Italian Botanist 21: 47–57 (2026)
doi: 10.3897/italianbotanist.21.182900
https://italianbotanist.pensoft.net

RESEARCH ARTICLE

Italian Botanist
Published by Società Botanica Italiana

Cinclidotus danubicus and *C. riparius* (Pottiales, Pottiaceae), two interesting moss species of watercourse ecosystems new to Liguria

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Academic editor: Annalena Cogoni | Received 18 December 2025 | Accepted 17 February 2026 | Published 5 March 2026

Citation: Spada CD, Olivieri L, Aleffi M, Aleffi A (2026) *Cinclidotus danubicus* and *C. riparius* (Pottiales, Pottiaceae), two interesting moss species of watercourse ecosystems new to Liguria. Italian Botanist 21: 47–57. https://doi.org/10.3897/italianbotanist.21.182900

Abstract

During a series of surveys of macrophyte communities carried out as part of the monitoring plan for the watercourses of Liguria, the moss species *Cinclidotus riparius* and *C. danubicus* were found. For both species, these records represent the first reports for the Region; however, while *C. riparius* was repeatedly recorded throughout the entire monitoring period and in several sites across different watercourses in the area, *C. danubicus* was collected in a single location. The presence and distribution of *C. riparius* across a relatively high number of sites characterized by marked geolithological similarities made it possible to highlight a strong correlation between the territorial distribution of the moss and the lithology of the surrounding areas. Conversely, the single record of *C. danubicus* is of particular significance due to its rarity within Italian territory. Both species are of considerable interest because of their important role as bioindicators of the degree of ecological integrity of watercourses and their ecosystems.

Keywords

Bryidae, bryophytes, Flora, Italy

Introduction

The implementation of the Italian legislation transposing Directive 2000/60/EC (Legislative Decree 152/2006 and subsequent amendments) has made it necessary to consider aquatic macrophytes for the assessment of the ecological status of water bodies,

thus including them as a biological quality element (BQE) within routine monitoring activities of watercourses. The macrophyte community is composed by different groups of aquatic plants such as algae, bryophytes, ferns, and angiosperms. In particular, bryophytes can be found in all watercourses and become dominant in mountain sections characterized mainly by rocky substrates. Moreover, the presence or absence of some of them (such as certain species of the moss genus *Cinclidotus* P.Beauv.) can be fully considered indicators of good or poor water quality.

This work illustrates the result relating to the discovery of *Cinclidotus danubicus* Schiffn. & Baumgartner and *C. riparius* (Host ex Brid.) Arn. in Liguria region during a series of surveys conducted between 2014 and 2023 on behalf of the Regional Environmental Protection Agency (ARPAL) along several watercourses distributed across the regional territory. The importance of their discovery is also highlighted in consideration of their role as bioindicators of the degree of ecological integrity of watercourses and their ecosystems.

Materials and methods

Study area description

From a geo-lithological point of view, two sectors can be identified in the Ligurian territory, each characterized by formations of different geological origins but both sharing a typically marl-limestone lithology. Riviera di Ponente, between Ventimiglia and Albenga, is characterized by marl-limestone and sandstone flysch formations, among which the limestone group of Mount Toraggio (1973 m a.s.l.), Mount Pietravecchia (2038 m), and Mount Saccarello (2200 m), the highest peak in the region, stands out. East of the Giovi range and up to the town of Chiavari, the coastal slope is predominantly composed of marl–limestone flysch; in the remaining portion, schistose-argillaceous flysch formations are found, and to a lesser extent, ophiolitic and sandstone successions. In the easternmost part of Liguria, limestone and sandstone rocks of flysch-like nature belonging to the Tuscan sequences crop out. The area between the two marl–limestone sectors is largely characterized by acidic volcanic formations, including gneiss, serpentinites, and ophiolites (Fig. 1) (https://geoportal.regione.liguria.it/catalogo/mappe.html).

The Ligurian climate is Mediterranean, but it displays a remarkable variety of microclimates due to the influence of the Ligurian Alps, which protect the region from northern winds, and to the characteristic arc-shaped morphology opening toward the south, with the mountain ridge extending from the French to the Tuscan border. Overall, two major climatic areas can be distinguished: the coastal territories, which feature a typically Mediterranean climate with mild, rainy winters and hot, often humid and sunny summers, and the more inland areas of the region, which show a semi-continental climate with cold, frequently snowy winters and very hot summers (http://www.centrometeo.com/articoli-reportage-approfondimenti/climatologia/5410-clima-liguria).

