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**RESEARCH ARTICLE**

# The abundance and diversity of benthic crustaceans along the coastal zone of Western Libya

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**Abstract**

This study was conducted in the intertidal zone of six rocky-substrate stations on the western Libyan coast: EL-Shajara harbour, Tajura, Ain azargh, Siahia Regata, Sabratha and Tellil, with a sectorial belt of 35-50 m long vertical to the coast and divided into meters, each square meter representing one sample. Samples were collected during September-October 2004 using a 25 × 25 cm quadrate. As for benthic animals recorded in all the stations, a total of 37 crustacean species were recorded, of which 6 were isopods, 23 decapods, 7 amphipods and one species of balanomorphs. The results showed noticeable difference between stations regarding the number of individuals, ranging between 374 and 4769. The results indicated that there were no significant differences in benthic crustaceans except EL-Shajara - Regata and EL-Shajara – Tellil, where there were significant differences in the number of species.

**Keywords:** Crustacea, intertidal zone, Libya, abundance, diversity

## Introduction

The crustacean animals are an essential part of fauna in the intertidal zone, which also includes other arthropods, molluscs, polychaetes and echinoderms. They have both ecological and economical importance; millions of tons of crustacean are caught in fisheries, besides their contribution in food webs.

Crustacea is a subphylum which belongs to Arthropoda and it includes more than 67,000 species (Zhang 2011). There are more than 30,000 species in the Mediterranean. The number of species differs according to depth and nature of locations. Amphipods are the most abundant crustaceans in the Mediterranean (Zakhama-Sraieb *et al*. 2009). The first study on crustaceans in Libya reported 18 species of amphipods (Maccagno 1939). During the Romanian Expedition, which was carried out in 1975-1976 on the coasts of Libya, 33 species were added to the Libyan list of amphipods (Tigãnus 1984), later Ortiz and Petrescu

(2007) listed 125 species of amphipods which belong to 27 families. Twenty species of Crustacea were collected along the Libyan coast by a French scientific expedition in 1966 (Rawag 2004); they added new records to the Libyan list of Crustacea. A survey along the Libyan coast between June 1993 and November 1994 indicated that the area between Misurata and Abukemash was the best crustacean fishing ground in the country (Kashout *et al*. 2002). Therefore, studies on crustacean diversity along the rocky shores of Libyan coast (from Ghott-Eroman to Tellil) are important to identify the crustacean fauna of Libya and to clarify the relationships between marine algae and the animals in the intertidal zone.

Studies on crustaceans have been carried out along the Mediterranean coasts in Greece (Kevrekidis and Galil 2003), Italy (Pastore 1972; Falciai 1997; Langeneck and Di Franco 2013), Malta (Crocetta *et al*. 2011), Spain (Guerra-García *et al.* 2009; Krapp-Schickel *et al.* 2011; Guerra-García and Sánchez-Moyano 2013), Tunisia (Zakhama-Sraieb *et al*. 2009; Zaouali *et al*. 2013), Turkey (Koçak *et al*. 2010; Bakir and Katağan 2013) and other countries (Lowry and Stoddart 1992; Ngoc-Ho 2003; Zenetos *et al*. 2005; Warburg *et al*. 2012).

The information is scarce on the littoral areas along the Libyan coast. This paper, thus, aimed to identify benthic crustaceans found among algae on rocky shores of intertidal zones along the western Libyan coast between Ghott-Eroman and Tellil.

## Materials and methods

*Study area*

This study was conducted in the intertidal zone of six locations characterized by rocky bottom (Figure 1) during September-October 2004.

*1. EL-Shajara harbor (Ghott-Eroman)*

It is a harbor for fishing boats located at 13°30′00″E, 32°50′06″N, characterized by flat rocky beach, exposed during the low tide. It includes some little pools.

*2. Tajura*

It is a flat rocky beach located at 13°22′00″E, 32°54′00″N, characterized by shallow waters. The area is semi-protected, exposed at low tide, but some areas still semi-immersed. It does not include big pools.

