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The diversity of Protura (Arthropoda, Hexapoda) in the Mediterranean area

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SUMMARY

The Mediterranean area is one of the biodiversity hotspots where some soil-borne taxa reach a high peak of diversity. Within this community, Protura is a poorly known taxon of euedaphic microarthropods. Based on the literature, 77 species belonging to 15 genera, arranged into four families and two orders have been recorded in the Mediterranean Basin. Records are concentrated in the northern part of this area (56 species are known in the North West and 28 in the North East), followed by Macaronesia (20 species) South-West (10) and South-East (6). This diversity distribution follows the uneven research effort dealing with this taxon. Much work is still needed, especially in areas that have been completely or largely neglected by researchers to date, before it can be considered that a solid knowledge base has been laid on Protura diversity and distribution.

INTRODUCTION

The Mediterranean area is one of the biodiversity hotspots (Myers et al., 2000; Blondel et al., 2010) where in particular some soil-borne organisms reach a high peak of diversity (di Castri & di Castri, 1981; Guerra et al., 2022). Within this community, and in particular among the microarthropods belonging to the soil mesofauna, Protura is one of the least known and least studied groups (Pass & Szucsich, 2011; Galli, 2022). Proturans are euedaphic microarthropods (Rusek, 2007) globally represented by 831 species belonging to 77 genera arranged in seven families and three orders (Galli, 2022). The aim of this paper is to review the species richness and distribution of Protura in the Mediterranean Basin.

MATERIALS AND METHODS

The literature on the distribution of Protura species has been reviewed, mainly selecting data on those species recorded within the IUCN Mediterranean biodiversity hotspot (https://www.iucn.org). The whole area was then divided into five parts (Figure 1):

- North-West Mediterranean - Portugal, Spain, France and Italy (facing Ligurian and Tyrrhenian Sea).

- North-East Mediterranean - Italy (facing Ionian and Adriatic Sea), Malta, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Turkey, Cyprus.

- South-West Mediterranean - Morocco, Algeria, Tunisia.

- South-East Mediterranean - Lybia, Egypt, Israel, Lebanon, Syria.

- Macaronesia ("Mediterranean part") - Madeira, Azores, Canary Islands.

Our knowledge on the distribution of proturan species is very patchy because sampling by experts does not sufficiently cover the area. The fauna of whole countries such as Tunisia and Egypt has never been studied and in others like Lebanon only a few localities have been investigated (Galli, 2022; Vahedi Moghadam et al., 2022). Even in the most studied countries, such as Italy, entire regions have been completely or almost neglected (Galli et al., 2011; Galli & Sarà, 2022). Therefore, whenever a species ascertained for one of the five areas of the Mediterranean Basin (e.g. NW) was reported from another country of the same area but outside the Mediterranean Basins (e.g. Central France), it was scored present (at least potentially) for this country.

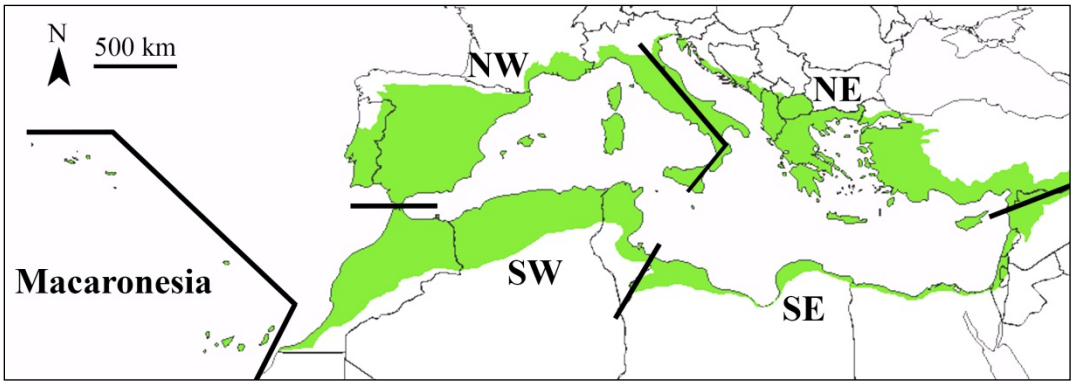

Figure 1. Study area: the Mediterranean Basin. The five areas (see Materials and Methods) adopted are abbreviated as follows: NW = North-West Mediterranean, NE = North-East Mediterranean, SW = South-West Mediterranean, SE = South-East Mediterranean, Macaronesia = "Mediterranean part" of Macaronesia.

