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Seasonal dynamics of macro-algae in the South Lake of Tunis

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Abstract. The macro-algae communities observed in the south lake of Tunis are characterized by the predominance of nitrophilous algae which are in the order of biomass importance: *Ulva*, *Cladophora* and *Enteromorpha*.We have noted seasonal changes of alga distribution. The wind appears to be one of the most important factors influencing this distribution. The total biomass reaches a maximum in the spring. Rapid decomposition of the biomass leads to a severe ecological imbalance, resulting in crises of anoxia and fish death.

A restoration project has already started. It aims at removal of contaminated muds and the introduction of a new circulation system.

The main objectives of this work were to collect information on the distribution and biomass of the phytobenthic communities as a first step in the constitution of a database for further comparison.

Keywords: Alga; Biodiversity; Biomass; Cartography; *Cladophora*; Eutrophication; Restoration; *Ruppia*; *Ulva*.

Introduction

The lagoon of Tunis, located in the North of Tunisia (Fig. 1), has been considered as one of the most eutrophicated lagoons of the Tunisian coast (Zaouali 1977; Caumette 1985). A fairway divides this lagoon into two parts commonly known as the South Lake and the North Lake of Tunis. This northern part of the lagoon was the subject of cleansing and bank restoration (Van Berk & Oostinga 1992). The success of this project (achieved in 1988) that led to an improvement of water quality and biological diversity (Shili 1995; Trabelsi et al. 2001), encouraged the Tunisian authorities to start a similar cleansing project in the South Lake. This part of the lagoon is 1100 ha in size. Its average depth ranges from 0.5 to1.0 m. Marine water from the Mediterranean Sea enters the lagoon via the Rades Canal. Continuous pollution by sewage and waste dumping into the lake had led to a proliferous algal development, bacterial contamination, fish kills and offensive smells during summer days (Zaouali 1977; Belkhir 1983).

Studies undertaken in the past of the flora of the South Lake of Tunis are scarce and often fragmentary. Thus, we have little indication of the original composition of the phytobenthic communities, their distribution, and their seasonal pattern (Heldt 1929; Belkhir 1980). The majority of studies were mostly related to the North Lake of Tunis (Belkhir 1984). Until the 1980s, these studies reported a progressive degradation of the benthic flora resulting in a species-poor community dominated by nitrophilous species of the genera *Ulva* and *Enteromorpha* (Menez & Mathieson 1981; Ben Maïz et al. 1987; Ben Maïz 1993). One of the few observations on the flora of the South Lake of Tunis (Shili 1995 unpubl.) described a predominance of *Ulva rigida* throughout the lake with a high algal cover in the northwestern and southeastern sectors.

In the marshy zones, located at the southern shore of the lake, *Ruppia maritima* formed mixed beds with the dominant green alga *Enteromorpha intestinalis* (Shili 1995).

The present study, carried out between March 1996 and February1997, deals with qualitative and quantitative seasonal variability of the occurring macrophyte communities. It is integrated in a multidisciplinary project entitled 'Study of the water quality of the complex south lake, port of Tunis and fairway', and aims to describe the state of the south lake ecosystem before the cleansing and restoration works.

Methods

Seasonal mapping of the dominant phytobenthic communities was carried out using G.P.S. (Global Positioning System). Homogeneous communities were delimited upon visual inspection along several north-south transects. Phytomass was collected monthly at five stations (Fig. 1) in three sample plots of 0.5m × 0.5m and sorted per species in the laboratory. Fresh weight was determined for each species after washing with fresh water and dry weight after drying at 80°C during 24 hr. Total biomass of the dominant phytobenthos species was determined through extrapolation based on the total area occupied and the cover attained.

Results

Ten green algae (*Chlorophyceae*), two red algae (*Rhodophyceae*) and two flowering plants (*Angiospermae*) were identified:

Chlorophyceae

Ulva rigida C. Agardh
Enteromorpha linza (Linnaeus) J. Agardh
Enteromorpha compressa (Linnaeus) Nees von Esenbeck
Enteromorpha intestinalis (Linnaeus) Link
Enteromorpha spec.
Cladophora prolifera (Roth) Kützing
Cladophora dalmatica Kützing
Cladophora spp. plur.
Chaetomorpha linum (O.F. Müller) Kützing
Rhizoclonium spec.