*3. Ain Azargha*

It is a flat rocky area including sandy rocks and others like rubble of construction materials. It is located off the administrative assembly Zat EL-emad, Tripoli at 13°09′43″E, 32°53′22″N. It is exposed at low tide.

*4. Siahia Regata*
It is a rocky beach of calcareous rocks located at 13°03′44″E, 32°51′38″N. It is characterized by exposed rocks at low tide. It includes few little pools.

*5. Sabratha (off Tumors Center)*
It is a harbor for fishing boats called Zuagha, located at (13°26′43″E, 32°48′55″N), as steep rocky shore characterized by some big pools. It is exposed completely at low tide. There are some signs of pollution by tar.

*6. Tellil beach*
It is a rocky-sandy beach, exposed completely at low tide. It is located at 13°24′53″E, 32°47′50″N, characterized by poor cover of algae and by small and big pools.

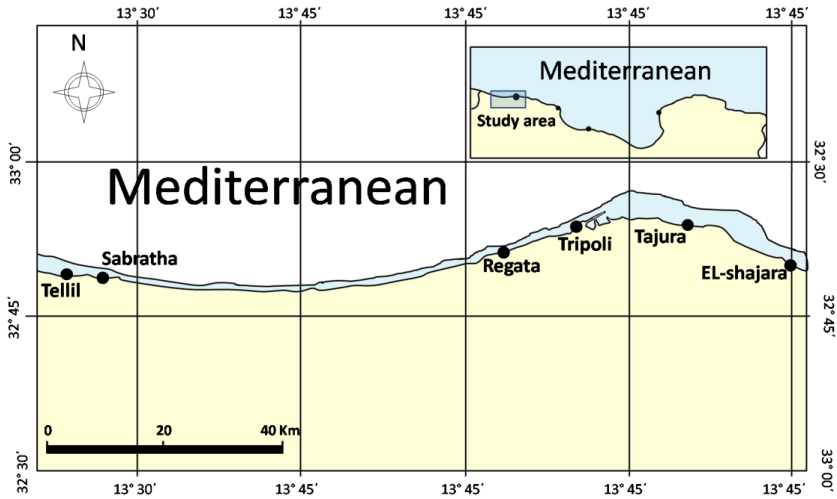


**Figure 1.** The sampling locations along the Libyan coast.

*Sampling*
Samples were collected during September-October 2004 from the intertidal zone of all locations using a 25 × 25 cm quadrate (0.0625 $m^3$) with a sectorial belt of 35-50 m long vertical to the coast and divided into meters, each square meter representing one sample (Boudouresque and Belsher 1997). The specimens were collected manually using a spatula; the collected specimens of each sample (square) were put in plastic bags, stored at -20º C until sorting. The specimens were later identified according to De Hass and Knorr (1979), Fischer *et al.* (1987), Tornaritis (1987), Riedl (1991).

*The statistical analysis*
The Chi-square test was used to compare the locations regarding the number of individuals and number of species, as well, Kruskal-Wallis test was used to compare data among locations (Daniel 1995).

*Diversity indices*
The diversity, richness, evenness and similarity indices of location communities were calculated:

*1. Margalef's species richness index (R):*
It is an index for the total number of species in a sample (Howaege 1998). It depends on the relationship between the number of species and the total number (observed) of individuals, which increases by sample volume (Ludwing and Reynolds 1988; Howaege 1998):

$$R = \frac{m-1}{Ln(N)}$$

where $m$ is the number of species in the sample and $N$ is the total number of individuals.

*2. Simpson's dominance index (λ)*
It is considered as the first index in regard to the ecological studies. Its values are restricted between 0 and 1. Value increase indicates that most of the individuals of the sample belong to one species, which means the sample has low diversity (Howaege 1998):

$$\lambda = \sum_{i=1}^{m} \frac{n_i(n_i-1)}{N(N-1)}$$

where $m$ is the total number of species, $n_i$ is the number of the individuals in the $i^{th}$ species and $N$ is the total number of individuals.

