

## Benthic macrophyte communities in the Ghar El Melh lagoon (North Tunisia)

Shili, A.<sup>1\*</sup>, Trabelsi, E.B.<sup>2</sup> & Ben Maïz, N.<sup>2</sup>

<sup>1</sup>Laboratoire de Diversité Biologique et Fonctionnement des Ecosystèmes Marins Côtiers, Faculté des Sciences de Luminy, Aix –Marseille II, France; <sup>2</sup>Société de Promotion du Lac de Tunis, BP 36, EL Bouhaira 1080 Tunis Cedex;  
\*Corresponding author; Fax +21671351334; E-mail [abdessailemshili@yahoo.fr](mailto:abdessailemshili@yahoo.fr)

**Abstract.** This work deals with the biodiversity and distribution of benthic macrophytes in the Ghar El Melh lagoon, a Mediterranean coastal lagoon located in the North of Tunisia. An inventory was made of the benthic flora and submerged macrophyte communities were mapped during two successive campaigns (the summer of 1999 and the winter of 2000). The following 24 macrophyte species were identified: seven red algae, two brown algae, 11 green algae, and four marine angiosperms. The results were compared with available data from the literature.

*Ruppia cirrhosa* is the most dominant species. It is found in all lagoon parts, except in the west sector. *Ruppia* beds are usually associated with *Cladophora* forming heterogeneous communities. During summer *Ruppia cirrhosa* shows a large distribution, covering an area of ca. 21.4 km<sup>2</sup>, with dense, extensive beds covering 80-100%. In winter, several *Cladophora* species have a very large distribution as well, covering nearly an area of 28.5 km<sup>2</sup> with an average cover of 46%. The green algae *Caulerpa prolifera* is confined to the eastern part of the lagoon which is mainly affected by seawater.

In comparison with previous situations, many transformations were observed in biodiversity and spatial distribution of the dominant communities. Thus, *Cymodocea nodosa* and *Zostera* beds, which dominated in the 1970s, were replaced by *Zostera* and *Caulerpa prolifera* in the 1980s and are currently succeeded by *Ruppia cirrhosa* and *Cladophora*.

Restoration of the Ghar El Melh lagoon will enable an increase in the exchange with the open sea and the circulation of water, in particular in the confined zones. This should considerably improve the water quality and would positively influence the phytobenthic communities.

