Research Article

Inventory of the fauna and flora of the Northeast new ecosystem of Bizerte lagoon (Tunisia), Southeastern Mediterranean sea

Abstract

Bizerte lagoon is a valuable socio-economic ecosystem which is renowned for its significant biodiversity and its strategic position in the Mediterranean and in northern Tunisia. It is characterized by an important biodiversity and a high biological productivity, which makes of it a nursery for several marine species. It is also a place of brood stock maturation for others and a feeding area for many migratory species. Its shores and maritime space host lots of human activities, such as coastal fishing, shellfish farming, maritime traffic, recreational fishing and nautical sports, besides 277 industries spanning several sectors of activity such as leather and textile as well as the refining of hydrocarbons and the steel industry. These activities cause severe pollution and result in many anthropogenic disturbances. The aim of this work is to study the sanitary state of Bizerte Lagoon using a biological and ecosystem approach that exploits bio-ecological indicators at the scale of specimen, population, community or whole ecosystem. The findings of this study have revealed the following facts: the peri-lagoon part of the Northeast zone is distinguished by an interesting biological diversity. According to statistical descriptors, the most abundant and frequent zoological groups are gastropod mollusks followed by crustaceans. In terms of diversity indexes, the values obtained showed that the Northeast zone has a poor to mediocre ecological status. This research demonstrates that Bizerte Lagoon is undergoing an anthropic pressure that has been jeopardizing the biodiversity of this ecosystem.

Keywords: anthropogenic disturbances, ecological indicators, biological diversity, fauna and flora inventory, Bizerte lagoon, Tunisia.

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Abbreviations: TSS, total soluble solids; FAO, food and agriculture organization of the united nations; Worms, World Register of Marine Species; A, Relative abundance; ni, Number of species; j, Total number of all individuals; RS, Number of species in the study; F, Frequency; Pa, Total number of samples containing the species; P, Total number of samples; H', Shannon Wiener Index; Pi: proportional abundance or percentage of importance of the species; S:total number of species; N:total number of individuals of all species in the sample; J', Pielou's clue; D, Simpson's diversity index; St, Station; ISPAB, higher institute of fisheries and aquaculture of Bizerte.

Introduction

Mediterranean lagoons are distinguished by a wide biological and ecological diversity. They are a natural heritage and a vital resource on which humans depend. However, these ecosystems are fragile and vulnerable to external aggression. Bizerte lagoon is a valuable socio-economic ecosystem which is renowned for its significant biodiversity and its strategic position in the Mediterranean. Undoubtedly, such a site offers a high potential for aquaculture. Based on the reports made by the General Directorate of the Environment and Quality of Life.[1,2] 277 industries spanning several sectors of activity such as leather and textile as well as the refining of hydrocarbons and the steel industry are located in the watershed of Bizerte Lagoon. These industries coupled with the heavily expanded agricultural activity and urban agglomerations around the lagoon have generated a progressive deterioration of the biodiversity of this area.[3]

A depletion of fisheries resources and the disappearance of many benthic species have led to the introduction of exogenous species. The evolution of the state of the ecosystems and the monitoring of the impacts of anthropic activities is based on different biological parameters, mainly the benthic communities, their composition and abundance. Several indexes have been developed to study the state of the environment, to identify the general trends of the communities and to infer the causes of variation.[4] In addition, these indexes are simple and standardized tools for a rapid assessment of the effects of an ecological imbalance in a coastal ecosystem. The aim of this work is to study the sanitary state of Bizerte Lagoon using a biological and ecosystem approach that exploits bio-ecological indicators at the level of specimens, population, community or whole ecosystem.