*3. Shannon's diversity index (H'):*
It is used to measure diversity in categorical data. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index value is zero when there is one species in the sample but increases either by having additional unique species, or by having a greater species evenness (Ludwing and Reynolds 1988):

$$H' = \sum_{i=1}^{m} \frac{n_i}{N} \left| Ln \frac{n_i}{N} \right|$$

where $m$ is the total number of species, $n_i$ is the number of the individuals in the $i^{th}$ species and $N$ is the total number of individuals.

*4. Heip's evenness index (E):*
It is an index which reveals the distribution of abundance among species in the sample, subsequently the value of evenness decreases when the distribution of

individuals among species is wide, and vice versa (Ludwing and Reynolds 1988):

$$E = \frac{e^{H'} - 1}{m - 1}$$

where *H'* is Shannon's diversity index and *m* is the total number of species.

*5. Sorensen's coefficient of similarity (Ss):*
It is a binomial test used for comparing the similarity of two samples. Its values restricted between 0 and 1. Value 0 means the two samples are completely different, while value 1 means that the two samples are the same (Howaege 1998):

$$Ss = \frac{2a}{2a + b + c}$$

where a is the shared species between sample 1 and 2, b is the unique species in sample 2 and c is the unique species in sample 1.

## Results and Discussion

*Diversity*
The results showed that 37 species of Crustacea were recorded in the western Libyan coast. They belong to four orders: Isopoda, Decapoda, Amphipoda, and Balanomorpha (Table 1). The number of sampled species varied between 14 (Tellil) and 29 (EL-Shajara) (Table 2). In previous studies twenty species were recorded in Libya (Sogreah 1977), 125 species of amphipods (Ortiz and Petrescu 2007). In similar studies in North Africa, 133 species of amphipods were recorded in Tunisia (Zakhama-Sraieb *et al*. 2009), Diwara *et al*. (2008) recorded 44 species in North Tunisia, while, in the eastern coast of Algeria, 45 species of Crustacea were recorded in Annaba (Frehi and Derbal 2005).

**Table 1.** Number of crustacean species in the study area.

| Order | No. of species |
|---|---|
| Isopoda | 6 |
| Decapoda | 23 |
| Amphipoda | 7 |
| Balanomorpha | 1 |
| Total | 37 |

There was no significant difference among locations (Kruskal-Wallis test, $\chi^2$= 1.003, df= 5, P > 0.05). In most pair-wise comparisons between locations, there was no significant difference ($\chi^2$ test, P > 0.05), which might be attributed to the similar algae fauna offering suitable habitat for crustaceans. The exceptions in the comparisons were seen between EL- Shajara and Regata (P < 0.05), and between EL- Shajara and Tellil (P < 0.025); these differences might be due to the human activities such as boat anchorage by fishermen, which is seen

commonly at EL-Shajara location, while Regata location is a rocky shore without fishing activities, as well, the number of specimens were low because of small area size of Tellil beach, which is characterized as a rocky-sandy beach.

**Table 2.** Number of species and individuals in the study locations.

| Location | No. of species | No. of individuals |
|---|---|---|
| EL-Shajara | 29 | 1410 |
| Tajura | 22 | 1713 |
| Tripoli | 17 | 4769 |
| Regata | 15 | 2109 |
| Sabratha | 19 | 1394 |
| Tellil | 14 | 374 |

*Abundance*

The total number of individuals sampled in this study varied from 374 in Tellil to 4769 in Tripoli (Table 2). There was no significant difference among locations (Kruskal-Wallis test, $\chi^2$= 2.86, df= 5, P > 0.05), although there was significant difference in pairwise comparison in most cases ($\chi^2$ test, P < 0.01) except between EL-Shajara and Sabratha (P > 0.1). This similarity between EL-Shajara and Sabratha, was supported also by Sorensen's coefficient of similarity (0.43), might be due to the fishermen activities in both locations.

The amphipods showed the highest abundance, in all locations, because of their ability to resist dry condition at low tide, and the nature of seabed which is rich in algae (diversity and density) (Riedl 1991). At the same time, the stones and boulders of the rocky shores offer shelters against the effect of waves (Crothers 1970; Bacchiocchi and Airoldi 2003). In California, amphipods were major component, numerically (Barnard 1961). This might due to the high ecological tolerance of many amphipod species (Bryazgin 1997).

