

The influence of the environment on the diversity of *Euglena* species and their abundance in the lagoon of Nador-Morocco

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Abstract. The main objective of this work is to study the spatial and temporal evolution and distribution of *Euglena* species in the Nador lagoon. The study is based on four sampling stations and covers two specific seasons, namely spring and summer 2018. Euglenes belonging to the genus *Euglena* are particularly interesting and well known in the field of research, due to their great diversity in terms of pigmentation, size and morphological characteristics. Samples taken at each of the four sampling stations were carefully identified morphologically using an inverted light microscope. In total, five species belonging to the genus *Euglena* were identified, namely: *Euglena viridis* O.F.Müller 1786, *Euglena Caudata* Hübner 1886, *Euglena Proxima* P.A.Dangard 1902, *Euglena tuberculata* Svirenko 1915, *Euglena* sp. Quantitative analysis of the species collected reveals some interesting results. The maximum cell density was recorded at station 4, located near the wastewater treatment plant, with a value of 55 cells per litre during the summer of 2019. In contrast, the minimum cell density was recorded at the same station 4, corresponding to Kariat Arekmen, with a value of 5 cells per litre during the spring period of 2019. These observations highlight significant variations in *Euglenes* cell density depending on geographical location and season. Keywords: Evolution, Distribution, genus *Euglena*, *Euglenes*, lagoon of Nador, Morocco.

1 Introduction

Euglenoid species diversity and abundance are fundamental aspects of the biodiversity of aquatic ecosystems. Euglenes are single-celled organisms belonging to the euglenoid group (Euglenophyta) and are present in a wide range of freshwater and saltwater habitats worldwide [1]. They play a crucial role in food webs, biomass production, and community dynamics [2]. Euglenoid species diversity refers to the variety of species present in a given habitat. Each euglenoid species has unique characteristics that enable it to adapt to specific conditions, such as nutrient availability, temperature, salinity, light and other environmental factors [3,4,5]. Consequently, the diversity of euglenoid species is influenced by the range of environmental conditions present in a particular ecosystem [6]. The abundance of euglenoid species refers to the relative quantity of each species within a given population [7]. Some euglenoid species may be more abundant than others due to their ability to exploit available resources efficiently, resist predators, or reproduce rapidly [8]. The abundance of euglenoid species can vary over time and space, depending on environmental fluctuations and biological interactions [9]. Understanding the diversity and abundance of euglenoid species is of great ecological and scientific importance [10]. These organisms play a key role in the functioning of aquatic ecosystems as primary producers and as a food source for many aquatic organisms [11]. Their diversity and

abundance can influence the structure and stability of biological communities [12]. The study of euglenoid species diversity and abundance also allows us to assess the health and integrity of aquatic ecosystems [13]. Changes in the composition of euglenoid communities may indicate environmental disturbances, such as pollution, eutrophication or climate change. Monitoring the diversity and abundance of euglenoid species can therefore serve as an indicator of the overall health of aquatic ecosystems [14]. In this article, we propose an in-depth review of the factors influencing euglenoid species diversity and abundance. We will explore the interactions between environmental factors, such as water characteristics, nutrient availability, temperature, light and other variables, and their impact on euglenoid species distribution. We will also address biological interactions, such as predation and competition, and their influence on euglenoid species diversity and abundance.

2 Materials and methods

2.1 Study area

The Nador Lagoon, also known as Sebkh Bou Areg or Mar Chica, is an important study area in northeastern Morocco, along the Mediterranean coast. It is located between latitudes 35°10'N and extends over a longitude range of 2°45' - 2°55'W [15].

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The Nador Lagoon is a lagoon ecosystem with a considerable surface area, covering around 115 km². It is the largest lagoon in Morocco and the second largest in North Africa. Its shape is semi-elliptical, elongated parallel to the coast, and morphologically integrated into the general geometry of the continent [16].

The Nador lagoon ecosystem was formed during a northwest/southeast-trending continental cyclone during the Holocene sea-level rise. It has evolved to become a diverse and dynamic habitat, home to a variety of plants, animals, and microorganisms [17,18]. The Nador lagoon is located downstream of a watercourse running south-west/north-west, comprising two successive plains: the Gareb and Bou Areg plains. It is also connected to the Mediterranean Sea by an artificial canal 300 m wide and 6.5 m deep [18].