Material and methods

Bizerte lagoon presentation: Bizerte Lagoon (Figure 1) is a coastal water body distinguished by its geostrategic position, located in the extreme north of Tunisia between latitudes 37° 08' and 37°15' and longitudes 9°45' and 9°57'. This ecosystem covers an area of 128 km^2 with a width of 11 km, a length of 13 km and an average depth of 7m.[5] Bizerte Lagoon is a receiving basin that constitutes an aquatic ecosystem impacted by marine and fresh water.[6] It is connected to the Mediterranean Sea through a canal of 7km in length, 300m in width and 12m in depth.[7] and with Lake Ichkeul, through Tinja Channel which is approximately 5km long and a few meters deep.[5]

The bottom of the lagoon is characterized by a deep central depression of 9 to 10 meters.[8] The currents that govern the lagoon are controlled by the tide, freshwater and marine inflow, the lake bathymetry and the winds.[9] Both surface and bottom water circulation follow the direction of the prevailing northwest wind. However, the movement of bottom water shows that the areas north and south of the lagoon are water renewal zones.[10] The tide, which is in the range of 20 cm, is subject to variations in the water height of the Mediterranean, while the tide in the lagoon is negligible.[9] The water temperature of Bizerte Lagoon is characterized by two main periods, a cold time from November to April and a warm time from May to October. The average temperature shows a seasonal variation with a maximum attaining (29°C) in August and a minimum of (11°C) in January.[10]

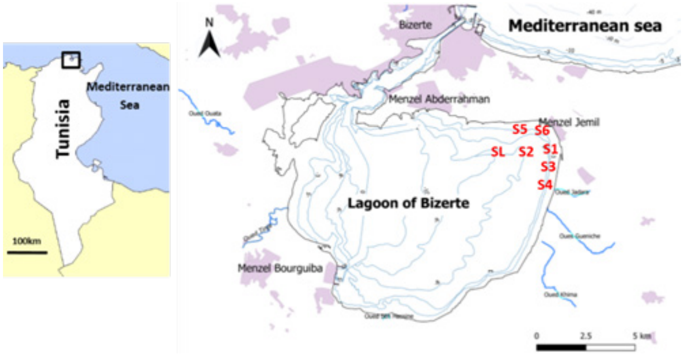

Figure 1 Bizerte lagoon geographical location and sampling stations.

The lagoon waters are characterized by a stable pH due to the important exchange with the Mediterranean. It oscillates little around 8 The salinity is variable between the rainy period and the warm one with an average equal to 35.[11] High salinities are usually recorded in summer and may reach 35.8, however, in winter it declines and achieve 33.9.[5] The average salinity difference between the cold season and the warm season is explained by the freshwater inflow from the rivers and Tinja Channel.[12]

The variation in the dissolved oxygen concentration is associated with climatic conditions. It oscillates between 4.15 mg ‰ in August and 6.34 in January with a spatial homogenization in August.[13]

The average concentrations of suspended matter in Bizerte Lagoon are low compared to other lagoons.[14] The load of water in suspended matter varies between 1 and 40 g.m-3.[8,12,15] At the estuaries of the rivers, TSS contents are higher at the mouth of Tinja channel (40 $g.m^{-3}$).[12]

On the other hand, the highest nitrite levels were recorded at the gully at 68 mg N/m^3.Lower levels were reported in the eastern part of the lagoon (46 mg N/m^3) and the lowest concentrations were found in the central part.[11]

Bizerte Lagoon is an extremely diverse ecosystem.[3] In fact, the composition of the phytoplankton population in this Lagoon is quite homogeneous throughout the entire water body. It is made up of 5 groups: Diatoms, dinoflagellates, chlorophyceae, euglenophyceae and cyanobacteria.[16] The plant community is dominated by the pennate diatom *Nitzschia closterium* (relative abundance ≥ 50%) except near Tinja Wadi, where *Chaetoceros socialis* is the most prevailing species.[17]

Bizerte Lagoon has a low zooplankton presence. The prevailing species include mainly copepods (Acartia, oithona and Centropages), jellyfish (*Rhizostoma pulmo*) and Appendicularia.[12]

