

ANNOTATED LIST OF CRUSTACEAN SPECIES RECORDED IN THE TUNIS
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ABSTRACT

During investigations conducted after the environmental restoration of the Tunis Southern Lagoon, a total of 44 crustacean species belonging to 27 families were recorded, including 19 decapods, 11 isopods, 10 amphipods, 3 cirripeds and a single stomatopod. Of these 44 species, 31 were autochthonous and 13 allochthonous. Six species were recorded in the area for the first time. The Tunis Southern Lagoon provides favourable environmental conditions for the settlement of alien species, mainly crustaceans. The occurrence of alien crustaceans plays an important economic and ecological role in this restricted brackish area, and enhances anthropogenic activities such as fishery of cephalopods and fishes.

Keywords: Brackish waters, autochthonous species, allochthonous species, ecological restoration, new settlements

ELENCO AGGIORNATO DELLE SPECIE DI CROSTACEI TROVATI NELLA LAGUNA
MERIDIONALE DI TUNISI (TUNISIA SETTENTRIONALE, MEDITERRANEO CENTRALE)

SINTESI

Durante le indagini condotte dopo il ripristino ambientale della laguna meridionale di Tunisi sono state trovate 44 specie di crostacei appartenenti a 27 famiglie, tra cui 19 decapodi, 11 isopodi, 10 anfipodi, tre cirripedi e un unico stomatopoda. Di queste 44 specie, 31 sono autoctone e 13 alloctone. Sei specie sono state rinvenute nell'area per la prima volta. La laguna meridionale di Tunisi offre condizioni ambientali favorevoli all'insediamento di specie aliene, soprattutto di crostacei. La presenza di crostacei non-indigeni svolge un ruolo economico ed ecologico importante in questa ristretta area salmastra, e accresce le attività antropiche quali la pesca di cefalopodi e pesci.

Parole chiave: acque salmastre, specie autoctone, specie alloctone, ripristino ecologico, nuovi insediamenti

INTRODUCTION

The Tunis Southern Lagoon had been strongly polluted by anthropogenic activities (Ben Souissi, 2002; Hermi & Aissa, 2002) and required thorough environmental restoration, which was achieved in September 2001 (Vandenbroek & Ben Charrada, 2001; Ben Souissi, 2002). Further, investigations were conducted throughout the lagoon to assess the restoration level and improvement of water quality (Jouini *et al.*, 2005; Ben Souissi *et al.*, 2005a). Occurrence of elasmobranch and teleost species, substantially established in the Tunis Southern Lagoon, could be considered as the most favourable consequence of the ecological restoration of this brackish area (Mejri *et al.*, 2004; Ben Souissi *et al.*, 2004, 2005b). However, analysis of stomach contents of many fish species has shown that crustaceans are generally recorded as prey species (Mejri, 2003; Ben Souissi *et al.*, 2004). It suggests that crustacean species play both ecological and economic roles in the Tunis Southern Lagoon, improving and enlarging the successful establishment of cephalopod and fish populations, as well as fishery activities.

The presence of crustacean species in the Tunis Southern Lagoon has been previously reported by Ben Souissi *et al.* (2003; 2005a). It generally concerned small species belonging to the genus *Sphaeroma* La-

treille, 1802; however, an overall study of crustacean fauna inhabiting the area had yet to be prepared. The aims of this paper are therefore to present a thorough inventory of crustacean species inhabiting the Tunis Southern Lagoon, with a particular emphasis on their origin, abundance and capture sites, and to examine the ecological and economic roles they play in this area.

MATERIAL AND METHODS

Study area

The Tunis Southern Lagoon (36°47' N, 10°17' E) is the southern part of the Lake of Tunis, which is divided in two areas by a navigation channel (Fig. 1). The Tunis Southern Lagoon, which extends over an area of 720 ha, has a regular depth of about 2.1 m and a maximum depth of 3.8 m. It appears as an ellipse stretching in the SW-NE direction, between 36°46'47" and 36°48'00"N, and 10°12'22" and 10°16'41"E. Its shores have been excavated and protected by large rocky stones.

Sampling procedure

Between February 2012 and June 2015, sampling was conducted in shallow coastal waters, at a depth of less than 3 m, at 10 stations. Samples were collected by dredging and scuba diving in stations 1 to 6, which are characterized by muddy bottom. At stations 7 to 10, located in intertidal rocky shores covered by algae, sampling from under stones was conducted manually (Fig. 1). The animals were removed by rinsing the vegetation in a big tray and recovered on a 1 mm mesh sieve, which retained all individuals, including small species. The retained specimens were sorted, fixed in 70% alcohol and then identified, using different identification keys (Fisher *et al.*, 1987; Froggia & Manning, 1989; Noel, 1992). The nomenclature adopted in this paper follows the World Register of Marine Species (WoRMS).

RESULTS AND DISCUSSION

A total of 44 crustacean species from 27 families were recorded in the Tunis Southern Lagoon. The most abundantly represented taxa were decapods (19 species), isopods (11 species), amphipods (10 species), barnacles (3 species) and stomatopods (1 species), with 6 species recorded in the area for the first time. Of the 44 crustacean species, 31 were autochthonous and 13 allochthonous (Tab. 1). The annotated list of identified species is given below.