2.2 Sampling stations

As part of this study, sampling campaigns were carried out seasonally (spring and summer 2019) at four specific stations in the Nador lagoon. The stations included Oued Caballo (Station 1), the Nador wastewater treatment plant (Station 2), Oued Bou Areg (Station 3), and Kariat Arakman (Station 4) (Figure 1 and Table 1).

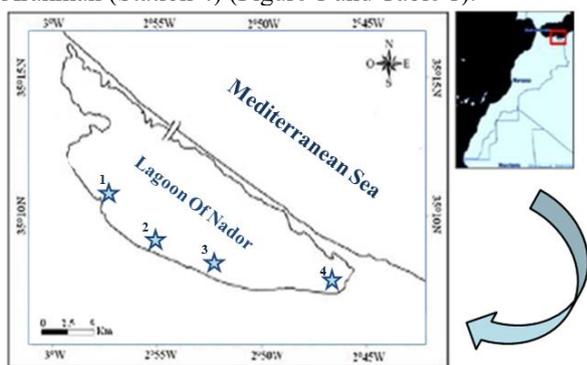


Fig. 1. Distribution of sampling stations.

Table 1. Coordinates of sampling stations and their depths.

Names	Locations	Maximum depth(m)
St1 Oued caballo	W002°54.325; N35°09.820	0.70
St2 Sewage treatment plant	W002°53.383; N35°08.299	0.60
St3 Oued Bou Areg	W002°51.443; N35°07.549	0.70
St4 Kariat Arakmane	W002°45.167; N35°06.401	1.48

The main objective of this study was to carry out a qualitative and quantitative assessment of the euglenoid species present in the lagoon.

To achieve this objective, water samples were collected at each sampling station, and physicochemical analyses were carried out to assess the lagoon's environmental parameters. This approach will provide a better understanding of the presence and distribution of euglena species in the Nador lagoon and their relationship with the physicochemical characteristics of the water. The results of this study will contribute to a better assessment of the lagoon's ecological status and the development of appropriate conservation measures.

2.3 Physicochemical analyses

As part of this study, physicochemical water parameters were measured to assess the environmental characteristics of the Nador lagoon. In situ measurements of parameters such as temperature and salinity were carried out using a specific probe, the ORION STAR A122.

This probe enables precise, direct measurements in the field. In addition, hydrogen potential (pH) was measured with a pH meter, using the IONOMETER-EUTECH-INSTRUMENTSCYBERSCAN-PH-510.

These in situ measurements provide real-time data on the physico-chemical conditions of the water. In addition, other measurements were carried out ex situ to assess phosphorus and nitrogen levels.

These measurements were carried out in the laboratory, using specific analytical methods to determine the concentrations of these elements in the water samples taken.

These measurements provide precise data on water characteristics, essential for assessing the environmental quality of the Nador lagoon.

2.4 Morphological identification

Phytoplankton sampling involves collecting water samples at different depths and at specific points in the ecosystem. Sampling methods may vary according to the objectives of the study, the sample size required and the characteristics of the ecosystem. Sampling is carried out using a plankton net, which is dragged through the water at various depths to collect planktonic organisms, including phytoplankton. Samples collected in the net are then analyzed in the laboratory to study phytoplankton composition and biodiversity.

Qualitative identification of phytoplankton was carried out using an inverse optical microscope. The quantitative study of phytoplankton was carried out using Utermöhl's sedimentation chamber method. Filtered samples were then placed in sedimentation chambers where they were left to stand for 24 hours, after which the cells were observed and counted using a Leica "DM-IRB" inverted optical microscope.

3 Results and Discussion

3.1 Physicochemical analyses

Water temperature is a key parameter that plays an essential role in many aspects of our aquatic environment. It influences marine life, biogeochemical cycles and the dynamics of aquatic ecosystems [19,20,21]. Water temperature variations can be observed on a variety of scales, from daily fluctuations to seasonal changes and longer-term trends [22].

Monitoring water temperature is crucial to understanding the dynamics of aquatic ecosystems, predicting future changes and taking appropriate

conservation measures to preserve the health and biodiversity of aquatic habitats [23,24].

