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Note

Floating marine litter as a raft for drifting voyages for *Planes minutus* (Crustacea: Decapoda: Grapsidae) and *Liocarcinus navigator* (Crustacea: Decapoda: Polybiidae)

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ABSTRACT

The Columbus crab *Planes minutus* and Arch-fronted swimming crab *Liocarcinus navigator*, within their distribution ranges in the Mediterranean, were found rafted on plastic macro-litter floating on the open south Adriatic. While *P. minutus* was recorded from inanimate flotsam outside of the Mediterranean, *L. navigator* is herein reported for the first time on floating marine litter. The role of floating litter as habitat or as a dispersal agent for marine invertebrates has received quite attention however, records of decapod crabs drifting on litter has been relatively sparse. Our results suggests that vast quantities of floating debris, comprised primarily of non-biodegradable plastic polymers, probably will augment natural floating substrates in the marine environment, potentially facilitating the spread of invasive species. The dispersion of rafting crabs through floating debris should be investigated given the high potential ecological risk of invasion by exotic species due to the increase in waste production (ecological risk assessment).

1. Introduction

Like other members of its genus, the Columbus crab *Planes minutus* (Linnaeus, 1758) (Crustacea: Grapsidae) is a relatively small pelagic crab species that is dependent upon most objects that float in the open waters, occupying a variety of flotsam types as clinging substratum, including pelagic marine animals such as sea turtles, jellyfish, siphonophores and gastropods as well as *Sargassum* seaweed (Davenport, 1992; Dellinger et al., 1997; Frick et al., 2004). The crab *P. minutus* can swim rapidly over short distances but with a limited endurance (Davenport, 1992). This activity still allows crossing from one object to another. The dependence on floating objects also becomes evident from the absence of this species in waters without flotsam. In addition to natural flotsam, there are also examples of *P. minutus* associated with larger floating plastic artifacts (e.g., crates, lids, buckets) off the Island of Madeira in the Atlantic Ocean (Dellinger et al., 1997).

The species *P. minutus* occurs in the Indian Ocean, Atlantic waters up to the North Sea and in the Mediterranean Sea (d'Udekem d'Acoz, 1999) where it is considered to be rare (Kocataş et al., 2001; Corsini-Foka and Pancucci-Papadopoulou, 2012). Scientific knowledge about this species in the Adriatic Sea is very scarce and sporadic with only four specimens recorded to date (Števčić, 1990; Vallini et al., 2011; *M. Kirinčić, 2010 personal observation*). The first reliable report of the presence of this species in the Adriatic comes from Števčić (1990) and is based on a specimen found near the island of Hvar (Croatia). However, this study does not provide any details on the nature of the floating substratum. Most recently, two specimens (male and female) of *P. minutus* were collected in 2010, both from the shell of loggerhead sea turtles *Caretta caretta*; one from open Adriatic waters (Carcinological collection of Natural History Musem Rijeka; C1547) (*M. Kirinčić, personal observation*) and one in Comacchio (north western Adriatic coast, Italy), from a loggerhead sea turtle stranded on the beach (Vallini et al., 2011).

The Arch-fronted swimming crab *Liocarcinus navigator* (Herbst, 1794) (Crustacea: Polybiidae) is known as a typical representative demersal crustacean species that is commonly found living on soft and hard substrates in the intertidal zone to the depths as much as 100 m in the subtidal zone (Davie, 2002). The species occurs from the Eastern Atlantic to the Mediterranean including the Black Sea (as *Polybius arcuatus* (Leach, 1814); d'Udekem d'Acoz, 1999). Even *L. navigator*, relatively rare in the North Sea, was found on the Dutch coast between drift mainly consisting of hydroids (Adema, 1991), there are no previous reports of its appearance on any kind of floating abiotic substrata. Unlike *P. minutus*, it has never been recorded in association

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with the loggerhead sea turtles (Števčić, 1990; Domènech et al., 2014). In the Adriatic *L. navigator* occurs on inshore sandy or detritic sandy substrates. It also occurs in sea grass meadows from 0.5 to 50 m depth, but is most usual in more shallow waters (Kirinčić and Števčić, 2008). In 2003 *L. navigator* was also found on muddy coastal substrates (Carcinological collection of Natural History Musem Rijeka; C1528) on the island of Krk, thus widening the previously known habitat preferences (*M. Kirinčić, personal observation*). It is considered as a locally frequent species with a high abundance throughout the Adriatic coast (Števčić, 1990).

