Folia Cryptog. Estonica, Fasc. 59: 69–81 (2022)
https://doi.org/10.12697/fce.2022.59.11

A recent update in red-listing of Estonian lichens: threat status of 168 species was assessed for the first time

Inga Jüriado[1], Polina Degtjarenko[1&2], Ede Oja[3] & Tiina Randlane[1]

[1]University of Tartu, Institute of Ecology and Earth Sciences, J. Liivi Str. 2, 50409 Tartu, Estonia
[2] University of Daugavpils, Institute of Life Sciences and Technology, Parādes 1a, 5401 Daugavpils, Latvia
[3]University of Tartu, Natural History Museum and Botanical Garden, Vanemuise Str. 46, 51014 Tartu, Estonia
E-mail: inga.juriado@ut.ee

Abstract: The threat status of 168 lichenized species growing mostly on rocks or ground were assessed in 2022 for the first time in Estonia. The IUCN Red List system (categories and criteria) were used for that purpose. Most of the assessed taxa were microlichens (163), while five macrolichen species were also evaluated. Among the assessed species, 91 were assigned to the threat categories (Critically Endangered – CR, Endangered – EN and Vulnerable – VU), 17 species were assigned to the category Near Threatened (NT), and 41 species were assigned to the category Least Concerned (LC). Category Data Deficient (DD) was assigned for 17 species and the category Regionally Extinct (RE) for two species. Among the threat categories, 35 species were assigned to the category EN, 34 species to VU, and 22 species to CR. In general, most of the evaluated species (81%, 137 species) were growing on different types of rock, 16% (28 species) of species were growing on soil, mosses or plant debris, and three taxa were growing on other substrata. Most of the threatened epigeic and epilithic microlichens were recorded on alvar grasslands growing on ground, limestone pebbles and flatrock or erratic boulders. Erratic boulders in various forest types and calcareous cliffs in clint forest were also important habitats for threatened species. Moreover, different rock substrates of anthropogenic origin (walls, buildings and abandoned limestone quarries) performed as significant habitat type for epilithic species. Bush encroachment of open habitats, especially in semi-natural grasslands, serves as the main threat for epigeic and epilithic lichens.

Kokkuvõte: 2022. aastal hinnati esmakordselt 168 Eestis peamiselt kivil ja maapinnal kasvava samblikuliigi ohustatust. Kasutati IUCN'i punase nimestiku kategooriate ja kriteeriumite süsteemi. Enamus hinnatud taksonitest olid pisisamblikud (163), suursamblikest olid hindamisel vaid viis liiki. Hinnatud liikidest 91 kuulusid ohukategooriatesse ('Kriitilises seisundis' – CR, 'Väljasuremisohus' – EN, 'Ohualdis' – VU), 17 liiki – kategooriasse 'Ohulähedane' (NT) ja 41 liiki – kategooriasse 'Soodsas seisundis' (LC). 17 liiki said staatuse 'Puuduliku andmestikuga' (DD) ja kaks liiki on regionaalselt välja surnud – RE . Ohukategooriate liikidest 35 liiki määrati kategooriasse EN, 34 liiki – kategooriasse VU ja 22 liiki – kategooriasse CR. Enamus hinnatud liikidest (81%, 137 liiki) kasvas kividel, 16% (28 liiki) kasvas mullal, maapinnasammaldel või taimejäänustel ja 3 liiki asustasid teistsuguseid substraate. Enamus ohustatud epiliitsetest ja epigeilistest pisisamblikest kasvavad loopealsetel maapinnal, lubjakiviklibul, paljanduval paeplaadil või rändrahnudel. Ohustatud samblikele on oluliseks kasvukohaks ka erinevates metsatüüpides leiduvad rändrahnud ja paepaljandid pangametsades. Lisaks on epiliitsetele samblikele oluliseks kasvupinnaks erinevad inimtekkelised tehissubstraadid ja kivimipinnad nagu ehitiste müürid ja seinad ning mahajäetud karjäärid. Nii maapinnal kui kivil kasvavatele samblikele on avatud kooslustes, eriti poollooduslikel niitudel, peamiseks ohuteguriks võsastumine.

Keywords: alvars, crustose lichens, epilithic lichens, epigeic lichens, microlichens, IUCN, lichen habitats, threat status

INTRODUCTION

The threat status of Estonian lichens was evaluated in 1988 for the first time; 40 species were included in the list of threatened lichens (Anonymous, 1993). Ten years later already 110 lichen species were included in Red Data Book (Randlane, 1998). In these two early Red Data Books of Estonia only macrolichens were evaluated using a conventional system of threat categories while the criteria for defining the categories were mainly intuitive-emotional (Lilleleht, 1998; Randlane et al., 2008). In 2008 the international IUCN Red List system of categories together with clearly established criteria was used for the first time in Estonia (Tartes, 2010). Altogether 464 lichen species were evaluated then out of the total 1019 lichenized and closely allied fungi recorded nationally at that time. Among evaluated species, mainly macrolichens, 213 were assigned to one of these IUCN categories: Regionally Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near

Threatened (NT) or Data Deficient (DD), while 251 species were assessed as Least Concern (LC) (Randlane et al., 2008). The next round of threat status assessments of Estonian lichens started in 2019 (Lõhmus et al., 2019). This process has been divided between five different projects of which one is still ongoing. Results of the two finished projects have been published already (Lõhmus et al., 2019; Randlane et al., 2021), and here we make the outcome of the third red-listing project public as well.

