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1 **Macrobenthic communities in the tidal channels around the Gulf of Gabès, Tunisia**

2

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17

18 **ABSTRACT**

19

20 A yearlong seasonal survey was carried out during 2016-2017 at 26 stations
21 representing four tidal channels of the north-western part of the Gulf of Gabès (Tunisia). The
22 area studied (characterized by a maximum tidal range of 2.3 m) was subjected to diverse
23 anthropogenic pressures: from the phosphate industry and its metallic pollution,
24 unauthorized bottom trawling in shallow water (known locally as 'Kiss'), and organic
25 pollution from the nearby urbanized areas. A total of 23,506 invertebrates representing 311
26 taxa were collected. Dominant taxa were the polychaetes with 51.4% of the individuals
27 collected and 39.3% of the taxa, the amphipods (18.6% and 15.5%), the tanaids (12.3% and
28 2.6%), and the molluscs (11.5% and 18.3%). The mean annual abundances varied widely
29 from one channel to another: from 300 to 3,700 ind.m⁻². The stations located in deeper
30 waters exhibited greater variability. Measurements of abundance revealed seasonal changes
31 with maximum values in winter, spring, and lower numbers in summer. Each tidal channel

1 was characterised by specific features in the fauna. The macrofauna were dominated by the
2 polychaete *Cirratulus cirratus* (mainly in spring) and the amphipod *Microdeutopus anomalus*
3 (mainly in winter), whilst both of the tanaids, *Apseudopsis gabesi* (the first sighting reported
4 for the area) and *A. mediterraneus*, were found to be abundant in winter in at least one of
5 the four channels. Species are mainly deposit feeders, herbivorous and omnivorous. The
6 analyses on spatial and temporal changes of the macrofauna population revealed variations
7 according to the composition of the fauna increasing or falling along the channels and as a
8 function of seasonal changes. In spite of a high level of anthropogenic activities, the
9 Ecological Status (ES) assessment (applying the AMBI and M-AMBI indices) attributed High or
10 Good ES for 10 stations, Moderate ES for 11 stations and five stations showed a poor ES at
11 least during one season. Sampling subtidal stations in the future to survey long-term
12 degradation of such ecosystems of the coastal environment of the Gulf of Gabès in Tunisia is
13 proposed.

14

15 Key words: Mediterranean Sea; macrofauna; seasonal changes; ecological status;
16 anthropogenic pressures

17

18 **1. Introduction**

19

20 In their recent literature review of the morphological, climatic, physical
21 oceanographic, biogeochemical and fisheries features describing the Gulf of Gabès, Béjaoui
22 et al. (2019) noted few studies on the benthic communities. They were thus confined to
23 publications by Seurat and Le Danois from the 1920's and 1930's (Seurat, 1924; Le Danois,
24 1925) with respect to the intertidal habitats and the studies of De Gaillande (1970) and
25 Poizat (1970) at the beginning of the 1970's who reported on the subtidal benthic sandy
26 habitats, and Ktari-Chakroun and Azouz (1971) who focused on the effect of trawling on the
27 typography of the seabed.

28 However, Béjaoui et al. (2019) had seemingly overlooked publications by Zaouali
29 (1993) and Ben Mustapha et al. (1999) covering the macrofauna of the shallow waters of the
30 Gulf of Gabès. Likewise, their review omits the most recent work on the benthic habitats of
31 the western and southern parts of the Gulf of Gabès, such as those on the macrobenthos
32 organisms in the sandy beach macrofauna (Pérez-Domingo et al., 2008), those covering the

1 intertidal zones colonised by *Zostera noltei* sea grass around the Kneiss Island (Moshabi et
2 al., 2015, 2016, 2017a, b), and those relating to the Boughrara lagoon in the south of the gulf
3 near Djerba Island (Khedhri et al., 2015, 2017). Other related studies were dedicated to the
4 impact of human activities on the benthic communities such as bait digging (Moshabi et al.,
5 2015), clam harvesting (Mosbahi et al., 2016), and the dredging operations in the channel
6 between the major port of Sfax and the offshore Kerkennah Islands (Aloui-Bejaoui and Afli,
7 2012). Moreover, there are also studies devoted to the effects of multiple stressors on the
8 subtidal communities in the shores near Sfax (Moshabi et al., 2019) and also in the Bay of
9 Skhira (Boudaya et al., 2019). These works suggest that the pollution effects remained
10 moderate and only had a local impact on the benthic structure, in spite of consistent
11 emissions going back several decades.

12 Many studies have sought to assess the level of contamination of the sediment or of
13 the seawater around the Gulf of Gabès. Some of these have been focused on marine species
14 including zooplankton in relation to the nearby phosphate industry and the relating
15 discharge of metals (cadmium, chromium, copper, mercury, lead and zinc). Others have
16 considered the effect of hydrocarbon contamination (Louati et al., 2001; Chouba and
17 Mzoughi-Aguir, 2006; Mezghani-Chaari et al., 2011; Serbaji et al., 2012; Hammas et al., 2013;
18 Zaghdien et al., 2014; El Zrelli et al., 2015, 2017, 2018; Ayadi et al., 2015, 2016 and reference
19 therein; Rabaoui et al., 2017; Drira et al., 2017; El Kateb et al., 2018; Naifar et al., 2018;
20 Béjaoui et al., 2019;). These studies were mostly relating to the marine environment around
21 the contaminating source but some were carried out further away such as around Djerba
22 Island and focussed on a patrimonial species such as *Posidonia oceanica*.

23 The study by Rabaoui et al. (2015) focussed on the relationship between the diversity
24 and structure of the benthic macrofauna in the presence of the heavy metal concentrations
25 in four shallow water sites around the Gulf of Gabès. They showed that the central part of
26 the gulf was the most polluted and contained the most-affected benthic communities.

27 Studies on the macrofauna of the habitats of soft-bottom organisms are linked both
28 to those living in the water column and those in the sediment, and are known to be excellent
29 indicators of the level of pollution. In recent times, studies using Foraminifera as an indicator
30 of pollution has been promoted in several coastal zones ranging from the Atlantic-
31 Mediterranean system to the Gulf of Gabès (Aloulou et al., 2012; Ayadi et al., 2015, 2016; El
32 Kateb et al., 2020). El Kateb et al. (2020) indicated a severe impact along the central part of

1 the Gulf of Gabès near the phosphate industry in Skhira and also along the western coast of
2 Djerba Island, but good conditions prevailed around the eastern part of Djerba Island.

3 There might thus seem to be a large number of studies on the pollution in the Gulf of
4 Gabès. Some of them are devoted on the effects of pollution on the biota including the soft-
5 bottom macrofauna, but few take into account seasonal pattern of the fauna neither benthic
6 habitat of the tidal channels.

7 This last factor arises from one of the oceanographic peculiarities of the Gulf of
8 Gabès: unlike much of the Mediterranean Sea, there is the presence of tidal range which is
9 one of the largest observed other than the north of the Adriatic (Béjaoui et al., 2019). The
10 tidal range reaches 2.3 m with a spring tide, which has two main consequences on the
11 benthic habitats. Firstly, the low tide leads to the presence of an expanded intertidal zone
12 especially around Kneiss Island, which is populated by rich benthic communities, which are
13 exploited by the fish at high tide and birds at low tide (Mosbahi et al., 2015, 2016, 2017a, b).
14 For this reason, the Kneiss ecosystem had been recognized as a Ramsar Zone and more than
15 50 marine bird species inhabit the area in winter. The second consequence of the tidal
16 action is the presence of tidal channels, networks which play an essential role in the
17 functioning of the tidal ecosystem as they serve as the major flow paths for water,
18 sediments and nutrients between the intertidal and subtidal zones (Bali and Gueddari, 2011;
19 Béjaoui et al., 2019). These tidal features are often exploited by the fishermen working from
20 small boats equipped with bottom trawling systems known locally as 'Kiss': such illegal
21 activity in shallow tidal channels at high tide can have a negative impact on the benthic
22 habitats. These tidal channels can also concentrate pollution originating from land sources,
23 often in relation to the phosphate fertilizer industry around the Bay of Skhira.

24 The objectives of this paper are: 1) to expand the knowledge of the structure of the
25 benthic habitats in the tidal channels of the Gulf of Gabès; 2) to update the ecological status
26 (ES) of the benthic communities in relation to local human activities, and 3) to compare the
27 structure and ecological status in this particular ecosystem with other similar shallow areas,
28 especially lagoons, around the Mediterranean Sea.

29

30 **2. Materials and methods**

31

32 *2.1. The area studied*

1

2 The Gulf of Gabès is a shallow region of sea located along the southern coast of
3 Tunisia that covers an area of around 36,000 km². It is characterized by a pronounced annual
4 water temperature cycle (13°C in winter to 29°C in summer) (Hattab et al., 2013; Béjaoui et
5 al., 2019) and an unusually high tidal range reaching 2.3 m, amongst the highest observed in
6 the Mediterranean Sea (Béjaoui et al., 2019). In the shallower regions of the Bay of Skhira
7 (1.5-20 m depth) at the western end, of the Gulf of Gabès, the sediment was dominated by
8 fine and medium sand near the coast, whereas muddy sand occurred in the deeper waters
9 (Brahim et al., 2015). Sand, sandy mud and muddy sands dominated in waters of 10-50 m
10 depth, whereas the deepest zone (50-200 m) was covered mainly by sandy mud (El Lakhrach
11 et al., 2012).

12 In the current study, four tidal channels were selected as representative of the
13 influence of local human activities across the north-western part of the Gulf of Gabès: the
14 Maltine Channel (CML), the Kneiss Islands Channel (CK), the Ben Khlaf Channel (CP) and the
15 Mimoun Channel (CM), this last channel being in the north-eastern part of the Kerkennah
16 Islands (Fig. 1). All details and descriptions of these channels have been reported by Fersi et
17 al. (2018).

18

19 *2.2. Sampling and laboratory procedures*

20

21 Sampling stations were positioned along lines running from the shallow upstream to
22 the deeper downstream parts of four tidal channels (Fig. 1). Seven stations were set up in
23 the Ben Khlaf and Mimoun Channels, and six in the Maltine and Kneiss Channels making a
24 total 26 stations. Sediments were collected with a 0.1m² Van Veen grab sampler: four
25 replicates were taken at each station representing a total surface of 0.4 m². This was
26 repeated in March (spring), July (summer) and September 2016 (autumn) and in January
27 2017 (winter). The sediment was sieved on a 1-mm mesh; after sorting, the individual
28 organisms collected were identified (under a binocular microscope), specifying to the lowest
29 taxonomic level possible. Species names were checked using the World Register of Marine
30 Species list (<http://www.marinespecies.org>) as available on 15 October 2017.

31 A fifth grab sample was used to provide sediment for granulometric and organic
32 matter analyses relating to each station: this was repeated for the four seasonal campaigns.

1 Likewise, at each station and for each season, measurements of sea water temperature
2 using a thermometer (WTW LF 196), of its salinity with a salinometer (WTW LF 196), and of
3 its pH with a pH meter (WTW 3110) was carried out close to the seabed (Fersi et al., 2018).
4 The transparency of the water was quantified using a Secchi disc (Fersi, 2019).

5 Applying the classification procedure described by the trophic guild analysis as
6 proposed by Mosbahi et al. (2017a, b, 2018), Fersi et al. (2018) and Boudaya et al. (2019),
7 the identified taxa were classified into five trophic categories as follows: Suspension feeders
8 (S), Deposit Surface feeders (DS), Herbivorous (HE), Sub-Surface Deposit feeders (SDF), and
9 Omnivores (O), the later including predators and necrophagous.

10 For granulometric analysis, sediment from each sample was homogenized and wet-
11 sieved through mesh sizes of 1000, 500, 250, 125 and 63 μm over 10 min. These results were
12 classified as: 1) silt and clay ($< 63\mu\text{m}$), 2) sand (63-1000 μm), and 3) gravel ($> 1000 \mu\text{m}$), this
13 last including coarse sand, gravel and shell debris.

14 The organic matter content was measured on dried samples by the method, 'loss on
15 ignition' at 450°C for 4 h. (Fersi et al, 2018).

16

17 *2.3. Benthic indices*

18

19 Collected data were used to calculate the species abundance (A) (quoted as the
20 number of ind. 0.4 m^{-2} or the number of ind. 1 m^{-2}) and to determine the most commonly
21 used biodiversity indices for each station, the taxonomic richness (TR), the Shannon-Weaver
22 diversity index (H') in \log_2 , and Pielou's evenness (J) for each of the 26 stations representing
23 the four channels. Data analysis was carried out using the PRIMER® software package
24 (version 6) from Plymouth Routines in Multivariate Ecological Research (Clarke & Gorley,
25 2006).

26 To quantify the ecological quality status (ES) of samples from each of the 26 stations
27 several benthic indices were applied, including the H' and J values. High values for H' and J
28 indicate a rich community where no dominant species were present, whereas low values
29 were typical of impoverished communities or those dominated by a single or relative few
30 species. The five ES classes set out by the European Water Framework Directive have been
31 used here: blue or unpolluted sites, good (green) for slightly polluted sites, moderate
32 (yellow) for moderately polluted sites, poor (orange) for heavily polluted sites, and bad (red)

1 for extremely polluted or azoic sites. The thresholds for H' and J values were those
2 previously defined by Dauvin et al. (2017).

3 Further analysis was performed using the AZTI Marine Biotic Index (AMBI) developed by
4 Borja et al. (2000) and M-AMBI (Multivariate AMBI) proposed by Borja et al. (2004) then
5 detailed by Muxika et al. (2007). AMBI used the proportions of ecological groups in terms of
6 their responses to a gradient of organic matter enrichment. The AMBI was calculated using
7 the software of AZTI on 30 June 2019. The taxa were classified into five Ecological Groups
8 (EG): EG-I (blue) taxa very sensitive to organic enrichment and habitat disturbance, that are
9 usually present only in unpolluted environments; EG-II (green), taxa indifferent to
10 enrichment or disturbance; EG-III (yellow), taxa tolerant of levels of organic matter
11 enrichment that might occur under normal conditions, where their populations could be
12 stimulated by such perturbation; EG-IV (orange): second-order opportunistic species and EG-
13 V (red), first-order opportunistic species that are able to resist a high level of disturbance.
14 The M-AMBI was calculated using the software of AZTI on 15 September 2020, according to
15 high conditions recommended for the Italian waters for existing undisturbed sites by Carletti
16 and Hesikainen (2009), i.e. AMBI: 0.5, TR : 30 and H': 4.

17

18 *2.3 Statistical analyses*

19

20 Data relating to temperature, salinity, pH, water transparency, sediment type and
21 organic matter contents were all treated using two-way ANOVA to test for differences in
22 each channel and across the season. Prior to this test, environmental data were pre-
23 processed by homogenization using a Shapiro-Wilk normality test and a Bartlett test. The
24 Tukey Honestly Significant Difference test was applied when ANOVA analysis suggested
25 significant differences.

26 The two-way ANOVA was used to investigate spatio-temporal changes (between
27 channels and seasons) in terms of taxonomic richness (TR) and total abundance of the
28 macrofauna in the Gulf of Gabès. Once again, a Shapiro-Wilk normality test and a Bartlett
29 test for homogeneity of variances were applied to the data. The Tukey Honestly Significant
30 Difference test was applied when the ANOVA analysis revealed significant differences.

31 The spatial and temporal changes with respect to all of the macrofauna taxa (the
32 abundance matrix) were analysed separately by the group-average sorting classification,

1 using a hierarchical clustering procedure (CLUSTER mode) based on the Bray-Curtis similarity
2 index with a Log (X+1) transformation of abundance values. To discern within different
3 groups which species primarily accounted for the observed difference of the whole group,
4 SIMPER (SIMilarity PERcentage) routines were performed using a decomposition of Bray-
5 Curtis similarity on log transformed abundance data (Clarke and Gorley, 2006).

