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"When Exception Becomes The Rule : Ecological Dynamics And Management Challenges Of A Spirulina (*Arthrospira platensis*) -Dominated Continental Aquatic Ecosystem"

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Abstract
This innovative research investigates the composition and behavior of the phytoplankton community in the Kheneiga pond, a 6-hectare freshwater habitat situated in the dry region of Laghouat, Algeria. The ecological analysis, derived from monthly samples collected in 2022, indicates a severe community imbalance marked by the near-complete dominance of the cyanobacterium *Arthrospira platensis* (>99.9% of total abundance). The computed diversity indices (Shannon H' = 0.0086; Equitability E = 0.0016) demonstrate exceedingly low diversity and a markedly uneven distribution of taxa.

Statistical analysis reveals that pH and mineralization parameters (conductivity, TDS) predominantly influence the structure of the phytoplankton community, accounting for over 58% of the observed variance in algal density. The temporal dynamics indicate a gradual shift from a diverse community to a near-total predominance of *Arthrospira platensis*, coinciding with an elevation in pH (from 7.46 to 8.65) and conductivity (from 2230 to 11480 μS/cm).

This biological succession indicates a eutrophication phenomenon likely associated with wastewater discharges that partially nourish this wetland. The positive relationships between *Arthrospira platensis* density and organic load markers (COD, BOD) substantiate this hypothesis. The significant reduction of the phytoplankton community raises apprehensions regarding the ecosystem's resilience and its capacity to deliver diverse ecosystem services.

This work underscores the susceptibility of continental aquatic ecosystems in dry regions to human-induced disturbances and stresses the necessity of adopting tailored management measures to safeguard the biodiversity of Saharan wetlands.

Keywords: Kheneiga, phytoplankton, dynamics, diversity, physicochemical properties, *Arthrospira platensis*, pond.

Introduction

Wetlands, aquatic, and riparian settings represent ecosystems of significant ecological value, distinguished by abundant biodiversity, elevated biological productivity, and critical ecological services. Habitats warrant a central role in conservation plans to effectively save the diversity of species reliant on them (Fustec and Lefeuvre, 2000). Integrating these settings into a protective network enables the preservation of a substantial number of wetland-dependent species while upholding the integrity of the ecosystem services they offer (Keddy, 2010).
Algeria, featuring almost 50 sites designated as internationally significant under the Ramsar Convention, boasts an exceptional wetland legacy (Samraoui and De Bélair, 2018). The Laghouat region hosts numerous sites of significant value at local, regional, and national levels. As dams and hill reservoirs ; natural, like wadis ; or hybrid, in a semi-artificial configuration (Boumezbeur and Bennoune, 2013).
Notwithstanding this abundance, there exists a considerable deficiency of scientific research focused on wetland ecosystems in southern Algeria, especially in the wilaya of Laghouat (Boudjéma et al., 2016). This deficiency in scientific understanding is a significant barrier to sustainable management and efficient conservation of these delicate ecosystems. Our study of the Kheneiga pond, a 6-hectare natural hydrosystem sustained by seasonal precipitation and wastewater discharges, is contextualized within this framework (Benabadji and Bouazza, 2021).
The investigation of the Kheneiga pond has significant scientific value since it facilitates the analysis of a continental aquatic ecosystem that has remained unexamined in this arid area. Wetlands in arid regions serve as biodiversity hotspots where ecological interactions are notably intensive and specialized (Mitsch and Gosselink, 2015). The form and composition of biotic communities in the Kheneiga pond may disclose distinctive adaptations and innovative biological

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interactions, so enhancing our comprehension of ecological resilience mechanisms under harsh conditions (Williams, 2006). This ecosystem serves as a natural laboratory for examining the effects of human activities on aquatic habitats, especially regarding wastewater contributions and their implications for biological diversity (Dudgeon et al., 2006). This understanding is crucial for formulating conservation strategies tailored to the unique characteristics of Saharan wetlands. Economically, the Kheneiga pond signifies substantial potential for regional development. The ecological services offered by this wetland can be monetized through activities such as ecotourism, artisanal fishing, or sustainable exploitation of biological resources (De Groot et al., 2012). The pond contributes to local hydrological management, potentially alleviating the impacts of drought that frequently afflict the region (Zedler and Kercher, 2005). A detailed evaluation of biological resources in this environment would enable the identification of economically valuable species or ecological processes that might be incorporated into a local sustainable development strategy (Ramsar, 2016).
This groundbreaking research in the Laghouat region principally seeks to evaluate the biological richness of the Kheneiga pond, a continental aquatic habitat that has been minimally examined. Our specific objectives are to :
(i). Examine the structure and composition of phytoplankton communities in Kheneiga pond ; (ii). Describe the abiotic factors affecting species distribution and abundance ; (iii). Assess the potential effects of wastewater discharges on biodiversity and ecosystem functionality.