Rhodophyceae

Gracilaria gracilis (Stackhouse) Steentoft, L.M. Irvine & Farnham
Gelidium spec.

Angiospermae

Ruppia cirrhosa (Petagna) Grande
Ruppia maritima L.

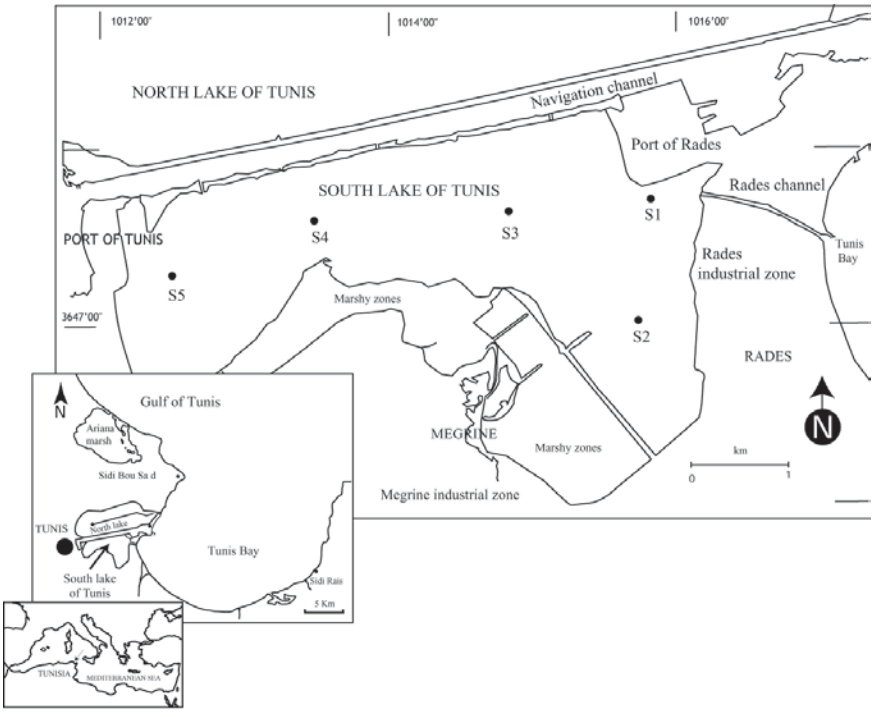

Fig.1. Geographical position of the South Lake of Tunis and location of the stations for phytomass sampling.

Ruppia cirrhosa was detected sporadically inside the lagoon; *Ruppia maritima* has been observed only in the southern marsh of the lagoon.

Several unidentified species of the *Chlorophyceae*, a species of *Cladophora* and an *Enteromorpha* species occur abundantly at the edges of urban-polluted zones, which are loaded with nutrients, whereas *Chaetomorpha linum* is observed only in the relatively sheltered zones and is not very frequent. *Rhizoclonium* spec. and *Cladophora dalmatica* occur often intermingled with other algae.

The *Rhodophyceae* are slightly nitrophilous but they developed only in zones under direct marine influence in the northern edges, primarily in the exchanges zones between the South Lake and the fairway. Their biomass is not very high.

Distribution of the phytobenthic communities

Results of the delimitation of the distribution areas of the dominant genera *Ulva, Cladophora* and *Enteromorpha* in the South Lake of Tunis during the four seasons are presented in Table 1. During the spring season *Ulva rigida* has its highest density in the southeast, centre and the north banks of the lagoon (Fig. 2). In the southwestern sector, where industrial waste is disposed, *Ulva rigida* is absent or present with low cover. With exception of the east sector, cover decreases generally from north to south. *Ulva rigida* occupied an area of 7.9 km^2 (71 % of the total lake area) with cover values from 10 to 100 %. Other *Chlorophyceae* cover small areas and are limited to the northeastern sector. *Cladophora prolifera*, for instance, occupies an area of only 0.3 km^2 (2.4 % of the total lake area).

In summer, *Ulva rigida* occurred with high densities in the northwest, the north banks, and the east near Rades Canal (Fig. 3), while in the spring *Ulva* was dominant in the west sector. At that time the south sector was abandoned. *Ulva* with cover values from 10 to 100 % occupied an area of 3.5 km^2 (32 % of the total lake area). The other *Chlorophyceae* cover small areas and are limited to the east sector.