6 The CLUSTER and BEST analyses and permutation tests were all carried out using the
7 PRIMER® v6 software package (Clarke and Gorley, 2006). The software package R was used
8 to perform ANOVA analysis and the Shapiro, Bartlett and Tukey tests.

9 To establish correlations between the relative position of the 26 stations , and the 11
10 abiotic parameters, the datasets were compared using the method of Principle Components
11 Analysis (PCA). Moreover, a PCA established the relative position of the 26 stations
12 according to the mean abundances of the taxa.

13

14 **3. Results**

15

16 *3.1. Environmental parameters*

17

18 Table 1 sets out the mean annual values of the environmental parameters of the 26
19 stations of the four tidal channels. Raw data were taken from in Fersi et al. (2018) and Fersi
20 (2019).

21 No differences were discerned between the water temperatures in the tidal
22 channels: the mean annual sea temperature fell in the range of 21.8 and 23.8°C recorded
23 across the stations (Table 1). The water temperature greatly changed with season with
24 minimum values recorded during the winter (12-13°C) and maximum in summer and autumn
25 (27-28°C) (Table 2). In spring the water temperatures were generally lower in the two tidal
26 channels CK and CM than observed in the CML and CP channels.

27 Water salinity varied from 36 to 47, and was significantly higher in the CML channel
28 (mean salinity > 40.0) than at the three other sites (mean salinity ranging from 37.5 to 44.5,
29 Table 1), but especially with respect to the CM channel during spring samples, although
30 there were no significant changes in this respect across the seasons (Table 2).

31 The pH values of the water samples were higher at the CK and CML channels than at
32 the two other sites (Table 1), these values being lowest in inter, higher in the autumn and

1 highest in summer and spring; the pH values of water from the CML channel were
2 significantly higher than those measured in the three other sites (Table 2).

3 Water transparency was linked with the water depth at the sampling station, the
4 transparency being higher in samples from the CM channels than in the others (Table 1), but
5 there were no significant changes with season or any difference between the channels
6 (Table 2).

7 The organic matter content in sediment samples was high at all time of the year in
8 the three shallow stations CP6, CML1 and CK1 and in the wintertime for the deeper station
9 CK6. Values were significantly higher in winter, but there were no significant difference
10 between these stations whilst the two stations CM1 and CM2 showed high mean values
11 (Table 2).

12 The stations located in the shallowest waters are mainly characterized by sand, whilst
13 gravel was found at the intermediate-depth stations, and the deeper stations were
14 dominated by fine sediment (Table 1). The sediment from station CP6 contained a higher
15 percentage of fine particles (muddy sand), whereas that from CP2 had a higher percentage
16 of sand and CML 4 a higher percentage of gravel (Table 1). There was no seasonal difference
17 in the percentage of fine particles between the stations (Table 2). Moreover, the percentage
18 of sand and gravel were significantly different between the two channels CML and CM which
19 have a higher percentage of gravel whereas sediment in the CK and CP channels was
20 dominated by sand.

21

22 3.2. General patterns of the fauna

23

24 Macrophytes and macroalgae were present in most of the stations of the four tidal
25 channels (Fersi et al., 2018). *Cymodocea nodosa* and *Zostera noltei* were mainly present in
26 the shallow stations while *Posidonia oceanica* was found in the deeper stations including the
27 deepest station CM7 at 15 m depth.

28 A total of 23,506 specimens representing 311 taxa were collected from the 26
29 stations across the four seasons. Among them, four zoological groups dominated: the
30 polychaetes representing 51.4% of specimens and 39.3% of the taxa, the crustaceans (34%
31 and 20 %) these comprising essentially amphipods (18.6% and 15.5%), tanaids with 12.3%

1 and 2.6%), and the molluscs (11.5% and 18.3%). The other groups together represented
2 6.2% of the specimens retrieved and 25.4% of the species.

3 Amongst the 311 taxa counted, the number was relatively similar in the four
4 channels, with 183 taxa recorded in CM, 177 in CK, 165 in CP and 150 in CML.

5 For the four tidal channels, the TR was greatest at around 100 taxa per 0.4 m² in
6 winter, and lowest in summer (Fig. 2). The TR was high all around the year at in the CM
7 channel (between 80 and 100 taxa per 0.4 m²), and low in the CML channel, especially during
8 summer and autumn. The winter values were generally higher than the summer values
9 (Table 3).

10 Across the four tidal channels it was the sampling stations in the deeper water that
11 exhibited greater diversification than the shallower stations that were mainly on fine sand,
12 whereas the stations in intermediate depths, mainly on gravel sediment, exhibited the
13 poorest (Fig. 3). Nevertheless, there was no significant difference of TR between the stations
14 themselves (Table 3).

15 In term of abundance values (count per 0.4 m²), high values were observed in the
16 spring along the CK tidal channel, and to a lesser degree in winter along the CP channel. Very
17 low abundances numbers were noted for the CM channel throughout the year, in for the CK
18 and CML channel in the summer and the CP channel in the autumn (Fig. 2; Table 6). Spring
19 abundance values were significantly higher than those for the summer and autumn, and
20 values for the CK channel were significantly higher than those for the CM (Table 3).

21 As observed for the measurements of TR, abundance values were higher in the
22 deepest and the shallowest stations, whereas the stations located in intermediate depths
23 where the poorest, especially along the CM channel (Fig. 3; Table 6). Moreover, there was
24 significant difference in abundance values observed for the CK and CM stations located
25 along the CK and CM channels (Table 3).

26 Measurements of H' and J showed a wide range of values from 0 (no fauna) to 4.95
27 for H' and 0 to 0.98 for J respectively. H' and J were low in the CML channel, whereas they
28 show high values in the CM channel. High values of J were observed in the CP channel, but
29 the corresponding H' values were low. Values of this parameter were also low in the CK
30 channel.

31 Across the four seasons, the deposit surface feeders were dominant in the sediments
32 of the CK channel, this dominance being shared with omnivorous species in the CM channel,

1 whilst herbivorous and deposit surface feeders species dominated in CML channel and
2 omnivorous in CP channel (Fig. 4). On the other hand, suspension feeders and the sub-
3 surface deposit feeders represented only a low percentage of the trophic groups (Fig. 4).

4

5 3.3. Spatial pattern of the benthic assemblages

6

7 A dendrogram based on the mean abundance data after a Log (X+1) transformation
8 of the data from the 26 stations showed a level of 38% of similarity separating the stations
9 into three groups of one and five groups of two or more (Fig. 5). The individual stations
10 were: CM5 (characterized by the tanaid *Apseudopsis ostroumovi* and the amphipod
11 *Microdeutopus anomalus*), CM4 (the polychaete *Cirratulus cirratus* and the bivalve *Pinctada*
12 *imbricata radiata*), and CK5 (the ophiurid *Amphipholis squamata* and *M. anomalus*). The first
13 group of 2 or more stations (Fig. 5) concerned the shallowest stations of the Ben Khlaf
14 Channel CP2 and CP7) (*Apseudopsis gabesi* and *Iphinoe serrata*). The second group
15 comprised the five CML stations along the Maltine Channel (*M. anomalus* and the gastropod
16 *Cerithium scabridum*). The third group included the five CM stations (*M. anomalus* and *C.*
17 *cirratus*) of the Mimoun Channel plus one station (CML6), which was the downstream
18 station of the Maltine Channel set on coarse sand. The fourth group gathered the five CK
19 stations of the Kneiss Channel (the polychaetes *C. cirratus* and *Sabella pavonina*), and the
20 fifth group comprised the five other CP stations of the Ben Khalf Channels (the tanaids
21 *Apseudopsis gabesi* and *A. mediterraneus*).

22 Overall, 85% of the stations were grouped according their location in the four tidal
23 channels.

24

25 3.4. Seasonal pattern of the benthic fauna

26

27 A dendrogram based on the mean abundance data after a Log (X+1) transformation
28 relating to the four seasons and the four tidal channels revealed a level of 36% of similarity
29 separating the stations into three groups of one, and three of two or more. The individual
30 stations were, Summer-CML (the gastropods *Cerithopsis tuberercularis* and *C. cirratus*),
31 Spring-CK (*C. serratus* and *S. pavonina*) and Spring-CML (the amphipods *Microdeutopus*
32 *anomalus* and *M. gryllotalpa*). The first group of two or more stations (Fig 6) comprised

1 seven season-channels: three from CP, two from CK and two from CML (*M. anomalus* and *C.*
2 *cirratulus*). The second group comprised four season-channels: CK in summer and those of
3 CM except in spring (the polychaetes *C. cirratus* and *Piromis eruca*). The third group covered
4 both the spring measurements at CM and CP and was characterized by the polychaetes
5 *Paradoneis armata* and *Lumbrineris latreilli*.

6 This analyse reveals a variable seasonal effect, high abundance in the CK channel in
7 spring, yet higher abundances in the other channels in winter than observed in other
8 seasons especially in summer when the abundances were very low. Again two species
9 dominated the fauna: the polychaete *C. cirratus*, and the amphipod *M. anomalus*.

10 In summary, both of the analyses on spatial and temporal factors show a
11 predisposition of the fauna to reflect the composition of that existing in each channel (either
12 upstream or downstream) and seasonal changes.

13 Table 4 lists the 10 dominant species found in each of the four tidal channels, which
14 together represent only 23 species. Each channel showed certain particularities: CK was
15 dominated by polychaetes, which were among the five top species found here; CM was
16 dominated by polychaetes and amphipods; CML was dominated by amphipods and
17 gastropods whereas channel CP was dominated only by peracarids (amphipods, tanaids and
18 cumaceans).

19 The polychaete *Cirratulus cirratus* was dominant in two channels with very high
20 abundance in the CK, and low abundance in CM. The amphipod, *Microdeutopus anomalus*,
21 dominated in CML and both tanaid *Apseudopsis gabesi* and *A. mediterraneus* in the CP
22 channel (Table 4). The mean annual abundances varied widely between the channels,
23 reaching 3,700 ind.m² for CK, 1,600 ind.m² for CP, 1,500 ind.m² for CML yet only 300 ind.m²
24 for CM.

25 In spring, the polychaete *Cirratulus cirratus* dominated largely in terms of the
26 abundance of the macrofauna of the four tidal channels (Table 5). In summer at a lower
27 density, the gastropod *Cerithiopsis tuberculatus* was the dominant species, and in the
28 autumn, another gastropod, *Cerithium scabridum*, dominated. In winter, the fauna was
29 dominated by the amphipods *Microdeutopus anomalus* and *Monocorophium acherusicum*,
30 and the tanaids, *Apseudopsis gabesi* and *A. mediterraneus* (Table 5).

31

32 *3.5. Relationships between fauna composition and environmental parameters*

1

2 The principal component analysis (PCA) performed for the 26 stations looking at the
 3 influence of each environmental parameter (e.g. sediment type: gravel, sand, silt-clay,
 4 organic matter; water conditions: salinity, temperature, pH, and transparency) on the
 5 biological variables (Flora) showed that few environmental factors greatly influenced the
 6 biological components (Fig. 7). The first principal component explained 92% of the inertia
 7 and the second 6%. The sediment type was the most discriminant factor with the opposition
 8 of sand to gravel on the first axis. Stations with high percentage of sand were on the positive
 9 part of the axis, while those with high percentage of gravel were on the negative part of the
 10 axis (see Table 1). The second axis opposed the high percentage of silt-clay as in the stations
 11 CML1 and CP6 to the Sand-Gravel pole (Table 6). The other parameters were at the centre of
 12 the analysis and did not contributed to the separation of the stations (Fig. 7).

13 Considering now the mean abundances of the taxa, the first principal component
 14 explained 74.7% of the inertia and the second 12.2% (Fig. 8). Only few species contributed to
 15 the separation of the stations, with the opposition of stations CK1, CK2 and CK3 dominated
 16 by the polychaetes *Cirratulus cirratus* and *Sabella pavonina* to the others stations and taxa.
 17 On the second axis, the station CP6 characterised by the tanaid *Apseudopsis gabesi*, the
 18 stations CP2 and CP5 and the tanaid *Apseudopsis mediterraneus*, the cumacean *Iphinoe*
 19 *trispinosa* and the polychaete *Lumbrineris latreilli* were opposed to the rest of the taxa
 20 mainly the amphipod *Microdeutopus anomalus*, and the polychaetes *Scoletoma impatiens*
 21 and *Scoloplos armiger*, and the other stations.

22

23 3.6. Ecological status of the benthic habitat

24

25 Considering now the proportion of taxa falling into each of the five Ecological groups,
 26 showed that most of the sampling stations were dominated by EG-I and EG-II taxa, the
 27 exceptions being five of the six stations in the CK channel (Fig. 9). The proportions of the
 28 sensitive species (classified as EG-I) was greatest at station CP2 whereas the lowest amount
 29 was found at station CK6. Conversely the proportion of the opportunistic taxa (EG-IV) was
 30 low or non-existent for most of the stations with the exception of five stations in the CK
 31 channel, where the sediment was highest in organic matter content, especially station CK6
 32 (Table 1): in this case, the fauna were dominated by polychaetes *Cirratulus cirratus*.

1 The AMBI scoring corresponded to High Ecological Status (for five stations), Good
2 (nineteen stations) and Moderate for the two stations CK2 and CK6 (Fig. 8). The moderate
3 status related to spring sampling at CK2, and CK6, and station CML5 (Table 6). The M-AMBI
4 scoring showed that 16 stations on 26 presented at least one moderate ES (Table 6). Five
5 values classified the CK2, CK6, CML4, CML5 and CP2 in spring or summer with a poor ES
6 (Table 6). Considering the parameter H', the poor and moderate ES corresponded only to
7 spring and summer samples, whereas the CML stations exhibited a degraded ES, status
8 throughout the year which is confirmed by the J value (Table 6).

9 10 **4. Discussion**

11
12 The current study provides the first description of the macrofauna of the tidal
13 channels traversing the Gulf of Gabès, along with information of the sedimentary texture of
14 these channels and the interactions between the abiotic/edaphic factors and the marine
15 invertebrates. The annual cycle of observations give an overview of the state of the benthic
16 habitats in the channel in 2016-2017 in relation to anthropogenic pressures in this area.

17 18 **4.1 Biodiversity and spatio-temporal composition of the macrobenthic fauna in the tidal** 19 **channels**

20
21 In this study, 311 taxa of benthic macrofauna were found and recorded. These taxa
22 were distributed across four main taxonomic groups. Amongst them, the polychaetes
23 dominated in both number of taxa and abundance. Taxonomic Richness and the abundance
24 of fauna were greatest in the upstream and downstream portion of each channel based on
25 sand and muddy sand, rather than the central portion of the tidal channels. This was
26 probably due to the presence of strong water currents midway along each channel and to
27 the presence of coarse sediment and shell debris in these same medium areas along with
28 the absence of macrophytes. The Taxonomic Richness in these channels was amongst the
29 highest found on any subtidal benthic soft-bottom communities along the Tunisian coasts. In
30 the Bay of Skhira, Boudaya et al. (2019) reported a total of 239 taxa from 28 subtidal stations
31 sampled once in April 2010, whilst Mosbahi et al. (2019) estimated a Taxonomic Richness of
32 only 106 from a seasonal sampling of 12 stations in Sfax shallow waters (2015-2016). For the

1 subtidal shallow habitats around the Gulf of Gabès, El Lakhrach et al. (2012) collected 205
2 species of mega-benthos invertebrates with the dominance of echinoderms (38%). In the
3 Gulf of Tunis Ayari and Afli (2003) recorded a total of 214 invertebrate species with the
4 dominance of polychaetes (63%), whilst Diawara et al. (2008) reported a total of 189 macro-
5 zoobenthic species retrieved from the Tunis lagoon.

