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Ecology and biogeography of oribatid mites (Acari: Oribatida) from the coastal region of Portugal

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Abstract

The oribatid mite populations in the soils of typical habitat types at the Ribeira de Aljezur, Western Algarve in Portugal, are presented with the main objective to detect a synecological structure in relation to habitat types. Five mite communities can be discriminated by means of a correspondence analysis and of the specific abundance values in the habitats: Communities in (1) salt marsh sites in the estuary river zone, (2) a dune meadow, (3) a sandy dune area with low shrubs, (4) coastal bush-land on rocky substrate, (5) a floodplain forest in the limnic river zone. The communities on dune and rocky substrates are less distinct. Ecological preferences and biogeographical distributions of all species are presented and discussed. This actual publication contributes 30 further species, recorded in Portugal for the first time. Altogether, the Portuguese oribatid fauna includes 253 documented species now. From the 28 Iberian species of the current contribution, 14 species are endemic for Portugal. Ten of these species are described originally from the presented material from the area of Ribeiro de Aljezur.

Keywords Ecology | biogeography | correspondence analysis | Acari

1. Introduction

In contrast to the large number of publications on oribatid mites and the large number of species recorded from Spain, the oribatid fauna of continental Portugal was sparsely known until 1990, when Gil & Subías published the first faunistic study from the most south-western region of the Algarve. 972 species are recorded from the Iberian Peninsula (Subías & Shtanchaeva 2012a,b), of which 218 are known from Portugal (Shtanchaeva et al. 2012 and cited papers). Many of the Portuguese records are recent, which indicates that the fauna is rather poorly known. Most of the publications are focussed on faunistics and systematics, partly with biogeographical comments on the species in particular.

The recent studies of the author in Portugal have been focussed on the oribatid mites in marine salt marshes and adjacent coastal habitats. A first ecological publication (Weigmann 2008a) concerned the oribatid fauna in littoral habitats in the lagoons of Aveiro (Northern Portugal) and of Faro (Southern Portugal). A series of papers (Weigmann 2008b, 2009a,b, 2010, 2011, 2012) dealt mainly with new and remarkable species from Portuguese salt marsh areas and additionally from littoral and terrestrial habitats at the coast near Aljezur (West-Algarve).

Main objective of the current contribution is the synecological analysis of the oribatid mite communities in the Ribeira de Aljezur river area, which can be subdivided into neighboured contrasting habitat types: salt marshes, dune complex, dune meadow, coastal bush-land ('matorral' shrubbery) and a floodplain forest. Does the pattern of oribatid mite communities correspond to the habitat type structuring of the coastal area?

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2. Materials and methods

Samples from coastal habitats at Ribeira de Aljezur, Atlantic coast of West-Algarve, were collected by the author from 2004 to 2011. The mentioned sample numbers in the following section may help the reader to find the corresponding site references in previous taxonomical papers (Weigmann 2008b, 2009a,b, 2010, 2011, 2012). The sites are characterized by vegetation type and locality in the river area. The characteristics of coastal vegetation are described in 'Natura 2000' (EU Commission 2007) and in Costa et al. (2000). The latter authors dealt particularly with the coastal vegetation of Portugal, including 'dunes and low-scrub plant communities', with Atlanto-Mediterranean climate and oceanic influence, mainly as strong wind and salt water spray.

2.1. The sites

S1: Salt marsh of Mediterranean type ('Mediterranean and thermo-Atlantic halophilous scrubs', *Sarcocornetea fruticosi* Br.-Bl. & Tüxen; see EU Commission 2007), dominated by *Sarcocornia*, *Atriplex, Sueda* shrubs on muddy soil of a small flat island in the river, with regular salt water influence; about 1.2 km from the Atlantic shore (37.342°N, 8.841°W). Sample series Po 194-205 (20.10.2010).

S2: Salt marsh of Mediterranean type, as S1. On sandy-muddy soil on the northern riverside, adjacent to a dune area, with regular salt water influence; about 1.2 km from the Atlantic shore (37.341°N, 8.840°W); linear distance to S1 about 80 m. Sample series Po 171-181 (22.03.2010).

S3: Salt marsh of Mediterranean type, as S1. An area on muddy soil with brackish water influence, formerly used as salines; about 2.3 km from the Atlantic shore (37.339°N, 8.834°W); linear distance to S1 about 1.2 km. Sample series Po 104-109, taken from the elevated border of the saline flats (09.09.2004).

S4: Salt marsh of Mediterranean type, as S1, an area on muddy soil with less regular brackish water influence, about 3.2 km from the Atlantic shore (37.331°N, 8.828°W); linear distance to S1 about 1.6 km. Sample series Po 120-125 (21.09.2004).

S-D: Transition zone between salt marsh S4 and border of a dry dune area, with debris and *Juncus* and *Carpobrotus* plants. Samples Po 126 and 127 (21.09.2004).

D1: Thermo-Atlantic white dune (see EU Commission 2007, Costa et al. 2000), dry to moist sandy dune site with scarce vegetation, with some bushes, e.g. *Ononis natrix*; with occasional salt water influence at extreme high tide; about 1.1 km from the Atlantic shore (37.344°N, 8.838°W). Sample series Po 128-135 (21.03.2006); 139-141 (23.10.2008), mostly taken under bushes.

D2: At upper border of site D1, soil and litter under large *Tamariscus* bushes. Samples 138 and 142 (23.10.2008).

DM: Grey dune meadow with grassy vegetation (occasionally grazed by cattle). Adjacent to sites D1 and R1 (37.342°N, 8.838°W). Sample series Po 147-149 (02.11. 2011).

R1: Coastal bush-land on a rock, about 10 m above site D1. Typical sclerophyllous scrub vegetation on rocky soil at the Atlantic coast ('matorral'; see EU Commission 2007, Costa et al. 2000), e.g. with *Pistacia terebinthus*, *Ulex* and *Cistus*. North-eastern riverside (37.344°N, 8.838°W). Sample series Po 143-146 (02.11.2011).

R2: Coastal bush-land on a rock slope, about 5–10 m above water level, matorral vegetation with some higher bushes, partly sandy soils. Estuary region, south-western riverside (37.342°N, 8.838°W); linear distance to R1 about 900 m. Sample series Po 150-161 (06.04.2009).

