* is seemingly quite wide. In North America it is most commonly found on mineral soil in grasslands, less often in forests or on river banks (Goffinet 2007). Also in Europe the ecology of the species is varying from grassland with dry mineral soils (Papp et al. 2000, Kara et al. 2008) to moist clay in arable fields (Krusenstjerna 1945). Lönnell (2002) and Hallingbäck (2010) describe the ecology based on the old Swedish collections as a pioneer on disturbed rather base rich clay, and mainly growing in fallow fields. Associated species in Sweden were *Fissidens taxifolius, Pleuridium subulatum, Tortula truncata* and *Riccia sorocarpa*. From Hungary Papp et al. (2000) list *Bryum argenteum, Bryum capillare, Mannia fragrans, Phascum cuspidatum, Riccia sorocarpa* and *Weissia longifolia* as associated species.

Pyramidula tetragona is autoicous and frequently found with sporophytes (Fig. 2). The spores are large, 45–72 µm in diameter, and nearly smooth. Specialised asexual reproduction may take place by small red rhizoidal tubers. In Sweden the species is found mainly from April to May and from October to November (Lönnell 2002), and a similar pattern is also reported from Hungary (Papp et al. 2000). It thus seems that under favourable conditions *P. tetragona* is able to develop mature sporophytes twice a year. To fully understand how this can take place we need to study the phenology of *P. tetragona* in more detail. Especially the timing of fertilisation in relation to sporophyte development is of importance. In much of the distribution area of *Pyramidula tetragona,* the summer is quite warm and dry and not suitable for growth and reproduction. Therefore it must have a rapid growth of gametophyte, rapid maturation of gametangia as well as rapid sporophyte development. In periods of unfavourable conditions, such as drought or frost, it probably survives as spores or tubers in the diaspore bank. Since neither the large spores nor the underground tubers are well adapted for long distance dispersal, the life strategy of *Pyramidula tetragona* is best described as an annual shuttle (sensu During 1992). This strategy relies upon a habitat that reoccurs at irregular intervals, but at the same location, and the duration of the favourable habitat may be short. The disturbance agent is man-made in the cases where it is growing in arable land (ploughing etc.), while animal trampling or other natural disturbance factors may dominate in grasslands. Climatic conditions are critical for a species with such a short time

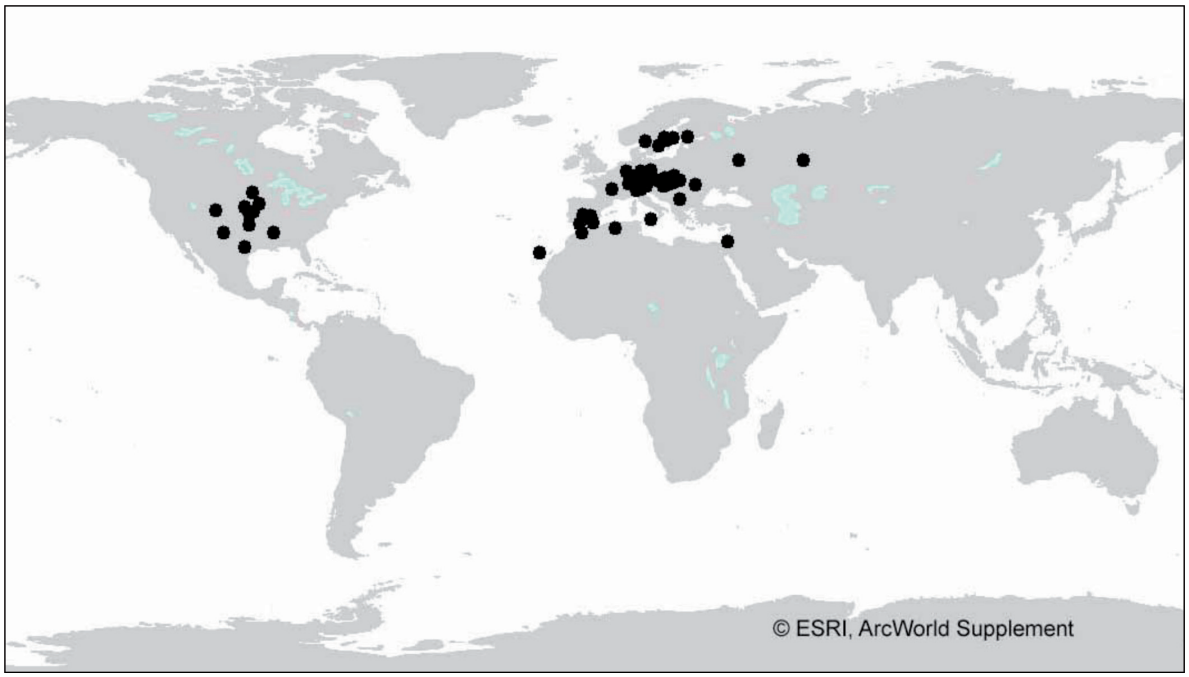

Figure 1. World distribution of *Pyramidula tetragona* (after Lönnell 2002).