**Keywords:** Biodiversity; Cartography; *Cladophora*; *Ruppia*; *Zostera*.

### Introduction

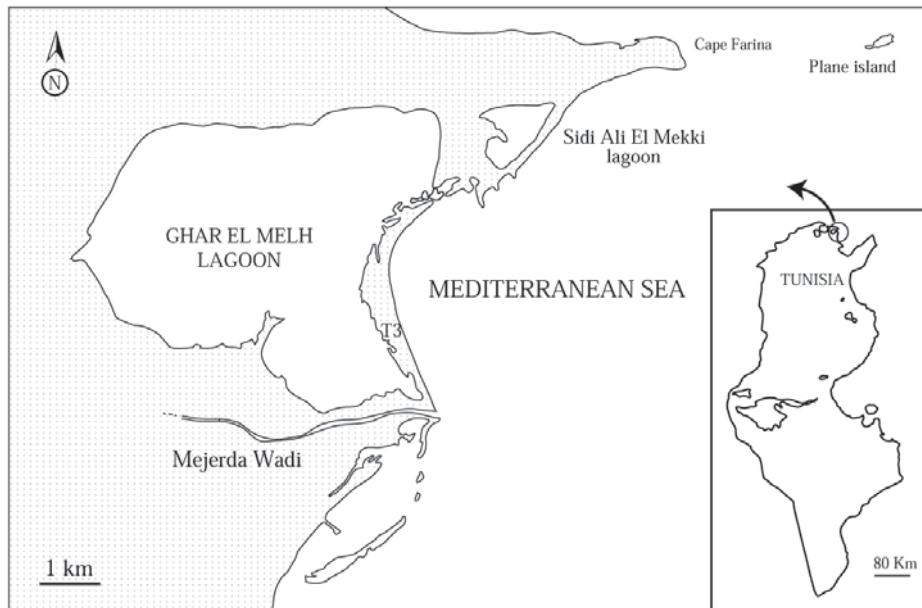
#### Site description

The Ghar El Melh lagoon is located in the north part of the Gulf of Tunis, between Ras Tarf (Cape Farina), and the estuary of Mejerda wadi (Fig. 1). This lagoon is 34 km<sup>2</sup> in size; it extends over a length of 7 km and a width of 4.5 km. The average depth is ca. 0.8 m with a maximum of 2 m. The bottom is relatively flat and muddy (Mansouri 1979). Before the deviation of the course of the Mejerda wadi the lagoon received sediments during periods of high water level in the river. Currently silting is less important and contains mainly urban effluents.

The lagoon is separated from the Mediterranean Sea by a small and fragile coastal strip. Exchange between the sea and the lagoon takes place in the east part of the lagoon through some small, 10 - 70 m wide channels. Gradually the number of channels has been reduced to only one, due to silting from the northern littoral of the Gulf of Tunis.

#### Water quality

Data describing the physical and chemical water parameters of the Ghar El Melh lagoon are available from Ktari-Chakroun & Romdhane (1984) and Romdhane (1985). Extreme values usually have a higher significance; indeed high annual climatic variation occurs in the Mediterranean basin (Tamisier & Boudouresque 1994). Annual rainfall varies from 336 to 936 mm (mean 576 mm). Mean monthly water temperatures are 9 to 11 °C from December to January, and 26 to 28 °C from July to August. In summer, high evaporation, caused by the hot weather and reduced connection with the open sea, lowers the water level and increases salinity. Mean values of salinity, with strong annual differences, vary from 32‰ in winter to 44‰ in summer with extreme values of 14‰ and 54‰ respectively in winter and summer. The salinity rises in an excessive way in



**Fig. 1.** Geographical position of the Ghar El Melh lagoon.

summer for lack of circulation of marine water, but decreases too much in winter through the contribution of continental water. Dissolved oxygen varies from 5.3 mg/l in summer to 8.9 mg/l in winter, and pH varies from 8.0 (winter) to 8.3 (summer). Phosphate varies from 0.5 to 2.1  $\mu\text{atg/l}$ . Concentrations of nitrate vary from 0.4 to 3.1  $\mu\text{atg/l}$ . For both phosphate and nitrate, highest values are recorded in autumn.

#### *Aquatic flora and vegetation*

In the early 1970s, the main aquatic plant community was formed by large monospecific beds of *Cymodocea nodosa* (Ben Alaya 1972). This species declined considerably and remained only in the east of the lagoon in the early 1980s (Romdhane & Ktari-Chakroun 1986). Between 1981 and 1983, the major part of the lagoon was covered by beds of *Zostera noltii* and *Z. marina* (Romdhane 1985; Romdhane & Ktari-Chakroun 1986). *Ruppia maritima* occurred mainly along the northern shorelines. The green alga *Caulerpa prolifera* formed mixed beds with *Zostera noltii* and was abundant in spring and summer in the east, the centre of the lagoon, and in the small lagoon of Sidi Ali El Mekki (Romdhane 1985). Nitrophilous algae such as *Ulva rigida*, *Enteromorpha intestinalis*, *Chaetomorpha linum* and algae of the genus *Cladophora* were relatively less frequent and appeared more particularly on the northern shores. Other sporadic species, e.g. *Bryopsis hypnoides* and *Acetabularia acetabulum* appeared seasonally (Romdhane & Ktari-Chakroun 1986).

#### *Present situation*

During the last few years the Ghar El Melh lagoon has been affected by the progressive restriction of seawater exchange (Menif 2000). This factor, with its various natural and anthropogenic interferences, such as pollution and silting, contributed to the alteration of the water and sediment quality, resulting in a decrease in biodiversity.

