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Xanthoria calcicola (Teloschistaceae, Ascomycota) still present on bark in Sweden

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Almost twenty years ago, a comprehensive survey of the status of the redlisted (‘protection-worthy’) lichens of southwestern Sweden was published (Arup et al. 1997). This publication quickly became an important baseline for subsequent Swedish red lists (Gärdenfors 2000, 2005, 2010) as well as further studies of the lichen flora of the region. The characteristic lichen Xanthoria calcicola Oken, at that time redlisted as Vulnerable (IUCN category 2), is one of the species included in the study (Arup et al. 1997). It was reported to grow on slightly alkaline substrates, mainly on churchyard walls, but also on church walls. It was refound at seven out of 13 earlier known localities (ca 50%), and 12 new localities were discovered (Arup et al. 1997). It was pointed out that there was no modern observation of X. calcicola growing on bark, in spite of several earlier reports between 1939 and 1948 of the species occurring on various deciduous trees (Aesculus hippocastanum, Acer spp., Fraxinus excelsior, Tilia spp. and Ulmus spp.). Arup et al. (1997) postulated that the disappearance of X. calcicola from the suboptimal bark substrate further corroborated its status as being in decline, probably referring to the hypothesis that ecological retardations start with marginal populations (Kawecki 2008).

Xanthoria calcicola belongs to a European southern-temperate element (Almborn 1948, as X. aureola), extending from southern Scandinavia to the Mediterranean, and from eastern Great Britain to Ukraine and the middle East (Wirth 1995, Hitch et al. 2009). In Sweden, the species has a southern distribution in the lowlands of the southernmost regions; Skåne, Gotland, eastern Småland and Halland (Arup et al. 1997, Nordin et al. 2016). The Swedish localities constitute the northern rim of the total geographical distribution of X. calcicola.

We made an attempted complete survey of the supposedly rare (included in all Swedish red lists before 2015; ArtDatabanken 2015) churchyard lichen X. calcicola within the south and west parts of Skåne, a total area of ca 5500 km² (Fig. 1). Primarily all churchyards and churches, abandoned churchyards, ruin churches and castle ruins were investigated. Xanthoria calcicola was searched for at all habitat types, including trees, at each locality, the number of thalli estimated, and occurrence of apothecia noted (Lindblom and Blom 2009).

Of totally 331 investigated localities, X. calcicola was found at 125 localities (38%). Fourteen of the localities harbour thalli growing on bark (11%) (Table 1, Fig. 1).
Table 1. Visited localities where *X. calcicola* was found on bark, arranged by year of first observation. All localities are churchyards, except Månstorps gavlar (Månstorp gables), which is a castle ruin since 1678. The two rediscoveries of *X. calcicola* on bark in our study (2010–2014) are growing on the same tree species as the original observation (1938–1939). *) total ITS haplotype. **) in our study (2010–2014).

| Locality            | Year of first obs. | Year revisited | Substrate tree spp. | Note (2010-2014) | No. thalli bark** | No. thalli stone** | Haplotypes* bark** | Haplotypes* stone** | Apotheciate bark** | Apotheciate stone** |
|---------------------|--------------------|----------------|---------------------|------------------|-------------------|--------------------|---------------------|---------------------|--------------------|---------------------|
| Mölleberga          | 1938               | 2010           | Tilia sp.           | one tree only.   | 17                | 0                  | C1, C3              | -                   | N                  | n/a                 |
| Barkåkra            | 1939               | 2012           | Aesculus hippocastanum | also on churchyard wall. | 3                | 180                | C3                  | C1, C3, C5          | Y                  | Y                   |
| Mellan-Grevie       | 1942               | 2012           | Fraxinus excelsior  | not found.       | -                 | -                  | -                   | -                   | n/a                | n/a                 |
| Hemmesdyinge        | 1943               | 2011           | Aesculus hippocastanum | only on churchyard wall. | -                | 5                  | -                   | C1, C2, C3, C6      | n/a                | Y                   |
| Lilla Isie          | 1943               | 2011           | Ulmus sp.           | only on tombstones/ churchyard wall. | -                | 47962              | -                   | C1, C3              | n/a                | N                   |
| Skabersjö           | 1946               | 2012           | Ulmus sp.           | only on churchyard wall. | -                | 80                 | -                   | C1, C3, C5          | n/a                | Y                   |
| Hyllie old          | 2000               | 2014           | Ulmus sp.           | only on churchyard wall. | -                | 11                 | -                   | C3, C5              | n/a                | Y                   |
| Kyrkoköpinge        | 2011               | -              | Ulmus laevis        |                  | 2                 | 5130               | C1                  | C1, C3              | Y                  | Y                   |
| Virke               | 2011               | -              | Tilia sp.           |                  | 20                | 875                | C2                  | C2                  | N                  | N                   |
| Hofterup            | 2011               | -              | Tilia sp.           |                  | 24                | 1833               | C3                  | C1, C2, C3          | Y                  | Y                   |
| Maglarp old         | 2011               | -              | Aesculus hippocastanum |                  | 4                 | 8120               | C1                  | C1, C2, C3, C5      | N                  | Y                   |
| Fleninge            | 2012               | -              | Aesculus hippocastanum |                  | 6                 | 347                | C3                  | C1, C3              | N                  | Y                   |
| Skegrie             | 2012               | -              | Tilia sp.           |                  | 200               | 2092               | C3                  | C1, C3, C5          | N                  | Y                   |
| Månstorps gavlar   | 2012               | -              | Fraxinus excelsior  |                  | 2                 | 4998               | C3                  | C1, C2, C3          | N                  | Y                   |
| Oxie                | 2012               | -              | Tilia sp.           |                  | 2                 | 15                 | C2                  | C1, C2, C3          | N                  | N                   |
| Bunkelöfo           | 2012               | -              | Tilia sp.           |                  | 8                 | 184                | PCR failed          | C1, C3              | N                  | Y                   |
| Båstad              | 2012               | -              | Tilia sp.           |                  | 5                 | 93                 | C3                  | C3                  | N                  | Y                   |
| Öja                 | 2013               | -              | Tilia sp.           | small thallus, no genetic sample | 1                | 10                 | -                   | C1, C3              | N                  | Y                   |
| Östra Nöbbelöv      | 2013               | -              | Tilia sp.           |                  | 1                 | 25                 | C3                  | C3                  | N                  | N                   |
The populations found on bark vary in size from 1 to ca 200 thalli (Fig. 2–5). All bark populations are small (1–24 thalli), except one (Skegrie churchyard, Fig. 5). Two are rediscoveries at localities where it has previously been collected on bark and 12 are new discoveries. In total, we have observed ca 300 thalli of \( X. \text{calcicola} \) growing on bark. At six of the previously known localities, including one where it was reported relatively recently (Malmqvist 2000), the species was not found (Table 1). At all localities except one \( X. \text{calcicola} \) in addition to bark was present on the surrounding churchyard walls. The only exception was Mölleberga churchyard (Fig. 4B), where there were virtually no lichens on the wall, indicating that it had been recently whitewashed (Lindblom and Blom 2010). The wall populations at localities where \( X. \text{calcicola} \) grows on bark were, on average, larger than other wall populations (1706 ± 2559 versus 489 ±1360 thalli), and a larger proportion of them possessed thalli with apothecia (71.4% versus 50.5%). Thus, localities with tree populations seem to have important source populations on walls in relation to localities with populations on walls only. Seemingly suitable churchyard trees were present at most of the investigated localities, indicating that colonization of \( X. \text{calcicola} \) on trees is a rare event. The trees harbouring \( X. \text{calcicola} \) were always growing close to the wall habitat, up to ≤ 5 m (Fig. 3). These results add to the hypothesis that trees are actually suboptimal habitats for \( X. \text{calcicola} \). Hence, bark populations are sinks (sensu Dias 1996) sustained by continuous supply of diaspores from the connected source population on walls (sensu Dias 1996).