RESULTS

Totally, based on the literature, 77 species belonging to 15 genera, arranged into four families and two orders have been recorded in the Mediterranean Basin (Table 1).

Most of the records relate to the northern parts of the Mediterranean Basin, where 56 species are reported from the North-West and 28 from the North-East. Macaronesia follows with 20 species. Only 10 and six species were recorded in the South-West and South-East, respectively.

Most species recorded in the Mediterranean Basin (49) belong to the Cosmopolitan genera *Protentomon*, *Acerentulus*, *Baculentulus*, *Berberentulus*, *Gracilentulus* and *Eosentomon*. Three species are among the northernmost members of the Subcosmopolitan genera *Silvestridia* and *Isoentomon*, which distribution is mainly tropical or subtropical. Five are part of the Holarctic genus *Proturentomon*. West Palearctic genera *Ionescuellum*, *Maderentulus*, *Podolinella*, *Tuxenidia*, *Acerentomon* and *Acerella* comprise the remaining 20 species (Galli & Rellini, 2020; Galli, 2022).

Table 1. Protura of the Mediterranean area. For abbreviations of the areas, see Figure 1. Doubtful data are marked with "?". Bibliography follows the alphabetical order.

Species	Area (Countries)	Bibliography
Acerentomata, Hesperentomidae		
Hesperentominae		
Ionescuellum carpaticum (Ionescu, 1930)	NE (Croatia, Bosnia and Herzegovina, Greece)	Cvijoivić, 1970, 1973; Galli, 2022; Nosek, 1973, 1978; Szeptycki, 2007
Ionescuellum condei (Nosek, 1965)	NW (Italy)	Galli, 2022; Galli et al., 2011; Szeptycki, 2007; Torti, 1981
Ionescuellum haybachae (Nosek, 1967)	NE (Bosnia and Herzegovina)	Cvijoivić, 1970, 1972, 1973, 1974a, 1974b, 1979; Galli, 2022; Nosek, 1973; Szeptycki, 2007
Acerentomata, Protentomidae		
Protentominae		
Protentomon atlanteum Condé, 1951	SW (Morocco)	Condé,1951b; Galli, 2022; Szeptycki, 2007; Tuxen, 1964
Protentomon barandiarani Condé, 1947	NW, Macaronesia (France, Madeira)	Condé,1947; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964, 1982
Protentomon fallax Condé, 1948	SW (Algeria)	Condé,1948; Galli, 2022; Szeptycki, 2007; Tuxen, 1964
Protentomon hellenicum Nosek, 1974	SE (Greece)	Galli, 2022; Nosek, 1978; Szeptycki, 2007
Protentomon perpusillum (Berlese, 1909)	NW (Italy)	Berlese, 1909; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2007
Proturentomon condei Nosek, 1967	NW, NE (Italy)	Galli, 2022; Galli et al., 2011
Proturentomon discretum Condé, 1961	NW (Spain, France)	Condé, 1961a, 1980; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Proturentomon minimum Berlese, 1908	NW, NE (Portugal, Spain?, Italy, Bosnia and Herzegovina, Greece)	Berlese, 1908a; Cunha, 1949; Cvijoivić, 1970, 1973, 1974a; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973, 1978; Szeptycki, 2007; Tuxen, 1964
Proturentomon pectinatum (Condé, 1948)	NW, NE, SW, SE (France, Greece, Morocco, Algeria, Lebanon)	Condé, 1948, 1951b, 1952, 1954a, 1961b, 1980; Galli, 2022; Nosek, 1978; Szeptycki, 2007; Tuxen, 1964; Vahedi Moghadam et al., 2022
Proturentomon picardi Condé, 1960	NW (Spain, France)	Condé, 1960; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964

