Epibiotic mites associated with the invasive Chinese mitten crab *Eriocheir sinensis* – new records of Halacaridae from Poland*

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Abstract

Seven epibiotic halacarid mites (*Caspihalacarus hyrcanus*, two species of *Copidognathus*, *Halacarellus petiti*, *Porohalacarus alpinus*, *Soldanellonyx monardi* and *S. chappuisi*), two oribatid mites (*Hydrozetes lacustris* and *Trhypochthoniellus longisetus*) and one water mite (*Piona pusilla*) were found on the setae-covered claws of eighteen Chinese mitten crabs (*Eriocheir sinensis*) collected from fresh and brackish waters in Poland and Germany. The most abundant of the 111 mite individuals recorded was one of the *Copidognathus* species ($N = 52$); this was followed by *H. petiti* ($N = 38$) and *C. hyrcanus* ($N = 13$). This is the first record of *H. petiti* and of the genus *Copidognathus* from Polish waters. The possibility of migrating over long distances assisted by catadromous mitten crabs enhances mite dispersal, as well as their introduction to new environments.

1. Introduction

The Chinese mitten crab *Eriocheir sinensis* (Crustacea, Brachyura, Varunidae) has a catadromous life cycle, involving several life stages that are characterized by different levels of tolerance to salinity: the most euryhaline are sexually mature specimens that can live in fresh and brackish waters as well as in the sea (Anger 1991, Veilleux & Lafontaine 2007). This invasive species, a native of East Asian waters, has colonized the coastline and rivers of Europe and North America during the last hundred years (Panning 1938, Cohen & Carlton 1997). In Europe, the oldest and largest self-sustaining population of *E. sinensis* inhabits the River Elbe and its tributaries in Germany. Nevertheless, because they are able to migrate long distances, adult specimens from this population have spread to neighbouring countries (Herborg et al. 2003, Czerniejewski et al. 2012). During the last few years mitten crabs have also increased in abundance in Baltic coastal brackish waters, where they probably encounter better trophic conditions than in their riverine habitats (Normant et al. 2002, Ojaveer et al. 2007, Drotz et al. 2010, Normant et al. 2012).

The exoskeleton of decapod crustaceans has been documented to represent an attachment surface for sessile epibionts which might appear there accidentally or intentionally (e.g. for masking the crab from foraging predators), some being either commensal or pathogenic (e.g. Abelló & Corbera 1996, McGaw 2006). In *E. sinensis*, not only the massive carapace but also the characteristic dense patches of setae covering the claws of adult specimens may well provide a habitat for many different organisms (Normant et al. 2007). Among them are mites belonging to the family Halacaridae, which made up 32.4% of the 1280 associated organisms found on thirteen such crabs collected in the River Havel in Germany (Normant et al. 2007). Being benthic throughout their life, halacarids may occur on different substrates, including basibionts (Bartsch 2008a). Unfortunately, none of the specimens found in the setae covering the claws of *E. sinensis* from German fresh water samples in the study of Normant et al. (2007) was identified to species level. Here, we present for the first time data on the diversity of mites collected from the mittens of *E. sinensis* from fresh and brackish waters.

2. Material and methods

A total of 18 crabs were analysed. They were collected in fresh (Germany) and brackish (Poland) waters in 2005–2008 (Figure 1). Crabs collected in German waters consisted of 4 specimens (males) from an artificial water course (the Gnevsdorfer Vorfluter) near Abbendorf and of 6 specimens (also males) from the Gülper See near Strodehne. In Poland, 5 specimens (3 males and 2 females) were caught in the Gulf of Gdańsk (southern Baltic Sea, salinity 7 PSU) and 3 others (2 males and 1 female) in the coastal Baltic Lakes Gardno and Łebsko (salinity 2 PSU). All the specimens were caught by local fishermen in fyke nets and then frozen at −20°C for further analysis. In the laboratory, the crabs were sexed on the basis of the abdominal structure (Panning 1952), after which their