The temperature of the Nador lagoon shows seasonal variations that influence its ecosystem. Springtime readings reveal temperatures ranging from a minimum of 17.9°C at station 3 (Oued Bou Areg) to a maximum of 22°C at station 4 (Kariat Arekmane). The spring period averages around 19.95°C. During the summer, temperatures rise, with minimum and maximum values recorded at 24.9°C and 26.9°C respectively. The summer average is around 25.9°C. These seasonal temperature variations play a key role in the dynamics of the Nador lagoon, affecting the distribution of aquatic species, biological productivity and ecological processes. They can also influence water quality, reproduction cycles and the migrations of living organisms in this fragile ecosystem. Continuous temperature monitoring of the Nador lagoon is therefore crucial to understanding and preserving this unique environment (Figure 2). Our results for the period studied are in agreement with previous studies [25-32]. These concordances enabled us to draw the conclusion that this development had no significant impact on the thermal homogeneity of the ecosystem as a whole, as no perceptible thermal zonation was observed. Thus, it appears that the opening of the new pass did not alter the existing temperature patterns in the study area. These results underline the importance of continuing to monitor thermal parameters to assess potential long-term changes and maintain ecosystem stability.

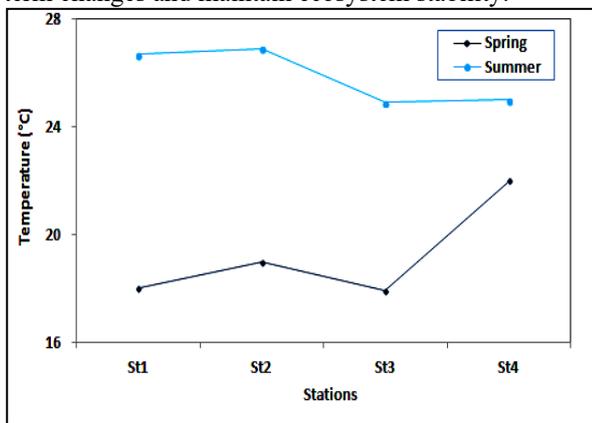


Fig. 2. Variations in temperature levels during spring and summer 2019 at the Nador Lagoon.

Salinity is a parameter that influences the physical and chemical properties of water. It measures the concentration of dissolved salt in a water sample. Salinity plays a crucial role in aquatic ecosystems, as it affects water density, the buoyancy of marine organisms and the distribution of species [33,34]. Marine ecosystems present a diversity of salinities, from the brackish waters of estuaries to the highly saline waters of lagoons or enclosed seas. Salinity also influences biogeochemical processes such as nutrient solubility, phytoplankton production and the circulation of ocean currents [33,34]. As part of this study, we carried out in-depth investigations into the salinity of Nador lagoon waters, focusing on four specific stations. During the spring period, we observed a variation in salinity, with a maximum value of 36.4 ppm recorded at station 1 (Oued Caballo) and a minimum value of 34.6 ppm observed at

station 2 (wastewater treatment plant). The average salinity for this period was around 35.5 ppm. These results concur with those obtained in previous studies [26,27], reinforcing the reliability of our measurements. For the summer period, our readings revealed minimum and maximum salinity values of 35 ppm at the Oued Caballo station and 38 ppm at the Kariat Arakmane station respectively. The average summer salinity was around 36.5 ppm. These results are in line with those reported in other studies [27, 28, 29, 30, 35], reinforcing the consistency of the measurements made (Figure 3). The data collected in this study provide valuable information on salinity levels in the Nador lagoon, both in spring and summer. These results provide an important reference for assessing potential future variations in salinity. Close monitoring of lagoon salinity is essential, as it plays a crucial role in the ecological balance of this aquatic ecosystem. Variations in salinity can influence species distribution, biological productivity and water quality, and can also be linked to environmental and anthropogenic factors.

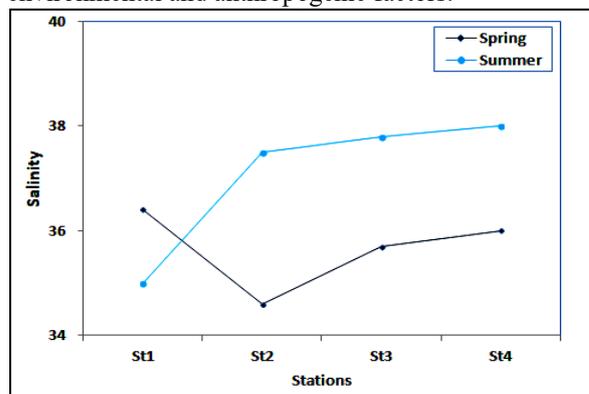


Fig. 3. Variations in salinity levels during spring and summer 2019 at the Nador Lagoon.