Plastic in the ocean, consisting of low-density polyethylene, polystyrene, or polypropylene is considered as main component of floating man-made marine litter (Pruter, 1987; Thiel and Gutow, 2005a, 2005b; Thiel and Haye, 2006) and is a major problem in the marine environment (Pruter, 1987; Stefatos et al., 1999). In the Mediterranean Sea the majority of marine litter are coming from land-based sources: shoreline and recreational activities including tourism, sewage and fishing related debris, dumping, medical and personal hygiene and than litter from waterways activities (UNEP, 2009). Common ecological impacts of marine plastic are entanglement and ingestion by a range of marine organisms, including invertebrates, some specific birds, sea turtles and mammals (see in: Derraik, 2002). Another important ecological impact associated with floating marine litter is the potential role in the long distance dispersion of marine invertebrates, termed rafting (Winston, 1982; Barnes, 2002; Thiel and Gutow, 2005b; Thiel and Haye, 2006, and other literature therein). Rafting on natural and anthropogenic floating material has been inferred as an important dispersal mechanism for many littoral marine invertebrates (Thiel and Gutow, 2005b; Thiel and Haye, 2006, and other literature therein). The dispersion of benthic organisms through solid materials of human origin has been considerable reported in oceans worldwide (Barnes and Fraser, 2003; Thiel and Gutow, 2005a, 2005b; Thiel and Haye, 2006, and other literature therein; Kiessling et al., 2015) as well as in the Mediterranean (Aliani and Molcardi, 2003). However, direct evidence of a successful dispersal of decapod crabs by rafting on anthropogenic litter has received relatively little attention (Donlan and Nelson, 2003).

In this study we report the first case of the finding of *L. navigator* on plastic marine debris in the Mediterranean Sea. This species has not been previously found in rafting assemblages there. The majority of the studies on the occurrence of *P. minutus* in some rafting materials in the Mediterranean Sea come from some observations on sea turtles (Cuesta et al., 1997; Casale et al., 2004; Domènech et al., 2014). There are a few findings in the published literature indicating the presence of this crab on plastic marine litter or being transported by rafting on it (see in: Thiel and Gutow, 2005b). We also present a new record of the grapsid crab *P. minutus* on floating marine debris and being transported by rafting in the Mediterranean Sea.

These observations highlight the potential role of floating marine litter as a vector of dispersal for invertebrate species. This suggests a risk of introduction of non-indigenous species and provides an impulse to examine the relationships between the increasing amount of abiotic marine floating debris, rafting communities and climate change in the Mediterranean Sea.

2. Material and methods

On September 17th 2014 two specimens of *P. minutus* and one juvenile individual of *L. navigator* were found by Žuljević A. and one of the Authors (Pallaoro A.) during visual sightings of floating objects in the open south Adriatic Sea (42 NM SW of Dubrovnik; 42°16, 38′N, 017°40, 37′E – in a area with a depth of 1226 m) (Fig. 1). Observations were made from the top deck of the R/V Bios 2.

The specimens were preserved in 70% ethanol and deposited in the collection of the Institute of Oceanography and Fisheries, Laboratory for Ichthyology and Coastal Fisheries (Split, Croatia). The morphology of the observed specimens was consistent with the taxonomic description available on World Register of Marine Species (WoRMS), (http://www.marinespecies.org/aphia.php?p=taxdetails&id=107462) for *P. minutus*, (Fransen and Türkay, 2007) and http://www.marinespecies.org/aphia.php?p=taxdetails&id=108048 for *L. navigator* (Türkay, 2004).

Carapace length (CL) and width (CW) were measured accurately using a digital caliper.

3. Results

Data on the collected material are given below.

3.1. Grapsidae

3.1.1. Planes minutus (Linnaeus, 1758)

Material examined: female CL = 21.6 mm, CW = 22.8 mm; female CL = 17.0 mm, CW = 18.1 mm; open southern Adriatic, Croatian waters; plastic sandal (Fig. 2a), sport shoe (Fig. 2b); 17. 09. 2014; both specimens have been observed “jumping” from one to another piece of floating plastic marine debris; Catalogue number IORPM2014-1; IORPM2014-2. Remarks: These findings represent the newest substantiated record of *P. minutus* on floating marine plastic litter and under rafting transportation along the Mediterranean coast.

