Study of the abundance of phytoplankton and determination of physico-chemical parameters at Cape 7 Aftissat (Region of Boujdour, southern Morocco), between 2019 and 2020

M. LAMDAK, L. A. LRHORFI, B. BOUHADDIOUI, M. AOUJI
S. SMAINI, A. HAL ABERRHAMAN, R. BENGUEDDOUR

Biology department, Laboratory Natural Resources and Sustainable Development, Faculty of Science, Ibn Tofail University

Abstract

Phytoplankton occupies a primordial trophic position in the marine ecosystem and therefore constitutes a key element in its functioning. Its proliferation depends on several biotic, abiotic and environmental factors. Our study consists in determining the seasonal temporal evolution and the search for physico-chemical parameters determining the presence of taxa in Cape 7 (Aftissat).
The results obtained made it possible to identify 6 most abundant species throughout the year: Alexandrium sp, Dinophisis sp., Gymnodinum sp Pseudo-Nitschia sp Lingulodium sp. and Prorocentrium sp. These species are endowed with a poisonous power. However, the density is maximum during the warm months and correlated positively with the variation in temperature and negatively with the variation in nitrate and phosphate. A clear increase in density was observed between 2019 and 2020.

Key words: Phytoplankton – physicochemical parameters – density – toxic power – Aftissat

I. Introduction

Most of the water on the surface of the earth is contained in the oceans (70%), the rest is contained in the crusts (nearly 30%), in the Free State or combined with silicates, and very incidentally in ice, aquifers, rivers and lakes, organisms and air. This vital element brings added economic value to many sectors such as agriculture, energy production and industry (Gleick, 1993; Costanza et al., 1997). Many studies have shown that, as a result of human actions, aquatic environments are modified and sometimes degraded. The alteration of one of the parameters can lead to various phenomena such as eutrophication (Ferreira et al., 2011), the proliferation of phytoplankton, anoxia, food poisoning (Vazquez, 1998 ; Dokulil, 2001).
Phytoplankton occupies, in the marine ecosystem, a primordial trophic position and therefore constitutes a capital element (Brink et al., 1977; Blasco et al., 1980; Berrada et al., 2000).
Phytoplankton is an extremely diverse collection of microorganisms spanning over 7 orders of magnitude (Beardall et al., 2008). These microorganisms proliferate intensively, thus forming red, brown or green waters which can be sources of nuisance, reducing the transparency of the water and the concentration of dissolved oxygen, and leading to a loss of biodiversity at all trophic levels. Many studies have tried to understand or predict observed trends in marine phytoplankton biodiversity by associating them with environmental factors (Powell et al., 2017; Righetti et al., 2019).

Therefore, we conducted a field study covering a wetland at Cape Aftissat in the region of Laayoune-Boujdour-Sakia El Hamra. The objective of this study is to highlight the diversity of microphytoplankton species in this area, thus studying the effect of environmental factors on the spatio-temporal variation of phytoplankton communities.

II. Material and methods

1. Study area

The Cape 7 zone (Aftissat), located 62 km south of the city Boujdour (latitude: 25.6146° or 25°36'53" north; longitude: -14.683° or 14°40'59" west The geomorphology of the coast is characterized by the dominance of cliffs with a limited narrow beach.The climate is characterized during the summer by the dominance of the wind, which generates the activity of Upwellings, which results in the enrichment of the water in mineral matter. The surface temperature between 18.4°C north Cape Boujdour and between 18.4°C and 21.6°C south Cape Boujdour. In the deepest waters, outside the upwelling zone, the temperature reaches 20°C to 21.6 °C. Surface currents are induced by atmospheric circulation.

2. Species identification

The counting of phytoplankton is carried out according to the Utermöhl method and the observation is carried out in 10 mL sedimentation tanks under an inverted microscope, of the Leica DM IRB type, after sedimentation for 24 hours. The determination is made using appropriate systematic identification keys (Nezan and Piclet, 1996). Density results are expressed as number of cells per liter (cell/L).

3. Measurement of physicochemical parameters

The physical parameters (temperature, salinity and pH) were measured using a multi-parameter probe. Dissolved oxygen was determined by Winkler's chemical method. The samples intended for the analysis of nitrite, nitrate and phosphate were taken from the subsurface at a depth of approximately 0.5 m in polyethylene bottles, preserved in the dark at a temperature of approximately 4°C. They were assayed by colorimetry according to the protocols described by Aminot and Kerouel, 2004.