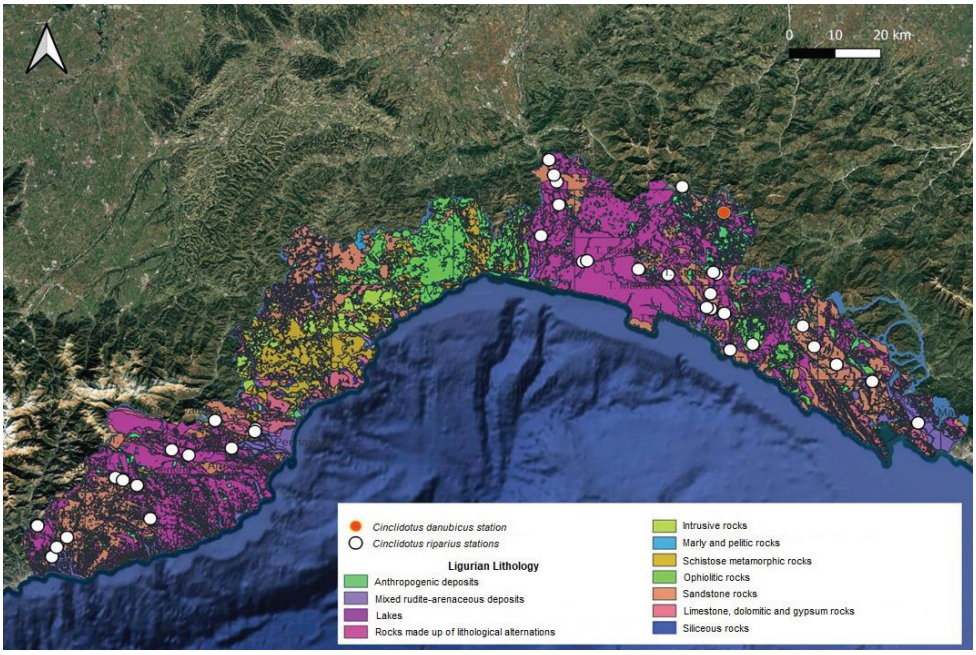

Figure 1. Geological features and distribution of *Cinclidotus riparius* and *C. danubicus* records in Liguria.

Data collection

The discovery of *Cinclidotus danubicus* and *C. riparius* in Liguria Region took place during a series of macrophyte surveys conducted between 2014 and 2023 along several watercourses distributed across the regional territory. The surveys of aquatic vegetation were aimed at evaluating the ecological status of water bodies by applying the national index RQE_IBMR, which is based on the study of aquatic vegetation and, in particular, on the presence and abundance of taxa considered indicators of specific ecological conditions in the surveyed river stretches (DL 152/2006 and subsequent amendments).

Sampling was carried out in accordance with the guidelines of the national ISPRA protocol (Minciardi et al. 2014), crossing and surveying each reach from bank to bank and taking into consideration the characteristic facies and the vegetation present. Each year, two survey campaigns were conducted (one in spring and one in late summer/autumn), corresponding to the period of maximum vegetative development of the aquatic community, in order to capture the entire community representative of the ecological conditions of the surveyed river stretch.

Specimens were identified using specific identification keys (Cortini Pedrotti 2001, 2006; Smith 2004; Guerra et al. 2006; Atherton et al. 2010; Casas et al. 2020). The collected samples are deposited in the Cryptogamic Herbarium of the University of Camerino (CAME).

Results and discussion

Description and distribution of the genus *Cinclidotus*

The genus *Cinclidotus*, belonging to the family Pottiaceae, includes 12 species of mosses. These species occur mainly in the Northern Hemisphere, with the highest diversity in northwestern Europe (France, Switzerland, Austria, and Germany), where six species are recorded (Hodgetts and Lockhart 2020). In Italy, four species are known: *Cinclidotus riparius* (Host ex Brid.) Arn., *C. aquaticus* (Hedw.) Bruch & Schimp., *C. fontinaloides* (Hedw.) P. Beauv., and *C. danubicus* Schiffn. & Baumgartner. While the first three species are widely distributed across many Italian regions, *C. danubicus* has been reported only from Friuli Venezia Giulia (Tacchi 2007) and Lazio (Philippi 1967; Cortini Pedrotti 2001; Aleffi et al. 2023).