Checklist of the Tunis Southern Lagoon

ORDER DECAPODA BRACHYURA
Family Euryplacidae
Eucrate crenata (De Haan, 1853) (Fig. 2A)

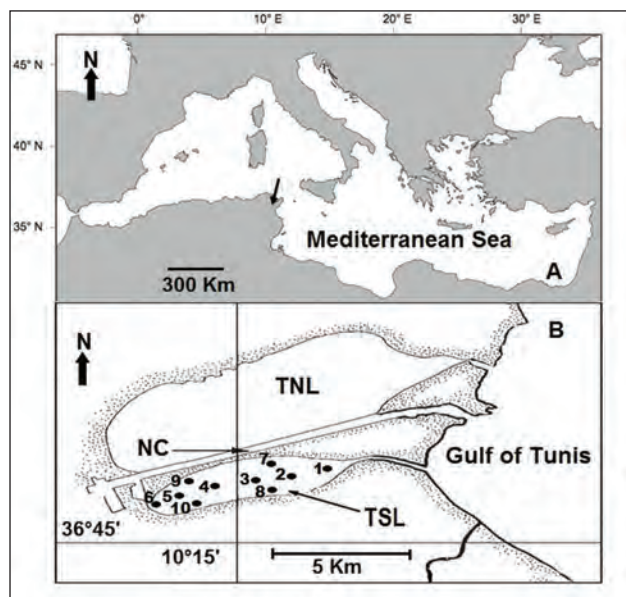


Fig. 1: A. Map of Tunisia pointing out in the north the site of Tunis Southern Lagoon. B. Tunis Northern Lagoon (TNL) separated from Tunis Southern Lagoon (TSL) by a navigation channel (NC). ST1-ST10 sampling stations in TSL.

Sl. 1: A. Zemljevid Tunizije z označeno Tuniško južno laguno v severnem predelu. B. Tuniška severna laguna (TNL), razmejena od južne (TSL) s plovnikom (NC). ST1-ST10 vzorčevalne postaje v TSL.

Tab. 1: List of the crustacean species in the Tunis Southern Lagoon per station.

* Alien species ● New records for the Tunis Southern Lagoon.

Tab. 1: Seznam vrst rakov na posamezni postaji v Tuniški južni laguni.

* Tujerodne vrste ● Novi podatki za Tuniško južno laguno.

| Stations | ST1 | ST2 | ST3 | ST4 | ST5 | ST6 | ST7 | ST8 | ST9 | ST10 |
|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Order: Decapoda | | | | | | | | | | |
| Family: Euryplacidae | | | | | | | | | | |
| * <i>Eurcate crenata</i> (De Haan, 1853) | + | - | - | - | - | - | - | - | - | - |
| Family: Pilumnidae | | | | | | | | | | |
| * <i>Pilumnopus vauquelini</i> (Audouin, 1826) | + | + | + | - | - | - | - | - | - | - |
| Family: Panopeidae | | | | | | | | | | |
| * <i>Rhithropanopeus harrisi</i> (Gould, 1841) | - | - | - | - | - | - | + | + | + | - |
| Family: Varunidae | | | | | | | | | | |
| * <i>Hemigrapsus sanguineus</i> (De Haan, 1835) | - | + | - | - | - | - | - | - | - | - |
| <i>Brachynotus sexdentatus</i> (Risso, 1827) | + | + | - | - | - | - | - | - | - | - |
| Family: Porcellanidae | | | | | | | | | | |
| <i>Porcellana plathycheles</i> (Pennant, 1777) | - | - | - | - | - | - | + | - | + | - |
| <i>Pisidia longicornis</i> Linnaeus, 1767 | + | - | - | - | - | - | - | - | - | - |
| Family: Plagusidae | | | | | | | | | | |
| <i>Euchirograpsus liguricus</i> H. Milne Edwards, 1853 | - | - | - | - | - | - | - | - | + | - |
| Family: Portunidae | | | | | | | | | | |
| <i>Carcinus aestuarii</i> Nardo, 1847 | + | + | + | - | - | - | - | - | - | - |
| Family: Grapsidae | | | | | | | | | | |
| <i>Pachygrapsus marmoratus</i> (Fabricius, 1787) | - | - | - | - | - | - | - | - | + | + |
| Family: Polybiidae | | | | | | | | | | |
| ● <i>Liocarcinus vernalis</i> (Risso, 1816) | - | - | - | - | - | - | - | + | - | - |
| Family: Inachidae | | | | | | | | | | |
| <i>Inachus dorsettensis</i> (Pennant, 1777) | - | - | + | - | - | - | - | - | - | - |
| Family: Palaemonidae | | | | | | | | | | |
| <i>Palaemon serratus</i> (Pennant, 1777) | - | + | + | - | - | - | - | - | - | - |
| <i>Palaemonvarians</i> Leach, 1813 | - | - | + | + | - | - | - | - | - | - |
| ● <i>Palaemon xiphias</i> Risso, 1816 | - | - | + | + | - | - | - | - | - | - |
| <i>Palaemon elegans</i> Rathke, 1837 | - | - | + | - | - | - | - | - | - | - |
| Family: Penaeidae | | | | | | | | | | |
| <i>Penaeus kerathurus</i> (Forskål, 1775) | + | + | - | - | - | - | - | - | - | - |
| Family: Upogebiidae | | | | | | | | | | |
| <i>Upogebia pusilla</i> (Petagna, 1792) | - | - | - | + | + | - | - | - | - | - |
| Family: Diogenidae | | | | | | | | | | |
| <i>Diogenes pugilator</i> (Roux 1829) | + | - | - | - | - | - | - | - | - | - |
| Order: Isopoda | | | | | | | | | | |
| Family: Sphaeromatidae | | | | | | | | | | |