Thus, until the current round of red-listing of Estonian lichens, mainly the threat status of macrolichens has been assessed. The group of epiphytic lichens is overwhelmingly the most well studied group of lichenized fungi in Estonia (e.g., Marmor et al., 2017; Lõhmus & Lõhmus, 2019; Liira et al., 2020) and, accordingly, the threat status of epiphytic and epixylic microlichens has been evaluated during recent years (Estonian Nature Information System EELIS, https://www.eelis.ee). Although the amount of the evaluated microlichens has increased considerably, the share of epigeic and epilithic taxa has remained insignificant (Lõhmus et al., 2019; Randlane et al., 2021). In this study the threat status of 168 lichenized species growing mostly on rocks or ground were assessed for the first time. Most of the total of 168 taxa were microlichens (163), while five macrolichen species were also evaluated; none of them have been assessed against IUCN Red List categories and criteria before.

MATERIAL AND METHODS

The main data source for species occurrence records was the PlutoF biodiversity database (https://plutof.ut.ee/; Abarenkov et al., 2010), that incorporates the data of specimens from all main Estonian herbaria (TUF, TALL and TAM). In addition, some literature records and the datasets of published and unpublished lichen research projects or inventories in Estonia were uploaded to the PlutoF database and made available for the expert group. Preparing the list of the species under evaluation and analysing their distribution data, different regions of Estonia were selected (e.g., North-, East- and South-Estonia) where additional field work was planned. Special effort was done to check the historical localities and to get new locality data to update the distribution maps of targeted species. Collected lichen samples were identified in the laboratory using stereo- or light microscope and chemical analyses. Reference samples are kept in TUF. The dataset of records gained during the field work was also uploaded to the PlutoF database. The taxonomy follows Randlane et al. (2021).

In principle, the same concept and the evaluation process as during the previous red list assessments of lichens in Estonia were used (Randlane et al., 2008; Lõhmus et al., 2019). The latest IUCN guidelines for using the Red List categories and criteria (IUCN Standards and Petitions Subcommittee, 2017, 2019) were applied as well as supplementary guidelines for applying IUCN Red List criteria for fungi (Dahlberg & Mueller, 2011). The following IUCN Red List categories were applied: RE, CR, EN, VU, NT, DD and LC. Of them, CR, EN and VU are threatened categories according to the IUCN guidelines. Similarly to the previous assessments (Randlane et al., 2008; Lõhmus et al., 2019), the species that had not been reliably reported from Estonia after 1950 were considered to be RE.

Applying IUCN criteria, criterium A (Population Size Reduction), B (Geographic Range), C (Small Population Size and Decline) and D (Very Small or Restricted Population) were assessed for each species and the highest according category was assigned to the species. Criterium E (Quantitative Analysis) was not used due to the insufficiency of data. We applied quantitative threshold levels for category NT provided in Dahlberg & Mueller (2011).

The length of a generation was considered 17 years for epilithic sexually dispersed species, while 7 years for one generation was considered for epigeic species or epilithic lichens having asexual propagules (soredia, isidia, blastidia) as the usual estimate for lichens (Gärdenfors, 2005; Lõhmus et al., 2019; Pykälä et al., 2019) (Appendix 1). The number of mature individuals (used in criteria C and D1) was considered up to 50 individuals per one locality. The population was treated as severely fragmented if the distance between localities was more than 50 or 100 km (for vegetatively or spore-dispersed species, respectively). Applying criteria A2 and A3, inferred or suspected decline of populations within the time length of three generations (i.e.,

51 years or 21 years) were used. For delimiting the populations and subpopulations, as well as counting extent of occurrence (EOO) and area of occupancy (AOO) we used PlutoF biodiversity database and the base map of the Estonian Land Board (https://geoportaal.maaamet.ee).

Assessment of the threat status of targeted lichen species was carried out during January–May 2022 by I. Jüriado and T. Randlane. The reviews of the assessments were provided by all authors and by lichen experts P. Lõhmus, A. Suija (University of Tartu) and L. Marmor-Ohtla (Tallinn Botanic Garden, Estonia). The process was performed using the Estonian Nature Information System EELIS (https://www.eelis.ee); the species assessment sheets (including the relevant map files) are available to the registered users of this information system.

RESULTS AND DISCUSSION

The threat status of Estonian lichens has been assessed since 1988 (Lilleleht, 1998), and the assessments of taxa that have not been evaluated previously are still ongoing (Randlane et al., 2021). In this Red List assessment, following IUCN categories and criteria, the threat status of 168 lichenized species growing mostly on rocks or ground were assessed for the first time in Estonia (Appendix 1). This constitutes nearly 20% of lichenized taxa of Estonia (Randlane et al., 2021) and represents the significant share of epilithic and epigeic species. This is an important accomplishment of ongoing red list assessment of lichens in Estonia. By now 86% of lichens recorded in Estonia have been assessed against IUCN Red List categories and criteria.

Distribution between the categories

Most of the evaluated species represented microlichens, only five macrolichen species (*Catapyrenium daedaleum*, *Enchylium polycarpon*, *Lathagrium auriforme*, *Scytinium plicatile* and *Umbilicaria vellea*) were included. Two of these, *Lathagrium auriforme* (found in 1932) and *Umbilicaria vellea* (found at the beginning of 20th century), are considered RE in Estonia, while other three are nationally endangered (Appendix 1). In principle, the threat status of Estonian macrolichens has been evaluated during previous assessment periods (Lilleleht, 1998; Randlane et al., 2008, 2021; Lõhmus et al., 2019), but some macrolichens had been overlooked or were not yet found in the region during previous assessments, such as *Catapyrenium daedaleum* (Suija et al., 2011).

Among the assessed species, 91 were assigned to the threat categories (CR, EN, VU), 17 species were assigned to the category NT and 41 species were assigned to the category LC. Data Deficient (DD) category was applied for 17 species, while NE category was not used for any species (Fig. 1). Among the threat categories almost equal number of species were assigned to categories EN (35) and VU (34), whereas 22 species were assigned as critically endangered (CR). Proportionally, among the evaluated species, the highest share, 54.2%, constituted the species of threat categories (CR, EN, VU) while 24.4% of the species belonged to the category LC.