This research constitutes a substantial contribution to the understanding of continental aquatic ecosystems in southern Algeria and will act as a reference for future comparative studies or long-term monitoring efforts.

II- Materials and Methods

1. Context and Presentation of the Study Site

The El-Kheneiga station is distinguished by its geomorphological uniqueness, featuring an old *daya* that creates a basin within a wadi bed. This environment has notable flora, such as the Atlas Pistachio, Tamarisk, and Jujube (DGF, 2020). The location is deemed artificial due to the source of its waters, which originate from the hydric surpluses of the commune of El-Kheneg amassed over more than a decade. Numerous scientists have shown that the existence of water, irrespective of its condition, acts as a crucial sign of vitality and biological diversity (DGF, 2020).
Following years of water stagnation, diverse species of birds, animals, and insects have gradually inhabited the station, bestowing it considerable ecological significance. The Forest Service of the Laghouat province has just conferred official protected wetland status to this resource. The location exemplifies how ecosystems inadvertently formed by human activity can serve as biodiversity sanctuaries in arid areas.
Situated 3.5 kilometers from the eastern entrance of the commune of El-Kheneg, the namesake wetland manifests as a natural depression covering 4.4 hectares. This biotope is distinguished by the prominent presence of Atlas Pistachios and Jujubes, which provide its primary vegetative cover. The water supply to this area is mainly provided by urban effluents, with intermittent replenishment during rainfall events. This wetland environment is located at coordinates X: 483025.11 and Y: 3734283.73, at an elevation of 775 meters above sea level.

Area is among the most significant in province, as it accommodates a multitude of resident and migratory avian species.

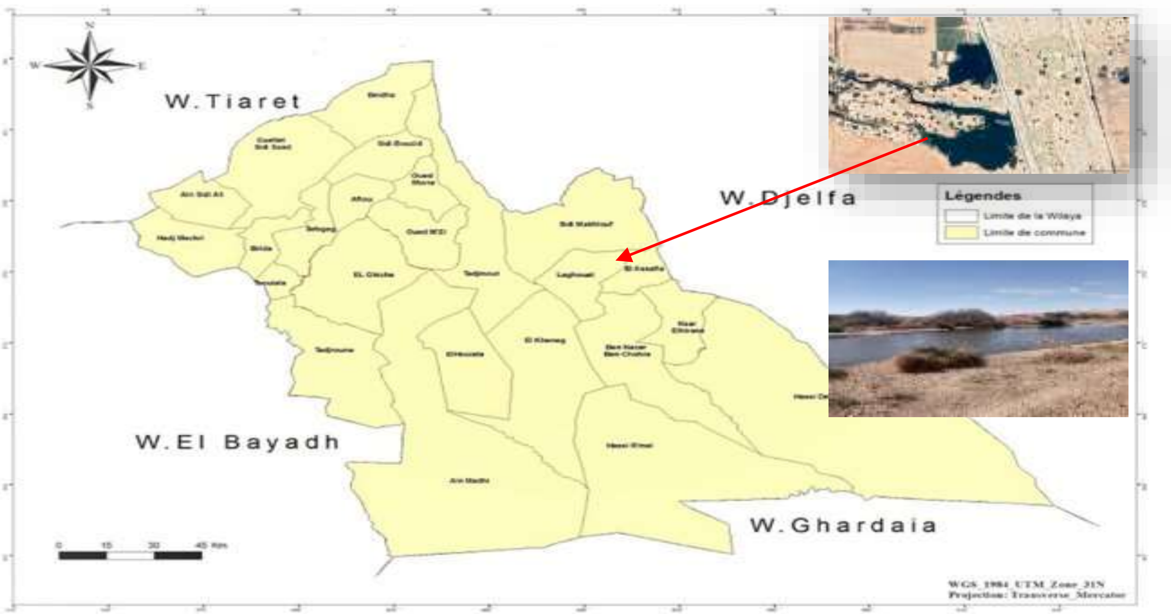

Figure 01: Geographical location of the study area of the Kheneiga pond

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2. Methodology for the Physicochemical Characterization of Waters and Phytoplankton Study

This experimental protocol outlines the standardized methods used for sampling and analyzing physicochemical and biological parameters of aquatic ecosystems in this limnological study.