6 In the port of Sidi Youssef in the west of Kerkennah Islands, ten locations ranging
7 from 0.9 to 5.65 m in depth were sampled by Scuba divers in the spring of 1997 (Aloui-
8 Bejaoui and Afli, 2012). 77 taxa were identified but at a very low abundance ranging from 6
9 to 96 ind.m⁻² which was probably due to dredging operations in the navigational channel: a
10 dominance of polychaetes and bivalves and low abundances of crustacean and among them
11 amphipoda, were reported. A similar observation was made in our study, which included the
12 Mimoun Channel in the south-east of the Kerkennah Islands: at this location, the
13 abundances were found to be the lowest (300 ind.m⁻²).

14 The mean abundance of the macrofauna from the intertidal zone around the Kneiss
15 Island was relatively high at 3,895 ind.m⁻² (Mosbahi et al., 2015), and similar to this of the
16 abundance of macrofauna in the Kneiss tidal channel with 3,800 ind.m⁻²: this is higher than
17 that found in the three other channels (ranging from 300 to 1,600 ind.m⁻²). The dominant
18 species living in this *Zostera noltei* seagrass were polychaetes (*Euclymene oerstedii*,
19 *Perinereis cultifera*, *Cirratulus cirratus*), amphipods (*Ampelisca brevicornis*, *Elasmopus rapax*,
20 *Gammarus insensibilis* and *Lysianassa pilicornis*), and bivalves (*Loripes lucinalis* and
21 *Ruditapes decussatus*) (Mosbahi et al., 2015). Only the polychaete *Cirratulus cirratus* was
22 present amongst the top abundant species in both intertidal and subtidal systems.

23 The abundances of the macrofauna of the mediolittoral zones in three beaches
24 surrounding the Gulf of Gabès varied between 550 and 1,190 ind.m⁻² (Perez-Domingo et al.,
25 2008), with the dominance of the amphipod *Bathyporeia guilliamsoniana*, the polychaete
26 *Scolelepis mesnili* and the bivalve *Donax trunculus*. This finding was similar to those observed
27 in other sandy beaches of the Mediterranean and along the north-eastern Atlantic coasts
28 (Perez-Domingo et al., 2008).

29 In order to estimate the effect of the phosphogypsum outfall on the macrofauna in
30 the Bay of Skhira, Boudaya et al. (2019) had sampled in April 2010, 28 stations in four lines
31 running inshore-offshore. Results showed that the stations nearest the source were the
32 most disturbed. The mean spring abundance was 2,705 ind.m⁻², which was higher than the

1 mean annual abundance of the CP channel (1,600 ind.m⁻²), which is in the same part of the
2 Gulf of Gabès. The dominant species were the polychaetes (*Melinna palmata*, *Lumbrineris*
3 *tetraura*, *Cirratulus cirratus*), the bivalves (*Pinctada imbricata radiata*, *Scrobicularia plana*),
4 the amphipods (*Cymadusa filosa*, *Dexamine spiniventris*, *Elasmopus rapax*, *Leucothoe incisa*)
5 and the sea star *Astropecten spinulosus*. All of these species were found in the tidal channels
6 in the present study. In the shallow coastal zone to the south of Sfax, Mosbahi et al. (2019)
7 had sampled during one year (April 2015-January 2016), from 12 stations located along four
8 inshore-offshore pollution gradient lines and identified three main groups of fauna, and the
9 four locations near the coast that were the most affected by human activities exhibiting low
10 taxonomic richness values (7-20) and low mean annual abundances (467-525 ind.m⁻²). An
11 intermediate zone (with for stations) gave intermediate values for TR (20-27) and
12 abundances (709-855 ind.m⁻²), and four offshore stations showed the highest values of TR
13 (25-29) and abundances (827-1,656 ind.m⁻²). In this region the fauna was dominated by
14 polychaetes, crustaceans and molluscs: most of the dominant species were polychaetes such
15 as *Lumbrineris tetraura*, *Amphicteis gunneri*, *Euclymene oerstedii*, *Melinna palmata*,
16 *Cirratulus cirratus*, or amphipods *Cymadusa filosa*, *Dexamine spiniventris*, *Gammarus*
17 *insensibilis*, *Elasmopus rapax*, *Leucothoe incisa* or the bivalve *Scrobicularia plana*.

18 Afli et al. (2013) had previously studied the macrofauna along the western coast of
19 the bay of Tunis (10 stations) and around Djerba Island in the south of Tunisia (11 stations).
20 The maximum abundance measured was 2,900 ind.m⁻², but most the stations showed
21 numbers lower than 500 ind.m⁻². The species diversity was greater in the Bay of Tunis than
22 around Djerba Island. The benthic macrofauna in the lagoon of Boughrara (south of the
23 Djerba Island) was separately studied at 13 stations in 2009-2010 by Khedhri et al. (2015).
24 The abundance found varied from a minimum of 66 to 7,792 ind.m⁻² during the summer and
25 5,094 ind.m⁻² in the autumn. Application of AMBI classified all the stations as having a 'high'
26 ecological status except one station, which was only classified as 'good'.

27 Ayari and Afli (2003) reported their first quantitative data from 30 stations from the
28 Bay of Tunis in March 2013. Four main benthic populations had been identified with mean
29 abundance values between 620 and 4,685 ind.m⁻². The polychate *Melinna palmata* and the
30 tanaid *Apseudes talpa* dominated the macrofauna. In a later study, Afli et al. (2008),
31 demonstrated in several coastal and lagoons systems in the North of Tunisia (the Bay of
32 Tunis, the Lagoon of Bizerte and the coastline of Dkhila in the Bay of Hammamet: 26

1 stations), a low Taxonomic Richness, that was associated with a moderate abundance with a
2 maximum of 470 ind.m⁻² in the Lagoon of Bizerte, 620 ind.m⁻² in the Bay of Tunis and 1,520
3 ind.m⁻² along the coast of Dkhila. In the same area in the North of the Tunisia, Afli et al.
4 (2009) had also studied two other lagoon systems: the southern lagoon of Tunis and the
5 lagoon of Ghar El-Melh where the salinity was very high in summer (~ 50). The abundance
6 was consistently higher in the southern lagoon of Tunis (1,279-7,547 ind.m⁻²) than in the
7 Lagoon of Gahr El-Mah (362-959 ind.m⁻²).

8 The sediment of the lagoon of Bizerte is made up by sand habitats and numerous
9 macrophyte meadows showing high abundances of amphipods with the dominance of
10 *Cymadusa filosa*, *Dexamine spinosa*, and *Elasmopus rapax* (Khammassi et al., 2019), which
11 were also abundant in the tidal channels of the Gulf of Gabès (Fersi et al., 2018). The fauna
12 found in the tidal channels of the Gulf of Gabès, was similar to those found in Tunisian and
13 Mediterranean lagoons, the main characteristic being the presence of high abundances of
14 Tanaids. Other than the polychaetes (with the dominance of *Cirratulus cirratus*, *Sabella*
15 *pavonina*; *Hediste diversicolor* and *Melinna palmata*), and the amphipods (with the
16 dominance *Microdeutopus anomalus*, and *M gryllotalpa*, *Elasmopus rapax*, and
17 *Monocorophium acherusicum*), the characteristic of the fauna in the tidal channels was the
18 high abundance of the tanaids of the genus *Apseudopsis* accounting for four known species
19 and the description of one new species *Apseudopsis gabesi* Esquete, 2019 (Esquete et al.,
20 2019). The richness of the tanaid species was notable with the presence of four other
21 species amongst the eight separately recorded by Fersi et al (2019) in this study for the
22 Tunisian. Most of the recorded *Apseudopsis* spp. were found in the Ben Khlaf (CP) channel
23 (94% of the specimens collected in the four channels). Furthermore, 82% of these specimens
24 were also sampled in winter. Only *A. mediterraneus* was found in the same area by Boudaya
25 et al. (2019) during a spring sampling campaign. *Apseudes talpa* was the only species of
26 tanaid recorded along the coast of Tunisia in large numbers in the mud habitat *Melinna*
27 *palmata*-*Apseudes talpa* in the Bay of Tunis (Ayari and Afli, 2003; Afli et al., 2009). The
28 diversity and high abundance of tanaids in tidal channels of the Gulf of Gabès are
29 noteworthy. Amongst the tanaids, *Apseudopsis latreillii* was the single species present at
30 very high abundances amongst the soft-bottom habitats, such as in the northern part of
31 Cotentin peninsular (Normandy, France), in the English Channel (20 to 23,000 ind.m⁻²), which
32 are amongst the highest recorded values anywhere in the world (Andres et al., 2020).

1 Many studies have been carried out in other lagoons around the Mediterranean and
2 the macrofauna sampled in the tidal channels of the Gulf of Gabès appeared to be typical of
3 such lagoons. On the other hand, the low contribution of molluscs, especially the bivalves,
4 may be in relation to strong tidal currents in the channels. In the Merja Zerga lagoon
5 (Morocco, Atlantic), the subtidal zone was composed of a coarser sediment and higher
6 Taxonomic Richness than the intertidal zone; in this lagoon three benthic communities
7 dominated by the bivalves were distinguished: *Cerastoderma edule*, *Scrobicularia plana* in
8 both subtidal and intertidal zones, and *Ruditapes decussatus* in the subtidal zone (Bazaïri et
9 al., 2003). Chaouti and Bayed (2017) studied the seasonal changes of the macrofauna at ten
10 stations located in the small Smir lagoon (3 km²), in the northwest of Morocco. The fauna
11 was made up from 42 species, dominated by crustaceans, polychaetes, and molluscs whilst,
12 the polychaete *Hediste diversicolor*, the two isopods *Sphaeroma hookeri*, *Cyathura carinata*,
13 and the two amphipods *Monocorophium acherusicum* and *Melita palmata* accounted for
14 more than 90% of the individuals collected. In this lagoon system, the sediment was not
15 considered as a temporal structuring factor whereas salinity and temperature, particularly in
16 summer, were factors determining the seasonal pattern of composition and abundance of
17 the community. As in the current study, the abundances were higher in winter and spring
18 (430-860 ind.m⁻²) than observed in summer (47 ind.m⁻²). In another small lagoon in the
19 eastern part of the Algerian coast (Mellah lagoon, 9 km²), the fauna was dominated by the
20 two polychaetes (*Capitella capitata* and *Spio decorata*), two crustaceans (*Microdeutopus*
21 *gryllotalpa*, *Monocorophium insidiosum*) and the mollusc (*Loripes lucinalis*) with a mean
22 abundances of 1,640 ind.m⁻² and a total taxonomic richness of 50 (Draredja et al., 2012). In
23 the northern part of the western basin of the Mediterranean Sea, in the muddy sand of the
24 lagoon of Prévost (France), Guelorget and Michel (1979) recorded very high abundances
25 (12,000 ind.m⁻²) at the beginning of the autumn period and very low abundances in summer
26 (200 ind.m⁻²) with a dominance of polychaetes (*Capitella capitata*, *Heteromastus filiformis*,
27 *Owenia fusiformis*), molluscs (*Scrobicularia plana*, *Polititapes aureus*, *Tapes decussatus*), and
28 amphipods (*Monocorophium insidiosum*, *Gammarrus insensibilis*).

29 The benthic community in the 50 km² lagoon of Lesina (Apulia, Italy, in the southern
30 Adriatic Sea,) was studied taking samples from July 2000 to June 2001 from 24 stations
31 (Nonnis Marzano et al., 2003a). The taxonomic richness was given as 53 with abundances
32 dominated by polychaetes (*Cirratulus cirratus*, *Cirriformia tentaculata*, *Hediste diversicolor*),

1 molluscs (*Ecrobia ventrosa*, *Cerastoderma glaucum*, *Abra segmentum*) and crustaceans,
2 mainly isopods and amphipods, including *Monocorophium insidiosum*, *Microdeutopus*
3 *gylotalpa*, and *Gammarus aequicauda*. The maximum abundance value was observed in
4 winter (2,000 ind.m²) and the minimum in summer (1,000 ind.m⁻²). In the Karavasta lagoon
5 (Albania, Adriatic Sea, 41 km²) 64 taxa were recorded from 14 sampling stations in April 2004
6 on the soft-bottom habitat, with the dominance of polychaetes, molluscs and crustaceans
7 (Nonnis Marzano et al., 2003b). The bivalves *Abra segmentum* and *Cerastoderma glaucum*
8 were the most common species, and the amphipod fauna collected in this lagoon was very
9 similar to those found in the tidal channels of the Gulf of Gabès (Fersi et al., 2018).

10 The dominant amphipod species in the tidal channels of the Gulf of Gabès were
11 *Microdeutopus anomalus* and *M. gryllotalpa*, *Monocorophium acherusicum*, *Dexamine*
12 *spinosa*, *Cymadusa filosa* and *Elasmopus rapa*: these are characteristic of areas with detritus
13 accumulation, and are associated with the occurrence of sea grass meadows as found in
14 many lagoons around the Mediterranean Sea (Fersi et al., 2018). As the dominant
15 amphipods were dominated by herbivorous grazers and detritus feeders, living mainly on
16 algae and sea grasses, the accumulation of herbivorous species linked to the accumulation of
17 macro-particulate detritus explains the dominance of this trophic group in the Maltine
18 Channel (Fig. 4). Furthermore, this trophic group was also dominant in the Kneiss and
19 Mimoun channels. On the other hand, the omnivores dominated in the Ben Khalf channel
20 (Fig. 4), where the suspension feeders and the sub-surface deposit feeders were weakly
21 represented suggesting that most of these species depended on food particles in the water
22 column or deposited at the surface of the sediment.

23

24 4.3. Ecological status of the tidal channels of the Gulf of Gabès

25

26 In spite, of the pressure from numerous anthropogenic activities in the Gulf of Gabès,
27 the Ecological Status (assessed by AMBI and M-AMBI Indices) revealed that the benthic
28 habitats appeared to be mainly in a good ecological condition with the exception of the
29 Kneiss Channel where the macrofauna was dominated by the opportunistic species
30 *Cirratulus cirratus* (Table 6). The diversity indices H' and J indices suggested a more degraded
31 environment (Table 6), not only in the Kneiss Channel, but also at most of the stations along
32 the Maltine and the Ben Khalf channels. Analogous more degraded ES were estimated with

1 M-AMBI mainly during the spring and summer periods, again when the polychaete *C.*
2 *cirratulus* dominated the macrofauna abundances.

3 Similarly, in the ten stations at the port of Sidi Youssef in the Kerkennah Islands, AMBI
4 classified all of the stations as having a high ecological status (Aloui-Bejaoui and Afli, 2012).
5 In the lagoon of Boughrara in the south of the Gulf of Gabès, Khedhri et al. (2015) reported a
6 high ecological status at all except one sampling station.

7 In the North of the Tunisia, the effects of human activities appeared to be more
8 localised such as the heavily polluted zones in the Bizerte lagoon, the mouth of the Hamoum
9 wadi and the harbours areas (Afli et al., 2008). In the study by Rabaoui et al. (2015), the
10 AMBI method was used to classify the 18 stations distributed across the four areas:
11 Kerkennah Island, Mahres, Gabès and Zarzis located around the Gulf of Gabès. Good or High
12 ecological status was ascribed with the highest values corresponding to the central parts of
13 the Gulf where the most heavy metal pollution had also been measured.