span for completing its life cycle, and even short periods of drought at a critical time may hamper fertilisation. Papp et al. (2000) demonstrates large between-years variation in above-ground populations at two localities in Hungary.

Since *P. tetragona* is naturally very rare in all European countries where it is recorded, the species is listed as vulnerable (VU) on the European red list for bryophytes (ECCB 1992), and it is also included in the Bern Convention Appendix I for strictly protected flora species (The list contains only 13 species of Musci). Additionally the species is included in many national red lists, e.g. Finland, Serbia and Montenegro, Sweden, Hungary and Switzerland (Sabovljevic et al. 2004, Schnyder et al. 2004, Gärdenfors 2010, Papp et al. 2010, Rassi et al. 2010). In Sweden *P. tetragona* has been found in some 10–15 localities (Lönnell 2002, Hallingbäck 2010), but the last record is from the county of Uppland, in 1943. The species has been actively searched for at many of the old localities and other presumably suitable localities, but with negative outcome (Lönnell 2002, 2004). Consequently *P. tetragona* is listed as regionally extinct (RE) in the Swedish red list (Gärdenfors 2010). The situation is much the same in Finland, where it also is classified as RE in the latest red list (Rassi et al. 2010). We have not been able to verify whether *P. tetragona* occurs in Denmark; some authors report it (Nyholm 1989) while others do not (Lönnell 2006). Thus the situation for the species in Fennoscandia seemed rather critical prior to the new discoveries from southeastern Norway.

Methods

As part of the Norwegian Species Initiative project Bryophytes of poorly known habitats we conducted field inventories of bryophytes of arable land, focusing on areas where we have little knowledge of the bryophyte flora and where the potential for new records of poorly known species is high. The Oslofjord area (southeastern Norway) is one of our focus areas, and within this area 12 regions were chosen for further investigation. The regions visited were chosen in order to cover the geographical variation in the area and to get a representative sample of habitats. During September to November 2011 four regions were visited: Østfold, Oslo, Romerike and Ringerike. Investigations of the bryophyte flora of the cultural landscape were mainly focused on cereal crop fields and pastures, but occasionally other open habitats like roadsides and open calcareous soils were included. The selection of localities was mainly based on old herbarium records, bedrock and soil quality and altitude. In each region the main goal was to visit a number of sites representative for the cultural landscape in the area. Exposure, substrate texture, moisture, and pH were factors that were taken into consideration.

Two of the four regions investigated, the central parts of Østfold and Romerike, are dominated by acidic soils. In Ringerike and Oslo, the investigations were focusing on calcareous soils. Both Ringerike and Oslo are a part of the Oslo Rift with limestone formed in the Cambrian, Ordovician and Silurian periods (Moen 1998). Most lowland

Figure 2. A dense tuft of *Pyramidula tetragona* with sporophytes at the locality on Storøya in Hole municipality. Photo: TH 2011.

areas in the Oslo Rift are strongly influenced by humans, and the cultural landscape contains a wide variety of potentially interesting bryophyte habitats.

Pyramidula tetragona was discovered in Ringerike and Oslo. All together, approximately 30 sites were investigated in these two regions. According to Moen (1998), the lowland areas of both Oslo and Ringerike are situated in the boreonemoral zone. The mean annual precipitation in Oslo (station Blindern) is 763 mm (Table 1). The Ringerike area (station Hole, only precipitation measuring) is slightly drier, with a mean annual precipitation of 520 mm (Table 1). The mean annual temperature is almost similar in the two regions, 5.7°C in Oslo (station Blindern) and 4.7°C in Ringerike (station Hønefoss) (Table 1). This marginal temperature difference is mainly caused by lower winter temperatures in Ringerike.

The nomenclature follows Hill et al. (2006) for mosses and Söderström et al. (2002) for liverworts. Threat status of red listed species in Norway is according to Hassel et al. (2010).

Results

Pyramidula tetragona was found in four of 30 localities investigated in the Ringerike (3) and Oslo (1) regions. The localities are restricted to the Oslo Rift with base rich bedrock.

