Natural History Sciences. Atti Soc. it. Sci. nat. Museo civ. Stor. nat. Milano, 11 (1): 53-60, 2024 DOI: 10.4081/nhs.2024.734

# Lichens from the *aurifodinae* of the upper Ticino river valley (N Italy)

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**Abstract** - *Aurifodinae* were open-pit gold mines of the Roman age which left behind them elongated heaps of rounded stones. They are located in lowland semi-natural landscapes, and can be seen as screes at a lower altitude and in a milder climate than typical mountain screes. We investigated the lichen biota of the *aurifodinae* remains in the upper Ticino river valley (western Po Plain, Northern Italy), in a small, discontinuous, 6.5 ha wide area. Metamorphic siliceous stones prevail, while calcareous stones are rare and scattered. We recorded 35 infrageneric taxa, including three species new to Piemonte: *Cladonia conista*, *C. cryptochlorophaea*, and *Placidiopsis cinerascens*. Several taxa are also new to the submediterranean ecoregion and/or to the Ticino river valley. The function of *aurifodinae* as a refugium for saxicolous lichens in the lowlands and their potential role in creating wide areas with open dry habitats in the past centuries are discussed.

**Keywords:** archaeological sites, biodiversity, lichen inventories, Po Plain.

**Riassunto** - Licheni dalle aurifodine dell'alta valle del Ticino (Italia settentrionale).

Le aurifodine erano miniere d'oro a cielo aperto di epoca romana che hanno lasciato dietro di sé cumuli di pietre arrotondate dalla forma oblunga. Esse si trovano in situazioni seminaturali a bassa quota, e possono essere considerate come delle pietraie situate ad un'altitudine inferiore e in un clima più mite rispetto alle pietraie di montagna. In questo lavoro è stato censito il biota lichenico dei resti di aurifodine situati nell'alta valle del Ticino (Pianura Padana occidentale, Italia settentrionale), in una piccola area discontinua di 6.5 ha. Le pietre sono principalmente riconducibili a rocce metamorfiche silicee, ma sono presenti in modo sparso anche pietre calcaree. Sono stati rilevati 35 taxa infragenerici, tra cui tre nuovi per il Piemonte: *Cladonia conista*, *C. cryptochlorophaea* e *Placidiopsis cinerascens*. Numerosi altri taxa sono nuovi per l'ecoregione submediterranea e/o per la valle del Ticino. Vengono brevemente discussi il ruolo delle aurifodine come rifugio per i licheni sassicoli alle basse quote e il loro possibile ruolo nell'aver favorito la presenza di vaste aree di habitat aperti aridi nei secoli passati.

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Received for publication: 6 November 2023
Accepted for publication: 27 February 2024
Online publication: 17 April 2024

**Parole chiave:** biodiversità, inventario di licheni, Pianura Padana, siti archeologici.

## INTRODUCTION

The value of archaeological heritage is perceived mainly from the cultural, historical and artistical points of view. However, archaeological sites can also hold a scientific interest as biodiversity refugia (Vanderplank *et al*., 2014; Attum *et al*., 2022; Heneidy *et al*., 2022), as demonstrated by lichens from both anthropized situations (e.g. Nimis *et al*., 1987) and sites surrounded by semi-natural landscapes (e.g. Favero Longo *et al*., 2022).

In north-western Italy, a rare but peculiar archaeological relic of the Roman age are the gold mines called *aurifodinae*. These were open-pit mines developed on secondary gold deposits in fluvial terraces, in which gold was found in specks or dust, rather than in nuggets. To extract gold, water was channeled upstream and used to wash away the finer sediment, from which the gold specks were collected. After years, or even decades, at the end of this process, the coarser sediment of the terrace, consisting of pebbles and stones, remained in place forming massive and elongated stone heaps that in some cases lasted, free from vegetation, until present days (Pipino, 2006, 2015). Remarkable *aurifodinae* are those found in Piemonte: in the Bessa Natural Reserve (Province of Biella), near Ovada (Province of Alessandria) and in the upper Ticino river valley (Province of Novara) (Pipino, 2015).

