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Spatial distribution and abundance of the megabenthic fauna community in Gabes gulf (Tunisia, eastern Mediterranean Sea)

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Abstract

The aim of this paper is to bring to light the knowledge of marine diversity of invertebrates in Gabes gulf. The spatial distribution of the megabenthic fauna community in Gabes gulf (Tunisia, Eastern Mediterranean Sea), together with the bottom type and vegetation cover, were studied. The abundance of the megabenthic fauna was represented by eight groups: Echinodermata (38%), Crustacea (21%), Tunicata (19%), Mollusca (13%), Porifera (4%), Cnidaria (3%), Bryozoa, and Annelida (2%). It was spatially more concentrated in the coast area of the gulf than in the offshore waters. This area, especially, in Southern Kerkennah, North-est of Gabes and North-east of Djerba appeared to be in a good ecological condition hosting a variety of species like the pagurids *Paguristes eremita* and *Pagurus cuanensis*, the brachyura *Medorippe lanata*, *Inachus dorsettensis*, the Gastropoda *Hexaplex trunculus*, *Bolinus brandaris*, *Aporrhais pespelecani*, and *Erosaria turdus*, the Bivalvia *Fulvia fragilis*, the Echinoidea *Psammechinus microtuberculatus*, *Holothuria polii*, *Ophiothrix fragilis* and *Antedon mediterranea*, and the Ascidiacea *Aplidium cf. conicum*, *Didemnum* spp, and *Microcosmus exasperatus*.

The species' compositions of the megabentic fauna community showed clearly that the spatial analysis represented the differences between the community of these two regions (inshore waters and offshore waters). These differences were closely related to peculiar characters of the fauna and biotopes (depth, bottom type and vegetation cover community). The results of the present study should be considered as a necessary starting point for a further analysis of priceless benthic fauna contribution to the marine environment and its organisms.

Keywords: Benthic soft communities, megabenthos, invertebrata, Gabes gulf (Tunisia) Central Mediterranean.

Introduction

The Tunisian marine zones, like the rest of the Mediterranean, are subject to an increasing pressure in the anthropogenic activities (urbanization, industry, tourism, overfishing and maritime traffic). The consequences can be detected on the general state of ecosystems, mainly in inshore waters which are more sensitive and more exposed (Zaouali, 1993b; Ben Mustapha *et al*., 1999; Ayari & Afli, 2003). In the last three decades, Gabes gulf was the best example that illustrated the disturbances that were mainly caused by the phosphate industry (Darmoul, 1988; Darmoul *et al*., 1980) , the bottom-trawling fishing (Hattour, 1991; M'Rabet, 1995), and a possible threat due to the climatic change (Zouari *et al*., 1996). However, to detect the possible changes, the use of some structural parameters such as simple numerical values (Shannon's diversity index) may be insufficient and the intrinsic characters of the populations should also be taken into account to detect these changes in species abundance (Zenetos & Simboura, 2001). The inventory study, abundance and the space distribution of the megabenthic fauna community in Gabes gulf could be a useful tool to monitor its spatial variation (in the inshore and offshore waters). The studies carried out in Tunisia on megabenthic fauna are generally very few. The benthos of Gabes gulf is little studied, and research started with Le Danois (1925) and followed mainly by Molinier & Picard (1954); Pérès & Picard (1956), De Gailland (1970), Ben Othman (1971a), Ktari-Chakroun & Azouz (1971), Fehri-Bedoui (1986), Zaouli (1993b) and Ben Mustapha *et al*. (1999). Our study represents a new contribution to the spatial distribution of this megabenthic fauna in the gulf.

Materials and Methods

Study area

This study was carried out in Gabes gulf, located

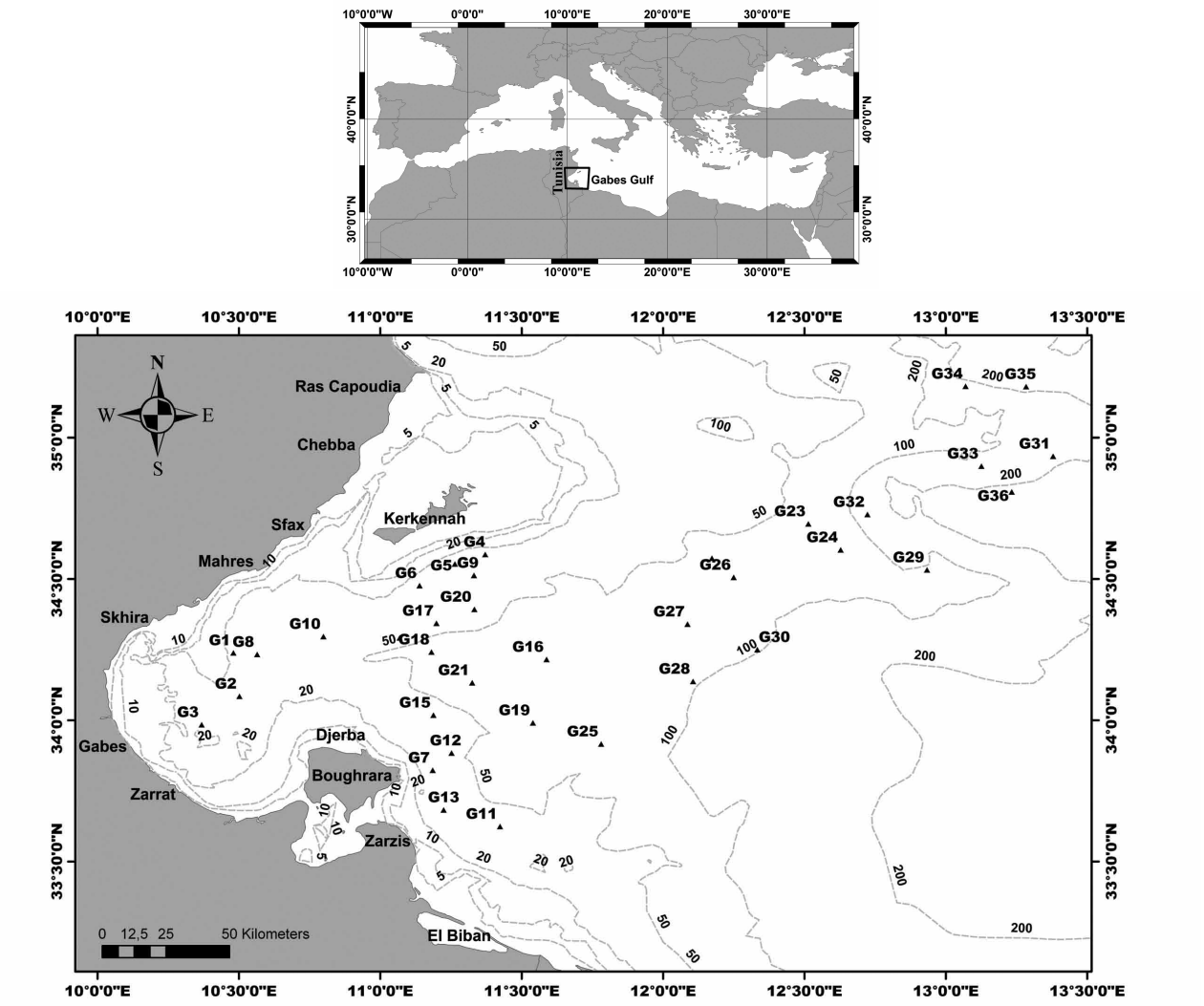


Fig. 1: Geographical map focusing on the megabenthic fauna sampling stations in Gabes gulf (Tunisia, Eastern Mediterranean Sea).

in the southern Ionian Sea (between 35°-33°N and 10-13.5ºE) and extends from "Ras Kapoudia" to the Tunisian-Libyan border (Fig. 1) with two large islands (Kerkennah & Djerba) and coastal lagoons (Bougrara & El Bibane). Its climate is dry (average annual precipitation: 210 mm year^{-1}) and sunny with strong easterly winds resulting in severe aeolian erosion. The Gabes gulf opens eastwards to the offshore area and has a wide continental shelf. The tide is semidiurnal, with a maximum range of about 2 m (Bradai, 2000). The vast area of the gulf's shallow water was affected by two differential effects of warming and cooling (Sammari *et al*., 2006). These observations were corroborated by Béranger *et al*. (2004) model, which showed that the superficial Algerian Current brought the upper layer eastwards and splits it into two branches at the Sicily Strait entrance, one flowing to the Tyrrhenian Sea, the other into the Sicily Strait. The latter is composed of two streams referred to as the Atlantic Ionian Stream (AIS) and the Atlantic Tunisian Current (ATC). Along the Tunisian coast, and during the cold period (winter-spring), the intermediate flow salinity (MAW, Modified Atlantic Water) is low (37.3 to 37.5 psu) closely resulting to that of the superficial layers. Conversely, during the warm season, the salinity strongly increased (>38 psu) and pronounced local circulation patterns were detected, most likely linked to a decline in the Eastern MAW-induced advection (Béranger *et al*., 2004).

Sampling

The megabenthic fauna species' samples were collected between 20 and 260 m depth in spring 2009 in 36 stations (Fig. 1). The inshore area depth in 21 sampling stations was <60 m and offshore waters depth in the remaining 15 stations was >60 m.

Sample methods

The megabenthic fauna was collected (i.e. about 10 mm side) on board of the boat R/V "Hannibal" of the *"Institut National des Sciences et Technologies de la*

Table 1. Bottom type and communities per station in Gabes gulf. The station localisation is shown in Figure 1.