Meanwhile the lagoon shows a high degree of homogeneity in the benthic populations in most parts of the basin.[17] The bottom of the lagoon is covered by:

Cauler spellingpa prolifera and *Cymodocea nodosa* beds in the central part;

Zostera marina at the level of communication with the sea;

A peripheral belt of *Zostera noltii* along the shoreline;

Ruppia spiralis at the outlet of Tindja Wadi; and

Chlorophyceae (Ulva and Enteromorphs) in the extreme northeast zone.[17]

The benthic macrofauna is dominated by thalassic species, reflecting a strong marine influence.[17] Fluctuations in the diversity and density of the fauna are seasonally related. During the winter and summer seasons, the specific richness increases, while it declines during spring in such a way that several taxa disappear.[18]

Sampling

In this study, we conducted two sampling surveys:

The first one was conducted in February 2018 representing sampling during the winter season since that year's winter was quite long compared to previous years.

The second survey was conducted inMay2018 representing a spring season sampling.

We selected 7 stations including 6 peri-lagoon and one control Lago on station, in order to make a comparison between the two environments (Figure 1). The geographical details of the sampling stations are presented in Table 1.

Table 1 Sampling station details

Station	GPS details
	Latitude Longitude
Lagoon station	37° 13.007 09° 56.040
Station 1	37° 13.148 09° 56.134
Station 2	37° 13.034 09° 56.114
Station 3	37° 12.870 09° 56.164
Station 4	37° 12.665 09° 56.189
Station 5	37° 13.080 09° 56.208
Station 6	37° 13.187 09° 56.135

Sampling was carried out using a dredge. This gear consists of a rigid frame on which a conical net bag is fixed and it enables the excavation of benthic populations. The samples were screened with a 45μm mesh sieve on a water jet facilitating the passage of the sediment particles, and the individuals were collected into petri dishes using pliers.

The identification of the species was made under a binocular magnifying glass (LEICA ES2), with two magnifications (*10) for the big individuals and (*30) for the small ones. Accordingly, their recognition was achieved through the use of the following identification keys:

FAO species identification sheets for Mediterranean and Black Sea fisheries.[19]

WoR MS global database.

Population studies have been made using statistical descriptors. These indexes often and strongly depend on the type of habitat and the quality status of the environment. The indicators can also be affected by the sampling method, the sample size and the identification procedures.[20]

Relative abundance(A): It is defined as the ratio of the number of species ‘n_i’ in station ‘j’ to the total number of all individuals in that station:

$$A_{ij} = n_i / N_j \textbf{ Or } A_{ij}(\%) = 100 * (n_i / N_j) \quad (1)$$

Five classes of species can be identified based on the irrelative abundance.[21]

If 0.5%<A_{ij}<4.9%→the species is classified as rare;

If 5%<A_{ij}<29.9%→the species is qualified as present;

If 30%<A_{ij}<49.9%→the species is classified as common;

If 50%<A_{ij}<79.9%→the species is considered abundant;

If 80%<A_{ij}<100%→the species classified as very abundant.

The abundance of the species is expressed by their type of reaction in terms of their susceptibility to pollution:

The most sensitive species disappear;

The in different ones survive;

The tolerant and opportunist ones take advantage of new conditions and grow.[20]

Specific richness (RS): It is an index used for the analysis of the taxonomic population structure and it is used to distinguish spatial variations as well as temporal variations. The specific richness represents the total or average number of species identified per unit area.[20]

$$RS = Number\ od\ species\ in\ the\ study \quad (2)$$

Frequency (F): The frequency of occurrence of a species is defined by the relation of the number of samplings as a percentage.[22] It is calculated as:

$$F = \frac{Pa}{P} * 100 \quad (3)$$

With

Pa: total number of samples containing the species;

P: total number of samples.

According to the value of F.[23] we distinguish:

Constant species: F≥50%;

Common species:10%<F<49%;

Rare species: F≤10%.

