INTRODUCTION

The Gulf of Gabes, located in the south eastern part of Tunisia, is considered as one of the most productive areas in the Mediterranean (Boudouresque & Meinesz, 1982). It is also the most important area for fishing in Tunisia (Jabeur et al., 2000). The coexistence of various industrial and urban activities in this region disrupts the stability of the ecosystem. Trawling is the most anthropogenic activity that disrupts the growth of seagrass and its associated fauna in the Gulf of Gabes (Ben Mustapha, 1995). After habitat destruction, introduced species are the second greatest threat to the local fauna.

Because of their great diversity in terms of number of species, but also because of their number of life history strategies, there is an increasing interest in using parasites as biological or ecological indicators of their fish host life conditions. Indeed, parasite communities appear to be important drivers of biodiversity, shape host population dynamics, alter interspecific competition and influence energy flow (Marcogliese, 2005). Moreover, all these factors can be influenced by environment disturbance (Sasal et al., 2007). Thus, the study of parasite communities of fishes can be used to identify contaminated habitats (Khan & Thulin, 1991; Schludermann et al., 2005) and verify the equilibrium of ecosystems (Bartoli et al., 2005).

Several studies of helminths have been made in the Gulf of Gabes such as Monogenea and Cestoda (Neifar et al., 2004; Derbel et al., 2007). Some studies on fish digeneans have been conducted in the North of Tunisia (Gargouri Ben Abdallah & Maamouri, 2008; Gargouri Ben Abdallah et al., 2010). This is the first attempt to survey the Digenea fauna off the southern coast (Gulf of Gabes). Our study aimed to list the Digenea species found in marine fish species in the Gulf of Gabes. The results presented in our paper also showed a possible use of parasites to reflect threats to the ecosystem in this region.

MATERIALS AND METHODS

Fish were caught off the coast of the Gulf of Gabes at Skhira (34° 05’ N; 10° 01’ E), Kerkenah (34° 45’ N; 11° 17’ E), and Sidi Mansour...
(34° 46' N; 10° 48' E) by local fishermen. The specimens, coming from the coastal fishing, were identified using Fisher et al. (1987) and Whitehead et al. (1984). These fish were dissected as soon as they had died and examined for digeneans. Living parasites were partially compressed beneath slide and coverslip and examined using an optical microscope. Some parasites were slightly compressed between a slide and coverslip and fixed with 70 % alcohol. Some living specimens were washed in cold saline then fixed in hot saline and preserved in 5 % formalin. All fixed specimens were stained with Semichon's acetic carmine. After dehydration using graded ethanol series, the parasites were cleared in clove oil and mounted in Canada balsam for identification.

We use the diversity index $M = N/N'$ (N: number of parasite species/N': number of fish species examined).

RESULTS AND DISCUSSION

During this study, 779 of teleost fishes from the Gulf of Gabes were examined for digenetic trematodes, comprising 32 species from 28 genera and 14 families. 53 species of trematodes were collected (Table I). These parasites belong to 42 genera and 15 families. 24 species, reported from Mediterranean Sea, are recorded for the first time off the coast of Tunisia (Table I). Among these species Lecithochirium sp. is reported from a new host Sardinella aurita, but it is a preadult that occurs in the swim bladder with prevalence of 13.89 % S. aurita may be an accidental host (Fig. 1). One metacercariae, Stephanostomum sp. encysted on the skin of Mullus surmuletus.