4. Statistical analyzes

The results are generally expressed as relative frequencies for qualitative variables and as mean ± deviation for quantitative variables. The differences were tested by Fisher (chi2 or ANOVA one way). The significance value is set at 5%. A principal component analysis was applied for the quantitative variables.

III. Results

1. Density of species recorded in the Aftissat area

The analysis of variance with a single classification criterion "season effect" and "year effect" did not show any significant difference either between the average seasonal densities or between the average annual densities and this for the species Alexandrium sp. ($t_{2019-2020}$=-0.148; p<0.876); Dinophysis sp. ($t_{2019-2020}$=-1.023; p<0.317) and; Gymnodinum sp. ($t_{2019-2020}$=-0.056; p<0.956). Indeed, the species Nitschia sp. and Prorocentrium sp are present all year round in the site with a slight increase during summer and autumn.. Indeed, in 2019, the density of Pseudo-Nitzschia sp. is gradually changing according to the seasons (r=0.954). It is maximum in autumn (n=1600) and minimum in winter (n=169). It is reversed in 2020, this density is maximum in spring and summer with densities of 5000 and 3166 respectively. The density therefore decreases according to the seasons (r=-0.30); (table 1).

Table (1). Temporal distribution of identified species

Year	Saison	Species					
		Alexandrium sp.	Dinophysis sp.	Gymnodinum sp.	Pseudo-Nitzschia sp.	Lingulodium sp.	Prorocentrium sp.
2019	Winter	**51(a)**	**15(a)**	**21(a)**	**160(a)**	**33(a)**	**30(a)**
	Spring	**93(a)**	**130(a)**	**217(a)**	**833(ab)**	**383(ab)**	**333(ac)**
	Summer	**83(a)**	**90(a)**	**350(a)**	**1533(b)**	**1266(b)**	**766(c)**
	Autumn	**110(a)**	**77(a)**	**293(a)**	**1600(b)**	**150(a)**	**2266(ab)**
	Moyenne	**85**	**78**	**220**	**1032**	**458**	**849**
	Fisher	**0,39 (p<0,75)**	**1,72 (p<0,24)**	**1,13 (p<0,39)**	**3,16 (p<0,05)***	**4,71 (p<0,035)***	**4,19 (p<0,047)***
2020	Winter	**70(a)**	**57(a)**	**103(a)**	**1100(a)**	**87(a)**	**193(a)**

	Spring	**113(a)**	**177(a)**	**270(a)**	**5000(b)**	**493(a)**	**390(a)**
	Summer	**93(a)**	**47(a)**	**327(a)**	**3166(ab)**	**400(a)**	**1600(a)**
	Autumn	**77(a)**	**157(a)**	**200(a)**	**2333(a)**	**190(a)**	**5333(b)**
	Moyenne	**88**	**109**	**225**	**2900**	**293**	**1879**
	Fisher	**0,28 (p<0,84)**	**3,58 (p<0,66)**	**0,97 (p<0,45)**	**7,11 (p<0,012)***	**2,73 (p<0,11)**	**11,80 (p<0,003)****

Abundance (nb cells / Liter)*100. *: significant difference; **: highly significant difference

In addition, the Fisher test shows significant differences between the average seasonal densities and between the years of study (2019 – 2020) for the species Prorocentrium sp., where average densities increase with the seasons, with correlation coefficients of r=+0.929) and r=+0.9 respectively). However, the average density of Lingulodium sp. Changes according to the seasons during 2019 (p<0.035) and remains stable during the year 2020 (p<0.11).

Table (2) presents the results of the classification of the identified species. Indeed, except for Pseudo-Nitzschia sp. (p<0.003), all other species showed no significant difference, although there is a trend for density to increase between 2019 and 2020, with a maximum variation of 181.01% recorded for Pseudo -Nitzschia sp. and a minimum change of 2.27% displayed for Gymnodinum sp. A reduction of 36% was marked for Lingulodium sp. On the other hand, the hierarchical classification of the different species identified has allowed them to be classified into three distinct groups according to their abundance (nb cell. / L): Alexandrium sp; Dinophysis sp.; Gymnodinum sp and Lingulodium sp. constitutes the first group, Prorocentrium sp. represents the second group and Pseudo-Nitschia sp constitutes the third group