During the assessment process, criteria D (Very Small or Restricted Population, 107 cases) and B (Geographic Range, 88 cases) were mostly used (Appendix 1). The data for applying criterium A (mainly A2 and A3, Population Reduction) were available in 18 cases and criterium C (Small Population Size and Reduction) was possible to use only in four cases. Criteria D and B were also most commonly used in previous IUCN assessments in Estonia (Randlane et al., 2008; Lõhmus et al., 2019), whereas also criteria A and C were frequently applied during the assessment process in 2019 but much less applied in this assessment due to the lack of relevant data.

Substrate groups

In general, most of the evaluated species (81%, 137 taxa) were growing on different types of rock or their host lichen was growing on rock (e.g., *Protoparmelia atriseda* and *Rimularia furvella*), 16% (28 taxa) of all species were growing on soil, mosses or plant debris, and three taxa were growing on other substrates (e.g., *Byssoloma subdiscordans* on tree) (Appendix 1). This classification is made according to the most common substrate habitation in Estonia as some species may occasionally grow both on calcareous rock or calcareous soil or both on granite or calcareous rock.

Of the evaluated epilithic lichens, 68 species were growing mainly on granite and 69 mainly on calcareous rocks (including also bricks, mortar and other kind of anthropogenic substrata).

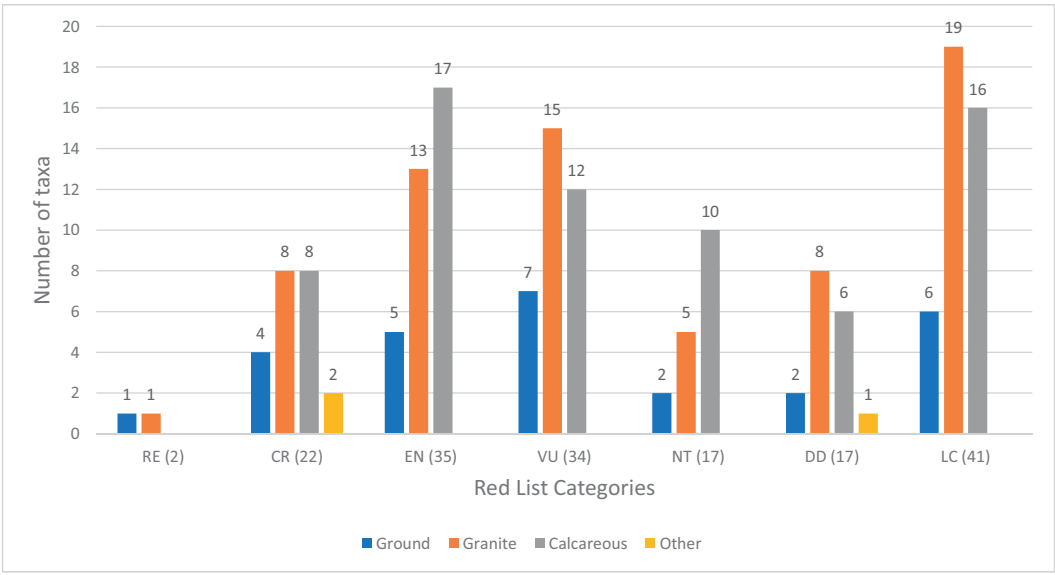

Fig. 1. Number of evaluated taxa among different IUCN Red List categories. Abbreviations of categories: RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient, LC – Least Concern. Number in the brackets is the total number of species assigned to the category. Ground – taxa growing on soil, mosses or plant debris on ground; Granite – taxa growing on erratic boulders and smaller acidic stones as pebbles or shingle; Calcareous – taxa growing on calcareous rock as exposed bedrock (flatrock) on alvars and quarries, calcareous cliffs, limestone pebbles or shingle, and calcareous stones and mortar of buildings and walls; Other substrate – taxa growing on trees, wood or other lichens.

The distribution of epilithic species on different rock types between different IUCN categories was quite similar, except there was slightly higher proportions of VU and LC species among lichens on granite than on calcareous rock while the proportion of calciferous epilithic taxa was higher in the categories EN and NT (Fig. 1). However, the conclusions about the threat status of a particular ecological group of species in Estonia cannot be drawn until the threat assessments of the remaining share of taxa will be completed in 2023.

Habitats and threat factors

In previous IUCN Red List assessments of Estonian lichens, where the epiphytes were also considered, different woody habitats as dry boreal and nemoral deciduous forests, wooded meadows and parks have been emphasised as important habitats for threatened epiphytes (Lõhmus et al., 2019; Randlane et al., 2021). Furthermore, alvar grasslands, boreal heath forests, dry heathlands, sandy dunes and various rock substrates have been pointed out as crucial habitats for threatened lichens in Estonia (Leppik et al., 2013, 2015; Jüriado et al., 2015, 2016; Lõhmus et al., 2019, Randlane et al., 2021). The evaluated epigeic and epilithic species in this study were mostly found in well-lit habitats: in different type of grasslands, but mostly on alvar grassland, on the seashore, and in lesser extent in woody habitats, for example on erratic boulders in parks or in forest (e.g., oligo-mesotrophic boreal, mesotrophic boreal, eutrophic boreo-nemoral forest), or on calcareous cliff in eutrophic boreo-nemoral forest (clint forest) (Tabel 1).

The results of IUCN Red List assessment of the epigeic microlichens in this study confirmed that the species assigned to threat categories (CR, EN, VU) and to the category NT, were mostly found on soil, epigeic mosses or plant debris on shallow soil alvars. For threatened

Table 1. Occurrences of evaluated taxa in different habitats. One species can inhabit several suitable habitats. For the abbreviations of categories see Fig. 1. Open habitats – different types of grasslands, dunes, bogs and open habitats near the seashore (both epigeic and epilithic species are considered), number of species found in alvar grassland is given in bracklets.