Stations (G)	Depth (m)	substrate, communities
6,14	29-51	Mud with *Ophiothrix fragilis* and *Antedon mediterranea*
5	28	Dead meadow of *Posidonia* and muddy sand with Polyclinidae
4,9	26-41	Detritical-muddy bottom and dead meadow of *Posidonia,* with Holothuroidea and polyclinidae
10	42	Sand bottom with *Antedon mediterranus* and Polyclinidae
1	22	Sandy mud, detritical and dead meadow of *Posidonia* with *Pinctada radiata* and Holothuroidea
8,2,3	22-32	Mud and dead meadow of *Posidonia* with *Fulvia fragilis*
11,18	52-58	Detritical coastal bottom with Ascidiacea and Demospongiae
21	55	Mud with *Ophiothrix fragilis*, Demospongiae and Ascidiacea
15	59	Mud with *Ophiothrix fragilis* and Demospongiae
12,27,20	50-59	Detritic-coastal bottoms with Ascidiacea
16,25	31-44	Sandy mud and dead meadow of *Posidonia* with Holothuroidea and Ascidiacea
13,7	35-46	Sandy mud with *Arthrocladia villosa* and Ascidiacea
17,34	70-83	Sand with Ascidiacea and Demospongiae
35	186	Sand with *Antedon mediterranea*
31,36,33,24,26	98-256	Sandy mud bottoms
29	110	Sandy mud with Ascidiacea and *Cidaris cidaris*
32,28	70-94	Muddy sand with brown algae (*Taonia atomaria*)
30,23	78-91	Sandy mud bottoms
22,19	60-64	Sandy mud with red algae (*Rytiphloea tinctoria* and *Phyllophora nevosa*)

Mer (INSTM)", using two experimental trawl types: i) type "shrimp" to the lower depths <60 m; and ii) vertical opening trawl "GOV" for depths >60 m. The horizontal opening was 23 and 15 m in the shrimp and GOV trawl, respectively, with a 20 mm mesh diameter both. The trawl was towed at a 2.9 knots medium speed for an hour. Before starting sorting, the bottom type (substrate, communities) and main characterizing vegetables and animal species were estimated and recorded. Thereafter, the megabenthic fauna samples were sorted and classified on board, only the most difficult species to identify were preserved in ethanol (70%) before being identified in laboratory. Specimens' identification were carried out on the basis of external and internal morphology, following the criteria in literature (Koehler, 1921, 1927; Forest & Guinot, 1956; Cherbonnier, 1960; Tortonese, 1965; Zariquiey, 1968; Fishier *et al*., 1987; Ramos-Espla, 1991; Koutsoubas, 1992; Desroy *et al*., 2003).

The Gabes gulf is characterized by heterogeneous substrate (coastal detritic, muddy detritic, sand, muddy sand, sandy mud and mud). However, its grounds are principally consitituted of mud and sand bottoms (Table 1). The vegetation and megabenthic fauna associated varied by substrate type and depth. Gabes gulf is largely covered with soft sediment, sandy, muddy and carbonate of biogenic origin with a terrigenous input (Burollet, 1979).

Data analysis

Analysis of biocenotic parameters (specific richness, S, abundance, A, diversity, H', and equitability, E, parameters) and statistical analysis (Dendrogram analysis) have been carried out. The specific richness (S) is the cumulated number of species in a station or in a site. The abundance (A) is the average per surface unit, related to one hectare. The Shannon-Wiener index (H') (Shannon & Weaver, 1963) is calculated at each station by the following formula:

$$H' = -\sum_{i=1}^{s} \mathrm{ni/N} \log_2 \left(\frac{\mathrm{ni}}{\mathrm{N}}\right)$$

Where *ni* is the individuals' number of the species i, N is the total number of individuals and S is the number of species at the station. The equitability E (H') (Pielou, 1966) is calculated at each station by the following formula:

$$E(H') = H'/\log_2 S$$

Dendrogram analysis was performed using PRIMER v5.0 for Windows XP (Clarke & Gorley, 2001), to identify the abundance of different megabenthic fauna group and the clustering samples with a similar species composition.

The megabenthic fauna mapping was performed using the geographic information system (GIS). GIS can

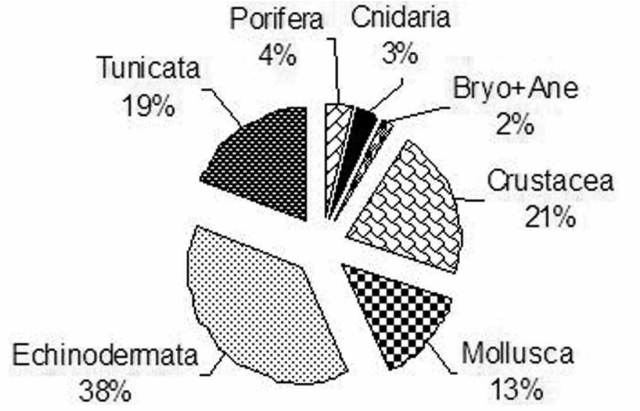


Fig. 2: Abundance percentages of the megabenthic fauna different groups in Gabes gulf (spring 2009).

cross the map data with other data through specialized applications and processing tools (Bouaziz, 2002). We divide quantitative abundance (A) into three class intervals according to the individuals' number (inds) per surface unit (1 hectare; ha):

A > 100 inds/ha: High abundance;

100<A>50 inds/ha: average abundance;

A< 50 inds/ha: low abundance.

Results

Inventory and spatial distribution

Megabenthic fauna assemblages in Gabes gulf were distributed in 208 species (Table 2). Eight groups were represented in order of abundance (%): Echinodermata (31 species, 38%), Crustacea (44 species, 21%), Tunicata (38 species, 19%), Mollusca (55 species, 13%), Porifera (21 species, 4%), Cnidaria (10 species, 3%), and finally, Annelida and Bryozoa (3 and 6 species, respectiviely, about 2%) (Fig. 2).

a) Echinodermata was the most abundant group (Table 2). In the coastal area, four species could be seen as dominating: *Ophiothrix fragilis* (present in the 33% of stations), *Antedon mediterranea* (28%), *Psammechinus microtubercultatus* (25%) and *Holothuria polii* (31%) with a maximum abundance of 494, 320, 114.50, 47.50 inds/ha, respectively. They were recorded, especially, in Southern Kerkennah and in Northern Djerba between 21 and 58 m depth (Table 2). *Astropecten aurianciacus* and *Coscinasterias tenuispina* were sampled in Southern Kerkennah and in Eastern Djerba (29-58 m depth) although they respectively appear in 36% and 19% of stations, with a low abundance (<20 inds/ha). *Echinaster sepositus* was collected in the entire gulf (26-186 m depth); it had occurred in 25% of stations. Whereas in the offshore waters, *Cidaris cidaris* was the only dominating species with a maximum abundance of 121.50 inds/ha. It was collected in deep waters between 61 and 256 m and was present in 28% of stations.

b) Crustacea was sampled, especially, in the inshore waters. The most important species for this group were *Trachysalambria palaestiniensi*, *Squilla mantis* and *Paguristes eremite* with a high abundance of 332, 175.25 and 121 inds/ha, respectively. They were present (22-58 m depth) in 36%, 25% and 36% of the stations, respectively. *Inachus dorsettensis* was developed in the inshore waters in 39% of stations, with an abundance of 11 inds/ha. *Inachus thoracicus* was sampled (in 14% of sations), only in the offshore waters between 70 and 110 m depth (Table 2).

c) Tunicata was dominated by four species *Microcosmus exasperatus*, *Aplidium* cf. *conicum*, *Styela plicata* and *Didemnum* spp which were sampled, especially, in the inshore waters with a high abundance of 313.5; 145, 47.75 and 25 inds/ha, respectively. Although they appeared in 19%, 44%, 11% and 36% of stations, respectively (Table 2). *Aplidium* cf. *conicum* and *Didemnum* spp were collected in the entire gulf (26-98 m depth).

Generally, *Microcosmus exasperatus* and *Styela plicata* were sampled together in the North-east of Gabes (21-32 m depth). *Polycitor adriaticum* was showed an average abundance (28 inds/ha) in Southern Kerkennah and in the North-east of Djerba (45-58 m depth), it was present in 8% of stations. *Ascidiella scabra* was collected (in 36% of stations) in Southern Kerkennah and North-east of Djerba (40-55 m depth) and in the offshore waters (70-83 m depth), with a maximum abundance of 22 inds/ha. *Ascidia mentula* appearing only in the offshore waters, it was present in 14% of stations, with a low abundance of 7 inds/ha.

d) Mollusca was dominated by eight species (4 gasteropoda, 2 Bivalva and 2 Cephalopoda). *Fulvia fragilis* was abundant in the North-east of Gabes between 21 and 32 m depth, with a high abundance (<300 inds/ha), in 8% of the stations. *Pinctada radiata* was present only in two coastal locations (in North-east of Gabes in 22 m and South-east of Sfax between 21 and 30 m depth) with a maximum abundance of 24 inds/ha. *Bolinus brandaris*, *Hexamplex trunculus*, *Aporrhais pespelecani* and *Erosaria turdus* had appeared in the inshore waters (especially, North-east of Gabes, Southern Kerkennah and North-east of Djerba) with a high abundance of 68; 29; 27 and 47 inds/ha, respectively. The two first species were present in 44% of stations, but *Aporrhais pespelecani* and *Erosaria turdus* were sampled in 25% and 8% of stations, respectively. *Sepia officinalis* and *Octopus vulgaris* were collected in the entire gulf (22-256 m depth) in 67% and 53% of stations, with a low abundance of 3.5 and 1.5 inds/ha, respectively (Table 2).

e) Porifera was dominated by 3 species *Suberites domuncula*, *Hippospongia communis* and *Aplysina aerophoba*. They were collected in the North-east of Djerba and Zarzis and in the offshore waters. *Suber-*

Table 2. Taxonomic composition of megabenthic fauna community in Gabes gulf (spring 2009) with their ecological groups. (S) South; (N) North; (SW) South-west; (SE) South-east; (NE) North-east; (E) East; (W) West.

