

Current knowledge on the Sicilian tardigrade fauna

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ABSTRACT

Based on the literature, and adding personal contribution, the author takes stock of the knowledge about the species of limno-terrestrial tardigrades present in Sicily and the main small islands around it (Aeolian Islands, Ustica, Egadi Islands). In total 111 species are reported: 108 from Sicily (main island), 35 from the Aeolian Islands, 17 from Ustica and 11 from the Egadi Islands. Two species are new records only for the respective islands, 13 are new records for the whole studied area, four of which are new also for the Italian fauna. A good 13 species (11.7%) are at present endemic for the studied area. The zoogeographic spread of the 111 Sicilian tardigrade species confirms the modern ideas about tardigrade zoogeography.

KEY WORDS

Tardigrada; Sicilian fauna; zoogeography; taxonomy.

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INTRODUCTION

In the Surveys on the Sicilian tardigrade fauna (Ustica, Aeolian and Aegadean archipelagos included) until 2009 allowed to recognize 94 terrestrial and freshwater species (Arcidiacono, 1962; 1964, Binda, 1969; 1978; Binda & Pilato, 1969a,b, 1971, 1972, 1984, 1985, 1987; Binda et al., 1980; Pilato, 1969, 1971a,b,c, 1973, 1974, 2009; Pilato & Catanzaro, 1988, 1989; Pilato et al., 1982, 1989, 2000).

Though that a number may have appeared high, the variety of Sicilian environments considered, the composition of Sicilian tardigrade fauna may be considered far away from being completely known; for this reason, I have recently carried out, in collaboration with G. Pilato and G. Sabella, new studies that until now have led us to describe four species new to science (Pilato et al., 2014; Lisi et al., 2014). The total number of limno-terrestrial tardigrade species up to now reported from Sicily (and surrounding small islands) is 98.

MATERIAL AND METHODS

The current study has been based only on the re-examination of abundant old material, from the Pilato and Binda collection (Museum of the Department of Biological, Geological and Environmental Sciences, section of Animal Biology “Marcello La Greca”, University of Catania), collected and partially identified in the far past but the results had remained unpublished; in some cases the old diagnosis had to be updated revealing new records, and even new species, which is not surprising considering that past tardigrade taxonomy was based on less strict criteria and some wrong convictions, so that little differences between populations, when noticed, were more easily attributed to individual variability within a single species rather than considered as an indication that the two populations belonged to distinct species. About the new records reported in Table 2, all the data about localities and samples are the only available, due to the fact that

at the time of collection it was not in use to take note of more detailed information.

All the studied specimens were mounted in polyvinyl lactophenol. Specific diagnosis was based on the original descriptions and eventual redescrptions (Plate, 1889; Cuénot, 1929; Marcus, 1936; Binda, 1971; Pilato & Sperlinga, 1975; Dastych, 1984; Binda & Rebecchi, 1992; Bertolani & Rebecchi, 1993; Pilato & Binda, 1997/1998; Pilato et al., 2003; Tumanov, 2006; Pilato et al., 2011) and on the monograph by Ramazzotti e Maucci (1983); by comparison, specimens of the Pilato and Binda collection of the following species were examined: *Hypsibius scabropygus* Cuénot, 1929, *Diphyscon pingue* (Marcus, 1936), *D. higginsii* Binda, 1971 and *D. chilense* Plate, 1889. All observations and measurements were made under x100 oil immersion using a Leica Phase Contrast Microscope equipped with a micrometer.

RESULTS

The progression of those studies has led to recognise other 13 species that represent new records for the studied area, and four of them are new records for the Italian fauna as well. The total number of limno-terrestrial tardigrade species for that area then raises to 111.

The updated checklist of limno-terrestrial tardigrade species present in Sicily (and surrounding small islands) is reported in Table 1, where the island in which each species was found is reported; I found it interesting to take into consideration also the presence of each species in north Africa, for having an idea of the faunal affinity with that region.

In total 111 species are reported (98 already known, plus 13 new findings): 108 from Sicily (main island), 35 from the Aeolian Islands, 17 from Ustica and 11 from the Egadi Islands. Two species are new records only for the respective islands, 13 are new records for the whole studied area, four of which are new also for the Italian fauna (Table 2).