	Open habitats (alvar)	Calcareous cliff in clint forest	Erratic boulders in forest or parklands	Anthropogenic habitats (buildings, stone walls, quarries)
RE	2 (1)		1	
CR	18 (4)	4	2	4
EN	33 (21)	10	6	7
VU	31 (19)	8	8	14
NT	17 (12)	5	2	11
DD	9 (4)	3	6	10
LC	40 (23)	9	8	26
Total	150 (84)	39	33	72

epigeic microlichens, the calcareous grasslands of less than 6 cm of soil layer with cryptogamic soil crust are the most suitable habitats (Leppik et al., 2013, 2015). The alvars with soil layer thickness up to 10 cm have already too dense higher plant vegetation for occurrence of epigeic microlichens (crustose lichens), and for such habitats the lichens of fruticose and foliose growth form are characteristic (Leppik et al., 2013, 2015). The characteristic members of alvar soil crust community, for example *Gyalolechia* spp., *Megaspora verrucosa*, *Psora decipiens*, *Squamarina lentigera*, *Toninia* spp., have been assessed against IUCN Red List categories already in 2008 and reassessed in 2019, and they are continuously considered as threatened species in Estonia (Randlane et al., 2008; Lõhmus et al., 2019). In this study many other epigeic taxa, including usual members of alvar soil crust community (e.g., *Agonimia gelatinosa, A. vouauxii*, *Chromatochlamys muscorum*), were assessed and evaluated as threatened by overgrowing of alvars due to the cessation of traditional management.

Moreover, threatened lichens on granite were frequently found on boulders in well-lit alvars (e.g., *Miriquidica deusta*, *Ophioparma ventosa*, EN) or open seashore habitats (e.g., *Acarospora sinopica*, EN; *Tremolecia atrata*, VU). Other set of threatened taxa of granite preferred also shady and more humid conditions, growing on granite boulders in forest (e.g., *Aspicilia laevata*, VU; *Pertusaria corallina*, CR) or on inundated stones along riversides (e.g., *Hydropunctaria rheitrophila*, VU; *Rinodina fimbriata*, CR) (Appendix 1). Threatened lichens on calcareous rocks were also mostly found in alvars and in the seashore (exposed bedrock and limestone pebbles) (e.g., *Clauzadea chondrodes*, EN; *Farnoldia jurana*, NT), as well as on calcareous cliffs usually in more shaded conditions in clint forest (e.g., *Alyxoria mougeotii, Gyalecta geoica* EN). Additionally, different habitats of anthropogenic origin are important for threatened lichens on rocks, for example old stone walls, buildings and abandoned limestone quarries (e.g., *Diplotomma venustum*, *Flavoplaca dichroa*, NT; Appendix 1).

For the epilithic lichens on exposed calcareous rocks, pebbles and erratic boulders the cessation of traditional management of alvar grasslands is the main threat as already established for epigeic lichens (Leppik et al., 2013, 2015) and also for epiphytes in junipers (Jüriado et al., 2015). The conservation practices on alvars should include grazing for suppressing the growth of shrubs and herbs (Leppik et al., 2015). Lichens on erratic boulders are also influenced for bush encroachment of alvars as the light conditions on boulders change by dense shrub cover and the lichens preferring well-lit conditions are vanishing. Epilithic communities on exposed bedrock (flatrock) and low height calcareous cliffs are endangered by overgrowing of mosses and higher plants due to the cessation of traditional management of habitats. In the same time, communities of shallow soil are most

prone of overgrazing and effects of trampling, so the careful balance in management practices are needed to sustain the valuable habitats (Eriksson & Rosén, 2008). Erratic boulders on seashore and close to the hiking trails are often target for climbing which is a direct anthropogenic threat factor not only for epilithic macrolichens (Randlane et al. 2021), but also the crustose species (e.g., *Pertusaria corallina*) are endangered. However, in 25% of assessed threatened epilithic microlichens in Estonia the threat factor is unknown: these are mostly lichens growing on erratic boulders in seashore (e.g., *Circinaria leprosescens*, *Flavoplaca microthallina*, VU). In fewer cases, the limestone mining, air pollution, climatic change and loss of old wooden buildings were also pointed out as threat factors.

ACKNOWLEDGEMENTS

The research was financed by the project no. 17332 of the Environmental Investment Centre (KIK). We are grateful to our colleagues Dr. Liis Marmor-Ohtla (Tallinn Botanic Garden), Dr. Piret Lõhmus and Dr. Ave Suija (University of Tartu) for the reviews of the IUCN assessments of evaluated species. Ave Suija is thanked also for additional lichen data and discussions concerning the assessment of some species. Mari Müür is thanked for databasing and technical assistance in curating the specimens in TUF. The authors thank the Reviewer for valuable comments on the manuscript.

REFERENCES

Abarenkov, K., Tedersoo, L., Nilsson, R. H., Vellak, K., Saar, I., Veldre, V., Parmasto, E., Prous, M., Aan, A., Ots, M., Kurina, O., Ostonen, I., Jõgeva, J., Halapuu, S., Põldmaa, K., Toots, M., Truu, J., Larsson, K-H. & Kõljalg, U. 2010. PlutoF – a Web Based Workbench for Ecological and Taxonomic Research, with an Online Implementation for Fungal ITS Sequences. *Evolutionary Bioinformatics* 6: 189–196. https://doi.org/10.4137/EBO.S6271

Anonymous. 1993. "Eesti punase raamatu" taimed, loomad ja seened (nov 1990) (Plants, animals and fungi of the Red Data Book of Estonia (Nov. 1990*)*. In: *Eesti A ja O*. Tallinn, Eesti Entsüklopeediakirjastus, pp. 54–60. (In Estonian).

Dahlberg, A. & Mueller, G. M. 2011. Applying IUCN red-listing criteria for assessing and reporting on the conservation status of fungal species. *Fungal Ecology* 4: 147–162.