Table (2). Evolution of planktonic species between 2019 and 2020

Species	**2019(a)**	**2020(b)**	**% réduction**	**Test t (p-value)**	**Classification group**
Alexandrium sp	85	88	-3,53%	(-0,158 ; p<0,876)	1
Dinophysis sp.	78	109	-39,74%	(-1,02 ; p<0,317)	1
Gymnodinum sp.	220	225	-2,27%	(-0,056 ; p<0,956)	1
Pseudo-Nitzschia sp	1032	2900	-181,01%	(-3,36 ; p<0,003)**	3
Lingulodium sp.	458	293	36,03%	(0,851 ; p<0,404)	1
Prorocentrium sp.	849	1879	-121,32%	(-1,35 ; p<0,192)	2

3 species among the 6 identified taxa are classified as having a high toxicity by most often producing phytotoxins. These unicellular micro-algae are Dinophysis, Prorocentrum and Pseudo nitzschia spp.

2. Physicochemical parameters

The knowledge of the marine environment is incomplete. Above all, temperature, salinity, oxygen content, phosphates and nitrates are evaluated. However, the factors influencing the ecology of planktonic forms are much more diverse and their interference impossible to grasp. The results of the parameter distribution is mentioned in Table (3).

Table (3). Description of the physico-chemical parameters in the Cape 7 zone (Aftissat)

Parameter	**Season**	**Average**	**Ecart Type**	**Minimum**	**Maximum**	**Fisher (P Value)**
Temperature °C	winter	17,0	1,3	16,0	19,0	23,593*** P<0,000
	spring	20,5	0,5	20,0	21,0	
	summer	22,3	0,8	21,0	23,0	
	autumn	19,2	1,6	16,0	20,0	
	Total	**19,8**	**2,3**	**16,0**	**23,0**	

Salinity ‰	winter	34,9	1,0	33,5	36,0	0,851 P<0,483
	spring	34,8	0,7	34,0	36,0	
	summer	34,4	0,5	34,0	35,0	
	autumn	34,3	0,8	33,0	35,0	
	Total	**34,6**	**0,8**	**33,0**	**36,0**	
Oxygen content mg/l	winter	9,5	0,4	9,0	10,0	0,285 P<0,835
	spring	9,8	0,4	9,5	10,5	
	summer	9,6	0,8	8,5	10,8	
	autumn	9,6	0,6	9,0	10,5	
	Total	**9,6**	**0,6**	**8,5**	**10,8**	
Nitrate µmol/l	winter	62,5	2,7	60,0	65,0	13,178*** P<0,000
	spring	54,2	5,8	45,0	60,0	
	summer	47,3	4,3	44,0	55,0	
	autumn	49,3	4,8	45,0	55,0	
	Total	**53,3**	**7,3**	**44,0**	**65,0**	
Phosphate µmol/l	winter	2,6	0,3	2,3	2,9	8,718** P<0,001
	spring	1,8	0,6	1,2	2,8	
	summer	1,6	0,2	1,3	2,0	
	autumn	2,2	0,3	1,8	2,5	
	Total	**2,1**	**0,5**	**1,2**	**2,9**	

Significant difference; **: highly significant difference; *: very highly significant difference**

The monthly distribution of the temperature recorded in the surface waters of the Aftissat site over the two years of study shows that the average annual temperature is 19.75 ± 2.25 C, with a minimum temperature recorded in winter (16 °C) and a maximum of 23 °C displayed in summer ($F= 23.59$; $p<0.000$). The mean monthly salinity distribution is 34.63±0.77‰ [Minimum=33 ‰; a maximum= 36 ‰] and a Fisher value=0.85 ($p<0.48$). As for the oxygen content mg/l, the average value is 9.63±0.55 mg/l, [min=8.5 and max=10.75] with an F value of 0.285 ($p<0.835$). Fisher's test shows a significant difference in mean nitrate µmol/l between the seasons ($F=13.18$, $p<0.000$) and between the years of the study ($F=3.04$; $p< 0.05$). The analysis of variance shows a highly significant difference between the seasons ($F=8.7$; $p<0.001$), with an interval of [1.20; 2.90 in winter]. The multiple correlation analysis between the parameters shows that the temperature is negatively correlated with Nitrate µmol/l ($r=-.680$; $p<0.000$) and Phosphate µmol/l ($r=-.717$; $p<0.000$), so that the latter two are positively correlated with each other ($r=0.578$; $p<0.003$).