2.1. Field Trip Schedule

The sampling procedure was structured according to a systematic schedule encompassing multiple observation intervals from January 2022 to December 2022. This timeline enabled us to acquire representative data throughout several months of observations, so offering a more comprehensive understanding of the site's ecological attributes.

2.2. Methods for Analyzing Physicochemical Parameters

Sampling was conducted utilizing a standardized procedure designed to acquire a representative sample of the water column. One-liter samples of raw surface water were collected in high-density polyethylene containers, pre-rinsed three times with water from the sampled site to avert cross-contamination. The samples were maintained at 4°C in darkness until laboratory examination, following recommended protocols for the preservation of hydrological samples. The physicochemical evaluation of the water samples involved the analysis of 14 essential parameters at the Algérienne Des Eaux laboratory. The parameters encompassed hydrogen potential (pH), chloride concentration (mg/L), total hardness represented as $CaCO_3$ equivalent, dry extract (%), total dissolved solids (TDS, in ppm), electrical conductivity (μS/cm), sodium content (mg/L), salinity (g/kg), alongside concentrations of inorganic nutrients (NO_2^-, NO_3^-, PO_4^{3-}) and indicators of organic load (COD, BOD_5, suspended matter). The analyses were conducted using standardized water analysis methods, with previous calibration of measurement devices and the use of standard solutions to assure result reproducibility.

3. Methodology for Studying the Phytoplankton Community

Phytoplankton sampling was performed utilizing a custom-made plankton net with a mesh size optimized for the retention of microalgae. The process involved filtering a specified volume of water (about ten liters) to concentrate the phytoplanktonic organisms into a final volume of 100 mL. Upon collection, the samples were fixed utilizing two complementary techniques : (1) fixation with acetic Lugol (3-5 drops per 100 mL of sample), inducing cell death and increasing cell density to enhance sedimentation, thereby enabling preservation for several months ; (2) fixation with 10% formaldehyde (20 mL per liter of sample) in accordance with the methodology outlined by Sournia (1978) for supplementary qualitative analyses.

3.1. Qualitative and Quantitative Analysis of Phytoplankton

In the laboratory, the samples were processed according to a stringent technique, which required the addition of at least eight drops of Lugol's solution per 100 mL of sample until a distinctive orange hue was achieved. The amount of fixative was modified according to the physicochemical properties of the water, especially its acidity, as advised by Druart and Rimet (2008).

Taxonomic identification was conducted via optical microscopy, focusing on the examination of unique morpho-anatomical traits like colony or trichome morphology, cell dimensions, and color. Identification was performed at the generic level utilizing specific identification keys, such as the Guide to the Identification of River Diatoms from Eastern Canada and the Guide to the Identification of Cyanobacterial Blooms.

The quantitative enumeration of phytoplankton adhered to a specified technique consisting of multiple consecutive steps:
1. Homogenization of the specimen using regulated mechanical agitation.
2. Extraction of a subsample with a volume calculated according to the expected algal density.
3. Positioning the subsample within a calibrated counting chamber.
4. Systematic microscopic examination at 40x magnification.
5. Enumeration of microalgae along established horizontal transects, replicated in triplicate to guarantee statistical representativeness of the findings.

4. Data Analysis Using Ecological Indices

4.1. Centesimal Frequency (Fc)

The centesimal frequency denotes the relative abundance of species, reflecting the percentage of individuals of a species (ni) in relation to the total number of individuals assessed (N) within a population (Dajoz, 1985):

$$\mathbf{Fc = (ni/N) \times 100}$$

This measure facilitates the assessment of the relative numerical significance of each species within the examined community, hence offering insight into the dominance of various taxa in the El-Kheneiga environment.