The Hemiuridae Lühe, 1901 represents the dominant family (12 species) followed by the Opecoelidae with 11 species in the Gulf of Gabes (Table I). This result is similar to that in the North Adriatic Sea where the Hemiuridae is the predominant family (Paradižnik & Radujković, 2007). However, Opecoelidae Ozaki, 1925 is the most important family in the Scandola Nature Reserve off Corsica and off the Lebanese coast (Bartoli et al., 2005; Saad-Fares, 1985). Members of Hemiuridae generally occur in the stomach, an acid environment to which they are well adapted (Bray, 1990; Pankov et al., 2006). The predominance of this family in the Gulf of Gabes may be a result of the resistance of this group to the environmental disturbance. Pérez-del Olmo et al. (2007) showed an increase in the diversity and abundance of the hemiuroids in the post-oil spill samples off the coast of Spain. These authors related the predominance of the hemiuroids to the enhancement of the populations of the benthic species such as the harpacticoid copepods, due to organic enrichment. Indeed, Acartia spp. are opportunistic harpacticoids which are known to serve as second intermediate hosts of a number of hemiuroids (Gibson & Bray, 1986). The analysis of the diversity of Digenea in the Gulf of Gabes shows that the most species of digeneans parasitize one host species (46 Digenea species), four were found in two host species and two were found in three host species. Some Digenea are known to be generalized in the Mediterranean Sea, such as Diphterostomum brusinae (Stossich, 1889), Hemiurus communis Odhner, 1905, and Lepocreadium pegorchis (Stossich, 1901). In the Gulf of Gabes, we found them in only one host fish although we examined several potential hosts. The failure transmission of digeneans to potential host may be related to environmental changes.