3.2. Polybiidae

3.2.1. Liocarcinus navigator (Herbst, 1794)

Material examined: 1 spm; CL = 8.5 mm, CW = 10.3 mm (Fig. 3); open southern Adriatic, Croatian waters; truck tyre that was buoyant; 17. 09. 2014; Catalogue number IORLN2014. Remarks: This occurrence of *L. navigator* represents the first substantiated record of the species on floating marine litter and under rafting transportation in general.

4. Discussion

With increasing pollution, variability and variety of marine litter may become a progressively more common substrate for marine organisms that depend on rafting for long-distance dispersal and even perhaps for those unexpected ones. The recent observations regarding *P. minutus* and especially *L. navigator* rafting on floating macro-litter highlight the role of plastic and other anthropogenic debris as rafts for dispersion across the marine waters. While *P. minutus* is known to colonize a variety of floating objects ranging from floating *Sargassum* (Sano et al., 2003), over tree trunks and buoys (Jara and Jaramillo, 1979) and sea turtles (Dellinger et al., 1997), they are comparatively rare on plastic debris (see in: Thiel and Gutow, 2005b). The last recorded occurrence for the Mediterranean was reported many years ago and based on a *P. minutus* specimen found among algae and the barnacle *Lepas anatifera* on a floating life-belt in Israel waters (Holthuis and Gottlieb, 1958). This species has been frequently found as a member of the rafting assemblages (Davenport, 1992; Dellinger et al., 1997). Observations from this study, as well as the literature data suggests that this crab can opportunistically colonize whichever substrates are available in pelagic environments where substrates are scarce.

While *P. minutus* is an obligate rafter species with adaptive characteristics attributable to a rafting existence (Davenport, 1992), no clear life history patterns were correlated with rafting for *L. navigator*, which has not been reported rafting on abiotic substrata previously. This small portunid crab was previously found on the drift mainly consisting of hydroids (Adema, 1991) and mixed sandy substrata from the shallow sublittoral to offshore (0–50 m) (Davie, 2002). Certain life history traits of *L. navigator* may be advantageous to rafting. Portunids are commonly known as “swimming crabs” and most are particularly efficient swimmers, using characteristic flattened paddles on the last pair of legs to facilitate locomotion through water (Davie,

Fig. 1. Sampling location of the Columbus crab *P. minutus* (Linnaeus, 1758) and the Arch-fronted swimming crab *L. navigator* (Herbst, 1794) on the open south Adriatic Sea. Black dot indicates sampling location.

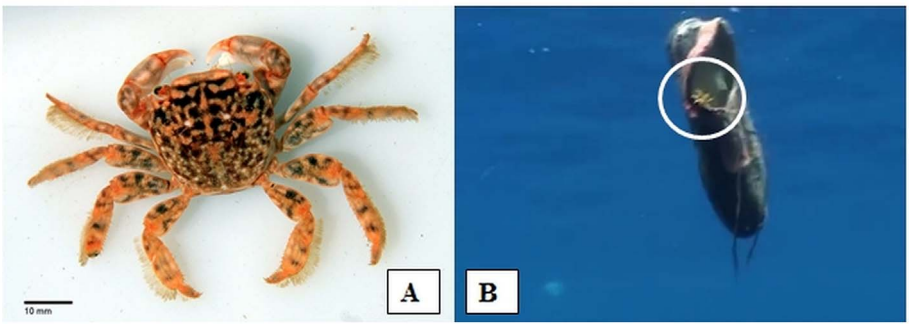

Fig. 2. The Columbus crab *P. minutus* (Linnaeus, 1758); A) live specimen immediately after collection; B) live specimen on sport shoe caught in the south Adriatic Sea. Photo by: A. Žuljević.

2002). This ability, in combination with their feeding habits of consuming a wide range of prey (polychaetes, crustaceans, molluscs, ophiuroids and fish) (Davie et al., 2012) would be advantageous to survival in an ephemeral food source habitat like floatsam. However, despite their potential capacity to survive during a rafting episode, this phenomenon could be considered as rare and this species as an accidental rafter.