To meet this situation, the Tunisian Government launched a multi-field study in order to rehabilitate the ecosystem of the lagoon. A scientific program was set up in 1999-2000 in order to (1) summarize the existing data, (2) examine the functioning and evaluate the richness of the whole ecosystem, (3) develop management proposals aimed at preventing a full loss of the aquatic ecosystem due to change in hydrodynamics, and (4) predict changes likely to occur in the near future after the completion of the proposal restoration project.

As part of the global rehabilitation program 'Study of the amelioration of the water quality of the Ghar El Melh lagoon', this work deals with the distribution and affinities of macrophyte communities. The main objective of our study is to describe the development of the lagoon ecosystem and to collect useful data for monitoring and prediction as part of the ecological modelling.

## Methods

We have investigated the biodiversity and distribution of the dominant macrophytes in the Ghar El Melh lagoon through exhaustive prospecting campaigns covering the whole lagoon both during the summer and the winter seasons. Observations were made in 137 stations during August 1999 and 148 stations during February 2000 by describing 14 north-south transects (T1 to T14) and one east-west transect (T15).

The dominant phytobenthic communities were mapped with the help of a GPS (Global Positioning System). The delimitation by type of homogeneous communities was carried out by observations along several transects at ca. 500 m distance and according to a prospecting itinerary along the lagoon shoreline (Fig. 2).

## Results

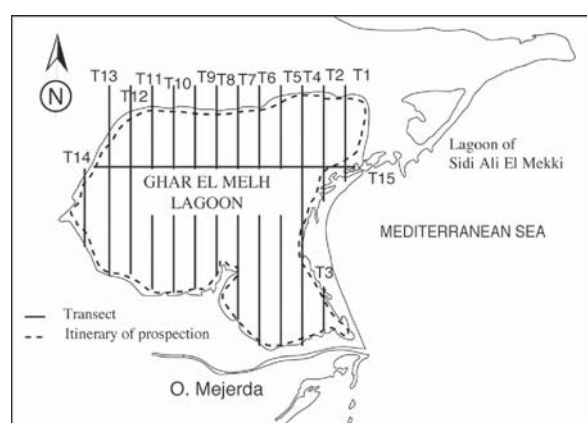
### *Species diversity*

In total 24 benthic macrophytes were observed in the Ghar El Melh lagoon, as reported in Table 1. The list contains for the most part seasonal macrophytes, including seven *Rhodophyceae* (red algae), two *Phaeophyceae* (brown algae), 11 *Chlorophyceae* (green algae) and four marine angiosperms.

### *Cartography of the phytobenthic communities*

Phytobenthic communities appear on almost the whole surface of the lagoon except on the western shoreline devoid of vegetation. The macrophytes are present on 96% of the area with rather variable covering rate from 0,1 to 100%. Phytobenthic communities are dominated by the angiosperm *Ruppia cirrhosa*, which appear in homogeneous or mixed beds covering 75% of the lagoon area, and by a filamentous green alga of the genus *Cladophora*. The latter is often found intermingled with the stems of *Ruppia* (Fig. 3).

During summer, the phytobenthic coverage reaches nearly 96% of the lagoon area and total cover of the species adds up to  $1.7 \times$  the surface of the lagoon. *Ruppia cirrhosa* shows a very large distribution, covering approximately 74 % of the lagoon area, with dense extensive meadows (80-100%). With an average covering density of 90%, *Ruppia* appears in almost all the lagoon area, except for the western part. Several *Cladophora*'s have also a large distribution, covering approximately 84% of the total area but with an average covering density of 46%, definitely less important than that of *Ruppia*. The *Cladophoras* appear especially at the central and eastern part of the lagoon. With regard to other



**Fig. 2.** Transects and itinerary for prospecting phytobenthic communities in the Ghar El Melh lagoon.

less dominant species, we note the presence of *Ulva rigida* whose distribution is limited to the northern littoral of the lagoon, in particular the sectors prone to a strong influence of urban effluents. *Caulerpa prolifera* develops in the North Eastern sector submitted to marine influence. *Cymodocea nodosa* and *Nanozostera noltii* appear only sporadically in a small sector influenced by seawater. We also note the presence of tufts of *Dasya* and *Rhizoclonium* covering surfaces of 0.8 and 0.4 km<sup>2</sup>, respectively. Areas devoid of benthic plants cover nearly 1.4 km<sup>2</sup>.