FF: Floodplain forest, 5 km upstream from sea shore in the floodplain, inundated at high water occasions; moist to wet *Alnus* and *Salix* stock with shrubberies on gley-soil (37.347°N, 8.846°W). Sample series Po 113-115 (09.09.2004) and Po 206-217 (30.10.2011).

Samples covered about 50 cm² each with a depth of about 3 cm. The mites were extracted using a modified Tullgren apparatus. The specimens were preserved in ethanol and after clearing in lactic acid they were studied in cavity slides.

Taxonomical sources. The oribatid species were determined using the monographs of Pérez-Iñigo (1993, 1997) and Subías & Arillo (2001) on the Spanish fauna, that on the German fauna by the author (Weigmann 2006), and additional special taxonomical literature. The systematic concept follows Norton & Behan-Pelletier (2009), Schatz et al. (2011) and Weigmann (2006).

Statistical methods. Statistical calculations and graphic diagrams were performed with Statistica 7.1 (StatSoft). The correspondence analysis of the site's communities is based on abundance data of those species with more than 3 specimens overall (site S-D omitted), as presented in table 1.

In the following systematic list of recorded species, biogeographical abbreviations of the species distributions are used: **COS** – cosmopolitan, **sCOS** – semi-cosmopolitan (with 2-3 regions out of Palaearctic), **PAL** – Palaearctic, **wPAL** – Europe and southern Mediterranean, **swPAL** – West-Mediterranean and Iberian Peninsula, **eu** – Europe, **nafr** – Palaearctic North-Africa, **iber** – Iberian (Spain and Portugal), **HOL** – Holarctic, **ETH** – Ethiopean region, **OR** – Oriental region, **NEA** – Nearctic region, **NEO** – Neotropic region, **AUS** – Australo-Pacific Region.

3. Results

3.1. Systematic list of recorded species

Ctenacaridae Grandjean, 1954

Ctenacarus araneolus (Grandjean, 1932)
Distr.: PAL, sCOS – Ecol.: In dry litter and debris.

Brachychthoniidae Thor, 1934

Brachychthonius pseudoimmaculatus Subías & Gil, 1991
Distr.: swPAL – Ecol.: Coastal bush-land (Gil & Subías 1990, Subías & Gil 1991)

Sellnickochthonius immaculatus Forsslund, 1942
Distr.: HOL – Ecol.: Eurytopic; in forests, open habitats and epilithic moss. – New for Portugal.

Poecilochthonius italicus (Berlese, 1910)
Distr.: HOL – Ecol.: In dry soils.

Cosmochthoniidae Grandjean, 1947

Cosmochthonius foliatus Subías, 1982
Distr.: swPAL (eu, nafr) – Ecol.: Diverse habitats (Gil et al. 1991).

Cosmochthonius spinosus Gil, Subías et Candelas, 1991
Distr.: swPAL (iber) – Ecol.: Coastal bush-land (Gil & Subías 1990, Gil et al. 1991).

Sphaerochthoniidae Grandjean, 1947

Sphaerochthonius splendidus (Berlese, 1904)
Distr.: PAL, COS – Ecol.: In dry soils.

Epilohmanniidae Oudemans, 1923

Epilohmannia cylindrica (Berlese, 1904)
Distr.: PAL, sCOS – Ecol.: In dry open habitats.

Euphthiracaridae Jacot, 1930

Acrotritia ardua (C. L. Koch, 1841)
Distr.: COS – Ecol.: Eurytopic, most frequent in forest soils.

Phthiracaridae Perty, 1841

Phthiracarus globosus (C. L. Koch, 1841)
Distr.: HOL – Ecol.: Eurytopic, most frequent in humic forest soils. – New for Portugal.

Phthiracarus sp. – One specimen, not determined.

Steganacarus applicatus (Sellnick, 1920)
Distr.: wPAL – Ecol.: Mainly in forest litter.

Crotoniidae Thorell, 1876

Camisia horrida (Hermann, 1804)
Distr.: HOL, OR, NEO – Ecol.: Preferring moss and lichens on trees, stones and soil. – New for Portugal.

Platynothrus peltifer (C. L. Koch, 1839)
Distr.: HOL, sCOS – Ecol.: Eurytopic, preferring humic soils, also in salty meadows.

Hermanniidae Sellnick, 1928

Hermannia pulchella Willmann, 1952 – sensu Woas 1981, Weigmann 2006. Probably partly confused in literature with *H. subglabra* Berlese, 1910
Distr.: PAL – Ecol.: In marine salt meadows and salt shrubs.

Hermanniellidae Grandjean, 1934

Hermanniella punctulata Berlese, 1908 – sensu Weigmann 2006 (Syn. '*H. picea*' sensu Willmann 1931, Subías 2012, Shtanchaeva et al. 2012. *Nothrus piceus* Koch, 1839 (CMA 29.2) is species inquirenda, obviously a *Hermannia* species)
Distr.: PAL, OR, NEA – Ecol.: In central Europe mainly in forest soils (Weigmann 2006).

Neoliodidae Sellnick, 1928

Neoliodes globosus (Subías & Gil, 1990)
Distr.: swPAL (iber: South Portugal; Spain) – Ecol.: On tree bark, stones and in litter (Pérez-Iñigo 1997).

Licnodamaeidae Grandjean, 1954

Licnodamaeus pulcherrimus (Paoli, 1908)
Distr.: PAL – Ecol.: In soils of dry bush land and dry meadows. – New for Portugal.

Licnobelbidae Grandjean, 1965

Licnobelba caesarea (Berlese, 1910)
Distr.: swPAL (iber, nafr) – Ecol.: In soils of dry bush land and dry meadows.

Gymnodamaeidae Grandjean, 1954

Arthrodamaeus femoratus (C. L. Koch, 1839)
Distr.: PAL, OR – Ecol.: In warm-dry habitats, in epilithic moss. – New for Portugal.

Arthrodamaeus hispanicus (Grandjean, 1928)
Distr.: PAL – Ecol.: In warm-dry open habitats.

Aleurodamaeidae Paschoal et Johnston, 1985

Aleurodamaeus setosus (Berlese, 1883)
Distr.: swPAL – Ecol.: In warm-dry open habitats.

Damaeidae Berlese, 1896

Damaeus flagellifer Michael, 1890
Distr.: swPAL – Ecol.: In litter of Mediterranean forests and shrubs (Pérez-Iñigo 1997).