Eriksson, M. O. G. & Rosén. E. 2008. *Management of Natura 2000 habitats. 6280 *Nordic alvar and precambrian calcareous flatrocks*.* European Commission. Technical Report 2008 16/24, 21 pp.

Gärdenfors, U. (ed.) 2005. *The 2005 Red List of Swedish species*. Artdatabanken, SLU, Uppsala, 496 pp.

IUCN Standards and Petitions Subcommittee. 2017. *Guidelines for Using the IUCN Red List Categories and Criteria. Version 13.* Prepared by the Standards and Petitions Subcommittee. http://www.iucnredlist.org/documents/RedListGuidelines.pdf

IUCN Standards and Petitions Committee. 2019. *Guidelines for Using the IUCN Red List Categories and Criteria. Version 14.* Prepared by the Standards and Petitions Committee. http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Jüriado, I., Kämärä, M.-L. & Oja, E. 2016. Environmental factors and ground disturbance affecting the composition of species and functional traits of ground layer lichens on grey dunes and dune heaths of Estonia. *Nordic Journal of Botany* 34: 244–255.

Jüriado, I., Leppik, E., Lõhmus, P., Randlane, T. & Liira, J. 2015. Epiphytic lichens on *Juniperus communis* – an unexplored component of biodiversity in threatened alvar grassland. *Nordic Journal of Botany* 33: 128–139.

Leppik, E., Jüriado, I., Suija, A. & Liira, J. 2013. The conservation of ground layer lichen communities in alvar grasslands and the relevance of substitution habitats. *Biodiversity and Conservation* 22: 591–614.

Leppik, E., Jüriado, I., Suija, A. & Liira, J. 2015. Functional ecology of rare and common epigeic lichens in alvar grasslands. *Fungal Ecology* 13: 66–76.

Liira, J., Suija, A. & Jüriado, I. 2020. Habitat and host specificity of epiphytic lichens in a rural landscape: cultural heritage habitats as refugia. *Biodiversity and Conservation* 29: 2141–2160.

Lilleleht, V. 1998. *Eesti punane raamat. Ohustatud seened, taimed ja loomad (Red Data Book of Estonia. Threatened Fungi, Plants and Animals).* Tallinn, Eesti Teaduste Akadeemia Looduskaitse Komisjon, 150 pp. (In Estonian).

Lõhmus, P. & Lõhmus, A. 2019. The potential of production forests for sustaining lichen diversity: a perspective on sustainable forest management. *Forests* 10: ARTN 1063.

Lõhmus, P., Marmor, L., Jüriado, I., Suija, A., Oja, E., Degtjarenko, P. & Randlane, T. 2019. Red List of Estonian lichens: revision in 2019. *Folia Cryptogamica Estonica* 56: 63–76.

Marmor, L., Randlane, T., Jüriado, I. & Saag, A. 2017. Host tree preferences of red-listed epiphytic lichens in Estonia. *Baltic Forestry* 23: 364–373.

Pykälä, J., Jääskeläinen, K., Rämä, H., Launis, A., Vitikainen, O. & Puolasmaa, A. 2019. Lichens. In: *The 2019 Red List of Finnish species*. Helsinki, pp. 263–312.

Randlane, T. 1998. Red list of Estonian macrolichens. *Folia Cryptogamica Estonica* 32: 75–79.

Randlane, T., Jüriado, I., Suija, A., Lõhmus, P. & Leppik, E. 2008. Lichens in the new Red List of Estonia. *Folia Cryptogamica Estonica* 44: 113–120.

Randlane, T., Jüriado, I., Degtjarenko, P. & Saag, A. 2021. New assessment of Least Concern lichens in the Red List of Estonia: are common species still common? *Folia Cryptogamica Estonica* 58: 199–212.

Randlane, T., Saag, A. & Suija, A. 2021. Lichenized, lichenicolous and allied fungi of Estonia. Ver. December 31, 2021 – http://esamba.bo.bg.ut.ee/checklist/est/home.php (assessed on 29.06. 2022).

Suija, A., Leppik, E., Jüriado, I., Lõhmus, P., Marmor, L. & Saag, L. 2011. New Estonian records and amendments: Lichenized, lichenicolous and allied fungi. *Folia Cryptogamica Estonica* 48: 154–158.

Tartes, U. 2010. Punane nimestik ja liigikaitse (Red Data List and species protection). In: *Eesti Teaduste Akadeemia seminari materjalid. Rahvusvahelise elurikkuse aasta 2010*. Tallinn, pp. 4–8. (In Estonian).

Appendix 1. 168 red-listed lichens according to the evaluation in 2022 together with the IUCN categories and applied criteria. The length of a generation (years) considered in the evaluation process (see Material and Methods) and habitat and substrate information is presented for each species (for explanations see Fig. 1 and Table 1). * – parasitic lichens at least in the early stages of their life cycle. Abbreviations of IUCN Red List categories: RE – Regionally Extinct, DD – Data Deficient, CR – Critically endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern.

