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Contribution to the knowledge of the bryoflora of running waters of Central Italy

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Abstract
The present study focused on the bryoflora of watercourses of the Tiber River basin watercourses (Central Italy). A total of 20 bryophyte species, which included 14 mosses and 6 liverworts, were collected at 32 river stations. Most species were recorded at stations of the watercourses' upper sections, which have rocky substrate and where there is cool and well oxygenated running water, with low trophic load. Only few species, such as *Leptodictyum riparium*, *Cinclidotus fontinaloides* and *Riccia fluitans*, were also found at stations of the middle and lower sections, which are characterized by slow-flowing, turbid, warm and eutrophic waters. Some species are widely distributed, among which *Fontinalis antipyretica* ssp. *antipyretica* and *Platyhypnidium riparioides*, while others are very rare, such as *Cinclidotus aquaticus*, *Dialytrichia mucronata* and *R. fluitans*. Some of the collected species are new regional records (*Hygroamblystegium fluviatile*, *D. mucronata*), regional confirmations of rare taxa in Italy (*C. aquaticus*) or confirmations of old regional reports (*Hygroamblystegium tenax*, *C. fontinaloides*, *Aneura pinguis*).

Keywords: *Aquatic flora, bryophytes, species distribution, Tiber River basin (Central Italy), watercourses*

Introduction

The aquatic bryoflora forms a significant part of macrophytes, particularly in the upper sections of watercourses, where the aquatic phanerogams are generally absent or rare (Haury & Muller 1991; Tremp 1999). Furthermore, it comprises several species which have proven to be useful as bioindicators for assessing water quality (Vrhosek et al. 1984; Vanderpoorten & Palm 1998; Tremp 1999; Vanderpoorten et al. 2000) or as bioaccumulators for detecting contaminants, such as heavy metals or radionuclides in running waters (Wehr & Whitton 1983; Claveri et al. 1995; Samecka-Cymerman et al. 2002; Ah-Peng & Rausch De Traubenberg 2004).

In Italy, the bryological flora of running waters has not been extensively investigated, except for fragmentary and historical data related to some taxa (Beguinot 1897; Philippi 1967; Allegrini & Vitali 1996) or sporadic studies limited to a few watercourses in Central-Southern Italy and Sicily (Fitzgerald & Bottini 1881; Cortini Pedrotti 1970; Lo Giudice & Privitera 1984; Laschin 1990; Privitera 1990; Allegrini 2000). Therefore, the aim of the present study was to study the bryoflora of watercourses in Central Italy, providing data on biodiversity, distribution and ecological features of this macrophyte component.

Study area

The study area was the Tiber River basin, and specifically, the Tiber River and its main tributaries (Figure 1).

The Tiber basin extends over an area of more than 17,000 km^2 and it is the largest catchment area of the Italian peninsula. It occupies a large part of the Tyrrhenian side of Central Italy, and flows through important cities, such as Rome, Perugia, Rieti and Terni. From a bioclimatic point of view, it is possible to separate the basin area into two main sectors: an upper-middle sector, situated in Tuscany and Umbria, with a temperate bioclimate (Biondi & Baldoni 1994), and a lower sector, situated entirely within Latium and characterized by a transitional Mediterranean bioclimate (Blasi 1994).

