Research Article

Occurrence of the invasive *Caprella scaura* Templeton, 1836 (Amphipoda: Caprellidae) in the Marchica coastal lagoon (Alboran Sea, Morocco)

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Abstract

Non-indigenous species are a recognized worldwide threat to biodiversity, to the economy and even to human health. Hence, analysis of principal descriptors of their occurrence is pivotal to set reliable conservation strategies and appropriate management. In this paper, we have reported the first record in the Marchica lagoon (Southern Alboran Sea) of the invasive *Caprella scaura* Templeton, 1836, an amphipod species likely native to the Indian Ocean and now recorded worldwide. *Caprella scaura* is widely distributed in the lagoon, and its abundance fluctuated between 3 and 337 ind./m². The species is well established in the Marchica lagoon and spreads over various ranges of depth (0.4 to 7.7 m), water temperature (14.21–28.97 °C), salinity (32.28–38.04) and substrates (bare and vegetated). This clearly confirms its large plasticity and highly invasive behaviour. The species has been introduced to the Marchica lagoon most likely via shipping activity. The recent settlement of three well established invasive species in the Marchica lagoon (*Bursatella leachii* Blainville, 1817, *Callinectes sapidus* Rathbun, 1896 and *Caprella scaura*) reveals that this coastal ecosystem is at risk of biological invasions and has to be monitored regularly in order to evaluate potential ecological impacts on the ecosystem.

Key words: non-indigenous, bioinvasion, Crustacea, Mediterranean

Introduction

Non-indigenous species (NIS) and subsequent biological invasions are considered to be one of the major threats to biodiversity (Doherty et al. 2016) and ecosystem services at the global scale (Pejchar and Mooney 2009).

The Mediterranean Sea has been characterized as a marine biodiversity hotspot (Coll et al. 2010) but also by hosting the highest known number of NIS of any other sea (Edelist et al. 2013; Zenetos et al. 2017; Bonanno and Orlando-Bonaca 2019). According to recent estimates, more than 820 multicellular NIS have been introduced to the Mediterranean Sea (Zenetos et al. 2017), with increasing abundance in many Mediterranean countries (Galil et al. 2018). Due to the spread of NIS and the threats they pose,

analysis of principal descriptors of their occurrence is pivotal to set reliable conservation strategies and appropriate management (Corriero et al. 2016; Ojaveer et al. 2018).

In the Mediterranean basin as a whole, the Ecosystem Approach (EcAp) is the guiding principle to the Mediterranean Action Plan (MAP) Programme of Work and all policy implementation and development undertaken under the auspices of the Barcelona Convention. At their 19th Ordinary Meeting (Athens, Greece, 9–12 February 2016), the Contracting Parties to the Barcelona Convention adopted a novel and ambitious Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP) with the ultimate objective of achieving the Good Environmental Status (GES) through the elaborated 11 Ecological Objectives (EO) and their respective common indicators. NIS are treated as a distinct Ecological Objective (EO2) of GES in the context of IMAP: "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem". The Common indicator of OE2 is based on "Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive non-indigenous species, notably in risk areas (EO2, in relation to the main vectors and pathways of spreading of such species in the water column and seabed, as appropriate)". Therefore, accurate and comprehensive information on NIS occurrence and distribution is crucial for Mediterranean countries to fulfil the needs of the IMAP requirements.

Caprella scaura Templeton, 1836 is a very aggressive caprellid species (Lim and Alexander 1986; Schulz and Alexander 2001) and a highly efficient disperser (Ros et al. 2015). Possibly native to the Indian Ocean, the species was long believed to be recorded for the first time in the Mediterranean Sea in the Venice lagoon (Italy) in 1994 (Sconfietti and Danesi 1996; Mizzan 1999). However, the re-examination of old samples collected in 1989–1990 in the Mar Piccolo di Taranto (Ionian Sea, Italy) showed that *C. scaura* was already well established there, and therefore, its introduction to the Mediterranean Sea should be dated back accordingly (Scipione 2015). Here, we report the first and extended record of *Caprella scaura* in the Marchica lagoon on the southern part of the Alboran Sea.

Materials and methods

Study area

The Marchica lagoon (Figure 1) is one of the largest coastal lagoons in the Mediterranean basin, with an area of over 115 km^2, and a maximum depth of 8 m. It is separated from the sea by a narrow sandbar (25 km long), with an average width between 300 and 400 m, but it reaches approximately 2 km at its southeastern part. The lagoon is connected to the sea through the artificial Bocana inlet opened artificially in 2011 (300 m wide and 6 m deep).