A special mention has to be made about the tardigrade fauna of North Africa, with which a remarkable affinity has come out: it shares with Sicily 40 species, representing a good 36.0% of the Sicilian species.

Thirteen species (11.7%) today result to be endemic for the studied area. Nine "terrestrial" more or less recently described, and 4 already reported

freshwater species: *Carphania fluviatilis* Binda, 1979 (the only freshwater species of the class Heterotardigrada), *Isohypsibius tubericulatus* Pilato et Catanzaro, 1990, *I. verae* Pilato et Catanzaro, 1990, and *Macroversum mirum* Pilato et Catanzaro, 1989.

As regards possible biogeographic evaluations, the geographic distribution of the 111 Sicilian tardigrade species seems to confirm the modern ideas about tardigrade biogeography. It was very hard in the past to make biogeographic evaluations about the species of this group, due to wrong convictions about species individual variability and poorly strict criteria for specific diagnosis, and an overestimated effect of passive dispersal; these had great impact on the believed geographic distribution of the species creating great confusion and making very difficult to study tardigrade species from a biogeographic point of view. However, thanks to a change in the evaluation of individual variability and the taxonomic criteria for specific diagnosis (eg. Pilato, 1975; 1979), as well as a reevaluation of the possibility of passive dispersal (Pilato, 1979) which reflected into a reconsideration of the geographic distribution of the species, many old diagnosis mistakes have been corrected (and this correction still continues today), and starting with McInnes (1994) and Pilato & Binda (2001), it is today universally accepted to consider tardigrade species from the biogeographic point of view.

Limiting myself to use the available data from the literature, in which old diagnosis mistakes very probably still hide, it is possible to notice that tardigrade species tend to have a limited geographic distribution, at the level of zoogeographic region, not cosmopolitan, or nearly such, as believed in the far past. In Table 3 the zoogeographic spread of the 111 Sicilian tardigrade species is reported and the data confirms the above expressed idea.

As regards the relatively high number of species reported from the literature as present in 7 zoogeographic regions, it must be stressed that those 17 species are mostly represented by species described in the far past (even about a century ago), so that there had been all the time, before the "revolution" of the last decades, for various authors to report the same species from all over the world; as a matter of fact, the correction of such diagnosis mistakes has been in the last decade one of the great goals of tardigrade taxonomists, and much still remains to be done.

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
CARPHANIIDAE						
<i>Carphania fluviatilis</i> Binda, 1978	E	*				
ECHINISCIDAE						
<i>Bryodelphax tatrensis</i> Weglarska, 1959		*		*		*
<i>Bryodelphax weglarskae</i> Pilato, 1972					*	
<i>Cornechiniscus lobatus</i> (Ramazzotti, 1943)		*				
<i>Echiniscus blumi</i> Richters, 1903		*	*			*
<i>Echiniscus trisetosus</i> Cuenot, 1932		*	*			*
<i>Echiniscus mediantus</i> Marcus, 1930		*	*			
<i>Echiniscus bisetosus</i> Heinis, 1908		*	*			*
<i>Echiniscus canadensis</i> Murray, 1910		*	*			*
<i>Echiniscus testudo</i> (Doyère, 1840)		*	*			*
<i>Echiniscus merokensis</i> Richters, 1904		*	*	*		*
<i>Echiniscus granulatus</i> (Doyère, 1840)		*	*			*
<i>Echiniscus quadrispinosus</i> (Richters, 1902)		*nr	*			
<i>Echiniscus carusoi</i> Pilato, 1972	E	*			*	*
<i>Echiniscus ramazzottii</i> Binda et Pilato, 1969	E		*			
<i>Parechiniscus chitonides</i> Cuénot, 1926		*				*
<i>Pseudechiniscus pseudoconifer</i> Ramazzotti, 1943		*				
MILNESIIDAE						
<i>Milnesium almatyense</i> Tumanov, 2006	NRI	*				
<i>Milnesium tardigradum</i> Doyère, 1840		*	*	*	*	*
EOHYPYSIBIIDAE						
<i>Bertolanius weglarskae</i> (Dastych, 1972)		*				
HYPYSIBIIDAE						
<i>Astatumen trinacriae</i> (Arcidiacono, 1962)		*				*
<i>Bindius triquetrus</i> Pilato, 2009	E	*				
<i>Diphascon belgicae</i> Richters, 1911		*				*
<i>Diphascon brevipes</i> Marcus, 1936		*				
<i>Diphascon carolae</i> Binda et Pilato, 1969		*				
<i>Diphascon chilense</i> Plate, 1888	NRS	*				
<i>Diphascon higginsii</i> Binda, 1971	NRS	*				*
<i>Diphascon nelsonae</i> Pilato, Binda, Bertolani et Lisi, 2005			*			
<i>Diphascon nobilei</i> Binda, 1969		*	*			
<i>Diphascon patanei</i> Binda et Pilato, 1971		*	*			
<i>Diphascon pingue</i> Marcus, 1936	NRS	*	*			
<i>Diphascon procerum</i> Pilato, Sabella et Lisi, 2014	E	*				
<i>Diphascon recamierei</i> (Richters, 1911)		*				
<i>Diphascon serratum</i> Pilato, Binda, Bertolani et Lisi, 2005	E	*				
<i>Diphascon scoticum</i> Murray, 1905		*				