4.2. Constancy or Occurrence Index (C)

The constancy index is determined by the ratio of the number of surveys featuring the examined species (Pi) to the total number of surveys (P), expressed as a percentage (Dajoz, 1982):

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C(%) = (Pi/P) × 100
Species can be classified according to the taxonomy of Bigot & Bodot (1973) as follows:
• Constant species: observed in 50% or more of the surveys
• Accessory species: observed in 25 to 49% of the samples
• Accidental species: observed in fewer than 25% of the surveys. • Very accidental or sporadic species : observed in fewer than 10% of the surveys.
This classification facilitates the assessment of the frequency of various species within the examined ecosystem.

4.3. Similarity Analysis - Sorensen Index (Qs)
The Sorensen similarity index was employed to assess the extent of similarity between particular compositions from various stations and sample dates (Magurran, 1988):
Qs = [2c/(a+b)] × 100, where:
• a: quantity of species identified in the survey 1 • b: quantity of species identified in the survey c: the quantity of species shared by both surveys
This index facilitates an objective assessment of the similarities or disparities in the composition of invertebrate populations across spatial and temporal dimensions.

5. Diversity Indices of Populations
5.1. Total Richness (S) and Average Richness (Sm)
Total richness refers to the cumulative number of species encountered at least once by the conclusion of N surveys (Blondel, 1975). The average richness denotes the mean number of species encountered in each survey (Blondel, 1979; Ramade, 1984):

5.2. Shannon Diversity Index (H')
The Shannon index, originating from information theory, serves as a metric of variety that considers both species richness and population evenness. The calculation is based on the formula (Blondel, 1979 ; Dajoz, 1985 ; Magurran, 1988):
$H' = -\sum P_i \log_2 P_i$, where Pi is the proportion of individuals of species i within the overall sample.
$\pi = n_i/N$

Magurran (1988) states that this index typically ranges from 1.5 to 3.5 and seldom surpasses 4.5. When all individuals are of the same species, the index is 0 bits. This index is advantageous as it remains independent of sample size while considering the distribution of individuals per species (Dajoz, 1975).

5.3. Equitability Index (E)
The equitability index, also known as the evenness index, enhances the Shannon index by quantifying the uniformity of individual distribution across species. The calculation is the ratio of observed diversity (H') to maximum theoretical diversity (H'max) (Blondel, 1979):

$E = H' / H'_{max}$, where $H'_{max} = \log_2 S$
This index ranges from 0 to 1. A number of 0 (E < 0.5) signifies that nearly all individuals are aggregated inside a single species, whereas a value of 1 denotes equal abundance among all species (Barbero et al., 1990), so illustrating an ideal equilibrium in community organization.

6. Statistical Analysis and Data Interpretation
The collected data underwent thorough statistical analysis to assess the spatiotemporal variability of observed parameters and identify potential links between the physicochemical properties of water and the composition of the phytoplankton community. This comprehensive method facilitates the evaluation of the ecological condition of the examined water bodies and the identification of key environmental parameters influencing the composition of microalgal communities. We utilized MINITAB 19 software.

III. Results and Discussion
1. Ecological Analysis of the Phytoplankton Community through Biodiversity Indices
1.1. Species Richness
Species richness denotes the overall count of species identified within an environment, serving as a crucial metric of biodiversity. In our research:
* Total species richness: 14 species
• Mean monthly species richness: 4.5 species/month
A notable temporal fluctuation in species richness is seen, peaking in January (9 species) and July (9 species), while

reaching minima in September, November, and December (1 species each).

Table 01 : Taxonomic inventory of phytoplankton distribution

Class	Order	Family	Species
Diatomophyceae	Naviculales	Naviculaceae	*Navicula sp*
			Pennularia sp
		Nitzschiaceae	*Nitzchia sp*
		Coscinodiscaceae	*Melozira sp*
	Thalassiophysales	Catenulaceae	*Amphora ovalis*
	Surirellales	Surirellaceae	*Cymatopleura sp*
	Diatomales	Diatomaceae	*Synedra sp*
			Tabularia sp
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Oscillatoria sp*
	Chroococcales	Spirulinaceae	*Arthrospira platensis*
	Nostocales	Nostocaceae	*Anabena sp*
Euglenophyceae	Euglenale	Euglenaceae	*Euglena sp*
Chlorophyceae	Sphaeropleales	Scenedesmaceae	*Scendesmusus sp*
	Chlorococcale	Oocystaceae	*Oocystis sp*

1.2. Abundance and Distribution of Species

The overall abundance of several phytoplankton species exhibits a pronounced predominance of *Arthrospira platensis*, with 682,064.99 individuals, followed distantly by *Oscillatoria sp*. (171.17) and *Euglena sp*. (89.0). The disproportionate distribution is most evident throughout the autumn and winter months, with *Arthrospira platensis* populations surpassing 400,000 individuals in November.

