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ORIBATID MITE COMMUNITIES IN ATLANTIC SALT MARSHES: AN ECOLOGICAL AND BIOGEOGRAPHICAL COMPARISON BETWEEN GERMAN AND PORTUGUESE SEA SHORES.

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Abstract

This contribution compares oribatid mite communities in salt marshes from Northern Germany (Sylt and Meldorf), Northern Portugal (Aveiro) and Southern Portugal (Faro), regarding the species composition and their dominance structures. Similar to the vertical zonation of the vegetation in the sites, the mite associations show characteristical vertical changes each. Yet, there is a more or less constant halophilous species stock in all regions, with *Ameronothrus schneideri*, *Zachvatkinibates quadrivertex* and *Hermannia pulchella*. Additional species characterize the median or upper salt marsh zones, contrasting between the three regions. The patterns of oribatid mite communities support biogeographical and ecological interpretations. As main factors the regional climate, the regional vegetation structure, the regular marine inundation and the substrate salinity are assumed.

Key-words

Oribatida, ecology, biogeography, Portugal, Germany

Introduction

The purpose of this study is to compare salt marsh communities of oribatid mites from southern and from northern Atlantic coasts of Europe with regard of possible biogeographic and ecological contrasts. From North Europe until the middle of the Portuguese Atlantic coast the vegetation aspect within the upper intertidal zone is more or less uniformly a grassy salt meadow. In the south of Portugal the aspect changes and we find predominantly halophilous scrubs in the respective intertidal zone, as can be observed in the middle-Atlantic and the Mediterranean regions. In all regions oribatid mites inhabit the eulittoral to supralittoral zones with salt vegetation of higher plants in differentiated species compositions and community patterns. The question arises whether the fauna of Oribatida follows the regional contrasts and the vertical vegetation zones of the salt marsh plants in a semiterrestrial to terrestrial sampling catena.

At the coasts of Portugal the oribatid mite communities of several areas with salt marsh vegetation were studied extensively in 1971 and additionally from 2003 to 2007; a publication of all results is in preparation. Within this contribution only the results from the Lagoon of *Faro* and from the Lagoon of *Aveiro* are presented which are supposed representative for the faunistic zonation of mite communities in salt marshes in southern and northern areas of Portugal. In the moderately warm climate of South Portugal the salt marshes are classified as "Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)", dominated by perennial vegetation of Chenopodiaceae (*Sarcocornia*, *Arthrocnemum*, *Atriplex, Suaeda*) (European Commission 2003). The studied area in the Lagoon of Faro (called " Ria

Formosa" by local ecologists; Machás & Santos 1999) includes wet salty intertidal plots of lower topographic level, similar plots of higher level, up to a dry adjacent slope of a dike on clay soil. The studied salt marshes in the Lagoon of Aveiro (called "Ria de Aveiro") are classified as „Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)", dominated by rush and grass species (*Juncus*, *Puccinellia*, *Festuca*) (European Commission 2003). The tidal dynamics and partly the water salinity are reduced in the lagoon (Mahowald et al. 2000).

The substrate of the lower zone of the sampling catena is sandy clay, that of the upper zone is sandy soil. The aspect of the vegetation is very similar to those in salt marsh meadows in northerly regions of Europe (from France to Denmark), but partly the same plant genera are represented by other species.

In salt marshes at the North Sea (west-coast of North Germany), classified as „Atlantic salt meadows", the oribatid mite communities were studied at several sites from 1966 to 1970 (Weigmann 1973). For this comparative analysis two areas in Germany were selected which look representative for two ecological variants of the vegetation zonation: At the shore of the Isle of *Sylt* the sampling catena is on sandy clay in the intertidal lower salt marsh and in a sandy dune area in the upper supralittoral zone; at the sampling catena near *Meldorf* all lower and upper salt marsh zones are characterized by heavy clay soil.