During the winter season, plant cover is almost constant, with an extension of ca. 32.7 km<sup>2</sup>, while the total cover of all species together reached  $1.9 \times$  the surface of the lagoon. In addition, we observed important changes on the community level as compared with the summer of 1999. Although the distribution of *Ruppia* beds was relatively broader, the density of the plants decreased considerably. In parallel, *Cladophora* experienced a more important extension and was found on nearly 94% of the surface of the lagoon.

**Table 1.** List of benthic macrophytes species observed in Ghar El Melh lagoon in comparison with previous studies: (1) Ben Alaya (1972); (2) Prunus et al. (1978); (3) Romdhane (1985) and Romdhane & Ktari-Chakroun (1986).

Species list	Present study		Previous studies		
	Summer	Winter	(1)	(2)	(3)
<b>Rhodophyceae</b>					
<i>Ceramium</i> spec.	X				
<i>Gracilaria gracilis</i> (Stackhouse) Steentoft, L. M. Irvine & Farnham	X				
<i>Dasya</i> spec.	X	X			
<i>Hypnea musciformis</i> (Wulfen) Lamouroux	X				
<i>Herposiphonia secunda</i> forma <i>tenella</i> (C. Agardh) M.J. Wynne		X			
<i>Polysiphonia sertularioides</i> (Grateloup) J. Agardh		X			
<i>Sphaerococcus coronopifolius</i> (Goodenough & Woodward) Stackhouse		X			
<b>Phaeophyceae</b>					
<i>Halopteris filicina</i> (Grateloup) Kützing		X			
<i>Dictyopteris membranacea</i> (Stackhouse) Batters	X				
<b>Ulvophyceae</b>					
<i>Acetabularia acetabulum</i> (Linnaeus) P.C. Silva	X				X
<i>Bryopsis hypnoides</i> Lamouroux					X
<i>Caulerpa prolifera</i> (Forsskål) J.V. Lamouroux	X	X	X		X
<i>Chaetomorpha linum</i> (O.F. Müller) Kützing	X	X		X	X
<i>Derbesia</i> spec.		X			
<i>Cladophora rupestris</i> (Linnaeus) Kützing	X	X			X
<i>Cladophora</i> spec. plur.	X	X		X	
<i>Codium bursa</i> (Linnaeus) C. Agardh					X
<i>Enteromorpha torta</i> (Mertens) Reinbold		X			
<i>Enteromorpha intestinalis</i> (Linnaeus) Link	X	X			X
<i>Enteromorpha linza</i> (Linnaeus) J. Agardh		X			
<i>Ulothrix</i> spec.					X
<i>Rhizoclonium</i> spec.	X	X			
<i>Ulva rigida</i> C. Agardh	X	X		X	X
<b>Angiosperms</b>					
<i>Cymodocea nodosa</i> (Ucria) Ascherson	X	X	X	X	X
<i>Ruppia cirrhosa</i> (Petagna) Grande	X	X			
<i>Ruppia maritima</i> L.	X	X			X
<i>Zostera marina</i> L.				X	X
<i>Nanozostera noltii</i> (Hornemann) Tomlinson & Posluzny	X	X	X		X

## Discussion

In comparison with the species listed previously from the same locations in the Ghar El Melh lagoon (Ben Alaya 1972; Prunus et al. 1978; Romdhane 1985; Romdhane & Ktari-Chakroun 1986) which included 13 species of submerged macrophytes, the species diversity has increased considerably with 24 species at present; the newcomers are for the most part seasonal macrophytes (Table 1). The quantitative relations between the species have changed as well. These changes can be related to the hydrological and sedimentary modifications of the lagoon ecosystem, affecting the water quality and the bottom of the lagoon.