Diversity indexes: Diversity indexes account for the number of species as well as the distribution of individuals of these species.[20] According to Peet.[24] two indexes have been developed:

Type I: index sensitive to variations in the significance of the rarest species: Shannon-Wiener index.

Type II: index sensitive to variations in the significance of the most abundant species: Simpson’s Index.

Shannon Wiener Index (H’): This index expresses diversity by accounting for the number of species and the abundance of individuals of each species.[20] It is measured according to the following equation:

$$H' = -\sum_{i=0}^{s} Pi \log Pi \quad (4)$$

With

P_i: proportional abundance or percentage of importance of the species $P_i=n_i/N$;

S: total number of species;

n_i: number of individuals of species in the sample;

N: total number of individuals of all species in the sample.

It is necessary to specify the base of the logarithm used (base 2 the most common, base 10, etc.). The Shannon index can also be used to evaluate the pollution of an environment.[20] (Table 2).

Table 2 Classification of pollution based on the value of H’ in sandy-muddy habitat[20,26]

Ecological status	Value of H'	Classification of pollution	
(red)	Bad	0<H'≤1,5	Azoic, very polluted
(orange)	Poor	1,5<H'≤3	Heavily polluted
(yellow)	Medium	3<H'≤4	Moderately polluted
(green)	Good	4<H'≤5	Transition zone
(blue)	Very good	H'>5	Referral site

Pielou’s clue(J’): The equitability index measures the distribution of individuals within species, it is calculated as follows:

$$J' = H' / H'_{max} \quad (5)$$

With

H'_{max}= log S (total number of species)

The value of this index varies from 0 to 1:

J’ tends to 0: dominance of one species;

J’ tends to1: equi-representation of individuals in the species.

Simpson’s diversity index (D): Simpson’s index is inversely proportional to diversity, so another formulation was proposed to account for diversity directly. Simpson’s diversity index is calculated in accordance with the following formula:

$$D = 1 - \sum n_i(n_i - 1) / N(N-1) \quad (6)$$

With

n_i: number of individuals of species I;

N: total number of individuals.

This index value varies between 0 (minimal diversity) and 1 (maximal diversity[20])

Results and discussion

Benthic populations

Benthic macroflora: During the two sampling surveys, the green alga “*Ulvalactuca*” and the red alga “*Gracilaria verucosa*” dominated the benthic macroflora, and were present throughout the study area with qualitative and quantitative variation between stations. The alga “*Caulerpa prolifera*” was found in stations 4,5 and 6 with a low density during the winter season, but it was only found in station 6 during spring.

As for the brown alga “*Cystoseira critinia*”, it was only observed at the lagoon station during the first sampling survey.

However, we came across phanerogams, essentially “*Cymodocea nodosa*” in all the sites except station 5, as well as

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"*Zostera lactuca*" which was found in low density in stations 4 and 5 in the winter period, while it was missing in May.

At the lagoon station, we identified the red alga "*Ceramium rubrum*" with a constant quantity during both seasons. In February, it was only found in station 6.

In May, a new species of green alga "*Chaetomorpha sp*" was discovered in stations 4, 5 and 6. Overall, the biomass of benthic plants dropped during spring compared to winter season, and some species were also missing.

Benthic macrofauna: The findings showed a significant specific richness consisting of numerous taxa of the following zoological groups: gastropods, bivalves, crustaceans, fish, ascidians, cnidarians, heterobranch mollusks and echinoderms. We noted a variation between the two sampling surveys, undertaken in February and May, coupled with a difference between the stations. We recorded the presence of 35 taxa during the winter survey, whereas in May the specific richness decreased to only 24 taxa. Indeed, some individuals were present during the first sampling survey at certain stations, yet disappeared during the second one such as the ascidians *Phallusia mammillata*, the bivalves *Donax venustus*, *Loripes lacteus* and the gastropods *Turritella*. Some species were found only in May, like the anemones *Anemonia sulcata* and *Anemonia virdis*. On the other hand, the crustaceans *Gammarus sp*., *Idoteabalthica*, and bryozoans were seen in all stations and during the two surveys. As was the case for the benthic macroflora, we observed a change in the qualitative and quantitative composition of the macrofauna between the different stations and across the seasons. The number of species dropped in most sites during the spring survey with respect to the winter survey, which reflects the impact of the environmental physicochemical factors on the abundance of the different species. The largest number of taxa was recorded at stations 2, 4 and 5, while the number of species at the other stations declined.