The selected sites give the possibility for biogeographical and ecological comparisons: (1) Portuguese vs. German salt marshes; (2) northern vs.southern salt marsh types in Portugal; (3); clay-dominated sites vs. sandy-clay sites: Faro vs. Aveiro sampling catena; Meldorf vs. Sylt sampling catena.

Material and Methods

Localities

Faro Lagoon (Portugal). Salt marsh areas in the western part of the lagoon, dominated by perennial vegetation of halophilous Chenopodiaceae (*Sarcocornia*, *Arthrocnemum*, *Atriplex, Suaeda*) in the topographical zones 2-4 with low to high level; zone 3 about 30-60 cm, zone 4 about 80 cm higher than zone 2. Zone 4 at an embankment of a moderately dry dam bordering salt marsh areas, with some *Sueda*, but dominated by non-salt-indicating plants. 10 sampling points.

Aveiro Lagoon (Portugal). Shores of the western border of the lagoon in the surrounding of Torreira and Costa Nova; localities with brackish and salty water and with salt marsh vegetation. Zone 2 with *Puccinellia* grass dominating, zone 3-4 with *Festuca rubra maritima* and *Juncus* dominating; zone 5 in the adjacent salt-tolerant meadow, with *Trifolium repens*, *Plantago maior*, *Bellis perennis*, grass species and others. 11 sampling points.

Meldorf (Germany). Salt marsh meadows on clay soil, near Meldorf; zone 2 dominated by *Puccinellia maritima*, zone 3 dominated by *Festuca rubra maritima*, zone 4 dominated by *Juncus gerardi* and *F. rubra maritima*. Zone 3 about 30 cm, zone 4 about 60 cm higher than zone 2 (details in Weigmann 1973). Monthly samples in two years.

Sylt (Germany). At the eastern shore (lee-side) of the Isle of Sylt. Sampling catenas near List and near Kampen from lower salt marsh level up to transition area salt marsh – dune complex; sand rich soils. Vegetation of zones 2-4 similar to that in Meldorf; zone 5 dominated by *Ammophila*, with some *Juncus gerardi, Festuca rubra maritima* and others. 15 sampling points.

Sampling and laboratory methods

The samples at each sampling point in Portugal were taken semi-quantitatively with a special shovel, about 250 cm², 1-2 cm depth. The mites were extracted using a modified Tullgren apparatus. The German samples were treated with a Macfaydyen-extractor. The specimens were stored in ethanol and after clearing they were studied microscopically in lactic acid in open hollow-ground microscope slides.

Oribatid mites determination and data treatment

The oribatid species from Portugal were determined with the Spanish text books of Perez-Iñigo (1993, 1997) and Subias & Arillo (2001) in combination with special literature, as cited in the text books, and with the German text book (Weigmann 2006), which was also thebasis for a redetermination of the German species. All sampling data of the mites were fused together for every locality and littoral zone, each, presented in table 1 as dominance percentages. The cluster analysis in figure 1 compares the communities of all sites after Southwood (1971), based on the dominance identities of each and all sites.

Results

Table 1 in the appendix presents the condensed data on the oribatid mite communities from the littoral zones of the four sites. The lowest zone 1 with pioneer vegetation (*Salicornia* or *Sarcocornia*) was very sparcely inhabited by oribatid mites, with similar species complex to that of zone 2, and these results are omitted. At the site Faro in zone 2 to 4 alltogether 16 species were collected; at the site Aveiro alltogether 18 species in zones 2 to 5, and 9 species from these in the zones 2 to 4. At the site Meldorf in zone 2 to 4 alltogether 13 species were collected; at the site Sylt alltogether 23 species in zones 2 to 5, and 13 species from these in the zones 2 to 4. As a general tendency, the species numbers increase from zone 2 to zone 5 (zone 4 in Faro is not fully representative in this regard because only one sampling point within this zone with about 250 cm² sampling size could be analyzed, including only 50 specimens).

