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SHORT COMMUNICATION

First occurrence of *Caprella scaura* Templeton, 1836 (Crustacea: Amphipoda) on off-coast fish farm cages in the Mediterranean Sea

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Abstract The non-indigenous caprellid *Caprella scaura* Templeton, 1836, native to the western Indian Ocean, was firstly recorded in the Mediterranean Sea in 1994, and all Mediterranean populations discovered to date are related to shoreline areas. A total of ten fish farms were sampled off the coasts of Spain (4), Italy (1), Croatia (2), Greece (1) and Malta (2). This is the first time that *C. scaura* has been reported from off-coast areas. Reproducing populations have been detected in fouling communities of three tuna farms off the coast of Croatia and Malta, which also signifies the first confirmed record of this species in both countries. The occurrence of successfully established and thriving populations of *C. scaura* Templeton, 1836 at floating off-coast fish farms underlines the importance of these structures as stepping stones in the species.

Keywords Aquaculture · Caprellid · Exotic · First record · Malta · Croatia

Introduction

Caprella scaura Templeton, 1836 is a caprellid amphipod, native to the western Indian Ocean. This caprellid was originally described from Mauritius and, after extensive dispersal, has been reported from several regions around the world. The first Mediterranean occurrence was recorded from Venice Lagoon (Italy) in 1994 (Mizzan 1999), and *C. scaura* has been subsequently reported from several localities along the coasts of Italy, Greece, Spain, Tunisia, Turkey, France and Morocco (Krapp et al. 2006; Martínez and Adarraga 2008; Souissi et al. 2010; Bakir and Katagan 2011; Ros et al. *in press*). Two possible pathways of introduction have been proposed for this species: (1) from the native Indian–Pacific through the Suez Canal and (2) from the Caribbean through the Strait of Gibraltar (Guerra-García et al. 2011).

The Mediterranean non-native populations discovered to date have been found clinging to a variety of sessile organisms (i.e. bryozoans, algae, seagrasses and mussels) and are related to shoreline areas, mainly marinas (Krapp et al. 2006; Guerra-García et al. 2011) and coastal lagoons (Mizzan 1999; Souissi et al. 2010; Prato et al. 2013), which are often highly susceptible to alien species (Occhipinti-Ambrogi et al. 2011). These areas generally experience high shipping activity; thus, the vector of introduction into the Mediterranean Sea is suspected to be hull fouling (Krapp et al. 2006), and the role of recreational boating in the secondary dispersal has also been discussed (Martínez and Adarraga 2008; Guerra-García et al. 2011 and references therein). In addition, aquaculture industry, and in particular the movement of fish cages, was also suggested as vector for introductions (Krapp et al. 2006; Martínez and Adarraga 2008). Little is known about the relation between *C. scaura* and aquaculture, except from reports on land-based aquaculture tanks on the Canary Islands (Guerra-García et al. 2011), and on fish farm cages in a semi-enclosed bay off the Turkey coast (Bakir and Katagan 2011), when fish farms were still located close to the coastal zone at shallow, sheltered sites. Notwithstanding this, no mention

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has been made for fish cages located in off-coast conditions.

Off-coast fish farms facilities are strongly connected via boating with ports and marinas for regular feeding and maintenance checks. And in the same way as other artificial marine structures, they provide novel available habitat for colonisation and settlement of a wide variety of marine organisms (Sarà et al. 2007). Bivalves, especially mussels, algae, hydroids and ascidians, have been found to be the main fouling organisms on aquaculture fish cages (Sarà et al. 2007; Fitridge et al. 2012). Regarding mobile epifaunal assemblages on floating structures, these are usually dominated by organisms with direct development, which may recruit their offspring directly to the parental raft (Thiel 2003), such as amphipods and in particular caprellids. Thus, high numbers and/or biomass of amphipods, especially caprellids, are found to be associated with fish farm fouling communities (Greene and Grizzle 2007).

