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ARTICLE

First comprehensive insights into the biogeography of the Caribbean intertidal oribatid mite fauna (Ameronothroidea)

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ABSTRACT

A decade ago the Caribbean was almost completely uncharted in terms of intertidal ameronothroid mites. Now the present data show that these organisms are a common component of the fauna of Caribbean shorelines. Two families of Ameronothroidea are present, the Fortuyniidae with three genera and four species and the Selenoribatidae with five genera and nine species. The most common species are the fortuyniid *Alismobates inexpectatus* and the selenoribatid *Carinozetes mangrovi*, both taxa were found in the Northern Caribbean, the Greater and Lesser Antilles as well as on Central American coasts. Six species are endemic to the Caribbean, *Litoribates bonairensis, L. floridae, Schusteria marina, Thalassozetes balboa, T. barbara* and *Thasecazetes falcidactylus*. Biogeographic patterns suggest that the genera *Carinozetes* and *Litoribates* may have evolved and diversified in the Caribbean region and that the Western Atlantic Bermudian intertidal oribatid mite fauna was largely shaped by Caribbean colonizers. Most of the species found in the Caribbean are typical rock dwellers and only a minority is represented by exclusive mangrove specialists. These species are seriously threatened by the significant progressive decline of mangrove ecosystems throughout the Caribbean.

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Fortuyniidae; Selenoribatidae; Central America; distribution; mangroves

Introduction

The Caribbean region comprises vast stretches of North, Central and South American coastlines and consists of several large landmasses known as the Greater Antilles and numerous smaller Islands, namely the Lesser Antilles, the Bahamas and the Turks and Caicos. This region represents a global biodiversity hotspot harbouring high levels of endemicity in plants and animals, with each of the subareas featuring a separate biota that fits together as a biogeographic unit [1]. This high biodiversity is a result of the complex and unique geographic history of the Caribbean. It is suggested that a proto-Antillean landmass existed in the middle Eocene (49–37 Mya) which became fragmented in the Oligocene (~30 Mya) and thereby formed large parts of the Greater Antilles, and the Lesser Antilles emerged sequently in the late Miocene (10–3 Mya) mostly by volcanic activity [2]. These events are closely linked to the rise of the Central American Isthmus, which concluded around 2.8 Mya ago and led to the formation of two strikingly different realms, the Caribbean Sea and the eastern Pacific Ocean [3]. Due to this unique geological history, the Caribbean has been of special interest for dozens of evolutionary biologists investigating vicariance and dispersal models of distribution [4] whereas most studies and debates focussed on non-flying vertebrates and their possible colonization routes [5]. The heightened biological interest in this area led to a comprehensive knowledge of the Caribbean fauna in general but information about some of the smallest arthropods, namely the ubiquitous oribatid mites, has been lacking for a long time.

Some decades ago, Mahunka [6] stated that the greatest gaps in information about oribatid mite distribution worldwide concerned Central America and the West Indies. Subsequent studies slowly revealed the presence of numerous species at least in certain Caribbean areas. For example, Schatz [7] reported 543 species to be present in Central America, Perez-Gelabert [8] listed more than 30 species known from the Greater Antillean Island Hispaniola and other authors [9,10] reported more than 150 species mainly from the Lesser Antilles. These numbers point to a highly diverse oribatid mite fauna in the Caribbean.

However, most of these species are typical terrestrial oribatid mites dwelling in soil, leaf litter, tree trunks, canopy, etc., and only a few are also known to occur in coastal habitats. Several lohmannid species regularly occur in the littoral environment. For example, *Meristacarus porcela* was found in mangrove leaf litter in Guatemala [7], other oribatid species, e.g. *Peloribates antillensis* or *Cultrobates heterodactylus* were also found in mangrove leaf litter in Panama [7] and thus are known to show occasional incursions into the intertidal environment, but none of these taxa are exclusively intertidal organisms. Only a single species listed in the catalogue of Central American species [7],

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namely *Fortuynia yunkeri*, represents a typical marine-associated species.