14 Amongst the 28 stations sampled in the Skhira Bay by Boudaya et al. (2019), the
15 AMBI protocol distinguished 13 offshore stations with good or high ES, 13 stations with a
16 moderate ES, and two stations (near the phosphor-gypsum outflow) with a poor ES.
17 Nevertheless, in the current study, the same AMBI method was able to identify a pollution
18 gradient falling away from the coast. Similarly, an inshore-offshore pollution gradient was
19 clearly identified by AMBI in the shallow coastal zone south of Sfax (Mosbahi et al., 2019).

20 All these results were similar, in spite of the very high and diverse anthropogenic
21 human pressures around the Gulf of Gabès and near to the coastal and lagoon Tunisian
22 ecosystems. **Based on the AMBI procedure**, the benthic communities were classified with a
23 high or good ecological status with the exception of those located near to outflows of
24 industrial and urban wastes. Two questions arise for this observation. Firstly, was **the AMBI**
25 procedure sufficiently sensitive to distinguish the negative effects of the human activities in
26 this area? In other words, were the species present in the Gulf of Gabès not classified in the
27 appropriate ecological groups? It was noted, for example, that some species found in the
28 Gulf of Gabès that are classified in EG-III should be in classified in EG-IV. However, it was
29 noticed that AMBI and M-AMBI indices based on the polluo-sensitivity of the macrobenthic
30 species had been designed to assess organic pollution on the sediment and not pollution by
31 other elements such as heavy metals. The second question is whether the effects of human
32 activities were softened with respect to the benthic macrofauna when considered at the

1 scale of the whole area of the Gulf of Gabès: the fish trawling and the pollution effects
2 remaining local?

3 Nevertheless, urban wastes contributed to the eutrophication of the water in the
4 shallowest coastal zones with the appearance of opportunistic macro-algae and the
5 concurrent deterioration of the sea grass areas and especially of the *Posidonia oceanica*
6 meadows (Ben Brahim et al., 2010; Bonacorsi et al., 2013; El Zrelli et al., 2018). *P. oceanica* is
7 a very sensitive species to pollution and the increase of turbidity in the shallowest parts of
8 the Gulf of Gabès had accelerated the reduction of seabed area covered by *Posidonia*
9 *oceanica*; a process which had begun at the beginning of the 1960'. On the other hand, the
10 meadows around the Kerkennah Islands, where there is little human impact (other than
11 overfishing) are in a better ecological status (Zaouali, 1993; Ben Brahim et al. 2010). All the
12 same, Hattab et al. (2013) have described a decline in fish catchment. All of these results
13 suggest that the higher impact on benthic habitat should be the over-fishing rather than
14 from the general pollution of the coastal ecosystem, and that impact of human activities
15 remained local. Moreover, the tidal currents in the tidal channels of the Gulf of Gabès could
16 dilute the pollution effects due to the mixing and oxygenation of both the sea water and the
17 sea bottom sediment. The same currents might actively contribute to the dispersion of
18 pollutants from these particular environments in to the Mediterranean Sea.

19

20 4.4. Future perspectives.

21

22 The present study was to locate the sampling stations following a line running from
23 the coast to the open sea in four representative tidal channels in the Gulf of Gabes in the
24 southern Tunisian coast. These tide channel systems, where the sediment type was the main
25 factor structuring the macrobenthic communities, had been never been studied before; they
26 were exposed to different man-made impacts (pollution from chemical and organic
27 effluents, over-fishing). In the case of small operations, fishermen use illegal bottom trawling
28 methods in shallow tidal channels at depths of 5 m or less, at high tide. Such systems
29 adversely affect not only on the juveniles of fish and shrimps, but also damage the benthic
30 habitats such as *Posidonia oceanica* meadows (Ben Brahim et al. 2010). Recently, (in October
31 2018) a team of inspectors counted the vessels equipped with the prohibited gear to provide
32 a realistic estimation of the total number of illegal trawlers operating in the Gulf of Gabès.

1 The mesh size of the nets used is much smaller than on a commercial trawler, which makes
2 them less selective and produces large amounts of by catch. Between 400 and 500 uch
3 trawlers were identified in the main ports around the Gulf of Gabès
4 (<https://fishact.org/2018/12/>).

5 Several initiatives for future work might be considered. The first is the complete
6 inventory of macro-zoobenthic species present in the Gulf of Gabès incorporating the
7 present study with other recent researches on benthic habitats in the Gulf of Gabès; this
8 would complement those given for all invertebrates (Afli, 2015) and for Polychaetes (Ayari et
9 al., 2009) and for alien species (Ounifi Ben Amor et al., 2016).

10 In spite of numerous studies on benthic organisms in the Gulf Gabès over the last two
11 decades, there is still a lack of studies in the shallow areas close to the major centres for the
12 phosphate industries

13 Another approach will be to estimate the total biomass of benthic organisms
14 collected during this study and thus to assess the rate of benthic production in the tidal
15 channels. It will be also interesting to sample fish trawled in the tidal channels by the
16 fishermen for the purpose of analysing stomachs contents to estimate the proportion of the
17 macrobenthos species in their diet. Consequently, it may be possible to develop food web
18 models for this tidal channel ecosystem as has previously been done for the whole of the
19 Gulf of Gabès to identify the maturity of this ecosystem (Hattab et al., 2013).

20 Finally, it might be worth carrying out a pluri-annual monitoring at selected stations
21 along these tidal channels to follow the long-term evolution of macrofauna in the absence of
22 human activities and especially from industrial discharges.

23

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25

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3

4 **References**

5

6 Afli, A., 2005. La biodiversité marine en Tunisie. Rapport de l'Institut National des Sciences et
7 Technologies de la Mer pour le Ministère de l'Environnement et du Développement Durable
8 et le Ministère de la Recherche Scientifique, de la Technologie et du Développement des
9 Compétences, 20 pp.

10 Afli, A., Ayari, R., Zaabi, S., 2008. Ecological quality of some Tunisian coast and lagoon
11 locations, by using benthic community parameters and biotic indices. *Estuar. Coast. Shelf Sci.*
12 *80*, 269-280.

13 Afli, A., Chakroun, R., Ayari, R., Aissa, P., 2009. Seasonal and spatial variability of the
14 community and trophic structure of the benthic macrofauna within Tunisian lagoonal and
15 Marine Coastal Areas (Southwestern Mediterranean). *J. Coast. Res.* *25*(6), 1198-1209.

16 Afli, A., Ibin Chaabane, K., Chakroun, R., Jabeur, C., Ramos-Espla, A.A., 2013. Specific diversity
17 of the benthic macrofauna within the western coast of the Tunis Bay and the Djerba Island
18 coast (south-western Mediterranean). *Bull. Inst. Natn. Sci. Tech. Mer de Salammbô* *40*, 51-
19 62.

20 Aloui-Bejaoui, N., Afli, A., 2012. Functional diversity of the macro-invertebrate community in
21 the port area of Kerkennah Islands (Tunisia). *Med. Mar. Sci.* *13*, 93-102.

22 Aloulou, F., Elleuch, B., Kallel, M., 2012. Benthic foraminiferal assemblages as pollution
23 proxies in the northern coast of Gabes Gulf, Tunisia. *Environ. Monit. Assess.* *184*, 777-795.

24 Andres, S., Pezy, J.P., Martinez, M., Baffreau, A., Baux, N., Méar, Y., Dauvin, J.C., 2020. Soft-
25 bottom macrobenthic communities in sandy enclaves from the North Cotentin Peninsula
26 (Central English Channel). *J. Mar. Biol. Oceanogr.* *9*:1, 1000278.

27 Ayadi, N., Aloulou, F., Bouzid, J., 2015. Assessment of contaminated sediment by
28 phosphate fertilizer industrial waste using pollution indices and statistical techniques in the
29 Gulf of Gabès (Tunisia). *Arabian J. Geosci.* *8*, 1755-1767.

30 Ayadi, N., Zghal, I., Aloulou, F., Bouzid, J., 2016. Impacts of several pollutants on the
31 distribution of recent benthic foraminifera: the southern coast of Gulf of Gabès, Tunisia. *Env.*
32 *Sci. Poll. Res. Int.* *23*, 6414-6429.

- 1 Ayari, E., Afli, A., 2003. Bionomie benthique du petit golfe de Tunis. Bull. Inst. Natn. Sci. Tech.
2 Mer de Salammbô 30, 79-90.
- 3 Ayari, R., Muir, A., Aissa, P., Paterson, G., Afli, A., 2009. An updated list of Polychaetous
4 annelids from Tunisian coasts (Western Mediterranean Sea). Cah. Biol. Mar. 50, 1-13.
- 5 Bali, M., Gueddari, M., 2011. Les chenaux de marée autour des îles de Kneiss, Tunisie :
6 sédimentologie et évolution. Hydrol. Sci. J. 56, 498-506.
- 7 Bazairi, H., Bayed, A., Glémarec, M., Hily, C., 2003. Spatial organization of macrozoobenthic
8 communities in response to environmental factors in a coastal lagoon of the NW African
9 coast (Merja Zerga, Morocco). Oceanol. Acta 26, 457-471.
- 10 Bejaoui, B., Ben Ismail, S., Othmani, A., Ben Abdallah-Ben Hadj Hamida, O., Chevalier, C., Feki-
11 Sahnoun, W., Harzallah, A., Ben Hadj Hamida, N., Bouaziz, R., Dahech, S., Diaz, F., Khouthir
12 Tounsi, K., Cherif Sammari, C., Pagano, M., Bel Hassen, M., 2019. Synthesis review of the Gulf
13 of Gabès (eastern Mediterranean Sea, Tunisia): Morphological, climatic, physical
14 oceanographic, biogeochemical and fisheries features. Estuar. Coast. Shelf Sci. 219, 395-408.
- 15 Ben Brahim, M., Hamza, A., Hannachi, I., Rebai, A., Jarboui, O., Bouain, A., Aleya, L., 2010.
16 Variability in the structure of epiphytic assemblages of *Posidonia oceanica* in relation to
17 human interferences in the Gulf of Gabès, Tunisia. Mar. Environ. Res. 70, 411-421.
- 18 Ben Mustapha, K., Hattour, A., Mhetli, M., El Abed, A., Tritar, B., 1999. Bionomie des étages
19 infra et circalittoral du golfe de Gabès. Bull. Inst. Nat. Sci. Tech. Mer Salammbô, Tunisia 26,
20 5-48.
- 21 Bonacorsi, M., Pergent-Martini, C., Bréand, N., Pergent, G., 2013. Is *Posidonia oceanica*
22 regression a general feature in the Mediterranean Sea? Mediterr Mar. Sci. 14, 193-203.
- 23 Borja, A., Franco, J., Perez, V., 2000. A marine Biotic Index to establish the ecological quality
24 of soft-bottom benthos within European estuarine and coastal environments. Mar. Poll. Bull.
25 40, 1100-1114.
- 26 Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Belzunce, M.J., Solaun, O., 2004.
27 Implementation of the European Water Framework Directive from the Basque Country
28 (northern Spain): a methodological approach. Mar. Pollut. Bull. 48, 209-218.
- 29 Boudaya, L., Mosbahi, N., Dauvin, J.C., Neifar, L., 2019. Trophic and functional organization
30 of the benthic macrofauna of an anthropogenic influenced area: the Skhira Bay (Gulf of
31 Gabès, central Mediterranean Sea). Env. Sci. Poll. Res. 26, 13522-13538.

- 1 Brahim, M., Abdelfattah, A., Sammari, C., Aleya, L., 2015. Surface sediment dynamics along
2 the Tunisian coast of Skhira (Gulf of Gabès, south-eastern Tunisia). *J. Afr. Earth Sci.* 112, 73-
3 82.
- 4 Carletti, A., Heiskanen, A.S., 2009. Water Framework Directive intercalibration technical
5 report, Part 3: Coastal and Transitional waters. *JRC Scientific and Technical Reports*, EUR
6 23838 EN/3, 244 pp.
- 7 Chaouti, A., Bayed, A., 2017. Spatial patterns of soft-bottom macroinvertebrates and
8 relationships with environmental conditions in a North African coastal (Smir Lagoon,
9 Morocco). *Vie Milieu* 58, 25-35.
- 10 Chouba, L., Mzoughi-Aguir, N., 2006. Trace metals (Cd, Pb, Hg) and total hydrocarbons in
11 superficial sediments from the coast of Gabès Gulf. *Bull. Inst. Nat. Sci. Tech. Mer* 33, 93-100.
- 12 Clarke, K.R., Gorley, R.N., 2006. *PRIMER v6: User Manual/Tutorial*. PRIMER-E Ltd, Plymouth.
- 13 Dauvin, J.C., Bakalem, A. Baffreau, A., Grimes, S., 2017. Benthic ecological status of Algerian
14 harbours. *Mar. Pollut. Bull.* 125, 378-388.
- 15 Diawara, M., Zouari-Tlig, S., Rabaoui, L., Ben Hassine, O.K., 2008. Impact of management on
16 the diversity of microbenthic communities in Tunis north lagoon: systematics. *Cah. Biol. Mar.*
17 49, 1-16.
- 18 Draredja, B., Melouah, Beldi, H., Benmarce, S., 2012. Diversité de la macrofaune benthique
19 de la lagune Mellah (Parc national d'El-Kala, Algérie nord-est). *Bull. Soc. Zool.* 137, 73-86.
- 20 Drira, Z., Sahnoun, H., Ayadi, H., 2017. Spatial distribution and source identification of heavy
21 metals in surface waters of three coastal areas of Tunisia. *Pol. J. Env. Stud.* 26, 1-13.
- 22 El Kateb, A., Stalder, C., Rüggeberg, A., Neururer, C., Spangenberg, J.E., Spezzaferri, S., 2018.
23 Impact of industrial phosphate waste discharge on the marine environment in the Gulf of
24 Gabès (Tunisia). *PLoS ONE* 13 (5) e0197731.
- 25 El Kateb, A., Stalder, C., Martinez-Colon, M., Mateu-Vicens, G., Francescangeli, F., Coletti, G.,
26 Stainbank, S., Spezzaferri, S., 2020. Foraminiferal-based biotic indices to assess the ecological
27 quality status of the Gulf of Gabès (Tunisia): Present limitations and future perspectives.
28 *Ecol. Ind.* 111, 105962.
- 29 El Lakhraçh, H., Hattour, A., Jarboui, O., El Hasni, K., Ramos-Espla, A.A., 2012. Spatial
30 distribution and abundance of the megabenthic fauna community in Gabès Gulf (Tunisia,
31 eastern Mediterranean Sea). *Mediterr. Mar. Sci.* 13, 12-29.