Table 1. Limno-terrestrial tardigrade species from Sicily; Ranks: NRS = new record for the whole studied area (Sicily and surrounding islands); NRI = new record also for the Italian fauna; E = endemic. In the geographic region column, "nr" indicates new record only for the single island/archipelago. Taxonomy according to Bertolani et al. (2014).

	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
HYPYSIBIIDAE						
<i>Diphascoson serratum</i> Pilato, Binda, Bertolani et Lisi, 2005	E	*				
<i>Diphascoson scoticum</i> Murray, 1905		*				
<i>Diphascoson ziliense</i> Lisi, Sabella et Pilato, 2014	E	*				
<i>Hypsibius convergens</i> (Urbanowicz, 1925)		*	*	*		*
<i>Hypsibius conifer</i> Mihelcic, 1938		*				
<i>Hypsibius dujardini</i> (Doyère, 1840)		*	*			*
<i>Hypsibius microps</i> Thulin, 1928		*	*			*
<i>Hypsibius pallidoides</i> Pilato, Kiosya, Lisi, Inshina et Biserov, 2011	NRI	*				
<i>Hypsibius pallidus</i> Thulin, 1911		*				
<i>Hypsibius ragonesei</i> Binda et Pilato, 1985	E	*				
<i>Hypsibius scabropygus</i> Cuénot, 1929	NRS	*				
<i>Mixibius saracenus</i> (Pilato, 1973)		*				
<i>Mixibius parvus</i> Lisi, Sabella et Pilato, 2014	E	*				
<i>Platicrista angustata</i> (Murray 1905)		*				*
RAMAZZOTTIIDAE						
<i>Ramazzottius oberhaeuseri</i> (Doyère, 1840)		*		*		
<i>Ramazzottius thulini</i> (Pilato, 1970)		*				
ISOHYPYSIBIIDAE						
<i>Doryphoribius doryphorus</i> (Binda et Pilato, 1969)		*		*		*
<i>Doryphoribius macrodon</i> Binda, Pilato et Dastych, 1980		*				
<i>Doryphoribius zappalai</i> Pilato, 1971		*				
<i>Eremobiotus alicatai</i> (Binda, 1969)		*				*
<i>Hexapodibius micronyx</i> Pilato, 1969		*				
<i>Isohypsibius arbiter</i> Binda, 1980	NRS	*				
<i>Isohypsibius austriacus</i> (Iharos, 1966)		*				*
<i>Isohypsibius dastychi</i> Pilato, Bertolani et Binda, 1982		*				
<i>Isohypsibius deconincki</i> Pilato, 1971		*				*
<i>Isohypsibius elegans</i> Binda et Pilato, 1971		*	*	*	*	*
<i>Isohypsibius granulifer</i> Thulin, 1928		*				
<i>Isohypsibius kristenseni</i> Pilato, Catanzaro et Binda, 1989		*				
<i>Isohypsibius longiunguis</i> Pilato, 1974		*				
<i>Isohypsibius lunulatus</i> (Iharos, 1966)		*	*			*
<i>Isohypsibius marcellinoi</i> Binda et Pilato, 1971		*				
<i>Isohypsibius monoicus</i> Bertolani, 1981		*				
<i>Isohypsibius nodosus</i> (Murray, 1907)		*				
<i>Isohypsibius pappi</i> (Iharos, 1966)		*			*	
<i>Isohypsibius prosostomus</i> Thulin, 1928		*				
<i>Isohypsibius reticulatus</i> Pilato, 1973		*				