Species of this genus are structurally robust, mostly cladocarpous, forming upright tufts of variable size, anchored to the substrate by a basal disc, dark green to almost black in color, with isodiametric leaf cells and pluristratified margins formed by cells similar in size to those of the lamina (Cortini Pedrotti 2001; Smith 2004). They inhabit typically aquatic environments and occur from lowlands to mountain areas. They generally prefer coarse and stable substrates (boulders and rocks) as well as the bases of trees along fast-flowing watercourses. *Cinclidotus riparius* and *C. fontinaloides* are common along zones subject to periodic submersion (seasonal or artificially induced), tolerating relatively long periods without water, whereas *C. aquaticus* and *C. danubicus* typically colonize permanently submerged habitats, though they can withstand short periods of emersion.

***Cinclidotus danubicus* Schiffn. & Baumgartner**

Cinclidotus danubicus is a medium-sized moss, up to 15 cm tall, forming loose or dense, extensive tufts, irregularly branched with long lateral branches (Erdağ and Kürschner 2010; Schnyder et al. 2016). It is green-brownish in color and characterized by rigid leaves, contorted or slightly incurved when dry, erect-spreading or slightly curved when moist, elliptic-linear or narrowly lanceolate, with a broad base gradually tapering to a sharp to mucronate apex, slightly secund, and up to 3–4 mm long. The leaf lamina is unistratose throughout; the costa is thick at the base, occupying about one quarter of the width of the basal lamina, reaching the apex or extending beyond it into a strong mucro. The margins are plane, entire, and bistratose. Laminal cells are isodiametric, quadrate to hexagonal, smooth, with median cells about 14–16 μm wide, and basal cells short-rectangular. Reports of sporophytes are rare and still poorly documented (Erdağ and Kürschner 2010).

Cinclidotus danubicus has a geographically restricted distribution, limited to a few countries of northwestern Europe, particularly France, Switzerland, Austria, and Germany (Hodgetts and Lockhart 2020). In Italy, only two records exist (Aleffi et al. 2023): one recent record from Friuli Venezia Giulia, along the Risorgiva del Timavo at San Giovanni di Duino (Tacchi 2007), and an older record from Lazio, where Philippi

(1967) collected it along the Tiber near Ponte Palatino. In the latter site, however, despite targeted searches in recent years, the species has not been found again due to major environmental changes along the river. *Cinclidotus danubicus* was collected in Liguria during the macrophyte survey conducted in late spring 2020 (June 3, 2020), in a stretch of the Aveto River upstream of Ponte Principe sull'Aveto toward Alpepiana, between the municipalities of Rezzoaglio and Santo Stefano, at 654 m a.s.l.. The coordinates of the site are as follows: 44°33'01.5432"N, 09°24'35.3485"E (Fig. 1). The sampling site lies within the Natura 2000 site IT1331104 – Parco della Val d'Aveto, currently designated as a Special Area of Conservation under the Habitat Directive 92/43/EEC. It is a virtually undisturbed site, with only minimal upstream nutrient input; the absence of significant environmental pressures in the surrounding and upstream areas identifies this location as a reference site for classification of the ecological status of the water body (DL 152/2006 and subsequent amendments).

The surveyed stretch lies within two geological formations characterized overall by calcareous-marly flysch (Flysch of Ottone and Flysch of Monte Rocco). In sections with higher fluvial dynamics – where the moss was collected – the substrate consists of large boulders and calcareous rocks washed by flowing to fast-flowing waters. The specimen was found in the more marginal portions of the active channel, generally subject to periodic submersion (Fig. 2).