Damaeus gracilipes (Kulczynski, 1902)
Distr.: HOL – Ecol.: In litter and moss in forests.

Metabelbella epidamaeiformis Ermilov, Shtanchaeva & Subías, 2012
Distr.: swPAL (southern Portugal) – Ecol.: In litter of *Quercus* and in leaf litter of a sandy dune (Ermilov et al. 2012) – in coastal scrubland R1. New for Portugal.

Porobelba sp. – One specimen, not determined.

Cepheidae Berlese, 1896

Cepheus latus C. L. Koch, 1835
Distr.: HOL, sCOS – Ecol.: In forest litter, on trunks and in moss cushions.

Zetorchestidae Michael, 1898

Microzetorchestes emeryi (Coggi, 1898)
Distr.: PAL – Ecol.: In moss and soil of dry habitats.

Peloppiidae Balogh, 1943

Ceratoppia bipilis (Hermann, 1804)
Distr.: HOL; sCOS – Ecol.: Mainly in diverse forest soils (Weigmann 2006), also in moss and lichens (Pérez-Iñigo 1997).

Gustaviidae Oudemans, 1900

Gustavia fusifer (C. L. Koch, 1841)
Distr.: PAL – Ecol.: In diverse forest soils and open habitats, also in Mediterranean scrubland (Pérez-Iñigo 1997).

Liacaridae Sellnick, 1928

Xenillus clypeator Robineau-Desvoidy, 1839
Distr.: HOL – Ecol.: Mainly in forest soils and arboricolous.

Xenillus halophilus Weigmann, 2011
Distr.: swPAL (southern Portugal) – Ecol.: In salt marshes of Mediterranean type.

Eremobelbidae Balogh, 1961

Eremobelba geographica Berlese, 1908
Distr.: wPAL – Ecol.: Mainly in moist meadows and forest soils. – New for Portugal.

Oppiidae Sellnick, 1937

Berniniella inornata (Mihelčič, 1957)
Distr.: wPAL – Ecol.: Eurytopic (cf. Subías & Arillo 2001). – New for Portugal.

Microppia minus (Paoli, 1908)
Distr.: COS – Ecol.: Eurytopic.

Oppia denticulata (R. & G. Canestrini, 1882)
Distr.: PAL – Ecol.: Eurytopic, in Iberian Peninsula with preference for soils of dry mediterranean habitats rich in organic matter (Subías & Arillo 2001). – New for Portugal.

Oppiella nova (Oudemans, 1902)
Distr.: COS – Ecol.: Eurytopic.

Oppiella (Moritzoppia) unicarinata (Paoli, 1908)
Distr.: HOL – Ecol.: Eurytopic.

Multioppia neglecta Pérez-Iñigo, 1969
Distr.: HOL, AUS (Hawaii) – Ecol.: In meadows, salt tolerant (Weigmann 2006); also in poor dry soils (Subías & Arillo 2001). – New for Portugal.

Oxyoppioides decipiens (Paoli, 1908)
Distr.: PAL – Ecol.: Indistinct; occasionally in diverse habitats. – New for Portugal.

Ramusella clavipectinata (Michael, 1885)
Distr.: PAL, sCOS – Ecol.: Eurytopic, salt tolerant.

Ramusella elliptica (Berlese, 1908)
Distr.: wPAL, NEA ? – Ecol.: Eurytopic.

Ramusella insculpta (Paoli, 1908)
Distr.: PAL – Ecol.: Eurytopic. – New for Portugal.

Ramusella mihelčiči (Pérez-Iñigo, 1965)
Distr.: swPAL – Ecol.: In diverse dry soils (Subías & Arillo 2001).

Ramusella terricola Subías & Rodriguez, 1986)
Distr.: swPAL – Ecol.: Mainly in mould-rich soils of moderately dry open habitats (Subías & Arillo 2001). – New for Portugal.

Serratoppia intermedia Subías & Rodriguez, 1988
Distr.: swPAL (iber) – Ecol.: Eurytopic.

Serratoppia minima Subías & Rodriguez, 1988
Distr.: swPAL (iber), NEO (Costa Rica) – Ecol.: Preference indistinct; occasionally in diverse moderately dry habitats (Subías & Arillo 2001).

Quadroppiidae Balogh, 1983

Coronoquadroppia guttata Weigmann, 2010
Distr.: swPAL (southern Portugal) – Ecol.: Original finding in coastal scrubland R1; recently collected in soil under *Quercus* trees (Ermilov et al. 2012).

Suctobelbidae Jacot, 1938

Suctobelbella acutidens (Forsslund, 1941)
Distr.: HOL, NEO – Ecol.: Eurytopic.

Suctobelbella sarekensis (Forsslund, 1941)
Distr.: HOL – Ecol.: Eurytopic.

Suctobelbella subcornigera (Forsslund, 1941)
Distr.: HOL, sCOS – Ecol.: Eurytopic.

Carabodidae C. L. Koch, 1843

Austrocarabodes ensifer (Sellnick, 1932)
Distr.: PAL – Ecol.: Mainly in Mediterranean and coastal scrubland (Pérez-Iñigo 1997).

Carabodes willmanni Bernini, 1975
Distr.: HOL – Ecol.: Often in moss and lichens, frequently at the sea shore (Pérez-Iñigo 1997). – New for Portugal.

Odontocepheus elongatus (Michael, 1879)
Distr.: HOL – Ecol.: Frequently in forests in litter layer and arboricolous.

Tectocepheidae Grandjean, 1954

Tectocepheus sarekensis Trägardh, 1910
Distr.: HOL – Ecol.: Eurytopic.

Tectocepheus velatus (Michael, 1880)
Distr.: COS – Ecol.: Eurytopic. – New for Portugal.

Cymbaeremaeidae Sellnick, 1928

Scapheremaeus corniger (Berlese, 1908)
Distr.: swPAL – Ecol.: In coastal scrubland, climbing bushes (Pérez-Iñigo 1997).

Micreremidae Grandjean, 1954

Micreremus brevipes (Michael, 1888)
Distr.: PAL – Ecol.: Mainly arboricolous, in moss and lichens. – New for Portugal.

Licneremaeidae Grandjean, 1931

Licneremaeus similis Pérez-Iñigo jr., 1990
Distr.: swPAL – Ecol.: Indistinct.

