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Bioindicators and Ecological Assessment of Drigh Lake Water Quality: Physico-Chemical, Biological and Hydrological Characterization Under Anthropogenic Influences

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ABSTRACT

Drigh Lake is a historically important freshwater lake located at N 27° 34', E 68°02' in the Province of Sindh, approximately 18 km northwest of Larkana and 10 km from Qambar towards Gaibi Dero Road at District Qambar @ Shahdadkot. The current study offers a comprehensive framework for assessing the water quality of Drigh Lake by integrating bioindicators with ecological and physico-chemical assessments to identify anthropogenic stressors causing environmental degradation. Water quality was evaluated through hydrological parameters including Temperature, Transparency, pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Salinity, Alkalinity, Chlorides, and Dissolved Oxygen, along with biological investigation revealed diverse phytoplankton communities dominated by Euglenophyta, Chlorophyta, Cynophayta, and Bacillariophyta, with phytoplankton abundance exceeding that of zooplankton. Zooplankton diversity included mainly Rotifera, Copepoda, and Cladocera. Seasonal variations significantly influenced plankton composition and abundance, thereby affecting water quality. The dominance of marshy, floating, and submerged macrophytes such as Typha domingensis, Phragmites vallatoria, Eichhornia crassipes, Nelumbo nucifera, and Hydrilla verticillate indicates eutrophic conditions driven by high nitrogen and phosphorus levels. The lake supports a productive fish community, including major carps and predatory species. This study showed that sewage discharge and agricultural runoff encouraged eutrophication and biodiversity loss. Diversity indices and bioassays highlight ecosystem vulnerability, emphasizing the need for certain management strategies to reduce pollution load, restore ecological balance, and ensure sustainable lake ecosystem.

Keywords: Drigh Lake, Water Quality Assessment, Bioindicators, Anthropogenic Stressors, Eutrophication.

INTRODUCTION

Drigh Lake is a famous historical lake located at N 27° 34', E 68° 02' in the province of Sindh, 18 km northwest of Larkana and 10 km from Kamber towards Gaibi Dero Road in District Kamber-Shahdadkot. The lake covers an area of 450 acres (182 ha), with a length of about 3 km, width of 2 km, and depth of 10 meters. It originated as a result of high floods during 1814. The lake was declared a wildlife sanctuary under the Sindh Wildlife Protection Ordinance in October 1972 and designed a Ramsar site in 1976. Monsoon rains feed the lake, and water enters from small canals on the North side as well as several small streams that join from the East. There is no outlet channel, and the water spread area varies depending on the seasons. Some parts of the water body dry during the pre-monsoon period in early summer. It covers a wide variety of habitats including marshes, mudflats, freshwater zones, open water with varying depths, and vegetated areas. Vegetation types comprise submerged, emergent, mixed, and grassland. The public waters and wetlands of Sindh are rich in aquatic vegetation, which can be divided into four groups: algae, floating plants, emergent plants,

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and submerged plants. These biological components, along with physico-chemical and hydrological traits, are important markers of water quality and ecosystem health, especially in light of growing human effects that jeopardize Drigh Lake's ecological integrity. Wastewater discharge, agricultural runoff, and industrial effluents are only a few of the direct and indirect ways that anthropogenic activities drastically change the quality of water.

The Integrated Function of Physico-Chemical and Biological Monitoring in Drigh Lake Water Quality Assessment

When combined, biological and Physico-chemical monitoring together provides a strong foundation for assessing the water quality of Drigh Lake under anthropogenic influences. The integration of both methods ensures a comprehensive assessment of Drigh Lake by connecting pollutant concentrations with their ecological consequences, thereby supporting effective management and restoration strategies.

Role of Bioindicators in Assessing Aquatic Ecosystem Health

By assessing bioindicators presents in aquatic ecosystem, environmental deterioration can be effectively evaluated and its impacts on the structure and functioning of the aquatic ecosystem may be determined.