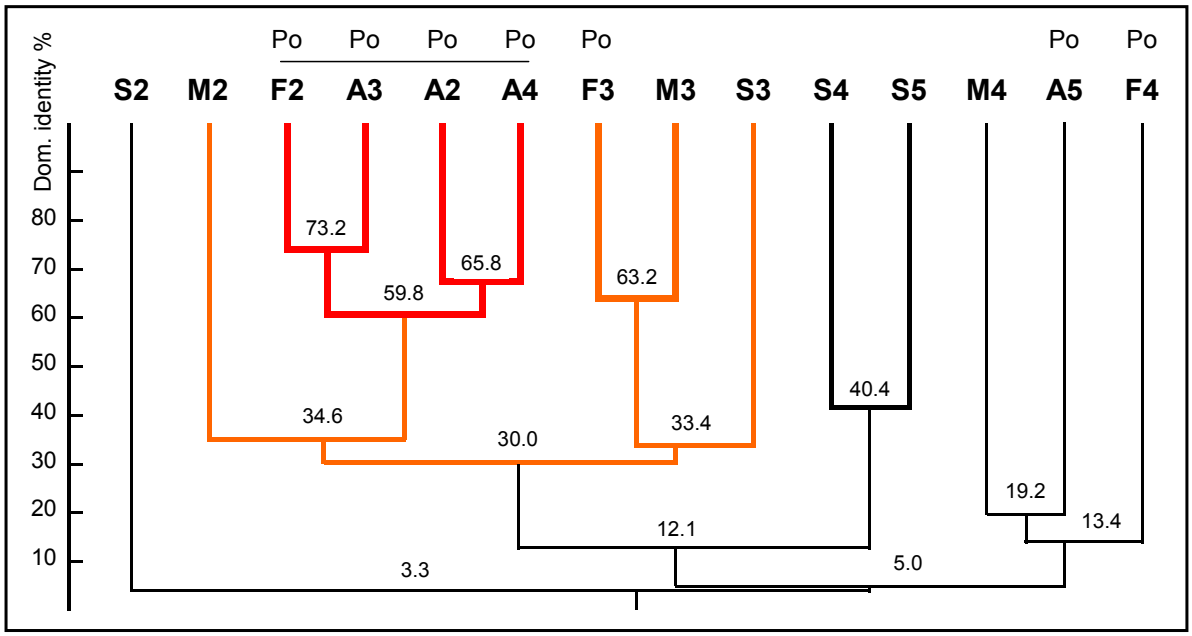

Figure 1. Cluster with the dominance identities (%) of the oribatid mite communities of the sites (S2-F4). Portuese sites indicated with *Po* (**A**: Aveiro; **F**: Faro); German sites (**S**: Sylt; **M**: Meldorf); numbers at the sites refer to the level in littoral zone

The species communities of every zone in the sites in Portugal and in Germany is compared with each other concerning the dominance identity. A high value indicates high sum of the dominance values of common species. The identity values are clustered in figure 1, resulting in small to larger subclusters of site/zone groups with descending species composition similarity.

A pure Portuguese subcluster in fig. 1 with high internal similarity is that formed by F2–A4 (in red). This subcluster is joined with site M2 from Germany; both together are joined with a mixed subcluster (F3–S3 with Portuguese and German sites) to a larger cluster (M2–S3; red and orange). This cluster with more than 30% internal dominance similarity is caused by high dominance values each of *Zachvatkinibates quadrivertex*, *Ameronothus schneideri* and partly of *Hermannia pulchella*. The first two species are dominant especially in the littoral zones 2 and 3, as indicated in figure 2 (cf. in detail in table 1), wereas *H. pulchella* prefers zones 3 and 4. Obviously, the clusters depend more on the ecological preferences of the dominant species than on the geographical position of the sites.

S2 fom the lower littoral level of the salt meadows in Sylt (Germany) is separated from all other site/zones whether being in low or high topographic level. This effect is caused by the extreme dominance of the halobiont species *Ameronothrus nigrofemoratus*, which occurs in Germany at sandy littoral salt marshes only, and which were not found in Portugal (cf. figure 2B).

