

## Further studies on the marine tardigrade fauna from Sardinia (Italy)

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### ABSTRACT

An investigation on the taxonomy and ecology of marine tardigrades was carried out in different intertidal and subtidal sites along the coasts of Sardinia (Italy). Particle size analysis of sediments revealed medium or medium-fine intertidal sands and coarse subtidal sands, the latter mainly formed by coralligenous debris. The systematic study was particularly relevant, leading to the identification of 25 species, of which 9 are new records for Sardinia, and 2 are new to science. With these new findings, the total number of species for Sardinia adds up to 47. The species found belong to the families Halechiniscidae (16 species; abundance 2 to 263 ind. 10 cm<sup>-2</sup>), Batillipedidae (6 species; abundance 2 to 574 ind. 10 cm<sup>-2</sup>) and Stygarctidae (3 species; abundance 0 to 13 ind. 10 cm<sup>-2</sup>). The present data confirm the existence of a remarkable diversity, both of intertidal and subtidal tardigrade fauna. Generally, the prevalently siliceous intertidal sands host a few number of species (sometimes with many individuals), while the subtidal sediments, which were mainly calcareous, show a higher number of species often with low density. In fact, in the intertidal sediments only 11 species were found, 5 belonging to Halechiniscidae and 6 to Batillipedidae. In the subtidal sediments, there was a much wider variety; Halechiniscidae showed the highest number of species (16), compared to the remaining families, while Stygarctidae, which were present only in subtidal sediments, accounted only for 3 species. In the intertidal zone the highest value of the diversity index (H') was 2.1 and in the subtidal zone it was 3.3.

Key words: Tardigrada, Heterotardigrada, Sardinia, Biodiversity

### 1. INTRODUCTION

The first records of marine tardigrades in Sardinia date back to 1964 when *Batillipes pennaki* Marcus, 1926 was found on the sandy beaches of the S. Marinella Gulf and S. Reparata Bay near Sassari (de Zio 1964; Grimaldi 1965). Since then, data about the Sardinian fauna have successively been obtained from different coastal localities intertidally and subtidally, with each revealing a high species richness, particularly in subtidal sediments (Grimaldi de Zio *et al.* 1983, 1988, 1990a, b; D'Addabbo Gallo *et al.* 1989, 1992; de Zio Grimaldi *et al.* 1992, 2003; Gallo D'Addabbo *et al.* 1999, 2005; de Zio Grimaldi & D'Addabbo Gallo 2001; Hansen *et al.* 2003).

With the exploration of 9 localities of the northern and western coast (Alghero, Asinara Gulf) and 9 new sites of the Orosei Gulf, our present study includes additional information about Sardinian tardigrade fauna.

### 2. METHODS

Sediment samples were obtained by direct hand coring (6.2 cm<sup>2</sup>) at depths ranging from 1 to 30 m, via SCUBA diving for the subtidal collection, from five sites in the Alghero Gulf, four sites in the Asinara Gulf (July 2005), and from nine sites in the Orosei Gulf (June 2002) (Fig. 1). Samples were treated with 7% MgCl<sub>2</sub> solution to anesthetize the animals and then preserved with 5% formalin/seawater. The animals were extracted

by washing in tap water and collecting them on a 42 µm mesh size sieve. Kaiser's glycerol-gelatin or Hoyer's fluid were used for making permanent mounts (Higgins & Thiel 1988). Identification and taxonomic studies on tardigrades were performed with a light microscope (Leica DM 2500) equipped with phase contrast and interference contrast. Abundance of tardigrades collected via 6.2 cm<sup>2</sup> corer, was calculated from the surface area sampled and reported to number of individuals per 10 cm<sup>2</sup>. In addition, Shannon-Wiener's diversity (H') and Pielou's indices (J') were calculated. Sediment was analysed for granulometry.



Fig. 1. Location map of Sardinia (Italy) sampling localities.

**Tab. 1.** Tardigrada species, number of specimens, density and diversity per site in the Sardinia Island. CS = coarse sand; MS = medium sand; MFS = medium fine sand; FS = fine sand. H' = Shannon-Wiener index; J' = Pielou's index.