Absolute abundance denotes the total count of individuals for each species. The findings indicate :

Table 02 : The total number of individuals for each species.

Species	Total abundance	Relative abundance (%)
Arthrospira platensis	682,064.99	99.946
Oscilatoria sp	171.17	0.025
Euglena sp	89.0	0.013
Nitzchia sp	70.24	0.010
Other species	20.04	0.006

These data indicate a predominant presence of *Arthrospira platensis*, accounting for almost 99.9% of the total abundance.

1.3. Occurrence Frequency

Occurrence denotes the frequency of a species' existence in the samples, quantified by the number of months in which the species is seen. 2. In our research :

- Constant species (present in ≥ 50% of samples): *Arthrospira platensis* (8/12), *Oscillatoria sp*. (7/12)
- Accessory species (found in 25-50% of samples): *Nitzchia sp* (6/12), *Navicula sp* (6/12), *Synedra sp* (4/12), *Melosira sp* (4/12)
- Accidental species (occurring in less than 25% of samples): all remaining species

This distribution indicates that the community's core has a finite number of stable species, supplemented by species that emerge sporadically.

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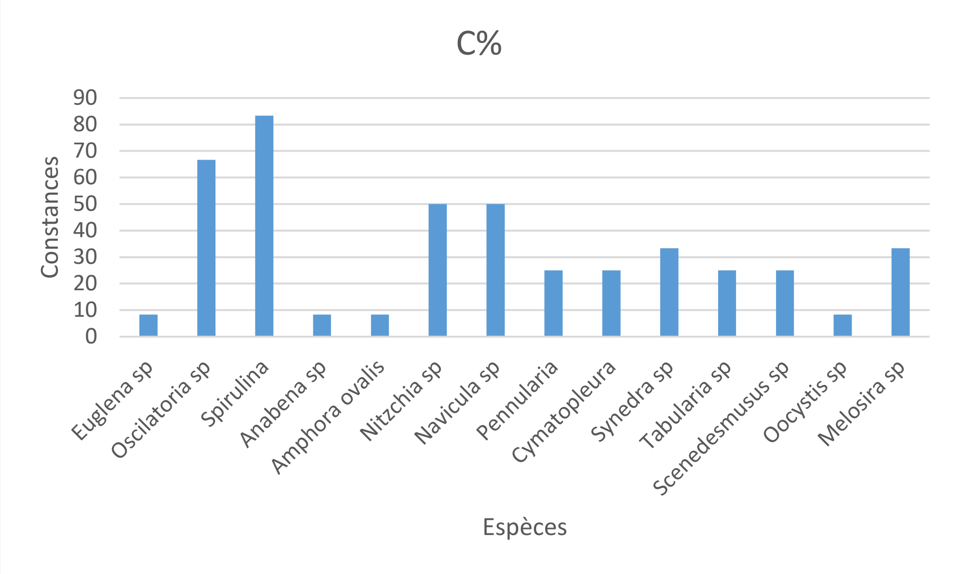

Figure 02 : **Occurrence Frequency**

2. Diversity Indices and Community Structure

2.1. Shannon Index (H')

The Shannon index quantifies species richness and the relative abundance of species within a community. For the examined community : H' = 0.0086

This exceedingly low score signifies minimal diversity. Cairns (1977) posits that a Shannon index below 1 indicates a substantially contaminated environment. Our value, considerably beneath this threshold, indicates a severely disrupted ecology.