pH is an important indicator of the acid-base balance of water, and significant variations can have impacts on aquatic life and biological processes [36,37]. It is therefore essential to closely monitor the pH of the Nador lagoon to understand its state of health and identify any changes that could affect the ecosystem. The pH of Nador lagoon waters, measured during the spring period, ranged from a minimum value of 7.65 at station 1, corresponding to Oued caballo, to a maximum value of 7.87 at station 4, corresponding to Kariat Arekman. The average recorded is around 7.77. In summer, the minimum pH value measured in the Nador lagoon is 7.89 at station 2, which corresponds to the wastewater treatment plant, and the maximum pH value recorded is 8.3 at station 4, with an average value of 8.09 (Figure 4). Our results are similar to those found by [25,27,28,40].

These pH variations in the Nador lagoon can be influenced by several factors, such as freshwater inputs, biological processes, human activities and environmental conditions. It is important to note that pH fluctuations can have an impact on aquatic life and biological processes in the lagoon. An inappropriate pH can disrupt the ecological balance of the ecosystem, affecting the health of living organisms and the availability of nutrients.

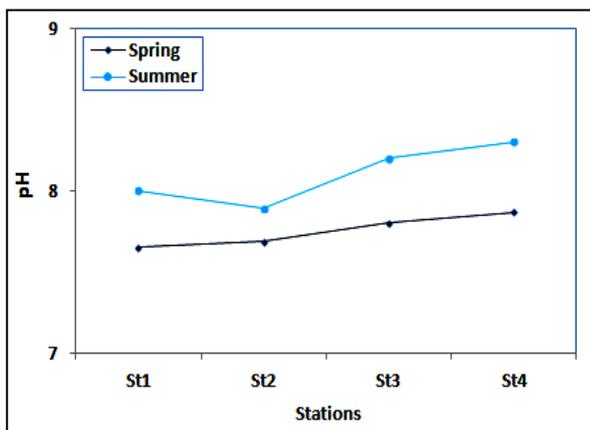


Fig. 4. Variations in pH Levels during Spring and Summer 2019 at the Nador Lagoon.

In this study, we also examined nitrate levels in the waters of the Nador lagoon. Nitrates are nitrogen compounds that occur naturally in the environment, but their high concentration may be the result of human activities such as intensive agriculture or wastewater runoff. During the spring period, nitrate values in the Nador lagoon ranged from a minimum value of 0.27mg/l recorded at station 4, corresponding to Kariat Arekman, to a maximum value of 0.76 mg/l measured at station 2, corresponding to the wastewater treatment plant, with an average of 0.515mg/l. During the summer period, the minimum nitrate value measured in Nador lagoon was 0.37 g/l recorded at station 4, and a maximum value of 0.98 mg/l at station 2, with an average value of 0.675mg/l (Figure 5).

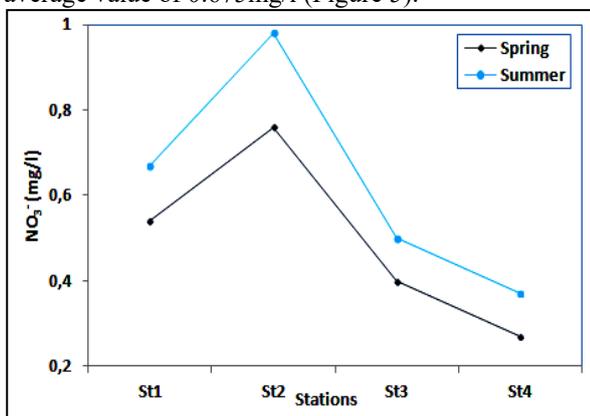


Fig. 5. NO₃⁻ variation during the two study periods (Spring and Summer 2019) at the Nador lagoon.

Our results are similar to those found by [27,28,41]. These results indicate the presence of nitrates in the waters of the Nador lagoon, although concentrations remain relatively low. Nitrates can come from a variety of sources, such as agricultural activities, wastewater discharges or runoff from farmland. It is important to carefully monitor nitrate levels, as high concentrations can lead to environmental problems, such as eutrophication of the water, which can upset the lagoon's ecological balance. Comparison of nitrate levels between the spring and summer periods shows variations, with slightly higher values in summer. This may be due to an increase in agricultural activity during this period, which can lead to an additional input of nitrates into the lagoon.

3.2 Taxonomic description

Euglena is a genus of single-celled organisms that belong to the group of euglenoids. These organisms are classified within the kingdom Protista, specifically in the phylum Euglenozoa. *Euglena* species are found in various aquatic environments, including freshwater, brackish water, and marine ecosystems.