The Impact of Hydrology and Nutrients on Aquatic Food Webs and Community Structure

The combined influence of numerous hydrological, physical and chemical elements determines the flora and fauna found in certain aquatic systems. Two of these elements unique to bodies of water are water density supports organisms living in suspension, called plankton. Phytoplankton and zooplankton form the base of aquatic food chains, supporting fish that feed on plankton. Diverse planktonic and benthic ecosystems are supported by dissolved and particulate nutrients. Macrophytes, which offer food, shelter, and breeding grounds, are supported by nutrient richness in shallow, slowly moving or stagnant waters.

Impact of Anthropogenic Pollution on Aquatic Communities and the Role of Bioindicators

Aquatic populations can be directly impacted by human activity through habitat modification, toxins, suspended solids, or oxygen depletion, as well as indirectly through changes in processes like chelation. Aquatic biota is altered by these chemical changes, which favour organisms that can withstand low oxygen or enriched nutrients. This provides the basis of using biota as indicators of water quality and pollution levels.

Biological and Ecological Assessment of Aquatic Ecosystem for Water Quality Evaluation

Biological assessment can identify general anthropogenic impacts, pollution from nutrients, pollutant transformations, long-term effects such as bioaccumulation, waste and atmospheric pollution impacts, hydrological modifications, and the effectiveness of protection measures. Changes in species composition, shifts in dominance, species impoverishment, high mortality of sensitive life stages, behavioural changes, metabolic disruptions, and morphological abnormalities are some of the ways that aquatic organisms react to toxic substances, excessive natural compounds, or physical habitat changes. Such type of reactions provides as the foundation for biological monitoring, which sheds light on ecological health and water quality. In addition, biological assessment offer water quality data, aid fishery management, define clean water standards, provide indication of pollution including inform ecological, economic, and policy decisions.

The Physico-chemical characteristics of Drigh Lake reported by previous studies show considerable seasonal and ecological variability. Water temperature ranges from 10 to 36 °C, with an approximate mean of 24–26 °C, reflecting a strong seasonal impact on plankton and fish metabolism (Yaseen & Ali, 2019). Water transparency varies between 40 and 180 cm, averaging around 80–100 cm, and is repeatedly reduced due to turbidity and algal blooms, signaling eutrophic conditions (Khan et al., 2014). The pH of lake rather alkaline, which ranges from 6.5 to 8.8 with a mean of 7.6-8.0, is ideal for the growth of phytoplankton (Bano & Siddiqui, 2016). With a mean of roughly 1100 mg/L, total dissolved solids (TDS) are stated to be between 900 and 1300 mg/L, suggesting a slightly brackish nature impacted by evaporation (WWF-Pakistan, 2004). Salinity ranges from 0.4 to 5.0 ‰, averaging 1.5–2.0 ‰, which can significantly influence species composition (Ramsar Secretariat, 2018). Alkalinity levels vary between 140 and 400 mg/L as $CaCO_3$, with a mean of about 220 mg/L, suggesting high buffering capacity and productive waters (Wetzel, 2001). Dissolved oxygen concentrations range from 5.5 to 10.0 mg/L, averaging 7.5–8.5 mg/L, which is generally supportive of aquatic life (Khan et al., 2014). Numerous groups of aquatic plants, such as periphyton, phytoplankton, mosses, filamentous algae, and macrophytes are useful markers of nutrient enrichment and water pollution. Researchers like Patrick and Hohn (1956), Fjerdingstad (1971), Coste (1978), Lange-Bertalot (1979), and Watanabe et al. (1988) have documented their use in water quality studies. The use of phytoplankton diversity and composition to evaluate the trophic state of lakes has been investigated in a number of studies. An early framework for ecological assessment was provided by Fjerdingstad (1964, 1965), who used microphytobenthos sessile microalgae and bacteria to categorize Danish waterways. Subsequent research by Lange-Bertalot (1979), Coste (1978), and Watanabe et al. (1988) highlighted Diatom's use as bioindicators of pollution in lotic system. Certain phytoplankton and perphytic algae exhibit very narrow pH tolerance ranges, making them useful indicators of water acidification. According to (Coste et al. 1991), diatoms in particular have been used more frequently to track river acidification.