Taxon	Percentage of occurrence by study (%)	High abundances (inds/ha)	Location and depth (m)
PORIFERA			
Acanthella acuta Schmidt, 1862	8	0.4	NE Djerba and Zarzis (50-58m) and offshore waters (65-186m)
Agelas cf. *oroides* (Schmidt, 1864)	19	0.35	NE Djerba and Zarzis (45-59m)
Aplysina aerophoba Schmidt, 1862	33	2.5	NE Djerba and Zaris (28-59m) and offshore waters (70-185m)
Calyx nicaeensis (Risso, 1826)	3	0.15	SE Kerkennah (31-45m)
Chondrosia reniformis Nardo, 1847	6	0.90	NE Djerba (35-45m)
Cliona viridis (Schmidt, 1862)			NE Djerba and Zarzis (31-50m)
Crambe crambe (Schmidt, 1862)	6	0.20	NE Djerba and Zarzis (30-50m)
Dysidea fragilis (Montagu, 1818)	11	2.20	NE Djerba and Zarzis (31-52m)
Dysidea tupha (Martens 1824)	6	0.5	NE Djerba and Zarzis (50-58m)
Haliclona mediterranea Griessinger, 1971	8	0.5	NE Djerba and Zarzis (50-58m)
Hippospongia communis (Lamarck, 1813)	33	10	NE Djerba and Zarzis (50-58m), S Kerkhennah (52-58m) and offshore waters (65-100m)
Ircinia variabilis (Schmidt, 1862)	3	0.2	NE Djerba and Zarzis (31-52m)
Ircinia sp.	11	0.65	NE Djerba and Zarzis (31-52m) and offshore waters (70-83m)
Petrosia ficiformis (Poiret, 1789)	19	0.30	NE Djerba and Zarzis (50-58m) and offshore waters (70-100m)
Raspaciona aculeate (Johnston, 1842)	17	0.40	NE Djerba and Zarzis (31m), NE Gabes (23m) and offshore waters (78-95m)
Sarcotragus foetidus Schmidt, 1862	3	0.15	NE Djerba and Zarzis (31-52m)
Sarcotragus spinosulus Schmidt, 1862	6	0.35	NE Djerba and Zarzis (31-52m)
Spongia officinalis (Linnaeus, 1759)	11	0.4	E Djerba and Zarzis (31-52m)
Suberites domuncula (Olivi, 1792)	33	26.50	NE Djerba and Zarzis (28-58m) and offshore waters (62-70m)
Tethya auranium (Pallas, 1766)	14	3	NE Djerba and Zarzis (31-58m)
Tethya citrina Sará & Melone, 1965	8	1	NE Djerba and Zarzis (31m)
HYDROZOA			
Eudendrium sp.	17	2.85	NE Djerba (31m), NE Gabes (22m) and offshore waters (62-186m)
Nemertesia antennina (Linnaeus, 1758)	14	1.45	SE Kerkennah (50-58m), NE Djerba (50m) and offshore waters (110m)
Sertularella sp.	6	1	S Kerkennah (35-58m), NE Djerba (31-50m)
ANTHOZOA			
Aglaophenia spp.	16	1.55	S Kerkennah (50-58m), E Djerba (50-58m) and offshore waters (70m)
Cerianthus membranaceus (Spallanzani, 1784)	6	0.5	W Djerba (21-25m)
Calliactis parasitica (Caouch, 1842)	19	21.5	S Kerkennah (40-55m) and E Djerba (42-46m)
Cladocora coespitosa (Linnaeus, 1767)	11	0.5	SE Kerkenna (26-32m) and NE Djerba (30-35m)
Epizoanthus arenaceus Delle Chiaje, 1823	20	5.10	S Kerkennah (54m) and E Djerba (31-46m)
Hormathia sp.	6	0.2	S Kerkennah (41-50m)
Pteroeides griseum (Pallas, 1766)	8	1	S Kerkennah (40-50m) and E Djerba (54m)
POLYCHAETA			
Aphroditidae sp.	8	1.5	S Kerkennah (27-54m) and NE Djerba (31-45m)
Diopatra neapolitana (Delle Chiaje, 1841)	6	0.6	Offshore waters (61-65m)
Laetmonice hystrix (Savigny, 1816)	11	4	S Kerkennah (27-54m)
CRUSTACEA			
Aegaeon cataphractus (Olivi, 1792)	14	6.05	S Kerkennah (26-30m) and NE Gabes (22-32m)
Balanus eburneus Gould, 1841	14	70	S Kerkennah (26-31m) and NE Gabès (22-32m)
Calappa granulata (Linnaeus, 1767)	3	0.40	Offshore waters (256m)
Calcinus tubularis (Linnaeus, 1767)	3	0.2	S Kerkennah (26-31m)
Chlorotocus crassicornis (Costa, 1871)	3	1	Offshore waters (256m)
Diogenes pugilator (Roux, 1828)	6	0.6	S Kerkennah (26-31m)
Dardanus calidus (Risso, 1827)	3	5.60	Offshore waters (70m)
Dromia personata (Linnaeus, 1759)	11	3.60	NE Djerba (45-52m) and offshore waters (70-91m)

(continued)

Table 2 continued

Taxon	Percentage of occurrence by study (%)	High abundances (inds/ha)	Location and depth (m)
Ethusa mascarone (Herbst, 1785)	8	2	S Kerkennah (26-54m)
Eucrate crenata de Haan, 1835	8	7.5	NE Gabes (21-32m)
Goneplax rhomboides (Linnaeus, 1758)	3	1	SE Kerkennah (41m)
Ilia nucleus Linnaeus, 1758	8	1.5	NE Gabes (21-32m)
Inachus dorsettensis (Pennant, 1777)	39	11	NE Gabes (21-23m), S Kerkennah (26-50m) and NE Djerba (42-59m)
Inachus thoracicus (Roux, 1830)	14	3.60	Offshore waters (70-110m)
Lambrus angulifrons (Latreille, 1825)	8	4	S Kerkennah (26-30m)
Latreillia elegans (Roux, 1830)	8	0.40	Offshore waters (108-256m)
Liocarcinus corrugatus (Pennant, 1777)	3	0.20	NE Gabes (21-32m)
Liocarcinus depurator (Linnaeus, 1758)	6	1	NE Gabes (21-23m)
Liocarcinus cf. *maculatus* (Risso, 1827)	3	0.2	NE Gabes (22m)
Liocarcinus sp.	8	1	NE Gabes (21 and 23m) and E Djerba (39-45m)
Macropipus tuberculatus (Roux, 1830)	3	0.30	Offshore waters (108m)
Macropodia longirostris (Fabricius, 1777)	19	7.5	S Kerkennah (26-58m) NE Djerba (31-43m)
Macropodia rostrata (Linnaeus, 1758)	8	1.5	S Kerkennah (50-58m)
Maja crispata Risso, 1827	8	3.75	NE Gabes (21-32m)
Medorippe lanata (Linnaeus, 1767)	14	3	S Kerkennah (31-52m), NE Djerba (42-60m) and offshore waters (110m)
Melicertus kerathurus (Forskal, 1775)	39	11	NE Gabes (22-32m) S Kerkennah (22-55m) and NE Djerba (31-58m)
Metapenaeus monoceros (Fabricius, 1798)	8	1.5	NE Gabes (22-32m) and S Kerkennah (26-30m)
Nephrops norvegicus (Linnaeus, 1758)	3	0.6	Offshore waters (256m)
Paguristes eremita (Linnaeus, 1767)	36	121	NE Gabes (22-32m), S Kerkennah (29-58m) and NE Djerba (31-60m)
Pagurus cuanensis (Bell, 1845)	25	9	S Kerkennah (40-50m) and NE Djerba (42-60m)
Pagurus excavatus (Muller, 1788)	3	1	Offshore waters (108m)
Pagurus prideauxi (Leach, 1815)	3	0.6	S Kerkennah (40m)
Pagurus cf. *alatus* (Fabricius, 1775)	3	2	NE Djerba (59m)
Parapenaeus longirostrus (Lucas, 1847)	14	14	Offshore waters (110-256m)
Parthenope angulifrons (Latreille, 1825)	14	3	S Kerkennah (26-30m) and E Djerna (31-45m)
Pilumnus hirtellus (Linnaeus, 1761)	22	5	NE Gabes (21 and 23m), S Kerkennah (40-58m) and NE Djerba (45-52m)
Pisa tetraodon (Pennant, 1777)	3	1	Offshore waters (82m)
Rimapenaeus similis (Smith, 1885)	6	0.2	NE Gabes (22-24m)
Sicyonia carinata (Brünnich, 1768)	14	17.50	SE Sfax (21-23m) and S Kerkennah (26-30m)
Solenocera membranacea (Risso, 1816)	3	0.2	NE Gabes (22-32m)
Squilla mantis (Linnaeus, 1758)	25	175.25	NE Gabes (22-32m) and S Kerkennah (29-50m)
Synalpheus gambarelloides (Nardo, 1847)	6	1.55	Offshore waters (70-82m)
Trachysalambria palaestiniensis (Steinitz, 1932)	36	332	NE Gabes (22-32m), S Kerkennah (22-29m) and NE Djerba (31-46m)
Palaemonetes antennarius (Milne-Edwards, 1837)	3	0.5	Offshore waters (61m)
GASTROPODA			
Aplysia sp.	3	0.3	SE Kerkennah (46m)
Aporrhais pespelecani (Linaneus, 1758)	25	27	NE Gabes (21-32m), S Kerkennah (29-51m) and NE et E Djerba (32-58m)
Buccinulum corneum (Linnaeus, 1758)	3	0.35	NE Djerba (55m)
Bolinus brandaris (Linnaeus, 1758)	44	68	NE Gabes (22-42m), S Kerkennah (26-55m) and NE Djerba (31-51m)
Bolma rugosa (Linnaeus, 1767)	3	0.2	S Kerkennah (36m)
Bulla striata Bruguière, 1792	6	0.8	E Djerba (38-40m)
Bursatella leachi De Blainville, 1817	3	0.2	E Djerba (31m)
Calliostoma granulatum (Born, 1778)	8	1.5	S Kerkennah (26-40m)
Calliostoma zizyphinum (Linnaeus, 1758)	6	1	S Kerkennah (26-40m)
Cassidaria echinophora (Linnaeus, 1758)	9	1.60	S Kerkennah (40-46m) and NE Djerba (28-55m)
Conus ventricosus Gmelin, 1791	8	1	S Kerkennah (45-48m)
Erosaria turdus (Lamarck, 1810)	8	47	NE Gabes (21-32m) and S Kerkennah (39m)

(continued)