Observation and analysis of around a hundred samples collected were used to identify 5 species of euglenoid listed in the Nador Lagoon (Table 2); namely: *Euglena viridis* O.F.Müller 1786, *Euglena Caudata* Hübner 1886, *Euglena Proxima* P.A.Dangeard 1902, *Euglena tuberculata* Svirenko 1915, *Euglena sp.* Taxonomic descriptions of the *Euglena* identified in the Nador lagoon.

- EMBRANCHEMENT: EUGLENOPHYTA
- CLASSE: EUGLENOPHYCEAE
- ORDRE: EUGLENALES
- GENRE: EUGLENA EHRENBERG, 1830.

Table 2. Characteristics of different *Euglena* species found in Nador Lagoon.

	St1	St2	St3	St4	Freq
<i>Euglena tuberculata</i> Svirenko 1915	+	+	-	-	2
<i>Euglena Caudata</i> Hübner 1886	+	+	-	-	2
<i>Euglena viridis</i> O.F.Müller 1786	-	+	-	-	1
<i>Euglena Proxima</i> P.A.Dangeard 1902	-	+	-	+	2
<i>Euglena sp</i>	+	+	+	-	3

Note: + Present. - Absent.

The Nador lagoon is a complex ecosystem with spatial variations in the physical and chemical characteristics of the water. Different areas of the lagoon may have distinct habitats and environmental conditions, which may influence the distribution and abundance of species, including *Euglena*. Consequently, the variations observed in *Euglena* cell densities between the different sampling stations could reflect differences in local lagoon conditions.

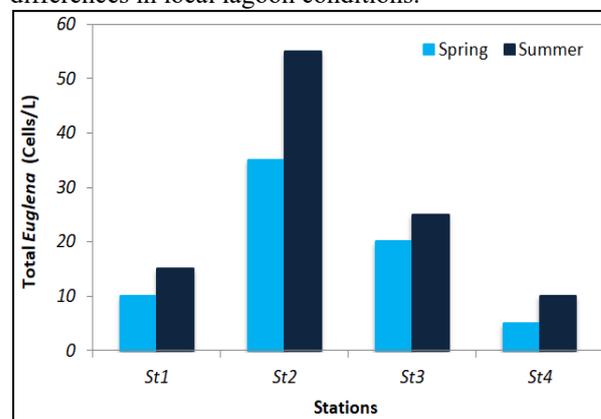


Fig. 6. Total of *Euglena* (Cells/L) in the sampling stations (Spring and Summer 2019).

From Figure 6, and according to the quantitative study of *Euglena* species, it is clear that the total cell density of *Euglena* in the waters of the Nador lagoon,

recorded at the 4 stations sampled, in two study periods (spring and summer 2019). It was found that the most abundant total cell density during the spring period was 35 cells/L at station 2, which corresponds to the wastewater treatment plant, and a minimum value of 5 cells/L at station 4, which corresponds to Kariat Arakmane.

However, the minimum and maximum cell densities of *Euglena* recorded during the summer of 2019 at the 4 stations sampled oscillated respectively between 55 cells/L at station 2 and 10 cells/L at station 4.

The maximum cell density values for *Euglena* in the Nador lagoon are higher than those identified in Lake Mezain - Béjaïa, which were 8 cells/L achieved by Abbaci and Adjaoud, 2016 [42]. On the other hand, the values of 1500 cells/L achieved by Anila et al. [43], recorded in Museum lake, Thiruvananthapuram-India, are lower than those in the Nador lagoon. These results suggest that *Euglena* density may vary according to season and location in the Nador lagoon, with higher values at the wastewater treatment plant (station 2) and lower values at Kariat Arakmane (station 4). Station 2, which corresponds to the wastewater treatment plant, may have higher levels of nutrients, such as nitrates and phosphates, due to the presence of treated domestic effluent. These additional nutrients can favour the growth of *Euglena* and lead to higher cell densities. In contrast, station 4, Kariat Arakmane (confined area), may be less influenced by human activities and have lower levels of nutrients, which could explain the lower cell densities.