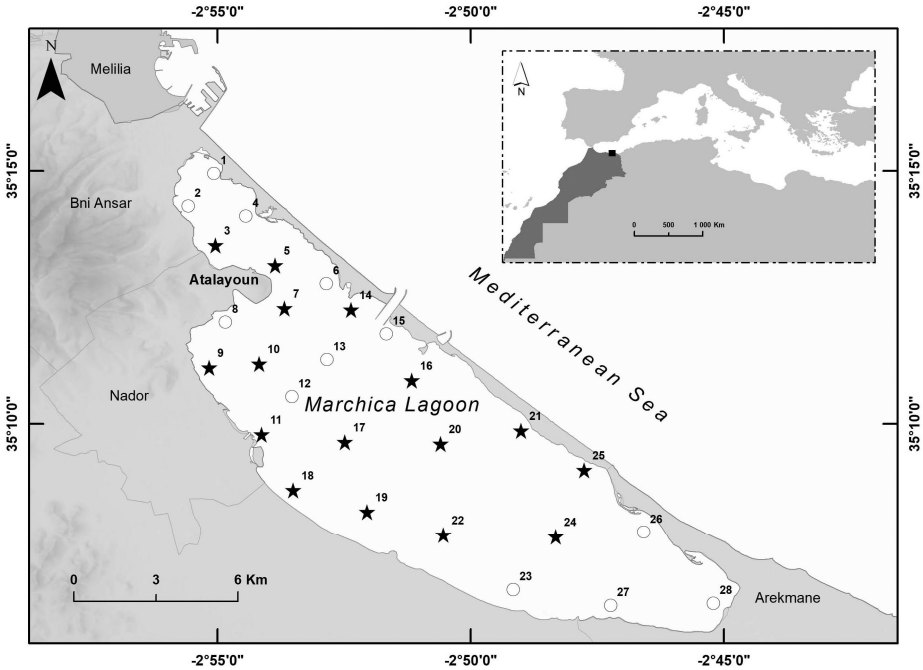

Figure 1. Map showing the geographical position of the Marchica lagoon and the sampling design (stations 1 to 28). Star symbols indicate stations where *C. scaura* was recorded.

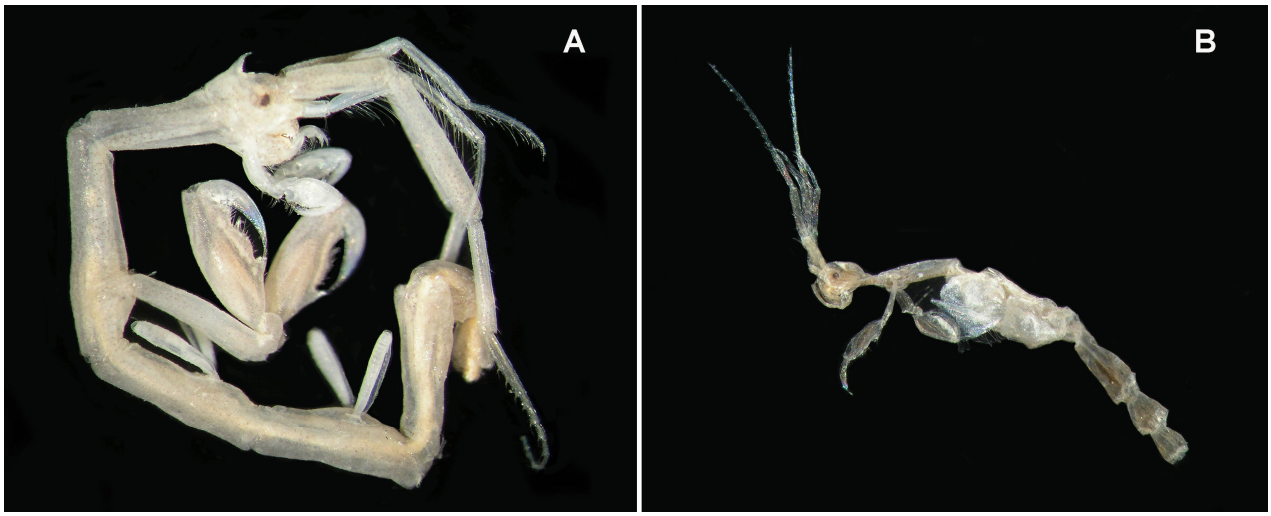

Figure 2. Lateral view (x15) of *Caprella scaura* (Templeton, 1836) from the Marchica lagoon: male (A), female (B) (Photos by Abdellatif Bayed).

Sample collection

Samples were collected from a total of 28 stations. At each station, three replicate collections were sampled seasonally (February: Winter, May: Spring, August: Summer and November: Autumn 2015) using a Van Veen grab (sampling surface of 0.1 m²). An additional sample of sediment was taken for granulometric analysis. Water salinity and temperature were measured *in situ* with a HANNA portable multiparameter.