Alien species could reach these off-coast waters alongside native species (Minour et al. 2012). For example, *Caprella mutica* Schurin 1935, another invasive caprellid, native to north-western Pacific sea, was first described in Europe in 1995 (Platvoet et al. 1995); since then, it has been reported from marinas, but also from fish farms, power stations, boat hulls and wind farms (Boos et al. 2011).

The present discovery of *C. scaura* on fish farm cages is the first record of this species on off-coast structures in the Mediterranean Sea. This finding is discussed highlighting the special characteristics of floating cage fouling and analysing the role of fish farms as potential vectors for introductions and secondary spread of alien species.

Materials and methods

A preliminary study of epifauna associated with fish farm fouling was carried out from May to October 2010. A total of ten fish farms, dedicated to the on-growing of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) or the Atlantic bluefin tuna (*Thunnus thynnus*), were sampled off the coasts of Spain (4), Italy (1), Croatia (2), Greece (1) and Malta (2). From each fish farm, four random replicates were collected by scraping fouling organisms from mooring ropes. Hereby, 20 cm of length per rope was cleared per sample. The samples were sieved through a 250-µm mesh with seawater in order to retain small specimens and juvenile organism and subsequently preserved in 4 % formalin seawater solution.

Individuals of *C. scaura* were sorted out, and the numbers per sample were recorded. Specimens were identified using morphological descriptions provided by Guerra-García (2003) and Krapp et al. (2006). All amphipod species and sessile organisms were identified, if possible to species level, the amphipod numbers per sample were counted and sessile organisms were blotted on absorbent paper to remove excess water and weighed. *C. scaura* abundances were standarised to the total amount of habitat per sample, calculated as the wet weight of all sessile organisms and presented as individuals/kg wet weight. Due to differing sampling procedures of Maltese samples, total amount of habitat could not be calculated, and the actual numbers of individuals were reported instead.

Results

A total of 642 specimens of *C. scaura scaura* were obtained from three of the fish farms sampled, all of them dedicated to the fattening of Atlantic bluefin tuna (*T. thynnus*). Two farms were located off the Croatian coast (Brac Island and Ugljan Island) and one north-east of Malta (Qawra) and confirmed the first record of *C. scaura* for both countries (Fig. 1).

The largest population was found off Brac Island (Croatia), where males, brooding and non-brooding females and subadults were found (Fig. 2), and the maximum density reached was 23653.9 individuals/kg wet weight habitat of which *B. neritina* represented 76.9 %. The average density amounted to 12367.8 ± 4308.3 individuals/kg wet weight habitat which was dominated by the bryozoan *Bugula neritina* and the mussel *Mytilus galloprovincialis*. *Caprella scaura* was the second most abundant epifaunal species (25.2 %), following the gammarid amphipod *Elasmopus rapax* with 45.2 %. Two others caprellid amphipods *Caprella equilibra* and *Caprella dilatata* were found as well, but only with less than 3 % of the total abundances.

Another population of *C. scaura* composed by males, brooding and non-brooding females and subadult individuals (Fig. 2) was found in the second Croatian farm, located off Ugljan Island. The average density was lower than at Brac Island and amounted to 1871.1 ± 333.4 individuals/kg wet weight habitat. The habitat was dominated by *M. galloprovincialis* (57.7 %) and scattered with ulvacean algae (10.0 %) and the phaeophyceae *Hydroclathrus clathratus* (10.8 %) as well as several individuals of the crinoid *Antedon mediterranea*. The species *E. rapax* (23.5 %), *C. scaura* (22.0 %), *Gammaropsis maculata* (19.5 %) and *Ericthonius brasiliensis* (15.7 %) accounted for more than 80 % of amphipods found at this fish farm.

Finally, *C. scaura* was also collected from a fish farm situated in the St Paul's Bay (Qawra) on the north-eastern coast of Malta. At this fish farm, 22 individuals of *C. scaura* were found, including brooding and non-brooding females and subadults, but no males were detected (Fig. 2).