A subcluster with S4–S5 from Sylt (Germany) is caused by common dominance of some salt tolerant and more or less eurytopic species (cf. figure 2B, second group of species).

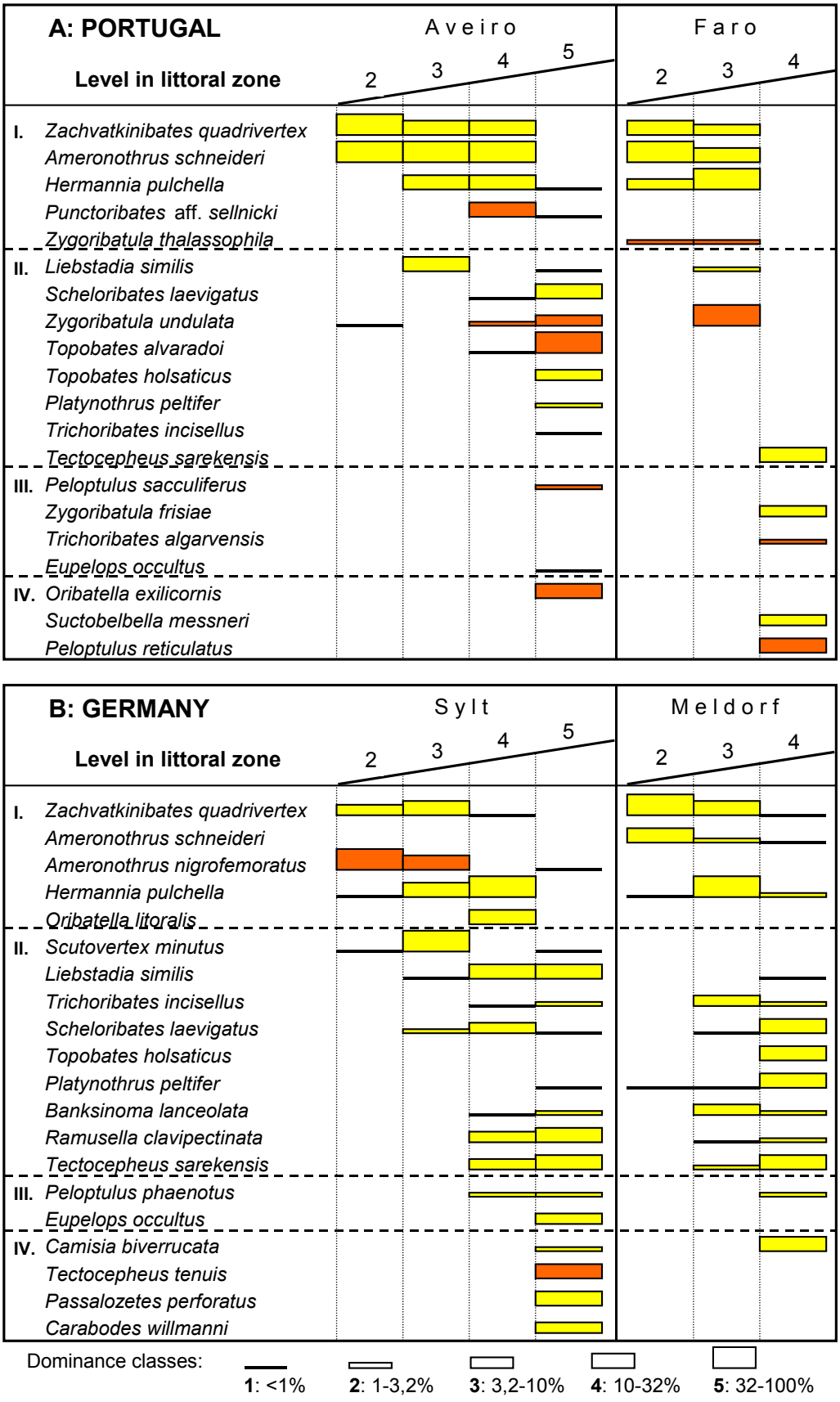

Figure 2. Occurrence of important species in the littoral zones in Portugal and in Germany (dominance classes). In yellow: species in both countries; in orange: in one only.