The identification of *Caprella scaura* (Figure 2) was based on morphological descriptions provided by Templeton (1836), Guerra-García (2003) and Krapp et al. (2006). The characteristics used are: (1) cephalon of both sexes

with anteriorly directed spine, (2) basis of gnathopod 2, as well as pereonites 1 and 2 elongated in males, (3) dorsal processes in pereonites, without ventral spine in females (Figure 2). The abundance of the species per station was expressed as the total number of individuals per m^2 (Ind./m^2).

Literature analysis

Extensive study of published data on *C. scaura* records in the Mediterranean was also conducted to determine the current distribution of this species in the Mediterranean. For mapping the temporal distribution of *C. scaura*, the data were divided into decades: before 2000, 2001–2010, and 2011–present. Regarding the date of finding (year), we refer to the first collection / observation date (when reported) and not the publication date. In cases where it was impossible to clarify the first collection / observation date, we noted that the species was found before the publication date.

Data analysis

Data were processed using Statistica software (StatSoft, Inc.). Correlations between abundance of *C. scaura* and the abiotic parameters (temperature, salinity, depth and % mud) were conducted using the Pearson coefficient. To test whether the mean abundance of *C. scaura* was similar across habitats and seasons, a two-way Analysis of Variance (ANOVA) was performed with the following factors: "Habitat" with two levels (bare habitat and vegetated habitat) and "Season" with four levels (winter, spring, summer and autumn). Prior to ANOVA, data were $\log(x_i+1)$–transformed (x_i = abundance of *C. scaura*). Normality was assumed and homogeneity of variance was tested with the Cochran's C-test.

Results and discussion

Caprella scaura showed a large distribution in the Marchica lagoon (Figure 1). A total of 1427 individuals of *C. scaura* were collected from 16 of the 28 stations in the sampling area during the whole study period with frequency of occurrence fluctuating between 14% in Spring and 36% in Summer (Supplementary material Table S1). Mean abundance per season varied between 9 and 16 Ind./m^2 (Figure 3) with no significant effect of season nor of habitat type (ANOVA, $p > 0.05$). Moreover, the abundance of the species showed no significant relationship with abiotic parameters (temperature, salinity, depth and % Mud) (Pearson coefficient, $p > 0.05$). The species is well established in the Marchica lagoon and spread over various range of depth (0.4 to 7.7 m), water temperature (14.21–28.97 °C), salinity (32.28–38.04) and substrates (bare and vegetated) (Table S2). This clearly confirms the invasiveness of the species and its capacity to spread over various environmental conditions (Lim and Alexander 1986; Schulz and Alexander 2001; Ros et al. 2015).

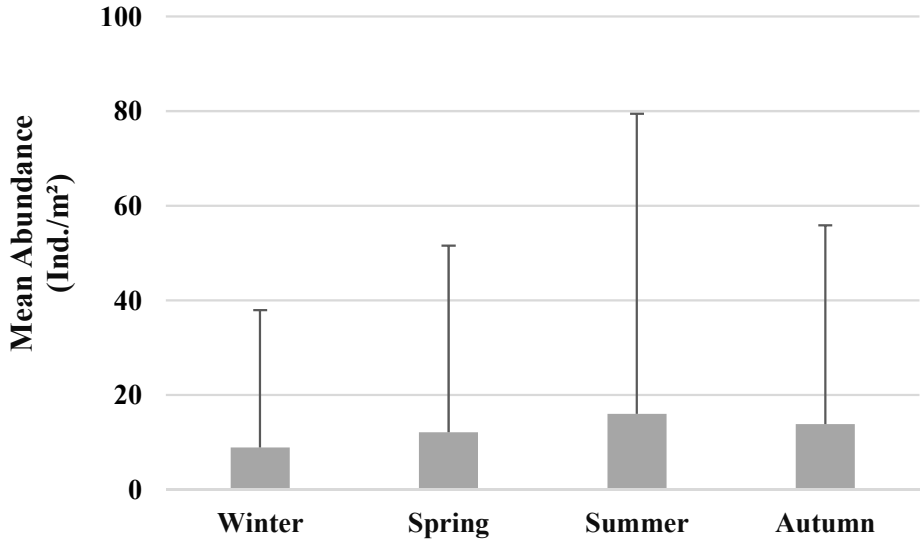

Figure 3. Seasonal variation in mean abundance (± SD) of *Caprella scaura* in the Marchica lagoon during 2015.