Table 2 continued

Taxon	Percentage of occurrence by study (%)	High abundances (inds/ha)	Location and depth (m)
Fusinus rostratus (Olivi, 1792)	11	5	S Kerkennah (26-55m) and NE Djerba (45-51m)
Hexamplex trunculus (Linnaeus, 1758)	44	29	NE Gabes (22-42m), S Kerkennah (26-58m) and NE Djerba (31-51m)
Luria lurida (Linnaeus, 1758)	3	0.2	NE Djerba (59m)
Natica sp.	14	1.5	S Kerkennah (26-31m)
Naticarius cruentatus (Gmelin, 1791)	8	0.5	S Kerkennah (26-31m)
Naticarius punctatus (Chemnitx & Karsten, 1789)	14	1.5	S Kerkennah (26-39m)
Philine aperta (Linnaeus, 1767)	6	1.5	NE Gabes (21m) and S Kerkennah (26m)
Tonna galea (Linnaeus, 1758)	6	0.5	S Kerkennah (26-55m)
Xenophora crispa (König, 1825)	6	1.20	Offshore waters (98-110m)
Zonaria pyrum (Gmelin, 1791)	8	1	NE Gabes (21-32m)
BIVALVIA			
Acanthocardia echinata (Linnaeus, 1758)	3	1	NE Djerba (32m)
Acanthocardia tuberculata (Linnaeus, 1758)	3	0.5	NE Djerba (32m)
Anadara diluvii (Lamark, 1805)	8	0.2	SW Kerkennah (26-45m)
Arca noae Linnaeus, 1758	8	1	NE Djerba (31-45m)
Callista chione (Linnaeus, 1758)	8	2	S Kerkennah (26-51m)
Chlamys flexuosa (Poli, 1795)	6	1	NE Gabes (22-32m)
Chlamys glabra (Linnaeus, 1758)	6	0.5	NE Gabes (22-32m)
Chlamys opercularis (Linnaeus, 1758)	6	0.80	NE Gabes (22m) and NE Djerba (58m)
Chlamys varia (Linnaeus, 1758)	6	1.5	NE Gabes (22m) and NE Djerba (58m)
Corbula gibba (Olivi, 1792)	8	1	NE Gabes (21-32m)
Fulvia fragilis (Forsskal, 1775)	8	272	NE Gabes (21-32m)
Glycymeris glycymeris (Linnaeus, 1758)	3	0.2	SE Kerkennah (26m)
Gregariella petagnae (Scacchi, 1832)	3	0.5	NE Djerba (30m)
Laevicardum crassum (Gmelin, 1791)	6	0.5	NE Gabes (21-32m)
Limaria inflata Link, 1807	6	1	NE Gabes (22-32m)
Modiolus barbatus (Linnaeus, 1758)	8	1.5	NE Gabes (22-32m)
Neopycnodonte cochlear (Poli, 1795)	19	2	NE Gabes (22-32m) and S Kerkennah (26-54m)
Ostrea tarentina (Issel, 1882)	3	0.2	NE Gabes (22m)
Ostreidae sp.	8	1	NE Gabes (22-32m) and offshore waters (186m)
Parvicardium exiguum (Gmelin, 1791)	8	0.2	NE Gabes (21-32m)
Pecten jacobeus Linnaeus, 1758	3	0.3	Offshore waters (98m)
Pinctada radiata (Leach, 1814)	6	24	NE Gabes (21m) and SE Sfax (21-30m)
Pinna nobilis Linnaeus, 1758	3	0.2	S Kerkennah (26m)
Plagiocardium papillosum (Poli, 1795)	3	1	NE Gabes (21-32m)
Solecurtus scopula (Turton, 1822)	3	0.2	S Kerkennah (35-45m)
Venericardia antiquata (Linnaeus, 1758)	8	4.80	S Kerkennah (26-41m)
Venus verrucosa Linnaeus, 1758	6	0.5	NE Gabes (21-32m)
SCAPHOPODA			
Dentalium sp.	8	1	NE Djerba (31-45m)
Fustiaria rubescens (Deshayes, 1825)	8	0.5	NE Djerba (31-45m)
CEPHALOPODQA			
Eledone moschata (Lamarck, 1798)	33	1.5	S Kerkennah (50-59m)
Octopus vulgaris (Lamarck, 1798)	53	1.5	The entire gulf between (22-256m)
Sepia officinalis Linnaeus, 1758	67	3.5	The entire gulf between (22-256m)
Sepietta oweniana (Orbigny, 1839–1841)	14	1	NE Gabes (22-32m) and offshore waters (65-256)
BRYOZOA			
Bugula sp.	3	0.05	NE Gabes (21m)

(continued)

Table 2 continued

Taxon	Percentage of occurrence by study (%)	High abundances (inds/ha)	Location and depth (m)
Chartella papyracea Ellis & Solander 1786	3	0.05	SE Kerkennah (26m)
Margaretta cereoides (Ellis & Solander, 1786)	3	0.1	Offshore waters (62m)
Pentapora fascialis (Pallas, 1766)	6	0.05	S E Kerkennah (26m) and NE Djerba (40m)
Reteporella grimaldii (Julien in Julien & Calvet, 1903)	22	0.6	NE Djerba (42-59m) and offshore waters (62-98m)
Scrupocellaria scruposa (Linnaeus, 1758)	11	0.2	NE Djerba (40-45m) and offshore waters (90-110m)
ECHINODERMAT			
Antedon mediterranea (Lamarck, 1816)	28	320	NE Gabes and SE Sfax (21-42m), S Kerkennah (45-58m) and offshore waters (186-256m)
Astropecten jonstoni (Delle Chiaje, 1827)	11	1	S Kerkennah (31-50m)
Astropecten irregularis (Pennant, 1777)	6	0.6	S Kerkennah (40-50m)
Astropecten spinulosus (Philippi, 1837)	6	0.5	NE Djerba (31-58m)
Astropecten aranciacus Linnaeus, 1758	36	14.72	S Kerkennah (29-58m) and NE Djerba (31-58m)
Anseropoda placenta (Pennant, 1777)	14	1.20	Offshore waters (70-110m)
Brissus unicolor (Leske, 1778)	6	0.5	S Kerkennah (26-31m)
Chaetaster longipes (Retzius, 1805)	3	0.3	Offshore waters (108m)
Centrostephanus longispinus (Philippi, 1845)	8	10.5	Offshore waters (70-110m)
Cidaris cidaris (Linnaeus, 1758)	28	121.56	Offshore waters (61-256m)
Coscinasterias tenuispina (Lamarck, 1816)	19	8.33	S Kerkennah (26-54m) and E Djerba (42-57m)
Echinaster sepositus (Retzius, 1783)	25	1.77	S Kerkennah (26m), N Djerba (31m) and offshore waters (62-110m)
Echinocardium mediterraneum (Forbes, 1844)	6	0.5	S Kerkennah (26-31m)
Echinus acutus (Lamarck, 1816)	14	9	Offshore waters (78-186m)
Hacelia attenuata (Gray, 1840)	6	1	Offshore waters (70 and 256m)
Holothuria forskali Delle Chiaje, 1823	8	3.5	NE Gabes (21-32m) and NE Djerba (31m)
Holothuria polii Delle Chiaje, 1823	31	47.45	NE Gabes (21-32m), S Kerkennah (26-41m) and NE Djerba (31-51m)
Holothuria tubulosa Gmelin, 1790	28	33.85	NE Gabes (21-32m), S Kerkennah (26-41m) and NE Djerba (31-51m)
Holothuiria mammata Grube, 1840	19	8	S Kerkennah (31-45m) and NE Djerba (31-51m)
Holothuria helleri von Marenzeller, 1877	6	0.3	Offshore waters (110m) and (256m)
Holothuria sanctori Delle Chiaje, 1823	3	2	NE Djerba (32m)
Ocnus syracusanus (Grube, 1840)	6	2.5	NE Gabes (22m) and E Djerba (45m)
Ophioderma longicaudum (Retzius, 1805)	11	2.5	S Kerkennah (31 and 44m) and NE Djerba (31-54m)
Ophiomyxa pentagona (Lamarck, 1816)	8	1	SE Djerba and Zarzis (37-43m) and offshore waters (62-65m)
Ophiothrix fragilis (Abildgaard, 1789)	33	495	S Kerkennah (29-58m), NE Djerba (46m) and offshore waters (70m)
Ophiura texturata Lamarck, 1816	17	8.5	S Kerkennah (26-50m) and NE Djerba (31-54m)
Paracentrotus lividus (Lamarck, 1816)	11	13.60	S Kerkennah (26-32m) and NE Djerba (31m)
Psammechinus microtubercultatus (Blainville, 1825)	25	114.53	S Kerkennah (26-50m) and NE Djerba (42-51m)
Schizaster canaliferus (Lamarck 1816)	6	0.3	Offshore waters (61-65m)
Spatangus purpureus (O.F.Muller, 1776)	14	0.5	Offshore waters (61-94m)
Stylocidaris affinis (Philippi, 1845)	17	27	Offshore waters (78-110m)
ASCIDIACEA			
Aplidium asperum Drasche, 1883	14	4	S Kerkennah (27-58m) and NW Djerba (31-45m)
Aplidium cf. *conicum* (Olivi, 1792)	44	145	The entire gulf between (26-98m)
Aplidium elegans (Girad, 1872)	17	25	S Kerkennah (54-58m), NE Djerba (41-45m) and offshore waters (62m)
Aplidiun haouarianum (Pérès, 1956)	14	4	S Kerkennah (54-58m) and NE Djerba (41-45m)
Aplidium proliferum (Milne-Edwards, 1841)	11	3	S Kerkennah (26-41m)
Aplidium aff. *pallidum* (Verrill, 1871)	6	2.80	S Kerkennah (36-38m)
Aplidium sp.	19	16	S Kerkennah (29-52m), NW Djerba (31-45m) and offshore waters (62-70m)
Ascidia mentula O.F. Müller, 1776	14	7	Offshore waters (90-256m)

(continued)