4 Conclusion

The diversity of *Euglena* species and the presence of specific ecological niches in the Nador lagoon suggest complexity and interconnection within this ecosystem. This study highlights the importance of preserving and maintaining the biodiversity of the Nador lagoon, as each species plays a unique role in the ecological balance of this fragile ecosystem. Each *Euglena* species has distinct morphological characteristics, specific environmental preferences and particular ecological requirements, suggesting the existence of varied conditions within the lagoon. The diversity of *Euglena* species in the Nador lagoon also indicates the presence of specific ecological niches. Each species occupies a particular habitat and is adapted to specific environmental conditions. This diversity of species and ecological niches suggests complexity and interconnectedness within the lagoon ecosystem.

References

1. C. Widad and A. Radia. Structural and functional diversity of microalgal communities proliferating within lacustrine ecosystems in the jijel region. Master Académique en Biologie, Option: Monitoring des Hydrosystèmes Continentaux. **72**, (2017). <http://dspace.univ-jijel.dz:8080/xmlui/handle/123456789/1740>
2. B. Wisseme. Dynamics and structure of phytoplankton in lentic and lotic environments.

- Academic Master in Marine and Continental Hydrobiology. Option: Aquatic Ecosystems. Université de jijel. **45**, (2020). <http://dspace.univ-jijel.dz:8080/xmlui/handle/123456789/7727K>.
3. B. Khatiwada., A. Sunna and H. Nevalainen, Molecular tools and applications of *Euglena gracilis*. From Biorefineries to bioremediation. Biotechnol. J. **117**(12), 3952-3967 (2020). https://link.springer.com/chapter/10.1007/978-3-319-54910-1_1.
4. S.D. Schwartzbach and S. Shigeoka. *Euglena*: biochemistry, cell and molecular biology. Cham, Switzerland: Springer Inter. Publ. **979** (2017). <https://link.springer.com/book/10.1007/978-3-319-54910-1>.
5. S. Inwongwan, N.J. Kruger, R. G. Ratcliffe et E. C. O'Neill, *Euglena* central metabolic pathways and their subcellular locations. Metabolites. **9**, 6.115 (2019). <https://doi.org/10.3390/metabo9060115>.
6. V. Ligorini. Evolutionary trajectories of phytoplankton communities and coastal lagoons of the Corsican coast and applications. Doctorate In Organism Physiology and Biology - Populations - Interactions in Population Biology and Ecology. Diss. Université Pascal. Paoli, **33**. (2023). <https://theses.hal.science/tel-04216739/>
7. A. P. Ajayan, J. W. Rijstenbil and K. A. Kumar. Environmental influence on the euglenoid species diversity and their abundance in Museum Lake, Thiruvananthapuram, India. Current Science, **118**(1), 94 (2020). <https://www.currentscience.ac.in/Volumes/118/01/0094.pdf#>.
8. H. Mickalide, S. Kuehn. Higher-order interaction between species inhibits bacterial invasion of a phototroph-predator microbial community. **9**(6), 521-533 (2019). <https://doi.org/10.1016/j.cels.2019.11.004>
9. P. Thompson, S. Hürlemann, Samuel F. Altermatt, Species interactions limit the predictability of community responses to environmental change. Am. Nat. **198**(6), 694-705 (2021).
10. A.Y. Kostygov, A. Karnkowska, J. Votýpka, D. Tashyreva, K. Maciszewski, V. Yurchenko, J. Lukeš. Euglenozoa: taxonomy, diversity and ecology, symbioses and viruses. Open Biology, **11**(3), 200407 (2021). <https://doi.org/10.1098/rsob.200407>.
11. S. Kottuparambil, R.L. Thankamony and S. Agusti. *Euglena* as a potential natural source of value-added metabolites. Rev. Algal Res. **37**, 154-159 (2019). <https://doi.org/10.1016/j.algal.2018.11.024>
12. C. Jacquet and F. Altermatt. The ghost of disturbance past: long-term effects of pulse disturbances on community biomass and composition. Proceedings of the Royal Society B, **287**(1930), 20200678 (2020). <https://doi.org/10.1098/rspb.2020.0678>
13. M. Manzoor, B. Muniza, K. Kulsum Ahmad, N. Khurshid. Bio-indicator species and their role in