Cladophora spec. plur. and *Enteromorpha* extend over an area of ca. 0.5 km^2 (4.5 % of the total lake area for each of the taxa). In the autumn of 1996, *Cladophora* spec. plur. extended over significant areas in the east and the central part of the South Lake. *Ulva rigida* was still present with high densities in the northwestern part and at the north banks of the lagoon. *Ulva* extended over an area of 3.6 km ^{2} (33 % of the total lake area) with cover values of 10 to 100 % (Table 1). During this period, *Cladophora* covered a rather significant area, ca. 7.2 km^2 (66 % of the total lake area), whereas *Enteromorpha intestinalis* was still confined to the western sector of the lagoon where it occurred only with low cover values.

Table 1. Seasonal distribution and variation of the phytomass of *Ulva, Cladophora* and *Enteromorpha* in the South Lake of Tunis.

Genus		Spring 1996		Summer 1996		Autumn 1996		Winter 1996-1997	
	Cover class (%)	Mean cover (%)	Area (km^2)	Mean cover (%)	Area (km^2)	Mean cover (%)	Area (km^2)	Mean cover (%)	Area (km^2)
Ulva									
	90 - 100	97	6.18	96	3.11	100	2.63	97	1.94
	50 - 90	70	0.85	78	0.07	70	0.30	80	0.97
	20 - 50	40	0.67	33	0.27	30	0.58	35	0.14
	10 - 20	13	0.18	10	0.01	12.5	0.09	10	0.01
Total area (km^2)			7.89		3.47		3.60		3.06
Biomass (dry weight tons)			1136		492		749		211
Cladophora									
	90 - 100	90	0.14	100	0.07	100	4.67	100	0.43
	50 - 90	50	0.07	60	0.11	71	0.21	75	0.99
	20 - 50	35	0	35	0	34	1.23	27	0.68
	10 - 20	15	0	15	0.30	10	1.14	13	0.03
Total area (km^2)			0.21		0.48		7.25		2.13
Biomass (dry weight tons)			10		22		394		63
Enteromorpha	90 - 100	-	0	-	0	-	0	-	0
	50 -90	-	0	-	0	-	0	-	0
	20 - 50	-	0	-	0	-	0	-	0
	10 - 20	20	0.20	17	0.41	-	0	-	0
Total area (km^2)			0.20		0.41		-		-
Biomass (dry weight tons)			1						
Total biomass (dry weight tons)			1147		514		1143		274