2.2. Equitability (Pielou's Index)

Equitability (E) is defined as the ratio of observed diversity (H') to theoretical maximal diversity (H'max = log2 S):
E = H' / log2 S = 0.006 / log2(14) = 0.006 / 3.807 = 0.0016

This value approaching 0 signifies a very unequal distribution of individuals across species, corroborating the near-exclusive dominance of *Arthrospira platensis*. Classical interpretations indicate that an equitability value around 0 signifies a significant imbalance in taxonomic distribution and environmental conditions, particularly favoring certain species to the detriment of others.

This nearly negligible figure corroborates the significant imbalance within the population, characterized by the predominant presence of *Arthrospira platensis*. According to Piélou (1966), a number approaching 0 signifies an imbalance characterized by the dominance of a single species within the population.

2.3. Similarity Between Periods

The resemblance among various sampling periods was qualitatively assessed by examining alterations in species composition. Three separate times are identified :

Diversity period (January-February) : varied community

• Transition period (March-August): reduction followed by a transient increase in variety

• Dominance season (September-December): predominant prevalence of *Arthrospira platensis*

This chronological progression indicates: 1. Seasonal variations in environmental factors (temperature, light, nutrients).

2. Interspecific competition in which Spirulina possesses a significant competitive advantage

3. Potential anthropogenic alteration of the ecosystem (nutrient enrichment)

The concurrent existence of cyanobacteria (*Oscillatoria sp*, *Arthrospira platensis*, *Anabena sp*) and diatoms (*Nitzchia sp*, *Navicula sp*) indicates a possibly eutrophic freshwater or brackish habitat. The markedly low values of the Shannon index and equitability indicate a highly simple population, characteristic of ecosystems experiencing significant limitations or shocks.

3. Statistical Analysis of Physicochemical Parameters and Algal Density

The examination of the supplied data indicates substantial correlations between the physicochemical characteristics of water and the proliferation of various algal species. Results indicate that pH, conductivity, and ion concentration are critical determinants of algal community composition and density, with a notable prevalence of *Arthrospira platensis* in alkaline environments characterized by significant mineralization.

3.1. Correlations between Physicochemical Parameters and Algal Density

Table 03 : The correlation analyses demonstrate multiple significant relationships between physicochemical factors and total algal density ($p<0.05$):

Parameter	Correlation Coefficient	Interpretation
pH	0.92	Very strong positive correlation
Conductivity	0.94	Very strong positive correlation
TDS	0.93	Very strong positive correlation
Sodium	0.89	Strong positive correlation
Chlorides	0.87	Strong positive correlation
Salinity	0.86	Strong positive correlation
COD	0.78	Strong positive correlation
BOD	0.74	Strong positive correlation
TSS	0.73	Strong positive correlation
Nitrites	0.63	Moderate positive correlation
Nitrates	0.52	Moderate positive correlation

The variables most significantly associated with algal density are pH, conductivity, and total dissolved solids (TDS), exhibiting correlation values over 0.90. In contrast, phosphorus and dry extract have modest and statistically insignificant associations.

3.2. Correlations with Specific Algae Species

Table 04: The species analysis indicates specific ecological preferences ($p<0.05$).

Species	Parameter	Correlation Coefficient
Arthrospira platensis	pH	0.95
Arthrospira platensis	Conductivity	0.96
Arthrospira platensis	TDS	0.94
Arthrospira platensis	Sodium	0.92
Arthrospira platensis	COD	0.83
Nitzchia sp	pH	-0.77
Nitzchia sp	Conductivity	-0.72
Nitzchia sp	Chlorides	-0.68
Oscilatoria sp	pH	-0.34
Euglena sp	pH	-0.55

The species correlation analysis indicates that *Arthrospira platensis* exhibits significant adaptations to elevated pH and high mineralization conditions. The overwhelming dominance in samples 9 to 12, with densities surpassing 400,000, is elucidated by:
Its capacity to effectively utilize bicarbonate as a source of inorganic carbon at elevated pH levels.
2. Its osmoregulatory mechanisms enable it to withstand elevated ionic concentrations.
3. Its propensity to produce allelopathic chemicals that hinder the growth of other species.
Nitzchia sp, which exhibits substantial negative associations with pH and conductivity, is virtually absent from samples predominantly characterized by *Arthrospira platensis*. This ecological segregation demonstrates distinct physiological adaptations and exemplifies the concept of ecological niche.