In the tropics there are only two oribatid mite families which have adapted to the marine littoral environment, leading a life between the tides: the Fortuyniidae, comprising four genera, *Alismobates, Circellobates, Fortuynia* and *Litoribates*, with 26 species and the Selenoribatidae, consisting of nine genera, *Arotrobates, Carinozetes, Indopacifica, Psednobates, Rhizophobates, Schusteria, Selenoribates, Thalassozetes* and *Thasecazetes*, altogether with 32 species. Although their morphology basically conforms to that of typical terrestrial taxa, these mites have longer claws to cope with tidal wave action [11] and possess plastron respiration systems to breathe during tidal inundation [12,13]. They inhabit rocky cliffs, boulder beaches, concrete structures or mangroves where they feed on different types of intertidal algae [14]. Although the above-mentioned *F. yunkeri* was reported in the 1950s from Central America [15], it represents no Caribbean species sensu strictu because it was found on the Pacific coast of Panama. The first record of an intertidal ameronothroid mite from the Caribbean region, was that of an undetermined selenoribatid species from the Lesser Antillean St. Lucia [16] and over a decade later, the first record of an undetermined fortuyniid species from the Caribbean coast of Costa Rica [17] followed. These two vague reports indicated the presence of marine associated taxa but left researchers uncertain of the real distribution for more than 20 years. Pfingstl [18] provided the first definitive species record from the Caribbean by describing *Thalassozetes barbara* from Barbados and from then on, new records and new species were published nearly every year. Pfingstl and Schuster [19] showed occurrences of three genera, *Alismobates, Fortuynia* and *Carinozetes*, on coasts of Barbados and the Greater Antilles and Pfingstl et al. [20] reported *Alismobates inexpectatus, Carinozetes mangrovi* and *T. barbara* from the coasts of Hispaniola. Shortly after, several new species were described, including *Schusteria marina* from Grenada and Martinique [21], *Litoribates bonairensis* and *Thasecazetes falcidactylus* from Bonaire [22], *Litoribates floridae* from Florida and *Thalassozetes balboa* from Panama and Florida [23]. The most recent publication [24] demonstrated a trans-Caribbean distribution of the selenoribatid *C. bermudensis* and *C. mangrovi*. In view of these recent findings it is evident that these intertidal oribatid mites are most likely a common component of the Caribbean intertidal fauna.

Most of the recent Caribbean records are a result of a three year project which yielded more yet unpublished data on the distribution of intertidal oribatid mites. Therefore, this paper aims to provide a foundation for taxonomic and biogeographic work on Caribbean intertidal mites by (1) reviewing and summarizing all existing records in literature, (2) adding yet unpublished data and compiling comprehensive up-to-date distribution information and (3) discussing biogeographic patterns.

Materials and methods

During a three-year project (2016–2019) on the biodiversity of intertidal oribatid mites, samples were collected on three field trips to different Caribbean regions. Samples of intertidal algae were scraped off the substrate (e.g. rock, mud, mangrove roots, etc.) with a knife, mostly during low tide and afterwards put in Berlese-Tullgren funnels for approximately 24 hours to extract living mites. Specimens were then picked with a fine brush and stored in absolute ethanol for transport and further investigation.

Voucher specimens from Caribbean regions are deposited in the following institutions (collection numbers are given only when provided by the museum; additionally, accession numbers for DNA-sequences archived in GenBank [https://www.ncbi.nlm.nih.gov/genbank/] are given): (a) Dominican Republic/Museo Nacional de Historia Natural "Prof. Eugenio de Jesús Marcano", Santo Domingo, *Alismobates inexpectatus* (MNHNSD 08.432, 08.433), *Carinozetes mangrovi* (MNHNSD 08.428–08.431) and *Thalassozetes barbara* (MNHNSD 08.426, 08.427); (b) Barbados/Natural History Museum Vienna, *T. Barbara* (NHMW 21,887); (c) Bonaire/Senckenberg Museum für Naturkunde Görlitz, *Litoribates bonairensis* (SMNG 56,670), *Thasecazetes falcidactylus* (SMNG) (56,671), GenBank accession nrs. MF997501-03; (d) Panama/Museo de Invertebrados Fairchild, Universidad de Panamá, *A. inexpectatus, C. mangrovi, T. balboa*, GenBank accession nrs. MK035018-19, (e) Florida/US National Museum, *Litoribates floridae*, GenBank accession nrs. MK035001-6; (f) Martinique/Senckenberg Museum für Naturkunde Görlitz, *Schusteria marina* (SMNG 56,570). Voucher specimens from yet unpublished records (see Table 2) are deposited in the collections of Senckenberg Museum für Naturkunde Görlitz, Germany and also in the collection of the Institute of Biology, University of Graz.

Distribution patterns are based on published literature and on numerous yet unpublished records. Apart from already published records, specimens from all Caribbean populations were determined to species level (morphospecies) to provide detailed overview of species distributions. For better orientation, the Caribbean region was partly divided into four larger geographic areas, the Greater Antilles, the Lesser Antilles, Central America and the Northern Caribbean, and these are given in the text and tables. Although not strictly Caribbean, certain records from the Pacific coast of Panama are also included in the table and the graphs. The vague Caribbean reports of Fortuyniidae

gen. sp. and Selenoribatidae gen. sp [16,17] were added to the maps showing the distribution of families but were omitted from the maps showing the occurrence of species because original material could not be accessed and thus not be identified to species level.

For photographic documentation, a specimen was air-dried and photographed using a Keyence VHX-5000 digital microscope with automated image stacking.

Maps were created using the free and open-source vector graphics editor Inkscape (https://inkscape.org) and graphs were further processed with Adobe Photoshop 7.0.