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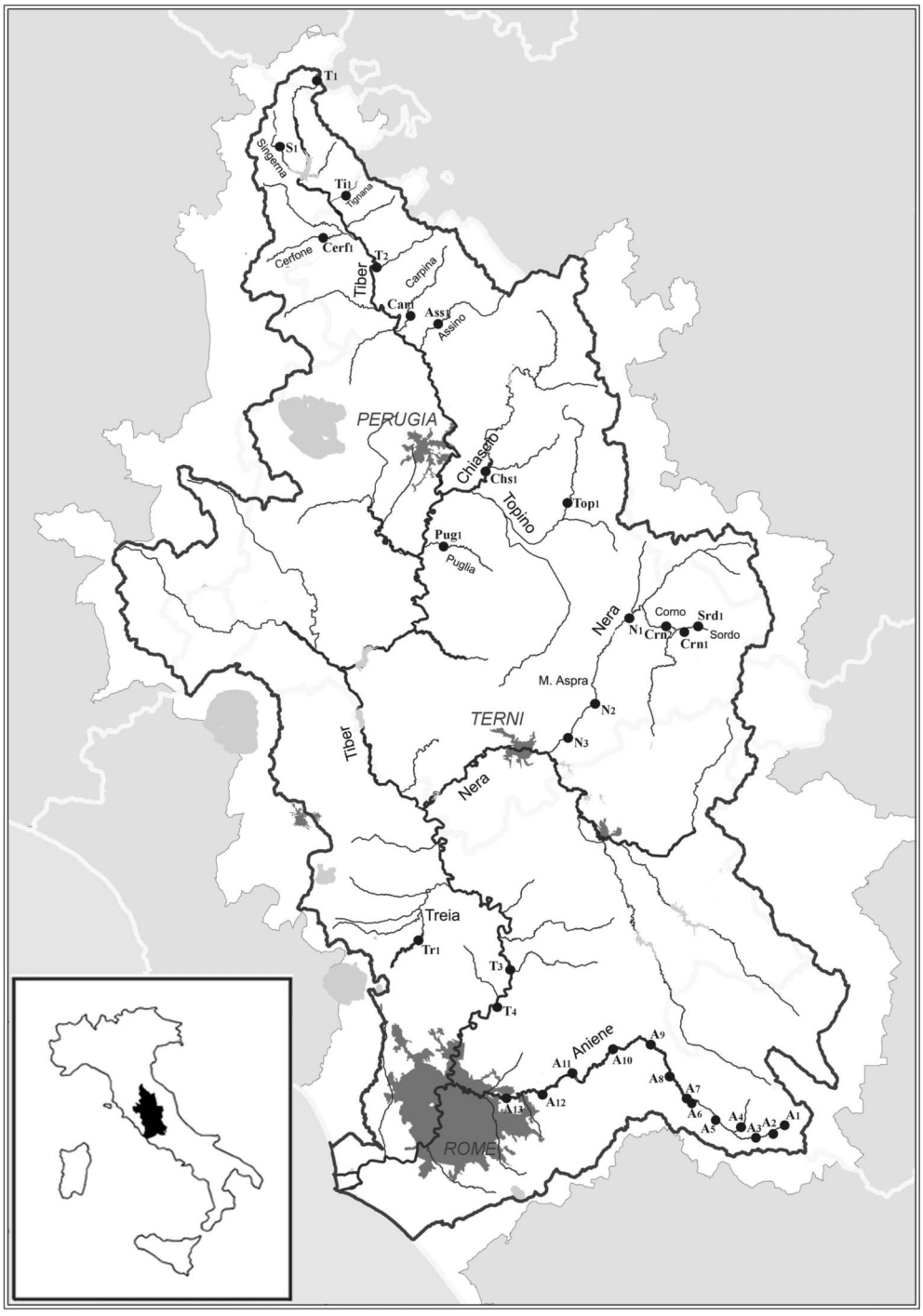

Figure 1. Tiber River basin and location of sampling stations. The stations located along the same watercourse are numbered sequentially according to the water flow direction: Tiber River (T_1–T_4), Singerna Stream (S_1), Tignana Stream (Ti_1), Cerfone Stream ($Cerf_1$), Carpina Stream (Car_1), Assino Stream (Ass_1), Chiascio River (Chs_1), Topino River (Top_1), Puglia Stream (Pug_1), Corno Stream (Crn_1–Crn_2), Sordo Stream (Srd_1), Nera River (N_1–N_3), Treia River (Tr_1), Aniene River (A_1–A_{13}).

The main lithotype of the basin is calcareous. The natural vegetation has generally a good state of conservation along the rivers in the mountainous and sub-mountainous zones of the basin. By contrast, most of the valleys and plains have lost much of their original river vegetation, mostly due to agricultural activities and urbanization. These land uses, occurring especially in the lower sections of many of the basin's watercourses, are the main cause of water mineralization and eutrophication (Casini & Giussani 2006).

Materials and methods

A total of 32 stations were selected along the watercourses of the Tiber River basin (Figure 1). The

Table I. UTM coordinates for each sampling station.