There is another difference between the situation of the early 1980s and that of today: the proliferous extension of the green nitrophilous algae that prefer eutrophic water with weak hydrodynamics (Belkhir 1980).

The green benthic algae (*Chlorophyceae*) with euryhaline and nitrophilous affinities, notably found in

the genera *Ulva*, *Enteromorpha*, *Chaetomorpha* and *Cladophora* build up a large amount of phytomass in the nutrient-rich parts of the lagoon, particularly in the shallow zones (Zaouali 1974; Menez & Mathieson 1981; Belkhir 1984; Ben Maïz et al. 1987; Ben Maïz 1993; Shili 1995; Shili et al. 2001; Trabelsi et al. 2001). The extension of these species followed the reduction of the exchange between the lagoon and the open sea (Romdhane 1985). Indeed, the growth and density of the nitrophilous algae are basically a function of the degree of eutrophication and the attenuation of the current water velocity. These conditions are found in the centre, western and southeastern parts of the lagoon where the circulation of water is slow and the water is charged with nutrients.

The present spatial distribution of several species shows significant changes in the dominant species in comparison to the state observed previously. *Nanozostera noltii* occupies only small areas, limited to the east of the lagoon. *Ruppia* and *Cladophora* which were concentrated



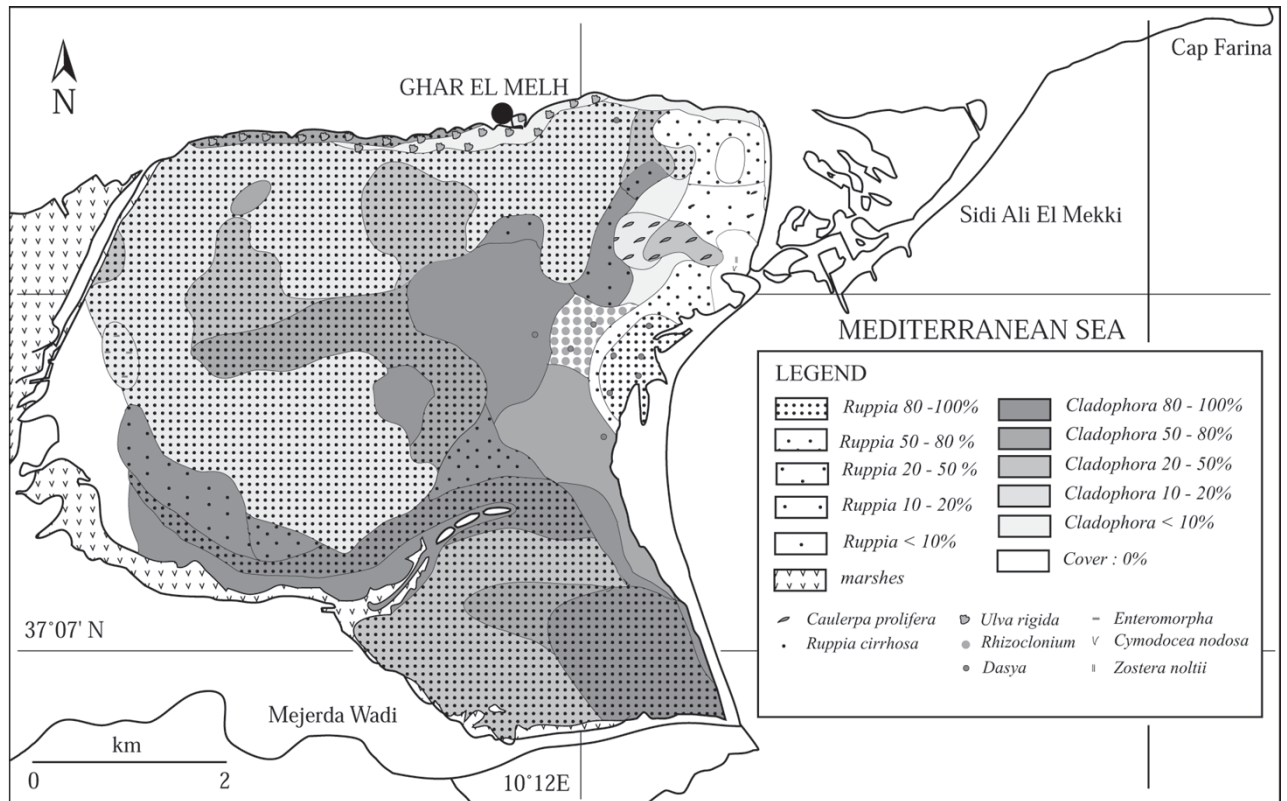


Fig. 3. Distribution of phytobenthic communities in the Ghar el Melh lagoon; August 1999.

along the northern shorelines are actually distributed everywhere in the lagoon. In addition to these transformations, various modifications were noted in the dominant communities:

1. *Cymodocea nodosa* which was abundant in the early 1970s (Ben Alaya 1972), is currently found in only very reduced areas exposed to marine influence.

2. *Caulerpa prolifera* which was abundant in the east and the centre of the lagoon occupies now only a few small areas. The mixed beds of *Zostera-Caulerpa* described by Romdhane (1985) in the southeastern sector left their place to *Ruppia* and dense tufts of *Cladophora*. In fact, *Caulerpa prolifera* which grows at different depths, is regarded as very sensitive to fluctuations in salinity (Pérès 1967; Meinesz 1980).