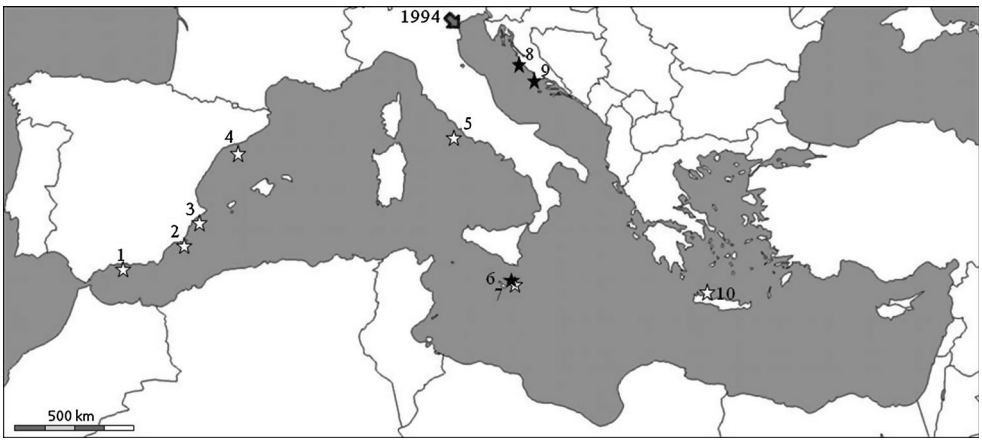

Fig. 1 Map of Mediterranean Sea showing sampling locations (star symbols: 1 = Málaga, Spain; 2 = Murcia, Spain; 3 = Alicante, Spain, 4 = Tarragona, Spain, 5 = Follonica, Italy, 6 = Qawra, Malta, 7 = Delimara, Malta, 8 = Ugljan Island, Croatia, 9: Brac Island, Croatia and 10 = Crete, Greece) and confirmed records of *C. scaura* at off-coast fish farms (*black stars*). The arrow indicates the first Mediterranean record (and year of first sighting) of *C. scaura* at Venice Lagoon

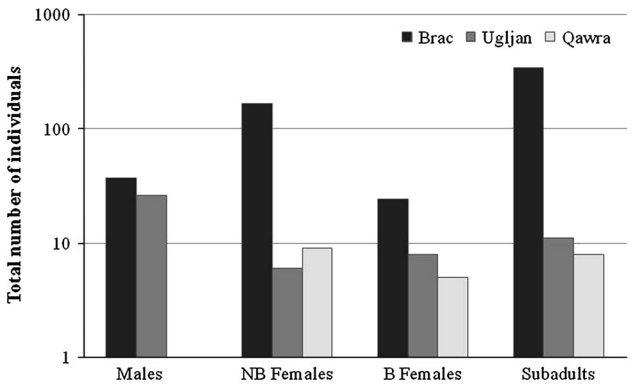

Fig. 2 Total number of males, brooding (*B*) and non-brooding (*NB*) females and subadult individuals of *C. scaura* at fish farms off Brac Island, Croatia ($n = 569$), Ugljan Island, Croatia ($n = 51$) and Qawra, Malta ($n = 25$) (Note the logarithmic scale for number of individuals)

Other amphipod species found at this farm were *E. brasiliensis*, *Jassa marmorata*, *C. equilibra*, *E. rapax* and *C.dilatata* and included two additional non-native amphipod species: the lessepsian *Stenothoe gallensis* and the cryptogenic *Cymadusa filosa*.

Discussion

In the present study, the occurrence of *C. scaura* in fouling communities at off-coast fish farms was confirmed for Croatian and Maltese tuna farms. This signifies the first confirmed record of this species for both countries. Ovigerous females and subadults were found in all samples, indicating successful reproduction and thriving populations and hence, the successful establishment of *C. scaura* at the above-mentioned locations.

Although the occurrence of *C. scaura* has been confirmed in several Mediterranean locations, such as Italy Greece, Spain, Tunisia, Turkey, France and Morocco (Krapp et al. 2006; Martínez and Adarraga 2008; Souissi et al. 2010; Bakir and Katagan 2011; Ros et al. *in press*), it has not been found on off-coast structures belonging to these countries yet. In contrast, the three fish farms from where *C. scaura* was found in this study are those of the ten fish farms investigated, which are closest to the location where *C. scaura* was discovered first in the Mediterranean, i.e. Venice Lagoon, in the northern Adriatic. By now, *C. scaura* has made its way out of the Adriatic and reached Malta, and presumably, it is just a matter of time to find them on structures off other countries as well.