| | | | | | | | | | | | |
|--|---|---|---|---|---|---|---|---|---|---|---|
| <i>Cymodoce truncata</i> (Leach, 1814) | + | + | + | + | + | + | + | + | + | + | + |
| <i>Sphaeroma serratum</i> (Fabricius, 1787) | - | - | - | - | - | + | + | + | + | + | + |
| ★ <i>Sphaeroma walkeri</i> Stebbing, 1905 | - | - | + | + | + | + | - | - | - | - | - |
| ★ <i>Sphaeroma venustissimum</i> (Monod, 1931) | - | - | - | - | - | - | + | + | + | + | + |
| ★ <i>Paradella diana</i> (Menzies, 1962) | - | - | - | - | - | - | - | + | + | + | + |
| ★ <i>Paracerceis sculpta</i> (Holmes, 1904) | + | + | + | + | + | + | + | + | + | + | + |
| <i>Dynamene edwardsi</i> (Lucas, 1849) | - | - | - | - | - | - | + | + | + | + | - |
| Family: Idoteida | | | | | | | | | | | |
| <i>Idotea balthica</i> (Pallas, 1772) | + | + | + | - | - | - | - | - | - | - | - |
| <i>Idotea chelipes</i> (Slabber, 1778) | - | - | - | + | + | - | - | - | - | - | - |
| Family: Cymothoidea | | | | | | | | | | | |
| ●★ <i>Anilocra pilchardi</i> Bariche & Trilles, 2006 | + | + | - | - | - | + | - | - | - | - | - |
| Family: Janiridae | | | | | | | | | | | |
| <i>Jaera (Jaera) hopeana</i> Costa, 1853 | - | - | - | - | - | - | + | + | + | + | + |
| Order: Amphipoda | | | | | | | | | | | |
| Family: Caprellidae | | | | | | | | | | | |
| ●★ <i>Caprella scaura</i> Templeton, 1836 | - | - | - | - | - | + | - | - | - | - | - |
| <i>Caprella equilibra</i> Say, 1818 | - | - | - | - | + | + | - | - | - | - | - |
| Family: Ampithoidae | | | | | | | | | | | |
| ★ <i>Cymadusa filosa</i> Savigny, 1816 | + | + | + | + | + | + | + | + | + | - | - |
| Family: Corophiidae | | | | | | | | | | | |
| <i>Monocorophium acherusicum</i> (Costa, 1853) | + | + | + | + | + | + | + | + | + | + | + |
| <i>Monocorophium insidiosum</i> (Crawford, 1937) | - | - | - | - | - | - | - | + | + | + | + |
| <i>Corophium orientale</i> Schellenberg, 1928 | - | - | - | - | - | - | + | + | - | - | - |
| Family: Gammaridae | | | | | | | | | | | |
| <i>Gammarus aequicauda</i> (Martynov, 1931) | + | + | + | + | + | + | + | + | + | - | - |
| <i>Gammarus insensibilis</i> (Stock, 1966) | - | - | - | - | - | - | - | - | + | + | + |
| Family: Talitridae | | | | | | | | | | | |
| <i>Orchestia stephenseni</i> Cecchini, 1928 | - | - | - | - | - | + | - | - | - | - | - |
| Family: Melitidae | | | | | | | | | | | |
| ● <i>Melita palmata</i> (Montagu, 1804) | - | - | + | + | - | - | - | - | - | - | - |
| Order: Cirripedia | | | | | | | | | | | |
| Family: Balanidae | | | | | | | | | | | |
| ★ <i>Amphibalanus eburneus</i> (Gould, 1841) | - | - | - | - | - | - | + | + | - | - | - |
| <i>Amphibalanus amphitrite</i> (Darwin, 1854) | - | - | - | - | - | - | + | + | + | + | + |
| Family: Sacculinidae | | | | | | | | | | | |
| ● <i>Sacculina carcini</i> Thompson, 1836 | + | + | - | - | - | - | - | - | - | - | - |
| Order: Stomatopoda | | | | | | | | | | | |
| Family: squillidae | | | | | | | | | | | |
| ★ <i>Erugosquilla massavensis</i> (Kossmann, 1880) | - | - | + | - | - | - | - | - | - | - | - |

Eucrate crenata originates from the Red Sea and was recorded in the Mediterranean off Port Said (Egypt) by Calman (1927), off southern Turkey (Enzenross *et al.*, 1992) and in Haifa Bay, Israel (Galil, 1997). In Tunisian waters, the species had first colonized the southern Gulf of Gabès, where it became abundant (Zaouali, 1993; Enzenross & Enzenross, 2000). *E. crenata* migrated northward to the Gulf of Tunis (Ben Souissi *et al.*, 2003) and the Bizerte Lagoon (Shaïek *et al.*, 2010). In the Tunis Southern Lagoon *E. crenata* was harvested in Station ST1 from among algae. All collected specimens were males of substantially the same average size – about 20 mm carapace width. The species was found in Station ST1 in a water column that was rather cloudy due to suspended matter inflowing from the Gulf of Tunis. In the Gulf of Gabès, the species inhabits muddy bottoms or *Posidonia* meadows (Zaouali, 1993).

Family Pilumnidae

Pilumnopeus vauquelini (Audouin, 1826) (Fig. 2B)

Pilumnopeus vauquelini originating from the Red Sea was recorded in the Mediterranean off Egypt (Calman, 1927), Israel and southern Turkey (Kocatas, 1981). The occurrence of *P. vauquelini* in the Tunis Southern Lagoon is the second record for the southern Mediterranean and the first record for Tunisian waters (Ben Souissi *et al.*, 2003). Male and female specimens were equally collected throughout the eastern part of the lagoon (ST1, ST2, and ST3). The average width of the specimens was 14.5 mm.

Family Panopeidae

Rhithropanopeus harrisi (Gould, 1841) (Fig. 2C)

Rhithropanopeus harrisi is a crab native to the Atlantic Ocean and was reported for the first time in the Mediterranean Sea from the Lagoon of Marano (Italy) and the Etang de Berre (France) (see Galil *et al.*, 2002). In Tunisian waters it was collected for the first time in the Tunis Southern Lagoon (Ben Souissi *et al.*, 2004). In recent surveys conducted in the area the crabs have been found under stones and among decaying vegetation.

Family Varunidae

Hemigrapsus sanguineus (De Haan, 1835) (Fig. 2D)

The Asian crab *Hemigrapsus sanguineus* was accidentally introduced to Le Havre harbour in 1999 (Breton *et al.*, 2002; Dauvin *et al.*, 2009). In Tunisian waters, the species was reported in the Tunis Southern Lagoon (Ben Souissi *et al.*, 2003). Three specimens, one male and two females, were sampled at Station ST2. The species is known to tolerate wide temperature and salinity changes (Epifanio *et al.*, 1998).