Fig. 1. – Lecithochirium sp. from Sardinella aurita. General morphology, ventral view. Scale bar = 150 μm.
| Digenea species                          | Digenea family           | Fish species                      | Fish family | Dates of collect (month/year) | P (%) | Abundance | Mean intensity |
|-----------------------------------------|--------------------------|----------------------------------|-------------|-------------------------------|-------|-----------|----------------|
| *Bucephalus anguilae* Špakuloa, Macko, Berrilli & Dezfili, 2002 | Bucephalidae            | Anguilla anguilla (n = 8)        | Anguillidae | 12/2005                       | 37.50 | 2.80      | 7.60           |
| *Deropristis inflata* (Molin, 1859)     | Deropristidae           | Anguilla anguilla                | Anguillidae | 12/2005                       | 100.00| 8.50      | 8.50           |
| *Terrestes acanthocephala* (Stossich, 1887) * | Felodistomidae       | Caranx cryosophila (n = 16)     | Carangidae  | 11/2005-2/2007                 | 32.00 | 4.40      | 1.40           |
| *Rhizocotyla galaeta* (Rudolfi, 1819) * | Bucephalidae            | Lichia amia (n = 7)              | Carangidae  | 8/2005-9/2006                  | 100.00| 33.50     | 33.50          |
| *Ectenurus lepidus* Looss, 1907 *       | Hemiuridae              | Trachurus trachurus (n = 18)    | Carangidae  | 5-10/2005-6/2005               | 33.00 | 0.33      | 1.00           |
| *Monascus filiformis* (Rudolfi, 1819) * | Felodistomidae          | Trachurus trachurus              | Carangidae  | 6-10/2005                      | 33.00 | 0.77      | 2.30           |
| *Bucephalus margaritae* (Ozaki & Ishibashi, 1934) * | Bucephalidae            | Trachinotus ovatus (n = 5)      | Carangidae  | 4/2005                        | 40.00 | 0.50      | 1.50           |
| *Lectobothrium jaffense* Fisch, 1982 *   | Hemiuridae              | Trachinotus ovatus               | Carangidae  | 4/2005                        | 80.00 | 1.60      | 2.00           |
| *Parahemiurus merus* (Linton, 1910) *    | Hemiuridae              | Sardinella aurita (n = 72)      | Clepeidae   | 1-6/2005-7/2005                | 40.28 | 2.05      | 5.10           |
| *Aphanurus stossichii* Monticelli, 1891  | Hemiuridae              | Sardinella aurita               | Clepeidae   | 1-6/2005-7/2005                | 40.28 | 0.28      | 7.00           |
|                                          |                         | Sardinina pikiardus (n = 30)    | Clepeidae   | 5-10/2005                      | 76.67 | 1.43      | 1.87           |
| *Lectobothrium sp.*                     | Hemiuridae              | Sardinella aurita               | Clepeidae   | 6/2005                        | 33.33 | 1.38      | 4.10           |
| *Prosohynchus aequalea* Odhner, 1905     | Bucephalidae            | Conger conger (n = 3)           | Congridae   | 1-6/2005                      | 66.66 | 8.00      | 12.00          |
| *Lectobothrium rufiviride* (Rudolfi, 1819) * | Hemiuridae            | Conger conger                    | Congridae   | 6/2005                        | 66.66 | 5.00      | 7.50           |
| *Helicometra fasciata* (Rudolfi, 1819)   | Opecoelidae             | Symbiosus tinca (n = 49)        | Labridae    | 2-3/2005                      | 49.00 | 4.81      | 9.83           |
|                                          |                         | Labris viridis (n = 41)         | Labridae    | 2-3/2005                      | 34.10 | 1.65      | 4.85           |
|                                          |                         | Sciacna umbra (n = 14)          | Sciaenidae  | 2-3/2005                      | 21.40 | 0.35      | 1.66           |
| *Schikka balaudretroma sparisonae* (Manter, 1937) | Haploplanchnida     | Chelon labrosus (n = 12)        | Mugilidae   | 10/2005                       | 28.00 | 2.42      | 8.50           |
|                                          |                         | Liza aurata (n = 12)            | Mugilidae   | 12/2005-8/2007                 | 41.66 | 3.08      | 7.40           |
|                                          |                         | Liza saliens (n = 11)           | Mugilidae   | 9/2006-11/2007                 | 45.45 | 1.81      | 4.00           |
|                                          |                         | Sparisona cretense (n = 30)     | Sparidae    | 9-10/2005                     | 53.00 | 6.26      | 11.75          |
| *Digroaster contracta* Looss, 1902       | Haploporidae            | Liza aurata                     | Mugilidae   | 8/2007                        | 41.66 | 3.08      | 7.40           |
|                                          |                         | Liza saliens                    | Mugilidae   | 11/2007                       | 9.00  | 0.27      | 3.00           |
| *Robina aurata* Pankov, Webster, Blasco-Costa, Gilsbin, Littlewood & Kostadinova, 2006 * | Hemiuridae            | Liza aurata                     | Mugilidae   | 8/2007                        | 16.66 | 0.33      | 2.00           |
| *Saccoceolium obesum* Looss, 1902        | Haploporidae            | Liza saliens                    | Mugilidae   | 9/2006                        | 18.00 | 0.27      | 1.50           |
| *Haploplanchnus caudatus* (Srivastava, 1939) | Haploplanchnida     | Mugil cephalus (n = 11)         | Mugilidae   | 9/2006-11/2007                 | 18.18 | 0.18      | 1.00           |
| *Haploplanchnus pachysonus* (Eysenhardt, 1829) | Haploplanchnida     | Mugil cephalus                   | Mugilidae   | 9/2006-11/2007                 | 63.63 | 1.09      | 1.71           |
| *Saturnius papermai* Overstreit, 1977 *  | Hemiuridae              | Mugil cephalus                   | Mugilidae   | 11/2007                       | 18.18 | 0.36      | 2.00           |
| *Opecoeloides farcatus* (Lühe, 1900) *   | Opecoelidae            | Mullus surmuletus (n = 72)      | Mullidae    | 2-3-4/2006                    | 52.77 | 3.43      | 6.47           |
|                                          |                         | Mullus barbatius (n = 24)       | Mullidae    | 9/2005                        | 45.83 | 4.00      | 8.72           |
| *Poracanthium farcatum* Dollfus, 1948 *  | Opecoelidae            | Mullus surmuletus                | Mullidae    | 2-3-4/2006                    | 13.88 | 0.40      | 3.57           |

* First records in Tunisia.