Results

Distribution of families

Recent research has uncovered the presence of Fortuyniidae and Selenoribatidae in the whole Caribbean region. Members of both families can be found along coastlines of the Greater and Lesser Antilles, Central America and the Northern Caribbean (Figure 1, Table 1) and show more or less consistent distributions. In Puerto Rico, Martinique and St. Lucia only selenoribatid mites have been reported so far but this may be due to low sampling activities in the respective locations. The Fortuyniidae are represented in the Caribbean by four species from three different genera, *Alismobates inexpectatus, Fortuynia atlantica, Litoribates bonairensis, Litoribates floridae*, and the Selenoribatidae by nine species from five different genera, namely *Carinozetes bermudensis, Carinozetes mangrovi, Carinozetes trifoveatus, Schusteria marina, Selenoribates quasimodo, Selenoribates satanicus, Thalassozetes balboa, Thalassozetes barbara* and *Thasecazetes falcidactylus*. Four of the species, *F. atlantica, C. trifoveatus, S. quasimodo* and *S. satanicus* are reported herein for the first time from the Caribbean (Table 2).

Distribution Fortuyniidae

Greater Antilles – There are relatively few records of fortuyniid species from the Greater Antilles. In the Dominican Republic *A. inexpectatus* and *F. atlantica* were found whereas the latter was only recorded from the Northern coast of the Samaná peninsula and the former was sampled from Samaná and from Boca Chica at the Southern coast (Figure 2). On Jamaica, only *F. atlantica* is known to occur.

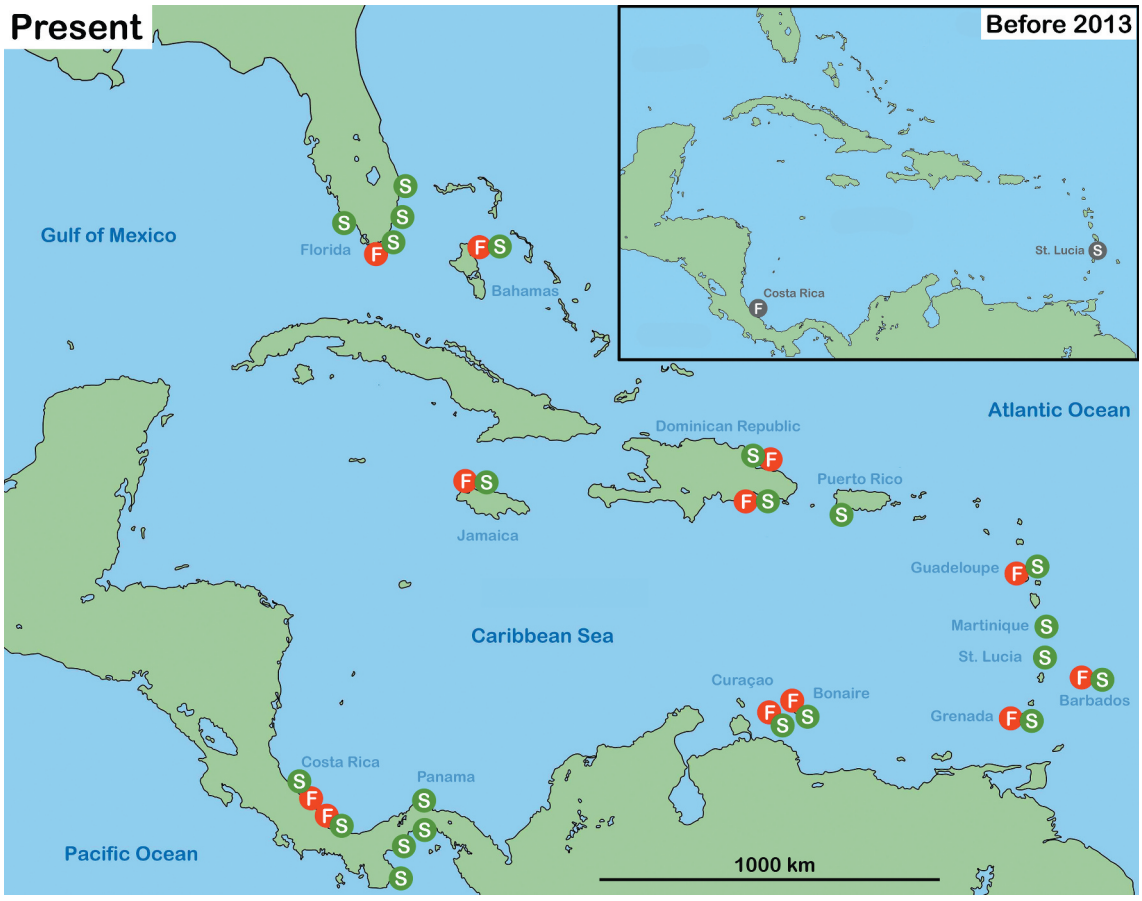

Figure 1. Graph highlighting how knowledge about the distribution of intertidal oribatid mites in the Caribbean area has changed over the last few years. Right insert showing records known before 2013; large map giving present state of knowledge for the two families occurring in this area. F = Fortuyniidae, S = Selenoribatidae.