Brachynotus sexdentatus (Risso, 1827)

Brachynotus sexdentatus is an autochthonous Mediterranean species inhabiting all types of substrates and is most abundant among algae and in harbours, under stones (Bouvier & Marcheurs, 1940). *B. sexdentatus* is a rare species in the Mediterranean and in the Atlantic (Stevčić & Galil, 1994), too. Only a few specimens were sampled in the lagoon on muddy bottoms at Station ST1.

Family Porcellanidae

Porcellana platycheles (Pennant, 1777)

This crab is common along the French coast and in Italian lagoons, where it lives under rocks (Zariquiey-Alvarès, 1956). In Tunisian waters it is considered rare (Zaabar, 1998). Three specimens were collected in the Tunis Southern Lagoon, from stations ST7 and ST10, both close to the navigation channel.

Pisidia longicornis Linnaeus, 1767 (Fig. 2E)

Pisidia longicornis is common throughout the European coast and western Mediterranean (Koukouras *et al.*, 2002), but rare in the Tunis Southern Lagoon: only 3 females were sampled at Station ST1.

Family Plagusiidae

Euchirograpsus liguricus H. Milne Edwards, 1853

The species is endemic to the Mediterranean, first reported from Spain (Zariquiey-Alvarès, 1968) and throughout the seashores of this sea (Stevčić & Galil, 1994). The first Tunisian specimen was recorded in the Lagoon of Bizerte, on rocky and sandy bottoms (Zaabar, 1998). In the Tunis Southern Lagoon, it was found on rocky substrate at Station ST9.

Family Portunidae

Carcinus aestuarii Nardo, 1847

The species is abundant in lagoons, estuarine waters and harbour basins (Cottiglia, 1983). This crab was previously recorded along the Tunisian coast (Zaabar, 1998). Our survey has shown that *C. aestuarii* is the most abundant crab collected in the Tunis Southern Lagoon, especially in its eastern areas at stations ST1, ST2 and ST3.

Family Grapsidae

Pachygrapsus marmoratus (Fabricius, 1787)

The species is known throughout the Mediterranean (Stevčić & Galil, 1994). In Tunisian waters, it was first reported on rocky bottom off Kelibia, a city located in the Cape Bon Peninsula (Forest & Guinot, 1956). The samples of this species studied in this survey were collected at Stations ST9 and ST10.

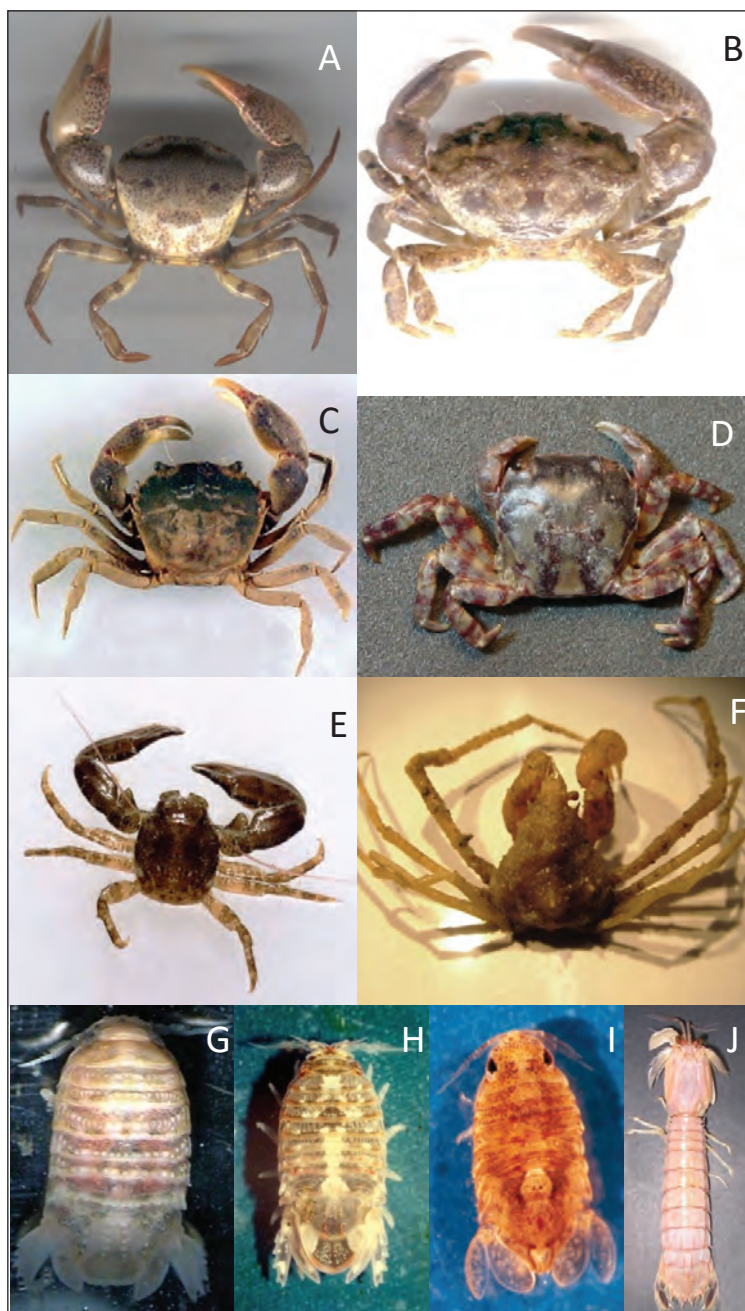


Fig. 2: Crustaceans species sampled in the Tunis Southern Lagoon. (A) *Eucrate crenata*: adult male (Carapace width - CW = 20 mm; carapace length - CL = 26 mm); (B) *Pilumnopus vauquilini*: adult male (CW = 20 mm; CL = 11.5 mm);(C) *Rhithropanopeus harrisi*: adult male (CW = 12 mm ; CL = 10 mm); (D) *Hemigrapsus sanguineus*: adult female (CW = 20 mm ; CL = 18 mm); (E) *Pisidia longicornis*: adult female (CW = 8 mm; CL = 9.5 mm); (F) *Inachus dorsettensis*: adult female (CW = 15 mm; CL = 30 mm); (G) *Sphaeroma walkeri*: adult male (CL = 14 mm); (H) *Sphaeroma venustissimum*: adult male (CL = 15 mm); (I) *Paradella diana*: adult male (CL = 8 mm); (J) *Erugosquilla massavensis*: adult male (CL = 201 mm).