Table I. – List of Digenean species collected from teleost fishes of Gulf of Gabes and their epidemiologic values.
| Digenea species                        | Digenea family      | Fish species (number of specimens) | Fish family | Dates of collects (month/year) | P (%) | Abundance | Mean intensity |
|----------------------------------------|---------------------|-------------------------------------|-------------|---------------------------------|-------|-----------|---------------|
| *Proctotrema bacillioveum* (Odhner, 1911) * | Opecoelidae         | *Mullus surmuletus*                 | Mullidae    | 2-3-4/2006                      | 20.83 | 1.46      | 7.00          |
| *Stephanostomum sp.*                   | Acanthocotylidae    | *Mullus surmuletus*                 | Mullidae    | 9/2005                          | 25.00 | 1.79      | 7.16          |
| *Prosohyochoeboides arcuatus* (Linton, 1900) * | Bucephalidae        | *Pomatomus saltatrix* (n = 14)     | Pomatomidae | 7/2005                          | 85.00 | 4.57      | 5.30          |
| *Paracryptogenius alysi* (Stossich, 1885) | Cryptogenimidae     | *Staenia umbra*                     | Staenidae   | 10/2005-7/2007                  | 21.40 | 0.71      | 3.33          |
| *Pleurorchis polyorchis* (Stossich, 1889) * | Acanthocotylidae    | *Staenia umbra*                     | Staenidae   | 10/2005                         | 7.00  | 0.07      | 1             |
| *Lecithobothrium texanum* (Chandler, 1941) * | Hemiuridae          | *Euthynnus alleteratus* (n = 14)   | Scombridae  | 11/2005-5/2007                  | 92.85 | 18.14     | 19.53         |
| *Lectobothrium excisum* (Rudolphi, 1819) | Hemiuridae          | *Scomber japonicus*                 | Scombridae  | 7-8/2005                        | 33.30 | 0.70      | 2.11          |
| *Prostomium orientalis* (Layman, 1930) * | Lepocreadiidae      | *Scomber japonicus*                 | Scombridae  | 5-7-8/2005                      | 29.60 | 0.62      | 2.12          |
| *Podocotyle temensis* Fischthal & Thomas, 1970 * | Opecoelidae         | *Scomber japonicus*                 | Scombridae  | 7-8/2005                        | 7.40  | 0.09      | 1.25          |
| *Lecithobothrium musculus* (Loos, 1907) * | Hemiuridae          | *Serranus scriba* (n = 21)         | Serranidae  | 4/2005-7/2007                   | 38.09 | 0.47      | 2.50          |
| *Bacigli erismensis* Fischthal, 1980     | Faustulidae         | *Boops boops*                       | Sparidae    | 9/2005                          | 27.77 | 2.00      | 7.20          |
| *Robnikolofiusium maritinezomezi* López-Román, Gijón-Botel, Kim & Vilca-Choque, 1992 * | Gyliauchenidae      | *Boops boops*                       | Sparidae    | 9/2005                          | 5.55  | 0.16      | 3.00          |
| *Macvicaria crassigula* (Linton, 1910)   | Opecoelidae         | *Diplodus annularis* (n = 43)      | Sparidae    | 1-4-7-11/2005                   | 11.60 | 0.13      | 1.20          |
| *Penacrinus barbatus* (Stossich, 1886)   | Opecoelidae         | *Diplodus vulgaris* (n = 33)       | Sparidae    | 11-12/2005-4/2006               | 15.15 | 0.24      | 1.60          |
| *Diplorhynchus brasianus* (Stossich, 1889) | Zoogonididae        | *Diplodus puntazzo* (n = 19)       | Sparidae    | 12/2005                         | 47.36 | 1.10      | 2.33          |
| *Pseudotrypanorhynchus bisielatis* Saad-Fares & Maillard, 1986 | Opecoelidae     | *Diplodus vulgaris*                 | Sparidae    | 2/2005-4/2006                   | 6.06  | 0.33      | 5.50          |
| *Aphallus tubarium* Rudolphi, 1819       | Cryptogenimidae     | *Dentex dentex* (n = 11)           | Sparidae    | 12/2005-2/2006                  | 36.36 | 1.45      | 4.00          |
| *Hemimerus communis* Odhner, 1905        | Hemiuridae          | *Dentex dentex*                     | Sparidae    | 2/2006                          | 18.18 | 0.81      | 4.50          |
| *Holochris pygmeus* Stossich, 1901       | Lepocreadiidae      | *Lithognathus mormyrus* (n = 30)   | Sparidae    | 2-5/2005                        | 20.00 | 0.56      | 2.83          |
| *Macvicaria mormyr* (Stossich, 1885)     | Opecoelidae         | *Lithognathus mormyrus*            | Sparidae    | 2-5/2005                        | 10.00 | 0.20      | 2.00          |
| *Centrodon spinosissima* (Stossich, 1883) | Mesometridae        | *Sarpa salpa* (n = 20)             | Sparidae    | 1/2006-10-2007                  | 10.00 | 0.95      | 9.50          |
| *Lepocreadia anguilla* (Stossich, 1901)  | Lepocreadiidae      | *Sarpa salpa*                      | Sparidae    | 1/2006-10-2007                  | 30.00 | 3.05      | 10.16         |
| *Mesometra brazycyloca* Lühe 1901       | Mesometridae        | *Sarpa salpa*                      | Sparidae    | 1/2006-10-2007                  | 35.00 | 0.50      | 1.40          |
| *Mesometra orbicularis* (Rudolphi, 1819) | Mesometridae        | *Sarpa salpa*                      | Sparidae    | 1/2006-10-2007                  | 60.00 | 4.20      | 7.00          |
| *Robnikolofiusium squamulatus* Rudolphi, 1819 | Gyliauchenidae     | *Sarpa salpa*                      | Sparidae    | 1/2006-10-2007                  | 50.00 | 6.55      | 13.10         |
| *Wardula capillata* (Rudolphi, 1819)    | Mesometridae        | *Sarpa salpa*                      | Sparidae    | 1/2006-10-2007                  | 10.00 | 0.10      | 1.00          |
| *Allopecoelus pedicellatus* (Stossich, 1887) | Opecoelidae        | *Sparus aurata* (n = 22)           | Sparidae    | 11/2005                         | 9.09  | 0.13      | 1.50          |
| *Macvicaria obovata* (Molin, 1859)      | Opecoelidae         | *Sparus aurata*                    | Sparidae    | 11/2005                         | 36.36 | 0.90      | 2.50          |
| *Allopecoelus turnisertis* Derbel & Neifar, 2009 * | Opecoelidae     | *Solea aegyptiaca* (n = 60)        | Soleidae    | 5/9/2005-3/2007                 | 13.30 | 3.50      | 0.46          |