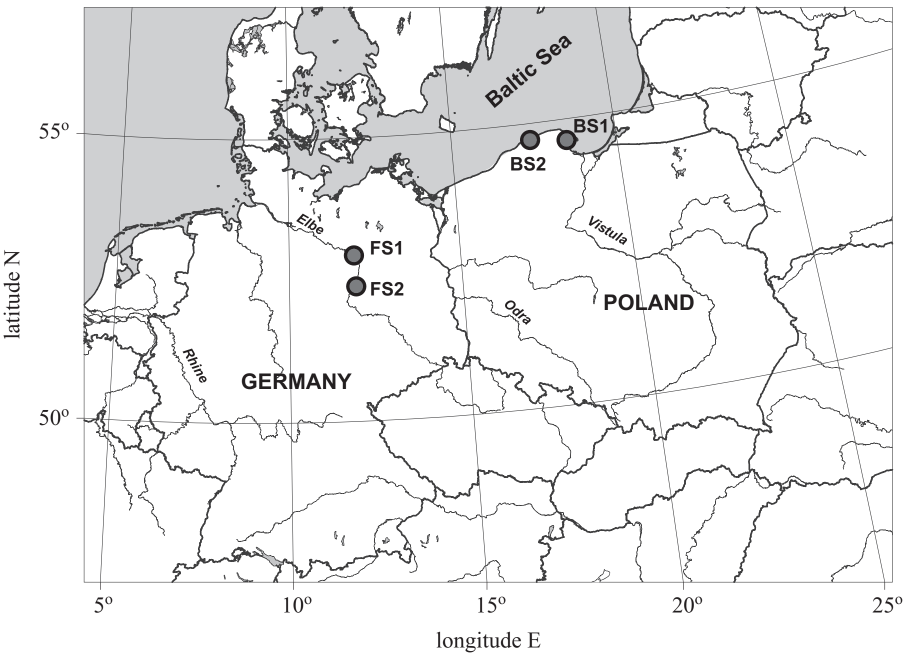

Figure 1. The sampling locations of *Eriocheir sinensis* in fresh waters (FS1 – Gnevsdorfer Vorfluter, FS2 – Gülper See; Germany) and brackish waters (BS1 – Gulf of Gdańsk, BS2 – Lakes Gardno and Łebsko; Poland)

carapace width was measured (± 0.1 mm). This varied from 58.6 to 80.1 mm in the fresh water specimens and from 57.2 to 79.3 mm in the brackish water specimens. Next, the setae covering the claws were removed with a scalpel and analysed under a stereomicroscope in order to separate the mites present. They were identified to specific or generic level on the basis of Vajnštejn (1980), Bartsch (2007) and Weigmann & Deischel (2007).

3. Results

Altogether, 111 epibiotic halacarid, oribatid and water mites belonging to 8 different genera were found associated with the mittens of the 18 crabs examined. Specimens from the genus *Copidognathus* could not be identified to species level, so they were described as *Copidognathus* A and *Copidognathus* B. Six different mite genera were found on the ten crabs from German fresh waters (Table 1). The most abundant ($N = 13$) species on the 18 crabs was the halacarid *Caspihalacarus hyrcanus* (Viets 1928). In addition, one *Porohalacarus alpinus* Thor, 1910 deutonymph, one *Soldanellonyx monardi* Walter, 1919 female, one *S. chappuisi* Walter, 1917 deutonymph and one *Copidognathus* sp. A male were found. Among the *C. hyrcanus* individuals were six protonymphs, five deutonymphs, one male and one larva. Besides halacarids, one oribatid mite (*Trhypochthoniellus longisetus* female) was also recorded. Mite diversity was higher in the

Table 1. Presence (+) of halacarid, oribatid and water mites in setae on the claws of *Eriocheir sinensis* from fresh (FS1 – Gnevsdorfer Vorfluter, FS2 – Gülper See) and brackish (BS1 – Gulf of Gdańsk, BS2 – Lakes Gardno and Łebsko) waters, as recorded in this study

Taxon	Fresh waters		Brackish waters	
	FS1	FS2	BS1	BS2
Halacarid mites				
Caspihalacarus hyrcanus	+			
Copidognathus sp. A	+	+		
Copidognathus sp. B			+	
Halacarellus petiti			+	+
Porohalacarus alpinus	+			
Soldanellonyx chappuisi		+		
Soldanellonyx monardi		+		
Oribatid mites				
Hydrozetes lacustris			+	+
Trhypochthoniellus longisetus	+			
Water mites				
Piona pusilla				+

Gnevsdorfer Vorfluter than in the Gülper See, where only *C. hyrcanus* was found.