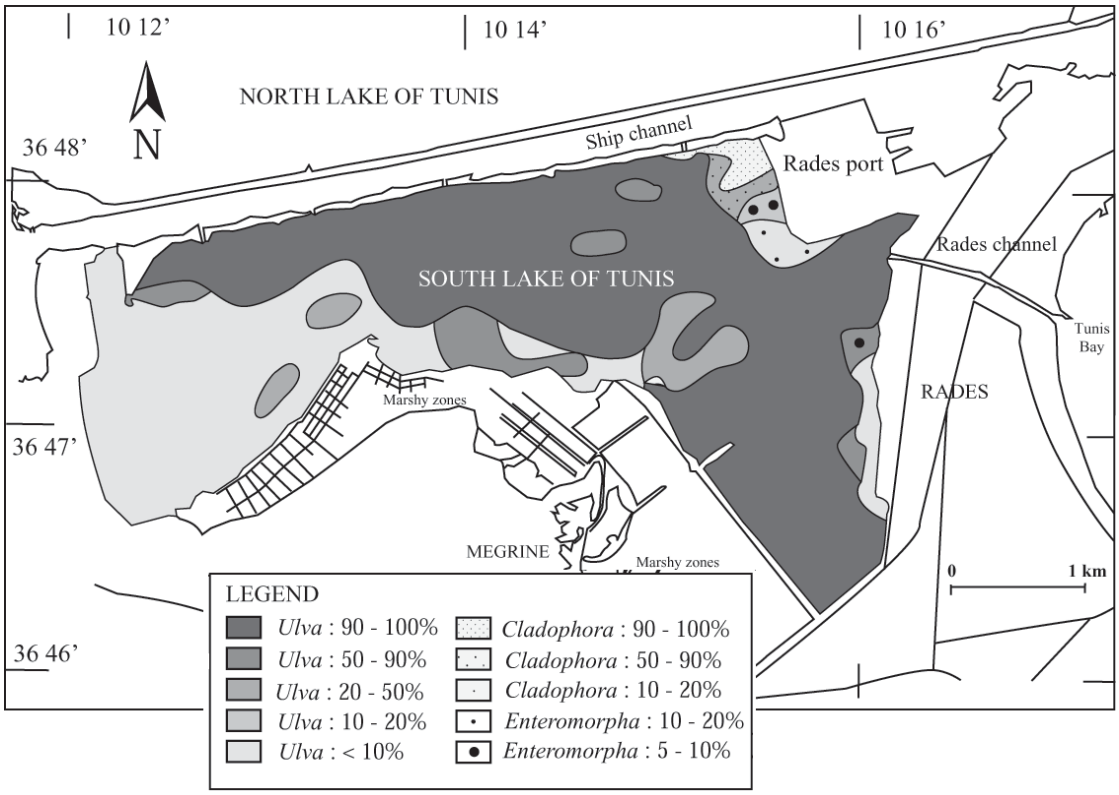

Fig. 2. Distribution of benthic macro-algae in the South Lake of Tunis during the spring of 1996.

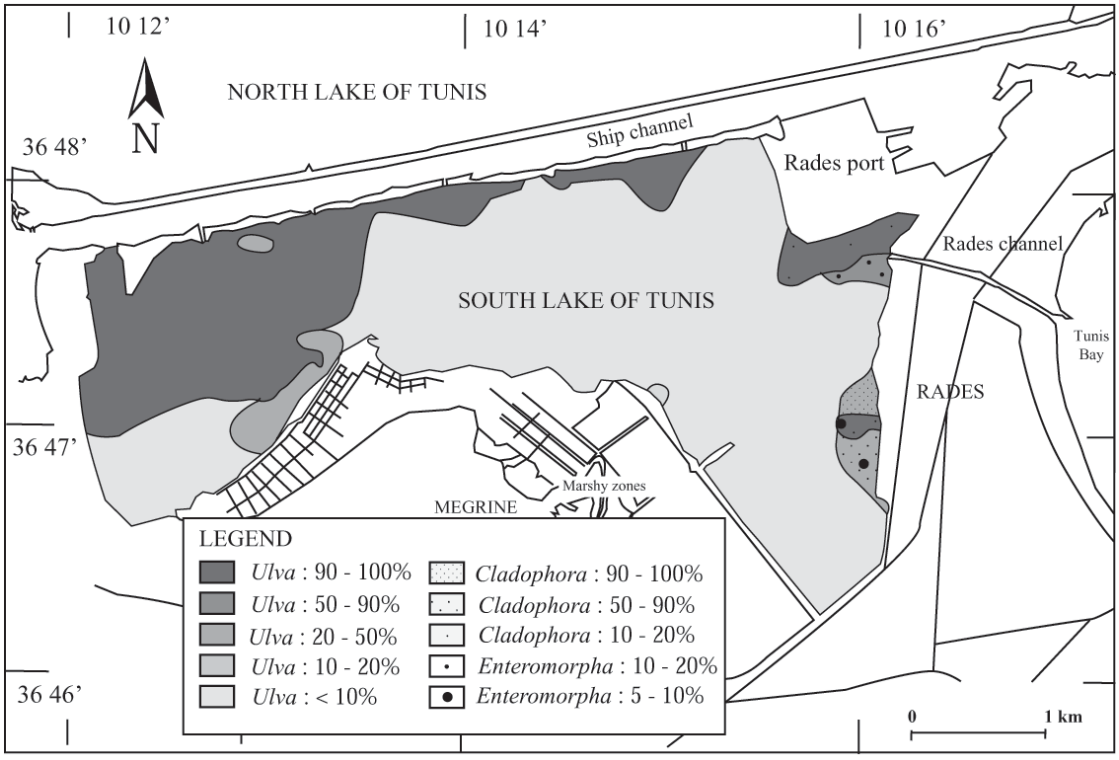

Fig. 3. Distribution of benthic macro-algae in the South Lake of Tunis during the summer of 1996.