Station	UTM coordinates
T_1	33 T – 48524.38 m N – 2648.27 m E
T_2	33 T – 48148.11 m N – 2765.11 m E
T_3	33 T – 46696.62 m N – 3047.53 m E
T_4	33 T – 46622.50 m N – 3018.36 m E
S_1	33 T – 48337.16 m N – 2590.99 m E
Ti_1	33 T – 48338.96 m N – 2674.34 m E
$Cerf_1$	33 T – 48189.31 m N – 2683.24 m E
Car_1	33 T – 48016.93 m N – 2838.07 m E
Ass_1	33 T – 48006.32 m N – 2897.50 m E
Chs_1	33 T – 47666.92 m N – 3118.03 m E
Top_1	33 T – 47658.08 m N – 3168.30 m E
Pug_1	33 T – 47563.48 m N – 2900.88 m E
Crn_1	33 T – 47311.30 m N – 3443.57 m E
Crn_2	33 T – 47388.73 m N – 3381.58 m E
Srd_1	33 T – 47398.20 m N – 3431.97 m E
N_1	33 T – 47424.55 m N – 3297.36 m E
N_2	33 T – 47253.20 m N – 3220.93 m E
N_3	33 T – 47164.39 m N – 3149.04 m E
Tr_1	33 T – 46735.34 m N – 2835.99 m E
A_1	33 T – 46387.62 m N – 3615.28 m E
A_2	33 T – 46372.80 m N – 3584.88 m E
A_3	33 T – 46354.26 m N – 3527.80 m E
A_4	33 T – 46368.98 m N – 3504.77 m E
A_5	33 T – 46403.13 m N – 3461.17 m E
A_6	33 T – 46431.37 m N – 3407.18 m E
A_7	33 T – 46430.12 m N – 3413.01 m E
A_8	33 T – 46468.60 m N – 3384.52 m E
A_9	33 T – 46541.73 m N – 3335.95 m E
A_{10}	33 T – 46537.47 m N – 3282.89 m E
A_{11}	33 T – 46502.29 m N – 3229.36 m E
A_{12}	33 T – 46478.64 m N – 3152.03 m E
A_{13}	33 T – 46442.58 m N – 3067.13 m E

Universal Transverse Mercator (UTM) coordinates of each stations are indicated in Table I.

The floristic surveys were conducted in June and October of the years 2007–2009. At each sampling station, an inventory of aquatic bryophytes was carried out on 50 m section of the watercourse. Bryophyte samples were taken from boulders, cobbles, or tree stumps that were in submerged conditions for most of the year.

The bryophyte specimens were deposited at the *Herbarium* of the University of Rome Tre.

Cortini Pedrotti (2001, 2005) was followed for the taxonomical determination of mosses and Paton (1999) for liverworts. Nomenclature and species distribution in Italy were updated according to Aleffi et al. (2008). Chorological features of the collected bryophytes were defined following Hill & Preston (1998).

Results

Twenty species were recorded in aquatic and sub-aquatic habitats, including 14 mosses and 6 liverworts (Table II).

The collected species belong to 7 orders and 13 different families. The most represented family is

Table II. List of collected bryophytes in watercourses of the Tiber River basin. For each species, chorological type and sampling station(s) are reported.