Species	Area (Countries)	Bibliography
Acerentomata, Acerentomidae		
Berberentulinae		
Acerentulus apuliacus Rusek & Stumpp, 1988	NE (Italy)	Galli, 2022; Galli et al., 2011, 2016; Rusek, & Stumpp,1988; Szeptycki, 2007
Acerentulus cassagnaui Nosek, 1969	NW (France)	Galli, 2022; Nosek, 1973; Szeptycki, 2007
Acerentulus catalanus Condé, 1951	NW, NE (Spain, France, Bosnia and Herzegovina)	Condé, 1951a; Cvijoivić, 1970, 1972, 1973, 1974a, 1976, 1979; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964; Živadinović et al., 1967
Acerentulus condei Nosek, 1983	NW, NE? (France, Italy, Slovenia?)	Galli, 2022; Galli et al., 2011; Nosek, 1983; Szeptycki, 2007
Acerentulus confinis (Berlese, 1908)	NW, NE, SW (Portugal, Spain, France, Italy, Slovenia, Bosnia and Herzegovina, Greece, Morocco, Algeria)	Berlese, 1980a, 1909; Condé, 1944a, 1944b, 1945, 1948, 1951b, 1961a, 1961b, 1980; Cunha, 1952; Cvijoivić, 1970, 1972, 1973, 1974a; Demmatteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Galli & Sarà, 2022; Nosek, 1973, 1977, 1978; Szeptycki, 2007; Tuxen, 1964, 1982
Acerentulus confinis maderensis Tuxen, 1982 [1]	Macaronesia (Madeira, Canary Islands)	Galli, 2022; Szeptycki, 2004, 2007; Tuxen, 1982
Acerentulus cunhai Condé, 1950	NW, Macaronesia (Portugal, Spain, France, Italy, Madeira, Canary Islands)	Aldaba, 1984; Condé, 1950, 1954b; Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2004, 2007; Tuxen, 1964, 1982
Acerentulus exiguus Condé, 1944	NW, NE (France, Italy, Bosnia and Herzegovina, Greece)	Condé, 1944a; Cvijoivić, 1970, 1972, 1973, 1974a, 1974b, 1976, 1979; Dematteis Ravizza, 1975; Galli, 2022; Galli et al., 2011; Nosek, 1973, 1977; Szeptycki, 2007; Tuxen, 1964; Živadinović et al., 1967
Acerentulus gerezianus da Cunha, 1952	NW, NE?, Macaronesia? (Portugal, Spain, Bosnia and Herzegovina?, Azores?)	Condé, 1957; Cunha, 1952; Cvijoivić, 1970, 1973; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Acerentulus ladeiroi da Cunha, 1952	NW, NE?, Macaronesia (Portugal, Spain, Bosnia and Herzegovina?, Madeira)	Cunha, 1950; Cvijoivić, 1970, 1973; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964, 1982; Živadinović et al., 1967
Acerentulus seabrai da Cunha, 1952	NW, NE (Portugal, Spain, Bosnia and Herzegovina)	Cunha, 1950; Cvijoivić, 1970; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964

Species	Area (Countries)	Bibliography
Acerentulus shrubovychae Galli & Capurro, 2013	NW (Italy)	Galli, 2022; Galli & Capurro, 2013
Acerentulus silvanus Szeptycki, 1991	Macaronesia (Canary Islands)	Galli, 2022; Szeptycki, 2004 2007
Acerentulus terricola Rusek, 1965	NW (Italy)	Galli, 2022; Galli et al., 2011
Acerentulus tolosanus Nosek, 1969	NW (Spain, France)	Condé, 1954b; Galli, 2022; Nosek, 1969b, 1973; Szeptycki, 2007
Acerentulus tortii Galli, Capurro, Lionetti & Zinni, 2017	NE (Greece)	Galli, 2022; Galli et al., 2017
Acerentulus traegardhi Ionescu, 1937	NW, NE (Spain, France, Italy, Bosnia and Herzegovina, Greece)	Aldaba, 1984; Condé, 1945; Cvijoivić, 1970, 1973, 1974b; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973, 1978; Szeptycki, 2007
Baculentulus macqueeni (Bernard, 1975) [2]	Macaronesia (Canary Islands)	Galli, 2022; Szeptycki, 2004, 2007
Berberentulus berberus (Condé, 1948)	NW, NE, SW, SE (France, Greece, Morocco, Algeria, Israel)	Broza et al., 1996; Condé, 1948, 1951b, 1952; Galli, 2022; Nosek, 1973, 1978; Szeptycki, 2007; Tuxen, 1964; Vahedi Moghadam et al., 2022
Berberentulus capensis (Womersley, 1931)	NW, Macaronesia (Portugal, France, Canary Islands)	Condé, 1945, Cunha, 1950; Galli, 2022; Nosek, 1973; Szeptycki, 2004, 2007; Tuxen, 1964
Gracilentulus atlantidis Szeptycki, 1993	NW, Macaronesia (Portugal, Canary Islands)	Galli, 2022; Szeptycki, 1993, 2004, 2007
Gracilentulus corsicanus Szeptycki, 1993	NW (France: Corsica)	Galli, 2022; Szeptycki, 1993, 2007
Gracilentulus fjellbergi Szeptycki, 1993	NW, Macaronesia (Portugal, Canary Islands)	Galli, 2022; Szeptycki, 1993, 2004, 2007
Gracilentulus gracilis (Berlese, 1908)	NW, NE, SW, Macaronesia (Portugal, Spain, France, Italy, Bosnia and Herzegovina, Greece, Morocco, Madeira)	Aldaba, 1985; Berlese, 1908b, 1909; Condé, 1945, 1951a, 1951b, 1961a, 1980; Cunha, 1949; Cvijoivić, 1970, 1973; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Galli & Sarà, 2022; Nosek, 1973, 1978, 1979; Szeptycki, 2007; Tuxen, 1964, 1982
Gracilentulus meridianus (Condé, 1945)	NW (Spain, France, Italy)	Condé, 1945, 1951a, 1980; Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Gracilentulus orousseti Szeptycki, 1993	NW (France: Corsica)	Galli, 2022; Szeptycki, 1993, 2007
Gracilentulus sardinianus Nosek, 1979	NW (Italy: Sardinia)	Galli, 2022; Nosek,1979; Szeptycki, 2007