Scutoverticidae Grandjean, 1954

Scutovertex arenocolus Pfingstl & Schäffer, 2009
Distr.: wPAL (iber, Germany) – Ecol.: In coastal dunes. – New for Portugal.

Scutovertex mikoi Weigmann, 2009
Distr.: swPAL (southern Portugal) – Ecol.: Mainly in coastal dunes.

Passalozetidae Grandjean, 1954

Passalozetes hispanicus Mihelčič, 1955
Distr.: wPAL – Ecol.: In dry soils (Pérez-Iñigo 1993). – New for Portugal.

Phenopelopidae Petrunkevitch, 1955

Eupelops acromios (Hermann, 1804)
Distr.: PAL, OR, ETH – Ecol.: In forests and bush-land, often arboricolous; also in open habitats.

Eupelops curtipilus Berlese, 1916
(Syn. *Pelops bilobus* Sellnick, 1928)
Distr.: PAL – Ecol.: In Spain in wooded and dry areas (Pérez-Iñigo 1993).

Eupelops somalicus (Berlese, 1916)
Distr.: PAL, ETH (north-east Africa) – Ecol.: In Portugal in soil under *Quercus* (Shtanchaeva et al. 2012); – in coastal bush-land (Weigmann 2011).

Eupelops torulosus (C. L. Koch, 1839)
Distr.: PAL – Ecol.: Eurytopic.

Peloptulus reticulatus Mihelčič, 1957
Distr.: PAL – Ecol.: Mostly in dry soils (cf. Weigmann 2008b). – New for Portugal.

Peloptulus sacculiferus Weigmann, 2008
Distr.: swPAL (southern Portugal) – Ecol.: In coastal bush-land.

Oribatellidae Jacot, 1925

Oribatella quadricornuta (Michael, 1880)
Distr.: HOL – Ecol.: In soil of forests and diverse open land, occasionally arboricolous.

Oribatella sp. – One specimen, not determined.

Oribatella tridactyla Ruiz, Subías & Kahwash, 1991 (cf. Weigmann 2011)
Distr.: swPAL – Ecol.: In dry soils.

Ceratozetidae Jacot, 1925

Trichoribates algarvensis (Subías & Gil, 1990)
Distr.: swPAL (southern Portugal, Spain) – Ecol.: Mostly in dry soils; coastal bush-land (Subías & Gil 1990).

Trichoribates clavatus Mihelčič, 1956
Distr.: swPal (iber) – Ecol.: In soils of dry habitats. – New for Portugal.

Trichoribates trimaculatus (C. L. Koch, 1835)
Distr.: HOL – Ecol.: In diverse habitat types of forests and open land, often arboricolous. – New for Portugal.

Chamobatidae Thor, 1937

Chamobates dentatus Mihelčič, 1956 (cf. Weigmann 2012)
Distr.: PAL – Ecol.: In litter of forests (Pérez-Iñigo 1993). – Abundant in floodplain forest stand FF.

Chamobates roynortoni Weigmann, 2012
Distr.: swPAL (southern Portugal) – Ecol.: In soil of coastal bush-land stands R1 and R2.

Humerobatidae Grandjean, 1970

Humerobates rostrolamellatus Grandjean, 1936
Distr.: HOL, sCOS – Ecol.: In forests and open landscape; regularly arboricolous; salt tolerant member of salt marsh communities.

Mycobatidae Grandjean, 1954

Minunthozetes quadriareatus Minguez, Subías et Ruiz, 1986
Distr.: swPAL – Ecol.: In dry and cultivated soils (Pérez-Iñigo 1993). – Dominant species in coastal bush-land R1 and R2; also frequent in dune area D2.

Punctoribates hexagonus Berlese, 1908 (*Minguezetes h.*: Subías et al. 1990a)
Distr.: HOL, OR – Ecol.: In moist and fresh meadows and fens; salt tolerant member of salt marsh communities. – New for Portugal.

Punctoribates palustris (Banks, 1895) – Revised by Behan-Pelletier & Eamer 2008. Subías 2000 regarded the cosmopolitan species *P. manzanoensis* Hammer, 1958 as synonym for *P. insignis* Berlese, 1910, sensu Mahunka & Mahunka-Papp, 1995 (both in the subgenus *Minguezetes* Subías et al., 1990: cf. Subías 2012). *P. manzanoensis* as well as *P. insignis* are regarded as synonyms of *P. palustris* (syn. nov.).
Distr.: HOL, NEO – Ecol.: Mainly in wet soils of bogs, meadows and forests (Behan-Pelletier & Eamer 2008). – Abundant in flood plain forest FF. – New for Portugal.

Punctoribates punctum (C. L. Koch, 1839)
Distr.: HOL, sCOS – Ecol.: Mainly in fresh soils of deciduous forests, also in meadows.

Oribatulidae Thor, 1929

Lucoppia burrowsi (Michael, 1890)
Distr.: HOL, AUS (Hawaii) – Ecol.: In poor rocky soils.

Oribatula polytuberculata Ermilov, Shtanchaeva, Subías & Orobitg, 2012
Distr.: swPAL (southern Portugal) – Ecol.: Originally from soil under *Cistus ladaniferus* and from a dune soil (Ermilov et al. 2012). – Found in flood plain forest FF.

Oribatula tibialis (Nicolet, 1855)
Distr.: HOL, OR – Ecol.: Eurytopic; in diverse habitats, frequently in moss on soil, epilithic and arboricolous.

Oribatula torrijosi Subías, Ruiz & Kahwash, 1990
Distr.: swPAL (iber) – Ecol.: In dry soils of bush-land and dune (Subías et al. 1990b, Gil & Subías 1990, Shtanchaeva et al. 2012). – Found in coastal bush-land R2 and in dune stand D1.

Zygoribatula dactylaris Subías, Ruiz & Kahwash, 1990
Distr.: swPAL (iber) – Ecol.: In soil of Mediterranean bush-land, moss and lichens (Pérez-Iñigo 1993, Gil & Subías 1990).

Zygoribatula exarata Berlese, 1916
Distr.: PAL – Ecol.: In dry to moist meadows and in moss (Pérez-Iñigo 1993), in bush-land (Gil & Subías 1990).

Zygoribatula frisiae (Oudemans, 1900)
Distr.: HOL – Ecol.: Abundant in various dry open habitats, in moss and lichens, frequently arboricolous.