Statistical descriptors

Relative abundance

Winter survey: In this study, we found that the most prevailing zoological group is the gastropods with35.16%. This group represents the common category and his dominance is explained by the abundance of the taxa *Cerithium alucastrum* and *Bulla amygdala* (195 and 106 individuals, respectively). Crustaceans represent 34.09%, and thus, come in the second place. The amphipods *Gammarus sp* and *Idotea balthica* are the most abundant (110and 118individuals, respectively). Bivalves (10.11%) and fish (13.95%) are designated as the present group. The other groups have a low numerical abundance and are described as rare: ascidians 4.25%, cnidarians 1.19% and echinoderms 0.98%.

Spring survey: The most important zoological group is the gastropods with a percentage of 42.11%, owing to the high proportion of the taxa *Cerithium vulgatum* (162 individuals). It is therefore referred to as the common group. Bivalves (13.39%) and crustaceans (24.12%) were identified as present.

Cnidarians are ranked third with 7.5%, thanks to the presence of the anemones *Anemonia sulcata, Anemonia virdis* and *Bunodactis sp*, which appeared in the second sampling survey. Fish are positioned next with (6.73%) as they were less prevalent than in the first survey. The rest of the groups are described as sparse and are represented by heterobranch mollusks (3.13%) and subsequently by echinoderms with 2.95%.

With regard to the lagoon station, we noticed a depletion of some species during the winter survey. As a matter of fact, the gastropods passed from 36.36 to 25% and fish disappeared. On the other hand, crustaceans rose and attained 50% while bivalves maintained the same percentage for both seasons.

Specific richness

The benthic macro fauna distribution revealed that the species richness during the winter survey exceeded that of the spring survey. Thus, in February, it ranged between 14 and 17 species at stations 3, 4 and 5, while it dropped to 6 and 8 species in May. At stations 1 and 4, it remained steady during both seasons with 10 species. At the lagoon station, it dropped from 11 species in February to 4 species in May. (Table 3).

Table 3 Distribution of species richness in the study area

Station Month	STlagoon	ST1	ST2	ST3	ST4	ST5	ST6
February	11	10	17	14	10	17	10
May	4	9	7	13	10	8	6

Frequency

Winter survey: In this work, we classified the species according to their frequency into two categories. The common class ranks first with 71.43%, and composed by the main groups of gastropods and crustaceans which account for 32% and 24% respectively, followed by fish 20%, bivalves 16%, and cnidarians and echinoderms with a percentage of 4% each.

The main species causing this distribution are *Cerithium vulgatum, Bulla amygdala, Hexaplex trunculus* and the crustacean *Sphaeroma hookeri*.

The second rank representing the steady type with 28.7% consists of 40% of gastropods, 30% of crustaceans and 10% of bivalves, fish and ascidians (Figures 2,3,4).

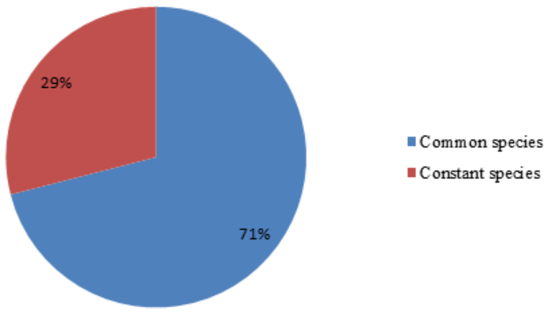

Figure 2 Total species frequency during the winter season.