Some species of Decapoda correlated positively with some species of algae, such as *Maia* and *Hyas* which are related to alga *Jania corniculata*. This alga offers shelter to decapods from waves and predators (Huni and Aravindan 1984) though these animals can be found with other algae. The algae cover plays an important role in benthic fauna (Leite *et al.* 2000).

The amphipod *Dexamine* sp. was the dominant species in all locations except Regata. *Dexamine spiniventris* were dominant in *Asparagopsis armata* (algae), which is mainly found in the low intertidal zone in Spain (Guerra-García *et al.* 2012), in eelgrass beds, *Zostera* spp. in Turkey (Karaçuha *et al.* 2009). In Regata, however, *Tanais cavolinii* was the most abundant species. Most species (28 species) were recorded in more than one location. Only six species were observed in all locations (Table 3). Each location may offer suitable conditions

for certain species which can lead to competition between species, the winner is the dominant one (Crothers 1970).

**Table 3.** A list of crustacean species recorded in the study.

| | Species | EL-Shajara | Tajura | Tripoli | Regata | Sabratha | Tellil |
|---|---|---|---|---|---|---|---|
| Isopoda | *Anthura gracilis* (Montagu, 1808) | 26 | 10 | - | 1 | 5 | - |
| | *Astacilla dilatata* (Sars, 1882) | 1 | - | - | - | 8 | - |
| | *Limnoria tripunctata* (Menzies, 1951) | 3 | - | 26 | 25 | 24 | 1 |
| | *Sphaeroma rugicauda* (Leach, 1814) | 22 | - | 201 | 162 | 100 | 9 |
| | *Tanais cavolinii* (Milne-Edwards, 1840) | 12 | 4 | 1986 | 723 | 3 | 6 |
| | *Tanais* sp. | - | - | 137 | 1 | - | - |
| Amphipoda | *Ampelisca* sp. | 3 | - | - | - | - | - |
| | *Dexamine* sp. | 591 | 668 | 2043 | 309 | 889 | 119 |
| | *Elasmopus* sp. | 51 | 2 | - | - | 1 | 1 |
| | *Gammarus* sp. | 1 | - | - | - | - | - |
| | *Leucothoe spinicarpa* (Abildgaard,1789) | 181 | 124 | 118 | 264 | 103 | 69 |
| | *Lysianassa longicornis* (Lucas, 1846) | 19 | 3 | - | - | - | 5 |
| | *Polycheria* sp. | 252 | 62 | 129 | 442 | 150 | 117 |
| Decapoda | *Achaeus cranchi* (Leach, 1817) | 1 | - | - | - | - | - |
| | *Alpheus dentipes* (Coutière, 1905) | 4 | 5 | 3 | - | - | - |
| | *Alpheus glaber* (Olivi, 1792) | - | 5 | - | - | - | - |
| | *Alpheus* sp. | - | 2 | - | - | - | - |
| | *Anapagurus* sp. | 26 | - | - | - | - | - |
| | *Athanas nitescens* (Leach, 1814) | 6 | 3 | 1 | - | 6 | 1 |
| | Decapoda sp. (1) | 1 | - | - | - | - | - |
| | Decapoda sp. (2) | 1 | - | - | - | - | - |
| | *Eriphia verrucosa* (Forskal, 1775) | - | 6 | - | - | - | - |
| | *Eupagurus prideauxi* (Leach, 1815) | 5 | - | - | - | - | - |
| | *Hippolyte* sp. | 1 | - | - | - | - | - |
| | *Hyas* sp. | 87 | 84 | 2 | 70 | 62 | 30 |
| | *Palaemon serratus* (Pennant, 1777) | 3 | 9 | 8 | 2 | 7 | - |
| | *Maja squinado* (Herbst, 1788) | 1 | - | - | - | 2 | - |
| | *Maja crispata* (Risso, 1827) | - | 3 | - | - | - | - |
| | *Pachygrapsus* sp. | - | 4 | 1 | 1 | 1 | 1 |
| | *Paguristes oculatus* (Fabricius, 1775) | 5 | 11 | 4 | 4 | 5 | - |
| | *Pagurus* sp. | 52 | 632 | 55 | - | 1 | 7 |