- monitoring water pollution. In : Freshwater pollution and aquatic ecosystems. Apple Academic Press, 321-347 (2021).
14. P. Chandel, D. Mahajan, K. Thakur, R. Kumar, S. Kumar, B. Brar and A. K.Sharma. A review on plankton as a bioindicator: A promising tool for monitoring water quality. *World Water Policy*. (2023). <https://doi.org/10.1002/wwp2.12137>
 15. M. Guillemain, J.P. Houzay. Geological studies on the Rif Mountains. III: Post-nappe Neogene and Quaternary Quaternary of the north-eastern Rif. Stratigraphy and tectonics of the basins of Mellila, Kert, Boudinar and the Kebdana piedmont. Notes from the Geological Survey of Morocco, **314**, 7-238 (1982).
 16. A. Louaya, N. Hamoumi, Morphodynamics and geomorphological evolution of the Nador lagoon complex (eastern Mediterranean coast, Morocco). *Rapport. Commission. Int. Mer. Med.* **38** (2007).
 17. O. Guelorget, J.P. Perthuisot, G.F. Frisoni and D. Monti. The role of containment in the biogeological organization of the Nador lagoon (Morocco). *Oceanol. Acta. Gauthier-Villars*, **10**(4), 435-44 (1987).
 18. K. Hilmi, A. Orbi, J.I. Lakhdar, F. Sarf. Current study of the Oualidia lagoon (Morocco) in autumn. *Bull. Inst. Sci.* (**26-27**), 67-71 (2005).
 19. W. Destravil, Influence of manageable and unmanageable terrestrial characteristics of minimally anthropized watersheds on the chemical quality of estuarine waters. Thesis, submitted to the Faculty of Graduate Studies. **120** (2013)
 20. C. Belajal and W. Hmidi, Synthesis on the pollution of aquatic ecosystems. Specialty: Applied Toxicology. University Echahid Hamma Lakhdar - El OUED. **83** (2020). <http://dspace.univeloued.dz/handle/123456789/7962>.
 21. O. Merakchi, H. Khammar, Hydro-ecological study "planktonic" of the dam of ourkis wilaya of Oum El Bouaghi. *Ecology of natural environments, Larbi Ben Mhidi University Oum El Bouaghi*. **98** (2021)
 22. J.S. Renaud, M. Bourget, C. StOnge, K.W. Eva, W. Tavares, A. Salvador Loye and M. Homer, (IJIAS), Rabat, **35**(4), 513-522 (2022).
 23. C. Bonhomme, Turbulences and waves in stratified natural environment: two case studies: study of the turbulent mixing and internal waves of the lake Pavin (Auvergne, France); influence of Rossby waves on the surface chlorophyll concentration in the upwelling of Peru. PhD thesis, Environmental Sciences and Techniques, ENPC-Paris Est. **263** (2008).
 24. C. Bachari, Modeling and mapping of marine pollution and bathymetry from satellite imagery. PhD thesis in Sciences of the Universe and Environment. Université du Val de Marne Paris XII. **274** (2009).
 25. H. Bazairi, A. Bayed and C. Hily, C. R. Structure and bioassessment of benthic communities of a lagoonal ecosystem of the Atlantic Moroccan coast|[Structure et bioévaluation de l'état écologique des communautés benthiques d'un écosystème lagunaire de la côte atlantique marocaine. *C. R. Biol. Elsevier*: **10-11**(328), 977-90 (2005). <https://doi.org/10.1016/j.crvi.2005.09.006>.
 26. M. Daoudi, L. Serve, N. Rharbi, F. El Madani and F. Vouvé. Phytoplankton distribution in the Nador lagoon (Morocco) and possible risks for harmful algal blooms. *Transit. waters bul.* **6**(1), 4-19 (2013). <https://doi.org/10.1285/i1825229Xv6n1p4>.
 27. O. Riouchi, F. El Madani, E. Abadie, A. Skalli and M. Baghour, The spatio-temporal evolution of the genus *Nitzschia Longissima* at the level of the lagoon in Nador, Morocco. *E3S Web Conf. EDP Sciences*, **234** 00081 (2021). <https://doi.org/10.1051/e3sconf/202123400081>
 28. O. Riouchi, F. El Madani, A. Skalli, M. Akodad, A. Moumen, H. Gueddari, Y. EL Yousfi and M. Baghour, Morphology and distribution of some marine diatoms of the genus *Rhizosolenia* in the lagoon of Nador (North East of Morocco). *Egypt. J. Aquat. Biol. Fish*, **26**(1), 387-399 (2022). <https://doi.org/10.21608/EJABF.2022.217624>.
 29. O. Riouchi, F. El Madani, A. Skalli, M. Akodad and M. Baghour. Morphology and distribution of some marine diatoms of the genus *Rhizosolenia* in the lagoon of Nador (North East of Morocco). *Aquac. Aquar. Conserv. Legis*, **15**(1), 314-326 (2022). <http://brujula.ual.es/publications/103930>.
 30. O. Riouchi, F. El Madani, E. Abadie, A. Skalli, M. Akodad, A. Moumen, H. Ait Hmeid, G. Azizi and M. Baghour. *Pseudo-Nitzschia* sp (*Bacillariophyceae*), seasonal distribution in the lagoon of Nador (Morocco). *E3S Web Conf. EDP Sciences*. **314**, 01003 (2021). <https://doi.org/10.1051/e3sconf/202131401003>
 31. A. Abouhala, R. Boukabous, J.E. Dafir and E.Talbauoi. Physico-chemical characterization of the Nador lagoon. *Actes Inst. Agron. Veto (Maroc)* **15**(4), 43-52 (1995).
 32. Z. Zerrouqi, M. Sbaa, A. Chafi and H. Aqil. Contribution to the study of water quality in the Nador lagoon: Impact of anthropization. *Bull Inst Sci, Rabat*, **35**, 51-59 (2013).
 33. L. Dagher, T. Hssaïda, S. Chakir, H. Slimani, M. Mouflih, N. Hamoumi and K. El Bouhmedi. Study of dinoflagellate cysts in surface sediments from the Moroccan Atlantic lagoon system of Oualidia-Sidi Moussa and the Mediterranean lagoon of Nador. *Bull. Inst Sci. Rabat, Sect. Sci. the Earth*. **38**, 1-18 (2016).
 34. J. Rodier, The analysis of natural water, waste water, sea water. *Denod, Paris* **1** (18) (1996).
 35. A. Aknaf, M. Akodad, M. Layachi, F. El Madani, A. Jaddar, A. Mesfioui, and M. Baghour. Study of the spatial and temporal variation of physical-chemical parameters characterizing the quality of surface waters of the lagoon Marchica–North-East