Table 2 continued

Taxon	Percentage of occurrence by study (%)	High abundances (inds/ha)	Location and depth (m)
Ascidia sp.	14	4	S Kerkennah (40-58m) and N Djerba (42-55m)
Ascidiella scabra (O F Müller, 1776)	36	22	S Kerkennah (40-58m), NE Djerba (42-55m) and offshore waters (70-83m)
Botryllus schlosseri (Pallas, 1776)	31	19.95	S Kerkennah (40-55m), NE Djerba (42-58m) and offshore waters (70-186m)
Botryllus sp.	19	10	S Kerkennah (40-55m), NE Djerba (42-58m) and offshore waters (70-110m)
Clavellina sp.	19	2	S Kerkennah (27-58m) and NE Gabes (22-32m)
Cystodytes dellechiajei (Della Valle, 1877)	8	1.5	S Kerkennah (52-58m) and NE Djerba (31m)
Diazona violacea (Savigny, 1816)	6	0.75	Offshore waters (108-110m)
Didemnum coriaceum Von Drasche, 1883	14	4.5	S Kerkennah (27-58m), WE Djerba (31-45m)
Didemnum fulgens (Milne Edwards, 1841)	19	10	S Kerkennah (27-58m), NW Djerba (31-45m)
Didemnum sp.	36	25	S Kerkennah (27-58m), NW Djerba (31-45m) and offshore waters (62-78m)
Diplosoma spongiforme (Giard, 1872)	3	1	S Kerkennah (58m)
Diplosoma sp.	6	0.80	S Kerkennah (52-58m)
Ecteinascidia turbinata Herdman, 1880	11	3.5	S Kerkennah (29-54m), E Djerba (50-55m)
Eudistoma spp.	14	7	S Kerkennah (27-55m), NE Djerba (51m)
Microcosmus exasperatus Heller, 1878	19	313.5	NE Gabes (21-32m), S Kerkennah (26-45m) and N Djerba (31-43m)
Microcosmus vulgaris Heller, 1877	3	1.10	Offshore waters (110m)
Molgula appendiculata Heller, 1877	3	1.5	NE Djerba (42-46m)
Molgula occulata Kupffer, 1875	3	2	NE Zarzis (44m)
Polycarpa cf. *comata* (Alder, 1863)	3	1	S kerkennah (54-57m)
Polyclinidae spp.	14	19.50	NE Gabes (21-32m), NE Djerba (42-55m) and offshore waters (63m)
Polycitor adriaticum (Von Drasche, 1883)	8	28	NE Djerba (45-58m) and offshore waters (62m)
Polycitor sp.	6	2.5	S Kerkennah (52-58m)
Polycitoridae sp.	11	4	NE Djerba (43-46m)
Pseudodistoma cyrnusense Pérès, 1952	19	5	S Kerkennah (26-41m)
Styela canopus (Savigny, 1816)	8	2.5	NE Djerba and Zarzis (31-46m)
Styela plicata (Lesueur, 1823)	11	46.75	NE Gabes (21-32m)
Synoicum cf. *duboscqui* (Harant, 1927)	8	1.5	S Kerkennah (52-58m)
Synoicum sp.	11	2	S Kerkennah (26-41m)
Tridemnum cereum (Girad, 1872)	19	8.5	S Kerkennah (27-58m), NE Djerba (31-52m)
Pyura dura (Heller, 1877)	8	2	NE Djerba (31-44m)

ites domuncula shows the greatest abundance between 28 and 70 m depth. In the inshore waters, *Suberites domuncula* and *H. communis* were collected in deep below 58 m. In the offshore waters, *H. communis* appeared at a 65 to 100 m depth, while *S. domuncula* was sampled only up to 70 m. *A. aerophoba* was sampled in the coastal area (especially, in the North-east of Djerba and Zarzis between 28 and 59 m depth) and in the offshore waters (70-185 m depth). These three species were present in 33% of stations, with an abundance of 26.50; 10 and 2.5 inds/ha, respectively (Table 2).

f) Cnidaria was dominated by two species *Calliactis parasitica* and *Epizoanthus arenaceus* which were present respectively, in 19% and 20% of the surveyed stations. These species showed a low abundance in the gulf, they were sampled especially, in Eastern Djerba (31-55 m depth). *C. parasitica* showed a 21.5 inds/ha abundance.

g) Annelida was represented only in the epibenthic megafauna by 3 species and was dominated by the single species *Laetmonice hystrix* which was present (in 11% of stations) especially, in Southern Kerkennah (27-54 m depth). This species showed a low abundance of 4 inds/ha (Table 2). The low density of this group can be explained in that most of this group's species were small in size, while the used fishing gear only received species of size >10 mm.

h) Bryozoa was dominated by the single species *Reteporella grimaldii* which was present in 22% of stations, it represented the lowest abundance in the gulf (0.6 inds/ha). It was collected in the North-east of Djerba (42-59 m depth) and in the offshore waters (61-98 m depth).

According to these observations, the megabenthic fauna community of Gabes gulf was distributed in two depth groups:

a) The inshore group (20-60 m depth), mainly with *Posidonia* meadows and macroalgae beds, with maerl bed patches, and represented by *Suberites domuncula*, *Calliactis parasitica*, *Epizoanthus arenaceus*, *Psammechinus microtubercultatus*, *Holothuria polii*, *H. tubulosa*, *Astropecten aurianciacus*, *Coscinasterias tenuispina*, *Ophiothrix fragilis*, *Aporrhais pespelecani*, *Bolinus brandaris*, *Hexamplex trunculus*, *Erosaria turdus*, *Pinctada radiata*, *Fulvia fragilis*, *Eledone moschata*, *Trachysalambria palaestiniensis*, *Squilla mantis*, *Melicertus kerathurus*, *Metapenaeus monoceros*, *Sicyonia carinata*, *Aegaeon cataphracta*, *Paguristes eremita*, *Pagurus cuanensis*, *Inachus dorsettensis*, *Macropodia longirostris, Pilumnus hirtellus, Didemnum* spp, *Aplidium* cf. *conicum*, *Polyclinidae* spp., *Ecteinascidia turbinata*, *Polycitor adriaticum*, *Eudistoma* spp. *Microcosmus exasperatus* and *Styela plicata*.

b) The offshore group was associated with a muddy detritic and terrigenous muddy bottoms with brown and red algae (>60 m depth) represented by *Cidaris cidaris*, *Stylocidaris affinis*, *Ascidia mentula*, *Echinus acutus* and *Echinaster sepositus*. Whereas *Antedon mediterranea*, *Hippospongia communis*, *Aplysina aerophoba*, *Medorippe lanata*, *Eucrate crenata*, *Sepia officinalis*, *Octopus vulgaris*, *Ascidiella aspersa*, *Botryllus schlosseri* and *Reteporella grimaldii* were present in the two depth groups.

Univariate analysis

In Gabes gulf, the megabenthic fauna abundance varied from 17 (in 98 m depth) to 880 inds/ha (in 22.5 m depth), and a specific richness from 6 (in 228 m depth) to 35 species (in 45 m depth) (Fig. 3a). The megabenthic fauna diversity decreased towards the offshore waters (H'= 1.05 bits/individual, 14 species, in 70 m depth). From the inshore waters, where H' reached a maximum of 4.03 bits/individual (in 43.5 m depth), and equitability had varied from 0.32 (in 57 m depth) to 0.88 (in 70.5 m depth) (Fig. 3b).

The megabenthic fauna community mapping showed high concentrations located along the shallow coastal fringe (20-60 m depth), with maximum abundances between 301 and 900 inds/ha, while their distribution was extremely low in offshore waters (Fig. 4a). The spatial distribution map of Echinodermata illustrated a high abundance (between 151 and 800 inds/ha) in the gulf's inshore waters (especially, in the South-west of Kerkennah and Northern Djerba), and to a lesser extent, in the North-east of Gabes and in the offshore waters (Fig. 4b). The Crustacea came in second position with a maximum abundance between 81 and 560 inds/ha. It was concentrated in the costal area of Sfax and Gabes, North-west of Djerba (20-30 m depth) and in Southern Kerkennah (Fig. 4c). Tunicata showed an elevated abundance especially, in the North-west of Djerba, Southern Kerkennah and the North-east of Gabes with a maximum between 61 and 400 inds/ha. It was abundant in the gulf from 20 to 80 m depth (Fig. 4d). On the other hand, the Mollusca group showed an average abundance in the gulf between 81 and 300 inds/ha. This group was abundant only in the coastal area especially, in the North-west of Djerba, the North-east of Gabes and the South-west of Sfax (Fig. 4e). Porifera showed a low abundance in the study area with a maximum between 9 and 33 inds/ha. It had been concentrated in the inshore waters of the gulf, especially, in the North-east of Djerba and Northern Zarzis (26-55 m depth) and in the offshore waters around 75 m depth and to a lesser extent in the gulf remainder (Fig. 4f). Cnidaria illustrated a low abundance in the entire gulf between 2.1 and 22 inds/ha. It was localised in the middle of the gulf, between the North-east of Djerba, Northern Zarzis, the South-east of Kerkennah and the offshore waters up to 100 m depth (Fig. 4g). Annelida proved a low abundance in the gulf between 4 and 9 inds/ha. It was particularly collected, in Southern Kerkennah and the North-east of Djerba between 25 and 50 m depth (Fig. 4h). Bryozoa was poorly distributed in the study area with a low abundance between 0.31 and 0.60 inds/ha. It was sampled in the North-east of Zarzis around 50 m depth and in the offshore waters up to 110 m depth (Fig. 4i).

Statistical analysis

Dendrogram analysis of the megabenthic fauna group indicated the presence of two major groups in the gulf; the first gathered (G1) the most abundant benthic phyla such as Echinodermata, Crustacea, Tunicata and Mollusca. The second gathered (G2) the least group represented such as Porifera, Cnidaria, Annelida and Bryozoa (Fig. 5).

Discussion

This study indicated that the community of the megabenthic fauna is well distributed in Gabes gulf with a remarkable abundance in the inshore area associated with a dead meadow of *Posidonia* and macroalgae beds (301<A<900 inds/ha), while the offshore waters zone presented a weak abundance (A<150 inds/ha). Pergent & Kempf (1993) suggest that seagrasses were found around Kerkennah and Djerba. The Northern Djerba was bordered by a seagrass mixed with *Cymodocea nodosa* and *Caulerpa prolifera* which contained more or less extensive *Posidonia* patches. Along towards Gabes and Skhira areas (in the gulf Western part) there is a low density of phytobenthos and an abundance of the dead meadow of *Posidonia* (Zaouali, 1993b; Ben Mustapha *et al*., 1999). This allows us to deduce that the density of the megabenthic fauna community is related to the condition of vegetation cover.

