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The role of marinas and recreational boating in the occurrence and distribution of exotic caprellids (Crustacea: Amphipoda) in the Western Mediterranean: Mallorca Island as a case study

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ABSTRACT

In the Mediterranean Sea, the number of alien marine crustacean species has increased over the past two decades. However, knowledge about small alien marine crustaceans, like caprellid amphipods, is still very scarce. To understand the role of marinas and recreational boating in the early step of the invasion process by non-indigenous caprellids, we studied the recreational boating pressure and the spatial distribution of caprellid species in Mallorca Island. We collected caprellids from 14 marinas and 9 exposed intertidal rocky shores between November 2011 and April 2012 and we analyzed the differences in habitat use of native and exotic caprellids. Eight caprellid species, six native and two exotic, were found. Alien caprellids were only present in marinas, reaching high densities of population. The analysis of recreational boating pressure reveals that Palma–Migjorn is the area that is subject to the highest potential risk of introduction of exotic species via ship fouling. In the secondary dispersal of alien caprellids, the study reflects that recreational boating seems effective as a secondary vector in the transport of exotic species from marinas to marinas but not from marinas to natural and exposed areas. An illustrated key of caprellids from Balearic Island is provided to differentiate native and non-indigenous species.

1. Introduction

Human-mediated biological invasions involve the transport of a species to an area where it does not naturally occur. Reducing the threat of new invasions requires a focus on the ways humans enable the transport and establishment of species in new areas (Floerl and Inglis, 2005). Despite the large number of private and commercial recreational boats in coastal locations worldwide, the role of recreational boating in the transport of non-indigenous species (NIS) has received little attention to date (Minchin et al., 2006). A recent study showed that recreational boats represent a high-risk vector both for primary introduction and secondary spread of marine NIS (Murray et al., 2011). Small recreational boats can travel long distances, and their relatively low speeds (compared to commercial ships) make them ideal vectors for fouling species (Minchin et al., 2006). These fouling assemblages reflect in part the composition of biotic assemblages within the marina in which small boats were moored (Floerl and Inglis, 2005). Marinas are critical entry points for NIS and may act as reservoirs for introduced species (e.g. Glasby et al., 2007). This is particularly important in the case of small invertebrates, like caprellid amphipods, because marinas' fouling communities include arborescent substrates such as bryozoans or hydroids which may act as habitat for non-indigenous caprellids (Ros et al., 2013a). These small marine crustaceans, commonly known as skeleton shrimps, are very successful colonizers of artificial hard substrate, reaching high densities in harbors and marinas (Ashton et al., 2010; Buschbaum and Gutow, 2005) including biofouling on ship hulls (Frey et al., 2009). They are also common in many littoral habitats being an important trophic link between primary producers and higher trophic levels (Woods, 2009). The morphology of caprellids, with reduced abdominal appendages which in other amphipods are used for swimming (Takeuchi and Sawamoto, 1998) as well as a lack of a planktonic larval stage, suggests that the cosmopolitan distribution of many littoral caprellids is facilitated by the fact that they are often associated with fouling communities on floating objects and vessels (Thiel et al., 2003). Marinas can also act as stepping stones for the colonization of natural habitats (Cangussu et al., 2010). Therefore, a high recreational boating pressure may involve a high risk of dispersion of exotic species. However, although marinas can act as reservoirs of non-indigenous caprellids, it is still unclear if these exotic caprellids can colonize natural and preserved intertidal rocky shores.

In the Mediterranean Sea, the number of alien marine crustacean species has increased over the past two decades (Galil, 2011). However, invasions are rarely reported amongst smaller-bodied and taxonomically more challenging taxa (Carlton, 2009) such as caprellid amphipods, sometimes difficult to identify to species level. Recently, two

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non-indigenous caprellids were found for the first time in marinas of the Balearic Islands, in the western Mediterranean Sea: *Caprella scaura* Templeton, 1836 and *Paracaprella pusilla* Mayer, 1890. The widespread species *C. scaura* was first recorded on the Northeastern coast of Spain in 2005 (Martínez and Adarraga, 2008), in southern Spain in 2010 (Guerra-García et al., 2011a) and on the islands of Mallorca and Menorca in 2011 (Ros et al., 2013b). *P. pusilla* was recorded for the first time in European waters of the South coast of Spain in 2010 (Ros and Guerra-García, 2012), and only one year later was detected for the first time in the Mediterranean Sea, on the islands of Mallorca and Ibiza (Ros et al., 2013b).

This study intends to provide new data to contribute to the knowledge of the diversity and distribution of crustacean caprellids along the coast of Mallorca comparing artificial habitat (marinas) with natural and exposed areas (intertidal rocky shores), including the detection of native and exotic species which have not been found previously in the Balearic Islands. We also compare the habitat use of native and exotic caprellids in the island to identify the habitats that are more susceptible to harbor introduced species and to understand the most probable vector for their introduction. Considering that the majority of exotic caprellids are introduced into a new area via ship fouling (Krapp et al., 2006) and dispersed secondarily via recreational boating (Ashton et al., 2006), this study will estimate the pressure of recreational boating in the different coastal regions of Mallorca to understand its role as a secondary vector in the dispersion of this group and to identify areas with a higher risk of introduction of alien species through this vector. In order to provide a monitoring tool for the early detection of exotic caprellids by non-taxonomic experts, we provide an illustrated key for the Caprellidea in the Balearic Island including the species detected in the present study in Mallorca and those detected previously for the Balearic Islands.