Species	Area (Countries)	Bibliography
Maderentulus maderensis (Condé, 1957)	NW, Macaronesia (Spain, Azores, Madeira, Canary Islands)	Condé, 1957; Condé & Nosek, 1970; Galli, 2022; Nosek, 1973; Szeptycki, 2004; 2007; Tuxen, 1964, 1982
Podolinella ruseki (Nosek, 1967)	NW (Italy)	Galli, 2022; Galli et al., 2016
Silvestridia artiochaeta Bonet, 1942 [2]	Macaronesia (Canary Islands)	Galli, 2022; Galli et al., 2021a; Szeptycki, 2007
Tuxenidia balcanica Nosek & Cvijović, 1969	NE (Bosnia and Herzegovina)	Cvijoivić, 1970, 1973, 1974b; Galli, 2022; Nosek, 1973; Nosek & Cvijoivić, 1969; Szeptycki, 2007
Tuxenidia hermonensis Szeptycki & Broza, 2004	SE (Israel)	Galli, 2022; Szeptycki, 2007; Szeptycki & Broza, 2004; Vahedi Moghadam et al., 2022
Acerentominae		
Acerentomon affine Bagnall, 1912	NW, NE (Spain, France, Italy, Slovenia, Bosnia and Herzegovina)	Aldaba, 1985; Condé, 1944b, 1945; Cunha, 1952; Cvijoivić, 1982; Galli, 2022; Nosek, 1973; Szeptycki, 2007
Acerentomon balcanicum Ionescu, 1933	NW, NE (Italy, Slovenia, Bosnia and Herzegovina, Greece)	Cvijoivić, 1970, 1972, 1974b, 1982; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Nosek, 1973, 1978; Szeptycki, 2007; Živadinović et al., 1967
Acerentomon brozai Szeptycki & Shrubovych, 2008	SE (Israel)	Galli, 2022; Szeptycki & Shrubovych, 2008; Vahedi Moghadam et al., 2022
Acerentomon condei Nosek & Dallai, 1982	NW (Italy: Sardinia)	Galli, 2022; Galli et al., 2011; Nosek & Dallai, 1982; Szeptycki, 2007
Acerentomon doderoi Silvestri, 1907	NW (Italy)	Demmatteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973; Silvestri, 1907; Szeptycki, 2007
Acerentomon dominiaki Szeptycki, 1977	NE (Turkey)	Galli, 2022; Vahedi Moghadam et al., 2022
Acerentomon gallicum (Ionescu, 1933)	NW (France, Italy)	Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Acerentomon italicum Nosek, 196	NW, NE (France, Italy, Slovenia)	Galli, 2022; Galli et al., 2016, 2021a, 2021b; Nosek, 1969a, 1973; Szeptycki, 2007
Acerentomon maius Berlese, 1908	NW (Italy)	Berlese, 1908b; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964