3. Global analysis

For a global analysis of all the species identified and the physico-chemical parameters studied, we used PCA. The two axes 1 and 2 alone absorb 55.53% of the total variation. The projection of the variables in space 1 and 2 made it possible to distinguish two groups (figure 1):

* The first group is located on the positive side of axis 1 and is characterized by the species Alexandrium sp., Dinophysis sp., Gymnodinum sp., Prorocentrium sp., and Pseudo-Nitzschia sp. whose presence depends positively on the variation, the temperature and negatively on the variation of the nitrate content,

* The second group located on the positive side of axis 2 is characterized by Lingulodium sp. Its presence depends positively on the oxygen content.

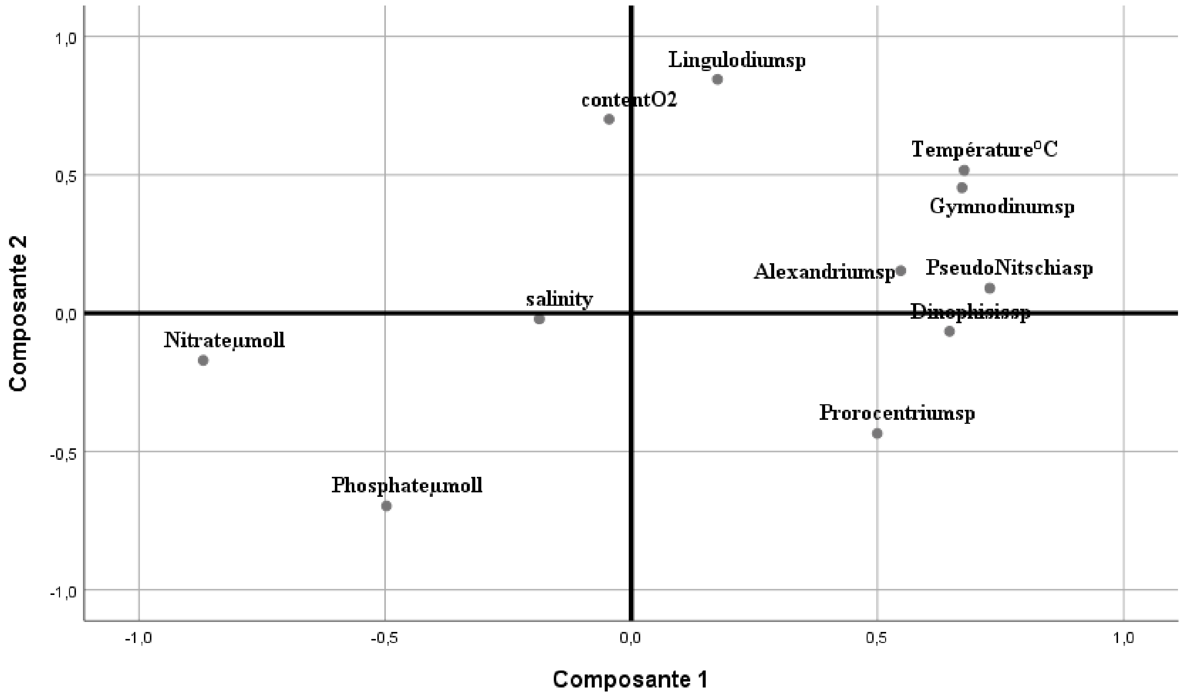

Figure (1). Présentation in ACP

Table (4) presents the two-by-two correlations between the species and the physical and chemical parameters. In effect,

- The species Alexandrium sp. and Dinophysis sp. Are not significantly correlated with any parameter.
- The density of Gymnodinum sp and Pseudo-Nitzschia sp. is positively correlated to temperature variation and negatively to nitrate and phosphate variation
- The abundance of Lingulodium sp. Is positively associated with variation in temperature and oxygen content and negatively correlated with variation in nitrate and phosphate
- The evolution of Prorocentrium sp. depends negatively on the variation of nitrate**.**

Table (4). Correlation between physico-chemical parameters and identified species