Unlike many other archaeological remains, the *aurifodinae* are generally found within semi-natural landscapes, which implies that lichens had literally millennia to recolonize the environment after the exploitation of the sites ceased. Under an ecological standpoint, these *aurifodinae* can be seen as screes located at a lower elevation – and therefore in a milder climate – than typical mountain screes. Furthermore, the lowland context is much poorer of natural stony substrates than the landscapes found at higher altitudes, and therefore such environments are likely to provide an interesting substitution habitat for saxicolous lichens which cannot be found elsewhere at this elevation – especially for silicicolous species, which are not able to colonize man-made basic substrates like mortar or concrete.

This research is a contribution to the study of the lichen biota of Italian *aurifodinae*. It also gives a further contribution to the knowledge of lichen diversity in the Ticino river valley, which has been continuously updated in the last thirty years (Valcuvia Passadore *et al*., 2002a, 2002b; Gheza, 2015, 2018; Gheza *et al*., 2018, 2019, 2022a).

## MATERIALS AND METHODS

### Study area

The study area is located in the "Ticino Piemontese" Natural Park (Province of Novara, Piemonte Region), a protected area established in 1978 that covers 6561 ha of the north-western side of the Ticino river valley south of Lake Maggiore and is now designated as a Special Area of Conservation (IT1150001 "Valle del Ticino") included within the UNESCO MAB Biosphere Reserve "Ticino Val Grande Verbano". The Ticino river valley is recognized as a focal area for biodiversity and an ecological corridor of paramount importance in the Po Plain (Bogliani *et al*., 2007).

The surveyed area is located on the western side of the upper Ticino river valley, in the municipalities of Pombia and Varallo Pombia. Here, at the top of the fluvial terrace bordering the lowest level of the river valley, some relics of ancient *aurifodinae* of the Roman period (II-I century b.C.) can still be found in the localities called "Campo dei Fiori" (45°39'26"N 8°39'55"E – 45°39'14"N 8°40'20"E, 215-223 m a.s.l.) and "Vallette di Pesorto" (45°40'03"N 8°40'03"E – 45°39'57"N 8°40'06"E, 220-218 m a.s.l.) (Pipino, 2006) (Fig. 1). The bioclimate is temperate continental (Rivas-Martínez *et al*. 2004), with a mean annual temperature of 13.1 °C and a total annual rainfall of 1190 mm.

In "Campo dei Fiori" the landscape of the *aurifodinae* is characterized by the still well-visible heaps of rounded stones that were left in place following the washout of the alluvial terraces for gold-mining. The shape of these heaps is mostly gently undulating (Fig. 2), but there are localized situations with more abrupt slopes, e.g. near the remains of wells, trenches, canals or dry walls. Such heaps can reach even 10 m of height. Stones are mostly siliceous, even if a scattered occurrence of calcareous material has been recorded. These stone heaps were likely more widespread and easily visible in the past, but to date most of the area has been colonized by a mixed woodland dominated by oaks (*Quercus robur* L. and *Q. petraea* (Matt.) Liebl.), chestnut (*Castanea sativa* Mill.), flowering ash (*Fraxinus ornus* L.) and Scots pine (*Pinus sylvestris* L.). However, open areas still occur, and stone heaps are currently extended on about 6.5 ha (Fig. 1). The exposed parts are dry and easily heated also in sunny days during the cold season, whereas at the edges, under the shading from the surrounding woodlands, cooler and wetter situations occur, also allowing a massive colonization by bryophytes.

In "Vallette di Pesorto" a few stone heaps are still detectable, although mostly covered by vegetation, whereas in the other localities indicated by Pipino (2006) the woodland has completely covered up the heaps; therefore, after having preliminary inspected these sites, we did not consider them in our lichen survey, which took place only in "Campo dei Fiori".