Table 1. Records of intertidal oribatid mite species in the Caribbean, divided into four geographic areas. Records without numbers represent yet unpublished occurrences.

Taxon	Greater Antilles	Lesser Antilles	Northern Caribbean	Central America
Fortuyniidae				
A. inexpectatus	Dom. Rep. [20]	Barbados, Curaçao, Guadeloupe	Bahamas, Florida	Costa Rica, Panama
F. atlantica	Dom. Rep. [19], Jamaica	Barbados, Grenada, Guadeloupe	Bahamas, Florida	-
L. bonairensis	-	Bonaire [22]	-	-
L. floridae	-	-	Florida [23]	-
Selenoribatidae				
C. bermudensis	-	Bonaire [24]	Bahamas [24]	Costa Rica [24], Panama [24]
C. mangrovi	Dom. Rep. [20,24], Jamaica [24], Puerto Rico [24]	Barbados, Grenada [24], Guadeloupe [24], Martinique [24]	Bahamas [24], Florida [24]	Panama [24]
C. trifoveatus		Barbados	Florida	Panama
Sch. marina	-	Grenada [21], Martinique [21]	-	-
Sel. quasimodo	-	-	-	Costa Rica, Panama
Sel. satanicus	-	Bonaire	-	Panama
Thal. balboa	-	-	Florida [23]	Panama [23]
Thal. barbara	Dom. Rep. [20]	Barbados [18], Curaçao, Grenada, Guadeloupe, Martinique	Bahamas	-
Thas. falcidactylus	-	Bonaire [22]	Florida	-

Lesser Antilles – *Fortuynia atlantica* occurs on Grenada, Guadeloupe and Barbados. *Alismobates inexpectatus* was also found on the latter two islands and additionally on Curaçao. From Bonaire there is only one fortuyniid species known, namely *Litoribates bonairensis*, which seems to be endemic for this island up to now.

Northern Caribbean – *Alismobates inexpectatus* und *F. atlantica*, both occur in Florida and the Bahamas. So far, all records made in Florida were only from the Florida Keys but here they are known from various landmasses of this chain of islands (Key Largo to Marathon). The records from the Bahamas only relate to New Providence Island, both species were found all over the island. *Litoribates floridae* (Figure 3) was only found on Islamorada, one of the islands of the Florida Keys and seems to be endemic for this area.

Central America – There are no reports of *F. atlantica* from Caribbean Central American coasts but *A. inexpectatus* was found on Isla Colón and Isla Bastimentos in Panama and on a beach in Manzanillo, Costa Rica.

Distribution Selenoribatidae

Greater Antilles – *Carinozetes mangrovi* is apparently widespread in the Greater Antilles with records from the Dominican Republic, Jamaica and Puerto Rico (Figure 4). *Thalassozetes barbara* is the second selenoribatid species known from the Greater Antilles and was reported from the north and south coast of the Dominican Republic.

Lesser Antilles – Bonaire harbours three selenoribatid species, *C. bermudensis, S. satanicus* and *T. falcidactylus* whereas these occurrences are the only findings of these species in the Lesser Antilles. *Schusteria marina* was reported from Martinique and Grenada and *C. trifoveatus* was only found on Barbados. *Carinozetes mangrovi* and *T. barbara* show the widest distributions in the Lesser Antilles, with the

Table 2. Details of first Caribbean records of four different intertidal oribatid mite species. TP = Tobias Pfingstl, AL = Andrea Lienhard, GK = Gernot Kunz, HS = Heinrich Schatz.

	country/region	location	date	coordinates	collector
Fortuynia atlantica	Jamaica	Discovery Bay	19.08.2012	18°28 10.13″N 77°24 56.96″W	TP
	Barbados	Bathsheba	25.02.2017	13°12 48.53″N 59°31 04.94″W	TP, AL
		Bridgetown	26.02.2017	13°04 58.51″N 59°36 35.38″W	TP, AL
		Oistins	27.02.2017	13°03 50.76″N 59°32.42.70″W	TP, AL
	Grenada	La Sagesse	27.02.2016	12°01 22.19″N 61°40 24.79″W	TP, AL
	Guadeloupe	Bois Jolan	20.02.2016	16°14 12.59″N 61°20 52.42″W	TP, AL
	Bahamas	Love Beach	19.02.2017	25°03 47.69″N 77°29 22.16″W	TP, AL
		Goodman Bay	19.02.2017	25°04 18.89″N 77°23 00.40″W	TP, AL
		South Beach	20.02.2017	25°01 04.89″N 77°32 48.67″W	TP, AL
		Jaws Beach	20.02.2017	25°04 15.67″N 77°18 24.73″W	TP, AL
		Montagu Beach	21.02.2017	25°03 58.17″N 77°18 17.95″W	TP, AL
	Florida	Islamorada	13.02.2017	24°53 36.32″N 80°40 09.10″W	TP, AL
Carinozetes trifoveatus	Barbados	Bathsheba	25.02.2017	13°12 48.53″N 59°31 04.94″W	TP, AL
	Florida	Marathon	13.02.2017	24°45 03.41″N 80°57 46.23″W	TP, AL
	Panama	Playa Venao	04.02.2017	7°25 35.33″N 80°12 22.58″W	TP, AL
		Playa Toro	04.02.2017	7°31 33.91″N 79°59 58.62″W	TP, AL
Selenoribates quasimodo	Costa Rica	Punta Mona	12.02.2018	9°38 21.97″N 82°38 58.37″W	GK
	Panama	Isla Colon	07.02.2017	9°21 08.52″N 82°15 31.15″W	TP, AL
Selenoribates satanicus	Bonaire	Lac Bay	24.04.2016	12°06 17.12″N 68°13 11.85″W	HS
	Panama	Lago Miraflores	02.02.2017	9°00 38.41″N 79°35 45.14″W	TP, AL
		Bocas del Toro	07.02.2017	9°23 21.98″N 82°14 13.47″W	TP, AL