Chorological type	Taxon	Station
	Bryopsida	
	Bryales	
	Plagiomniaceae	
European temperate	*Plagiomnium affine* (Blandow) T.J.Kop.	A_2; A_5
European temperate	*Plagiomnium undulatum* (Hedw.) T.J.Kop.	A_1; A_2
	Dicranales	
	Fissidentaceae	
Circumpolar wide-temperate	*Fissidens viridulus* (Sw. ex Anon.) Wahlenb. var. *viridulus*	A_5
	Hypnales	
	Amblystegiaceae	
Circumpolar wide-temperate	*Cratoneuron filicinum* (Hedw.) Spruce	T_1; Top_1
European Boreo-temperate	*Hygroamblystegium fluviatile* (Hedw.) Loeske	$Cerf_1$; A_2
Circumpolar temperate	*Hygroamblystegium tenax* (Hedw.) Jenn.	N_1; Ass_1; A_1
Circumpolar temperate	*Leptodictyum riparium* (Hedw.) Warnst.	Pug_1; A_{13}
Circumpolar Boreo-temperate	*Palustriella commutata* (Hedw.) Ochyra	S_1; Top_1
	Brachytheciaceae	
Circumpolar southern-temperate	*Platyhypnidium riparioides* (Hedw.) Dixon	T_1; N_2; N_3; Crn_2; $Sord_1$; Ti_1; S_1; Crn_1; Car_1; A_1; A_2; A_3; A_5; A_7
	Fontinalaceae	
Circumpolar Boreo-temperate	*Fontinalis antipyretica* (Hedw.) ssp. *antipyretica*	T_4; A_4; A_6; A_7; A_9; A_{10}; A_{11}; A_{12}; A_3; A_5; A_9; A_{12}; Tr_1; T_1; N_1; N_2; N_3; Srd_1; Crn_2; Chs_1
	Orthotrichales	
	Orthotrichaceae	
European temperate	*Orthotrichum stramineum* Hornsch. ex Brid.	A_6
	Pottiales	
	Pottiaceae	
Mediterranean-Atlantic	*Cinclidotus aquaticus* (Hedw.) Bruch & Schimp	A_5
European southern-temperate	*Cinclidotus fontinaloides* (Hedw.) P. Beauv.	T_2; A_3; A_5; A_{12}
Mediterranean-Atlantic	*Dialytrichia mucronata* (Brid.) Broth.	N_2
	Marchantiopsida	
	Marchantiales	
	Conocephalaceae	
Circumpolar Boreo-temperate	*Conocephalum conicum* (L.) Dumort.	S_1; A_2; A_5
	Lunulariaceae	
Sub-Mediterranean-sub-Atlantic	*Lunularia cruciata* (L.) Lindb.	A_1; A_5

(*continued*)

Table II. (*Continued*).

Chorological type	Taxon	Station
	Marchantiaceae	
Circumpolar Boreo-temperate	*Marchantia polymorpha* L. ssp. *polymorpha*	T_3; A_4; A_2; A_5
	Ricciaceae	
Circumpolar southern-temperate	*Riccia fluitans* L.	T_3
	Metzgeriales	
	Aneuraceae	
Circumpolar wide-boreal	*Aneura pinguis* (L.) Dumort.	N_2; S_1
	Pelliaceae	
Circumpolar southern-temperate	*Pellia endiviifolia* (Dicks.) Dumort.	A_1; A_5

Amblystegiaceae (5 species, 4 genera), followed by Pottiaceae (3, 2).

Based on the frequency and distribution of all the collected species (Figure 2), *Fontinalis antipyrstica* ssp. *antipyretica*, sampled in almost 60% of the investigated stations, may be considered the most abundant and common species. *Platyhypnidium riparioides*, with a frequency of over 40%, is widely distributed too. On the other hand, other species are very rare, among which *Dialytrichia mucronata*, *Cinclidotus aquaticus* and *Riccia fluitans*.

Some species, such as *F. antipyretica* ssp. *antipyretica*, *C. aquaticus* and *Hygroamblystegium fluviatile*, usually live on stones submerged in water, while others, such as *R. fluitans* and *Aneura pinguis*, generally float on the water surface. *P. riparioides*, *Leptodictyum riparium*, *Hygroamblystegium tenax*, *D. mucronata*, *Palustriella commutata* and *Cinclidotus fontinaloides* colonize pebbles constantly submerged or even stones which may periodically remain dry. In addition to these typical aquatic bryophytes, some species are more linked to the damp environment of riverbanks, including most of the collected liverworts, such as *Pellia endiviifolia*, *Conocephalum conicum*, *Lunularia cruciata* and *Marchantia polymorpha* ssp. *polymorpha*, and some mosses, such as *Fissidens viridulus*, *Orthotrichum stramineum*, *Plagiomnium undulatum* and *Plagiomnium affine*.

Regarding the biogeographical characteristics of the sampled bryo flora, the circumpolar chorotype is the most common chorological type (60%), and its temperate subcategories the most widespread. It is followed by the European temperate chorotype (25%) and the Mediterranean-Atlantic one (15%).