Description of new localities

1) Buskerud, Hole, near the farm Nøstret

Pyramidula tetragona was found in the upper, northwestern margin of a stubble field with cereal crops, gently sloping towards southeast. The field margin borders towards a narrow tongue of forest that stretches into arable land. The forest mainly consists of deciduous trees, e.g. *Acer platanoides*, that had shed its leaves onto the area where *P. tetragona* was growing. The locality is exposed to the sun from morning until mid day, but the forest shades the

Table 1. Precipitation (mm) and temperature data (°C) for the last normal period (1961–1990) and 2011 (Norwegian Meteorological Institute 2011). Only the growing season (April–November) is included.

OSLO Station Oslo (Blindern)

	Normal period (April–November)		2011 (April–November)	
	Precipitation	Temperature	Precipitation	Temperature
April	41	4.5	40	9.4
May	53	10.8	68	11.3
June	65	15.2	157	15.9
July	81	16.4	107	18
August	89	15.2	189	16.1
September	90	10.8	150	12.7
October	84	6.3	75	7.6
November	73	0.7	15	4.6
Mean		10.0		12.0
Sum	576		801	

RINGERIKE Station Hole and Hønefoss

	Normal period (April–November)		2011 (April–November)	
	Precipitation (Hole)	Temperature (Hønef.)	Precipitation (Hole)	Temperature (Hønef.)
April	25	4.5	21	9.2
May	44	11	29	10.5
June	56	15	149	15.4
July	69	16.5	118	17.2
August	67	15	102	15.2
September	63	10.8	102	11.9
October	62	5	36	6.5
November	44	–1.2	3	3.5
Mean		9.6		11.2
Sum	430		560	

margin of the field during the afternoon. *Pyramidula tetragona* was found only within a few meters from the field margin. It was growing in small scattered groups of plants along a distance of less than 50 m. *Acaulon muticum* (VU), another red-listed moss species found at this locality, was fairly common. Other bryophytes growing here include *Barbula unguiculata, Phascum cuspidatum, T. modica, T. truncata* and *Riccia sorocarpa*.

Locality data: *Pyramidula tetragona* (Brid.) Brid. Bu: Hole, Nøstret, UTM (WGS84) 32 V 56765 666067, 100 m a.s.l. 24.10.2011. Leif Appelgren, Torbjørn Høitomt and Niklas Lönnell (TRH).

2) Buskerud, Hole, in the southernmost end of Hurumåsen/Burudåsen nature reserve

During fieldwork in Hurumåsen/Burudåsen nature reserve a large piece of soil dominated by *Weissia controversa* and *Fissidens bryoides* was collected. When examined more closely, the collection contained two fertile shoots of *P. tetragona*. The collection is from 15 April 2011, but *P. tetragona* was not identified until November the same year.

The locality in the southernmost part of Hurumåsen/Burudåsen nature reserve is situated on the top plateau of a limestone ridge. The relevant part of the ridge is a former grassland, but is now overgrown with small pine trees and bush vegetation. To the west the ridge ends in a steep cliff.

The last meter or two towards the edge is still open, and this margin is characterized by open and unstable calcareous soil. The cliff is W facing, and the last few metres of the top plateau are gently sloping in the same direction. The two single shoots of *P. tetragona* were collected in the margin along the top of the cliff. The entire margin was investigated by bryologists both in May and October, but no more shoots were discovered.

Other common mosses in the site were the endangered (EN) *Pterygoneurum ovatum*, *Ditrichum flexicaule*, *Abietinella abietina*, *Rhytidium rugosum*, *Tortula modica*, *Weissia controversa* and *Fissidens bryoides*.

Locality data: *Pyramidula tetragona* (Brid.) Brid. Bu: Hole, in the southernmost end of Hurumåsen/Burudåsen nature reserve. UTM (WGS84) 32 V 57209 666489, 97 m a.s.l. 15.04.2011. Torbjørn Høitomt and Siri Lie Olsen (TRH).

3) Buskerud, Hole, 100 m W of Storøya farm

The *P. tetragona* locality W of the farm Storøya is situated in a narrow unstable margin between an arable field and open, dry pine forest on calcareous soil (Fig. 3). The site is SSE facing in gently sloping terrain and gets plenty of sunshine throughout the day because of the open arable field in front. The substrate is slightly sandy calcareous clay. Approximately 40–50 m of the margin seemed to be suitable for *P. tetragona*, but it was only growing in a small area of 0.1 × 0.1 m. All together we found 28 fertile shoots divided into three groups of 22, 3 and 3 shoots, respectively. The absence of *P. tetragona* along most of the margin may be explained by a slightly higher amount of acidic organic matter from the pine trees. *P. tetragona* grew in the area furthest away from the pine trees, by a small clearing in the forest.