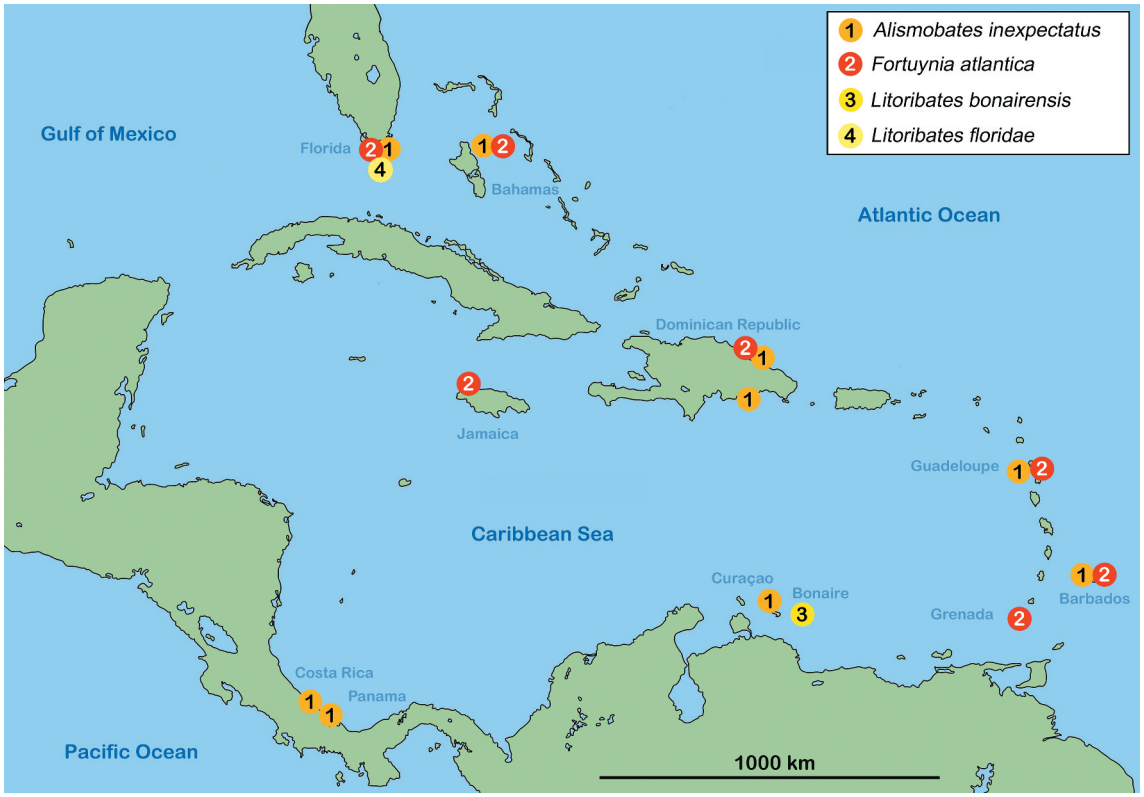

Figure 2. Map of the Caribbean showing distribution of fortuyniid species in this geographic region.