Species	Temperature °C	Salinity ‰	Teneur en Oxygen content mg/l	Nitrate µmol/l	Phosphate µmol/l
Alexandrium sp.	0,257 (p<0,226)	-0,118 (p<0,583)	0,188 (p<0,379)	-0,294 (p<0,163)	-0,220 (p<0,301)
Dinophysis sp.	0,320 (p<0,127)	0,130 (p<0,546)	0,139 (p<0,516)	-0,296 (p<0,160)	-0,199 (p<0,350)
Gymnodinum sp.	,580** (p<0,003)	-0,206 (p<0,335)	0,330 (p<0,116)	-,647** (p<0,001)	-,507* (p<0,011)
Pseudo-Nitzschia sp.	,487* (p<0,016)	0,051 (p<0,811)	-0,089 (p<0,679)	-,663** (p<0,000)	-,546** (p<0,006)
Lingulodium sp.	,554** (p<0,005)	0,068 (p<0,753)	,455* (p<0,026)	-0,395 (p<0,056)	-,669** (p<0,000)
Prorocentrium sp.	0,181 (p<0,398)	-0,226 (p<0,287)	-0,127 (p<0,553)	-,457* (p<0,025)	0,049 (p<0,819)

IV. Discussion

The data show that the Cape7 of Aftissat (southern Morocco) is characterized by a diversified spectrum of planktonic species, such as Pseudo-Nitzschia, Alexandrium, Prorocentrum, Dinophysis, and Gymnodinum, most of which have a toxic power. These results are comparable to those found by Somoue et al. (2020) in the Oualidia, Lagoon, Morocco; in Algeria by Taleb and Noui (2011) and Benfiala et al. (2013). An increase in the biomass of the identified species was noticed in the site between 2019 and 2020. The presumed causes of this increase were the influxes of new nutrients in Cape 7. The seasonal variation shows a significant effect on the distribution of species especially in summer and in autumn. According to a study by Elghrib et al. (2022).

In terms of density, the south is more productive than the north of the study area; this is due to the almost permanent presence of permanent ascending currents (upwelling) which are at the origin of the enrichment of the zone in nutritive elements known as the phenomenon of eutrophication, (Makaoui et al., 2005; Garras, 2016). This is considered a determining factor in fish production (Binet 1991; Nieto et al., 2012). According to Minas et al., 1982, Cape Boujdor in Dakhla (26°N - 23°30'N) and between Capes Barbas and Blanc (22°N - 21°N), is a frontal zone where the waters meet, Central South Atlantic (ECSA), warm and rich in nutrient salts, and the Central North Atlantic Waters (ECNA) (Binet 1991; Makaoui et al., 2005), hence the richness of its phyto and zooplankton populations. Our work complements the study carried out on phytoplankton in the Cape Boujdor area in Dakhla.
On the other hand, and according to Berraho (2007) and in most phytoplanktons, reproduction is spread over the whole year with periods of more intense spawning, specific to each species. This is compatible with our results which affirm the presence of the identified species throughout the year with seasonal variations. In the summer period, planktonic populations are very abundant (Binet, 1991) this is in perfect agreement with our results.

V. References

Aminot, A. and Kérouel, R. (2004) Hydrology of marine ecosystems: Parameters and analyzes, Ifremer

Beardall, J., Allen, D., Bragg, J., Finkel, Z.V.,Flynn, K.J., Quigg, A.,Rees, T.A.V., Richardson, A. and Raven, J.A. (2008) Allometry and stoichiometry of unicellular, colonial and multicellular phytoplankton. New Phytologist, Tansley Review

Benfiala, Z., Mefatih, H. and Rouighi, Z. (2013) Contribution to the Determination of the Phytoplankton Community Inhabiting Méggarine Lake (Touggourt) License Thesis

Berrada, D., Berrada, F., Benzekri, A. and Jabry, E. (2000) Seasonal evolution of phytoplankton populations in the El Kansera lake-reservoir (Morocco), in relation to certain abiotic and biotic parameters Hydroecol. Appl., 12 (1–2), pp. 207-231

Berraho, A. (2007) Spatialized relationships between environment and ichthyoplankton of small pelagics of the Moroccan Atlantic coast (central and southern areas). Doctoral Thesis, Univ. Mohammed V, Rabat, 161 p.