- 1 El Zrelli, R., Courjault-Rade, P., Rabaoui, L., Castet, S., Michel, S., Bejaoui, N., 2015. Heavy
2 metal contamination and ecological risk assessment in the surface sediments of the coastal
3 area surrounding the industrial complex of Gabès city, Gulf of Gabès SE Tunisia. Mar. Pollut.
4 Bull. 101, 922-929.
- 5 El Zrelli, R., Courjault-Rade, P., Rabaoui, L., Daghbouj, N., Mansour, L., Balti, R., Castet, S.,
6 Attia, F., Michel, S., Bejaoui, N., 2017. Biomonitoring of coastal pollution in the Gulf of Gabès
7 (SE, Tunisia): use of *Posidonia oceanica* sea grass as a bioindicator and its mat as an archive
8 of coastal metallic contamination. Environ. Sci. Pollut. Res. 24, 22214-22225.
- 9 El Zrelli, R., Rabaoui, L., Ben Alayae, M., Daghbouf, N., Casteta, S., Bessona, Ph., Michelh, S.,
10 Béjaoui, N., Courjault-Radéa, P., 2018. Seawater quality assessment and identification of
11 pollution sources along the central coastal area of Gabès Gulf (SE Tunisia): evidence of
12 industrial impact and implications for marine environment protection. Mar. Poll. Bull. 127,
13 445-452.
- 14 Esquete, P., Fersi A., Dauvin, J.C. 2019. The family Apseudidae Leach, 1814 (Crustacea:
15 Tanaidacea) in the Gulf of Gabès (Mediterranean Sea): taxonomic and biogeographic
16 remarks and description of *Apseudopsis gabesi* Esquete sp. nov. Mar. Biod. 49, 1695-1711.
- 17 Fersi, A., Dauvin, J.C., Pezy, J.P., Neifar, L., 2018. Amphipods from tidal channels of the Gulf
18 of Gabès (central Mediterranean Sea). Med. Mar. Sci. 19, 430-443.
- 19 Fersi, A., Esquete, P., Neifar, L., Dauvin, J.C., 2019. Tanaidaceans (Crustacea: Peracarida)
20 from the Gulf of Gabès. Cah. Biol. Mar. 60, 453-460.
- 21 Fersi, A., 2019. Les communautés macrozoobenthiques des chenaux de marée du golfe de
22 Gabès. Thèse de Doctorat, Université de Sfax, Tunisie et Université de Caen, France. 319 pp.
- 23 Guélorget, O., Michel, P., 1979. Les peuplements benthiques d'un étang littoral
24 languedocien, l'étang du Prévost (Hérault). 2. Etude quantitative de la macrofaune des
25 sables. Tethys 9, 65-77.
- 26 Gaillande de D., 1970. Peuplements benthiques de l'herbier de *Posidonia oceanica*, de la
27 pelouse à *Caulerpa prolifera* et du large du golfe de Gabès. Téthys 2, 373-384.
- 28 Hammas, I., Horchani-Naifer, K., Férid, M., 2013. Characterization and optical study of
29 phosphogypsum industrial waste. Stud. Chem. Process. Technol. 1, 30-36.
- 30 Hattab, T., Ben RaisLasram, F., Albouy, C., Salah Romdhane, M., Jarboui, O., Halouani, G.,
31 Cury, P., Le Loc'h, F., 2013. An ecosystem model of an exploited southern Mediterranean

- 1 shelf region (Gulf of Gabès, Tunisia) and a comparison with other Mediterranean ecosystem
2 model properties. *J. Mar. Syst.* 128, 159-174.
- 3 Khammassi, M., Jourde, J., Zaabar, W., Laabidi, S., Sauriau, P.G., Sghaier Achouri, M., 2019.
4 Inventory and new records of benthic amphipods from macrophytes and fine sand
5 communities of the Bizerte lagoon (Tunisia, SW Mediterranean Sea). *Mar. Biodiv. Rec.* 12,
6 24.
- 7 Khedhri, I., Djabou, H., Afli, A., 2015. Trophic and functional organization of the benthic
8 macrofauna in the lagoon of Boughrara-Tunisia (SW Mediterranean Sea). *J. Mar. Biol. Ass.*
9 *U.K.* 95, 647-659.
- 10 Khedhri, I., Afli, A., Aleya, L., 2017. Structuring factors of the spatio-temporal variability of
11 macrozoobenthos assemblages in a southern Mediterranean lagoon: How useful for
12 bioindication is a multi-biotic indices approach? *Mar. Poll. Bull.* 114, 515-527.
- 13 Ktari-Chakroun, F., Azouz, A., 1971. Les fonds chalutables de la région sud-est de la Tunisie
14 (Golfe de Gabès). *Bull. Inst. Nat. Sci. Tech. Mer Salammbô, Tunisia* 2, 5-47.
- 15 Le Danois E., 1925. Recherches sur les fonds chalutables des côtes de Tunisie (Croisières du
16 chalutier 'Tranche' en 1924. *Ann. Station Océanogr. Salammbô* 1, 1-56.
- 17 Louati, A., Elleuch, B., Kallel, A., Saliot, A., Dagaut, J., Oudot, J., 2001. Hydrocarbon
18 contamination of coastal sediments from the Sfax area (Tunisia), Mediterranean Sea. *Mar.*
19 *Poll. Bull.* 42, 445-452.
- 20 Mezghani-Chaari, S., Hamza, A., Hamza-Chaffai, A., 2011. Mercury contamination in human
21 hair and some marine species from Sfax coasts of Tunisia: levels and risk assessment. *Env.*
22 *Monit. Ass.* 180, 477-487.
- 23 Moshabi, M., Dauvin, J.C., Neifar, L., 2015. Spatial distribution and abundance of the
24 intertidal benthic macrofauna from the Kneiss islands (Gulf of Gabès, Tunisia). *Cah. Biol. Mar.*
25 56, 319-328.
- 26 Mosbahi, N., Pezy, J.P., Dauvin, J.C., Neifar, N., 2016. Spatial and temporal structures of the
27 macrozoobenthos from the intertidal zone of the Kneiss Islands (Central Mediterranean Sea).
28 *Open. J. Mar. Sci.* 6, 223-237.
- 29 Mosbahi, N., Dauvin, J.C., Neifar, L., 2017a. Polychaete fauna from the intertidal zone of the
30 Kneiss Islands (Central Mediterranean Sea). *Medit. Mar. Sci.* 18, 215-228.
- 31 Mosbahi, N., Blanchet, H., Lavesque, N., De Montaudouin, X., Dauvin, J.C., Neifar, L., 2017b
32 Main ecological features of benthic macrofauna between Mediterranean and Atlantic

- 1 intertidal sea grass bed- a case study. J. Mar. Biol. Oceanogr. 6, 2. DOI: 10.4172/2324-
2 8661.1000174
- 3 Mosbahi, N., Dauvin J.C., Neifar, L., 2018. Molluscs associated with intertidal *Zostera noltei*
4 Hornemann beds in southern Tunisia (Central Mediterranean): seasonal dynamics and
5 environmental drivers. Vie Milieu 68, 221-235.
- 6 Mosbahi N., Moncef Serbaji M., Pezy J.P., Lassad Neifar L., Dauvin J.C., 2019. Response of
7 benthic macrofauna to multiple anthropogenic pressures in the shallow coastal zone south
8 of Sfax (Tunisia, Central Mediterranean Sea). Environ. Poll. 253, 474-487.
- 9 Muxika, I., Borja, A´., Bald, J., 2007. Using historical data, expert judgement and multivariate
10 analysis in assessing reference conditions and benthic ecological status, according to the
11 European Water Framework Directive. Mar. Pollut. Bull. 55, 16-29.
- 12 Naifar, I., Pereira, F., Zmemla, R., Bouaziz, M., Elleuch, B., Garcia, D., 2018. Spatial distribution
13 and contamination assessment of heavy metals in marine sediments of the southern coast of
14 Sfax, Gabès Gulf, Tunisia. Mar. Poll. Bull. 131, 53-62.
- 15 Nonnis Marzano, C., Scaleri Liaci, L., Fianchini, A., Gravina, M.F., Mercurio, M., Corriero, G.,
16 2003a. Distribution, persistence and change in the macrobenthos of the lagoon of Lesina
17 (Apulia, southern Adriatic Sea). Oceanogr. Acta 26, 57-66.
- 18 Nonnis Marzano, C., Gravina, M.F., Fianchini, A., Portacci, G., Gherardi, M., Tursi, A.,
19 Corriero, G., 2003b. The macrozoobenthos of the Karavasta lagoon system (Albania): local
20 assemblages and geographical comparisons. Mar. Ecol. 31, 622-632.
- 21 Ounifi Ben Amor, K., Rifi, M., Ghanem, R., Draief, I., Zaouali, J., Ben Souissi, J., 2016. Update
22 of alien fauna and new records from Tunisian marine waters. Medit. Mar. Sci. 17, 124-143.
- 23 Perez-Domingo, S., Castellanos, C., Junoy, J., 2008. The sandy beach macrofauna of Gulf of
24 Gabès (Tunisia). Mar. Ecol. 29, 51-59.
- 25 Poizat C, 1970. Hydrodynamisme et sédimentation dans le golfe de Gabès (Tunisie). Téthys
26 2, 267-296.
- 27 Rabaoui, L., El Zrelli, R., Ben Mansour, M., Balti, R., Mansour, L., Tlig-Zouari, S., Guerfel, M.,
28 2015. On the relationship between the diversity and structure of benthic macroinvertebrate
29 communities and sediment enrichment with heavy metals in Gabès Gulf, Tunisia. J. Mar.
30 Biol. Ass. U.K. 95, 233-245.
- 31 Rabaoui, L., El Zrelli, R., Balti, R., Mansour, L., Courjault-Radé, P., Daghbouj, N., Tlig- Zouari,
32 S., 2017. Metal bioaccumulation in two edible cephalopods in the Gulf of Gabès, south-

- 1 eastern Tunisia: environmental and human health risk assessment. *Env. Sci. Poll. Res.* 24,
2 1686-1699.
- 3 Serbaji, M.M., Azri, C., Medhioub, K., 2012. Anthropogenic contributions to heavy metal
4 distributions in the surface and sub-surface sediments of the Northern Coast of Sfax. Tunisia.
5 *Int. J. Env. Res.* 6, 613-626.
- 6 Seurat L.G., 1924. Observations sur les limites, les faciès et les associations animales de
7 l'étage intercotidal de la petite Syrte (Golfe de Gabès). *Bull. Station Océanogr. Salammbô* 3,
8 1-72.
- 9 Zaghden, H., Kallel, M., Elleuch, B., Oudot, J., Saliot, A., Sayadi, S., 2014. Evaluation of
10 hydrocarbon pollution in marine sediments of Sfax coastal areas from the Gabès Gulf of
11 Tunisia, Mediterranean Sea. *Environ. Earth. Sci.* 72, 1073-1082.
- 12 Zaouali, J., 1993. Les peuplements benthiques de la petite Syrte, golfe de Gabès – Tunisie.
13 Résultats de la campagne de prospection du mois de juillet 1990. Etude préliminaire:
14 biocénoses et thanatocénoses récentes. *Mar. Life*, 3, 47-60.
- 15
16

1 Fig. 1. Map of the study area showing the location of sampling stations in the four channels
2 traversing the Gulf of Gabès.

3

4 Fig 2. Mean abundance figures of the total macrofauna (■) (with standard deviation) and of
5 the total species richness (○) per 0.4 m² in each of the four channels (CK: Kneiss; CM:
6 Mimoun CML: Maltine; CP: Ben Khlaf) which were sampled across the four seasons running
7 from spring 2016 to winter 2017.

8

9 Fig. 3. Mean abundance figures of the total macrofauna (■) (with standard deviation) and of
10 the total species richness (○) per 0.4 m² at the 26 sampling stations covering the four
11 channels (CK: Kneiss; CM: Mimoun CML: Maltine; CP: Ben Khlaf) sampled four times from
12 spring 2016 to winter 2017.

13

14 Fig. 4. The proportion of the different trophic groups in the macrofauna retrieved from the
15 four channels during the four sampling seasons from spring 2016 to winter 2017. Channels -
16 CK: Kneiss, CM: Mimoun, CML: Maltine, CP: Ben Khlaf. Trophic groups - DS, Deposit Surface
17 feeders; HE, Herbivorous; O, Omnivores including predators and necrophagous; S,
18 Suspension feeders; SDF, Sub-Surface Deposit Feeders.

19

20 Fig. 5. Cluster dendrogram showing the distribution of mean abundances of species (for each
21 of the four seasons and at each of the 26 stations) as a function of the Bray-Curtis similarity
22 index following a Log (X+1) transformation of the abundances values of the 311 taxa.
23 Channels, CK: Kneiss; CM: Mimoun CML: Maltine; CP: Ben Khlaf.

24

25 Fig. 6. Cluster dendrogram showing the distribution of mean abundances of species (at all
26 stations sampled, in each of the four channels and for the four seasons) as a function of to
27 the Bray-Curtis similarity index following a Log (X+1) transformation of the abundances of
28 the 311 taxa. Channels, CK: Kneiss; CM: Mimoun CML: Maltine; CP: Ben Khlaf. Seasons, Win:
29 winter; Aut: autumn; Sum: summer; Spr: spring.

30

31 Fig. 7. Principal Component Analysis (PCA) (axis 1 and 2) relating to the position of the 26
32 stations) and the mean values of the environmental parameters.

1

2 Fig. 8. Principal Component Analysis (PCA) (axis 1 and 2) relating to the mean Abundance of
3 the macrofauna accounted in the 26 stations and the environmental parameters. Ccir:
4 *Cirratulus cirratus*, SPav: *Sabella pavonina*; Mano: *Microdeutopus anomalus*; Simp:
5 *Scoletoma impatiens*; Sarm: *Scoloplos armiger*; Csav: *Chondrochelia savignyi*; Llat:
6 *Lumbrineris latreilli*; Iphi: *Iphinoe trispinosa*; Amed: *Apseudopsis mediterraneus* and Agab:
7 *Apseudopsis gabesi*.

8

9 Fig. 9. Mean proportion of taxa classified under the five Ecological Groups. EG-I (blue), EG-II
10 (green), G-III (yellow), EG-IV (orange) and EG-V (red) with the value of the AMBI index (black
11 point on each of the 26 stations located along the four tidal channels). AMBI statuses: High:
12 $0.0 < \text{AMBI} \leq 1.2$; Good: $1.2 < \text{AMBI} \leq 3.3$; Moderate : $3.3 < \text{AMBI} \leq 4.3$; Poor $4.3 < \text{AMBI} \leq$
13 5.5 ; Bad: $5.5 < \text{AMBI} \leq 7.0$.

14

1 Table 1. Main characteristics of the sediment at each sampling station located along the four
2 tidal channels (mean \pm standard deviation). Gravel ($> 1000 \mu\text{m}$), sand ($63\text{-}1000 \mu\text{m}$), silt and
3 clay ($< 63\mu\text{m}$); OM: Organic Matter. Channels: CP: Ben Khlaf, CML: Maltine, CK: Kneiss, CM:
4 Mimoun.

5
6 Table 2. Results of the ANOVA tests on environmental parameters. Gravel ($> 1000 \mu\text{m}$), sand
7 ($63\text{-}1000 \mu\text{m}$), silt and clay ($< 63\mu\text{m}$). OM: Organic Matter. Channels, CP: Ben Khlaf, CML:
8 Maltine; CK: Kneiss; CM: Mimoun. Seasons: Win: winter; Spr: spring; Sum: summer; Aut:
9 autumn. Df: degree of freedom. F: test values. P: probability.

10
11 Table 3. Results of the two-way ANOVA analysis (season and position factors) applying the
12 Tukey test on values for Taxonomic richness, abundance, J: Pielou evenness, H' Shannon
13 diversity and the AMBI. Acronyms as for Table 2.

14
15 Table 4. Mean abundance (given as number per m^2) of the ten dominant species in the four
16 tidal channels (CK: Kneiss; CM: Mimoun. CML: Maltine; CP: Ben Khlaf).

17
18 Table 5. Mean abundance (A), given as number per m^2 , of the ten dominant species across
19 the four seasons.

20
21 Table 6. Values for the benthic indices for samples taken from the 26 stations set along the
22 four tidal channels (CK: Kneiss; CM: Mimoun. CML: Maltine; CP: Ben Khlaf) across the four
23 seasons (Spr: spring; Sum: summer; Aut: autumn, Win: winter). Taxonomic Richness (TR),
24 Abundance (A) per 0.4 m^2 , Shannon diversity (H'), Pielou's evenness (J), AMBI, Ecological
25 Quality Status (High: blue, Good: green, Moderated: yellow, poor: orange and bad: red)

26

Fig 1.