**Table 3.** Continued.

| | Species | EL-Shajara | Tajura | Tripoli | Regata | Sabratha | Tellil |
|---|---|---|---|---|---|---|---|
| Decapoda | *Pilumnus hirtellus* (Linnaeus, 1761) | 35 | 13 | 2 | 12 | 2 | 1 |
| | *Pilumnus* sp. | 4 | - | - | - | - | - |
| | *Thoralus* sp. | 2 | 7 | - | - | 23 | - |
| | *Xantho* sp. | 14 | 65 | 34 | - | 1 | 7 |
| | *Balanus perforatus* (Bruguière, 1789) | - | - | - | 80 | - | - |

*Sorensen's coefficient of similarity (Ss):*
The location showed approximate values of Sorensen's coefficient of similarity, which varied between 0.33 and 0.44 (Table 4). This similarity was, probably, due to that all locations are characterized by rocky bottom.

**Table 4.** Sorensen's coefficient of similarity for crustacean species among locations.

| Station | EL-Shajara | Tajura | Tripoli | Regata | Sabratha |
|---|---|---|---|---|---|
| **Tajura** | 0.38 | | | | |
| **Tripoli** | 0.37 | 0.41 | | | |
| **Regata** | 0.33 | 0.37 | 0.44 | | |
| **Sabratha** | 0.43 | 0.43 | 0.44 | 0.40 | |
| **Tellil** | 0.37 | 0.40 | 0.43 | 0.38 | 0.41 |

*Diversity indices*
The stations showed obvious variation in respect of the diversity indices (Table 5). The Margalef's species richness index showed that EL-Shajara was the richest station (8.90), which indicating that it was the most diverse location in respect of crustacean species. This characteristic was supported by the Shannon's diversity index (H'= 0.86); while the least diverse station was Regata (4.21). The Shannon's diversity index were between 0.86 (EL-Shajara) and 0.57 (Tripoli). The highest value of Heip's evenness index was in Regata (0.36) while the lowest value was recorded in Sabratha (0.15). According to Simpson's dominance index, there was obvious dominance of some species in Sabratha (0.43), but less obviousness recorded in Regata (0.21).

The nature of the location of EL-Shajara as a harbor for fishing boats may offer better surroundings or the boats may carry animals to the location. This location contains floating pontoons which create suitable habitats for subtidal epibiota (Connell 2000). The lowest value of Margalef's species richness index was recorded in Regata (R= 4.21). Some environmental factors effect species diversity, including 1. seasonality, 2. spatial heterogeneity, 3. competition, 4. predation, 5. habitat type, 6. environmental stability and 7. productivity

(Rosenzweig 1995). In this study, some similar locations, in respect of habitat characteristics, were not similar in terms of species.

**Table 5.** Diversity indices of crustaceans in the study area. (R: Margalef's species richness index; H': Shannon's diversity index; He.: Heip's evenness index; λ: Simpson's dominance index).

| Location | No. individuals | No. species | Indices | | | |
|---|---|---|---|---|---|---|
| | | | R | H' | He. | λ |
| EL-Shajara | 1405 | 29 | 8.90 | 0.86 | 0.22 | 0.23 |
| Tajura | 1713 | 22 | 6.49 | 0.69 | 0.19 | 0.30 |
| Tripoli | 4769 | 17 | 4.35 | 0.57 | 0.17 | 0.36 |
| Regata | 2109 | 15 | 4.21 | 0.78 | 0.36 | 0.21 |
| Sabratha | 1394 | 19 | 6.04 | 0.59 | 0.15 | 0.43 |
| Tellil | 374 | 14 | 5.05 | 0.73 | 0.34 | 0.24 |

The western coast comprises the best fishing ground along the Libyan coast, including the crustacean fisheries (Contransimex 1977; Sogreah 1977; Kashout *et al*. 2002). The result of this study supports this situation.

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