Four different mite genera were found on the eight crabs from Polish brackish waters (Table 1). The most abundant ($N = 52$) of the 93 mites found was the halacarid *Copidognathus* sp. B, followed by the halacarid *Halacarellus petiti* (Angelier 1950, $N = 38$). Two females of the oribatid *Hydrozetes lacustris* and one larva of the water mite *Piona pusilla* were found. Identified were 21 males, 28 females and two protonymphs of *Copidognathus* sp. B, as well as 14 males, 22 males and two larvae of *H. petiti*. Five specimens of *Copidognathus* sp. B from the brackish waters of the Gulf of Gdańsk were found to be infected by the suctorian ciliate *Praethecacineta halacari* Schulz, 1933. Each mite was infected by one or two suctorian ciliates. The number of mite genera was identical in the crabs from both brackish water sampling sites; however, their abundance was much higher ($N = 86$) in the specimens from the Gulf of Gdańsk than in those from Lakes Gardno and Łebsko ($N = 7$).

4. Discussion

Halacarids, a primarily marine mite family that may also inhabit brackish and fresh waters, were the most diverse and abundant group found to be associated with the setae of Chinese mitten crabs. These mites have already been recorded many times in the brachial cavity or on the gills of different decapods, like crayfish or crabs (Table 2). To date, only pathogenic protozoans from the genus *Epistylis*, eggs of Oligochaeta from the genus *Branchiobdella* and metacercariae of an unidentified digenean species have been found in the gills of *E. sinensis* (Sobecka et al. 2011). While most of the organisms internally associated with decapods could be regarded as facultative parasites that feed on basibiont tissues, it seems that the mites occurring on *E. sinensis* are commensals, which use the dense setae on the crabs' claws only as a habitat. The structure of the setae resembles that of the phytal (e.g. the seaweed *Pilayella*), which is frequently inhabited by different fauna, including halacarid mites (Bartsch 1989). Mites can colonize setae when crabs feed on algae and vascular plants, which dominate in their diet (Fladung 2000, Czerniejewski et al. 2010). It might be assumed that the association of halacarids with the crabs is probably facultative and temporary. Because adult crabs moult the carapace relatively rarely, just once a year (Panning 1938), epibiotic mites potentially spend considerable amounts of time on the basibiont. The finding of males and females of *Copidognathus* sp. B, *H. petiti* or *C. hyrcanus* together with their larvae or nymphal stages on the same crab indicates that halacarids may complete their life cycle in the crabs' setae, where they probably find diverse items of

Table 2. List of halacarid species associated with decapod crustaceans, as recorded in previous studies (*continued on next page*)

Halacarid species	Decapod species	Location on the host	Place of record	Reference
Arhodeoporus arenarius Newell, 1947	*Libinia emarginata*	–	Rhode Island, US	Bartsch (1979)
Astacopsiphagus parasiticus Viets, 1931	*Astacopsis serratus*	gill chamber	Queensland, Australia	Viets (1931)
Caspihalacarus hyrcanus Viets, 1928	*Eriocheir sinensis*	setae on chelipeds	fresh water, Germany	present study
Copidognathus celatus Bartsch, 1979	*Libinia emarginata*	among cuticular structures	Rhode Island, USA	Bartsch (1979)
Copidognathus gasconi (Gil & Garzon, 1979)	*Peltarion spinulosum*	gill chamber	Uruguayan coast	Gil & Garzón (1979)
Copidognathus libiniensis Pepato, Santos & Tiago, 2005	*Libinia spinosa*	–	São Sebastião Island, Brazil	Pepato et al. (2005)
Copidognathus maculatus Bartsch, 1979	*Libinia emarginata*	–	Atlantic North West, USA	Bartsch (1979)
Copidognathus matthewsi Newell, 1956	*Parribacus antarcticus*	on the gills	Hawaiian Islands	Newell (1956)
Copidognathus menippensis Pepato, Santos & Tiago, 2005	*Menippe nodifrons*	–	São Sebastião, Brazil	Pepato et al. (2005)
Copidognathus novus Bartsch, 1980	*Libinia emarginata*	–	eastern United States	Bartsch (1979)
Copidognathus punctatissimus Gimbel, 1919	*Libinia emarginata*	–	Rhode Island, US	Bartsch (1979)
Copidognathus stevcici Bartsch, 1976	*Maja squinado*	between eggs	Adriatic Sea	Bartsch (1976b)
Copidognathus sp. A	*Eriocheir sinensis*	setae on chelipeds	fresh water, Germany	present study
Copidognathus sp. B	*Eriocheir sinensis*	setae on chelipeds	brackish waters, Poland	present study

Table 2. (*continued*)