3. Nitrophilous algae such as *Ulva rigida*, *Enteromorpha intestinalis*, *Chaetomorpha linum* and algae of the genus *Cladophora* are currently extending and more abundant in the lagoon.

4. Other rare species such as *Bryopsis hypnoides* and *Acetabularia acetabulum* which appeared seasonally, are further expelled from the lagoon.

5. The current conditions and the reduction of the marine influence in the lagoon are rather favourable for

the development and the extension of *Ruppia* which replaced *Zostera*. Obviously, the diversification of the benthic macrophytes is reduced and the progression of green nitrophilous algae is stimulated. Their density indicates the degradation of water quality of the lagoon.

The improvement of the water quality of the lagoon and thus of the biodiversity will depend on the control of the sources of pollution, the increase in the exchanges between the lagoon and the sea, the improvement of the hydrodynamic conditions in the lagoon, and the correction of the shoreline of the banks, this in order to avoid the stagnation of water in some refuges favourable to accumulation of green algae along the north shorelines.

Restoration of the Ghar El Melh lagoon should first of all facilitate the exchange of water with the Mediterranean Sea and the circulation of water inside the lagoon, in particular in the sensitive zones, which experience critical situations in summer at the time of the massive dieback of the nitrophilous algae. Improved water quality will stimulate the phytobenthic communities. We must urgently preserve the marine communities already existing in the northeast of the lagoon while hoping for a faster restoration of this ecosystem.

**Acknowledgements.** The authors are particularly grateful to Mr. Lotfi Bacchar, head of the office of 'Eco-Ressources International' for his invaluable assistance.