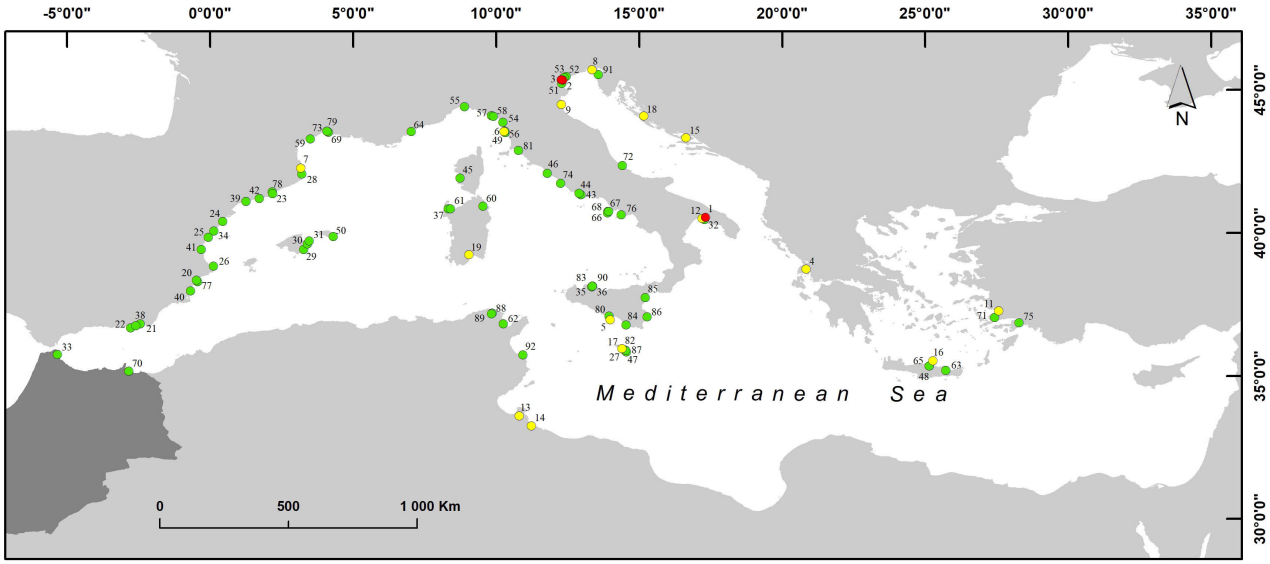

Figure 4. Records of *Caprella scaura* in the Mediterranean Sea. Green circles indicate the most recent sites (after 2010) where the species has been found. Yellow circles indicate the localities registered between 2000–2010, and red circles represent records occurred before 2000. For details see Supplementary material (Table S3).

Caprella scaura has successfully spread along Mediterranean countries in a short time period. Up-to-day, *C. scaura* is confirmed and well established in 10 out of the 21 Mediterranean countries (Figure 4; Table S3). In the southern Mediterranean coasts, the species was recorded only in two countries: 1) Morocco in Marina Smir (Ros et al. 2014) and recently in the Marchica lagoon (Present study), 2) Tunisia in Boughrara lagoon (Ben Souissi et al. 2010), El Bibane lagoon (Ben Souissi et al. 2010), Tunis lagoon (Ounifi Ben Amor et al. 2017), Bizerte lagoon (Chebaane et al. 2018; Khammassi et al. 2019) and Monastir Bay (Chebaane et al. 2019). The differences in the distribution pattern of *C. scaura* between the northern and the southern Mediterranean coasts have to be treated with caution. They are most probably linked to the evident lack of scientific data and

production in several southern regions of the Mediterranean basin (Coll et al. 2010). In the Marchica lagoon, knowledge on peracarids is scarce and old (Guélorget et al. 1987; Zine 1989; Menioui and Zine 1995; Boussalwa et al. 2000). In this context, this study has not only extended the known distribution range of *C. scaura* in the Alboran Sea and the north-eastern coast of Morocco, but also increased knowledge on amphipod diversity in Morocco.

At the Mediterranean scale, *C. scaura* was found in 77% of the records on man-made substrates in harbours and marinas, 16% in coastal lagoons, and 7% in fishing farms (Table S3). This supports the fact that shipping is the main vector for both the primary introduction and the secondary spread of NIS, via ballast water or biofouling (Ruiz et al. 2000; Streftaris et al. 2005). In our case, the presence of yachting marina of Atalayoun inside the Marchica lagoon, as well as artisanal fishing harbours, suggests that its expansion is most likely facilitated by shipping activity through biofouling and in a lesser concern ballast water (Bakır and Katağan 2011; Ros et al. 2013). Moreover, the surrounding harbours and marinas, such as the Beni Ansar harbour and the Melilla marina, could act as a potential source of individuals to the Marchica lagoon.