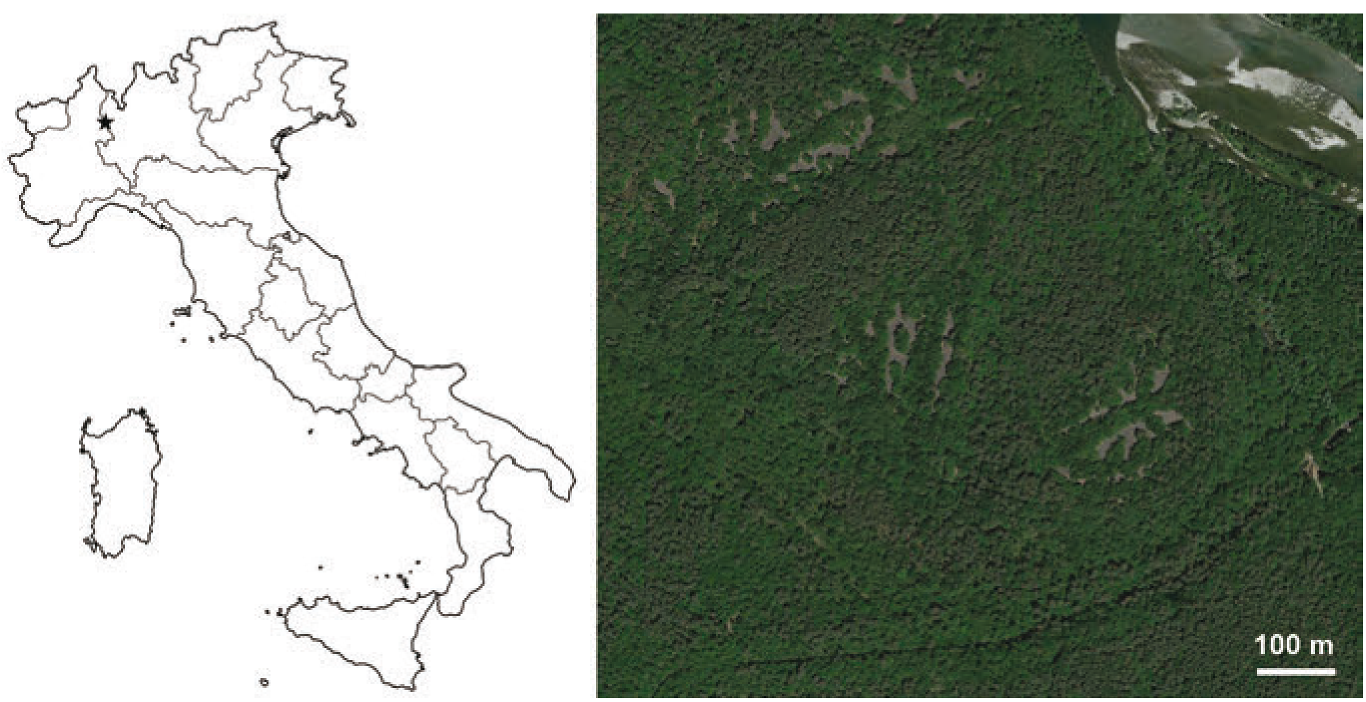


Fig. 1 - Location of the study area in Northwestern Italy (left) and ortophoto view of the *aurifodinae* in "Campo dei Fiori" (right). / Localizzazione dell'area di studio nell'Italia nordoccidentale (sinistra) e visuale in ortofoto delle aurifodine in località "Campo dei Fiori" (destra).

Fig. 2 - Wide-angle views of some stone heaps in “Campo dei Fiori”. / Visuali grandangolari di alcuni dei cumuli di pietre in località “Campo dei Fiori”.

**Sampling, identification and characterization of the lichen biota**

Lichens were sampled only in the peculiar environment of the *aurifodinae*, both directly on the stones and on the thin soil or moss layers developed between the stones in the most sheltered situations. All the specimens were identified in the laboratory by means of the keys provided in ITALIC 7.0 (Martellos *et al*., 2023; Nimis & Martellos, 2024). Specimens of *Cladonia*, *Lepraria* and *Stereocaulon* were checked by means of thin-layer chromatography (TLC) in solvents A, B and C, to investigate their metabolites (Elix, 2014). All the specimens are deposited in GG's private herbarium.

The main features of the lichen biota were analyzed: (1) growth form; (2) photobiont type; (3) reproduction strategy; ecological indices related to (4) pH of substrate, (5) solar irradiation, (6) aridity/humidity, (7) eutrophication; (8) poleotolerance index; (9) altitudinal distribution in Italy; (10) rarity in the submediterranean belt of Italy. All information was retrieved from ITALIC 7.0. An unidentified *Acarospora* species was left out of these analyses.

Nomenclature follows ITALIC 7.0.