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	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
<i>Isohypsibius ronsisvallei</i> Binda et Pilato, 1969		*				
<i>Isohypsibius sattleri</i> Richters, 1902		*	*	*		*
<i>Isohypsibius silvicola</i> (Iharos, 1966)		*				
<i>Isohypsibius tetractyloides</i> Richters, 1907		*				
<i>Isohypsibius tubereticulatus</i> Pilato et Catanzaro, 1990	E	*				
<i>Isohypsibius verae</i> Pilato et Catanzaro, 1989	E	*				
<i>Parhexapodibius lagrecai</i> (Binda et Pilato, 1969)		*	*	*		*
<i>Pseudobiotus matici</i> (Pilato, 1971)		*				
<i>Pseudobiotus kathmanae</i> Nelson, Marley et Bertolani, 1999		*				
<i>Thulinus ruffoi</i> (Bertolani, 1982)		*				
<i>Thulinus stephaniae</i> (Pilato, 1974)		*				
MACROBIOTIDAE						
<i>Macrobiotus diffusus</i> Binda et Pilato, 1987		*	*	*	*	*
<i>Macrobiotus echinogenitus</i> Richters, 1904		*	*			*
<i>Macrobiotus harmsworthi</i> Murray, 1907		*	*	*	*	*
<i>Macrobiotus hufelandi</i> Schultze, 1834		*	*	*	*	*
<i>Macrobiotus insuetus</i> Pilato, Sabella et Lisi, 2014	E	*				
<i>Macrobiotus islandicus</i> Richters, 1904		*				*
<i>Macrobiotus macrocalix</i> Bertolani et Rebecchi, 1993	NRS	*				
<i>Macrobiotus nuragicus</i> Pilato et Sperlinga, 1975	NRS	*				*
<i>Macrobiotus pallarii</i> Maucci, 1954		*	*			*
<i>Macrobiotus patiens</i> Pilato, Binda, Napolitano et Moncada, 2000		*nr	*	*		
<i>Macrobiotus persimilis</i> Binda et Pilato, 1972		*	*	*		*
<i>Macrobiotus pilatoii</i> Binda et Rebecchi, 1992	NRS	*				
<i>Macrobiotus polonicus</i> Pilato, Kaczmarek, Michalczyk et Lisi, 2003	NRI	*				
<i>Macrobiotus sapiens</i> Binda et Pilato, 1984		*				
<i>Macrobiotus simulans</i> Pilato, Binda, Napolitano et Moncada, 2000		*	*			
<i>Macrobiotus terminalis</i> Bertolani et Rebecchi, 1993	NRS	*				
<i>Paramacrobiotus areolatus</i> (Murray, 1907)		*	*		*	*
<i>Paramacrobiotus csotiensis</i> (Iharos, 1966)		*				
<i>Paramacrobiotus richtersi</i> (Murray, 1911)		*	*	*	*	*
<i>Minibiotus furcatus</i> (Ehrenberg, 1859)		*	*			
<i>Minibiotus intermedius</i> (Plate, 1889)		*	*	*		*
<i>Minibiotus pseudofurcatus</i> (Pilato, 1972)		*			*	
<i>Minibiotus weinerorum</i> (Dastyh, 1984)	NRI	*				
<i>Richtersius coronifer</i> (Richters, 1903)		*				*
<i>Tenuibiotus tenuis</i> (Binda et Pilato, 1972)		*				
<i>Xerobiotus pseudohufelandi</i> (Iharos, 1966)		*	*	*		*