Discussion

The recorded bryoflora consists of a low species number which can be justified by the peculiar habitat of the watercourses.

Considering the chorological features of this flora, the prevailing presence of species with main distribution in temperate zones is in agreement with the bioclimatic characteristics of the upper and middle sectors of the Tiber basin, where most of the aquatic bryophytes were found. The not-negligible presence of Mediterranean-Atlantic species is probably linked to the typical microclimatic conditions of the river ecosystems, which are humid and generally fresh.

Most of the bryophyte species were recorded at stations of upper river sectors that were described in Ceschin et al. (2010) as having rocky substrates and fast-flowing, fresh, clear, oxygenated waters, with a low trophic load. These ecological conditions limit the development of phanerogams; at these stations, in fact, the aquatic flora is almost exclusively composed of bryophyte and algal communities. Similar observations were also made by other authors (Haury & Muller 1991; Suren 1996; Vanderpoorten & Palm 1998). Only few species, such as *L. riparium*, *C. fontinaloides* and *R. fluitans*, were also found in stations of middle and lower river sectors that were reported in Ceschin et al. (2010) as having slow, warm, turbid waters, with a higher trophic pollution. Indeed, these species show tolerance to eutrophic waters, as already demonstrated in other studies (Vanderpoorten et al. 1999; Vanderpoorten & Klein 2000; Scarlett & O'Hare 2006).

F. antipyretica ssp. *antipyretica* showed a wide distribution since it was recorded both in the upstream and downstream sectors of watercourses, which have different environmental conditions; this underlines the euriecious behaviour of this species. *P. riparioides* also has a high frequency in the study area but, contrary to *F. antipyretica*, it occurs especially in stations of the upper sectors, showing therefore a less euriecious behaviour.

Some of the collected species are interesting either because they are rare in Italy or because they were never reported at regional level (Aleffi et al. 2008). For instance, *H. fluviatile* is a quite rare moss in Italy, and its findings from the Cerfone Stream and Aniene River are the first records in Tuscany and Latium. *C. aquaticus* is also rather rare in Italy, and it was found in the Latium region along the Aniene, confirming reports published before 1950. Other species, although common in Italy, are interesting at regional level, such as *D. mucronata*, as its finding along the Nera River is the first record in Umbria; *H. tenax* and *C. fontinaloides* for Umbria and Latium and *A. pinguis*, only for Latium, confirm records prior to 1950.

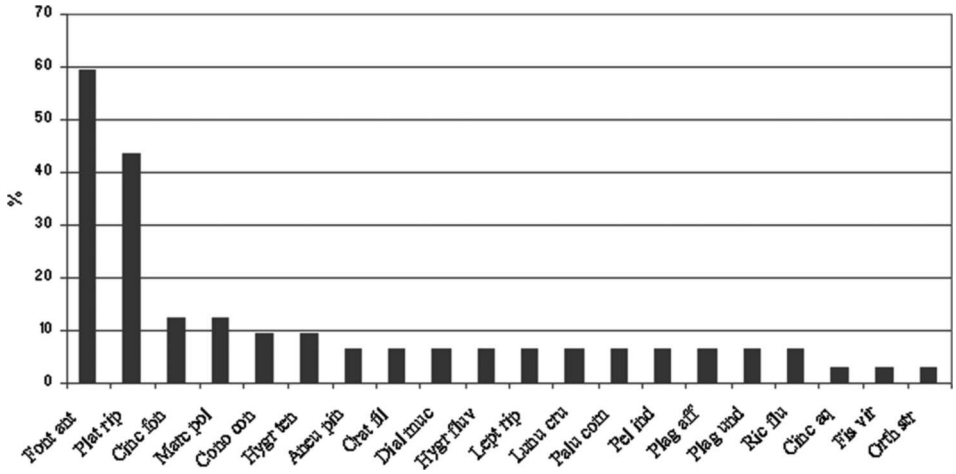

Figure 2. Species frequency in watercourses of the Tiber River basin.

Previous records of *Cinclidotus danubicus* from the Tiber River within the city of Rome (Philippi 1967) and *L. riparium* from the upper sector of the Nera River (Cortini Pedrotti 1982) were not confirmed by the present study.

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