## RESULTS

About 150 specimens were collected and identified, and 35 taxa were recorded (Tab. 1). Three are new to Piemonte, eight to the submediterranean ecoregion, 17 to the Ticino river valley (Tab. 1). Three species are listed in the Red List of the terricolous lichens of Italy (Gheza *et al*., 2022b): *Cladonia caespiticia* and *Cladonia cryptochlorophaea* as "near threatened", *Cladonia conista* as "data deficient". One species belonging to the genus *Acarospora* remained unidentified, since only sterile specimens were found.

The lichen biota of *aurifodinae* is mainly composed by crustose (n=18; 53%) and fruticose (n=12; 35%) species, whereas foliose (n=3; 9%) and leprose (n=1; 3%) species are less represented. All taxa have a green alga as photobiont: coccoid algae prevail (n=31; 91%), whereas a single species (3%) has a trentepohlioid alga, and two species (6%) are cephalolichens. Most species reproduce by means of sexual spores (n=21; 62%), whereas fewer preferentially reproduce by means of vegetative propagules, i.e. soredia (n=11; 32%) or isidia (n=2; 6%).

The analysis of the ecological indices (Fig. 3) revealed that the taxa prefer subacidic to subneutral substrates, situations with moderate to high direct solar irradiation, intermediate humidity, and low eutrophication.

Most taxa have a broad elevational range, being however mainly centered in the submediterranean, montane, and subalpine belts (Fig. 3). About ¾ of the taxa are rare in the submediterranean ecoregion, the rest including common, widespread taxa (Fig. 3). The index of poleophoby/poleotolerance shows that most species are typical of natural and semi-natural environments, with only a few species (n=7; 21%) able to tolerate a strong human impact (Fig. 3).

## DISCUSSION

In the *aurifodinae* of "Campo dei Fiori", the number of lichen taxa is not high, nonetheless it is relevant for a site located at a low altitude in the Po Plain, with many saxicolous species usually absent from lowland areas.

Overall, the lichen biota is composed of species related to moderately to highly irradiated situations, with intermediate needs for water, and mostly developed on poorly eutrophicated, subacidic to subneutral siliceous substrates. The absence of widespread nitrophytic saxicolous species which are common in the surrounding countryside (e.g. *Lecanora campestris* (Schaer.) Hue, *Lecidella stigmatea* (Ach.) Hertel & Leuckert, *Protoparmeliopsis muralis* (Schreb.) M. Choisy; pers. obs.), and the occurrence of several taxa sensitive to eutrophication, suggest that the site is not eutrophicated. This is probably related to a buffer effect provided by the woodlands surrounding the *aurifodinae*.

*Cladonia* was the most represented genus, including two species new to Piemonte. They occurred together with a widespread, morphologically similar species, *C. chlorophaea*, from which they can be distinguished with certainty only by the analysis of secondary chemistry. These findings highlight the importance of inventories carried out considering chemical data from a high number of specimens in such difficult groups, since morphologically similar specimens collected in the same site can easily belong to different species, as in this case. The two species new to Piemonte have recently been discovered also in some dry *Corynephorus*-grasslands located along the Ticino river near Pombia, not far from the *aurifodinae* (Gheza, unpubl. data). The only revision of the *Cladonia chlorophaea* complex *s. lat.* in Italy has been carried out almost forty years ago (Coassini Lokar *et al*., 1986), and several recent findings (e.g. Gheza *et al*., 2018; Ravera *et al*., 2022; this study) suggest that new investigations would be necessary to better clarify the distribution of this group in Italy.

Interesting findings are also related to material in the genus *Stereocaulon*, as in the case of the first record of *Stereocaulon vesuvianum* from Piemonte in the last 150 years, since Isocrono *et al*. (2004) only cited the historical records by Baglietto and Carestia (1867, 1880). Furthermore, this species had never been reported before from the submediterranean belt in Italy, being only known from upland areas. The occurrence of *Stereocaulon pileatum* is here confirmed in the Ticino river valley after the record by Valcuvia Passadore *et al*. (2002a, 2002b), who did not report a precise locality, but referred to a record from the Swiss side of Lake Maggiore, near Locarno (Ammann, 1971). This is therefore the first original record of the species from Italy after the 1940s (cf. the literature cited by Nimis, 1993, 2016).

The occurrence of two species usually bound to freshwater habitats, i.e. *Ionaspis lacustris* and *Verrucaria dolosa*, is surprising. The former is considered a proper aquatic species, whereas the latter was reported often from moist habitats, such as from the splash-zone of streams, but also from habitats less strictly related to water, e.g. woodlands (Nimis, 2016; Nimis & Martellos, 2024).