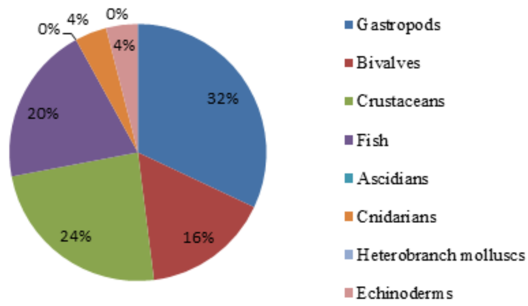

Figure 3 Classification of zoological groups of common species during the winter season.

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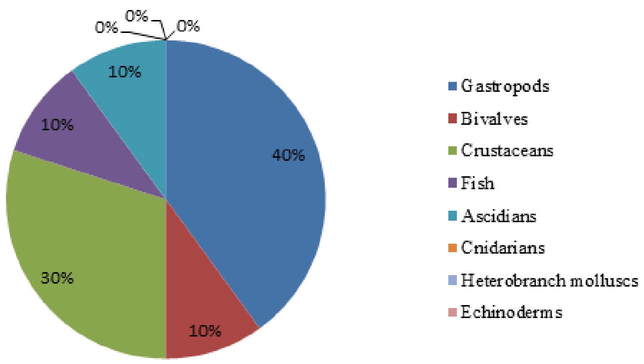

Figure 4 Zoological group classification of constant species during the winter season.

Spring survey: The achieved findings allowed to group the species under two categories of whichthe first type qualified as common with 66.67%. The species which correspond to this group include 3 gastropods *Buccinumhum phreysianum*, *Murex brandaris* and *Fasciolari alignaria*, 3 bivalves *Scrobicularia plana*, *Fulvia fragilis* and *Flexopecten glaber*, 4 fish species *Aphanius fasciatus*, *Gobius niger*, *Lithognathus mormyrus* and *Syngnathus abaster*, 3 cnidarians *Anemonia sulcata*, *Anemonia virdis*, *Bunodactis sp*, a heterobranchus mollusk *Colpodaspis sp* and an echinoderm *Amphiura filiformis*. The second rank is occupied by species of the constant category at a percentage of 33.33%, including gastropods (40%), crustaceans (30%), then bivalves, fish and ascidians (10%) (Figures 5,6,7).

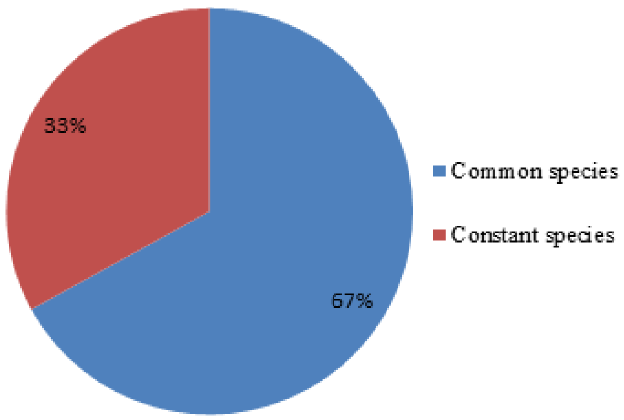

Figure 5 Total frequency of species featuring during the spring season.

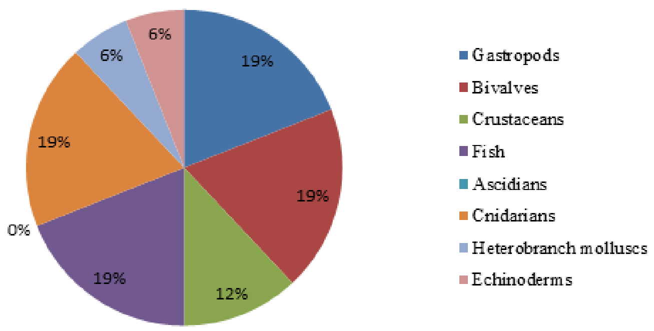

Figure 6 Classification of zoological groups of the common species during the spring season.