- Morocco. *J. Mater. Environ. Sci.* **8**(9), 3216-3225 (2017).
36. D. Ghazali, A. Zaid. Study of the physico-chemical and bacteriological quality of water from the Ain Salama-Jerri spring (Meknes-Morocco region). *LARHYSS J.* **12**(12), 25-36 (2013).
 37. N. Nouayti, D. Khattach and M. Hilali. Assessment of physico-chemical quality of groundwater of the Jurassic aquifers in high basin of Ziz (Central High Atlas, Morocco) Evaluation de la qualité physico-chimique des eaux souterraines des nappes du Jurassique du haut assine Ziz (Haut Atlas central, Maroc). *J. Mater. Environ. Sci.* **6**(4), 1068-1081 (2015).
 38. L. Pepin, Variations in atmospheric CO₂ content during the last 4 glacial-interglacial cycles, based on the analysis of the Vostok core (Antarctica): implications for climate and carbon cycle evolution. Ph.D. thesis in Geophysics, Geochemistry, Geomicrobiology. Université Joseph-Fourier-Grenoble I. 256 (2000).
 39. F. Noisette, H. Egilisdottir, D. Davoult and S. Martin. Physiological responses of three temperate coralline algae from contrasting habitats to near-future ocean acidification. *J. Exp. Mar. Biol.* **448**, 179-187 (2013).
<https://doi.org/10.1016/j.jembe.2013.07.006>.
 40. F. El Madani, Ecological characterization of the Nador lagoon ecosystem based on its phytoplankton population. Ph.D. Thesis, Faculty of Science, Mohammed First University, Morocco. 209 (2012).
 41. O. Riouchi, F. El Madani, A. Skalli, M. Akodad, A. Moumen and M. Baghour. Qualitative and Quantitative Study of Dinoflagellate Cysts in Surface Sediments of the Nador Lagoon (North-East Morocco). *Egypt. J. Aquat. Biol. Fish.* **25**(4), 753-765 (2021).
<https://doi.org/10.21608/EJABF.2022.217624>.
 42. R. Abbaci, N. Adjaoud. Contribution to the identification of Euglenophytes from Lake Mézaïa (Bejaïa), Ministry of Higher Education and Scientific Research University A. MIRA – Bejaïa. **70**, (2016).
 43. P. Anila, W. Rijstenbil and K. G. Ajit Kumar. Environmental influence on the euglenoid species diversity and their abundance in Museum Lake, Thiruvananthapuram, India. In. *Curr. Sci.* **118**(1), 94 (2020). <https://doi.org/10.18520/cs/v118/i1/94-102>