Figure 2 includes the most dominant 20 species each from Portugal and from Germany, with more than 2 % dominancy at least in one site (exceptionally *Oribatula tibialis* and *Dissorhina ornata* not included; see Table 1). The species of both regions are grouped together in four groups with different ecological preferences. Species in common in the Portuguese (resp. Iberian) and German region are coloured yellow, the species with ocurrence restricted to Portugal or Germany are marked in orange.

The first group of species in figure 2A and 2B consists of halobiont species, which occur in salty habitats only. In the lower littoral zone 2 of all sites in Portugal and Germany, where the salt marsh is flooded nearly daily during tidal high waters the halobiont species *Zachvatkinibates quadrivertex* and *Ameronothrus schneideri* are dominant; yet on the sandy substate of Sylt in Germany *A. schneideri* is substituted by *A. nigrofemoratus*. *Hermannia pulchella* has relevant dominance values in zones 2 to 4, mostly with optimum in zone 3, where the marine water inundation is less regular. *Oribatella litoralis* is a characteristic species in dryer salt marsh meadows of the zone 4 of the Sylt site (the species occurs in the upper salt marsh also in Portugal at the shore of the Minho River (own unpublished records) and in other German dry littoral sites). *Puncoribates* aff. *sellnicki* seems to prefer the upper zone 4 in the lagoon of Aveiro; *Zygoribatula thalassophila* is less dominant in zone 2-3 of the Faro sites, a halobiont species descibed for the French Atlantic coast (Grandjean, 1935); both species do not occur in Germany. Summed up, even in the group of halobiont species the zones 2 to 4 are differently inhabited, probably following the decreasing salt and wetness status of the salt marsh zones from low to high topographic level.

The second group of species in figure 2A and 2B includes halotolerant species which are found as well in salty as in salt free habitats and which are not restricted to dry supralittoral zones; these species are more or less frequent "attendents in salt marsh communities" (Weigmann 1973), and some species are common for both studied regions. Most of these species prefer the upper topographic levels of zones 4 to 5. All species in the German sites inhabit Iberian localities also (Subias & Gil-Martin 1997). But in the Portuguese sites, there are two species which were not found in Germany, up to now: *Zygoribatula undulata* and *Topobates alvaradoi*.

The third group of species in figure 2A and 2B includes species with supposed optimum in salt-free habitats which may be regarded as "guests" in the uppermost salt marsh zone 4 and the adjacent supralittoral zone 5. *Peloptulus sacculiferus* and *Trichoribates algarvensis* are found in Portugal only (Gil & Subias 1990).

The fourth group of species in figure 2A and 2B avoids the salt marsh zones 2-4 with regular marine influence and occurs only in adjacent dry habitats, as coastal dunes are (supralittoral zone 5 in figure 2). *Oribatula exilicornis* and *Peloptulus reticulatus* are not represented in Germany, whereas *Tectocepheus tenuis* is not recorded on the Iberian Peninsula.

Discussion

Most of all, the distribution of the halophilous oribatid mites is important in the scope of this study. Generally, there is present a constant and dominant complex of halophilous species in the salt marsh zones from North Germany to South Portugal including *Zachvatkinibates quadrivertex*, *Ameronothrus schneideri* and *Hermannia pulchella*. (In the Sylt site from Germany *A. schneideri* is substituted by *A. nigrofemoratus*, which is most probably caused by the sandy substrate in the Sylt littoral zone; cf. Weigmann 1973). These "indicator species" for littoral salt marshes do not discriminate between the Southern Portuguese salt vegetation with scrub plants and the Northern Portuguese and German salt vegetation of the grassy type. A similar ecological preference of low salt marsh zones by these species was described by Luxton (1964, 1967) for British coasts and by Weigmann (1973) for some more German sea shore sites.