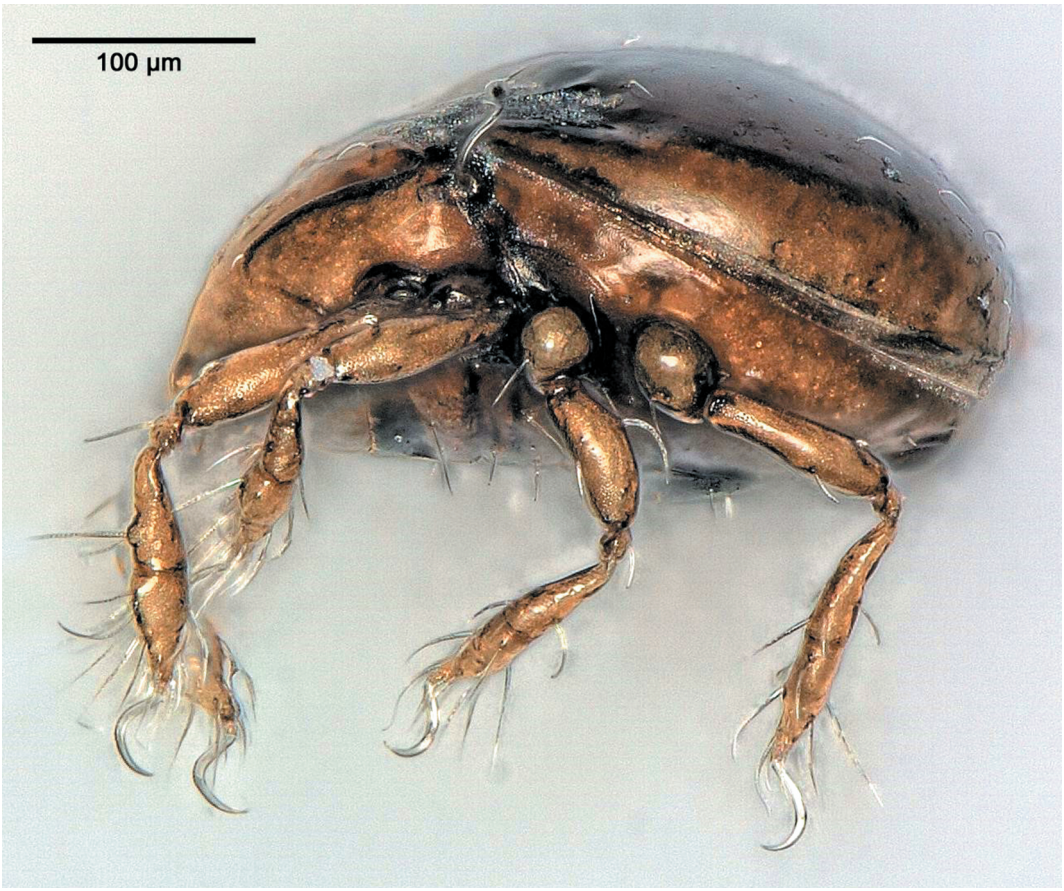

Figure 3. Stacked stereomicroscopic image of Caribbean endemic *Litoribates floridae* in lateral view.

former occurring on Barbados, Grenada, Guadeloupe and Martinique and the latter on Barbados, Curaçao, Grenada, Guadeloupe and Martinique.

Northern Caribbean – Again the reports from the Bahamas only relate to New Providence Island but here *C. bermudensis, C. mangrovi* and *T. barbara* were