Halacarid species	Decapod species	Location on the host	Place of record	Reference
Halacarellus petiti (Angelier, 1950)	*Eriocheir sinensis*	setae on chelipeds	brackish waters, Poland	present study
Limnohalacarus wackeri	*Astacus astacus*	brachial cavity	Poland	Wiszniewski (1939)
Walter, 1914	*Orconectes limosus*	brachial cavity	Lake Ińsko, Poland	Zawal (1998)
Lohmanella falcata Hodge, 1863	*Libinia emarginata*	–	Rhode Island, USA	Bartsch (1979)
Porohalacarus alpinus	*Astacus astacus*	brachial cavity	Poland	Wiszniewski (1939)
Thor, 1910	*Potamobius leptodactylus*	brachial cavity	Poland	Wiszniewski (1939)
	Orconectes limosus	brachial cavity	River Ina, Lake Ińsko, Poland	Zawal (1998)
	Eriocheir sinensis	setae on chelipeds	fresh water, Germany	present study
Soldanellonyx chappuisi Walter, 1917	*Eriocheir sinensis*	setae on chelipeds	fresh water, Germany	present study
Soldanellonyx monardi Walter, 1919	*Eriocheir sinensis*	setae on chelipeds	fresh water, Germany	present study
Thalassarachna basteri (Johnston, 1836)	*Libinia emarginata*	–	Rhode Island, USA	Bartsch (1979)
Thalassarachna longipes (Trouessart, 1888)	*Libinia emarginata*	–	Rhode Island, USA	Bartsch (1979)

food, like fungi, organic matter and algae, as well as potential prey in the case of predators (Normant et al. 2007).

The occurrence of oribatid mites (*H. lacustris* and *T. longisetus*) as well as water mites (*P. pusilla*) on crabs was probably occasional. *T. longisetus* is a globally widespread species (Weigmann 1997, Kagainis 2011, Mahunka 2011, Olmeda et al. 2011, Subías 2011), which was earlier reported in fresh water as free-living, associated with moss, hydrophytes, soil etc. Olmeda et al. (2011) also reported this species as a parasite of the tilapia fish (*Oreochromis niloticus*). The eurytopic *P. pusilla* is likewise a widely distributed species, occurring in small water bodies and the phytolittoral of lakes (Biesiadka 1972, Zawal 1992, 2006, 2007). Its larvae parasitize Diptera (Davids 1997, Zawal 2003).

There were noticeable differences in the diversity and abundance of epibiotic mite species found in the crabs from fresh and brackish waters. The former had a higher diversity of mites, but a much lower abundance. This could have been due, for example, to a lower abundance in the environment, or to greater crab mobility, in consequence of which mites have fewer opportunities to colonize their setae. Only halacarids from the genus *Copidognathus* were found in both environments. *P. alpinus* and *S. monardi* were associated only with fresh water mitten crabs here, but they can also inhabit slightly brackish coastal waters (Bartsch 2007). *P. alpinus* has been recorded in the brachial cavity of the crayfish *Astacus astacus*, *Astacus (Potamobius) leptodactylus* and *Orconectes limosus*, collected in Polish fresh waters (Table 2) near the German border (Wiszniewski 1939, Zawal 1998). There are records of this species from all continents except Antarctica, i.e. from North America (Canada, United States), Australia (Western Australia) and New Zealand, Asia (Turkey, Russia), Africa (Algeria) and Europe (from Finland in the north to Italy in the south, from Iceland and north-western France to Russia) (Bartsch 2007, 2009, 2011). It occurs mostly in oligo- and mesotrophic waters (Bartsch 2007), but also in mosses in springs, colonies of the zebra mussel *Dreissena polymorpha* and in aquaria. *P. alpinus* was also found as an epibiont on *Phragmites* reeds (Bartsch 2007), and was reported from charcoal filters in waterworks (Husmann 1982). *S. monardi* and *S. chappuisi* are widely distributed species living in a variety of habitats. The former species is commonly found in sediment and mud, amongst mosses and vascular plants, in both hypogean and epigean, stagnant and flowing, continental and coastal waters (Bartsch 2008c). It has been recorded from Europe (from Finland to Italy), Africa (Kenya, Tunisia), North America (Canada, US), the Hawaiian Islands, the Falkland Islands, Asia (Java, Japan), Australia (New South Wales, Queensland) and New Zealand. Two subspecies of *S. monardi* have been reported from Japan and one from Java (Bartsch 1996, 2007, 2008a,b, 2009, 2011, Chatterjee et al. 2010). *S. chappuisi* inhabits interstitial waters, lakes down to great depths, and streams in Europe, North America, Korea, Japan and South America (Bartsch 1996, 2007, Pešić et al. 2010).