As in the other localities, we found other red listed species growing in the near vicinity of *P. tetragona*. *Acaulon muticum* (VU) was growing scattered, but not rare along the 40–50 m long margin, and *Weissia longifolia* (VU) was found in two smaller areas with a total of approximately 15 tufts. The dominant moss species was, however, the more common *Phascum cuspidatum*. Other common mosses and liverworts at the site were *Tortula modica*, *Pleurozium schreberi* and *Riccia sorocarpa*.

Figure 3. The locality on Storøya in Hole is situated along the margin between a cereal crop field and a calcareous pine forest. Photo: TH 2011.

Locality data: *Pyramidula tetragona* (Brid.) Brid. Bu: Hole. 100 m W of Storøya farm. UTM (WGS84) 32 V 56916 665738, about 40 m a.s.l. 02.12.2011. Torbjørn Høitomt and Kåre Arnstein Lye (TRH).

4) Oslo, Bygdøy, by Frognerkilen between Rodeløkken and Oscarshall

This locality, which is the only known locality outside Hole municipality, is situated on the Bygdøy peninsula in Oslo, approximately 30 km from the main distribution in Hole. The locality at Bygdøy is, unlike the others, affected by grazing. *P. tetragona* was found on bare, calcareous soil disturbed by trampling and natural erosion on the edge of a vertical rock wall rising from the sea. The locality is SE facing and gets plenty of sunshine throughout the day. An area of approximately 10 × 5 m seemed to be suitable habitat for P. *tetragona*, but it grew only in a small section of 0.5 × 1 m. In this area we found about 15 fertile shoots, scattered or in small tufts. We have no obvious explanation for this sparse occurrence.

The moss flora at this site contained a mixture of species favoured by disturbance, such as. *Tortula modica* and *Weissia controversa*, and species requiring a more stable substrate, for instance *Hypnum cupressiforme*, *Fissidens dubius*, *Abietinella abietina*, *Tortella tortuosa* and *Ditrichum flexicaule*. *Encalypta vulgaris* (VU) was common on the rock wall below where *P. tetragona* was found.

Locality data: *Pyramidula tetragona* (Brid.) Brid. Oslo: Bygdøy, by Frognerkilen between Rodeløkken and Oscarshall. UTM (WGS84) 32 V 59460 664291, about 10 m a.s.l. 24.11.2011. Torbjørn Høitomt and Kåre Arnstein Lye (TRH).

Discussion

The discovery of *Pyramidula tetragona* in Norway is very surprising, especially in light of its current status as regionally extinct in the neighbouring countries Finland and Sweden. The finding of altogether four localities indicates that this is not the result of a recent local introduction. The species has probably been in its Norwegian localities for a long time, but restricted periods of favourable growth conditions on the edge of the distribution range, combined with small populations and low bryological activity in this kind of habitats, may explain why it has not been discovered earlier. The growing season 2011 was more humid and warmer than normal, with an exception for the relatively dry October and November, and it is possible that this was a year with very favourable growth conditions for *P. tetragona*. B. Papp (2012, pers. comm.) reports that a period of moist weather conditions may facilitate development of *P. tetragona* in Hungary. How the species responds to seasonal variation in temperature and precipitation in Norway, will hopefully be revealed through future monitoring of the populations.

All the new Norwegian localities are influenced by human agricultural activity: cereal crop fields or grasslands influenced by grazing. The main threat to *P. tetragona* is probably cessation of agricultural practices followed by a succession of bushes and trees. This is what we see in the Hurumåsen/Burudåsen nature reserve, were grazing no longer takes place. However, in this reserve measures have been taken to open up the vegetation, and hopefully the management will have a positive effect on the *P. tetragona* population. The fact that the species is mainly found along cereal crop field margins indicates that such areas are important habitats for *P. tetragona*. Whether disturbance, relatively low nitrogen and pesticide deposition, high pH, climatic conditions, or a combination of these factors are the most important, remains to be proven.

To further understand the biology and environmental constraints of *P. tetragona*, it would be of great interest to monitor the future development of the populations at the four newly discovered localities. It is important to obtain information on both agricultural practice and climatic data at the localities, as these may be the most important factors for population development. The four localities presented are the only known localities in Fennoscandia, and it is essential to build up knowledge on the biology of *P. tetragona* to be able to establish conservation practices that can secure the persistence of the species also in the future.

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