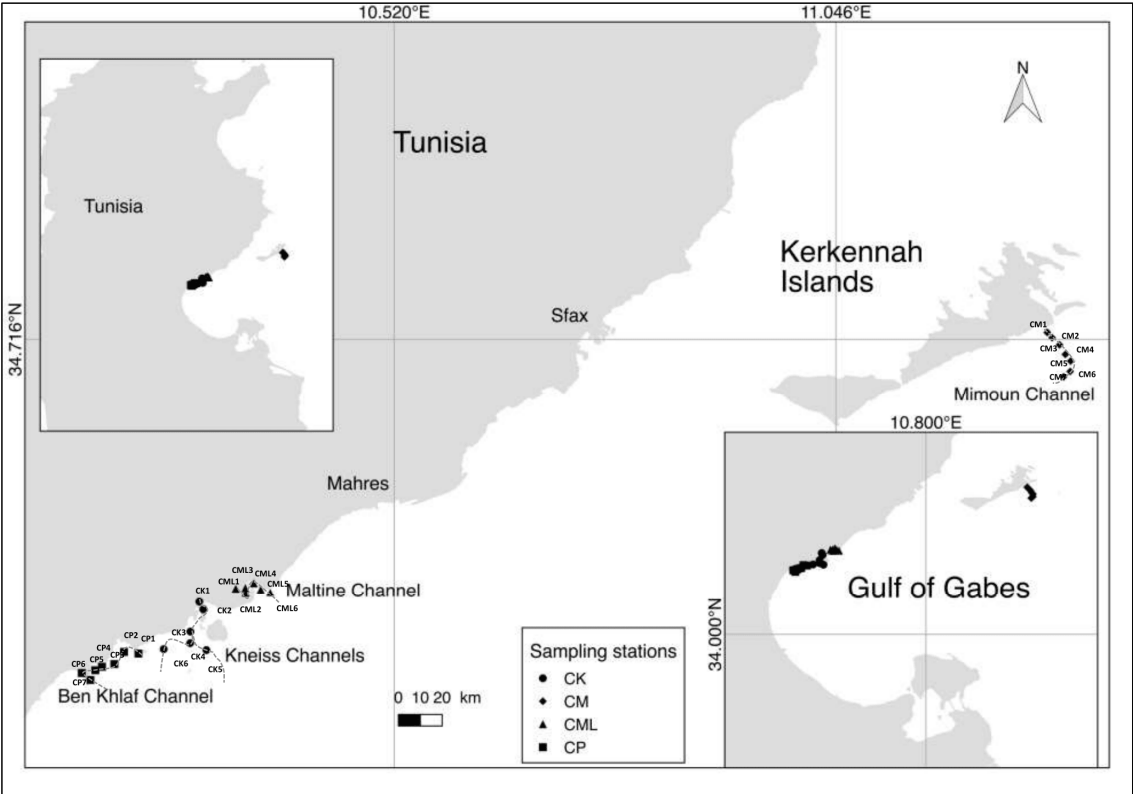


Fig. 2

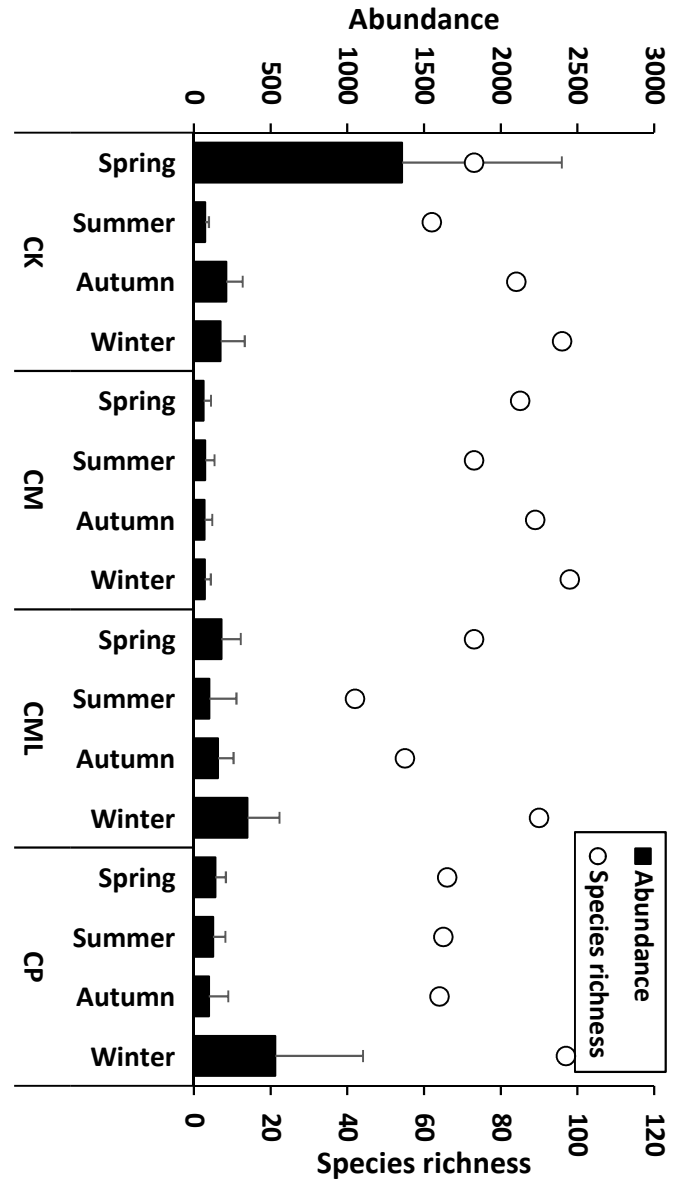


Fig. 3

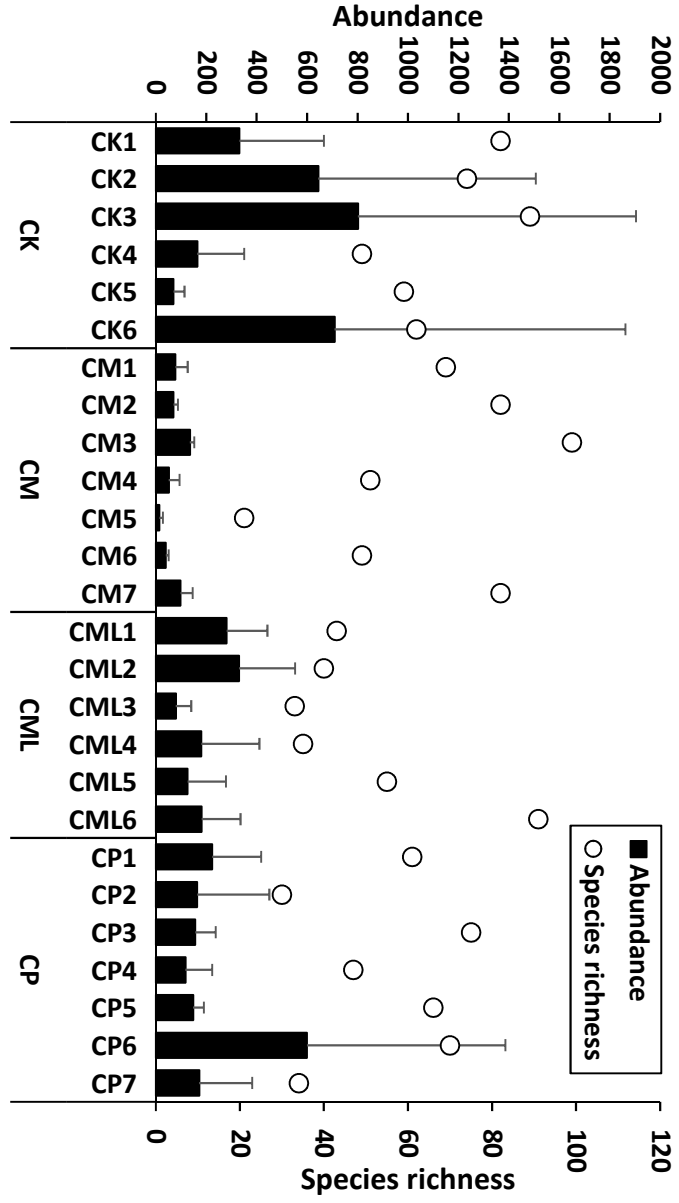


Fig. 4

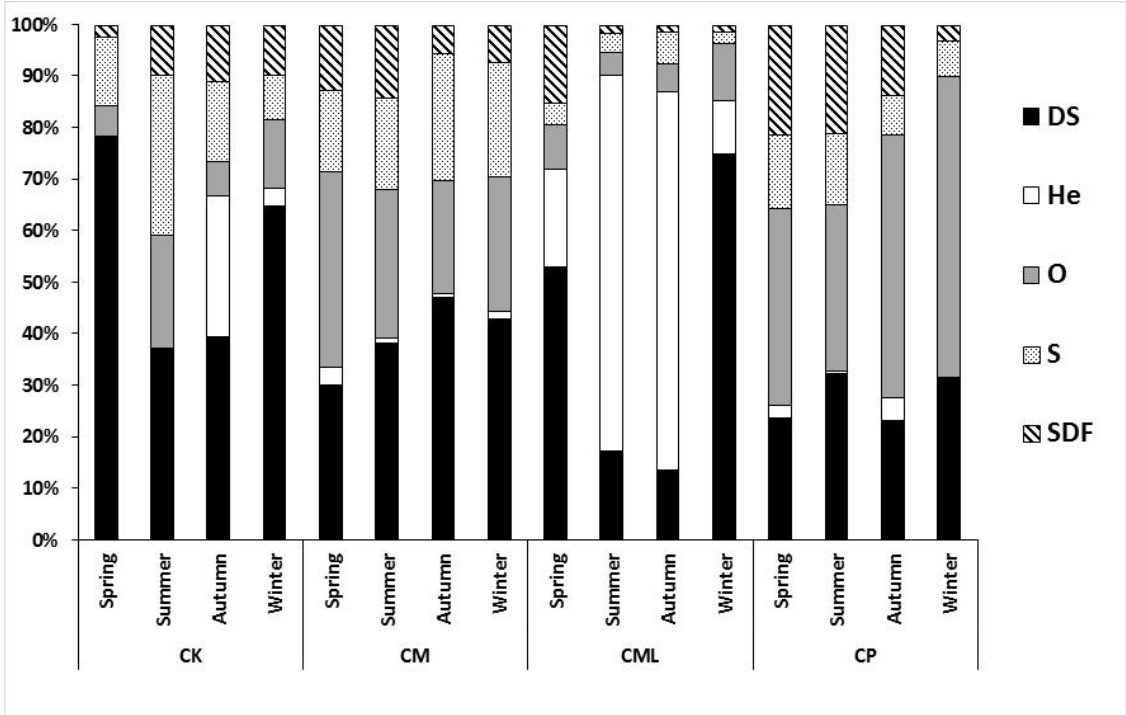


Fig. 5

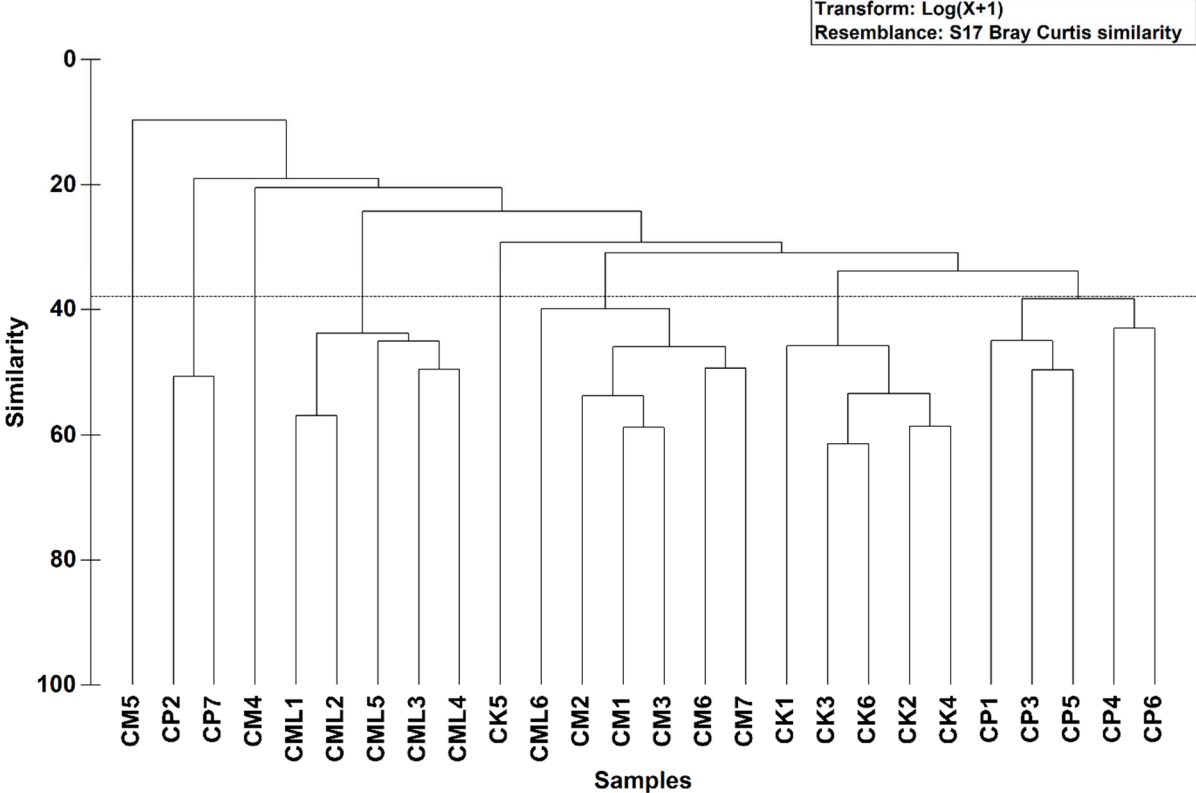


Fig. 6

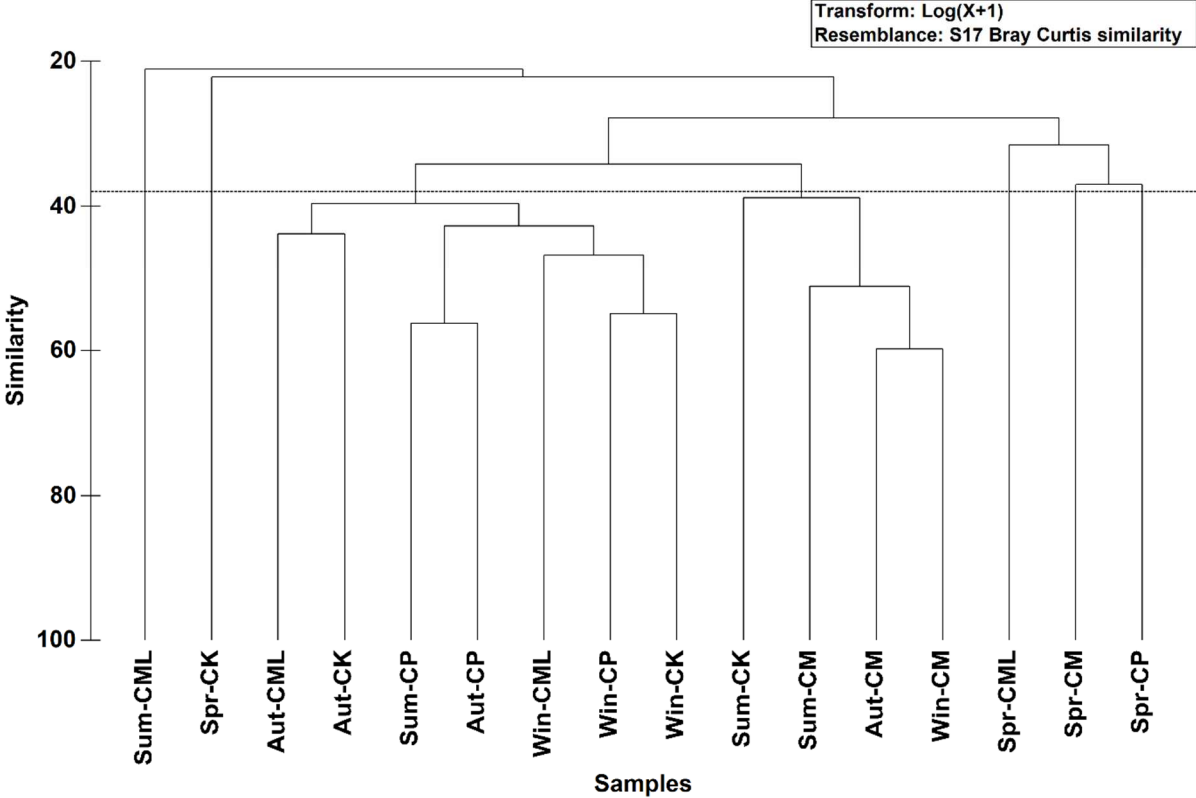


Fig. 7

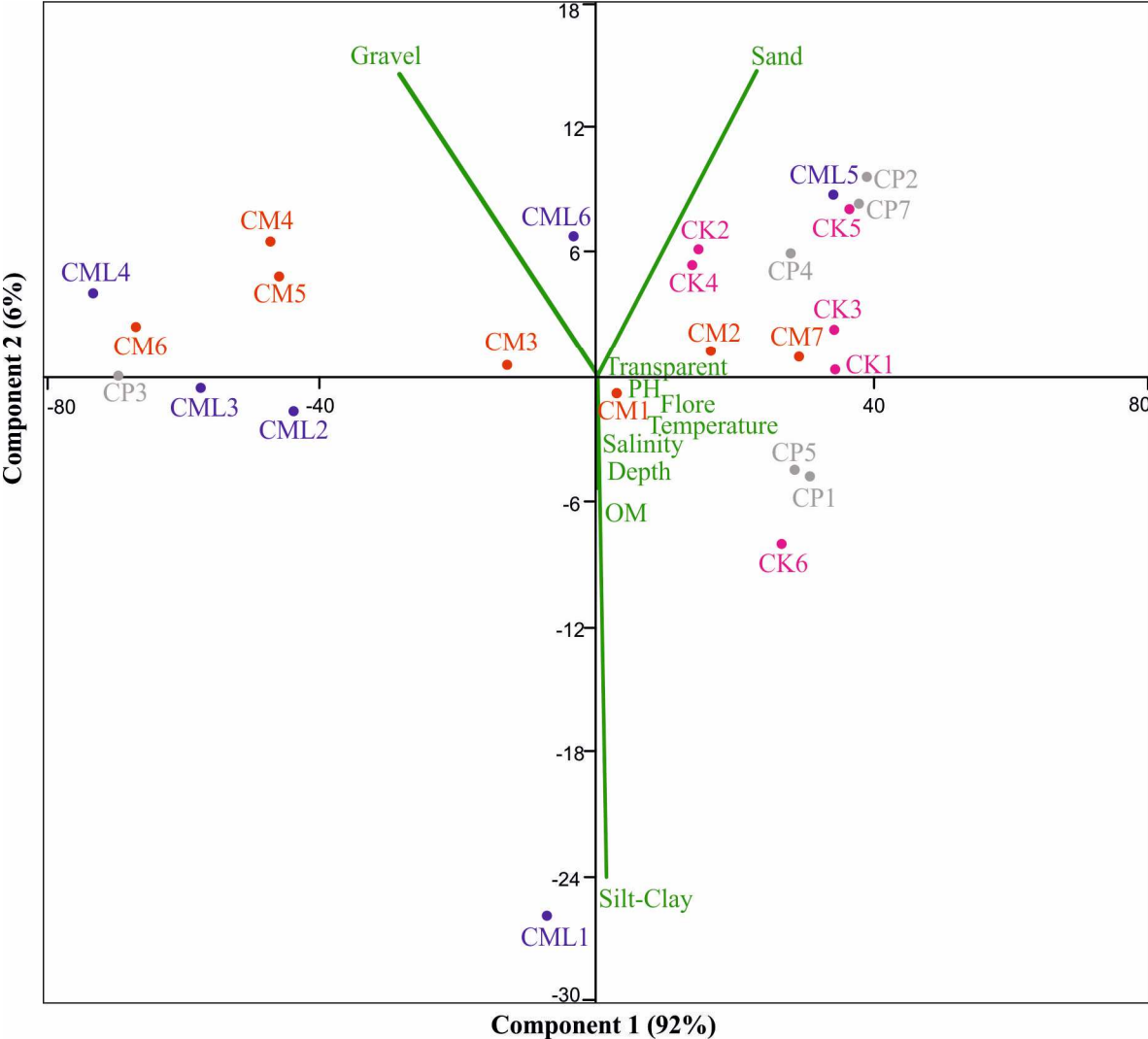


Fig. 8

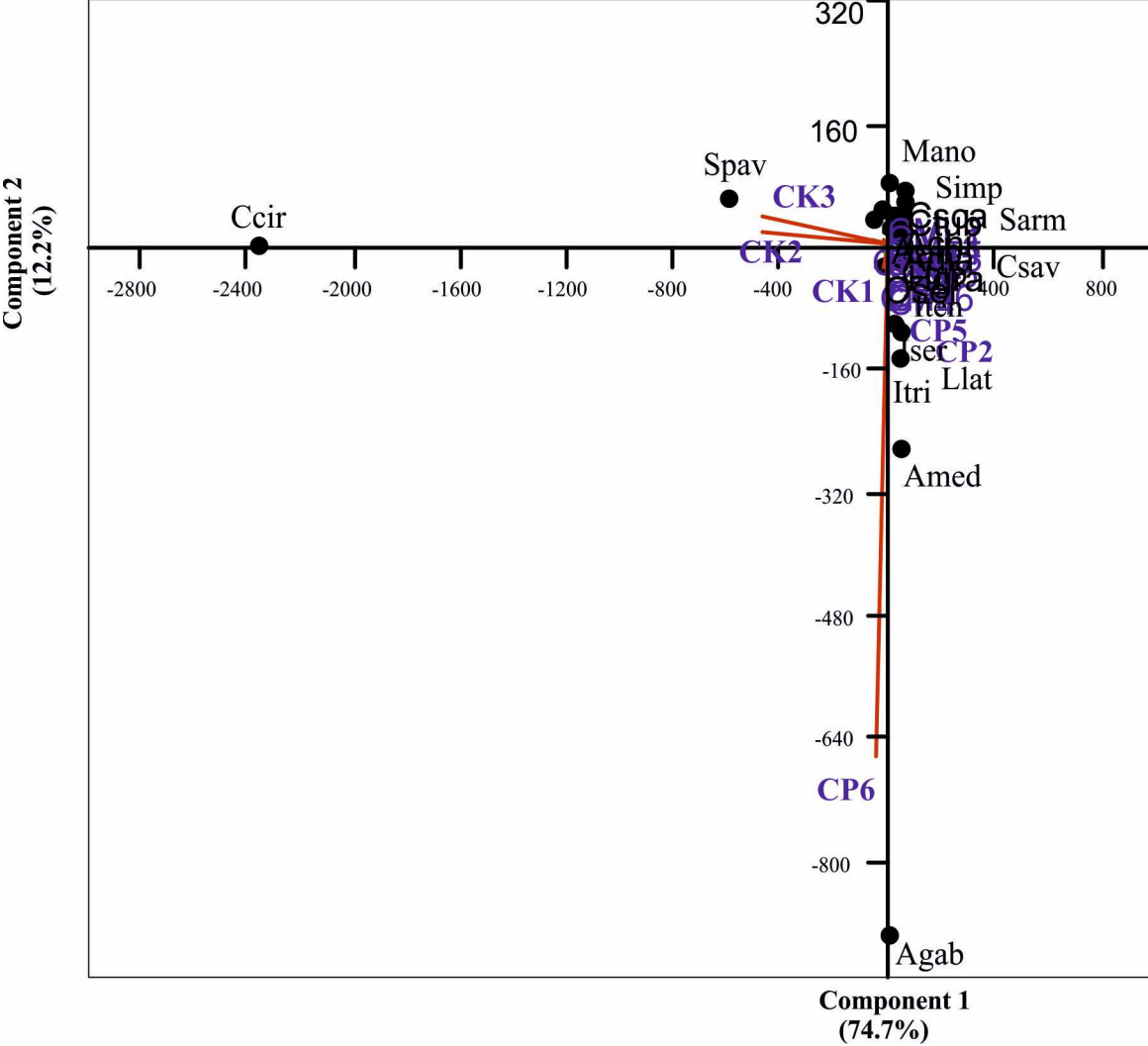


Fig. 8

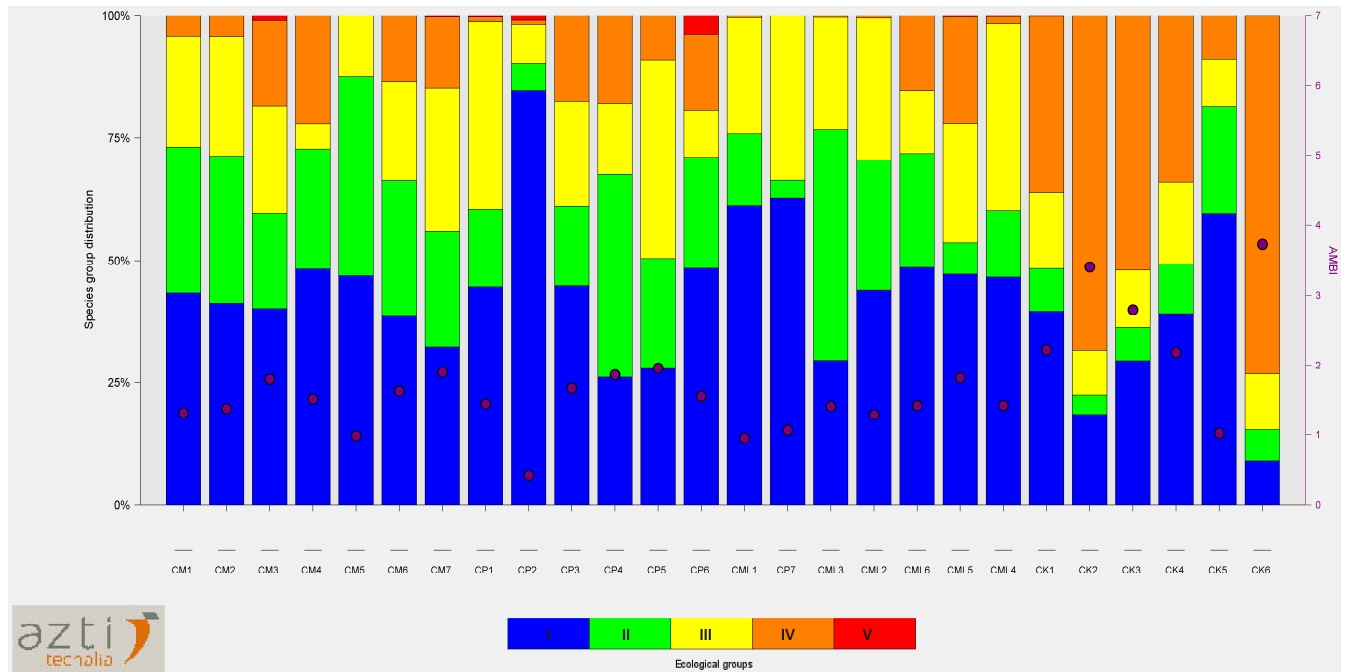


Table 1. Main characteristics of the sampling stations in the four tidal channels (mean±standard deviation).Gravel (> 1000 μm), sand (63-1000 μm), silt and clay (< 63μm); OM: Organic Matter; channels: CP: Ben Khlaf, CML: Maltine, CK: Kneiss, CM: Mimoun.

Station	Depth (m)	Gravel (%)	Sand (%)	Silt-Clay (%)	Salinity (psu)	Temperature (°C)	PH	Transparency	OM %
CP 1	3.5	2.0 ± 1.2	84.8 ± 10.4	12.6 ± 10.5	39.7 ± 0.8	23.1 ± 7.4	8.0 ± 0.2	1.2 ± 0.3	2.8 ± 3.0
CP 2	2.8	1.7 ± 1.6	96.6 ± 2.2	1.5 ± 0.6	39.6 ± 0.6	23.4 ± 7.4	8.1 ± 0.3	1.1 ± 0.4	0.9 ± 0.6
CP 3	3.2	76.3 ± 15.9	18.5 ± 11.0	4.8 ± 5.2	39.2 ± 0.4	23.4 ± 7.1	8.2 ± 0.3	1.6 ± 0.4	2.4 ± 2.2
CP 4	6.1	7.9 ± 3.5	87.8 ± 4.7	3.8 ± 2.4	39.0 ± 0.4	23.5 ± 7.2	8.2 ± 0.2	1.5 ± 1.1	1.1 ± 0.5
CP 5	7.6	3.7 ± 2.5	83.6 ± 6.3	12.3 ± 5.9	38.9 ± 0.4	23.7 ± 7.3	8.2 ± 0.2	2.2 ± 0.8	1.9 ± 1.0
CP 6	11.9	2.1 ± 1.1	62.4 ± 3.5	34.9 ± 2.7	38.8 ± 0.4	23.6 ± 7.2	8.2 ± 0.2	3.8 ± 0.6	7.3 ± 1.2
CP 7	0.9	2.0 ± 1.3	95.3 ± 2.5	2.4 ± 1.2	39.0 ± 0.6	23.8 ± 7.3	7.3 ± 0.8	1.2 ± 1.2	1.9 ± 1.9
CML 1	1.0	22.2 ± 8.6	49.8 ± 13.5	27.6 ± 4.8	44.5 ± 1.9	22.5 ± 6.9	8.3 ± 0.3	0.6 ± 0.1	9.3 ± 1.3
CML 2	2.1	57.2 ± 9.6	35.4 ± 13.6	7.0 ± 9.3	42.8 ± 1.9	22.3 ± 6.6	8.4 ± 0.4	1.4 ± 0.5	3.1 ± 3.9