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	rank	Sicily	Aeolian Archipel.	Ustica	Aegadean Archipel.	North Africa
MURRAYIDAE						
<i>Dactylobiotus parthenogeneticus</i> Bertolani, 1982		*				
<i>Dactylobiotus dispar</i> (Murray, 1907)		*				
<i>Macroversum mirum</i> Pilato et Catanzaro, 1989	E	*				
<i>Murrayon pullari</i> (Murray, 1907)		*				
NECOPINATIDAE						
<i>Necopinatum mirabile</i> Pilato, 1971		*				

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MILNESIIDAE	<i>Milnesium almatyense</i> Tumanov, 2006 NRI Cesarò (Messina) “Portella Femmina Morta”; moss sample. Ramacca (Catania); moss sample.
HYPYSIBIIDAE	<i>Diphascon chilense</i> Plate, 1889 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Diphascon higginsii</i> Binda, 1971 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Diphascon pingue</i> (Marcus, 1936) Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Hypsibius pallidooides</i> Pilato, Kiosya, Lisi, Inshina et Biserov, 2011 NRI Belpasso (Catania) “Contrada Milia”; chestnut leaf litter <i>Hypsibius scabropygus</i> Cuénot, 1929 Isnello (Palermo) “Pizzo Antenna” Madonie Mountains; lichens on tree trunk.
ISOHYPYSIBIIDAE	<i>Isohypsibius arbiter</i> Binda, 1980 Belpasso (Catania) “Contrada Milia”; chestnut leaf litter. Bronte (Catania) “Contrada Rinazzo”; moss sample.
MACROBIOTIDAE	<i>Macrobotus macrocalix</i> Bertolani et Rebecchi, 1993 Contessa Entellina (Palermo), Contrada Mazzaporro, - Nebrodi Mountains; moss sample <i>Macrobotus nuragicus</i> Pilato et Sperlinga, 1975 Mandanici (Messina), Madonie Mountains; moss sample <i>Macrobotus pilatoii</i> Binda et Rebecchi, 1992 Madonie Mountains; <i>Sphagnum</i> sample <i>Macrobotus polonicus</i> Pilato, Kaczmarek, Michalczyk et Lisi, 2003 NRI Maletto (Catania) “Sciara St. Venera”; moss sample - Catania; moss sample <i>Macrobotus terminalis</i> Bertolani et Rebecchi, 1993 Cesarò (Messina), Mt. Soro (Nebrodi Mountains); moss sample <i>Minibiotus weinerorum</i> Dastych, 1984 NRI Isnello (Palermo) “Pizzo Antenna” Madonie Mountains; lichens on tree trunk.

Table 2. New records of limno-terrestrial tardigrade species for Sicily and surrounding islands.
NRI = new record also for the Italian fauna.

Palearctic (of which endemic)	Present in 2 zoogeographic regions	Present in 3 zoogeographic regions	Present in 4 zoogeographic regions	Present in 5 zoogeographic regions	Present in 6 zoogeographic regions	Present in 7 zoogeographic regions	Total
40 (13)	19	15	5	11	4	17	111
36.0% (11.7%)	17.1%	13.5%	4.5%	9.9%	3.6%	15.3%	100%

Table 3. Zoogeographic spread of the limno-terrestrial tardigrade species of Sicily.

CONCLUSIONS

As it can be seen, a limited study of old material may reveal new records and even new species, also with the change of old diagnoses, not correct in the light of the modern criteria; this, as well as improving knowledge in general, allows to go ahead in the progress of tardigrade taxonomy and biogeography. The current study, thanks to the promising results obtained, still goes on and intends to proceed with the correction of very old literature mistakes (which affect the correct knowledge of tardigrade biodiversity and species geographic distribution), enrich faunistic and biogeographic knowledge, and put in evidence the variety and eventual peculiarity of Sicilian tardigrade fauna, with repercussions on general knowledge of Sicilian biodiversity.

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