Zygoribatula lenticulata Minguez & Subías, 1986
Distr.: swPAL – Ecol.: Indistinct. – Some specimens from sandy dune meadow D3. – New for Portugal.

Pseudoppia longissima (Weigmann, 2009)
Distr.: swPAL (southern Portugal) – Ecol.: Coastal bush-land R1. on rocky substrate.

Pseudoppia mediocris (Mihelčič, 1957)
Distr.: PAL – Ecol.: Typical for Mediterranean bush-land (Pérez-Iñigo 1993, Gil & Subías 1990). – Coastal bush-land R2.

Scheloribatidae Jacot, 1935

Scheloribates (Euscheloribates) algarvensis Weigmann, 2009
Distr.: swPAL (southern Portugal) – Ecol.: In saltmarsh plots S1-S3.

Scheloribates (Hemileius) initialis (Berlese 1908)
Distr.: PAL, sCOS – Ecol.: Mainly in forest soil and litter. – New for Portugal.

Scheloribates (Hemileius) robustus Pérez-Iñigo, 1969
Distr.: swPAL (iber, nafr) – Ecol.: Mainly in forest soil and litter. – New for Portugal.

Scheloribates (Scheloribates) ibericus Weigmann, 2010
Distr.: swPAL (southern Portugal) – Ecol.: Abundant in bush-land plot R1, one specimen in dune meadow D3. (The finding of '*S. fimbriatus* Thor, 1930' in Gil & Subías 1990 refers most probably to *S. ibericus*)

Scheloribates (Scheloribates) litoralis Weigmann, 2010
Distr.: swPAL (southern Portugal) – Ecol.: In salt marsh plot S3.

Scheloribates (Scheloribates) minifimbriatus Mínguez, Subías & Ruiz, 1986
Distr.: swPAL – Ecol.: In cultivated soil, less abundant in more natural habitats (Mínguez et al. 1986).

Haplozetidae Grandjean, 1936

Haplozetes differens Weigmann, 2010
Distr.: swPAL (southern Portugal) – Ecol.: Two specimens in bush-land plot R1.

Haplozetes similis Subías & Gil-Martín, 1995
Distr.: swPAL (southern Portugal) – Ecol.: In coastal bush-land (Subías & Gil-Martin 1995; cf. '*Incabates* sp.' in Gil & Subías 1990).

Peloribates glaber Mihelčič, 1956
Distr.: swPAL – Ecol.: Mainly in woodland and Mediterranean bush-land (Pérez-Iñigo 1993). – New for Portugal.

Pilobates carpetanus Pérez-Iñigo, 1969
Distr.: swPAL (iber) – Ecol.: In dry open habitats (Pérez-Iñigo 1993). – Some specimens in bush-land plot R1.

Protoribates hakonensis Aoki, 1994
Distr.: PAL (Japan, southern Portugal) – Ecol.: In Japan from a moor with *Phragmites*, Botanical Garden of Wetlands. First European finding, abundant in floodplain forest FF.

Protoribates tohokuensis Fujikawa, 2003
Distr.: PAL (Japan, southern Portugal) – Ecol.: In Japan from Beech forest soil. First European finding, highly abundant in floodplain forest FF.

Galumnidae Jacot, 1925

Galumna paragibbula Weigmann, 2011
Distr.: swPAL (southern Portugal) – Ecol.: Some specimens in bush-land plot R1.

Galumna tarsipennata Oudemans, 1914
Distr.: PAL, NEO – Ecol.: In soils of deciduous forests and moist moor soils. – New for Portugal.

Pergalumna nervosa (Berlese, 1915)
Distr.: HOL, sCOS – Ecol.: In diverse forest and bog soils. – New for Portugal.

Pilogalumna crassiclava (Berlese, 1914) –
Syn.: *Galumna allifera* Oudemans, 1915
Distr.: PAL – Ecol.: In forest soils (Pérez-Iñigo 1993). – In dune plot D2 and bush-land plot R2.

Pilogalumna ornatula Grandjean, 1956
Distr.: swPAL – Ecol.: In moss and on rocks (Pérez-Iñigo 1993). – New for Portugal.

3.2. Ecology of the oribatid mite communities

The collected samples derive from five contrasting coastal habitat types along the river Ribeira de Aljezur: salt marsh sites (S1-S4), a dune meadow (DM), dune sites (D1, D2), rocky bush-land (R1, R2), and a floodplain forest (FF). Additionally, two samples represent a transitional zone between S and D habitat (S-D), which is not included in synecological analyses below because of the low number of collected oribatid mite specimens and its questionable status as a distinct community.

Table 1 presents all findings of oribatid mites in the sites. The species are grouped after their ecological preference in the habitat types; rare species at the bottom of the table are not grouped. The ecological species groups are:

- **I.** Species with preference for salt marsh sites (S1-S4);
- **II.** Species with preference for a meadow on dune sand (DM);
- **III.** Species with preference for dune sites (D1, D2);
- **IV.** Species with preference for rocky sites (R1, R2); This group includes sub-groups IVa (only in R1) and IVb (only in R2);
- **V.** Species with preference for the floodplain forest (FF).

The abundance values of the site groups corresponding to the species groups are outlined by heavy lines in table 1.

Mites with salt marsh preference (group I). This species assemblage is represented by five species, which clearly prefer salt marsh sites. Of these, only *Xenillus halophilus* occurs additionally in the rocky site R1 with considerable abundance, but it inhabits all salty sites with overall highest abundance. Two further species were recently described from these sites: *Scheloribates (Euscheloribates) algarvensis* and *Scheloribates litoralis* seem to be halophilous species with occurrence in salt marshes of Mediterranean type. The halophilous *Hermannia pulchella* inhabits only site S1, mostly exposed to salt water inundation. *Humerobates rostrolamellatus* occurs in all salty sites, an eurytopic species with tolerance to soil salt content.

Mites with dune meadow preference (group II). The oribatid mite population in site DM is dominated by *Galumna tarsipennata*, which inhabits also the floodplain forest with considerable abundance. Further species (see table 1) indicate dry habitat preference.

Mites with sandy dune preference (group III). This species group is dominated by *Scutovertex* species, *S. arenocolus* and *S. mikoi*. There is some faunistic overlap with the rocky and the forest sites (R, FF) concerning *Ramusella clavipectinata*, *Tectocepheus sarekensis*, *Cosmochthonius foliatus* and *Minunthozetes quadriareatus*.