Tab. 1 - List of the recorded taxa with their substrates. Symbols are used to mark: * species new to Piemonte; # species new to the submediterranean ecoregion; ° species new to the Ticino river valley. Chemistry is reported only for those species whose secondary metabolites were checked by means of TLC. / Lista dei taxa rilevati con i relativi substrati. I simboli sono utilizzati per contrassegnare: * specie nuove per il Piemonte; # specie nuove per l'ecoregione submediterranea; ° specie nuove per la valle del Ticino. I dati chimici sono riportati solamente per le specie i cui metaboliti secondari sono stati indagati tramite cromatografia su strato sottile.

| | | **Taxon** | **Substrate** | **Metabolites** |
|---|---|---|---|---|
| 01 | | *Acarospora sp*. (only sterile specimens found) | Siliceous stones | – |
| 02 | | *Candelariella vitellina* (Hoffm.) Müll. Arg. | Siliceous stones | – |
| 03 | | *Cladonia caespiticia* (Pers.) Flörke | Soil, siliceous stones | Fumarprotocetraric acid |
| 04 | | *Cladonia chlorophaea* (Sommerf.) Spreng. | Soil | Fumarprotocetraric acid |
| 05 | | *Cladonia coccifera* (L.) Willd. | Soil, siliceous stones | Usnic acid, isousnic acid, zeorin |
| 06 | | *Cladonia coniocraea* (Flörke) Spreng. | Soil | Fumarprotocetraric acid |
| 07 | * | *Cladonia conista* (Nyl.) Robbins | Soil | Fumarprotocetraric acid, bourgeanic acid |
| 08 | *° | *Cladonia cryptochlorophaea* Asahina | Soil | Cryptochlorophaeic acid, fumarprotocetraric acid, paludosic acid |
| 09 | | *Cladonia furcata* (Huds.) Schrad. subsp. *furcata* | Soil | – |
| 10 | | *Cladonia macilenta* Hoffm. | Soil | Barbatic acid, didymic acid, thamnolic acid |
| 11 | | *Cladonia pyxidata* (L.) Hoffm. | Soil, siliceous stones | Fumarprotocetraric acid |
| 12 | | *Cladonia rei* Schaer. | Soil, siliceous stones | Fumarprotocetraric acid, homosekikaic acid |
| 13 | ° | *Diploschistes scruposus* (Schreb.) Norman | Siliceous stones | – |
| 14 | #° | *Ionaspis lacustris* (With.) Lutzoni | Siliceous stones | – |
| 15 | #° | *Lecanora pannonica* Szatala | Siliceous stones | – |
| 16 | | *Lecidea fuscoatra* (L.) Ach. | Siliceous stones | – |
| 17 | ° | *Lecidea grisella* Flörke | Siliceous stones | – |
| 18 | ° | *Lecidea lithophila* (Ach.) Ach. | Siliceous stones | – |
| 19 | #° | *Lecidea obluridata* Nyl. | Siliceous stones | – |
| 20 | | *Lecidella anomaloides* (A. Massal.) Hertel & H. Kilias | Siliceous stones | – |
| 21 | #° | *Lepraria borealis* Loht. & Tønsberg | Bryophytes | Atranorin |
| 22 | *° | *Placidiopsis cinerascens* (Nyl.) Breuss | Siliceous stones | – |
| 23 | | *Rhizocarpon geographicum* (L.) DC. subsp. *geographicum* s. lat. | Siliceous stones | – |
| 24 | # | *Rhizocarpon geographicum* subsp. *diabasicum* (Räsänen) Poelt & Vězda | Siliceous stones | – |
| 25 | | *Rhizocarpon reductum* Th.Fr. | Siliceous stones | – |
| 26 | #° | *Rhizocarpon tetrasporum* Runemark | Siliceous stones | – |
| 27 | ° | *Rufoplaca arenaria* (Pers.) Arup, Søchting & Frödén | Siliceous stones | – |
| 28 | # | *Stereocaulon pileatum* Ach. | Siliceous stones | – |
| 29 | #° | *Stereocaulon vesuvianum* Pers. var. *vesuvianum* | Siliceous stones | Stictic acid, atranorin |
| 30 | ° | *Trapelia placodioides* Coppins & P. James | Siliceous stones | – |
| 31 | ° | *Verrucaria dolosa* Hepp | Calcareous stones | – |
| 32 | | *Verrucaria nigrescens* Pers. f. *nigrescens* | Calcareous stones | – |
| 33 | | *Xanthoparmelia conspersa* (Ach.) Hale | Siliceous stones | – |
| 34 | ° | *Xanthoparmelia tinctina* (Maheu & A. Gillet) Hale | Siliceous stones | – |
| 35 | ° | *Xanthoparmelia verruculifera* (Nyl.) O. Blanco, A. Crespo, Elix, D. Hawksw. & Lumbsch | Siliceous stones | – |