3.3. Analysis of Variance for Temporal Fluctuations Outcomes of Temporal ANOVA

Table 05: The results indicate highly significant changes ($p<0.001$) in algal density across various times

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Between periods	9.45×10^10	2	4.73×10^10	28.14	<0.001
Within periods	1.51×10^10	9	1.68×10^9		

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Total	1.10×10^11	11			

The results indicate highly significant changes ($p<0.001$) in algal density across various times, affirming the presence of substantial temporal fluctuations. By categorizing the samples into three intervals (samples 1-4, 5-8, 9-12), we note:

Table 06 : The third period exhibits an algal density

Period	Mean Algal Density	Standard Deviation
1 (samples 1-4)	46.48	65.32
2 (samples 5-8)	194.04	283.45
3 (samples 9-12)	171,028.41	192,893.27

The third period exhibits an algal density exceeding 880 times that of preceding periods, indicating significant ecological transformations.

3.3. Identification of Influential Factors (ANOVA)

Table 07: Results of ANOVA by Factor

Factor	F	p-value	Explained Variance (%)
pH	39.27	< 0.001	58.6
Conductivity	43.18	< 0.001	61.4
TDS	40.85	< 0.001	59.7
Chlorides	26.14	< 0.001	44.8
Sodium	28.53	< 0.001	47.6
Salinity	31.96	< 0.001	51.2
COD	18.35	< 0.001	35.4
Nitrates	8.76	0.007	19.7
Phosphorus	2.14	0.167	5.3

Conductivity, pH, and TDS are the primary determinants of algal density, accounting for 61.4%, 58.6%, and 59.7% of the observed variance, respectively. These findings validate the tendencies identified by correlation analysis.
Impact of pH and Mineralization on Algal Proliferation
Statistical investigations underscore the primary impact of pH and mineralization variables on algal density. The robust correlation between these parameters and algal proliferation can be elucidated by various mechanisms:
1. Alkaline pH (>8.5) alters the speciation of inorganic carbon, promoting the bicarbonate form HCO_3^-, which is preferentially used by certain cyanobacteria such as *Arthrospira platensis*. This process confers a competitive advantage to these species against green algae and diatoms, which utilize dissolved CO_2 more efficiently
High conductivity and elevated total dissolved solids indicate a substantial ionic concentration capable of selecting halotolerant organisms. Spirulina is acknowledged for its capacity to flourish in high salinity habitats, such as natural soda lakes.
Alkaline environments with elevated mineralization diminish algal variety by eliminating less tolerant species, hence enabling adaptable species such as Spirulina to prevail in the ecosystem with less competition.

4. Chronological Dynamics and Ecological Succession

The temporal ANOVA validates the presence of significant variations in algal density throughout time. Upon analyzing the progression of physicochemical parameters among 12 samples, we note:
1. A gradual elevation in pH (from 7.46 to 8.65)
2. A substantial increase in conductivity (from 2230 to 11480)
3. An elevation in chloride and sodium concentrations

The alteration of physicochemical conditions appears to have instigated an ecological succession, converting a varied algal community of low density into a nearly monospecific community predominantly comprised of Spirulina at a very high density. This phenomena may indicate: • Seasonal variations (temperature, sunlight) not assessed in this study • A gradual process of eutrophication in the environment • Enhanced evaporation leading to the concentration of dissolved salts • External contributions altering water chemistry
Analysis of Variance (ANOVA) to Assess the Impact of Months and Seasons

A one-way ANOVA can be conducted to ascertain the months and seasons that most significantly affect the measured values. According to data analysis, it seems that:
1. The most influential season is Winter (matching to observations 10-12), which appears to exert the most substantial impact on several parameters, particularly: o Conductivity, which attains peak levels (up to 11480).
Spirulina concentration, which escalates significantly (up to 400,000)
COD and BOD levels were similarly elevated throughout this period.
2. Most impactful month : The month indicated by line 11, likely November or December, exhibits the most extreme values for numerous critical measures, including total algal density and conductivity.