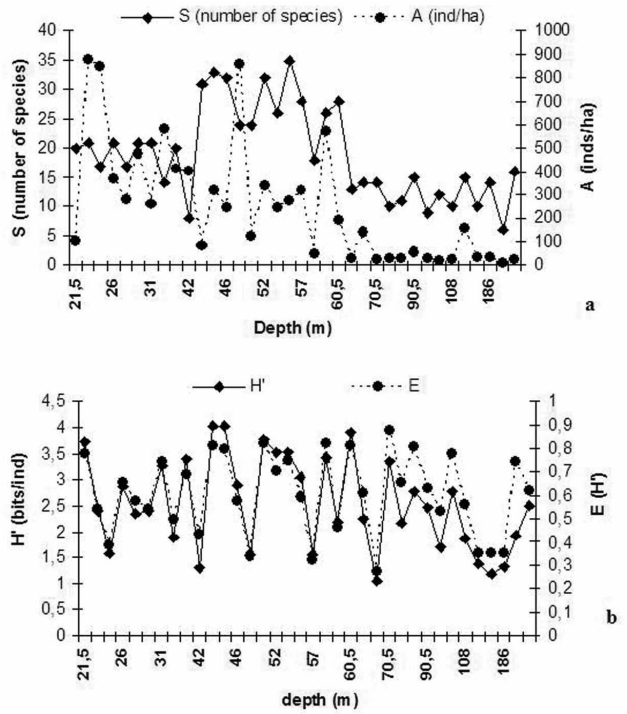


Fig. 3 (a,b) : Spatial variability of the principal biod versity parameters: abundance (A), specific richness (S), Shannon-Wiener index (H') and equitability (E).

In Gabes gulf, we counted 8 groups and 208 species of the megabenthic fauna, colonizing this area (31 species of Echinodermata, 44 Crustacea, 38 Tunicata, 55 Mollusca, 21 Porifera, 10 Cnidaria, 3 Annelida and 6 Bryozoa) (Table 2). The most abundant fauna communities are *Ophiothrix fragilis*, *Trachysalambria palaestiniensis*, *Aplidium* cf., and *conicum*, these species were abundant between 20 and 60 m depth) (Tables 1 and 2).

The spatial distribution of the megabenthic fauna community in Gabes gulf may be affected, if the factors related to the disturbance sources still persist (industrial rejections and benthic trawling), and the possible increase of the fine sediment (Ben Mustapha *et al*., 1999). The present state showed some spatial separation between the gulf's different groups of megabenthic fauna.

The Echinodermata group coupled with environmental factors (such as bottom type and vegetation cover) played important roles in the benthos ecosystems, and the effects of sea urchins, sea stars and holothurians over the benthic community structure were significant. The Echinodermata was concentrated in the inshore and, to a lesser extent, in the offshore waters of Gabes gulf. It was dominated in the inshore waters by *Ophiothrix fragilis*, *Psammechinus microtubercultatus* and *Holothuria polii* and with other echinoderm species on mud or sandy mud bottoms associated with a dead meadow of *Posidonia* (Tables 1 and 2). Whereas in the gulf's offshore waters, *Cidaris cidaris*, *Stylocidaris affinis* and *Echinus acutus* were dominated on sand bottom together with other species of echinoderms as *Centrostephanus longispinus*, *Hacelia attenuata*, *Anseropoda placenta*, *Chaetaster longipes*, *Spatangus purpureus* and *Holothuria helleri*. *Antedon mediterranea* and *Echinaster sepositus* were present in both areas (inshore and offshore waters) with other megabenthic fauna on sand or mud bottoms. *Ophiothrix fragilis* was sampled on mud bottom at a depth <70 m. The elevated density of these gulf's species was probably due to their lifestyle, which was characterized by very short periods, allowing a dynamic generation, thus, a more active population. *A. mediterranea* and *O. fragilis* was distributed throughout the gulf and abundant in Southern Kerkennah on mud bottom and in the offshore waters around 250 m depth on sandy mud bottom. These results were consistent with previous observations. Koehler (1924) regards *A. mediterranea* as a primarily littoral species, which lives among algae, rocks or attached to various animals; Ranson (1924) and Cherbonnier (1956) noted that on the Tunisian coast, the species was found by 25 m on seagrass *Posidonia* and *Halimeda*; and Tortonese (1965) assigns it in bathymetric limits ranging from (0-200 m depth). *Holothuria polii* accompanied by *H. tubulosa* were present in the entire inshore waters of the gulf (especially, in Northern Djerba) on sandy mud bottom together with the *Posidonia*'s remains. Bruun (1940) and Cherbonnier (1956) confirm that *H. tubulosa* associated with *H. polii* are very common on the coast of Tunisia on sand bottom (0-40 m depth), or to 50 m limit, particularly in Gabes gulf (espacilly, in Ras Kaboudia, Djerba and El Biban) and in Tunis gulf. In the coastal area, on detrital and mud bottoms, we harvested an abundance of *P. microtubercultatus* with some specimens of *Paracentrotus lividus* (Tables 1 and 2). Currently, we noted that *P. lividus* appeared to be rare in Gabes gulf (in >23 m depths). The cause could be the competition with the sea urchin *P. microtubercultatus* which was very common there (21-51 m depth). Many authors have reported the abundance of *P. lividus* in the gulf between 4 to 44 m depth on different habitats (Le Danois, 1925; De Gaillande, 1970; Ben Othman, 1971b; Ktari-Chakroun & Azouz 1971; Fehri-Bedoui, 1986; Zaouali, 1993b; Ben Mustapha *et al*., 1999). Sea urchins were considered to be the most important herbivores in the Mediterranean, because of the high abundance in the overgrazing phenomena (e.g. Kempf, 1962; Nedelec, 1982; Verlaque, 1987; Hereu, 2004). Bruun (1940) sampled *P. microtubercultatus* with other echinoderms on mud bottoms around 80 m. *C. cidaris* and *S. affinis* were found in the offshore waters (75-260 m depth). Cherbonnier (1956) has sampled *Cidaris cidaris* and *Stylocidaris affinis* in the Tunisian waters (40-250 m depth). *Schizaster canaliferus* appeared in the offshore waters on sandy mud bottom of red algae (*Rytiphloea tinctoria* and *Phyllophora nevosa*) around 61 m depth. *S. purpureus* were sampled on muddy sand bottom of brown algae (*Taonia atomaria*) between 70 and 94 m depth (Tables 1 and 2).

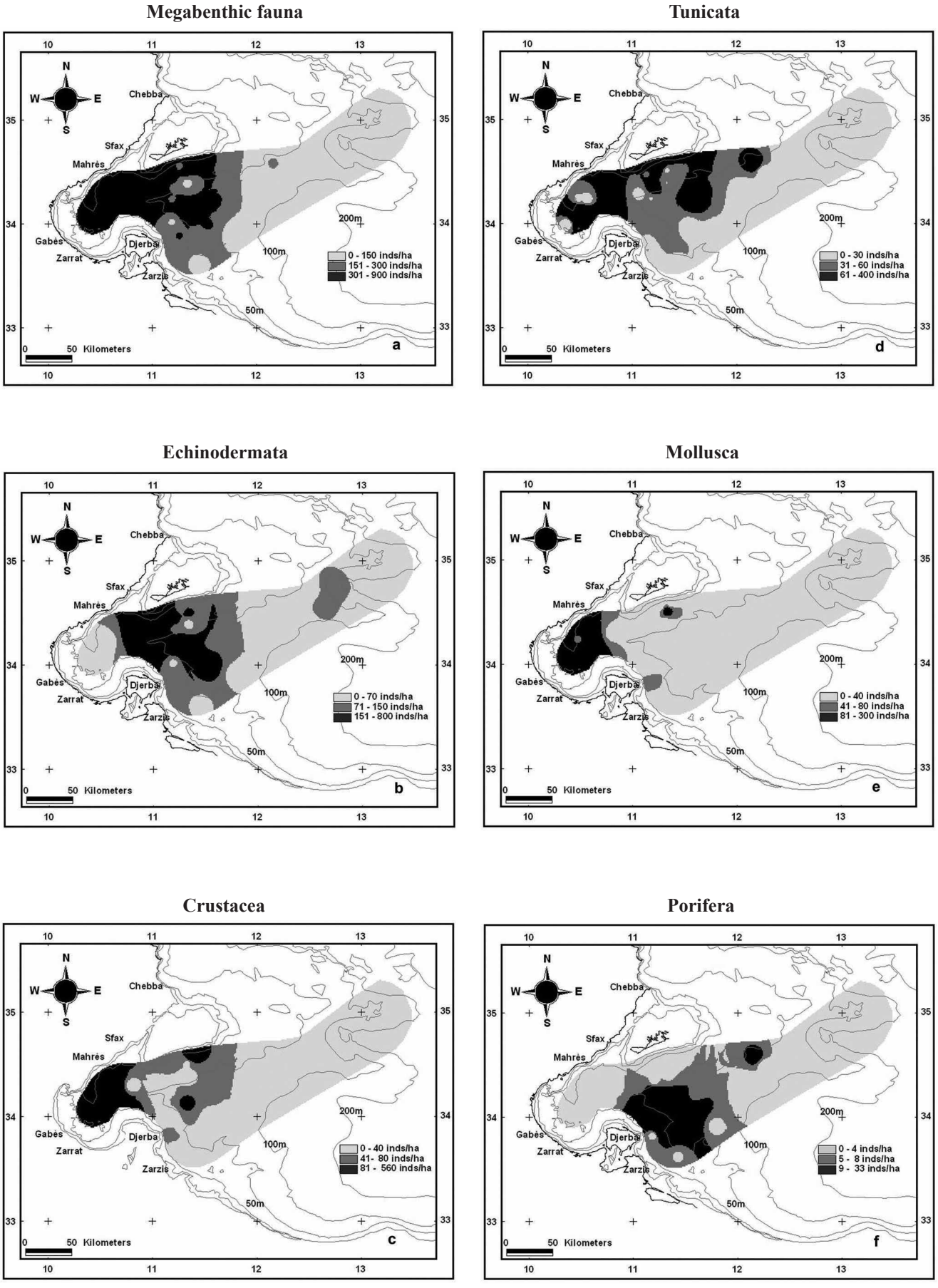
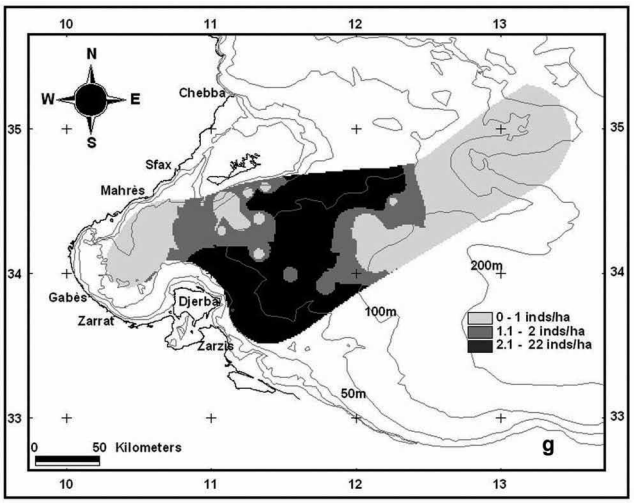
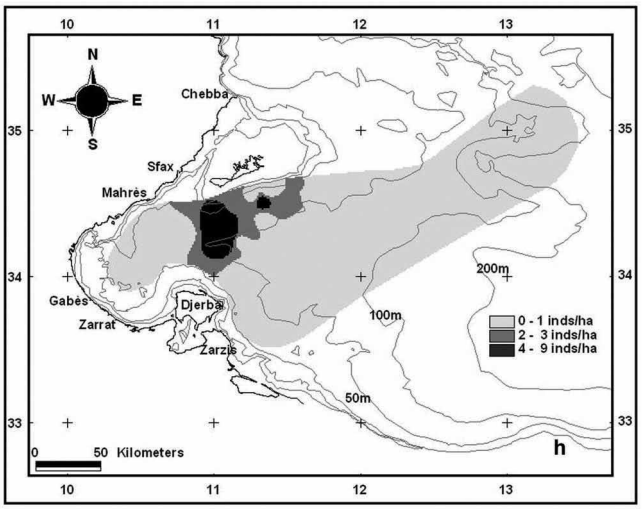