Marinas represent high-risk sites for both primary introduction and secondary stepping-stone invasion events (Murray et al. 2011; Ashton et al. 2014; Ferrario et al. 2017). The recreational marinas represent an important entry points for NIS in the Mediterranean, and, at a certain rate of incoming / outgoing traffic, these may act as significant hubs for the transfer of NIS to other localities (Ulman et al. 2019).

With regard to artificial structures, NIS have been reported to prefer them to natural surfaces (Arenas et al. 2006). Artificial substrates are abundant in port areas, where environmental stress due to pollution and to salinity and temperature fluctuations, among other causes, results in formation of wide bare patches that are suitable for NIS settlement (Arenas et al. 2006; Mineur et al. 2012; Geraldi et al. 2014). In the Marchica lagoon, *Caprella scaura* was found on natural habitats corresponding to different types of substrates, associated, when vegetated, to seagrass beds and algae. This revealed the higher invasive potential and the large plasticity of the species to spread in the Mediterranean Sea. The expansion success of this NIS could be aided by their high densities, fecundity and growth rates (Martinez and Adarraga 2008; Guerra-García et al. 2011; Baeza-Rojano et al. 2013), wide physiological tolerances (Cockman and Albone 1987), and their ability to attach to boats hulls (Cook et al. 2007).

Establishing national NIS lists and understanding their pathways of introduction, impacts, and control options is essential for efficient prevention, detection, and management of bioinvasions (Katsanevakis et al. 2015), especially within the framework of the recent invasive species policies, both at the Mediterranean scale (IMAP) and at the European scale

under the Marine Strategy Framework Directive (MSFD) (Servello et al. 2019). Up-to-now, three NIS have been recently recorded and are well established in the Marchica lagoon. These are the Mollusc *Bursatella leachii* Blainville, 1817 (Selfati et al. 2017), the blue crab *Callinectes sapidus* Rathbun, 1896 (Oussellam and Bazairi 2018 *in* Chartosia et al. 2018) and the Amphipod *Caprella scaura* (present study). Their recent settlement in the Marchica lagoon reveals that this coastal ecosystem is at risk of biological invasions and should be monitored regularly in order to evaluate the impact of these invasive species on the ecosystem.

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References

Arenas F, Bishop JDD, Carlton JT, Dyrynda PJ, Farnham WF, Gonzalez DJ, Jacobs MW, Lambert C, Lambert G, Nielsen SE, Pederson JA, Porte JS, Ward S, Wood CA (2006) Alien species and other notable records from a rapid assessment survey of marinas on the south coast of England. *Journal of the Marine Biological Association of the United Kingdom* 86: 1329–1337, https://doi.org/10.1017/S0025315406014354

Ashton G, Davidson I, Ruiz G (2014) Transient small boats as a long-distance coastal vector for dispersal of biofouling organisms. *Estuaries and Coasts* 37: 1572–1581, https://doi.org/10.1007/s12237-014-9782-9

Baeza-Rojano E, Calero-Cano S, Hachero-Cruzado I, Guerra-García JM (2013) A preliminary study of the *Caprella scaura* amphipod culture for potential use in aquaculture. *Journal of Sea Research* 83: 146–151, https://doi.org/10.1016/j.seares.2013.04.014

Bakir K, Katağan T (2011) On the occurrence of *Caprella scaura* Templeton, 1836 (Crustacea: Amphipoda) in Turkish waters. *Zoology in the Middle East* 52: 125–126, https://doi.org/10.1080/09397140.2011.10638491

Ben Souissi J, Kahri C, Ben Salem M, Zaouali J (2010) Les espèces non-indigènes du macrobenthos des lagunes du sud-est tunisien: point sur la situation. *Rapport de la Commission internationale pour l'exploration scientifique de la Mer Méditerranée (CIESM)* 39 : 449

Bonanno G, Orlando-Bonaca M (2019) Non-indigenous marine species in the Mediterranean Sea-Myth and reality. *Environmental Science & Policy* 96: 123–131, https://doi.org/10.1016/j.envsci.2019.03.014

Boussalwa E, Douira A, Mokhtar N (2000) Contribution à l'étude typologique d'une lagune exposée à la pollution, la lagune de Nador (Maroc) : distribution des Crustacés. *Cahiers de Biologie Marine* 41 : 255–263

Chartosia N, Anastasiadis D, Bazairi H, Crocetta F, Deidun A, Despalatović M, Di Martino V, Dimitriou N, Dragičević B, Dulčić J, Durucan F, Hasbek D, Ketsilis-Rinis V, Kleitou P, Lipej L, Macali A, Marchini A, Ousselam M, Piraino S, Stancanelli B, Theodosiou M, Tiralongo F, Todorova V, Trkov D, Yapici S (2018) New Mediterranean Biodiversity Records (July 2018). *Mediterranean Marine Science* 19: 398–415, https://doi.org/10.12681/mms.18099