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Absconditella sphagnorum Vězda & Poelt	DD		7	1				1
Acarospora cervina A. Massal.	LC		17	1	1		1	3
Acarospora fusca B. de Lesd.	DD		17	1			1	2
Acarospora glaucocarpa (Ach.) Körb.	LC		17	1	1		1	3
Acarospora macrospora (Hepp) A. Massal. ex Bagl.	**VU**	**B1ab(iii)+2ab(iii); D1**	17	1	1		1	3
Acarospora moenium (Vain.) Räsänen	LC		7	1	1		1	3
Acarospora sinopica (Wahlenb.) Körb.	**EN**	**D**	17	1				2
Acarospora smaragdula (Wahlenb.) A. Massal.	**VU**	**D1**	17	1				2
Acarospora veronensis A. Massal.	LC		17	1			1	2
Acrocordia conoidea (Fr.) Körb	**EN**	**D**	17		1			3
Acrocordia salweyi (Keight. Ex Nyl.) A.L. Sm.	**CR**	**D**	17		1		1	3
Adelolecia kolaënsis (Nyl.) Hertel & Rambold	**CR**	**B1ab(i, ii,iii,iv)+2ab(i, ii,iii,iv); C2a(i); D**	17	1				3
Agonimia gelatinosa (Ach.) M. Brand & Diederich	**VU**	**D1**	7	1			1	1
Agonimia globulifera M. Brand & Diederich	LC		7	1			1	1
Agonimia tristicula (Nyl.) Zahlbr.	LC		7	1			1	1
Agonimia vouauxii (B. de Lesd.) M. Brand & Diederich	**VU**	**D1**	7	1			1	1
Alyxoria mougeotii (A. Massal.) Ertz, Frisch & G. Thor	**EN**	**B1ab(iii)+2ab(iii); C2a(i); D**	17		1			3
Arthonia calcarea (Turner ex Sm.) Ertz & Diederich	**CR**	**B1ab(iii)+2ab(iii); D**	7	1	1			3
Arthrorhaphis citrinella (Ach.) Poelt*	**CR**	**B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv)**	7	1				1
Aspicilia grisea Arnold	**EN**	**D**	17	1				2
Aspicilia laevata (Ach.) Arnold	**VU**	**D1**	17			1		2
Atla wheldonii (Travis) Savic & Tibell	**CR**	**B1ab(iii)+2ab(iii); D**	7	1				1
Bacidia adastra Sparrius & Aptroot	DD		7			1	1	4
Bacidia bagliettoana (A. Massal. & De Not.) Jatta	LC		7	1			1	1

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Bacidia caligans (Nyl.) A.L. Sm.	DD		7				1	3
Bacidia coprodes (Körb.) Lettau	DD		7		1			3
Bacidia herbarum (Stizenb.) Arnold	**VU**	**C1; D1**	7	1	1			1
Bacidina egenula (Nyl.) Vězda	**VU**	**D1**	7	1	1		1	3
Bacidina inundata (Fr.) Vězda	LC		17			1		2
Bagliettoa calciseda (DC.) Gueidan & Cl. Roux	LC		17	1	1		1	3
Bagliettoa steineri (Kušan) Vězda	**CR**	**D**	17	1				3
Bilimbia microcarpa (Th. Fr.) Th. Fr.	LC		7	1			1	1
Blastenia ammiospila (Wahlenb.) Arup, Søchting & Frödén	**CR**	**D**	7	1				1
Blastenia crenularia (With.) Arup, Søchting & Frödén	**EN**	**B1ab(iii)+2ab(iii); D**	7	1				3
Blennothallia crispa (Huds.) Otálora, P.M. Jørg. & Wedin	**EN**	**B1ab(i,iii,iv)+2ab(ii,iii,iv); D**	7	1			1	3
Bryoplaca jungermanniae (Vahl) Søchting, Frödén & Arup	**CR**	**A2ac+3c+4c; B1ab(iii)+2ab(iii); D**	7	1				1
Bryoplaca sinapisperma (Lam.) Søchting, Frödén & Arup	LC		7	1				1
Buellia aethalea (Ach.) Th. Fr.	**NT**	**D1+2**	17	1				2
Buellia badia (Fr.) A. Massal.	**CR**	**D**	17	1				2
Byssoloma subdiscordans (Nyl.) P. James	**CR**	**D**	7					4
Calogaya pusilla (A. Massal.) Arup, Frödén & Søchting	LC		17	1			1	3
Caloplaca chlorina (Flot.) Sandst.	LC		17	1		1	1	2
Caloplaca grimmiae (Nyl.) H. Olivier*	**CR**	**D**	17	1				2
Caloplaca stillicidiorum (Vahl) Lynge [s. lat.]	**NT**	**A3c; B1ab(iii)+2ab(iii); D1**	7	1				1
Candelariella aurella (Hoffm.) Zahlbr.	LC		17	1			1	3
Candelariella kuusamoënsis Räsänen	**CR**	**B2ab(i,ii,iv); D**	17	1			1	4
Catapyrenium daedaleum (Kremp.) Stein	**EN**	**B1ab(iii)+2ab(iii); C1; D**	7	1	1			1
Catillaria aphana (Nyl.) Coppins	**EN**	**D**	17	1	1		1	3
Catillaria atomarioides (Müll. Arg.) Kilias	DD		17	1			1	2
Catillaria chalybeia var. *chalybeia* (Borrer) A. Massal.	LC		17	1				2
Catillaria lenticularis (Ach.) Th. Fr.	**VU**	**D1**	17	1				3
Catillaria minuta (A. Massal.) Lettau	**EN**	**D**	17	1	1			3
Chromatochlamys muscorum (Fr.) H. Mayrhofer & Poelt	**NT**	**A2c+3c; B1ab(iii)+2ab(iii); D1**	7	1			1	1