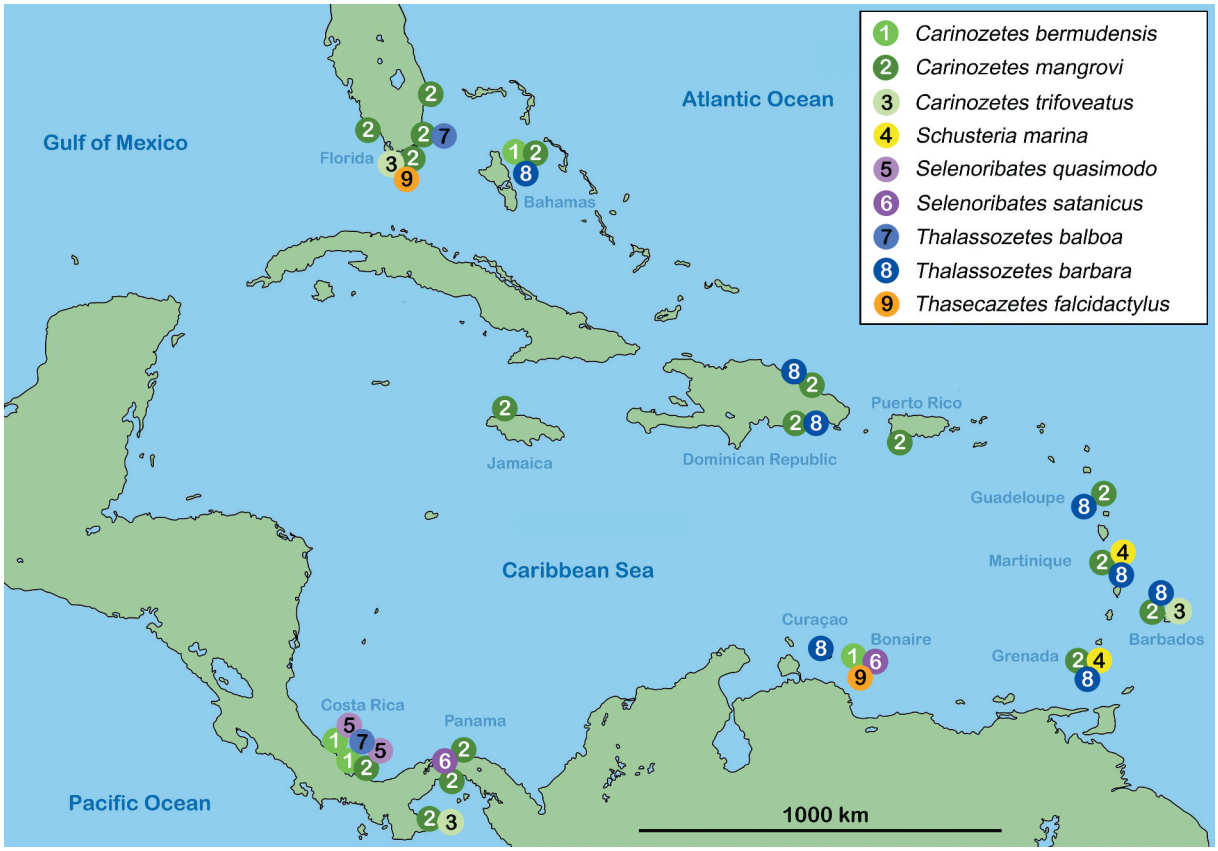

Figure 4. Map of the Caribbean showing occurrences of selenoribatid species in this geographic region.

found on several locations whereas *C. mangrovi* was most abundant in the mangroves of South Beach and *T. barbara* on the rocky northern shore (e.g. Compass Point, Paradise Island). *Carinozetes mangrovi, C. trifoveatus, T. balboa* and *T. falcidactylus* are all occurring in Florida. Apart from *C. mangrovi*, all species were only found in single locations, *C. trifoveatus* and *T. falcidactylus* on the Florida Keys (Marathon, Islamorada) and *T. balboa* on Key Biscayne in Miami City. *Carinozetes mangrovi*, on the other hand, was found in high numbers at various locations, i.e. West Palm Beach, Miami, Florida Keys and even in Naples and Bonita Springs at the Gulf of Mexico.

Central America – The coasts of Panama are quite diverse in terms of selenoribatid species, six different species are known to occur here. *Carinozetes trifoveatus* was found at the Pacific coast of Panama whereas *C. bermudensis, T. balboa* and *S. quasimodo* were found at the Caribbean shoreline of Panama. *Carinozetes mangrovi* was the only species which was found in high numbers at various locations at both the Pacific and the Caribbean coast of Panama. *Selenoribates satanicus* was found on Isla Colón and was sampled from the shore of the Panama Canal approximately eight kilometres away from the open ocean which represents a quite unique finding. From the Caribbean coast of Costa Rica, so far, only two selenoribatid species are known from a single location, namely *C. bermudensis* and *S. quasimodo*.

Ecological remarks

Based on literature records and comprehensive sampling in the years 2016–2018, the Caribbean species can be classified into three ecological categories (Table 3): rock dwellers, mangrove inhabitants and euryoecious species occurring on rocks as well as in mangrove habitats. Typical rock dwellers are *A. inexpectatus,*

Table 3. Occurrences in different environments (rocky and mangrove habitats) of the Caribbean species based on 109 samples taken in the years 2016–2018. R – rock dweller; E – euryoecious species; M – mangrove dweller.

Taxon	rock	mangrove	class
Fortuyniidae			
Alismobates inexpectatus	25	1	R
Fortuynia atlantica	14	2	R
Litoribates bonairensis	0	2	M
Litoribates floridae	0	2	M
Selenoribatidae			
Carinozetes bermudensis	3	2	E
Carinozetes mangrovi	25	21	E
Carinozetes trifoveatus	4	0	R
Schusteria marina	1	1	E
Selenoribates quasimodo	2	0	R
Selenoribates satanicus	0	1	M
Thalassozetes balboa	2	0	R
Thalassozetes barbara	35	1	R
Thasecazetes falcidactylus	0	2	M

F. atlantica, C. trifoveatus, S. quasimodo, T. balboa and *T. barbara*, all of these species were found on rocky substrates in more than 90% of all samples. Typical mangrove species are *L. bonairensis, L. floridae* and *T. falcidactylus*, whereas they were found without exception in mangrove leaf litter. *Carinozetes mangrovi, C. bermudensis* and *S. marina* are euryoecious species, they occurred nearly equally in rocky environments and mangrove habitats, whereas these mangrove habitats were mostly mangrove roots overgrown with intertidal algae. *Selenoribates satanicus* is difficult to classify because it was found only in two samples, once in mangrove leaf litter and once in leaf litter from the shore of the Panama Canal which does not represent a mangrove habitat.

With regard to the ecological classification, species belonging to the same group, were often found together at the exact same location. In nearly 50% of all samples at least two species occurred syntopically, in less than 10% a maximum of three species was found in the same patch of algae. *Alismobates inexpectatus* and *T. barbara* were found most frequently together, followed by *A. inexpectatus* and *F. atlantica. Carinozetes trifoveatus, T. balboa* and *T. barbara*, on the other hand, never occurred syntopically.