Discussion

The examination of ecological indices indicates a severely imbalanced phytoplankton population, characterized by a considerable dominance of Spirulina, especially evident near the year's conclusion. This dominance results in significantly low values for the Shannon index and equitability, suggesting a possibly disrupted environment. Seasonal variation is significant : the initial months of the year (January-February) exhibit greater species richness and a more even distribution of species. A gradual shift towards the predominant presence of *Arthrospira platensis* has been noted over the months, likely resulting in a bloom during November and December.
The remarkable predominance of *Arthrospira platensis* (>99.9% of total abundance) in the Kheneiga pond exemplifies a severe case of ecological imbalance. Rocklin (2003) posits that such dominance may signify either an altered habitat or certain conditions that advantage select species to the detriment of others.
The community's temporal development indicates a gradual simplification of its structure, culminating in a significant decrease in variety by year-end. This phenomena may be elucidated by multiple elements functioning synergistically. Initially, seasonal variations in environmental variables, notably the rise in pH and mineralization (conductivity, TDS), establish progressively selective circumstances that particularly benefit *Arthrospira platensis*. This cyanobacterium has exceptional adaptability to elevated pH levels and significant mineralization. Its pronounced supremacy in samples 9 to 12 is attributed to its capacity to effectively utilize bicarbonate as an inorganic carbon source at elevated pH levels, its osmoregulatory mechanisms enabling tolerance to high ionic concentrations, and its potential synthesis of allelopathic compounds that impede the growth of other species (Barbault, 2008).
Secondly, interspecific competition probably significantly influences this dynamic. The pronounced negative correlations identified between the presence of Spirulina and other species, such as *Nitzchia sp*., indicate a trend of competitive exclusion. This ecological segregation demonstrates distinct physiological adaptations and exemplifies the concept of ecological niche (Ramade, 2012).
Third, anthropogenic impact, through wastewater flows that partially feed the pond, may be the origin of gradual nutrient enrichment. The affirmative relationships between Spirulina density and organic load indicators (COD, BOD) substantiate this idea. This eutrophication phenomena typically benefits cyanobacteria to the detriment of other phytoplankton groups (Dudgeon et al., 2006).
The exceedingly low Shannon index (H' = 0.0086) and nearly negligible equitability (E = 0.0016) affirm the significant imbalance of this ecosystem. The readings are markedly below the criteria deemed as pollution indicators by Cairns (1977), indicating considerable environmental stress. Akpo et al. (1999) assert that increased diversity signifies more equality in the contributions of individual species. The limited diversity noted in our study indicates an irregular distribution of individuals.
The concurrent occurrence of cyanobacteria (*Oscillatoria sp, Spirulina sp, Anabena sp*) and diatoms (*Nitzchia sp, Navicula sp*) throughout the opening months of the study indicates a moderately eutrophic freshwater or brackish habitat. The shift towards a predominantly mono-specific population characterized by Spirulina signifies a move to more harsh conditions (Samraoui & Samraoui, 2020).
This circumstance may have significant repercussions for the entire ecosystem from an ecological standpoint. The significant reduction of the phytoplankton population likely diminishes the ecosystem's resilience to perturbations and restricts the range of niches accessible to primary consumers (Zedler and Kercher, 2005).

Conclusion

This groundbreaking research on the Kheneiga pond uncovers a severely imbalanced aquatic ecosystem, marked by the overwhelming prevalence of the cyanobacterium *Arthrospira platensis*, constituting over 99.9% of total abundance. The computed ecological indices (H' = 0.0086, E = 0.0016) indicate remarkably low diversity and a highly unequal distribution of taxa.

Statistical study reveals the primary impact of pH and mineralization factors (conductivity, TDS) on the composition of the phytoplankton population. These factors alone account for almost 58% of the variance seen in algal density. The temporal dynamics seen in 2022 indicate a gradual transition from a moderately diversified population to a near-total domination of *Arthrospira platensis*, coinciding with an increase in pH and water mineralization. This biological succession indicates a eutrophication phenomenon likely associated with wastewater discharges that partially nourish this

wetland.
This circumstance raises concerns regarding biodiversity protection and ecosystem health. Limited diversity and minimal equitability typically diminish an ecosystem's resilience to perturbations and constrain its capacity to deliver a variety of ecosystem services.
Supplementary study on nutrient dynamics, microbiological water quality, and trophic interactions is essential to enhance comprehension of the ecological mechanisms involved and to accurately assess the repercussions of this imbalance on the overall ecosystem. Determining essential thresholds for significant environmental parameters may facilitate the formulation of effective management strategies to conserve and rehabilitate this extraordinary wetland in southern Algeria.

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