Site	Alghero Gulf					Asinara Gulf				Orosei Gulf								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Depth	0	1	1	0	20	0	0	5	7	0	5	7	30	0	1	5	7	0
Mean Grain Size	1.5		0.25			2.25	0.25	1.5		0.25				1.5		0.25	1.5	2.25
Sediment type	MS		CS			MFS	CS	MS		CS				MS		CS	MS	MFS
Taxa																		
Stygarctidae																		
<i>Parastygarctus biungulatus</i> Morone De Lucia <i>et al.</i> , 1984																		
<i>Parastygarctus mediterranicus</i> Gallo D'Addabbo <i>et al.</i> , 2001																		
<i>Parastygarctus sterreri</i> Renaud-Mornant, 1970																		
Halechiniscidae																		
<i>Dipodartus subterraneus</i> (Renaud-Mornant, 1959)																		
<i>Florarctus antillensis</i> Van der Land, 1968																		
<i>Florarctus asper</i> Renaud-Mornant, 1989																		
<i>Florarctus hulingsi</i> Renaud-Mornant, 1976																		
<i>Florarctus n. sp.</i>																		
<i>Halechiniscus greveni</i> Renaud-Mornant & Deroux, 1976																		
<i>Halechiniscus remanei</i> Schulz, 1955																		
<i>Halechiniscus tuleari</i> Renaud-Mornant, 1979																		
<i>Orzeliscus belopus</i> Du Bois Reymond Marcus, 1952																		
<i>Paratanarctus kristenseni</i> D'Addabbo Gallo <i>et al.</i> , 1992																		
<i>Syraconyx qivitoq</i> Kristensen & Higgins, 1984																		
<i>Syraconyx sardiniae</i> D'Addabbo Gallo <i>et al.</i> , 1989																		
<i>Tholoarctus natans natans</i> Kristensen & Renaud-Mornant, 1983																		
<i>Actinarctus doryphorus</i> Schulz, 1935																		
<i>Actinarctus physophorus</i> Grimaldi de Zio <i>et al.</i> , 1982																		
<i>Tanarctus gracilis</i> Renaud-Mornant, 1980																		
Batillipedidae																		
<i>Batillipes dicrocercus</i> Pollock, 1970																		
<i>Batillipes littoralis</i> Renaud-Debyser, 1959																		
<i>Batillipes pennaki</i> Marcus, 1946																		
<i>Batillipes similis</i> Schulz, 1955																		
<i>Batillipes spinicauda</i> Gallo D'Addabbo <i>et al.</i> , 2005																		
<i>Batillipes n. sp.</i>																		
Total	1	2	6	255	43	55	38	160	162	8	32	74	105	4	356	344	222	150
Species number	1	1	2	11	12	3	4	7	6	3	5	5	7	1	2	3	4	3
Total Density (n. ind. 10 cm <sup>-2</sup> )	2	3	10	411	69	89	61	258	261	13	52	119	169	6	574	555	358	242
H'	0	0	0.7	2.1	3.3	0.5	1.3	1.2	1.3	1.5	1.8	2.1	1.5	0	0.2	0.2	1	0.4
J'	0	0	0.7	0.6	0.9	0.3	0.6	0.4	0.5	0.9	0.8	0.9	0.5	0	0.2	0.1	0.5	0.2

### 3. RESULTS

The systematic study revealed a total of 25 species (Tab. 1) belonging to 3 families: Stygarctidae (3 species), Halechiniscidae (16 species), and Batillipedidae (6 species). Of these, two species, recorded from the Alghero Gulf, are new to science: (*Florarctus n. sp.*, and *Batillipes n. sp.*), while 9 other species are new records for Sardinia. The latter includes: *Parastygarctus biungulatus* Morone de Lucia *et al.*, 1984, *Parastygarctus mediterranicus* Gallo D'Addabbo *et al.*, 2001, *Florarctus asper* Renaud-Mornant, 1989, *Florarctus antillensis* Van der Land, 1968, *Halechiniscus tuleari* Renaud-Mornant, 1979, *Tanarctus gracilis* Renaud-Mornant, 1980, *Actinarctus physophorus* Grimaldi de Zio *et al.*, 1982, *A. doryphorus* Schulz, 1935, and *Batillipes spinicauda* Gallo D'Addabbo *et al.*, 2005. The highest number of species (21) was recorded in the Alghero Gulf, followed by the Orosei (13 species) and Asinara Gulfs (10 species). In intertidal sediments, 12 species were recorded, including 5 Halechiniscidae and 6 Batillipedidae. In subtidal sediments, 22 species were recorded, represented by 16 Halechiniscidae, 1 Batillipedidae, and 3 Stygarctidae. According to the indexes H' and J', diversity was highest at location 5 in the Alghero Gulf (3.3; 0.9, respectively), followed by the

Orosei (2.1; 0.9) and Asinara Gulfs (1.3; 0.6) (Tab. 1 and Fig. 2).