Chebaane S, Shaiek M, Zakhama-Sraieb R (2018) A new record and range extension of an invasive amphipod *Caprella scaura* Templeton, 1836 in Tunisia, North Africa. *Journal Black Sea / Mediterranean Environment* 24: 255–262, http://doi.org/10.6084/m9.figshare.7905242.v1

Chebaane S, Sempre-Valverde J, Dorai S, Kacem A, Ramzi Sghaier Y (2019) A Preliminary inventory of alien and cryptogenic species in Monastir Bay, Tunisia: spatial distribution, introduction trends and pathways. *Mediterranean Marine Science* 20: 616–626, https://doi.org/10.12681/mms.20229

Cockman B, Albone P (1987) Caprellidae of the Swan River estuary. In: John J (ed), Swan River estuary, ecology and management. Environmental Studies Group report no. 1. Curtin University of Technology, Perth, Australia, pp 163–177

Coll M, Piroddi C, Steenbeek J, Kaschner K, Ben Rais Lasram F, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T, Danovaro R, Estrada M, Froglia C, Galil BS, Gasol JM, Gertwagen R, Gil J, Guilhaumon F, Kesner-Reyes K, Kitsos M-S, Koukouras A,

Lampadariou N, Laxamana E, López-Fé de la Cuadra CM, Lotze HK, Martin D, Mouillot D, Oro D, Raicevich S, Rius-Barile J, Saiz-Salinas JI, San Vicente C, Somot S, Templado J, Turon X, Vafidis D, Villanueva R, Voultsiadou E (2010) The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. *PLoS ONE* 5: e11842, https://doi.org/10.1371/journal.pone.0011842

Cook EJ, Jahnke M, Kerckhof F, Minchin D, Faasse M, Boos K, Ashton G (2007) European expansion of the introduced amphipod *Caprella mutica* Schurin 1935. *Aquatic Invasions* 2: 411–421, https://doi.org/10.3391/ai.2007.2.4.11

Corriero G, Pierri C, Accoroni S, Alabiso G, Bavestrello G, Barbone E, Bastianini M, Bazzoni AM, Bernardi Aubry F, Boero F, Buia MC, Cabrini M, Camatti E, Cardone F, Cataletto B, Cattaneo Vietti R, Cecere E, Cibic T, Colangelo P, De Olazabal A, D'onghia G, Finotto S, Fiore N, Fornasaro D, Fraschetti S, Gambi MC, Giangrande A, Gravili C, Guglielmo R, Longo C, Lorenti M, Lugliè A, Maiorano P, Mazzocchi MG, Mercurio M, Mastrototaro F, Mistri M, Monti M, Munari C, Musco L, Nonnis-Marzano C, Padedda BM, Patti FP, Petrocelli A, Piraino S, Portacci G, Pugnetti A, Pulina S, Romagnoli T, Rosati I, Sarno D, Satta, CT, Sechi N, Schiaparelli S, Scipione B, Sion L, Terlizzi A, Tirelli V, Totti C, Tursi A, Ungaro N, Zingone A, Zupo V, Basset A (2016) Ecosystem vulnerability to alien and invasive species: A case study on marine habitats along the Italian coast. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26: 392–409, https://doi.org/10.1002/aqc.2550

Doherty TS, Glen AS, Nimmo DG, Ritchie EG, Dickman CR (2016) Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences* 113: 11261–11265, https://doi.org/10.1073/pnas.1602480113

Edelist D, Rilov G, Golani D, Carlton JT, Spanier E (2013) Restructuring the sea: profound shifts in the world's most invaded marine ecosystem. *Diversity and Distributions* 19: 69–77, https://doi.org/10.1111/ddi.12002

Ferrario J, Caronni S, Occhipinti-Ambrogi A, Marchini A (2017) Role of commercial harbours and recreational marinas in the spread of non-indigenous fouling species. *Biofouling* 33: 651–660, https://doi.org/10.1080/08927014.2017.1351958

Galil BS, Marchini A, Occhipinti-Ambrogi A (2018) Mare Nostrum, Mare Quod Invaditur - The History of Bioinvasions in the Mediterranean Sea. In: Queiroz A, Pooley S (eds), Histories of Bioinvasions in the Mediterranean Environmental History, vol 8. Springer, Cham, pp 21–49, https://doi.org/10.1007/978-3-319-74986-0_2

Guélorget O, Perthuisot JP, Frisoni GF, Monti D (1987) Le rôle du confinement dans l'organisation biogéographique de la lagune de Nador (Maroc). *Oceanologica Acta* 10 : 435–444