Sl. 2: Vrste rakov, ugotovljenih v Tuniški južni laguni. (A) *Eucrate crenata*: odrasel samec (CW = 20 mm; CL = 26 mm); (B) *Pilumnopus vauquilini*: odrasel samec (CW = 20 mm; CL = 11.5 mm);(C) *Rhithropanopeus harrisi*: odrasel samec (CW = 12 mm ; CL =10 mm); (D) *Hemigrapsus sanguineus*: odrasla samica (CW = 20 mm ; CL = 18 mm); (E) *Pisidia longicornis*: odrasla samica (CW = 8 mm; CL = 9.5 mm); (F) *Inachus dorsettensis*: odrasla samica (CW = 15 mm; CL = 30 mm); (G) *Sphaeroma walkeri*: odrasel samec (CL = 14 mm); (H) *Sphaeroma venustissimum*: odrasel samec (CL = 15 mm); (I) *Paradella diana*: odrasel samec (CL = 8 mm); (J) *Erugosquilla massavensis*: odrasel samec (CL = 201 mm).

Family Polybiidae

Liocarcinus vernalis (Risso, 1816)

The species is reported throughout the Mediterranean (Forest & Guinot, 1956; Zariquiey-Alvarès, 1956; Noël, 1992; Stevčić & Galil, 1994). In Tunisia it was first recorded off Zembra Island (Forest & Guinot, 1956). In the Tunis Southern Lagoon, a single ovigerous female was collected. *L. vernalis* is a coastal species, living in the sandy intertidal zone and brackish lagoons (Fischer *et al.*, 1987).

Family Inachidae

Inachus dorsettensis (Pennant, 1777) (Fig. 2F)

The species is reported throughout the Mediterranean (Zariquiey-Alvarès, 1956; Noël, 1992; Stevčić & Galil, 1994). The first Tunisian specimen was recorded in the Gulf of Tunis (Forest & Guinot, 1956) and the subsequent ones in the Gulf of Gabès (Ktari-Chakroun & Azzouz, 1971). During our study, specimens of this species were found at Station ST3 in seagrass *Cymodocea nodosa* (Ucria) Ascherson, 1870.

DECAPODA CARIDEA

Family Palaemonidae

Palaemon serratus (Pennant, 1777)

The species is widely distributed in the Atlantic, the Mediterranean and the Black Sea (Zariquiey-Alvarès, 1968). *P. serratus* has been reported in moderately polluted harbour basins (Cottiglia, 1983). This shrimp is rare in the Tunis Southern Lagoon, in fact, only 12 specimens were collected from the fronds of algae during the autumn period.

Palaemon varians Leach, 1813

Palaemon varians is a Mediterranean brackish water shrimp (Hayward & Ryland, 1996). The species was first recorded in Tunisian waters in the Sebkhia Kelbia salt flat (Heldt, 1954). The species is rare in the lagoon under study.

Palaemon xiphias Risso, 1816

The species is found throughout the Mediterranean and in the Atlantic areas such as Morocco, the Canary Islands and Madeira (Holthuis, 1980). In the Tunis Southern Lagoon, we collected ovigerous females from *Cymodocea* seagrass. This species is typically found in seagrass meadows (Fresi *et al.*, 1984).

Palaemon elegans Rathke, 1837

The species is widely distributed in European coastal waters, from the Black Sea, Mediterranean Sea and

North Sea to the Atlantic shore of Norway (Grabowski, 2006). In Tunisian waters the species was first reported off Salammbô by Karen & Raymond (1972). Five specimens of *Palaemon elegans* were captured during our survey at Station ST3 in the Tunis Southern Lagoon.

Family Penaeidae

Penaeus kerathurus (Forskål, 1775)

This large benthic shrimp is distributed within the 100 m of depth. It is widespread off the east coast of the Atlantic and throughout the Mediterranean Sea (Holthuis, 1980). All the specimens sampled from the eastern part of the lagoon under study were at a juvenile stage. The same trend has been observed in Italian lagoons, where only juvenile specimens enter the lagoons, while the adult ones return to the open sea (Cottiglia, 1983).

DECAPODA GEBIIDEA

Family Upogebiidae

Upogebia pusilla (Petagna, 1792)

This species occurs in the Mediterranean Sea, extending from the shores of the Iberian Peninsula (Zariquiey-Alvarès, 1956) across French waters (Noël, 1992) to the Aegean Sea (Lewinsohn & Holthuis, 1964). Specimens of *Upogebia pusilla* were harvested from the middle of the Tunis Southern Lagoon, covered in the *Caulerpa prolifera* algae. This species tolerates moderate changes in salinity, but cannot survive long periods in water with a salinity lower than that of marine water.

DECAPODA ANOMURA

Family Diogenidae

Diogenes pugilator (Roux 1829)

Diogenes pugilator has a wide geographical distribution in the eastern Atlantic, from Ireland to the Gulf of Guinea and the Mediterranean (Barnes, 1999). *D. pugilator* is a euryhaline hermit crab, inhabiting sandy and muddy sandy bottoms. It mainly occurs in lagoons and coastal areas, in shallow waters of up to several meters in depth (Cottiglia, 1983). In the lagoon under study, 9 specimens were collected from empty shells of *Cerithium vulgatum* at Station ST1.