* First records in Tunisia.

Table I (continued). – List of Digenean species collected from teleost fishes of Gulf of Gabes and their epidemiologic values.
In this case, the helminth infects its preferential host species (Mackenzie, 1999).

The community of Digenea species shows that 16 species of fishes are parasitized by different families of Digenea species. Little interspecific competition and enough available space and resources may exist in the hosts. In this study, there are more species of Digenea than species of fish. The number of helminth species per host species was variable. Only Symphodus ocellatus (n = 40), Symphodus cinereus (n = 36) and Pagrus caeruleostictus (n = 34) were entirely devoid of Digenea. By contrast, in the literature, digenean parasites are known to be present in these hosts in the Mediterranean Sea. For example, in the nature reserve off Corsica, five species were collected from S. ocellatus and two species from S. cinereus (Bartoli et al., 2005). Allopodocotyle pedicellata (Stossich, 1887) is collected from P. caeruleostictus off the Lebanese coast (Saad-Fares, 1985). Among the possible reasons explaining the complete absence of certain Digenea in the Gulf of Gabes is the absence or low prevalence of the intermediate host. In addition, the environmental change can affect parasite transmission. For example, Bartoli & Boudouresque (1997) show the low prevalence of digenean species from S. ocellatus in the sites colonized by the introduced alga Caulerpa taxifolia. Many introduced algal species are widespread in the Gulf of Gabes such as C. taxifolia, Caulerpa racemosa and Halophila stipulacea. As the result of this invasion, the infralittoral communities have changed. Several authors have described the highly floristic changes, which have occurred in invaded areas with C. taxifolia (Verlaque & Fritayre, 1994; Villele & Verlaque, 1995). The structure of the population of most species of fish has changed, and the number of individuals and the biomass have declined significantly. As far as invertebrates are concerned, the changes are less conspicuous. It is mainly the numbers of the polychaeta and mollusc individuals which have declined. Additional sampling is necessary to support these hypotheses.