Table 2. Seasonal development of mean phytomass of the macro-algae in three zones in the South Lake of Tunis.

	Total phytomass (g dry weight/m^2)							
	Spring		Summer		Autumn		Winter	
	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.	Mean	St.dev.
East Zone (stations 1, 2)	169.93	58.18	54.31	77.94	127.09	63.17	46.92	65.10
Central zone (stations 3, 4)	174.62	49.04	8.08	16.11	7.89	19.33	12.67	24.06
West zone (station 5)	12.08	14.64	81.29	29.40	210.49	115.83	44.11	18.35

In winter, the extension areas of most algae were reduced compared to the preceding seasons. *Ulva rigida* was limited to the northwestern sector and the north banks of the lagoon while *Cladophora* spec. plur. still occurred with significant cover at the east and the centre of the lagoon. *Ulva* showed significant cover (10 to 100 %) over an area of 3.1 km^2 (28 % of the total lake area) (Table 1). *Cladophora* covered an area which was relatively more reduced with an extension of only 2.1 km^2 (20 % of the total lake area). *Enteromorpha* was observed sporadically at the north banks of the lagoon. Thus, the extension area of *Ulva* in the southern lake of Tunis reached 7.9 km^2 in spring 1996, while in summer, it was reduced to 3.5 km^2, and then remained with a range of 3.0 - 3.6 km^2 in autumn and winter.

Phytomass

The macrophytes phytomass decreased in the beginning of the summer in all lagoon stations (Table 2), except for the western compartment. This decrease is very remarkable in the central stations. In autumn, extension of *Cladophora* in the east and the centre of the lagoon involved a large increase in phytomass. Towards the end of this season, the significant biomass of *Ulva* as observed in the western part of the lagoon during September showed a gradual decrease during winter.

The total phytomass of the dominant macro-algae of the South Lake of Tunis was evaluated for all four seasons. The results are presented in Table 1.

With regard to the spatial development, we note that the large biomass of macro-algae was affected in spring primarily in the southeastern zone of the lagoon, in summer in the western zone, in autumn in the east and west zones, and finally in winter in the northwestern zone.

Discussion

The phytobenthic communities observed in the South Lake of Tunis during our study (March 1996 - February 1997) are characterized by the predominance of three kinds of large nitrophilous green algae, which are in order of biomass importance: *Ulva, Cladophora* and *Enteromorpha*.

From spring to summer, an important modification has affected the distribution of macro-algae. Indeed, in the south sector, *Ulva* has strongly decreased, whereas in the western sector, which was almost deprived of vegetation, we have noted a strong accumulation of *Ulva*. The wind appears one of the most important factors influencing this distribution.

During autumn, the distribution of *Ulva* showed a few modifications. Indeed, *Ulva* is still localized in the western part of the lagoon where it occurs with high densities. On the other hand *Cladophora* spec. plur. showed a proliferous extension and occurred with significant cover in the east sector, the centre and the north banks of the lagoon. However, in the west of the lagoon the cover remained low. In autumn, the extension area of *Cladophora* (66% of the total lake area) largely exceeded that of *Ulva*.

Cladophora, which covered a reduced area during spring and summer with *Enteromorpha*, has significantly extended in autumn, but diminished in winter. From autumn to winter, the algal cover has decreased and *Ulva* reached its minimum extension. Large variation in the distribution of *Ulva rigida* was also reported from other Mediterranean lagoons, notably the North Lake of Tunis (Belkhir 1984; Ben Maïz 1993) and the Venice lagoon (Sfriso & Marcomini 1996). In the central part of this latter lagoon a remarkable regression of *Ulva rigida* was reported since 1990. Climatic changes are supposed to have triggered the progressive reduction of *Ulva* cover and production, with 80% in 1993 and 95% in 1995 until its almost complete disappearance in 1996 (Sfriso & Marcomini 1996).

Total spring biomass was estimated as 1147 tons of dry weight, which is about the same as the autumn value of 1143 tons but much higher than the summer and winter values, which are 514 and 274 tons, respectively.

However, we note that from spring to summer, the total biomass of the macro-algae was reduced by almost 55%. The phytomass loss was found to be 633 tons of dry weight. The decomposition of such biomass causes anaerobic conditions over large areas which results in the release of nauseous odours from H_2S, hydrogen sulfide (Stirn 1966).