2. Materials and methods

2.1. Study area

The survey was carried out on Mallorca Island, located in the center of the western Mediterranean. Mallorca is the largest of the Balearic Islands with 719 km of coastline (Fig. 1). In spite of having a large number of marine protected areas (MPAs) in comparison with other Mediterranean regions, it is characterized by intense maritime traffic and is the location with the highest number of moorings in Spain (FEAPDT, 2011). All of this makes this island a potential hot spot of biological invasions via shipping traffic.

2.2. Sampling

The sampling program was conducted between November 2011 and April 2012 and was divided in two parts: an artificial (anthropogenic) hard substrate survey, carried out in marinas (recreational ports), to detect presence and quantify abundance of native and non-indigenous caprellids; and a natural hard substrate survey, carried out in natural rocky shores, with two aims (1) detect the presence of alien caprellids in natural habitats and (2) characterize the diversity of caprellid fauna in natural hard substrata due to scarce studies about this group in the study area. In the artificial hard substrate survey, a total of 14 recreational marinas along the whole coast of Mallorca were sampled to ensure a complete review of the total fouling communities which proliferate on artificial hard substrate including floating pontoons, ropes, buoys, wheels and ship hulls. When caprellids were detected in a type of fouling substrate (hydroids, bryozoans or macroalgae), three random replicates of each substrate were taken by hand and fixed in situ in 90% ethanol. In the natural hard substrate survey, we selected 9 natural rocky shores well exposed to wave action and located in relatively undisturbed areas with a low anthropic pressure. In this case, we collected hydroids and macroalgae from the intertidal zone directly by hand at low tide, and subtidal snorkeling provided algal samples from shallow waters (1–5 m deep). Each substrate was collected individually from different rocks to avoid a patchy effect and to adequately sample caprellid diversity, until a volume of approximately 150 ml of substrata was completed (see Guerra-García et al., 2011b; Thiel et al., 2003). Samples were preserved in 90% ethanol.

2.3. Laboratory processing

All caprellids were sorted and identified to species level. Abundance of caprellids was expressed as number of individuals/1,000 ml of substrate because of the different structure of the substrate types (see Pereira et al., 2006). Volume of substrates was estimated as the difference between the initial and final volume when placed into a graduated cylinder with a fixed amount of water.

2.4. Statistical analysis

The affinities among native and non-native caprellid species based on their presence/absence in the sampling stations were established through cluster analysis using the UPGMA (unweighted pair group method using arithmetic averages), based on the Bray–Curtis similarity index.

To characterize the frequencies of small craft movement in the different coastal regions of Mallorca, we use the Index of Recreational Port Capability (RPCI). This index refers to the number of moorings/marina berths available within a given region of coastline in kilometers (Occhipinti-Ambrogi, 2002). In order to simplify the subsequent analysis, the anchoring zones have been grouped according to five HEMUs (Homogeneous Environmental Management Units) of Mallorca (Balaguer et al., 2011). Concentrations of marinas and berthing space (high RPCI) are likely to be associated with high frequencies of small craft movements (Minchin et al., 2006). However, not all boats located in marinas operate at the same time or with the same frequency, and there is a significant proportion that hardly ever, or never sail (Balaguer et al., 2011). To estimate the secondary dispersal potential of exotic species by recreational boating, we developed a simple but useful index for comparison between different areas: the Recreational Boating Dispersal Index (RBDI), which consists of the number of boats that sail regularly within a given region of coastline in kilometers. To estimate the number of boats that sail regularly on Mallorca Island we used the study by Balaguer et al. (2011), which estimated that the percentage of boats leaving their marina to navigate on the busiest day of the high season on Mallorca Island was 49% with 87% of these vessels staying in the waters around Mallorca.

3. Results

3.1. Caprellids assemblages and habitat use

A total of eight caprellid species were found during the sampling program, 6 native, *Caprella acanthifera* Leach, 1814, *Pseudoprotella phasma* (Montagu, 1804), *Caprella hirsuta* (Mayer, 1890), *Caprella liparotensis* Haller, 1879, *Caprella danilevskii* Czerniavski, 1868 and *Caprella grandimana* Mayer, 1882; and 2 non-native, *C. scaura* and *P. pusilla*. On the basis of their presence/absence in the sampling stations, caprellids found in the present study were classified in three groups (Fig. 2): species found in intertidal exposed rocky shores (group I), species found both in marinas and intertidal exposed rocky shores (group II) and species found exclusively in marinas (group III). All native species belonged to group I except *C. acanthifera* which was found in both intertidal exposed rocky shores and marinas, belonging to group II. All non-native caprellids belonged to group III. Eighteen different substrate species hosted caprellids (Table 1) and four of these, *Eudendrium racemosum*, *Corallina elongata*, *Dictyota dichotoma* and *Cystoseira crinita* were present both in artificial hard substrate (marinas) and in natural