CML 3	2.1	67.6 ± 10.7	26.4 ± 12.9	5.8 ± 6.5	42.7 ± 1.9	22.2 ± 6.3	7.9 ± 1.1	1.2 ± 0.1	1.7 ± 1.2
CML 4	3.1	80.6 ± 13.1	17.8 ± 11.9	1.5 ± 1.2	41.6 ± 0.3	22.3 ± 6.4	8.4 ± 0.3	1.6 ± 0.1	1.5 ± 1.9
CML 5	4.4	4.3 ± 4.1	93.5 ± 4.4	1.7 ± 0.9	41.0 ± 0.8	22.4 ± 6.3	8.3 ± 0.3	1.7 ± 0.2	1.4 ± 2.2
CML 6	3.7	30.7 ± 7.5	66.9 ± 6.7	2.0 ± 1.6	40.1 ± 1.0	22.8 ± 6.3	8.3 ± 0.3	1.6 ± 0.5	1.5 ± 1.9
CK 1	2.0	1.6 ± 1.9	89.8 ± 3.6	8.5 ± 2.7	39.8 ± 1.0	22.9 ± 7.7	8.2 ± 0.2	1.4 ± 0.4	4.2 ± 2.1
CK 2	8.5	18.1 ± 6.2	78.5 ± 7.2	3.1 ± 1.6	39.5 ± 1.2	22.2 ± 8.4	8.3 ± 0.3	1.6 ± 0.6	0.7 ± 0.2
CK 3	5.3	2.3 ± 1.8	90.3 ± 6.0	6.9 ± 4.3	39.4 ± 1.3	21.8 ± 8.3	8.3 ± 0.4	2.4 ± 1.1	2.4 ± 2.0
CK 4	7.4	17.5 ± 2.2	78.5 ± 3.2	3.6 ± 1.7	39.1 ± 0.6	21.9 ± 8.4	8.3 ± 0.4	2.2 ± 1.0	1.6 ± 1.6
CK 5	5.3	2.6 ± 2.5	94.9 ± 4.6	2.5 ± 4.6	39.1 ± 0.6	22.3 ± 7.6	8.3 ± 0.4	2.7 ± 0.4	1.7 ± 2.0
CK 6	8.3	4.0 ± 3.9	80.9 ± 4.7	14.4 ± 3.5	39.1 ± 0.5	22.3 ± 7.8	8.2 ± 0.3	1.9 ± 0.6	5.8 ± 4.6
CM 1	3.3	24.1 ± 4.3	67.7 ± 6.8	7.6 ± 3.3	40.5 ± 1.6	22.3 ± 7.0	8.1 ± 0.3	2.5 ± 0.4	5.8 ± 7.7
CM 2	3.3	14.6 ± 2.2	78.1 ± 5.7	6.6 ± 7.4	40.1 ± 1.9	22.8 ± 6.1	8.0 ± 0.3	1.8 ± 0.5	5.2 ± 6.5
CM 3	3.6	35.8 ± 5.9	57.4 ± 1.1	6.1 ± 5.1	40.0 ± 1.1	22.4 ± 6.5	8.0 ± 0.3	2.1 ± 0.6	4.9 ± 5.9
CM 4	4.1	62.8 ± 5.7	36.5 ± 5.3	0.4 ± 0.2	39.4 ± 2.7	21.8 ± 7.7	8.0 ± 0.3	2.2 ± 0.5	1.7 ± 2.9
CM 5	10.0	61.6 ± 8.0	36.6 ± 8.9	1.5 ± 0.9	37.8 ± 1.1	22.9 ± 5.7	8.0 ± 0.3	3.8 ± 0.3	1.8 ± 2.4
CM 6	13.5	75.7 ± 5.7	21.6 ± 3.3	2.4 ± 4.0	37.7 ± 1.1	22.6 ± 5.5	8.0 ± 0.2	3.0 ± 0.4	2.5 ± 3.3
CM 7	15.0	5.7 ± 1.2	86.7 ± 5.9	6.8 ± 5.6	37.5 ± 1.2	22.6 ± 5.6	7.9 ± 0.1	3.2 ± 0.6	5.4 ± 6.2