Under normal conditions (excluding depression periods) and during the summer, *Ulva rigida* was able to double its weight and reach its optimal growth in 4 to 10 days (Belkhir 1980). During the summer of 1976 in the North Lake of Tunis, a considerable biomass development was observed from July onwards. The appearance and further development of floating thalli at the water surface increased when the insolation increased and the water transparency became low (Belkhir 1980; Belkhir & Hadj Ali Salem 1981).

Analysis of hydroclimatic and physico-chemical parameters and anthropogenic factors enabled us to explain the dynamics of algae communities in the South Lake of Tunis. In March we observed a significant extension of *Ulva* all over the South Lake, except for the western part. This sector received directly used water and excesses of rainwater coming from the Onas Canal (which surrounds the North Lake of Tunis). Fresh water induced a dramatical decrease in salinity below the average value of 3.4%, primarily in the western sector of the lake where 1.8% was measured in February 1996. This may explain the absence of *Ulva* in this sector. Indeed, *Ulva* developed only if salinity remains above 20 g/l but it prefers high concentrations of ammonium nitrogen (Schneider 1977; Belkhir 1980).

The extreme southwest of the lagoon is influenced by communal and industrial effluents in addition to run-off waters. In this sector, we note the absence of macro-algae the year round. Even *Enteromorpha*, which could be found in zones of direct discharge, despite its capability to resist low salinity (Zaouali 1974), was not found.

By the first week of June 1996, *Ulva* appeared in a state of degradation while the transparency of water was very low (the ratio transparency/depth does not exceed 0.50 in all the lake stations). Then, the floating mass of algae, which formed a 'green tide' on the water surface in the southeastern sector of the lake, disappeared completely. A part of the *Ulva* vegetation degraded on the spot but the greater part was degraded further after having been transported by the currents towards the northwest banks of the lake. Two weeks later, the south lake experienced an imbalance of the lagoon ecosystem; the growth of *Ulva* was stopped, probably because of lack of incidental light (due to an excessive growth of phytoplankton). The high temperatures recorded during the summer season facilitated the degradation of algal biomass whose decomposition requires a very high consumption of dissolved oxygen. This led to anoxia, red water phenomenon (due to the proliferous extension of microalgae), release of bad smells, and death of small fishes. A similar phenomenon was described for the Venice lagoon. During the 1980s the 'bloom' of *Ulva rigida* had a dramatic effect on the lagoon ecosystem and became an important nuisance to man and his activities. The biomass of this green macro-alga, in certain areas with a slow water renewal, reached

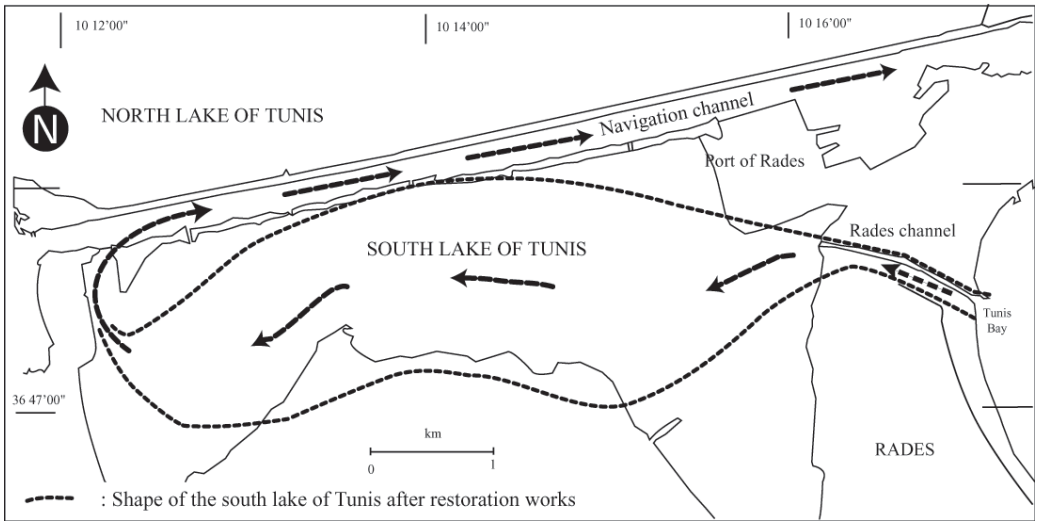

Fig. 4. The morphology of the South Lake of Tunis (Anon. 1991) and the direction of water circulation envisaged by the restoration model.

values higher than 10 kg fresh weight/m^2 (Ravera 2000). As a result, only a few tolerant and opportunistic species could become very abundant and replace the most sensitive species, causing a progressive decline in species diversity. This in its turn affected the use of the lagoon as a natural resource for fishing (Runca et al. 1996; Ravera 2000).