Zachvatkinibates quadrivertex is most abundant in the lower littoral zones in all studied sites in Germany and Portugal, whereas *Hermannia pulchella* prefers the medium and upper salt marsh zones in all sites and therefore is less dominant in the lower zone 2. In the site Meldorf, Weigmann (1973) recorded some ecological key data over two years: the zone 2 with highest abundance of *Z. quadrivertex* and *Ameronothrus schneideri* is characterized by about 220 marine tidal inundations per year and regularly by high soil wetness. Zone 3 with highest abundance of *Hermannia pulchella* (at that time determined as *H. subglabra*) is characterized by about 90 inundations per year and by moderate soil water content, in mean. Both zones do not differ significantly in the fluctuating soil salt contents (zone 2 with 0,7-3,0 %; zone 3 with 0,3-2,8 % salinity).

Other halophilous oribatid species, which are included in the first group of species in figure 2, were found only at one site each. *Punctoribates* aff. *sellnicki* is a species new for science, which was recorded only at the Aveiro site with more than 70 specimens, mostly in the topographical zone 4, which is characterized by salt meadow vegetation in the comparatively seldom inundated level. *Zygoribatula thalassophila* was described from the shore of the Bretagne in France (Grandjean 1935); this new finding in the Lagoon of Faro is the second one (as far as I know) and confirms the assumed ecological preference for salty habitats. The biogeographical preference is incertain.

Ameronothrus nigrofemoratus was found at the Sylt site only; it is a holarctic species with a distribution in arctic to moderately cold climates, occuring in Europe in Atlantic salt marshes northern than France (Schulte 1975). It has been recorded in sandy salt marshes in Germany and Denmark (Weigmann 1973; Koehler et al. 2008). *Oribatella litoralis* inhabits moderately dry and salty zones in coastal meadows at some German localities (Strenzke 1952; Weigmann 1973; Koehler et al. 2008). It was declared as nominal species of the "*Oribatella arctica litoralis* synusia of salt meadows" at the German Atlantic coast by Strenzke. Within this study it occurs at Meldorf only; yet, a new record in Northern Portugal (salt marsh at the Rio Minho: Weigmann, unpublished) expands the geographical range to South Europe.

Within the species group II in figure 2, there are some widely distributed "meadow species" in common at the Aveiro site in Portugal and the German sites, as *Liebstadia similis*, *Scheloribates laevigatus*, *Topobates holsaticus*, *Platynothrus peltifer* and *Trichoribates incisellus.* This may be due to the vegetation similarity within these sites contrasting to the Faro site. Besides *Ameronothrus nigrofemoratus* In figure 2, there is only *Tectocepheus tenuis* restricted to a German site. In contrast, there are several species restricted to Portuguese sites: *Punctoribates* aff. *sellnicki*, *Zygoribatula thalassophila, Zygoribatula undulata, Topobates alvaradoi, Peloptulus sacculiferus, P. reticulatus, Oribatella exilicornis* and other seldom species (see table 1). All these species (except *P. reticulatus*) were never recorded in Central or Northern Europe and indicate a biogeographical differentiation.

Summed up, the community pattern similarities and contrasts between the studied sites can explained partly by biogeographical distributions of species, partly by their ecological reactions. The zonation patterns within each site show obvious similarities between the localities in both countries, at least regarding the lower zones of the littoral habitats.