ORDER ISOPODA

Family Sphaeromatidae

Cymodoce truncata (Leach, 1814)

This species has a wide geographic distribution throughout the seas and oceans of the world (Dumay, 1972). Dridi & Prunus (1980) were the first to report it in Tunisian lagoons. It is a very common species in the Tunis Southern Lagoon. *C. truncata* generally lives in association with the isopod *Sphaeroma serratum*, amidst various species of seaweed and wrapped in empty barnacle tests.

Sphaeroma serratum (Fabricius, 1787)

This isopod species inhabits the shallow waters of the Atlantic coasts of Europe and Africa, and of the Mediterranean Sea (De Hureau, 1979). In the lagoon under study, the species was found under stones, algae and in empty barnacle tests. *S. serratum* is able to withstand large changes in temperature and salinity (Charmentier & Charmentier-Daures, 1994).

Sphaeroma walkeri Stebbing, 1905 (Fig. 2G)

Sphaeroma walkeri is commonly found in the Indian Ocean and the Red Sea among intertidal fouling communities, and has been reported in warm and warm-temperate waters (Galil, 2008). The species was first recorded in Tunisian waters in the Tunis Southern Lagoon by Ben Souissi *et al.* (2003), where *S. walkeri* was found in very shallow water, generally less than 3 m deep. All records so far are from the intertidal zone, except for one from India, where the isopod was collected in waters up to 46 m deep (Carlton & Iverson, 1981). *S. walkeri* inhabits different bottoms and is found among fouling communities. The species colonizes empty barnacle shells, such as *Balanus amphitrite amphitrite* Darwin, 1854, spaces between benthic fauna, oscula of sponges, especially *Ircinia* sp. and *Chondrosia reniformis* (Nardo, 1847), and ascidians, such as *Phallusia mammillata* (Cuvier, 1815), *Ecteinascidia turbinata* (Herdman, 1880), *Asciidiella aspersa*, (Müller, 1776), *Ciona intestinalis* (Linnaeus, 1767). Ounifi Ben Amor *et al.* (2010) noted that the highest densities of *S. walkeri* were observed among sponges during spring and summer. The presence of specimens in all developmental stages, throughout the year, showed that the species is substantially established in the Tunis Southern Lagoon (Ounifi Ben Amor *et al.*, 2015 a).

Sphaeroma venustissimum (Monod, 1931) (Fig. 2H)

Sphaeroma venustissimum was first described from specimens collected off the Mauritanian coast (Monod, 1931). It has been reported in the waters off Morocco, the southwestern Iberian Peninsula (Hoestlandt, 1959), off Portugal (Jacobs, 1987) and Spain (Junoy & Castelló, 2003). The species entered the Mediterranean Sea through the Strait of Gibraltar and was first recorded in this region in the Tunis Southern Lagoon (Ben Souissi *et al.*, 2005a). This species of tropical Atlantic origin, considered "alien" at the time of its first occurrence in the Mediterranean Sea, has since been removed from alien species lists, as its presence in the Mediterranean Sea can be explained by a natural range expansion rather than an anthropic action (Zenetos *et al.*, 2012). *S. venustissimum* is an intertidal lucifugous species, often found under stones covered by biofouling, or inside empty tests of barnacles.

Paradella diana (Menzies, 1962) (Fig. 2I)

Paradella diana has a wide geographic distribution extending from the waters off Atlantic and Pacific coasts to South America and Brazil (Nelson & Demetriades, 1992). It is an immigrant species from the Red Sea, reported for the first time in the Mediterranean from the Alexandria harbour (Atta, 1987). The species was locally collected for the first time during surveys carried out in the Tunis Southern Lagoon (Bey *et al.*, 2001). During our recent surveys, the species was sampled in seaweed and under stones from the lagoon shores.

Paracerceis sculpta (Holmes, 1904)

This is a migratory species of Indo-Pacific origin, reported for the first time in the Mediterranean by Rezig (1978) in the Tunis Northern Lagoon. In the Tunis Southern Lagoon, the species was collected among barnacle tests and algae in all stations and throughout the year.

Dynamene edwardsi (Lucas, 1849)

The species was mentioned in association with *Paracerceis sculpta* (Rezig, 1978). Dridi & Prunus (1980) also reported some specimens in the Bizerte Lagoon. *D. edwardsi* was collected among algae during spring and a similar pattern was reported by As Zaouali-Laidain (1974) and Ben Souissi (2002).

Family Idoteidae

Idotea balthica (Pallas, 1772)

The species has a wide geographical distribution. It has been reported in the Mediterranean Sea, the Black Sea, the Red Sea and in the Indian Ocean (Monod, 1923). It is uncommon in the Tunis Southern Lagoon; it was only found during spring and summer in zones characterized by a clear marine influence, at Stations ST1, ST2 and ST3.

Idotea chelipes (Slabber, 1778)

This isopod has a wide distribution and a high tolerance for confinement (Quignand, 1984). Several specimens were collected in the mid-part of the lagoon under study, hidden among the algae *Ulva* and *Gracilaria*.

Family Cymothoidae

Anilocra pilchardi Bariche & Trilles, 2006

Anilocra pilchardi is a parasitic of Indo-Pacific origin, first reported from off Lebanon (Bariche & Trilles, 2006). In previous studies, the species had been locally collected from the Lagoons of Boughrara and Bahiret El Bibans (Ben Souissi *et al.*, 2010). In the present study, the species was collected from fish caught in the lagoon.

Family Janiridae

Jaera (Jaera) hopeana Costa, 1853

The species is found mainly in the Mediterranean and Black Seas (Prunus & Pantoustier, 1976). Qualified as an ectocommensal species by Naylor (1972), this minuscule isopod had been regularly collected from branchial appendices of *Sphaeroma serratum*, probably seeking better oxygenation. The spatial distribution of this isopod in the Tunis Southern Lagoon is similar to that of the lesser specimens of *S. serratum*, the ones not exceeding 10 mm in total length.