Ecosystem development after completion of the restoration project

The project of cleaning and restoration of the South Lake of Tunis aims at:
1. Stopping all the sources of harmful effects;
2. Dredging the narrow Rades Canal connecting the lake to the Bay of Tunis;
3. Dredging the lagoon bottom;
4. Modification of the shape of the banks to avoid water stagnation (by banking the sensitive zones favourable to accumulation of green algae along the shorelines). The grounds gained at the expense of the lagoon area will be used to extend the urban part of the cities Tunis and Rades;
(5) Introduction of a new mode of water circulation, i.e. a circulation with a single direction which functions through the natural system of the tides – similar to the model effective in the North Lake of Tunis (Van Berk & Oostinga 1992). The supply of marine water proceeds through the Rades Canal, while the release proceeds through the fairway (Fig. 4).

The new conditions arising from the restoration will induce transformations in the nature and distribution of the phytobenthic communities. We cannot deal with the future of the South Lake ecosystems without considering the impact of the cleansing of the North Lake of Tunis. After the restoration of the North Lake Ben Charrada (1992), Ben Maïz (1993), Shili (1995) and Trabelsi (1995) described an improvement in its ecosystem related to a radical transformation of the dominant phytobenthic communities. Nitrophilous species almost completely disappeared, while the nitrophilous *Ulva rigida* was replaced by the less nitrophilous *Chaetomorpha linum*. At the same time the phanerogams *Ruppia cirrhosa, Zostera noltii* and *Cymodocea nodosa* reappeared (Shili 1995; Trabelsi et al. 2001).

The change in the hydrological regime is one of the causes involving the modification of the chemical and biological characteristics of the coastal lagoons (Comin et al. 1990, 1991). *Ruppia* which includes opportunistic and not very competitive species (Verhoeven 1979) was found in the North Lake of Tunis after the cleansing because of the favourable conditions (turbidity and salinity in the tolerance ranges) which were formed. It developed initially in the east zone, then progressed and extended in all the north sectors of the lake (Shili 1995).

The composition of the plant communities also changed in relation to the renewal of the water conditions, with communities dominated by *Ruppia* and *Cymodocea* found only in the northeastern part of the lake. Communities with *Ruppia* alone or *Ruppia-Zostera* occurred in several places in the north part and communities with *Ruppia-Chaetomorpha* in the entire lake, with a prevalence of *Ruppia* in the north part and *Chaetomorpha* in the south part (Shili 1995). Thus, the appearance and development of the macro-algae are influenced by the currents and the nutrient contents of the water.

The restoration projected in the South Lake of Tunis are likely to involve hydrological modifications, notably an increase of the water level and current velocity. These transformations will induce modifications of salinity and the nutrient contents of water. Concerning the phytobenthic communities we hope for a significant reduction of the nitrophilous species and probably the disappearance of the species *Ulva rigida*. The water depth (ca. 2 m) and its good circulation do not allow an excessive development of the algae species. The phanerogam *Ruppia cirrhosa* will be able to develop and extend in the entire South Lake, as it was the case in the North Lake of Tunis. The development of *Ruppia cirrhosa* would be of great interest for the development of this ecosystem. This species is the subject of several experiments of transplantation with the aim to use it for the restoration of the lagoon bottom (Comin et al. 1990). Transplantation of *Ruppia* plants in this lagoon would be possible in order to accelerate the rehabilitation of this ecosystem.

References

Anon. 1991. *Etude d'aménagement du lac sud de Tunis, SERAH & SOTINFOR Rapport Général*. Direction des ports maritimes. Ministère de l'Equipement et de l'Habitat. Tunis, TN.