These findings raise further questions such as how and when the juvenile stage *L. navigator* specimen started out the rafting voyage? It is also unclear whether this is just an isolated incident or if other examples have occurred and not been noticed. Bearing in mind that the studied specimen was found in the juvenile stage and its species life stages are known (Moksnes et al., 2014), it may suggest that it could have arrived on floating substrata only as a larva. As with other portunid crabs, *L. navigator* presents a relatively high number of larval stages and the late stage larvae commonly swim at the surface, particularly at night (Moksnes et al., 2014). Following settlement on a floating item, the continuity of its evolution remains unknown. As previously has been considered, the finding of this species hitchhiking on rafts could be just an accidental case. Here we do not assume that this occurrence represents a common phenomenon, but more likely it was previously overlooked due to the lack of adequate targeted research. However, since little is known about the life cycle of *L. navigator* and to avoid any controversies in order to explain this phenomenon, further studies must be carried out in order to clarify the details of this event. Although the portunid crabs tend to be substrate specialists (Davie, 2002), unusually large anthropogenic floating debris such as plastics, may effectively disperse even habitat-

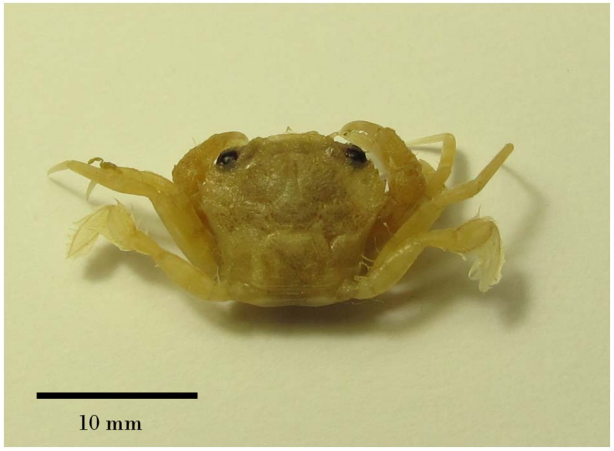

Fig. 3. Juvenile of the Arch-fronted swimming crab *L. navigator* (Linnaeus, 1758). Photo by: A. Žuljević.

specialised species such as *L. navigator* by functioning as substrata for their hosts.

Dispersal of marine and terrestrial organisms on floating objects has significant biogeographical and ecological implications (Thiel and Gutow, 2005a, 2005b; Thiel and Haye, 2006). It has long been known that certain grapsid crabs may be transported over long distances by clinging to drifting debris or in hull fouling (Zaouali et al., 2007), but this has never been observed for *L. navigator*. Passive dispersal of organisms rafting on abiotic items floating over the sea surface may account for the transport of animals to areas otherwise unavailable by other natural dispersal mechanisms (Thiel and Gutow, 2005a, 2005b). Under circumstances in which the area for settlement is limited, the colonization of floating substrata may become a highly valuable strategy for survival of marine invertebrates. Pelagic crabs are reliant on floating substrata which form a limited resource in their marine environment in terms of attachment substratum and in many cases also food for rafters (Thiel and Gutow, 2005a, 2005b).

Although there has been increasing attention to plastic pollution in the Adriatic Sea over the past two decades (Kwokal and Štefanović, 2011; Liubartseva et al., 2016), since this type of pollution represents a global threat to marine biodiversity (Derraik, 2002), the ecological implications have been relatively little studied (Đuras-Gomerčić et al., 2009; Lazar and Gračan, 2011). According Liubartseva et al. (2016) the mean floating plastic debris half-life in the Adriatic is found to be approximately 43.7 days, which allows us to define the Adriatic Sea as a highly dissipative system with respect to floating plastics. As stated by Thiel and Gutow (2005a, 2005b), Thiel and Haye (2006), and by Kiessling et al. (2015), the worldwide increasing abundance of marine plastic is drastically increasing species opportunities to colonize and disperse, and this also applies to the Mediterranean region (Aliani and Molcardi, 2003) and potentially this type of substrate may facilitate the spread of invasive species.

Generally speaking, this study only allows us to confirm the occurrence of *P. minutus* and *L. navigator* rafting on floating marine litter. In this paper we do not assume that this occurrence represents a common phenomenon, but more likely was previously overlooked due to the lack of adequate targeted research. As there is a lack of research on assemblages derived from plastic-associated rafting (especially long term monitoring), future studies may reveal a larger ecological role posed by anthropogenic plastic debris to marine species.

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