Together with *C. danubicus*, and within the same facies, several other bryophyte species were recorded, including *C. fontinaloides* (Hedw.) P.Beauv., *Cratoneuron filicinum* (Hedw.) Spruce, and *Rhynchostegium riparioides* (Hedw.) Cardot. Overall, the community is characterized by a clear dominance of algal taxa, such as the genera *Cladophora* Kützing, *Diatoma* Bory, and *Spirogyra* Link. Along the sampling localities, the riparian vegetation consists of a typical riparian formation dominated by *Salix eleagnos* Scop., *S. purpurea* L., *Alnus glutinosa* (L.) Gaertn., and *A. incana* (L.) Moench, and secondarily by *Corylus avellana* L., *Fraxinus excelsior* L., and *Cornus sanguinea* L. The riparian belts are in turn surrounded by relatively extensive woodlands, mainly composed of *Quercus pubescens* Willd. woods and *Alnus glutinosa* (L.) Gaertn. forests.

Cinclidotus riparius **(Host ex Brid.) Arn.**

Cinclidotus riparius forms compact or loose, relatively robust tufts, dark green to blackish in color, reaching up to 8 cm in height. It has erect leaves, vaguely appressed and sometimes slightly contorted when dry, erect-spreading with often reflexed apices when moist; leaves are ovate-elliptic to narrowly ligulate, plane in the upper part, with obtuse or rounded and usually apiculate apices. The leaf margins are very thick and plane; in cross-section they are generally oval and composed of 2–5 layers of cells of more or less similar size. The costa is percurrent or extending into a short mucro; basal cells are short-rectangular, and the upper cells are quadrate to hexagonal, smooth or slightly papillose, 8–16 μm wide at mid leaf. The sporophyte has a terminal, erect, thick, yellow-reddish seta, bearing an emergent, erect, ellipsoidal capsule (Cortini Pedrotti 2001; Smith 2004).

Figure 2. Leaf (**A.** ×40) and margin section of leaf (**B.** ×250) of the *Cinclidotus danubicus* Ligurian sample.

This species is generally found on stable rocky substrates or at the base of trees, in periodically exposed environments and along the flood zone of watercourses. It is sometimes found together with *Cinclidotus fontinaloides* (Hedw.) P.Beauv. In sterile specimens, the two species can be distinguished by the cross section of the leaf margin: *C. riparius* has margins composed of cells of fairly uniform size, whereas in *C. fontinaloides* the inner marginal cells are smaller and have thicker cell walls than the outer ones (Smith 2004). They also differ in other features: *C. riparius* has leaves from elliptic to narrowly ligulate, symmetrical, with obtuse to rounded apices, while *C. fontinaloides*

has ovate-lanceolate, often asymmetrical leaves with a more pointed apex. In fertile forms, *C. riparius* has an emergent capsule above the perichaetial leaves, whereas in *C. fontinaloides* the capsule develops and remains enclosed within the perichaetial leaves (Cortini Pedrotti 2001; Smith 2004). This species can also be easily confused with *Dialytrichia mucronata* (Brid.) Broth. (formerly included in the same genus), which differs in having recurved and papillose-crenate margins, whereas *C. riparius* has plane, scarcely papillose margins (Cortini Pedrotti 2001; Smith 2004).

Distribution. *Cinclidotus riparius* (Host ex Brid.) Arn. is a moss widely distributed in many rivers and streams. Records highlight a broad distribution across Europe (Hodgetts and Lockhart 2020). In Italy, it has been recorded in recent years for the following regions: Valle d'Aosta in Les Îles (Saint-Marcel) (Miserere et al. 2015); Piemonte in the Stura di Viù, Chisone, and Evançon streams (Ceschin et al. 2015); Friuli Venezia Giulia at the Risorgiva del Timavo in San Giovanni di Duino and in Val Rosandra (Tacchi 2007); Trentino-Alto Adige in the Gocciadoro Park (Trento) (Pokorny et al. 2006); Veneto in Ca' Trenta, Val del Covolo (Schio), and Preara (Montecchio) (Scortegagna 2015); Marche along the Tronto River (Ceschin et al. 2015); Lazio along the Aniene River (Ceschin et al. 2015); Abruzzo in the Gole of S. Venanzio in the Aterno Valley (Mastracci and Düll 1991) and in the upper course of the Sangro River (Allegrini 2000). Records from Sicily refer to Lo Giudice and Privitera (1984) for the Alcantara River and to Privitera (1990) for the Vicarietto stream. In Tuscany and Sardinia, records all date before 1968 (Aleffi et al. 2023); in particular, Philippi (1967) reports the species in the Arno River in Tuscany, while Cortini Pedrotti (1966) reports it in Sardinia at the Su Cologone spring.