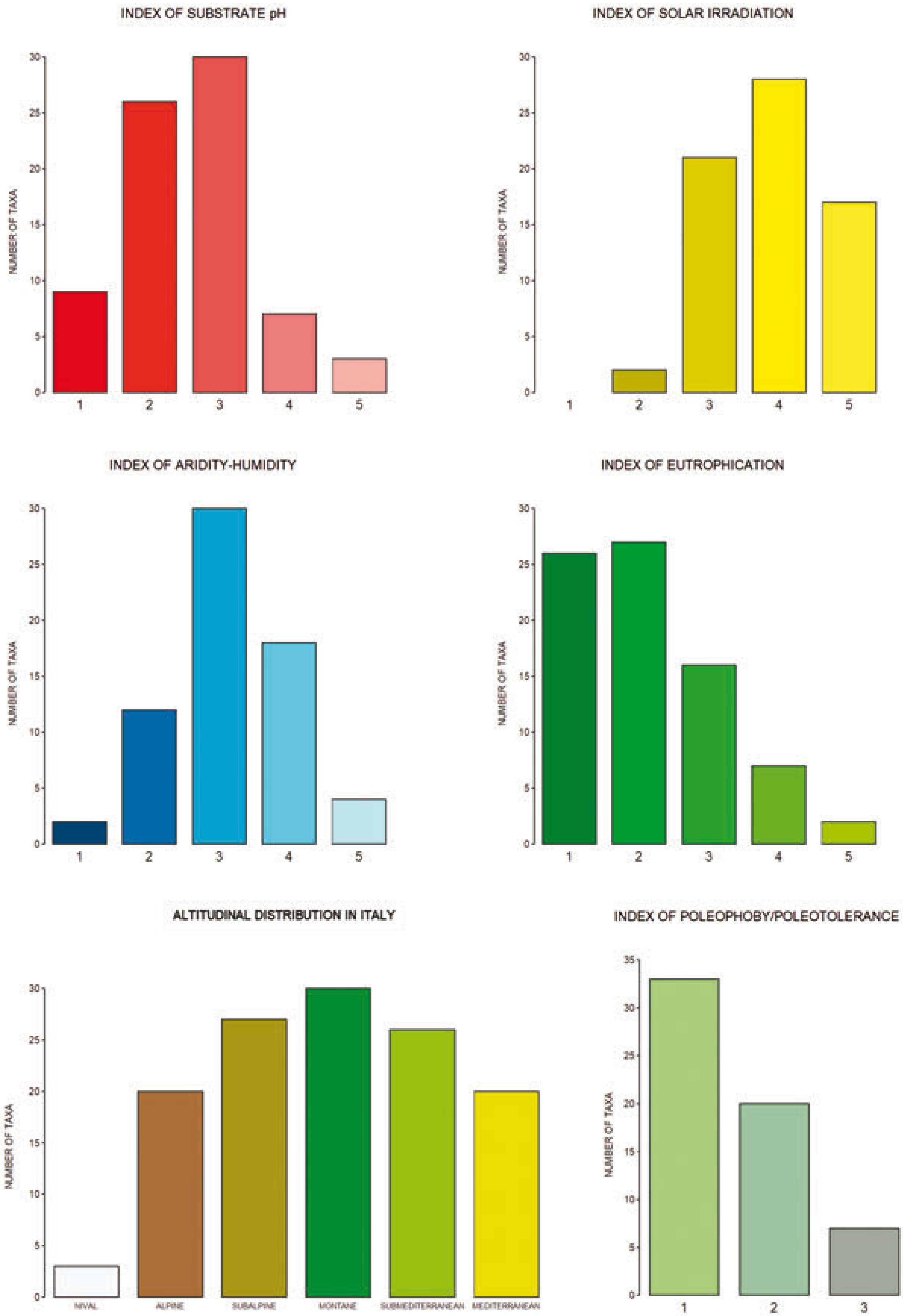


Fig. 3 - Graphs of ecological and poleotolerance indices, altitudinal distribution and rarity of the lichen biota of the *aurifodinae* of "Campo dei Fiori". / Grafici degli indici ecologici e di poleotolleranza, della distribuzione altitudinale e della rarità del biota lichenico delle aurifodine di "Campo dei Fiori".

The occurrence of several lichen species previously recorded in Italy only in upper altitudinal belts has been already highlighted from the Ticino river valley and other areas of the western Po Plain hosting open dry habitats along main rivers (Gheza, 2015, 2018, 2020). The role of the great rivers in the "dealpinization" of alpine taxa has been suggested to foster such events for vascular plants (e.g. Assini *et al*., 2013). However, this is not yet clear for lichens, which may have benefited of residual habitats to persist to the present days after the last glaciation. Under this perspective, the wide stone heaps of the *aurifodinae* can better be seen as refugia or substitution habitats for saxicolous lichens. These structures make available widely differentiated substrates fostering lichen diversity for at least three reasons: (1) stones have often a different origin, including magmatic and metamorphic rocks (Pipino, 2006), but also carbonate, and sedimentary rocks; (2) stones have also different sizes, ranging from about 10-15 cm to 60-70 cm (Pipino, 2006); (3) heaps morphology varies in exposure and shading, originating several microhabitats that can be colonized by species with well-differentiated ecological requirements. Furthermore, in spite of being superficially similar to the wide stone deposits in the riverbed, *aurifodinae* are not comparable to them: in fact, the latter are heterogeneous, stable and sheltered environments, whereas the riverbed is a flat and unstable location frequently disturbed by river dynamics.

Besides its relevance for saxicolous lichens, the manmade habitat of the *aurifodinae* is locally important also for terricolous lichens, and it was likely even more important in the past. Archaeological evidence suggests that *aurifodinae* had been widespread along the western side of the river valley, at least from Varallo Pombia down to Cameri (Pipino, 2006), although