ORDER AMPHIPODA

Family Caprellidae

Caprella scaura Templeton, 1836

Caprella scaura, originating from the Indian Ocean, was first recorded in the Mediterranean Sea in the Lagoon of Venice (Sconfiatti & Danesi, 1996). In Tunisia, 278 specimens in all were locally sampled for the first time in the Lagoons of Boughrara and Bibans among the algae *Gracilaria* and *Polysiphonia* (Ben Souissi *et al.*, 2010). *C. scaura* was reported in the Tunis Southern Lagoon at Station ST6 among fronds of *Chaetomorpha linum* (O.F.Müller) Kützing, 1845.

Caprella equilibra Say, 1818

It is a cosmopolitan species from warm-temperate seas, found also in the Mediterranean and in the Black Sea, as well as in the Atlantic, Pacific and Indian Oceans (Chevreux & Fages, 1925). This amphipod had been previously mentioned in the Tunis Southern Lagoon by Zaouali-Laidain (1974). In this survey, several specimens were collected during spring and summer from the fronds of *Chaetomorpha linum*.

Family Ampithoidae

Cymadusa filosa Savigny, 1816

Cymadusa filosa is a Lessepsian species that has long been considered polymorphic and pantropical (Ledoyer, 1984). This amphipod was previously observed in the Lagoons of Ghar El Melh and Bizerte (Chevreux, 1910; Dridi & Prunus, 1980; Zakhama-Sraieb *et al.*, 2009) and in the southern and northern parts of the Lagoon of Tunis (Ouirane, 1998; Gharbi, 2000), too. We collected this species in almost all the stations of the southern lagoon associated with the amphipod *Gammarus aequicauda* (Martynov, 1931). This amphipod is especially abundant during spring.

Family Corophiidae

Monocorophium acherusicum (Costa, 1853)

The species has a worldwide distribution (Bellan-Santini & Desrosiers, 1976). *M. acherusicum* pervades the

entire Tunis Southern Lagoon (Vuillemin, 1965; Zaouali-Laidain, 1974), with its 11,605 specimens second in number only to *Cymodoce truncata*.

Monocorophium insidiosum (Crawford, 1937)

The species is commonly found in lagoons (Taramelli & Pezzali, 1986), but locally it is a less abundant species. A total of 274 specimens were observed at stations ST8, ST9 and ST10.

Corophium orientale Schellenberg, 1928

This is an endemic species of the Mediterranean Sea, found mainly in brackish waters under seaweed (Bellan-Santini *et al.*, 1992). In Tunisian waters, the species was previously found in Garaâ Ichkeul (Dridi & Prunus, 1980). A total of 1,579 specimens were sampled in the Tunis Southern Lagoon during our survey.

Family Gammaridae

Gammarus aequicauda (Martynov, 1931)

This species has a wide geographical distribution, and is considered very common in the Mediterranean (Bellan-Santini, *et al.*, 1992). It is well documented in Tunisian waters (Gharbi, 2000), and common in the Tunis Southern Lagoon, where 10,285 specimens were collected.

Gammarus insensibilis (Stock, 1966)

This is a euryhaline and eurythermal species, widespread in the lagoon environments of the Mediterranean (Taramelli & Pezzali, 1986). It can be found at low depths (maximum 15 m) in slightly brackish water, under rocks and vegetation (Gharbi, 2000). The specimens of *G. insensibilis* collected in the study area were occasionally associated with *G. aequicauda*.

Family Talitridae

Orchestia stephensi Cecchini, 1928

It is an endemic species of the Mediterranean Sea. In Tunisian waters, the species was first recorded in the northern lagoon by Gharbi (2000) and later confirmed in the southern lagoon, too (Ben Souissi, 2002). In the study area, 2,134 specimens were observed at Station ST6 among algae.

Family Melitidae

Melita palmata (Montagu, 1804)

Melita palmata is a common species in lagoons, estuaries and brackish waters off the European coast of the Atlantic Ocean, as well as of the Baltic, Mediterranean and Black Seas (Lincoln, 1979). *M. palmata* was report-

ed for the first time off Bizerte, in northern Tunisia by Chevreux (1911). We collected this species in the Tunis Southern Lagoon from algae and seagrasses.

ORDER CIRRIPIEDIA

Family Balanidae

Amphibalanus eburneus (Gould, 1841)

Native to the entire western Atlantic, the species invaded the Mediterranean, the Black Sea, the Caspian Sea and spread further into the Indian Ocean, to Japan and other Pacific Islands (Hayward & Ryland, 1996). In Tunisian waters it was first found at an archaeological site in Carthage (Southward *et al.*, 1998). Recently, it has been reported in the Gulf of Gabès by El Lakhrach *et al.* (2012). Its presence in the Tunis Southern Lagoon is limited to the shores.

Amphibalanus amphitrite (Darwin, 1854)

Amphibalanus amphitrite is a common species, found on both natural and artificial bottom (Relini, 1980). In the Tunis Southern Lagoon, the species is found in compact colonies on hard substrates, such as buoys and mussel shells. *A. amphitrite* was very abundant in the lagoon before its restoration.

Family Sacculinidae

Sacculina carcini Thompson, 1836

Sacculina carcini is a specific cirripede parasite of the crab *Carcinus aestuarii* (Lützen, 1981). It appears as a sort of sac, slightly flattened anteroposteriorly and of a vaguely pentagonal outline, implanted in the space between the crab's abdomen and cephalothorax. *S. carcini* invades the host completely and alters its hormonal balance (Larsen *et al.*, 2013). In our survey, this species of parasite was observed in 4 adult males of *C. aestuarii*.