Batillipedidae is the family represented by the highest density, (2 to 574 ind. 10 cm<sup>-2</sup>), followed by Halechiniscidae (2 to 263 ind. 10 cm<sup>-2</sup>) and Stygarctidae (0 to 13 ind. 10 cm<sup>-2</sup>). The highest total density was recorded in the Orosei Gulf in medium and coarse sands at depths of 1 and 5 m (sites 15 and 16) with 574 and 555 ind. 10 cm<sup>-2</sup> respectively. The newly described species *Batillipes spinicauda* accounts for this density and represents 99% of the total number of individuals at these sites. Generally, *B. spinicauda* is also the most widely distributed species, encountered at 12 of the 18 sites.

Particle-size analysis of the sediments (Tab. 1) revealed medium or medium-fine intertidal sands and coarse subtidal sands, the latter primarily formed by coralligenous debris.

### 4. DISCUSSION

In general, Sardinian tardigrade fauna appears very rich and includes 47 species in family Halechiniscidae (30 species), Batillipedidae (9 species), Stygarctidae (4 species), Echiniscoididae (2 species), Neostygarctidae (1 species), and Neoarctidae (1 species), thus constituting 61% of the total number of species of the Mediter-

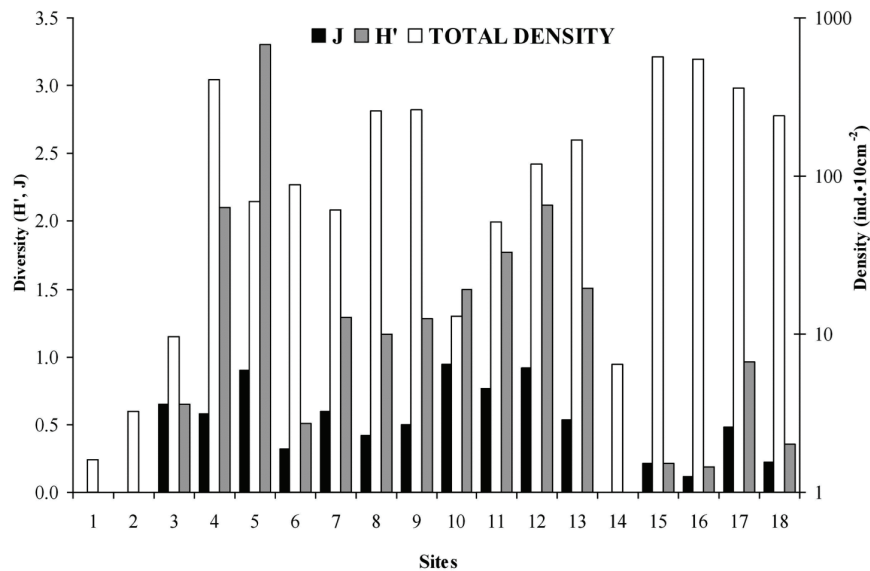


Fig. 2. Density (Log scale) and diversity of Sardinian tardigrade fauna.

ranean Sea. The distribution of tardigrades in the three gulfs is as follows: 3 families and 13 species has been recorded from the Orosei Gulf, while 3 and 2 families, and 21 and 10 species has been recorded from the Alghero and Asinara Gulf respectively. Until now, the Orosei Gulf seems to provide the best habitat, and it represents the widest distribution of tardigrades families and species.

Among the new records of Sardinia, it is worth noting the finding of (a) *Parastygarctus mediterranicus* Gallo D'Addabbo *et al.*, 2001 at 30 m depth, previously known only from two subtidal caves at the Tremiti Islands; and (b) two new species, *Florarctus* n. sp. and *Batillipes* n. sp., in the Alghero Gulf.

Considering all previous and present data about Sardinian tardigrades, it seems evident that the subtidal zone is richer than the intertidal zone (39 and 15 species, respectively). This finding is in agreement with de Zio Grimaldi & D'Addabbo Gallo (2001) who, in fact quote that of the 77 species known at that time in the Mediterranean Sea, only 4 (5%) were exclusively intertidal, 20 (26%) common to both intertidal and subtidal, and the remaining 53 (69%) found only in the subtidal zone. These differences between intertidal and subtidal tardigrade fauna might not only depend on the physical conditions (i.e. wave action, granulometry, etc.), but (also) on the chemical composition of the sediment. The intertidal sands are in fact mainly siliceous, whereas the subtidal ones are calcareous with organogenous debris, known to be more attractive to meiofauna (Gallo D'Addabbo *et al.* 1999). Moreover, subtidal environments seem to be particularly suitable to the family Halechiniscidae, showing a much higher number of species in comparison to other families in this environment. In this respect, our data from the Mediterranean Sea are also in agreement with results from the North Atlantic

Sea by Hansen *et al.* (2001), who found a high number of species (35) in the Faroe Bank deep calcareous sediment, where the Halechiniscidae constituted the majority of species (88%).

#### ACKNOWLEDGMENTS

We sincerely thank the anonymous reviewers for improving the quality of this paper.

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