Binet, D. (1991) Plankton dynamics in West African coastal waters : balanced and unbalanced ecosystems. West African fisheries. Ed. ORSTOM, 117-136

Blasco, D., Estrada, M. and Jones, B. (1980) Relations between the phytoplankton distribution and composition and the hydrography in the upwelling region near Cabo Corbeiro Deep-Sea Res., 27, pp. 799-821

Brink, K.H., Jones, B.H., VanLeer, J.C., Mooers, C.N.K., Stuart, D.W., Stevenson, M.R., Dugdale, R.C., Heburn, G.W. (1977) Physical and biological structure and variability in an upwelling center off Peru near 15 S during March

Costanza, R., Arge, R., de Groot, R., Stephen, F.K., Monica, G., Bruce, H., Karin, L., Shahid, N.R., O'Neill, V., Jose, P., Robert, G.R., Paul, S.K.K. and van den Marjan, B. (1997) The Value of the World's Ecosystem Services and Natural Capital. Nature, 387, 253-260

Dokulil, M., Chen, W. and Cai, Q. (2000) Anthropogenic Impacts to Large Lakes in China: The Tai Hu Example. Aquatic Ecosystem Health and Management, 3, 81-94

Elghrib, H., Somoue, L., Elkhiati N., Berraho, A., Makaoui, A., Bourhim, N., Salah, S., Ettahiri, O. (2012). Distribution of phytoplankton in the upwelling zones of the Moroccan Atlantic coast located between the latitudes 32°30′N et 24°N phytoplankton. Comptes Rendus Biologies ; Volume 335, Issue 8, Pages 541-554

Ferreira, J.G., Andersen, J.H., Borja, A., Bricker, S.B., Camp, J., Da Silva, M.C., Garcés, E., Heiskanen, A.S., Humborg, C., Ignatiades, L., Lancelot, C., Menesguen, A., Tett, P., Hoepffner, N. and Claussen, U. (2011) Overview of Eutrophication Indicators to Assess Environmental Status within the European Marine Strategy Framework Directive. Estuarine, Coastal and Shelf Science, 93, 117-131

Garras, S. (2016) Modeling of the trophic state of the Smir dam reservoir in Morocco. Mohammed V University - Agdal, Faculty of Sciences, Rabat

Gleick, P.H. (1993) Water Resources: A Long-Range Global Evaluation. Ecology Law Quarterly, 20, 141-149

Makaoui, A., Orbi, A., Hilmi, K., Zizah, S., Larissi, J. and Talbi, M. (2005) Plankton from Cape Boujdor-Cape Blanc. The upwelling of the Atlantic coast of Morocco between 1994 et 1998. C. R. Geoscience, 337, 1518-1524

Minas, H.J., Codispoti, L.A. and Dugdale, R.C. (1982) Nutrient and primary production in the upwelling region of Northwest Africa. Rapport Cons. Int. Explor. Mer, 180: 148 – 183

Nezan, E. and Piclet, G. (1996) Practical guide to the use of phytoplankton analyses. Ifremer, Department of the Environment and Coastal Development, 66 p.

Nieto, K., Demarcq, H. and Mc Clatchie S. (2012). Mesoscale frontal structures in the Canary Upwelling System: new front and filament detection algorithms applied to spatial and temporal patterns, Remote Sensing of Environment, 123, 339–346

Noui, M. and Taleb, R. (2011) Physico-Chemical Characteristic and Trophic Level of a Brackish Water Body (Méggarine Lake)

Powell, M.G. and Glazier, D.S. (2017) Asymmetric geographic range expansion explains the latitudinal diversity gradients of four major taxa of marine plankton, Paleobiology, 42, 196-208

Righetti, D., Vogt, M., Gruber, N., Psomas, A. and Zimmermann, N.E. (2019). Global patterns of phytoplankton diversity driven by temperature and environmental variability. Sci. Adv., 5, eaau 6253

Somoue, L., Demarcq, H., Makaoui, A., Hilmi, K., Ettahiri, O., Ben Mhamed, A., Agouzouk, A., Baibai, T., Larissi, J., Charib, S., Kalmouni, A. and Laabir, M. (2020) Influence of ocean - lagoon exchanges on spatio-temporal variations of phytoplankton assemblage in an Atlantic Lagoon ecosystem (Oualidia, Morocco). Regional Studies in Marine Science, 40, 101512 (14p.)

Vazquez, G. and Favila, M.E. (1998) Status of the Health Conditions of Subtropical Atezea Lake. Aquatic Ecosystem Health and Management, 1, 245-255