Geraldi NR, Smyth AR, Piehler MF, Peterson CH (2014) Artificial substrates enhance non-native macroalga and N_2 production. *Biological Invasions* 16: 1819–1831, https://doi.org/10.1007/s10530-013-0629-2

Guerra-García JM (2003) The Caprellidea (Crustacea: Amphipoda) from Mauritius Island, western Indian Ocean. *Zootaxa* 232 : 1–24, https://doi.org/10.11646/zootaxa.232.1.1

Guerra-García JM, Ros M, Dugo-Cota A, Burgos V, Flores-León AM, Baeza-Rojano E, Cabezas MP, Núñez J (2011) Geographical expansion of the invader *Caprella scaura* (Crustacea: Amphipoda: Caprellidae) to the East Atlantic coast. *Marine Biology* 158: 2617–2622, https://doi.org/10.1007/s00227-011-1754-z

Katsanevakis S, Deriu I, D'Amico F, Nunes AL, Pelaez Sanchez S, Crocetta F, Arianoutsou M, Bazos I, Christopoulou A, Curto G, Delipetrou P, Kokkoris Y, Panov V, Rabitsch W, Roques A, Scalera R, Shirley SM, Tricarico E, Vannini A, Zenetos A, Zervou S, Zikos A, Cardoso AC (2015) European Alien Species Information Network (EASIN): supporting European policies and scientific research. *Management of Biological Invasions* 6: 147–157, https://doi.org/10.3391/mbi.2015.6.2.05

Khammassi M, Jourde J, Zaabar W, Laabidi S, Sauriau PG, Achouri MS (2019) Inventory and new records of benthic amphipods from macrophytes and fine sand communities of the Bizerte lagoon (Tunisia, SW Mediterranean Sea). *Marine Biodiversity Records* 12: 1–10, https://doi.org/10.1186/s41200-019-0182-5

Krapp T, Lang C, Libertini A, Melzer RR (2006) *Caprella scaura* Templeton, 1836 sensu lato (Amphipoda: Caprellidae) in the Mediterranean. *Organisms, Diversity and Evolution* 6: 77–81, https://doi.org/10.1016/j.ode.2005.04.004

Lim S, Alexander C (1986) Reproductive behavior of the caprellid amphipod *Caprella scaura* typica Mayer, 1890. *Marine and Freshwater Behaviour and Physiology* 12: 217–230, https://doi.org/10.1080/10236248609378648

Martinez J, Adarraga I (2008) First record of invasive caprellid *Caprella scaura* Templeton, 1836 sensu lato (Crustacea: Amphipoda: Caprellidae) from the Iberian Peninsula. *Aquatic Invasions* 3: 165–171, https://doi.org/10.3391/ai.2008.3.2.6

Menioui M, Zine NE (1995) Etat des connaissances sur la biodiversité (faune benthique) d'une lagune méditerranéenne: lagune de Nador. *Rapports de la CIESM* 34: 83

Mineur F, Doherty EJ, Minchin D, Bohn K, MacLeod A, Maggs CA (2012) Changing coasts: marine aliens and artificial structures. *Oceanography and Marine Biology - An Annual Review* 50 : 189–234, https://doi.org/10.1201/b12157-5

Mizzan L (1999) Le specie alloctone del macrozoobenthos della Laguna di Venezia: il punto della situazione. *Bollettino del Museo civico di storia naturale di Venezia* 49: 145–177

Murray CC, Pakhomov EA, Therriault TW (2011) Recreational boating: a large unregulated vector transporting marine invasive species. *Diversity and Distributions* 17: 1161–1172, https://doi.org/10.1111/j.1472-4642.2011.00798.x

Ojaveer H, Galil BS, Carlton JT, Alleway H, Goulletquer P, Lehtiniemi M, Marchini A, Miller W, Occhipinti-Ambrogi A, Peharda M, Ruiz GM, Williams SL, Zaiko A (2018) Historical baselines in marine bioinvasions: implications for policy and management. *PLoS ONE* 13: e0202383, https://doi.org/10.1371/journal.pone.0202383

Ounifi Ben Amor K, Ben Amor MM, Rifi M, Ben Souissi J (2017) Diversity of crustacean species from Tunis Southern Lagoon (Central Mediterranean) after an ecological restoration. *Cahiers de Biologie Marine* 58: 49–57, https://doi.org/10.21411/cbm.a.cc457186

Pejchar L, Mooney HA (2009) Invasive species, ecosystem services and human well-being. *Trends in Ecology & Evolution* 24: 497–504, https://doi.org/10.1016/j.tree.2009.03.016