## References

- Belkhir, M. 1980. *Eutrophisation du lac de Tunis: Etude physico-chimique et biomasses phytoplanctonique et macro-algale*. Thèse 3ème cycle, Faculté des Sciences, Tunis, TN.
- Belkhir, M. 1984. Dynamique des peuplements algaux dans le lac de Tunis. *Bull. Inst. Natl. Tech. Océanogr. Pêche Salammô* 11: 41-69.
- Ben Alaya, H. 1972. Répartition et condition d'installation de *Posidonia oceanica* Delile et *Cymodocea nodosa* Asherson dans le Golfe de Tunis. *Bull. Inst. Océanogr. Pêche Salammô* 2,3: 331-415.
- Ben Maïz, N. 1993. Evolution des peuplements phyto-benthiques après les travaux d'assainissement dans le lac Nord de Tunis. In: Boudouresque, C.F., Avon, M. & Pergent-Martin, Ch. (eds.) *Qualité du milieu marin. Indicateurs biologiques et physico-chimiques*, p. 89-104. Gis Posidonie Publications, Fr.
- Ben Maïz, N., Boudouresque, C.F. & Ouahchi, F. 1987. Inventaire des algues et phanérogames marines benthiques de la Tunisie. *Giorn. Bot. Ital.* 121: 259-304.
- Ktari-Chakroun, F. & Romdhane, M.S. 1984. Etude de quelques paramètres physico-chimiques de la lagune de Ghar El Melh. *Bull. Inst. Natl. Sci. Tech. Océanogr. Pêche Salammô* 11: 177-201.
- Mansouri, M.R. 1979. *Contribution à l'étude de la sédimentation littorale historique et actuelle au voisinage du delta de la Medjerda (Etude du Lac de Ghar El Melh et de la Sebkhia de l'Ariana)*. Thèse de spécialité, Université de Bordeaux I, FR.
- Meinesz, A. 1980. Contribution à l'étude des Caulerpales (Chlorophytes). Thèse de Doctorat, Université de Nice, Fr.
- Menez, E.G. & Mathieson, A.C. 1981. The marine algae of Tunisia. *Smithson. Contrib. Mar. Sci.* 10: 1-59.
- Menif, D. 2000. Les gobiidés des côtes tunisiennes: Morphologie et biologie de *Zosterisessor ophiocephalus* (Pallas, 1811) et *Gobius niger* Linnaeus, 1758. Thèse de Doctorat, Université de Tunis, TN.
- Pérès, J.M. 1967. Bionomie benthique dans le système phytal. *Rec. Trav. Stat. Mar. Endoume* 42 (58): 1-113.
- Prunus, G., Dridi, M.S. & Savoures, S. 1978. Les peuplements littoraux et leur intérêt écologique dans les milieux lagunaires du Nord de la Tunisie. *Bull. Off. Natl. Pêche Tunisie* 2 (1-2): 227-234.
- Romdhane, M.S. 1985. *La lagune de Ghar El Melh: milieu, peuplement, exploitation*. Thèse de 3ème cycle, Faculté des Sciences, Université de Tunis, TN.
- Romdhane, M.S. & Ktari-Chakroun, F. 1986. Les peuplements benthiques de la lagune de Ghar El Melh. *Bull. Inst. Natl. Sci. Tech. Océano. Pêche Salammô* 13: 95-108.
- Shili, A. 1995. *Contribution à l'étude des peuplements à Ruppia (Monocotylédone, Potamogetonaceae) dans le lac nord de Tunis*. D.E.A. Faculté des Sciences. Tunis, TN.
- Shili, A., Trabelsi, E.B. & Ben Maïz, N. 2001. Seasonal dynamics of macroalgae in the south lake of Tunis. In: Özhan, E. (ed.) *Proceedings of the Fifth International Conference on the Mediterranean Coastal Environment, MEDCOAST 01, 23-27 October 2001, Hammamet, Tunisia*, Vol. 2, pp. 933-944. Middle East Technical University, Ankara, TU.
- Tamisier, A. & Boudouresque, C.F. 1994. Aquatic bird populations as possible indicators of seasonal nutrient flow at Ichkeul Lake, Tunisia. *Hydrobiologia* 279/280: 149-156.
- Trabelsi, E.B., Shili, A. & Ben Maïz, N. 2001. Marine flora of the North lake of Tunis 12 years after its restoration. In: Özhan, E. (ed.) *Proceedings of the Fifth International Conference on the Mediterranean Coastal Environment, MEDCOAST 01, 23-27 October 2001, Hammamet, Tunisia*, Vol. 2, pp. 915-922. Middle East Technical University, Ankara, TU.
- Zaouali, J. 1974. *Les peuplements malacologiques dans les biocénoses lagunaires tunisiennes*. Etude de l'espèce pionnière *Cerastoderma glaucum* Poiret (1789). Thèse de Doctorat d'Etat, Université de Caen, FR.

Received 28 May 2002;

Accepted 9 December 2002.

Final version received 24 December 2002.

Coordinating Editor: C. Pergent-Martini.