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. 1983. Notions d'hydrologie comparée dans le lac de Tunis et le Golfe de Tunis. *Bull. Inst. Nat. Tech. Océanogr. Pêche Salammbô* 10: 5-26.

Belkhir, M. 1984. Dynamique des peuplements algaux dans le lac de Tunis. *Bull. Inst. Nat. Tech. Océanogr. Pêche Salammbô* 11: 41-69.

Belkhir, M. & Hadj Ali Salem, M. 1981. Contribution à l'étude des mécanismes d'eutrophisation dans le lac de Tunis: évolution des paramètres physico-chimiques et biologiques. *Bull. Inst. Nat. Sci. Tech. Océanogr. Pêche Salammbô* 8: 81-98.

Ben Charrada, R. 1992. Le lac de Tunis après les aménagements. Paramètres physico-chimiques de l'eau et relation avec la croissance des macro-algues. *Marine Life* 1: 29-44.

Ben Maïz, N. 1993. Evolution des peuplements phyto-benthiques après les travaux d'assainissement dans le lac Nord de Tunis. pp. 89-104 In: Boudouresque, C. F., Avon, M. & Pergent-Martin, Ch. (eds.) *Qualité du milieu marin. Indicateurs biologiques et physico-chimiques,* 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.

Caumette, P. 1985. *Rôle des bactéries phototrophes et des bactéries sulfato-réductrices dans les milieux lagunaires*. Etudes et thèses. Edit. ORSTOM, Paris, FR.

Comin, F.A., Menendez, M.L. & Lucena, J.R. 1990. Proposals for macrophyte restoration in eutrophic coastal lagoons. *J. Hydrobiol.* 200/201: 427-436.

Comin, F.A., Menendez. M.L. & Martin, M. 1991. Short-term effects of decreasing water discharge on the chemical and biological characteristics of eutrophic coastal lagoons. *Mem. Inst. Ital. Idrobiol.* 48: 9-22.

Heldt, H. 1929. Le lac de Tunis (partie nord): résultats des pêches au filet fin. *Stat. Océanog. Salammbô* 2 : 1-76.

Menez, E.G. & Mathieson, A.C. 1981. The marine algae of Tunisia. *Smithson. Contrib. Mar. Sci.* 10: 1-59.

Ravera, O. 2000. The lagoon of Venice: the result of both natural factors and human influence. *J. Limnol.* 59: 19-30.

Runca, E., Bernstein, A., Postmac, L. & Di Silviod, G. 1996. Control of macro-algae blooms in the lagoon of Venice. *Ocean Coastal Manage.* 30: 235-257.

Schneider, W. 1977. *Bilan des substances nutritives du lac de Tunis 1976/1977*. Report Inst. Frésénius Gmbh, Minist. de l'Agriculture, Tunis, TN.

Sfriso, A. & Marcomini, A. 1996. Decline of *Ulva* growth in the lagoon of Venice. *Bioresourse Technol.* 58: 299-307.

Shili, A. 1995. *Contribution à l'étude des peuplements à Ruppia (Monocotylédone, Potamogetonaceae) dans le lac nord de Tunis*. D.E.A. (Diplôme d'Etude Approfondie) Faculté des Sciences, Université de Tunis, TN.

Stirn, J. 1966. *Lac de Tunis Nord. Assainissement, Tome I, Etude et recherche, première partie*. Rapport Ministère de l'Agriculture, Tunis,TN.

Trabelsi, E.B. 1995. *Contribution à l'étude des Chaetomorpha (algue Chlorophyceae) dans le lac nord de Tunis*. D.E.A. Faculté des Sciences, Université de Tunis, TN.

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 Cctober 2001, Hammamet, Tunisia*, Vol. 2, pp. 915-922. Middle East Technical University, Ankara, TU.

Van Berk, A.H. & Oostinga, H. 1992. North lake of Tunis and its shores: Restauration and development. *Terra Aqua* 49: 23-32.

Verhoeven, J.T.A. 1979. The ecology of *Ruppia* dominated communites in Western Europe. I.- Distribution of *Ruppia* representatives in relation to their autecology. *Aquat. Bot.* 6: 197-268.

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.

Zaouali, J. 1977. Le lac de Tunis: facteurs climatiques, physico-chimiques et crises dystrophiques. *Bull. Off. Natl. Pêch. Tunisie* 1 (1): 37-49.

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