During the macrophyte surveys, this species was repeatedly found in 39 monitoring sites across various watercourses throughout Liguria (Fig. 1). A complete list of all monitoring sites of the watercourses, corresponding coordinates, and dates of occurrence is available in the Suppl. material 1. *Cinclidotus riparius* was mainly found along the marginal portions of the active riverbed and, more sporadically, in submerged lotic sections more strongly influenced by natural or artificial fluctuations in discharge (Fig. 3).

In many of the surveyed stretches, the moss was collected together with other bryophyte species, including *Cinclidotus aquaticus* (Hedw.) Bruch & Schimp., *C. fontinaloides* (Hedw.) P.Beauv., *Rhynchostegium riparioides* (Hedw.) Cardot, *Palustriella commutata* (Hedw.) Ochyra, and *Cratoneuron filicinum* (Hedw.) Spruce. Regarding riparian vegetation, the localities where *C. riparius* was found are highly differentiated from one another, due to their varying positions in the territory and the different degrees of anthropogenic influence or naturalness. These factors determine the presence or absence of specific plant communities and their structural integrity, as well as the morphological characteristics of the sampled river stretches. Overall, these are riparian tree-shrub formations dominated by *Salix alba* L., *S. purpurea* L., *S. eleagnos* Scop., *Populus nigra* L., and *Alnus glutinosa* (L.) Gaertn. An exception is the locality in the Pennevaira stream, at Madonna di Curagna in the municipality of Nasino (Savona), where the riparian vegetation consists of a rich and diversified formation featuring *Carpinus betulus* L., *Fraxinus excelsior* L., *Fraxinus ornus* L., along with *Alnus glutinosa* (L.) Gaertn.

Figure 3. Leaf (**A.** ×40) and cross-section of the leaf margin (**B.** ×250) of the Ligurian sample of *Cinclidotus riparius*.

The comparison of *Cinclidotus riparius* occurrence sites with regional geological mapping (Fig. 1) highlights a greater distribution of records within the two lateral quadrants of the Ligurian territory. In particular, the areas with the highest number of occurrences lie inland and along the hilly areas of the eastern sector, roughly from Cornigliano Ligure to the border with Tuscany, and in the western sector from

Borghetto Santo Spirito to the border with France. The only *Cinclidotus danubicus* locality is also located within the western quadrant. Both quadrants share a typically calcareous–marly lithology. Conversely, the area situated between the two quadrants (dominated mainly by volcanic formations) shows no significant findings. Beyond the geo-lithological features of the surrounding territory, all sites share hydro-morphological characteristics that collectively describe the sampled stretches: torrent-like river segments, shaded, characterized by stable and coarse substrates (boulders and rocks), with waters ranging from moderately to highly turbulent, and with marginal areas of moderate to slow flow strongly shaped by fluvial dynamics.

Conclusions

The large-scale monitoring of river macrophytes throughout the Liguria Region has shown that *Cinclidotus danubicus* Schiffn. & Baumgartner is particularly rare, having been found only once and during a single survey campaign, at a stretch of the Aveto River. The collection and reporting of this species is of notable importance – not only because it represents the first record for the Region, but also due to its rarity in Italy and its particular ecological significance as a bioindicator of the environmental integrity of watercourses. Conversely, the collection of *Cinclidotus riparius* (Host ex Brid.) Arnott across a relatively high number of sites allowed us to confirm its broad distribution in Liguria. Furthermore, the overlap between geological mapping and the sampled sites highlighted a strong correlation between the moss territorial distribution and the geo-lithological features of the surrounding areas, with a preference for calcareous substrates. Integrating additional sampling sites and/or new watercourses within the Ligurian hydrographic network may, in the future, allow for further insights into the ecology and distribution of these two species in the region.

Acknowledgements

Special thanks to Federica Morchio and Sara Costa of the Regional Agency for Environmental Protection of the Liguria Region (ARPAL), Water Quality Unit, for granting access to and authorization to publish the data.

Financial support by Fondazione per la Flora Italiana for the publication fee is gratefully acknowledged.

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Supplementary material 1

Watercourses, sites, corresponding coordinates, and dates of occurrence of *Cinclidotus riparius* in Liguria region

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Data type: docx

Link: https://doi.org/10.3897/italianbotanist.21.182900.suppl1