MATERIAL AND METHODS

The purpose of this study was to assess the water quality of Drigh Lake, emphasizing the integration of bioindicators with ecological assessments to monitor anthropogenic stressors that cause adverse environmental effects. The Sampling scheme was scheduled from different selected stations on seasonal basis. Field visits were regularly carried out for collection of water, plankton, fish, and macrophytes. Various scientific instruments, gears and tools were used for collection of data related to the study. The Water Quality Analysis of Physicochemical parameters were measured in situ or analyzed in the laboratory following APHA (1992) standards i.e. Temperature, Transparency of water was measured with help of Sechhi Disk (Black/ White disc). Total salinity (%) and sodium (mg/l) were measured with the help of HM digital meter model SB1500PRO. Electrical Conductivity EC and Total Dissolved Solids TDS were measured with the help of 5star Multi meter. The pH of water quality was measured with digital pH meter model WTW 320. Total alkalinity (CaCO3) (P&M) (mg/L) of water was measured through water test titration kit (Lohand Hangzzhou Biological, LH, ISO 9001). For obtaining the results followed by the calculation (Phenolphthalein alkalinity: N1 (drops number) x10ml water sample, total alkalinity (N1+N2)X10 ml= 00 mg/l. Total Hardness was measured through the water testing Kit of LH biological (Lohand Hangzzhou Biological, LH, ISO 9001). Result was calculated Total Hardness mg/L= Vx200 (mg/l). Dissolved Oxygen was measured through the modified Wrinkler methods.

Analysis of Plankton Productivity

The plankton are most important members of aquatic ecosystem. Therefore, the knowledge about collection and study is essential to conduct ecological study of any water body. During the lake survey, plankton were gathered using plankton nets with different mesh sizes. The samples were preserved in sterilized plastic jars and sampling bottles. 2-5% formalin was added for preservation of plankton samples. The plankton samples were preserved in ice boxed for transportation to the laboratories for detailed assessments. Qualitative and quantitative sampling schemes were applied for this study. In the laboratory the identification was carried out with taxonomic keys of Desikachary (1959), Prescott (1962), Mizuno and Takahashi (1991), Cook (1996) and Battish (1992).

Analysis of Fish and Macrophytes

Fish and macrophytes were among the freshwater biota present in Drigh Lake water. Fishermen used multi-mesh gillnets of different sizes, such as 65-50-40-30-24-18, to collect samples of fish species. Following a half-hour to an hour of fishing using various nets, the same fish sample specimens were preserved in 5-10% formalin and brought into the lab for identifications. The bottom aquatic plants were gathered using Bambo stakes, Gripner, and hand picking, while the macrophyte samples were manually gathered from various locations. The samples for detailed analyses of the plants were kept in polyethylene bags and brought to the lab for its examination. The taxonomic key and illustration provided by Desikachary, (1959), Prescott, (1962) and Cook, (1996) were used for identification.

RESULTS

Water Quality Parameters

The analysis of water quality parameters is most important before going to conduct environmental and ecological studies. Physical- chemical parameters are the key factors which support the survival, growth and dispersal of aquatic organisms. The air temperature in the Drigh Lake ranged from 16 to 45 °C from January to July, while the water temperature varied from 10 to 34 °C. These suspended solids contribute to decreased water clarity and affect light penetration, which is crucial for aquatic plants and phytoplankton. They are frequently introduced by seasonal monsoon runoff, inflows from nearby streams and canals, and disturbances connected to adjacent agricultural activities in rice fields. Secchi depths were frequently constrained by suspended sediments from runoff and intense plankton blooms, indicating the lake's eutrophic tendencies. Transparency was typically moderate to low. Due to a rise in suspended particles and algal blooms, transparency (42-167 cm) was frequently decreased throughout the rainy season. The pH remained slightly alkaline, on average found between 6.2 and 8.9 with slight seasonal variations due to the surrounding march vegetation and carbonate supplies. The lake relatively brackish nature was confirmed by the total dissolved solids, which ranged from 956 to 1294 mg/L due to evaporation in the sporadic salty inflows. Despite the increased hardness levels brought on by calcium and magnesium, these elements support the production of shells in all mollusks and enhance overall chemical stability. However, due to wind mixing and photosynthesis from an abundance of aquatic plants and phytoplankton, dissolved oxygen remained strong, usually 6.2-9.7 mg/L or more, providing favourable circumstances for fish and other invertebrate aquatic lifeforms. Nutrient levels particularly phosphates were consistently high enough to sustain prolific growth of macrophytes like Typha domingensis, Phragmites vallatoria, Eichhronia crassipes, and lotus species alongside dominant phytoplankton groups (Cyanophyta, Chlorophyta, Euglenophyta, Bacillariophyta) that outnumbered zooplankton (Rotifera, Copepoda, Cladocera). Such patterns highlight the lake's eutrophic stage and the urgent need for management to curb future environmental degradation, as do observed fish communities like Labeo rohita, Catla catla, Wallago attu and fading waterbirds.