Table 2. Results of the ANOVA tests on environmental parameters. Gravel (> 1000 μm), sand (63-1000 μm), silt and clay (< 63 μm); OM: Organic Matter; channels, CP: Ben Khlaf, CML: Maltine; CK: Kneiss; CM: Mimoun. Seasons, Win: winter; Spr: spring; Sum: summer; Aut: autumn. Df: degree of freedom; F: test values; P: probability.

		Df	F	P	Tukey test
Gravel	Season	3	0.27	0.85	
	Station	3	13.18	<0.001	CK; CP \neq CM; CML
Sand	Season	3	0.08	0.97	
	Station	3	12.65	<0.001	CK; CP \neq CM; CML
Silt-Clay	Season	3	0.90	0.44	
	Station	3	2.05	0.11	
Salinity	Season	3	1.87	0.14	
	Station	3	29.39	<0.001	CML \neq CM; CP; CK
Temperature	Season	3	2,192.81	<0.001	Win \neq Spr; Sum; Aut Spr \neq Aut; Sum
	Station	3	16.36	<0.001	CP \neq CK; CM; CML
Ph	Season	3	23.46	<0.001	Aut; Win \neq Spr; Sum
	Station	3	5.68	<0.01	CML \neq CM
Transparency	Season	3	1.21	0.31	
	Station	3	2.40	0.07	
OM	Season	3	12.17	<0.001	Win \neq Spr; Sum; Aut
	Station	3	1.13	0.34	
	Σ	88			

Table 3. Results of Two-way ANOVA (season/station factors) with Tukey test on Taxonomic richness, abundance, J: Pielou evenness, H' Shannon diversity and AMBI. Channels CP: Ben Khlaf, CML: Maltine; CK: Kneiss; CM: Mimoun. Season, Win: winter; Spr: spring; Sum: summer; Aut: autumn. Df: degree of freedom; F: test values; P: probability.

		Df	F	P	Tukey test
Taxonomic richness	Season	3	3.51	<0.05	winter≠summer
	Station	3	1.89	0.12	
Abundance	Season	3	5.63	<0.01	spring≠ summer; autumn
	Station	3	5.01	<0.01	CK≠ CM
J	Season	3	0.69	0.56	
	Station	3	12.88	<0.001	CM ≠ CML; CK; CP
H'	Season	3	2.22	0.09	
	Station	3	9.54	<0.001	CM ≠ CML; CK; CP
AMBI	Season	3	2.24	0.08	
	Station	3	2.09	0.11	
	Σ	98			

Table 4. Mean abundance (A, per 1 m²) of the ten dominant species in the four tidal channels (CK: Kneiss; CM: Mimoun. CML: Maltine; CP: Ben Khlaf).

CK		CM		CML		CP	
Taxa	A	Taxa	A	Taxa	A	Taxa	A
<i>Cirratulus cirratus</i>	2,523	<i>Cirratulus cirratus</i>	69	<i>Microdeutopus anomalus</i>	480	<i>Apseudopsis gabesi</i>	439
<i>Sabella pavonina</i>	453	<i>Microdeutopus anomalus</i>	61	<i>Cerithium scabridum</i>	293	<i>Apseudopsis mediterraneus</i>	387
<i>Orbinia sertulata</i>	128	<i>Piromis eruca</i>	33	<i>Cerithiopsis tubercularis</i>	181	<i>Iphinoe serrata</i>	112
<i>Melinna palmata</i>	100	<i>Elasmopus rapax</i>	19	<i>Monocorophium acherusicum</i>	175	<i>Apseudopsis annabensis</i>	98
<i>Hediste diversicolor</i>	82	<i>Chondrochelia savignyi</i>	19	<i>Microdeutopus gryllotalpa</i>	117	<i>Monocorophium acherusicum</i>	92
<i>Monocorophium acherusicum</i>	73	<i>Glycera fallax</i>	18	<i>Cirratulus cirratus</i>	77	<i>Cirratulus cirratus</i>	80
<i>Microdeutopus anomalus</i>	67	<i>Golfingia (Golfingia) elongata</i>	17	<i>Apseudopsis gabesi</i>	40	<i>Iphinoe trispinosa</i>	77
<i>Scoletoma impatiens</i>	67	<i>Pinctada imbricata radiata</i>	16	<i>Abra alba</i>	37	<i>Sabella pavonina</i>	75
<i>Abra alba</i>	63	<i>Loripes orbiculatus</i>	16	<i>Scoloplos armiger</i>	33	<i>Lumbrineris latreilli</i>	74
<i>Tricolia speciosa</i>	58	<i>Melinna palmata</i>	15	<i>Notomastus latericeus</i>	31	<i>Microdeutopus anomalus</i>	66

Table 5. Mean abundance (A) per 1 m² of the ten dominant species in the four seasons.

Spring		Summer		Autumn		Winter	
Taxa	A	Taxa	A	Taxa	A	Taxa	A
<i>Cirratulus cirratus</i>	2,325	<i>Cerithiopsis tubercularus</i>	179	<i>Cerithium scabridum</i>	285	<i>Microdeutopus anomalus</i>	427
<i>Sabella pavonina</i>	333	<i>Cirratulus cirratus</i>	77	<i>Cirratulus cirratus</i>	151	<i>Apseudopsis gabesi</i>	383
<i>Microdeutopus anomalus</i>	125	<i>Sabella pavonina</i>	71	<i>Sabella pavonina</i>	85	<i>Apseudopsis mediterraneus</i>	289
<i>Melinna palmata</i>	107	<i>Microdeutopus anomalus</i>	51	<i>Microdeutopus anomalus</i>	75	<i>Monocorophium acherusicum</i>	210
<i>Monocorophium acherusicum</i>	92	<i>Chondrochelia savignyi</i>	45	<i>Apseudopsis gabesi</i>	62	<i>Cirratulus cirratus</i>	198
<i>Hediste diversicolor</i>	82	<i>Lumbrineris latreilli</i>	29	<i>Tricolia speciosa</i>	59	<i>Iphinoe serrata</i>	106
<i>Hilbigneris gracilis</i>	79	<i>Elasmopus rapax</i>	26	<i>Cymadusa filosa</i>	55	<i>Apseudopsis annabensis</i>	93
<i>Microdeutopus gryllotalpa</i>	73	<i>Protocirrineris chrysoderma</i>	24	<i>Orbinia sertulata</i>	52	<i>Iphinoe trispinosa</i>	90
<i>Scoletoma impatiens</i>	67	<i>Orbinia sertulata</i>	24	<i>Abra alba</i>	45	<i>Sabella pavonina</i>	79
<i>Orbinia sertulata</i>	65	<i>Monocorophium acherusicum</i>	22	<i>Lamellaria perspicua</i>	37	<i>Abra alba</i>	71

Table 6. Values of the Taxonomic Richness (TR) and Abundance (A) per 0.4 m², Shannon diversity (H'), Pielou's evenness (J), AMBI, Ecological Status (High: blue, Good: green, Moderated: yellow, poor: orange and bad: red) of the 26 stations from the four tidal channels (CK: Kneiss; CM: Mimoun. CML: Maltine; CP: Ben Khlaf) in the four seasons (Spr: spring; Sum: summer; Aut: autumn, Win: winter).

Stations	TR				A				H'				J				AMBI				M-AMBI			
	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win
CK1	31	18	28	37	818	52	251	204	3.00	3.15	3.27	4.25	0.60	0.76	0.68	0.81	2.67	0.53	1.26	1.72	0.61	0.68	0.73	0.77
CK2	22	11	31	39	1923	41	357	255	1.37	2.50	2.61	4.38	0.31	0.72	0.53	0.83	3.83	1.50	2.25	1.94	0.36	0.52	0.64	0.78
CK3	22	17	33	55	2442	103	226	436	1.90	2.96	3.86	4.37	0.42	0.72	0.77	0.75	3.04	1.76	1.59	2.08	0.45	0.59	0.78	0.84
CK4	27	18	15	11	443	95	53	66	3.30	3.32	3.07	2.79	0.69	0.80	0.79	0.81	2.25	2.51	2.21	1.25	0.63	0.57	0.57	0.58
CK5	9	20	27	9	77	64	123	16	2.25	3.57	3.88	2.95	0.71	0.82	0.82	0.93	0.25	1.29	1.51	0.47	0.55	0.68	0.75	0.64
CK6	21	15	28	19	2435	85	252	63	1.31	2.35	3.71	3.68	0.30	0.60	0.77	0.87	4.04	3.07	1.25	1.81	0.34	0.45	0.76	0.65
CM1	25	31	12	37	62	121	15	112	4.36	3.87	3.51	4.76	0.94	0.78	0.98	0.91	1.25	1.33	2.00	1.30	0.77	0.78	0.59	0.84
CM2	34	20	38	26	93	52	72	60	4.61	3.63	4.96	4.18	0.90	0.84	0.94	0.89	1.68	1.07	1.02	1.10	0.81	0.70	0.92	0.74
CM3	41	30	41	47	150	116	150	125	4.72	4.24	4.29	4.95	0.88	0.87	0.80	0.90	1.36	1.97	1.89	1.92	0.89	0.76	0.82	0.85
CM4	13	4	24	26	26	5	94	81	3.40	1.92	3.58	3.97	0.92	0.96	0.78	0.84	1.27	1.50	1.23	1.69	0.63	0.43	0.72	0.70
CM5	3	11	9	6	3	34	10	10	1.58	2.29	3.12	2.52	1	0.66	0.98	0.97	1.00	2.38	0.75	0.90	0.45	0.46	0.65	0.56
CM6	16	15	20	19	50	22	44	41	3.78	3.73	3.91	3.77	0.94	0.95	0.90	0.89	1.47	2.36	1.50	1.46	0.64	0.60	0.70	0.68
CM7	27	42	34	26	60	165	100	66	4.08	4.57	4.34	4.2	0.86	0.85	0.85	0.89	1.86	1.80	1.88	2.09	0.74	0.89	0.78	0.69
CML1	14	18	10	18	376	458	165	124	1.90	1.23	1.05	3.31	0.50	0.29	0.32	0.80	1.36	0.33	1.44	1.37	0.55	0.55	0.46	0.64
CML2	21	10	14	9	288	66	348	612	2.94	1.35	0.81	1.58	0.67	0.40	0.21	0.50	2.31	0.41	1.46	0.81	0.59	0.53	0.47	0.53
CML3	7	4	16	13	66	7	155	89	2.08	1.95	1.18	2.29	0.74	0.97	0.29	0.62	1.73	1.93	1.42	1.11	0.44	0.40	0.51	0.60
CML4	11	1	9	24	96	1	105	519	1.96	0	1.80	2.56	0.57	0	0.57	0.56	1.05	3.00	1.31	1.51	0.50	0.36	0.51	0.61
CML5	15	8	18	39	72	23	56	352	2.89	2.27	3.64	3.38	0.74	0.76	0.87	0.64	3.44	3.20	2.17	1.42	0.46	0.38	0.63	0.75
CML6	48	13	31	53	172	42	114	399	4.84	3.23	4.12	4.58	0.87	0.87	0.83	0.80	1.01	1.93	1.94	1.66	0.95	0.56	0.76	0.87
CP1	10	16	21	39	150	108	121	514	2.18	3.04	3.37	3.56	0.65	0.76	0.77	0.67	1.97	0.89	0.84	1.87	0.49	0.63	0.72	0.72
CP2	6	9	6	17	38	14	9	593	1.62	2.95	2.42	1.84	0.63	0.93	0.93	0.45	2.88	1.07	2.00	2.58	0.34	0.56	0.48	0.44
CP3	38	35	14	33	226	214	49	135	4.25	4.17	3.06	4.09	0.81	0.81	0.80	0.81	1.80	2.30	1.71	1.29	0.80	0.78	0.56	0.77
CP4	27	14	3	15	204	51	4	211	3.62	2.92	1.50	1.92	0.76	0.77	0.95	0.49	2.42	1.68	0.37	2.69	0.65	0.56	0.52	0.44
CP5	15	31	13	29	115	199	111	167	2.73	3.66	2.50	3.86	0.70	0.74	0.67	0.79	2.71	2.34	1.68	2.03	0.49	0.70	0.55	0.70
CP6	14	24	31	43	104	161	363	1768	2.46	3.27	3.39	2.93	0.64	0.71	0.68	0.54	2.07	1.61	2.46	2.31	0.50	0.67	0.67	0.66
CP7	-	-	10	28	-	-	23	321	-	-	2.48	2.88	-	-	0.75	0.60	-	-	2.02	2.01	-	-	0.51	0.61