Species	Area (Countries)	Bibliography
Acerentomon meridionale Nosek, 1960	NW, NE (France, Italy, Slovenia, Bosnia and Herzegovina)	Condé, 1980; Cvijoivić, 1970, 1972, 1973, 1974a, 1974b, 1976, 1979, 1982; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Nosek, 1960, 1973; Szeptycki, 2007; Tuxen, 1964; Živadinović et al., 1967
Acerentomon microrhinus Berlese, 1909	NW, NE (France, Italy, Slovenia, Bosnia and Herzegovina)	Berlese, 1909; Condé, 1945; Cvijoivić, 1970, 1972, 1973, 1974b; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Acerellinae		
Acerella muscorum (Ionescu, 1930)	NW, NE, SE (Spain, France, Italy, Slovenia, Bosnia and Herzegovina, Greece, Israel)	Aldaba, 1985; Arbea, 1989; Condé, 1947, 1951a; Cvijoivić, 1970, 1772, 1973, 1974a, 1974b, 1976, 1979, 1982; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Nosek, 1973, 1978, 1979; Szeptycki, 2007; Vahedi Moghadam et al., 2022; Živadinović et al., 1967
Acerella tiarnea (Berlese, 1908)	NW (Spain, France, Italy)	Arbea, 1993; Berlese, 1908b, 1909; Condé, 1961a, 1980; Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1973; Szeptycki, 2007; Trave et al., 1954; Tuxen, 1964
Eosentomata, Eosentomidae		
Isoentominae		
Isoentomon atlanticum (Condé, 1947) [2]	NW (France)	Condé, 1947, 1980; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964, 1975
Isoentomon serinus Szeptycki, 2004 [2]	Macaronesia (Canary Islands)	Galli, 2022; Szeptycki, 2004, 2007
Eosentominae		
Eosentomon armatum Stach, 1926	NW, NE (Portugal, Spain, France, Italy, Slovenia)	Arbea, 1993; Condé, 1945, 1947, 1951a; Cunha, 1950; Galli, 2022; Galli et al., 2011, 2021a; Szeptycki, 2007
Eosentomon canarinum Szeptycki, 2004	Macaronesia (Canary Islands)	Galli, 2022; Szeptycki, 2004, 2007
Eosentomon coiffaiti Condé, 1961	NW (Spain: Minorca)	Condé, 1961a; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Eosentomon condei da Cunha, 1950	NW (Portugal, Spain)	Cunha, 1950; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964

Species	Area (Countries)	Bibliography
Eosentomon delicatum Gisin, 1945	NW, NE, SW, Macaronesia (Portugal, Spain, France, Italy, Slovenia, Croatia, Greece, Morocco, Algeria, Madeira, Canary Islands)	Arbea, 1993; Condé, 1948, 1952, 1954b, 1960, 1961a, 1961b, 1980; Cunha, 1949; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Nosek, 1960, 1973, 1978, 1979; Szeptycki, 2004, 2007
Eosentomon denisi Condé, 1947	NW (Spain, France)	Aldaba, 1986b; Condé, 1947; Galli, 2022; Nosek, 1973; Szeptycki, 2007; Tuxen, 1964
Eosentomon gamae Aldaba, 1986	Portugal	Aldaba, 1986a; Galli, 2022; Szeptycki, 2007
Eosentomon germanicum Prell, 1912	NW?, NE?, SW?, Macaronesia? (Spain?, France?, Italy?, Greece?, Morocco?, Algeria?, Madeira?)	Condé, 1945, 1948, 1951b, 1952, 1954b, 1960, 1961a, 1961b, 1980; Condé & Nosek, 1970; Galli, 2022; Galli et al., 2011; Nosek, 1973, 1978; Szeptycki, 2007
Eosentomon lusitanicum Aldaba, 1986	NW (Portugal)	Aldaba, 1986a; Galli, 2022; Szeptycki, 2007
Eosentomon mirabile Szeptycki, 1984	Macaronesia (Canary Islands)	Galli, 2022; Szeptycki, 2004, 2007
Eosentomon mixtum Condé, 1945	Macaronesia (Madeira)	Galli, 2022; Szeptycki, 2007; Tuxen, 1982
Eosentomon noseki Tuxen, 1982	NW, Macaronesia (Spain, Italy, Madeira, Canary Islands)	Galli, 2022; Galli et al., 2011; Szeptycki, 2004, 2007; Tuxen, 1982
Eosentomon pinkyae Arbea-Polite, 1990	NW (Spain)	Arbea-Polite, 1990; Galli, 2022; Szeptycki, 2007
Eosentomon romanum Nosek, 1969	NW (Italy)	Dematteis, 1972; Galli, 2022; Galli et al., 2011; Nosek, 1969a, 1973; Szeptycki, 2007
Eosentomon saharense Condé, 1951	SW (Morocco [3])	Condé, 1951b; Galli, 2022; Szeptycki, 2007; Tuxen, 1964
Eosentomon semiarmatum Denis, 1927	NW (Spain, France)	Arbea, 1993; Denis,1927; Galli, 2022; Szeptycki, 2007; Tuxen, 1964
Eosentomon transitorium Berlese, 1908	NW, NE, SW (Spain, France, Italy, Slovenia, Bosnia and Herzegovina, Greece, Morocco, Algeria)	Berlese, 1908a, 1909; Condé, 1961a, 1961b, 1980; Dematteis, 1972; Galli, 2022; Galli et al., 2011, 2021a; Galli & Sarà, 2022; Nosek, 1973, 1978; Szeptycki, 2007; Trave et al., 1954; Živadinović et al., 1967