ORDER STOMATOPODA

Family Squillidae

Erugosquilla massavensis (Kossmann, 1880) (Fig. 2)

The Mantis shrimp *E. massavensis* originates in the Persian Gulf and the Red Sea (Frogliia & Manning, 1989). It migrated through the Suez Canal into the Mediterranean Sea, where it was first recorded off the Mediterranean coast of Egypt, wrongly identified as *Squilla africana* Calman, 1917 by Steuer (1936). Since 1960, *E. massavensis* has successively established in the eastern Levant and south-eastern Turkey (Holthuis, 1961; Galil *et al.*, 2002; Bakir & Çevirgen, 2012). Its westernmost extension range to date has been reported in waters off the coast of Libya (Shakman & Kinzelbach, 2007) and recently in Tunisia in the Gulf of Gabès and the Tunis Southern Lagoon (Ounifi Ben Amor *et al.*, 2015b). The captures of specimens in open waters, such as the Gulf

of Gabès, and restricted brackish areas, such as the Tunis Southern Lagoon, suggest a possible adaptability of *E. massavensis* to salinity changes.

Crustacean fauna of the Tunis Southern Lagoon

Of the 44 crustacean species reported in the area only 29 were listed before the restoration. 6 species are new records for the Tunis Southern Lagoon, among them two Lessepsian species – the amphipod *Caprella scaura* and the isopod *Anilocra pilchardi* (Tab. 1). The distribution of the species in the lagoon shows that most of them (41%) were collected at the stations near the Bay of Tunis (ST1, ST2, ST3), which highlights the role of marine flux.

Although our study focuses on the crustacean species occurring in the Tunis Southern Lagoon, previous papers showed that molluscs and fishes were qualitatively and quantitatively represented in the area (Ben Souissi *et al.*, 2005b; Eteres *et al.*, 2011). Molluscs played an important role in the settlement of crustacean fauna in the lagoon. Indeed, we have observed that some species of crustaceans, such as *Sphaeroma serratum*, *S. walkeri* and *S. venustissimum*, take refuge in empty shells of bivalves. All specimens of hermit crab *Diogenes pugilator* were collected from empty shells of the gastropod *Cerithium vulgatum*. Some barnacles, such as *Amphibalanus eburneus* and *A. amphitrite*, were also related to the presence of empty mussel shells of *Fulvia fragilis* and *Mytilus galloprovincialis* (Lamarck, 1819).

The ichthyofauna is quite diversified and has concomitantly allowed for the resumption of fishing activities in the area after restoration. An investigation conducted in 2014 among the local fishermen aware of the fishing grounds showed that the fish fauna comprised at least 90 species (Ben Souissi *et al.*, 2015). The presence of small crustaceans probably enhanced settlements of fish species in the lagoon, both elasmobranchs (Mejri *et al.*, 2004) and teleosts (Ben Souissi *et al.*, 2005a, 2005b; Ben Amor *et al.*, 2008). Previous studies on the feeding habits of the elasmobranch and teleost species recorded in the area showed that their preferential preys or at least their secondary preys were crustaceans (Capapé & Azzouz, 1976; Capapé & Zaouali, 1979; Bradaï, 2000; Rafrafi-Nouira *et al.*, 2016). Therefore, the occurrence of fishes in the area is closely related to the availability of crustaceans in the area.

A comparison was carried out between crustacean fauna of the Tunis Southern Lagoon and other brackish areas of Mediterranean and Tunisian lagoons, which is shown in Table 2. It is evident that the number of species in the Tunis Southern Lagoon is one of the largest, second only to that of the French Thau Lagoon and the Moroccan Merja Zerga, despite a smaller surface area. Such patterns confirm that the Tunis Southern Lagoon has been successfully restored and represents a favourable biological environment for numerous fish species.

Tab. 2: Number of crustacean species recorded in various Mediterranean lagoons.
Tab. 2: Število vrst rakov ugotovljenih v nekaterih sredozemskih lagunah.

| Country | Lagoon | Species number | Area surface (ha) | Authors |
|---------|-----------------------|----------------|-------------------|--|
| Morocco | Merja Zerga | 74 | 7300 | Bazairi <i>et al.</i> (2003) |
| France | Thau Lagoon | 110 | 7500 | Cataudella <i>et al.</i> (2014) |
| Tunisia | Monastir Lagoon | 10 | 340 | Mortier (1979) |
| Tunisia | Ghar El Meleh Lagoon | 12 | 3000 | Ben Romdhane & Ktari-Chakroun (1986); Chakroun (2004) |
| Tunisia | Bizerte Lagoon | ± 20 | 15000 | Zaouali & Lévy (1981) |
| Tunisia | Tunis Northern Lagoon | 44 | 2200 | Tlig <i>et al.</i> , 2008; Diawara <i>et al.</i> (2008) |
| Tunisia | Tunis Southern Lagoon | 44 | 700 | This study |

New marine species are regularly and continuously recorded in Tunisian waters, mainly in lagoon environments, which are considered hotspots for the settlement of invasive species (Ounifi Ben Amor *et al.*, 2016). Such colonisations are probably the result of the restoration of the area, which facilitated the introduction of species previously unknown to the area, and consequently the abundance of crustacean species reported in the present paper.

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DOPOLNJEN SEZNAM VRST RAKOV IZ TUNIŠKE JUŽNE LAGUNE (SEVERNA TUNIZIJA, OSREDNJI MEDITERAN)

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POVZETEK

V okviru raziskav po posegu okoljskega restavriranja Tuniške južne lagune so avtorji popisali 44 vrst rakov iz 27 družin, med katerimi je bilo 19 vrst rakov deseteronožcev, 11 vrst rakov enakonožcev, 10 vrst postranic, 3 vrste rakov vitičnjakov in ena vrsta morskih bogomolk. Med temi 44 vrstami je bilo 31 samoniklih in 13 tujerodnih. Šest vrst je bilo na obravnavanem območju prvič zabeleženih. Tuniška južna laguna nudi ugodne okoljske pogoje za naselitev tujerodnih vrst, predvsem rakov. Pojavljanje tujerodnih rakov ima pomembno ekonomsko in ekološko vlogo v omejenih somornih okoljih, obenem pa podpira razne antropogene dejavnosti kot sta lov glavonožcev in rib.

Ključne besede: somorne vode, samonikle vrste, tujerodne vrste, ekološko restavriranje, ponovno naseljevanje

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