Additionally, more than 20,000 floating cages exist within 10 km offshore of the entire Mediterranean coast, taking into account tuna and other fish cages, mainly gilthead sea bream, *S. aurata*, and European sea bass, *D. labrax* (Trujillo et al. 2012). The high number and concentration of fish cages provides hard substrata in off-coast areas where it is naturally absent; thus, fish farms would be acting as stepping stones that help *C. scaura* to disperse through the Mediterranean.

Fish farm fouling differs from other off-coast fouling communities in different ways. The main differences are related to the floating features of the installation, in which the benthic communities are influenced by the exposure to the hydrodynamic conditions (Perkol-Finkel et al. 2008), or to the high nutrient levels originated by releases of fish production (Cook et al. 2006 and references therein). However, the most differentiating factor is the routine mechanical cleaning of the cages carried out by fish farm staff, during which most of the organisms are removed, creating opportunities of colonisation by additional species and initiation of ecological succession in the absence of

climax community structure (Greene and Grizzle 2007; Fitridge et al. 2012). The combination of these factors provides a unique habitat where amphipod assemblages are characterised by high population densities, which can create situations where fish farms act as source points (Boos et al. 2011).

Moreover, fish farms attract large aggregations of wild fish in their surroundings (Dempster et al. 2002). This concentration of fish increases the fishing pressure around the farms, with commercial and recreational fishing vessels moving around different fish farms along the same coastal area (Arechavala-Lopez et al. 2011). Thus, fishing vessels attracted by fish farms could also spread *C. scaura* not only from one farm to another but also between coastal and off-coast locations.

Potential competition for both space and food resources may exist among epifaunal organisms due to the high densities of *C. scaura* observed, especially at Brac Island where maximum densities larger than 20,000 individuals per kg habitat were found. Competition has been suggested as the reason for finding lower abundances of the caprellids, *C. equilibra* and *C. dilatata* (both common members of Mediterranean fish farm fouling; Fernandez-Gonzalez, unpublished data) in harbours where *C. scaura* was present (Guerra-García et al. 2011; Ros et al. 2013). These abundance patterns have been found also during the present study.

Despite of the thriving populations of *C. scaura* and its role as competitor on off-coast structures, it was absent from seven out of ten investigated fish farms in this study. This may also be related to the residence time, i.e. the longer *C. scaura* is present in a specific area, the more probability of spread to off-coast areas, and the present results may be just a snapshot of an ongoing process in the dispersal of the species. However, the occurrence of *C. scaura* on fish farms may also be dependent on the type of fish held in the cages, since it was only found in tuna farms in this study. In contrast to the latter, in which whole bait fish is used for feeding, sea bream/sea bass farming is characterised by the use of fish food, generating particulate waste output qualitatively and quantitatively different from tuna fatting (Vita et al. 2004). Additionally, fish abundance and species composition of aggregated fish assemblages around both kinds of fish farms are different (i.e. larger fish aggregation around sea bream/sea bass farms; Bacher et al. 2012). This could result in lower invasibility of sea bream/sea bass farms related to predation rates or competition with pre-existing detritivore species in the fouling community.

Aquaculture is considered one of the major vectors of marine bioinvasions, mainly due to the intentional introduction of non-native species for culture, or the unintentional introduction of other species associated with cultured species, such as parasites or epiphytes (Minchin et al. 2009). However, *C. scaura* does not pertain to any of the mentioned cases. In this case, aquaculture is providing suitable habitat, acting as a new vector of dispersion through a stepping stone process, which can lead to favour the invasion success of *C. scaura* in the Mediterranean. This may also hold true for *S. gallensis* and *C.filosa* (Zenetos et al. 2010), which were found along with *C. scaura* on the studied fish farms. This underlines and supports the role of off-coast structures (i.e. fish farms) as important pathways in the dispersal of non-native species.

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