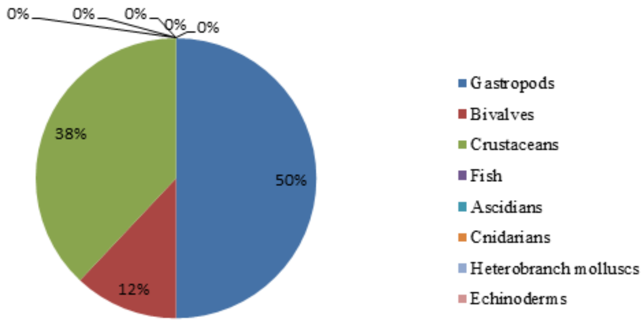

Figure 7 Zoological group classification of the constant species during the spring season.

Diversity indexes

Shannon wiener index(h')

Floristic diversity: For floristic diversity, Shannon index values span from 0.09 at station 3 to 0.87 at station 6 during the winter season. In May, H' ranged from 0.08 at station 1 to 1.05 at station 6. In the lagoon station, H' values were almost identical for the two sampling surveys (Table 3).

Faunal diversity: H' diversity index values which were computed were nearly identical for the two sampling surveys. In February, H' ranged from 1.42 (station 4) to 2.31 (station 5). During the spring season, H' values oscillated between 1.28 (station 4) and 2.15 (station 3). H' value dropped from 1.30 to 0.62 in the lagoon station during both seasons because of the reduced species richness value. According to the classification of Simboura and Zenetos (2002), the ecological status of the peri-lagoon stations of the northeastern part of Bizerte Lagoon is rated as poor to mediocre. These findings demonstrated that stations 1 and 4 are azoic and highly polluted, while the rest of the stations are considered as severely polluted (Table 4).

Pielou's regularity index(J')

Floristic diversity: In the month of February, the Pielou index ranged from 0.08 (stations 3 and 4) to 1 to 0.5 (station 6). In May, the values of J' were between 0.07 (station 1) and 0.65 (station 6). For the lagoon station, the values were high and close to 1 during both seasons, which explains the environmental balance (Table 3).

Faunal diversity: Equitability index values at the peri-lagoon stations are not significantly different between the two sampling periods. They are high for all the stations, revealing a diverse environment. The lagoon station has a less value of J' than the other investigated stations, which implies a lower diversity.

Simpson's index

Floristic diversity: In both surveys, the Simpson index was rather low in all the sites, indicating that they are marked by a poor floristic diversity. The lagoon station has a more diverse flora compared to the peri-lagoon stations (0.64) (Table 4).

Faunal diversity: Simpson's index ranged from 0.62 to 0.87 for the month of February and from 0.68 to 0.86 during the month of May. These values suggest that the study area is characteristically stable in diversity during both seasons. The lagoon station is less diverse than the peri-lagoon stations (Table 5).

Table 4 Summary of floristic species diversity according to biodiversity indexes

Station	ShannonH'		PielouJ'		Simpson	
	February	May	February	May	February	May
S.lagoon	1.19	1.12	0.74	0.81	0.64	0.64
S1	0.55	0.08	0.50	0.07	0.01	0.03
S2	0.22	0.52	0.16	0.47	0.10	0.31
S3	0.09	0.11	0.08	0.1	0.03	0.04
S4	0.11	0.55	0.08	0.5	0.03	0.34
S5	0.21	0.64	0.15	0.46	0.09	0.30
S6	0.87	1.05	0.54	0.65	0.42	0.56

Table 5 Summary of the diversity of fauna species according to the biodiversity indexes