their remains are presently found only in a few places. The occurrence of such structures, and probably also of the mechanical disturbance related to their exploitation, is likely to have played a key role in maintaining for a long time wide extents of disturbed bare soil suitable for colonization by dry grassland and heathland vegetation (cf. Rahmonov & Oleś, 2010), that are the richest habitats for terricolous lichens in lowland landscapes (Gheza 2015, 2018; Gheza *et al*., 2019, 2020; Ravera *et al*. 2022).

The present study is a further example of how sites of archaeological and cultural interest can also represent valuable sites for lichen diversity (e.g. Nimis *et al*., 1987, 1992; Nascimbene & Salvadori, 2008; Favero Longo *et al*., 2022). *Aurifodinae* represent an archaeologically and culturally interesting evidence of a past human activity; unfortunately, this heritage is often neglected (Pipino, 2006, 2015), and no conservation measures are set to preserve what most people regard just as "piles of stones". Consequently, vegetation is rapidly engulfing them. The impending disappearance of the *aurifodinae* remains will drag along itself the disappearance of some valuable lichen taxa, including species of conservation concern, if no contrasting measures will be taken. In general, making a compromise which allows the preservation of both archaeological and environmental components is required when managing archaeological heritage (Caneva *et al*., 2018; Cicinelli *et al*., 2018), and Favero-Longo *et al*. (2022) showed that raising awareness towards the relevance and the conservation needs of lichen biodiversity is successfully possible in such sites. However, in the case of the *aurifodinae*, awareness should be raised also for the archaeological object *per se*, and not only for the biodiversity it supports.

**Acknowledgements**

We thank Dr. Edoardo Villa for the authorization to carry out this research within the Ticino Piemontese Natural Park; Prof. Helmut Mayrhofer (University of Graz) and Dr. Francesca Bottegoni for helping with the identification of some specimens; Dr. Manuela Mandrone and Prof. Ferruccio Poli (University of Bologna) for their support to carry out TLCs.

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