Mites with rocky bush-land preference (group IV). This species assemblage is the richest in species number. We can discriminate three subgroups: The first subgroup contains the species with common occurrence in both sites R1 and R2, which are separated from each other by the river; this subgroup is dominated by *Minunthozetes quadriareatus*, inhabiting also the dune site D2, and by *Oppiella (Moritzoppia) unicarinata*. The subgroups IVa (from R1) and IVb (from R2) include remarkable numbers of species and specimens each, not inhabiting the other subgroup. This ecological diversity may not be overvalued, because the sites show a high degree of habitat heterogeneity. There is some minor overlap in species with the dune sites.

Mites with floodplain forest preference (group V). The population of this site is rich in species and specimens and it differs strongly from the populations of the other habitat types regarding the species composition. Among the seven species with highest abundance, *Protoribates tohokuensis* and *P. hakonensis* (described from Japan) were recorded in Portugal, as well as the Western-Palaearctic, for the first time. The other abundant species, *Acrotritia ardua*, *Punctoribates*

Table 1. Abundance of all oribatid mite species in the sites at Ribeira de Aljezur, grouped after occurrence in the habitat groups.

		salt marsh				trans.	dune			rocky		forest
		S1	S2	S3	S4	S-D	DM	D1	D2	R1	R2	FF
I.	*Xenillus halophilus*	92	27	6	31	1				23		
	Hermannia pulchella	72										
	Scheloribates (Eu.) algarvensis	23	5	9								
	Humerobates rostrolamellatus	5	1	8	22	1				1		
	Scheloribates litoralis			6								
	Ctenararus araneolus					10					2	
II.	*Galumna tarsipennata*						110					20
	Carabodes willmanni						16			4	2	
	Zygoribatula lenticulata						15					
	Trichoribates algarvensis						12	1		6		
	Zygoribatula exarata						5			3		
	Zygoribatula dactylaris						2					
	Lucoppia burrowsi						2			2		3
III.	*Scutovertex arenocolus*							145	2	2		
	Scutovertex mikoi							137			6	
	Multioppia neglecta		1				1	57	18	2		
	Ramusella clavipectinata							54	13	44		
	Tectocepheus sarekensis					2		34	11			21
	Austrocarabodes ensifer							23	4		2	
	Brachychth. pseudoimmaculatus							21	5	5		
	Pilogalumna ornatula							17				
	Scheloribates (He.) initialis								16			
	Cosmochthonius foliatus							8	14		20	
	Eupelops torulosus							5	13			
	Pilogalumna crassiclava								11		19	
IV.	*Minunthozetes quadriareatus*		1				1		66	690	25	1
	Oppiella (Mo.) unicarinata									128	16	
	Zygoribatula frisiae						1	81	7	48	9	
	Odontocepheus elongatus									12	37	
	Licnobelba caesarea						1			1	23	
	Neoliodes globosus							1		1	16	
	Phthiracarus globosus									13	3	
	Microzetorchestes emeryi									12	3	
	Chamobates roynortoni									12	2	
	Gustavia fusifer									6	7	
	Cepheus latus									5	3	

		salt marsh				trans.		dune		rocky		forest
		S1	S2	S3	S4	S-D	DM	D1	D2	R1	R2	FF
	Arthrodamaeus hispanicus									2	3	
	Eupelops acromios							1		1	1	
IVa.	*Serratoppia intermedia*									44		
	Scheloribates minifimbriatus							3		42		
	Scheloribates ibericus						1			32		
	Oribatella tridactyla									31		
	Metabelbella epidamaeiformis									24		
	Eupelops somalicus									23		
	Scheloribates (He.) robustus									22		
	Pilobates carpetanus									12		
	Licneremaeus similis									11		
	Poecilochthonius italicus								1	11		
	Oribatula tibialis									10		
	Pseudoppia longissima									7		
	Peloptulus sacculiferus									6		
	Galumna paragibbula									5		
	Coronoquadroppia guttata									2		
	Haplozetes differens									2		
	Suctobelbella sarekensis							2		2		
	Tectocepheus velatus									2		1
IVb.	*Pseudoppia mediocris*										64	
	Sphaerochthonius splendidus								6		26	
	Aleurodamaeus setosus										21	
	Eupelops curtipilus										20	
	Hermanniella punctulata										20	
	Oribatula torrijosi							1			17	
	Xenillus clypeator					4		3	4		12	1
	Passalozetes hispanicus						2	10			10	
	Peloptulus reticulatus							3			3	
	Cosmochthonius spinosus										4	
	Licnodamaeus pulcherrimus										2	
V.	*Protoribates tohokuensis*											502
	Acrotritia ardua											195
	Punctoribates hexagonus											115
	Chamobates dentatus											112
	Punctoribates punctum											101
	Protoribates hakonensis											91

	salt marsh				trans.		dune		rocky		forest
	S1	S2	S3	S4	S-D	DM	D1	D2	R1	R2	FF
Eremobelba geographica											90
Punctoribates palustris											35
Pergalumna nervosa											29
Microppia minus	9						6				24
Ramusella elliptica											24
Oppiella nova											21
Ramusella insculpta											12
Sellnickochthonius immaculatus											10
Damaeus gracilipes											5
Oribatula polytuberculata											5
Ramusella mihelcici											4
Oxyoppioides decipiens											2
Scapheremaeus corniger									1		2
Arthrodamaeus femoratus										1	
Berniniella inornata							1				
Camisia horrida							1	3		3	
Ceratoppia bipilis									1		
Damaeus flagellifer										1	
Epilohmannia cylindrica											1
Haplozetes similis										1	
Micreremus brevipes									1		
Oppia denticulata											1
Oribatella quadricornuta											1
Oribatella sp.											1
Peloribates glaber			1								
Phthiracarus sp.											1
Platynothrus peltifer											1
Porobelba sp.											1
Ramusella terricola							1				
Serratoppia minima							2				
Steganacarus applicatus										1	
Suctobelbella acutidens							2				
Suctobelbella subcornigera							1				
Trichoribates clavatus							1				
Trichoribates trimaculatus									1		
sum of individuals (total 4475)	201	35	30	53	18	169	622	194	1315	405	1433
No. of samples	12	11	6	7	2	3	12	2	4	10	16

hexagonus, *P. punctum*, *Chamobates dentatus* and *Eremobelba geographica*, are characteristic of wooded habitats; the latter prefers moist soil.