The analysis of parasite species richness of different hosts showed that Sarpa salpa has the richest fauna (six species). The helminth fauna of this teleost is distinct consisting mainly of members of two families (Mesometridae and Gyliacuchenidae). These species have many adaptive characteristics favouring the settlement on the peculiar gut wall of this herbivorous fish and to survive in a medium rich in plant detritus. Bartoli (1987) suggested that the digeneans of S. salpa are not true parasites but endocommensal symbionts. So, these species are not immunogenic, or at least only slightly so, since they do not feed upon the host itself but upon its intestinal chime. In most cases this results in a high parasite density with the co-occurrence of the various species.

Several authors use the diversity index M, which reflects the digenean species diversity in a specific geographical area (Bartoli et al., 2005; Oguz & Bray 2006; Keser et al., 2007). In the Gulf of Gabes this index is M = 1.7. After Bartoli et al. (2005) the highest ratio (3.8) is observed in the Scandola Nature reserve. By contrast the lowest ratio is reported for the Adriatic and North-western Italian coast (M ≤ 2), while an intermediate situation is observed for the Eastern Mediterranean (M > 2). The diversity of Digenea in the Gulf of Gabes is the lowest and closer to that found in the Adriatic (Fig. 2).

The comparison of the data reported for the Sparidae in the Gulf of Gabes with the north east of Tunisia (M = 2.9) (Gargouri Ben Abdallah & Maamouri, 2008) shows lower diversity in the Gulf of Gabes (M = 2.3). This result can be explained by the changes in the structure and the function of marine ecosystem in the south of Tunisia by human activities and the impact of exotic species. In contrast, the north coast shows...
lower impact of the trawling because the bottom is mainly rocky not favouring this type of fisheries (Ben Mustapha et al., 2002).

Previous studies have identified many factors influencing parasite species richness such as host traits, latitude, geographical range, phylogeny and the number of host individuals examined per species. The low diversity of Digenea in the Gulf of Gabs shows an unstable ecosystem with a decrease of the biomass and densities of hosts. In contrast, the higher digenean diversity in the Scandola Nature reserve is related to the stability of the equilibrium of the ecosystem (Bartoli et al., 2005). Thus the diversity of Digenea reflects the stability of the site. Parasite communities may be good indicators of environmental disturbance because they reflect complex interactions between a possible stressor and either free-living larval stages or populations of their intermediate and final hosts (Overstreet, 1988; Schludermann et al., 2003). On the other hand, a diverse and abundant community of parasites may be reflective of a diverse and abundant community of hosts. Hudson et al. (2006) suggested that a healthy ecosystem should be one with many parasites because they reflect the presence of many different types of organisms based on the variety of complex life cycles (Marcogliese & Cone, 1997). The disturbance in the Gulf of Gabs is essentially a result of the impact of overfishing and the use of destructive fisheries such as illegal trawling causing the degradation of Posidonia oceanica (Hattour, 1991; Ben Mustapha, 1995; Ramos-Esplá et al., 2000). A decline in the cover of P. oceanica has been recorded in many parts of the Mediterranean Sea, and has been attributed to several natural and anthropogenic impacts. Illegal trawling has been identified as one of the most important direct causes of large scale degradation of P. oceanica meadows (Martin et al., 1997; Pasqualini et al., 2000; González-Corraa et al., 2005; Kiparissis et al., 2011). The impact of trawling on P. oceanica produces a reduction of canopy cover and an increase of detritus by erosion, which has an important influence on the invertebrate community (Sánchez-Jerez & Ramos-Esplá, 1996). Sea grass beds are spatially complex and biologically productive ecosystems that provide habitats and food resources for a diversified fish fauna and act as an important nursery area for many species. The damage of this ecosystem causes a qualitative and quantitative change in the structure of intermediate hosts, and therefore a modification in the frequency of Digenea fauna.

ACKNOWLEDGEMENTS

We are grateful to Dr R.A. Bray for useful comments and linguistic revision.

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Accepted on February 22nd, 2012

Received on September 9th, 2011

Parasite. 2012, 19, 129-135