Station	Shannon		Pielou		Simpson	
	February	May	February	May	February	May
S.lagoon	1.30	0.62	0.54	0.45	0.52	0.35
S1	1.88	1.82	0.82	0.83	0.79	0.79
S2	2.27	1.38	0.80	0.71	0.87	0.68
S3	1.46	2.15	0.55	0.84	0.62	0.86
S4	1.42	1.28	0.62	0.56	0.64	0.85
S5	2.31	1.81	0.82	0.87	0.86	0.79
S6	1.77	1.48	0.79	0.83	0.78	0.74

From this study, the species richness found ranges between 10 and 17 in winter, while it varied between 6 and 13 during the spring season. This result is congruent with the values (between 2-17) found by Afli et al.[25] Moreover, the fauna survey undertaken by these authorsin Bizerte Lagoon demonstrated that the species richness decreased during the spring season, which is in agreement with our results. This reveals an imbalance in species richness between various seasons. In 2001, Fezzani et al.[18] reported that the distribution of benthic communities is seasonally driven. Frissoni et al.[17] mentioned that the benthic vegetation is marked by the presence of phanerogams and chlorophyceae in the extreme northeast of the lagoon, which is consistent with the present study. Beji.[26] reported that phanerogams, mainly *Cymodoceanodosa*, are the most dominant algal species while we found *Ulva lactuca* to be the most prevailing species in both sampling periods. On the one hand, the abundance of this alga suggests that the environment is rich in nutrient salts. On the other hand, it is considered an indicator of the occurrence of organic pollution and that the environment is under severe threat from anthropogenic influx.[27]

In both seasons, the most abundant zoological group was gastropod mollusks followed by crustaceans. These groups are referred to as common by frequency. Other groups, such as echinoderms, are less represented. In contrast, Fezzani et al.[18] reported the dominance of crustaceans (62%) followed by mollusks. As a matter of fact, the abundance of gastropods is explained by their tolerance to metallic pollution. In terms of frequency, the bivalve *Ruditapes decussatus* is designated as constant with a percentage of 66.66%. Following Mkawar et al.[27] this species is considered an indicator of the presence of heavy highly toxic metals and which adversely affect the biodiversity of the ecosystem.

In this work, we found that the Shannon index varied between 1.42 and 2.31 during the winter season and between 1.28 and 2.15 in the spring, which signifies a seriously polluted poor ecological state (azoic). Similar findings were reported by Jlassi.[21] who stated that H' oscillated between 0.5 and 2.8. Regarding the index of equitability J', our results showed that it ranged between 0.4 and 0.9 which is in congruence with the results published by Jlassi[21].In our studied stations, we noted that there is no significant difference in Simpson's index during the sampling periods with values ranging between 0.62 and 0.87.

Conclusion

Bizerte Lagoon is undergoing an anthropic pressure that has been jeopardizing the biodiversity of this ecosystem. The aim of our study is to draw up an appraisal of the environment quality of this lagoon environment based on its faunistic and floristic richness so as to conduct an inventory of the benthic populations around the northeastern islets of Bizerte Lagoon. The findings of this study have revealed the following facts:

i. the peri-lagoon part of the Northeast zone is distinguished by an interesting biological diversity;

ii. according to statistical descriptors, the most abundant and frequent zoological groups are gastropod mollusks followed by crustaceans;

iii. the values of diversity indexes obtained showed that the Northeast zone has a poor to mediocre ecological status according to the classification of Simboura and Zenetos.[28]

The flora inventory consists of four phyla: rhodophyceae, chlorophyceae, pheophyceae and phanerogams. Meanwhile, the fauna inventory is made up of eight zoological groups: gastropods, bivalves, crustaceans, fishes, ascidians, cnidarians, hetero branch molluscs and echinoderms.

Fluctuations in the diversity of benthic populations can be attributed to seasonal variations in climatic factors (temperature, salinity, etc.) which impact species' life cycles.

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Conflicts of interest

Authors declares there are no conflicts of interests.

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