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Circinaria caesiocinerea (Nyl. ex Malbr.) A. Nordin, Savić & Tibell	**VU**	**D1**	17	1			1	2
Circinaria contorta (Hoffm.) A. Nordin, Savić & Tibell ssp. contorta	LC		17	1				3
Circinaria leprosescens (Sandst.) A. Nordin, Savić & Tibell	**VU**	**D1**	7	1				2
Clauzadea chondrodes (A. Massal.) Clauzade & Cl. Roux	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				3
Clauzadea metzleri (Körb.) Clauzade & Cl. Roux ex D. Hawksw.	**NT**	**A2c+3c; B1ab(iii)+2ab(iii); D1**	17	1	1		1	3
Diploschistes scruposus (Schreb.) Norman	**NT**	**D1**	17	1		1		2
Diplotomma alboatrum (Hoffm.) Flot.	**NT**	**D1**	17	1			1	2
Diplotomma venustum Körb.	**NT**	**D1**	17	1			1	3
Dirina massiliensis f. *sorediata* (Müll. Arg.) Tehler	**CR**	**B1ab(iii)+2ab(iii); D**	17		1			3
Eiglera flavida (Hepp) Hafellner	**CR**	**D**	17	1			1	3
Enchylium polycarpon (Hoffm.) Otálora, P.M. Jørg. & Wedin	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				3
Epilichen scabrosus (Ach.) Clem.*	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				1
Epiphloea byssina (Hoffm.) Henssen & P.M. Jørg.	DD		7				1	1
Farnoldia jurana (Schaer.) Hertel	**NT**	**A2c+3c; B1ab(iii)+2ab(iii), D1**	17	1				3
Flavoplaca citrina (Hoffm.) Arup, Frödén & Søchting	LC		7	1	1		1	3
Flavoplaca dichroa (Arup) Arup, Frödén & Søchting	**NT**	**D1**	7	1			1	3
Flavoplaca marina (Wedd.) Arup, Frödén & Søchting	**VU**	**D1**	17	1				3
Flavoplaca microthallina (Wedd.) Arup, Frödén & Søchting	**VU**	**D1**	17	1				3
Gyalecta geoica (Wahlenb. ex Ach.) Ach.	**EN**	**B1ab(i,iii,iv)+2ab(ii,iii,iv); D**	17	1	1			3
Gyalecta jenensis (Batch) Zahlbr.	**VU**	**B1ab(i,iii,iv)+2ab(ii,iii,iv); D1**	17	1	1		1	3
Gyalecta subclausa Anzi	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				3
Gyalidea fritzei (Stein) Vězda	**CR**	**D**	17	1	1		1	3
Hydropunctaria maura (Wahlenb.) C. Keller, Gueidan & Thüs	LC		17	1				3
Hydropunctaria rheitrophila (Zschacke) C. Keller, Gueidan & Thüs	**VU**	**D1**	17			1		2
Hydropunctaria scabra (Vězda) C. Keller, Gueidan & Thüs	DD		17			1		2
Lathagrium auriforme (With.) Otálora, P.M. Jørg. & Wedin	RE		7	1				1
Lecania erysibe (Ach.) Mudd	LC		7	1			1	3
Lecania rabenhorstii (Hepp) Arnold	**VU**	**D1**	17	1			1	3
Lecania sordida Reese Næsborg	DD		7				1	3
Lecanora andrewii de Lesd.	LC		17	1				2

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Lecanora campestris (Schaer.) Hue	**NT**	**D1**	17	1			1	3
Lecanora cenisia Ach.	LC		17	1			1	2
Lecanora helicopis (Wahlenb.) Ach.	LC		17	1				2
Lecanora intricata (Ach.) Ach.	LC		17	1				2
Lecanora orosthea (Ach.) Ach.	**EN**	**B1ab(iii)+2ab(iii); D**	7	1				2
Lecanora perpruinosa Fröberg	**NT**	**D1**	17	1	1		1	3
Lecanora salina H. Magn.	LC		17	1				2
Lecanora soralifera (Suza) Räsänen	**CR**	**D**	17	1				2
Lecanora zosterae (Ach.) Nyl.	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				1
Lecidella carpathica Körb.	LC		17	1	1		1	3
Lecidella scabra (Taylor) Hertel & Leuckert	LC		7	1			1	2
Leproplaca chrysodeta (Vain. ex Räsänen) J. Laundon	**NT**	**B1ab(iii)+2ab(iii); D1**	7	1	1		1	3
Micarea erratica (Körb.) Hertel, Rambold & Pietschm.	**EN**	**D**	17	1			1	3
Micarea lithinella (Nyl.) Hedl.	DD		17	1			1	2
Micarea ternaria (Nyl.) Vězda	**EN**	**D**	7	1		1		1
Miriquidica deusta (Stenh.) Hertel & Rambold	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				2
Mycobilimbia berengeriana	**VU**	**A2bc+3bc**	7	1	1			1
Mycobilimbia hypnorum (Lib.) Kalb & Hafellner	LC		7	1				1
Opegrapha rupestris Pers.*	**VU**	**B1ab(i,iii,iv)+2ab(ii,iii,iv); D1**	17	1	1		1	3
Ophioparma ventosa (L.) Norman	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				2
Parabagliettoa dufourii (DC.) Gueidan & Cl. Roux	**NT**	**A2c+3c; B1ab(iii)+2ab(iii); D1**	17	1			1	3
Pertusaria corallina (L.) Arnold	**CR**	**D**	17			1		2
Petractis clausa (Hoffm.) Kremp.	**VU**	**B1ab(iii)+2ab(iii); D1**	17	1	1		1	3
Polyblastia albida Arnold	LC		17	1	1		1	3
Polyblastia cupularis A. Massal.	DD		17	1	1		1	3
Polyblastia nidulans (Stenh.) Arnold	DD		17	1	1		1	3
Polyblastia sendtneri Kremp.	**EN**	**B1ab(iii)+2ab(iii); D**	7	1	1		1	3
Polysporina simplex (Davies) Vězda	DD		17	1				2
Porpidia cinereoatra (Ach.) Hertel & Knoph	**EN**	**D**	17	1		1		2
Porpidia macrocarpa (DC.) Hertel & A.J. Schwab	**NT**	**D1**	17	1		1		2