Heterothallic species require two compatible partners to produce sexual diaspores and, hence, outbreeding is promoted. Interestingly, we have, although extremely rarely, observed thalli of this heterothallic species with apothecia on bark (Table 1, Fig. 4A). Thus, \( X. \text{calcicola} \) can potentially disperse by ascospores even when growing on a suboptimal substrate as tree bark. However, whether these ascospores are viable, able to resynthesis with a photobiont, and establish the lichen thallus remains to examine.

It is notable that we never observed \( X. \text{calcicola} \) growing on trees in tree avenues and parks with an environ-
ment closely resembling churchyards. Such habitats are very common in the open and predominantly cultural landscape of Skåne. During our many travels across Skåne before and during our field study we have searched countless random deciduous trees (of the same species as those colonized by X. calcicola) outside churchyards without ever finding X. calcicola. Neither in the extensive field work of Arup et al. (1997) were any tree populations discovered. Observations of young colonizing populations (small thalli) on walls, cemented posts, etc., at distances up to more than 1 km from known source populations, as well as preliminary statistical analyses from our study, indicate that X. calcicola is not strongly delimited by dispersal distances at the scale of our investigation area. We argue that the reason why X. calcicola has not yet been found on trees away from wall populations is a combination of diaspore density dilution by distance from sources and a clearly suboptimal habitat; there are simply so few diaspore hits on such trees that establishment becomes extremely rare.

Preliminary results from fungal ITS data of samples from the localities with populations of X. calcicola (methods following Lindblom and Ekman 2005) reveal that haplotypes found in bark samples are always present in the surrounding wall populations (Table 1). The molecular data suggest that each population of X. calcicola occurring on bark is a subsample of the connected wall population.

Our results support the hypothesis that establishment on trees are dependent on wall populations in close vicinity, continuously bombarding the suboptimal tree habitats with diaspores. The Mölleberga churchyard locality, where the churchyard wall has recently been whitewashed and the wall population are now without X. calcicola.

Figure 4. Xanthoria calcicola on bark. (A) Apotheciate thallus on Ulmus laevis growing close to the churchyard wall, which harbours a large population (Kyrkoköping church). (B) Small population growing on one Tilia sp. close to the churchyard wall, which seems recently whitewashed and almost free of lichens (Mölleberga church, Lindblom and Blom 2010).

Figure 5. The largest bark population found, with approximately 200 thalli growing on bark of 22 Tilia sp. trees. The surrounding wall population is also very large (Table 1) (Skegrie church).
thalli, would be an interesting case study for investigating whether a population on bark can sustain over time without continuous supply of diaspores.

*Xanthoria calcicola* is no longer redlisted in Sweden, based on the results of our field investigation submitted to the Swedish expert committee for lichens (ArtDatabanken 2015). Clearly, conservation of this beautiful lichen should focus on the churchyard wall populations, addressing the main threats of whitewashing and pressure cleaning.

**Conclusions**

*Xanthoria calcicola* in Skåne is more frequently occurring on tree bark than previously assessed.

Trees are suboptimal habitats for *X. calcicola* and only colonized when in close vicinity of an established wall population.

Even when growing on a suboptimal substrate, in this case tree bark, the heterothallic species *X. calcicola* is able to produce apothecia.

The most obvious threat to epiphytic *X. calcicola* is the cutting down of the host tree. In addition, thorough cleaning of walls near the trees is a threat, because it could eradicate the potential source population.

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