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Appendix

Table 1. Dominance values (%) of all oribatid mite species

	PORTUGAL							GERMANY						
	AVEIRO				FARO			SYLT				MELDORF		
Site code and littoral zone	**A2**	**A3**	**A4**	**A5**	**F2**	**F3**	**F4**	**S2**	**S3**	**S4**	**S5**	**M2**	**M3**	**M4**
Ameronothrus nigrofemoratus (L. Koch, 1879)								95,8	18,4		0,2			
Ameronothrus schneideri (Oudemans, 1903)	49,7	53,4	34		73,6	21,8						15,9	1,3	0,2
Astegistes pilosus (C. L. Koch, 1841)										0,3				
Banksinoma lanceolata (Michael, 1885)										0,3	1		6,7	2
Camisia biverrucata (C. L. Koch, 1839)											1,9			13,7
Camisia spinifer (C. L. Koch, 1835)											0,2			
Carabodes marginatus (Michael, 1884)											0,8			
Carabodes willmanni Bernini, 1975											8,1			
Dissorhina ornata (Oudemans, 1900)											2,1			
Eupelops occultus (C.L. Koch, 1835)				0,4							8,5			
Eupelops sp.				0,4										
Galumna obvia (Berlese, 1915)				0,4										
Hermannia pulchella Willmann, 1952		22,5	19,9	0,4	9,7	68,2		0,2	20,1	36,4		0,1	58,7	1,3
Humerobates rostrolamellatus Grandj., 1936			0,4			0,4								
Liebstadia similis (Michael, 1888)		13,5		0,4		3,1			0,3	18,5	17,2			0,8
Malaconothrus monodactylus (Michael 1888)				0,4										
Oribatella exilicornis Berlese, 1910				6,3										
Oribatella litoralis Strenzke, 1950										16,4				
Oribatula tibialis (Nicolet, 1855)					2,4	0,4								
Passalozetes perforatus (Berlese, 1910)											11			
Peloptulus phaenotus (C.L. Koch, 1844)										2,4	2,7			1,8
Peloptulus reticulatus Mihelcic, 1957							30							
Peloptulus sacculiferus Weigmann, 2008				1,1										

Table 1 ff

	AVEIRO				FARO			SYLT				MELDORF		
Site code and littoral zone	**A2**	**A3**	**A4**	**A5**	**F2**	**F3**	**F4**	**S2**	**S3**	**S4**	**S5**	**M2**	**M3**	**M4**
Platynothrus peltifer (C.L. Koch 1839)				2,9							0,2	0	0,6	21,1
Pulchroppiella plurisetosa (Mihelcic, 1956)						0,4								
Punctoribates aff *sellnicki* (Willmann, 1928)	0,4	0,6	31,7	0,8										
Quadroppia quadricarinata (Michael, 1885)											0,2			
Ramusella clavipectinata (Michael, 1885)										9,6	19,7		0,2	1,6
Scheloribates laevigatus (C.L. Koch, 1835)			0,4	11,3					2,3	8,1	0,2		0,1	10,6
Scheloribates sp. 7					0,3									
Scutovertex minutus (C. L. Koch, 1835)								0,3	35,2		0,4			
Suctobelbella messneri Moritz, 1971							4							
Tectocepheus sarekensis Trägardh, 1910							18			7,2	10,4		2	23,4
Tectocepheus tenuis Knülle, 1954											13			
Topobates alvaradoi (Perez-Inigo, 1969)			0,4	61,4										
Topobates holsaticus Weigmann, 1969				4,5										20,8
Trichoribates algarvensis (Subias & Gil, 1990)							2							
Trichoribates incisellus (Kramer, 1897)				0,4						0,3	2,1		5,8	2,5
Xenillus tegeocranus (Hermann, 1804)						0,6								
Zachvatkinibates quadrivertex (Halbert, 1920)	49,7	10,1	11,3		11,2	3,2		3,7	23	0,6		84	24,6	0,3
Zygoribatula friesiae (Oudemans, 1900							6							
Zygoribatula thalassophila Grandjean, 1935					2,8	1,8								
Zygoribatula undulata Berlese, 1916	0,2		1,8	8,8			40							
species	**4**	**5**	**8**	**15**	**6**	**9**	**6**	**4**	**6**	**11**	**19**	**4**	**9**	**13**
Sum of all species at a site		**18**				**16**				**23**			**13**	
Sum of specimens	304	178	274	342	223	406	50	574	304	335	517	4716	849	1743