[1] *Acerentulus confinis maderensis* is considered a distinct species (Szeptycki, 2007).
[2] On the distributions of *Baculentulus macqueeni*, *Isoentomon atlanticum* and *Isoentomon serinus* see Galli & Rellini (2020). The same considerations are also valid in the case of *Silvestridia artiochaeta* known from Central and South America and Canary Islands.
[3] In the considered area, but close to the Sahara desert.

DISCUSSION

More than 9% of all known species of Protura worldwide (Galli, 2022) live in the Mediterranean area despite it covers less than 1.5% of the world's land masses (Fady-Welterlen, 2005). These data, confirms the importance of this area as a biodiversity hotspot (Blondel et al., 2010), even though probably affected by a geographic bias in studies on the distribution of Protura (Galli, 2022). The same bias may explain the disparity in the number of species recorded in different parts of the Mediterranean Basin, with a higher richness in the North-western part and a high species density in Macaronesia (Pass & Szucsich, 2011; Galli & Rellini, 2020; Galli, 2022). Moreover, the knowledge gaps that characterize every aspect of the biology of Protura (Pass & Szucsich, 2011; Galli et al. 2019a) make it impossible to identify endemic species of the Mediterranean with absolute certainty even though some species are known only from their type area within the Mediterranean Basin (Szeptycki, 2007; Galli, 2022). This, for example, is the case for *Protentomon atlanteum*, *P. hellenicum*, *Acerentulus apuliacus*, *A. shrubovychae*, *Gracilentulus corsicanus*, *G. sardinianus* and *Eosentomon saharense* (Galli, 2022). Similarly, the poor knowledge on the ecology of these animals does not allow to identify species closely related to the typical habitats of the Mediterranean area. The only study of this topic, although far from being exhaustive, is that by Galli et al. (2019b). After an in depth analysis of data on the Italian fauna, these authors have identified some assemblages of proturan genera/species related to different habitats.

More generally, another highly understudied aspect of Protura biodiversity is the probable presence of cryptic species (see for example the case of *Eosentomon transitorium* hihlighted by Fratello & Sabatini, 1989). Unfortunately, the integrative approach necessary to solve this problem was hampered by the inherent difficulties of extracting DNA from proturans (Pass & Szucsich, 2011). Only the application of a non-destructive DNA extraction method (Böhm et al., 2011) made it possible to overcome this difficulty and undertake some preliminary studies in which the morphological diversification could be correlated to genetic distances between populations (Resh et al., 2014). However, to date, DNA-based studies in proturan taxonomy are few, even in relation to the very modest number of specialists. Only 209 sequences of Protura are available on BOLD (https://boldsystems.org), 180 of which relate to records labeled with a species name. Therefore, the integrated approach that in the case of taxa such as springtails has made a significant contribution to systematics in recent years (Sun et al., 2017; Chang et al, 2020, 2021; Winkler et al., 2020) for Protura is still at its beginning without any striking results being obtained (e.g. Galli et al., 2021). An acceleration of research in this area would therefore be desirable, provided that a balanced approach is maintained that gives due weight to morphological and molecular data (Zamani et al., 2021).

Beyond specific research on Protura, an important source of study material could be specimens collected in the context of research focused on other taxa of soil mesofauna, or on the ecology of soils in general (e.g. Salmon et al., 2008; Menta et al., 2015). Such material is mostly thrown away or remains indeterminate in private and public collections. With this respect, networks of researchers such as Research Gate (https://www.researchgate.net/) and FAO Netsob (https://www.fao.org/global-soil-partnership/netsob/en/) could help to obtain a more effective collaboration and a fruitful exchange of study material between research groups.

All in all, much research is still needed, especially in areas that have been completely or largely neglected by specialists to date, before we reach a solid knowledge base on Protura diversity and distribution. However, gaps in our knowledge will be difficult to solve as long as the policies adopted in research and

development continue to relegate taxonomy and systematics to a secondary role (IUCN, 2022).

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