Ros M, Vázquez-Luis M, Guerra-García JM (2013) 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. *Journal of Sea Research* 83: 94–103, https://doi.org/10.1016/j.seares.2013.04.004

Ros M, Guerra-García JM, Navarro-Barranco C, Cabezas MP, Vázquez-Luis M (2014) The spreading of the non-native caprellid (Crustacea: Amphipoda) *Caprella scaura* Templeton, 1836 into southern Europe and northern Africa: a complicated taxonomic history. *Mediterranean Marine Science* 15: 145–155, https://doi.org/10.12681/mms.469

Ros M, Vázquez-Luis M, Guerra-García JM (2015) Environmental factors modulating the extent of impact in coastal invasions: The case of a widespread invasive caprellid (Crustacea: Amphipoda) in the Iberian Peninsula. *Marine Pollution Bulletin* 98: 247–258, https://doi.org/10.1016/j.marpolbul.2015.06.041

Ruiz GM, Rawlings TK, Dobbs FC, Drake LA, Mullady T, Huq A, Colwell RR (2000) Global spread of microorganisms by ships. *Nature* 408: 49–50, https://doi.org/10.1038/35040695

Schulz MK, Alexander CG (2001) Aggressive behavior of *Caprella scaura* Mayer, 1890 (Crustacea: Amphipoda). *Marine and Freshwater Behaviour and Physiology* 34: 181–187, https://doi.org/10.1080/10236240109379071

Scipione MB (2015) *Caprella scaura* Templeton, 1836: new data able to date back its presence in the Mediterranean Sea. In: Coasta FO, Cunha MR (eds), Book of Abstracts - Proceedings of the 16th International Colloquium on Amphipoda (ICA), Aveiro, Portugal, 7-11 sept 2015

Sconfietti R, Danesi P (1996) Structural variations in Peracarids communities at the opposite extremes of the Malamocco basin (Lagoon of Venice). *Atti Società Italiana Ecologia* 17: 407–410

Selfati M, El Ouamari N, Crocetta F, Mesfioui A, Boissery P, Bazairi H (2017) Closing the circle in the Mediterranean Sea: *Bursatella leachii* Blainville, 1817 (Mollusca: Gastropoda: Anaspidea) has reached Morocco. *BioInvasions Records* 6: 129–134, https://doi.org/10.3391/bir.2017.6.2.07

Servello G, Andaloro F, Azzurro E, Castriota L, Catra M, Chiarore A, Crocetta F, D'Alessandro M, Denitto F, Froglia C, Gravili C, Langer M, Lo Brutto S, Mastrototaro F, Petrocelli A, Pipitone C, Piraino S, Relini G, Serio D, Xentidis N, Zenetos A (2019) Marine alien species in Italy: A contribution to the implementation of descriptor D2 of the marine strategy framework directive. *Mediterranean Marine Science* 20: 1–48, https://doi.org/10.12681/mms.18711

Streftaris N, Zenetos A, Papathanassiou E (2005) Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. *Oceanography and Marine Biology - An Annual Review* 43: 419–453, https://doi.org/10.1201/9781420037449.ch8

Templeton R (1836) Descriptions of some undescribed exotic Crustacea. *Transactions of the Entomological Society of London* 1: 185–198, https://doi.org/10.1111/j.1365-2311.1839.tb03207.x

Ulman A, Ferrario J, Forcada A, Arvanitidis C, Occhipinti-Ambrogi A, Marchini A (2019) A Hitchhiker's guide to Mediterranean marina travel for alien species. *Journal of Environmental Management* 241: 328–339, https://doi.org/10.1016/j.jenvman.2019.04.011

Zenetos A, Çinar ME, Crocetta F, Golani D, Rosso A, Servello G, Shenkar N, Turon X, Verlaque M (2017) Uncertainties and validation of alien species catalogues: The Mediterranean as an example. *Estuarine, Coastal and Shelf Science* 191: 171–187, https://doi.org/10.1016/j.ecss.2017.03.031

Zine N (1989) Etude de la malacofaune de la lagune de Nador et dynamique de population de *Venerupis decussata* (Linné 1767). PhD Thesis, Faculty of Science, Rabat, Morocco, 97 pp

Supplementary material

The following supplementary material is available for this article:

Table S1. Abundance (Ind./m²) by station and season of *Caprella scaura* in the Marchica lagoon during 2015.

Table S2. Values of abiotic parameters by station and season in the Marchica lagoon during 2015.

Table S3. Published records of *Caprella scaura* from the Mediterranean Sea.

Appendix 1. References for Table S3.

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http://www.reabic.net/journals/bir/2020/Supplements/BIR_2020_ElKamcha_etal_SupplementaryMaterial.xlsx