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Porpidia soredizodes (Lamy ex Nyl.) J.R. Laundon	**VU**	**D1**	7	1		1		2
Porpidia speirea (Ach.) Kremp.	**EN**	**D**	17	1				2
Porpidia tuberculosa (Sm.) Hertel & Knoph	LC		7	1		1	1	2
Protoblastenia calva (Dicks.) Zahlbr.	**VU**	**B1ab(iii)+2ab(iii); D1**	17	1	1			3
Protoblastenia incrustans (DC.) J. Steiner	**NT**	**D1**	17	1	1		1	3
Protoparmelia atriseda (Fr.) R. Sant. & V. Wirth*	**EN**	**D**	17	1				2
Protoparmelia badia (Hoffm.) Hafellner	LC		17	1				2
Protothelenella corrosa (Körb.) H. Mayrhofer & Poelt	DD		17			1		2
Pseudoleptogium diffractum (Körb.) Müll. Arg.	**VU**	**B1ab(iii)+2ab(iii); D1**	17	1				3
Pseudosagedia chlorotica (Ach.) Hafellner & Kalb	**VU**	**D1**	17	1		1		2
Pseudosagedia linearis (Leight.) Hafellner & Kalb	**EN**	**D**	17	1	1			3
Psorotichia schaereri (A. Massal.) Arnold	**NT**	**A2c+3c; B1ab(iii)+2ab(iii); D1**	7	1	1		1	3
Pyrenodesmia aloclza (A. Massal.) Arnold	**EN**	**B1ab(iii)+2ab(iii); D**	17	1				3
Pyrenodesmia variabilis (Pers.) A. Massal.	LC		17	1			1	3
Rhizocarpon cinereovirens (Müll. Arg.) Vain.	DD		17	1				2
Rhizocarpon distinctum Th. Fr.	LC		17	1		1		2
Rhizocarpon ferax H. Magn.	**CR**	**D**	17	1				2
Rhizocarpon geminatum Körb.	**EN**	**B1ab(i,iv)+2ab(ii,iv); D**	17	1		1		2
Rhizocarpon grande (Flörke ex Flot.) Arnold	**EN**	**B2ab(iii); D**	17	1				2
Rhizocarpon lavatum (Fr.) Hazsl.	**EN**	**D**	17	1		1		2
Rhizocarpon lecanorinum Anders	LC		17	1		1		2
Rhizocarpon macrosporum Räsänen	**VU**	**D1**	17	1			1	2
Rhizocarpon petraeum (Wulfen) A. Massal.	**VU**	**B1ab(iii,iv)+2ab(ii,iii,iv); D1**	17	1				2
Rhizocarpon polycarpum (Hepp) Th. Fr.	**NT**	**A3c; B1ab(iii)+2ab(iii); D1**	17	1				2
Rhizocarpon reductum Th. Fr.	LC		17	1		1	1	2
Rhizocarpon richardii (Lamy ex Nyl.) Zahlbr.	**VU**	**D1**	17	1				2
Rhizocarpon subgeminatum Eitner	**CR**	**D**	17	1				2
Rhizocarpon submodestum (Vainio) Vainio	DD		17	1			1	2
Rhizocarpon umbilicatum (Ramond) Flagey	**VU**	**B1ab(iii)+2ab(iii); D1**	17	1				3

Species	Red List Category	Criteria	Length of a generation (years)	Habitat				Substrate: 1 – ground, 2 – granite, 3 – calcareous rock, 4 – other substrata
				Open habitats (incl. alvar, bogs, dunes)	Calcareous cliff in clint forest	Erratic boulders in forest or parks	Anthropogenic habitats (buildings, stone walls, quarries)	
Rimularia furvella (Nyl. ex Mudd) Hertel & Rambold*	**VU**	**A2bc+3c; B1ab(i,iii,iv)+ 2ab(ii,iii,iv); D1**	7	1				2
Rimularia intercedens (H. Magn.) Coppins	**CR**	**D**	17	1				2
Rinodina bischoffii (Hepp) A. Massal.	LC		17	1	1		1	3
Rinodina confragosa (Ach.) Körb.	**VU**	**D1**	17	1				2
Rinodina conradii Körb.	**VU**	**D1**	7	1		1		1
Rinodina fimbriata Körb.	**CR**	**D**	17	1		1		2
Rinodina gennarii Bagl.	LC		17	1				2
Rinodina immersa (Körb.) Arnold	LC		17	1	1		1	3
Rinodina milvina (Wahlenb.) Th. Fr.	**EN**	**D**	17	1				2
Sagiolechia protuberans (Ach.) A. Massal.	LC		17	1			1	3
Sarcogyne privigna (Ach.) A. Massal.	**VU**	**D1**	17	1			1	2
Sarcosagium campestre (Fr.) Poetsch & Schied.	**VU**	**D1**	7	1		1	1	1
Schaereria fuscocinerea (Nyl.) Clauzade & Cl. Roux	LC		17	1				2
Scoliciosporum umbrinum (Ach.) Arnold	LC		17	1		1	1	2
Scytinium plicatile (Ach.) Otálora, P.M. Jørg. & Wedin	**EN**	**B2ab(iii); D**	17	1			1	3
Thelocarpon impressellum Nyl.	**VU**	**D1**	7	1		1	1	1
Thelocarpon laureri (Flot.) Nyl.	**EN**	**B2ab(iii); D**	7	1		1	1	1
Trapelia coarctata (Sm.) M. Choisy	**VU**	**D1**	17			1	1	2
Trapelia glebulosa (Sm.) J.R. Laundon	**EN**	**D**	17	1		1		2
Trapelia placodioides Coppins & P. James	LC		7	1		1	1	2
Trapeliopsis pseudogranulosa Coppins & P. James	DD		7			1		1
Tremolecia atrata (Ach.) Hertel	**VU**	**D1**	17	1				2
Umbilicaria vellea (L.) Hoffm.	RE		17	1		1		2
Variospora dolomiticola (Hue) Arup, Søchting & Frödén	**CR**	**B1ab(iii)+2ab(iii); D**	17	1				3
Variospora velana (A. Massal.) Arup, Søchting & Frödén	**EN**	**B1ab(iii)+2ab(iii); D**	17	1	1			3
Xanthocarpia crenulatella (Nyl.) Frödén, Arup & Søchting	**EN**	**B2ab(iii); D**	17	1	1		1	3