Fig. 4 (a,b,c,d,e,f,g,h,i): Spatial distribution of the megabenthic fauna groups abundance.

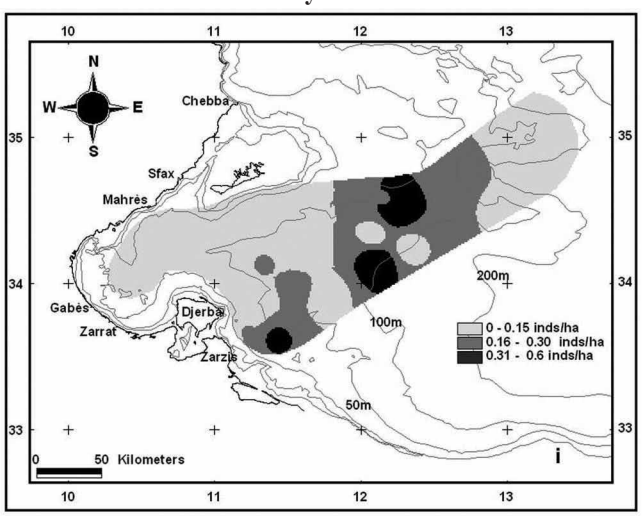
Cnidaria



Annelida



Bryozoa



(continued) Fig. 4 (a,b,c,d,e,f,g,h,i): Spatial distribution of the megabenthic fauna groups abundance.

Crustacea group was concentrated in the gulf's inshore waters (20-60 m depth), especially, in the costal area of Sfax and Gabes and North-west of Djerba (<32 m depth) on sand or mud bottoms with a dead meadow of *Posidonia* (with a maximum abundance between 81 and 560 inds/ha). In the North-east of Gabes, this group was dominated by eight species (*T. palaestiniensis* (the most abundant ones with 332 inds/ha), *Eucrate crenata*, *Maja crispate*, *Squilla mantis*, *Paguristes eremita*, *Sicyonia carinata*, *Inachus dorsettensis* and *Melicertus kerathurus*) on mud bottom with *Fulvia fragilis*. Several authors announced the possible competition from exotic species *M. monoceros*, *T. palaestinensis* and *R. similis* with *M. kerathurus* (Jarboui & Ghorbel, 1995; Missaoui & Zaouali, 1995; Ben Abdallah *et al*., 2003; Ben Abdallah Hadj Hamida *et al*., 2009). According to our study, we observed a high abundance in exotic species, especially, in *T. palaestinensis* but, the most abundant crustaceans intruders showed a highly localized distribution, especially, on mud or muddy sand bottoms localized in the Western gulf. While the endemic species *M. kerathurus* showed a well spread distribution and properly structured throughout the inshore waters of the gulf. Galil *et al*. (2002) noted that *T. palaestinensis* was a nocturnal species that lived on sand or muddy sand bottoms (6-300 m depth). It was collected in Tunisia on unstable mud without phytobenthos or muddy sand bottoms with *seagrasses* meadows (of *Posidonia* or *Cymodocea*), between 5 and 50 m depth (Zaouali, 1993b; Missaoui & Zaouali 1995; Missaoui *et al*., 2003). Bradai (2001) stresses that *M. monoceros* had become very abundant, especially, in the Western area of Gabes gulf (Mahrès and Skhira) at a depth ranging from 20 to 50 m, but their value is lower than that of native prawn *M. kerathurus*. *E. crenata* was captured only in the North-east of Gabes (22-32 m depth), on mud bottom with a dead meadow of *Posidonia* and *Fulvia fragilis* (Tables 1 and 2). Galil *et al*. (2002) signaled that this Brachyura is an exotic species that lives on sand and silt bottoms (10-100 m depth). In Gabes gulf, Zaouali, (1993a) and Missaoui *et al*. (2003) signaled it (5-20 m depth) on detrital shelly mud with a dead meadow of *Posidonia* and silted with *Cymodocea* and impacted bottoms with phosphogypsum. In the offshore waters, we noted the presence of *Nephrops norvegicus*, *Chlorotocus crassicornis, Calappa granulata* on sandy mud bottoms (Tables 1 and 2) with very low abundance (<1.5 inds/ha). *Parapenaeus longirostrus* and *Latreillia elegans* were reported on sandy mud or sand bottoms (108-256 m depth). *Medorippe lanata* (3 inds/ha) was collected on heterogeneous substrates (sands, muds, muddy sands and detrital coastal bottoms) in two areas.

The benthic Tunicata were distributed in the major part of the gulf with a high abundance (between 61 and 400 inds/ha). It was concentrated in the costal area, especially, in the North-west of Djerba and in Southern Kerkennah on sand or mud bottoms and in the offshore

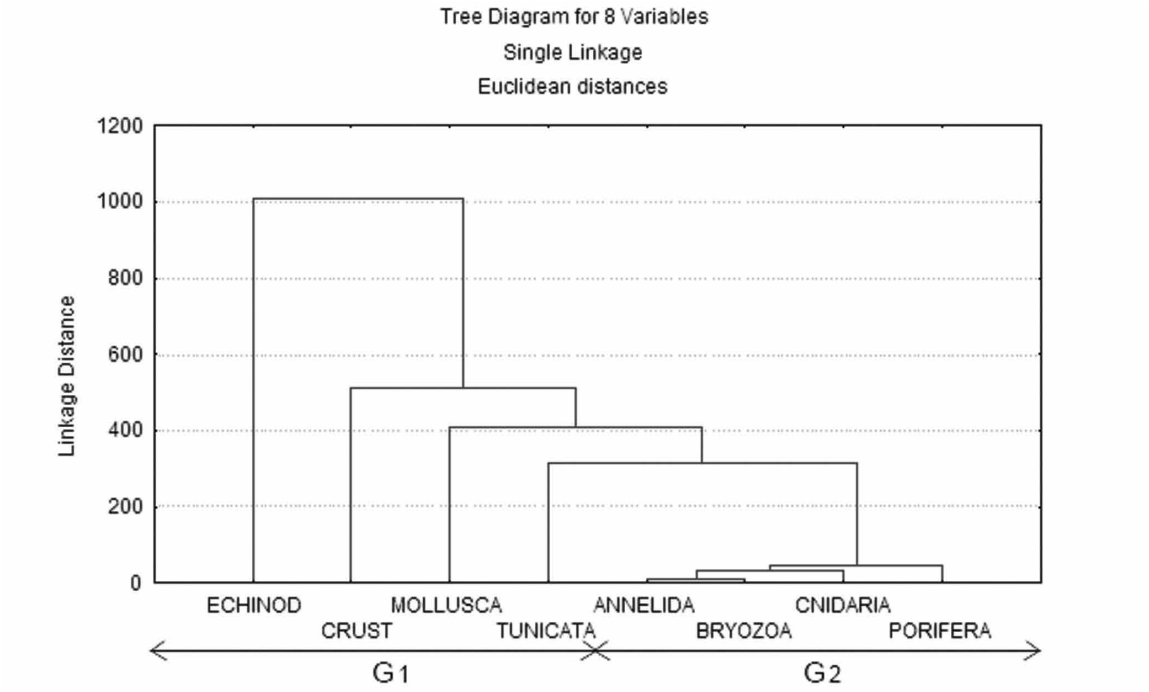


Fig. 5: Dendrogram of the megabenthic fauna groups of the Euclidean distance between the sampled stations.

waters up to 98 m depth. This group is used as indicators of industrial pollution in Gabes gulf. In the coastal area, we note the relatively large presence of many species of Tunicata which are dominanted by *Aplidium* cf. *conicum*, *Didemnum* sp, and *Microcosmus exasperatus* with other Ascidiacea such as *Polycitor adriaticum* and *Eudistoma* spp on different types of bottom (sands, muds, muddy sands and detrital coastal bottom). The Similar results were reported in Tunisia by Pérès (1954) and Pérès & Picard (1956). *Styela plicata* is usually accompanied by a high density of *M. exasperatus* on mud bottom with *Fulvia fragilis* (especially, in the North-east of Gabes). Their presence may be linked to the industrial pollution of this site. *Ecteinascidia turbinata* was sampled in Eastern Djerba on sandy mud bottom with *Arthrocladia villosa* and in Southern Kerkennah (29-55 m depth) on muddy sand or mud bottoms. These results are consistent with previous observations; Pérès (1954) and Calvin Calvo (1995) regard *E. turbinata* as frequent in the sunny biotopes of the western Mediterranian basin. This group is dominated, in the offshore waters, by *Ascidia mentula* linked to sand or muddy sand bottoms with brown algae (*Taonia atomaria*). *Diazona violacea* and *Microcosmus vulgaris* are another interesting and rare species in the gulf. These two Ascidiacea were collected on sandy mud bottom with Ascidiacea and *Cidaris cidaris* around 110 m depth (in the same station) (Tables 1 and 2).