Discussion

Apart from some terrestrial oribatid mite species that were occasionally found in Caribbean littoral environments, for example *Meristacarus porcela* in Guatemala and *Peloribates antillensis* and *Cultrobates heterodactylus*, both in Panama [7], the Caribbean intertidal environment was almost completely uncharted in terms of intertidal oribatid mites before 2013, and it was unknown if these mites do really exist there. The present data clearly confirm the occurrence of Fortuyniidae and Selenoribatidae in the Caribbean and show that these families are distributed throughout this region representing a common component of the local intertidal fauna. There are still large gaps in the distribution, for example along the South American shoreline, Cuba, northern Central America, which are without a doubt caused by the lack of sampling activities in these areas.

Most of the genera present in the Caribbean can be found in the subtropics and tropics all over the world but *Carinozetes, Litoribates* and *Thasecazetes* are so far confined to the Caribbean and adjacent regions, namely the Western Atlantic and the Eastern Pacific [25,26], suggesting the evolutionary origin of these taxa in these regions. Pfingstl and Lienhard [21] already stated that *Carinozetes* may be derived from an ancestral Western Atlantic *Schusteria* clade and the present data support this assumption. Apart from *S. marina* in the south-western area of the Caribbean, *Schusteria* is completely lacking in this region whereas *Carinozetes* is present throughout the Caribbean which indicates that this genus most likely evolved and diversified in this area. The records of *Carinozetes* from the Eastern Pacific further show that the genus has evolved and spread long before the closure of the Central American Isthmus approximately 2.8 mya ago [3]. A similar evolutionary scenario is assumable for *Litoribates* as its absence from Western Atlantic areas suggests an Eastern Pacific ancestry. The monotypic *Thasecazetes*, on the other hand, is restricted to the Caribbean but records are yet so scarce that it is impossible to make any assumptions concerning its biogeographic history.

Prior to this study, many of the present species were only known from Bermuda in the Western Atlantic, and based on the young geological age of this archipelago it was assumed these species are derived from populations somewhere in the Caribbean [27]. Bermuda is situated in the Gulf Stream and intertidal oribatid mites are thought to be mainly transported between landmasses by drifting along ocean currents [27]. Transport along the Gulf Stream from North- and Central America to Bermuda has been hypothesized for several terrestrial lohmannid species, for example *Lohmannia similis* and *Meristacarus porcela*, two mite species also known to often occur in the littoral zone [28]. Moreover, based on experimentally inferred survival times, it was demonstrated that *Fortuynia atlantica* and *Carinozetes bermudensis* theoretically could survive transport along the Gulf Stream from Central America to Bermuda [27]. The present data confirm this biogeographic link and suggest that the Bermudian intertidal mite fauna was largely shaped by Caribbean colonizers. It is likely that Caribbean ocean currents and gyres play an important role in the dispersal of these coastal associated organisms but final evidence is still lacking.

However, in Fortuyniidae and Selenoribatidae there seem to be species with wide distribution areas and only a few with strongly limited occurrences. The fortuyniid *A. inexpectatus* and *F. atlantica* and the selenoribatid *C. mangrovi* and *T. barbara* show a trans-Caribbean occurrence indicating high dispersal potential and most other species show either a disjunct distribution or at least a wider distribution in larger geographic areas of the Caribbean. Only *Litoribates bonairensis* and *L. floridae* apparently represent short-range endemics as they were found only in a single location. But this picture may be misleading because some of the more widely distributed species were shown to consist of distinct genetic lineages and some of the lineages show smaller distribution areas. For example, *Carinozetes mangrovi* possesses a northern lineage and an Antillean lineage [24]. Indeed, there are indications that some of the other widely distributed morphospecies, e.g. *A. inexpectatus, F. atlantica* and *T. barbara*, may also consist of geographically restricted genetic lineages, possible cryptic species respectively,

as indicated by preliminary molecular genetic investigations (unpublished data) but until such patterns are finally verified further discussion is premature.

From an ecological point of view, it is interesting that the majority of species represent rock dwelling taxa and only a minority are exclusive mangrove specialists. The cause for this disparity is unknown and more comprehensive data is necessary to draw conclusions in this respect, but increasing mangrove degradation and deforestation may play a role. Caribbean mangroves have declined by approximately 24% over the last quarter century as a result of coastal development and human exploitation [29]. Indeed, deforestation rates in mangroves are four times larger than those in terrestrial tropical rainforests [30] and this may already have caused several mangrove associated species to become extinct in the Caribbean area, especially those on smaller islands. Moreover, climate change and its consequences are expected to cause an additional significant decline of mangrove ecosystems throughout the Caribbean [29] which will most likely further reduce the diversity of mangrove dwelling intertidal oribatid mite species.

Despite the present data, knowledge about the intertidal oribatid mite fauna of the Caribbean is still incomplete and thus we cannot estimate consequences of mangrove loss or other threats. Further comprehensive studies are necessary to understand the evolutionary history and to predict possible future scenarios for these organisms in this region.

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