There were also differences in mite diversity and abundance among the crabs collected at different sites within the same water body type/country. This was probably due to variability in ecological factors. For example, the diversity of mites in the crabs from the Gnevsdorfer Vorfluter was the highest (4 taxa were identified) but the abundance was the lowest ($N = 5$). This water body is a canal of depth not exceeding four metres, linking the River Havel with the Elbe, and the bottom is mostly sandy with very little mud. On the other hand, in the crabs collected from the Gülper See, our second sampling site in Germany, the three halacarid taxa identified were present in greater abundance ($N = 13$). The Gülper See is a small, fresh water lake of depth 0.8–1.0 m. Its bottom is mostly muddy, but a significant part is covered with the empty shells of the zebra mussel *D. polymorpha*. The flora consists of the water lilies *Nymphaea alba* and *Nuphar lutea*, Canadian waterweed *Elodea canadensis*, pondweed *Potamogeton* spp. and the common reed *Phragmites australis* (Nixdorf et al. 2004). Mite diversity in the crabs' setae could also reflect seasonality: three crabs collected from brackish waters in June and July had the highest abundances of mites (52 epibionts per crab) compared to those collected in November (maximum: 1 epibiont per crab).

C. hyrcanus was recorded from brackish waters in the Caspian and Black Seas (Viets 1928, Bartsch 2004). It was also found in fresh water, in the Dniepr and Danube, in the latter river upstream as far as Bratislava (Motaş & Şoarec-Tănăsachi 1943, Szalay 1970, Bartsch & Panesar 2000). It recently colonized the Rhine in the Netherlands and France (Bij de Vaate et al. 2002), as well as in Germany near Karlsruhe (Martens et al. 2006). In the present study, *C. hyrcanus* was found on crabs collected from the Gnevsdorfer Vorfluter in Germany, which lies ca 600 km north-east of Karlsruhe. Presumably, *E. sinensis* was a vector in the introduction of this halacarid species to Polish waters. *C. hyrcanus* is similar to *H. petiti* (Bartsch 1996), a halacarid that inhabits shallow brackish and fresh waters, where it lives on various substrata, often on soft sediment. The genus *Caspihalacarus* was recently synonymized as *Halacarellus* by Bartsch & Gerecke (2011). Although the known distribution of *H. petiti* covers the north-eastern Atlantic, and the Baltic and Mediterranean Seas (Angelier 1950, Bartsch 1976a, Green & MacQuitty 1987), this is the first record of this species in Polish waters. Arguably, mitten crabs assist in the dispersal of *Copidognathus* sp., one of the largest and geographically most widespread halacarid genera, whose representatives inhabit diverse environments (Chatterjee et al. 2006, 2008, 2012, Bartsch 2008a, 2009). Eight representatives of this genus have already been reported as epibionts of different decapods (Table 2). *Copidognathus* occurs mostly in marine waters, with few species adapted to fresh and brackish habitats (Bartsch 1996). Hence, the catadromous *E. sinensis* could enable these halacarids to cross geographical and ecological boundaries, and thus to colonize new areas together with their own associate, the suctorian ciliate *P. halacari*. This latter species is a common epibiont on halacarid mites, reported from the Atlantic, Indian and Pacific Oceans (Dovgal et al. 2008, 2009). Although *Copidognathus* species have already been recorded in Germany, here we report this genus from Polish waters for the first time.

The dispersal of fresh and sea water mites often takes place passively, with the aid of other organisms (Bartsch 1989). The considerable migration capabilities of *E. sinensis* appear to be beneficial to epibiotic mites, promoting their dispersal as well as their introduction to new environments. Although the Chinese mitten crab, a semi-terrestrial species, spends a considerable amount of time out of the water, the dense setae prevent the mites suffering from desiccation.

The International Union for the Conservation of Nature and Natural Resources has placed *E. sinensis* on its list of the 100 most invasive alien species in the world because it has led to extinctions among native invertebrates, modified habitats by its intensive burrowing activities, caused losses in fisheries and aquaculture by consuming bait and trapped fish, and damaged gear (Lowe et al. 2000). However, in the context of hosting as well as dispersing and introducing associated organisms to new habitats, it also seems to have a considerable impact on biodiversity. Similar effects for alien species have been recorded in terrestrial ecosystems (Veldtman et al. 2011). On the other hand, knowledge of epibiotic species can provide important information on the ecology and migration routes of the host species. Unfortunately, however, the available information on the spatial and seasonal abundance of mites in Polish and German water bodies inhabited by *E. sinensis* is at present insufficient for such a detailed interpretation.

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