On the other hand, the Mollusca were abundant only in the coastal area, especially, in the North-west of Djerba on detrital coastal bottom, North-east of Gabes and South-west of Sfax on mud bottoms. *Fulvia fragilis* (272 inds/ha) was abundant in the North-east of Gabes on mud bottom (21-32 m depth). Zenetos *et al*. (2003) signaled that *F. fragilis* is a species living in shallow waters on sand, mud or muddy sand bottoms with *Zostera* sp. *Pinctada radiata* is present in the North-east of Gabes and the South-east of Sfax (21-30 m depth) on sandy mud or detritic bottoms. In the gulf, the preferred depth of these two species (*F. fragilis* and *P. radiata*) is about 21 m. Moreover, the North-east of Gabes is characterized by mud bottoms with *F. fragilis*, and the South-east of Sfax is characterized by muddy sand bottom with *P. radiata*. Rosso (1978) shows the colonization of *P. radiata* across Gabes gulf, where it has an exceptional prosperity (Tlig-Zouari & Zaouali, 1994, 1998; Ben Mustapha *et al*., 1999). *Bolinus brandaris* and *Hexamplex trunculus* have appeared in the entire coastal area (22-58 m depth) on different types of bottom. *Aporrhais pespelecani* was sampled especially, in the North-east of Gabes, Southern Kerkennah and Eastern Djerba (21-58 m depth) on mud or muddy sand bottoms. *Erosaria turdus* was very abundant in the North-east of Gabes, at around 22 m depth on mud bottom with *F. fragilis*. Its abundance in the gulf is confirmed in an experimental trawl (Ben Soussi *et al*., 2005) and is also harvested by Boyer & Simbille (2006). *Luria lurida* is interesting and rare species in the gulf, and probably localized in a specific site on detritic-coastal bottom around 59 m depth (Tables 1 and 2). It was reported in Gabes gulf by Seurat (1929) and Ktari-Chakroun & Azouz (1971). In the 1920's, this porcelain was frequent in the gulf (Seurat, 1929). We believe that the main cause of the scarcity of *L. lurida* is the competition with introduced species *Erosaria turdus* which has the same ecological niche. *Buccinulum corneum* was

sampled in the North-east of Djerba in 55 m depth on mud bottom with *Ophiothrix fragilis*, *Demospongiea* and *Ascidiacea H. trunculus* and *B. brandaris*, which reveal a substrate type of coastal detrital. *Glycymeris glycymeris* and *Dentalium* sp. were indicative of mud bottom, *Corbula gibba* was an indicator of muddy and unstable bottoms, *Venericardia antiquata* proved the presence of a soft substrate of intermattes and *Venus verrucosa* demonstrated a soft silted bottom. We also noted the presence of Mollusc *Parvicardium exiguum* which indicated it was a very muddy and polluted substrate. We noted the presence of molluscs (gastropods and bivalves), which is a sign of relatively large muddy environments. In the offshore waters, we noted rare species of Mollusca as *Xenophora crispa*, *Ostreidae* sp. Wherase *Sepietta oweniana* was sampled in two areas.

The phylum of Porifera was concentrated in the Eastern part of gulf (especially, in the North-east of Djerba, Northern Zarzis and offshore waters). *Aplysina aerophoba* was collected in the inshore waters (29-50 m depth) on detrital coastal or mud bottoms with *Ophiothrix fragilis* and Demospongiae and in the offshore waters on sand bottom. Topsent (1934) has reported it to a depth of 38 m in Gabes gulf. *Hippospongia communis* is well present in the gulf up to 100 m depth. The Similar result was reported in Gabes gulf by Ben Mustapha *et al*. (2002, 2003a, 2003b, 2004). *Suberites domuncula* is a coastal species, which was collected up to 70 m depth on different types of bottoms; it generally, wears one Paguridae. These three species were common in the gulf, they did not seem threatened. Among other Demospongiae in the gulf, we noted *Dysidea* sp, *Cliona viridis* and *Haliclona mediterranea* with a low density. *Spongia officinalis* was sampled (with a low abundance (0.4 inds/ha)) in the gulf up to 50 m depth on detrital coastal bottom. Fehri-Bedoui (1986); Ben Mustapha and El Abed (2001); Ben Mustapha *et al*. (2002, 2003a, 2003b, 2004) affirm that it was frequent in *Posidonia*, *Cymodocea*, lawn *Caulerpa prolifera*, coastal detrital bottoms (1-100 m depth). This species appeared to be rare and threatened.

Cnidaria was localised in the middle part of gulf with low abundance. It was present especially, in the North-east of Djerba, Northern Zarzis on detrital coastal bottom with a dead meadow of *Posidonia* and in the offshore waters on sand bottoms. The mainly present species for this group are *Calliactis parasitica*, *Epizoanthus arenaceus*, *Eudendrium* sp. and *Nemertesia antennina*. *Calliactis parasitica* was the most common especially, in Eastern Djerba (40-50 m depth) on detrital coastal bottom. *Cladocora coespitosa* was present in two locations around 31 m depth in the South-east of Kerkennah, on detritical-muddy bottom, and in the North-east of Djerba on detrital coastal bottom. Zaouali (1993b) and Ben Mustapha *et al*. (1999) have noticed the abundance of dead tests of this endemic species in the Western part of Gabes gulf (11-21 m depth).

Annelida showed a low abundance in the gulf, which was mainly present in Southern Kerkennah on muddy sand bottom with a dead meadow of *Posidonia*. For this group, the most common species in the inshore waters was *Laetmonice hystrix*. *Diopatra neapolitana* was sampled on sandy mud bottom with red algae (*Rytiphloea tinctoria* and *Phyllophora nevosa*) in the offshore waters (60-64 m depth).

This study illustrated that phulum of Bryozoa represented the lowest abundance and presence, compared to other groups. It was distributed in the North-east of Zarzis on detrital coastal bottom, and in offshore waters on sand bottoms, in many of the gulf's sites. The two abundant species for this group were *Reteporella grimaldii* and *Scrupocellaria scruposa*. The most common one is *R. grimaldii*. This species appeared in the inshore waters on bottom with *Arthrocladia villosa* and *Ascidiacea* and on sandy mud bottom with red algae. In the offshore waters, *R. grimaldii* also appeared on sandy mud bottom with red algae (*Rytiphloea tinctoria* and *Phyllophora nevosa*) at around 61 m depth and in the bottom with brown algae (*T. atomaria*) between 70 and 94 m. Azouz (1971); Ktari-Chakroun & Azouz (1971); Ben Mustapha *et al*. (1999, 2002) indicated that this species was clean of coralline, and present in the *Posidonia* grass and *Caulerpa* on detrital coastal (1-80 m depth).

Generally, H' and E (H') ,present in the offshore waters, showed less fluctuation compared to the inshore waters, where the abundance and the specific richness appeared lower on average than those of inshore waters. These parameters' analysis already showed the first decrease signs in the abundance of megabenthic fauna community, by deep, going from coast area to oceanic area. In the offshore waters, the abundance was high enough, but the specific richness is low, which only shows some depth species, such as the *Parapenaeus longirostrus*, *Chlorotocus crassicornis, Latreillia elegans*, *Cidaris cidaris*, *Stylocidaris affinis* and *Ascidia mentula*.

The bottom in Gabes gulf was successively covered by sand, sandy mud and muddy sand from 10 to 50 m depth; it was characterized by succession of muddy sand, sandy mud and sand from 50 to 80 m depth, and the sediment became an increasingly muddy sand from 80 to 200 m depth (Ben Othman, 1973). But this study showed a progressive siltation of the inshore waters in the Western gulf, especially, in Southern Sfax, North-east of Gabes and Western Djerba (Fig. 1 and Table 1). The siltation phenomena and seagrass meadows degradation were probably the consequences of higher fishing impact on Gabes gulf and the phosphogypsum rejection (by chemical industries located in Northern Gabes). These results were confirmed by Darmoul *et al*., 1980; Béjaoui *et al*., 2004; Hattour, 1991; Zaouali, 1993b; M'Rabet, 1995; Ben Mustapha *et al*., 1999.

Conclusion

The present study indicated that the spatial distribution of the megabenthic fauna communities in Gabes gulf showed a concentration in the inshore waters, especially, in Southern Kerkennah and the North-east of Djerba. The South-west of Kerkennah was characterized by a mud bottom with *Ophiothrix fragilis* and *Antedon mediterranea*, the South-east of Kerkennah was characterized by a sandy bottom with *Aplidium* cf. *conicum* and other Polyclinidae, the North-east of Djerba was marked by a sandy mud bottom with Holothuroidea (*Holothuria polii* and *H. tubulosa*), Northern Zarzis was distinguished with detrital coastal bottom with Demospongiea, Eastern Djerba was characterized by sandy mud bottom with *Arthrocladia villosa* and North-east of Gabes was characterized by mud bottom with *Fulvia fragilis*. The offshore waters were percieved by sand bottoms, sandy mud bottoms with red algae (*Rytiphloea tinctoria* and *Phyllophora nevosa*) and muddy sand bottom with brown algae (*Taonia atomaria*). This site has showed the lowest density of the megabenthic fauna community.

The distribution of megabenthic fauna community is closely related to bottom type, vegetation cover and depth. The inshore waters appear, today, more balanced on the ecologic level.

Echinodermata, Crustacae, Tunicata and Mollusca represent key-taxons in the megabenthic fauna community, particularly in Gabes gulf and future studies are needed to elucidate the community structure spatially and temporally over an annual survey.

Acknoledgements

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