Statistical analysis of the similarities between the oribatid mite populations. By means of a correspondence analysis, the qualitative and quantitative relations between the populations of the sites are evaluated, using the species identity between the sites and the abundance of common species (as can be seen by Table 1) for a multivariate comparison. In Figs 1 and 2 the sites are plotted (two dimensions each with high eigenvalues) in relation to each other, based on the species representations in the sites.

Fig. 1 outlines the relations between all sites (site DM in table 1 omitted). We can observe a closed site group with S1-S4 indicating high internal similarity within the salt marsh populations. A second separated group includes the dune and rocky sites (D1, D2, R1, R2) with no distinct sub-grouping of the two habitat types. The floodplain forest site is most distant from the other site groups, whereas the dune meadow site (DM) appears intermediate between FF and the dune-rock-group. For studying the internal relationship of the dune and rocky sites group, a second correspondence analysis is performed (Fig. 2), omitting sites FF and DM. In this statistical approach, the salt marsh sites group is used as out-group for the D and R sites. Again we cannot observe an obvious sub-grouping of D versus R sites but a remarkable differentiation on a moderate degree between the oribatid mite populations of the sites.

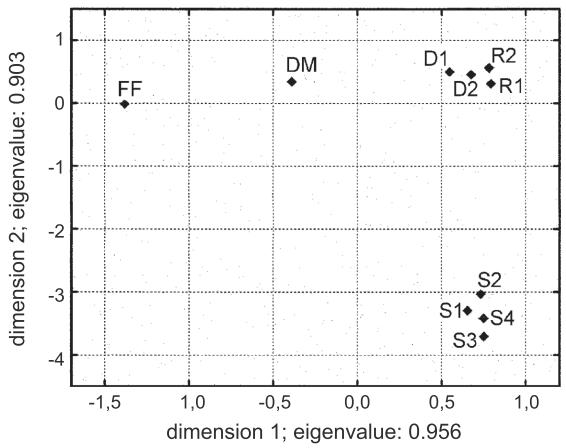

Figure 1. Similarities between the oribatid mite communities of the sites, calculated by means of a correspondence analysis.
S1-S4 – salt marsh sites; **D1**, **D2** – dune sites; **DM** – dune meadow; **R1**, **R2** – rocky sites; **FF** – floodplain forest.

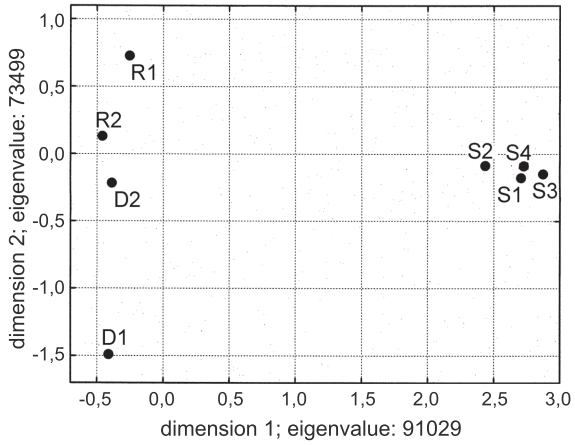

Figure 2. As fig. 1; **DM** and **FF** omitted.

3.3. Biogeography of the species

Altogether, 108 species were recorded from the habitats in the area of Ribeira de Aljezur. The known distributions are given for all species in the systematic list (chapter 3.1). Three single specimens could not be determined with certainty and are excluded from the following analysis. Thirty species are distributed in the Palaearctic and additionally in other biogeographical regions than the Holarctic (see Fig. 3).

- 75 species can be allocated to the Holarctic region in total,
- 62 of these species inhabit the Palaearctic region only,
- 43 Palaearctic species are restricted to the western Palaearctic (Europe and Mediterranean),
- 28 species occur only in the Iberian Peninsula,
- 14 species are endemic for Portugal. Ten of these species were described based on specimens from the area of Ribeiro de Aljezur.

All species which currently appear to be endemic for Portugal were recently described and may be recorded in other countries in the future; these species, listed in systematic order, are: *Metabelbella epidamaeiformis* Ermilov, Shtanchaeva & Subías, 2012; *Xenillus halophilus* Weigmann, 2011; *Coronoquadroppia guttata* Weigmann, 2010; *Scutovertex mikoi* Weigmann, 2009;

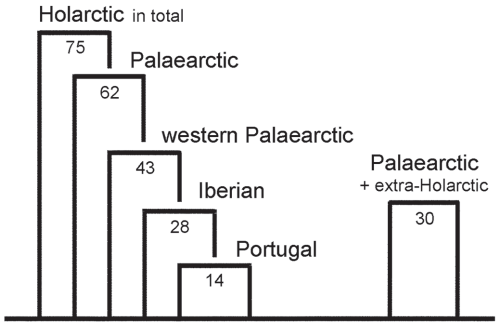

Figure 3. Number of oribatid species with distribution in biogeographical regions (The subregions of Holarctic are interleaved; i.e. from 75 Holarctic species in total 62 are Palaearctic, e.t.c. from 28 Iberian species 14 are constricted to Portugal).

Peloptulus sacculiferus Weigmann, 2008; *Chamobates roynortoni* Weigmann, 2012; *Oribatula polytuberculata* Ermilov, Shtanchaeva, Subías & Orobitg, 2012; *Pseudoppia longissima* (Weigmann, 2009); *Scheloribates (Euscheloribates) algarvensis* Weigmann, 2009; *Scheloribates (Scheloribates) ibericus* Weigmann, 2010; *Scheloribates (Scheloribates) litoralis* Weigmann, 2010; *Haplozetes differens* Weigmann, 2010; *Haplozetes similis* Subías & Gil-Martín, 1995; *Galumna paragibbula* Weigmann, 2011.

As reported in the introduction, Shtanchaeva et al. (2012) compiled the inventory of Oribatida in Portugal with altogether 218 species. Concerning the recent Iberian and Mediterranean lists of oribatid mites (Subías & Shtanchaeva 2012a, b), five published records of species are to be added: *Zachvatkinibates eoeryi* Mahunka, 1972 (found in the lagoon of Faro: Weigmann 2009a), *Protozetomimus behanae* and *Chamobates roynortoni*, most recently described, and records of *Protoribates hakonensis* and *P. tohokuensis* (Weigmann, 2012). Additionally, this current publication contributes 30 further species, recorded in Portugal for the first time. Summing up, the Portuguese oribatid fauna now includes 253 documented species.

4. Discussion

Comments on remarkable species. *Xenillus halophilus* is known only from the area of Ribeira de Aljezur being most abundant in the salt marsh sites and also present in bush-land site R1. Therefore, the following ecological characterization should be regarded as preliminary: the species seems not to be halophilous but rather halotolerant; the salt marsh sites are inundated regularly by salty or brackish water, alternatively by fresh river water in times of floodwaters; yet site R1 is on a small hill without river water influence. *Hermannia pulchella* is a well known and characteristic species of Palaearctic salt marshes of the Mediterranean type (in South Portugal in Faro lagoon (Weigmann 2008a) and in salt marsh of Ribeira de Boina near Portimão; unpublished) as well as the Atlantic type (from Northern Europe to North-Portugal: Weigmann 1973, 2008a; unpublished records from Rio Cavado and Rio Miño in North Portugal). *Humerobates rostrolamellatus* occurs in all salty sites of this study, and the author recorded it in similar habitats in the estuary region of the rivers Rio Cavado and Rio Miño (North Portugal; unpublished) and Ribeira de Boina (South Portugal; unpublished). It is an eurytopic species with obvious tolerance of soil salt content, but generally with preference for tree bark, and regularly it is found in humid and dry soils (Pérez-Iñigo 1993), such as in coastal bush-land of southern Portugal (Gil & Subías 1990).

The presence of two Japanese *Protoribates* species in the floodplain forest, new for Portugal and Europe, is indeed surprising. *Protoribates tohokuensis* was described from a mountain Beech forest in Japan, which does not concur well with the new finding; *P. hakonensis* was recorded from a moor in Japan, which is a habitat congruent with records from Portugal. The Portuguese floodplain site is surrounded by a plain moor meadow with *Juncus*, which has been planted with rice in the past. This moor meadow is nearly devoid of oribatid mites, probably because of the long-term inundation in the winter months. The high number of individuals of both species indicates best conditions in the floodplain forest itself, and an invasion from the moor meadow in recent times seems implausible. The disjunct distribution in Japan and in Portugal remains unexplained, but introduction with plant material into the former rice fields is a possibility.

Punctoribates palustris (Banks, 1895) was described originally from North America. After a recent revision and redescription by Behan-Pelletier & Eamer (2008), an evaluation of material from Portugal (and also from Etang de Salses, Carmargue in France) became possible, as well as a comparison with the description of *P. manzanoensis* Hammer, 1958 (from South America; after Shaldybina 1975 also in Kazakhstan and Far East) and the redescription of *P. insignis* Berlese, 1910 by Mahunka & Mahunka-Papp 1995 (originally from Sicily; Neotropical and Subtropical [except Ethiopean region] after Subías 2012). As a result, the junior synonymy of *P. insignis* and *P. manzanoensis* with *P. palustris* is proposed (syn. nov.). Additionally, *P. longiporosus* Balogh, 1963, a species from Angola, which occurs also in Madagascar, China and Oriental region (after Subías 2012) is suspected to be a junior synonym; if this proves correct, *P. palustris* is a cosmopolitan species.

Comments on the oribatid mite communities. Comparing the communities at the sites by means of a multivariate correspondence analysis, we can discriminate four distinct groups of communities: (1) at all salt marsh sites, (2) at all dune and rocky sites, (3) at the dune meadow, (4) at the floodplain forest. The ecological difference between the dune and the rocky sites is less distinct in this analysis than in a qualitative evaluation of species assemblages. Overall, the statistical approach results in a preliminary pattern of similarities and differences between the communities at the habitat types that needs further qualitative biological interpretation. Regarding the species dominance structure of the communities, we can discriminate five groups, each characterized by a particular set of species (species groups I–V in Table 1; cf. chapter 3.2.).

The salt marsh community of oribatid mites from Ribeiro de Aljezur looks quite specific compared with the communities from salt marshes of Faro lagoon (South Portugal) and Aveiro lagoon (North Portugal) as presented earlier (Weigmann 2008a). Only one halophilous species, *Hermannia pulchella*, a species with wide spread distribution in Atlantic salt marshes from southern to northern Europe, is common to all three Portuguese regions. Two further halophilous species with similar wide distribution, *Zachvatkinibates quadrivertex* and *Amneronothrus schneideri*, dominate the Portuguese salt marsh communities at Faro and Aveiro but seem absent at Ribeiro de Aljezur. In contrast, four species, *Xenillus halophilous*, *Scheloribates algarvensis*, *Humerobates rostrolamellatus* and *Scheloribates litoralis*, inhabit the Aljezur salt marshes but do not inhabit those at Faro and Aveiro. Apparently, the ecological conditions at Ribeiro de Aljezur are specifically affected by the river dynamics.

The sites group D and R with dune sand or rocky substrate show a remarkable internal similarity which is caused by 21 species in common (27 %) at the two habitat types, with 77 species overall. Yet there are only three dominant species in common in the dune and rocky habitats, *Ramusella clavipectinata*, *Minunthozetes quadriareatus* and *Zygoribatula frisiae*. Other species with remarkable abundance (groups III and IV) separate the dune community from that on rocky substrate, e.g. *Scutovertex arenocolus*, *S. mikoi*, *Pilogalumna ornatula*.

In 1990 Gil & Subías published a species list from the most south-western region of Portugal at Cabo de São Vicente, from a coastal bush-land being similar in ecological habitat characters to sites R1 and R2 of this study, which are situated about 40 km to the north of Cabo de São Vicente. Comparing the list with 62 species in Gil & Subías (1990; including taxonomic emendations in Subías & Gil 1990 and Subías & Gil-Martin 1995) with the findings from R1 and R2 (together 66 species; Table 1) about 30 of the 98 species found in the two studies are in common. The coastal bush-land in Western Portugal covers large areas from Cabo de São Vicente in the south of the Algarve to the north at Sines in the Alentejo, mainly in the Natural Park 'Costa Vicentina and Sudoeste Alentejano'. The heterogeneity of the coastal bush-land vegetation (cf. Costa et al. 2000), partly caused by human influences as plant cutting and ruderalization, probably relates to the high number of oribatid species and to some diversity of the communities.

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