Table 1. Water Quality Parameters of Drigh Lake

Parameter	Range (Min–Max)	Mean ± SD	NEQS/WHO Limit

Temperature (°C)	14.0–35.0	24.7 ± 5.8	–
Transparency (cm)	42–167	85.4 ± 40.2	–
pH	6.2–8.9	7.7 ± 0.8	6.5–8.5
Total Suspended Solids (mg/L)	16–44	28.2 ± 7.1	150 mg/L
Total Dissolved Solids (mg/L)	956–1294	1158 ± 102	3500 mg/L
Salinity (‰)	0.4–4.8	1.6 ± 1.1	–
Alkalinity (mg/L as $CaCO_3$)	142–389	215 ± 45	–
Hardness (mg/L as $CaCO_3$)	142–389	243 ± 62	500 mg/L
Dissolved Oxygen (mg/L)	6.2–9.7	7.8 ± 1.2	>4–6 mg/L

WHO stands for World Health Organization, SD for Standard Deviation, and NEQS for National Environmental Quality Standards (Pakistan). Monthly sampling from four stations provided the data (2010–2013).

Table 2. Seasonal variation in water quality parameters of Drigh Lake

Parameter	Winter	Spring	Summer	Monsoon / Autumn
Water Temperature (°C)	Low	Moderate	High	Moderate
Transparency (cm)	High	Moderate	Low	Lowest
pH	Slightly alkaline	Alkaline	Alkaline	Variable
TDS / Salinity	Moderate	Moderate	High	Variable
Dissolved Oxygen	High	Moderate	Variable	Lower
Nutrients (PO_4^{3-})	Low–Moderate	Moderate	High	High

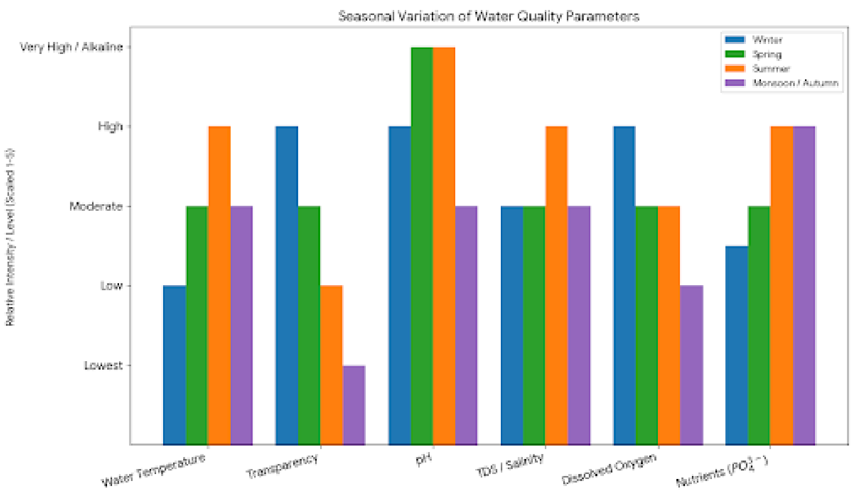

Figure 1: Seasonal variation in water quality

Plankton Productivity That the Cyanophyta, Chlorophyta, Euglenophyta, and Bacillariophyta are the four main algal groups into which the research identified different phytoplankton communities. These assessments showed that phytoplankton populations frequently outnumbered zooplankton in terms of biomass and abundance, significantly increasing the lake's natural productivity. Strong phytoplankton growth is made possible in Drigh Lake by suspended micronutrients in the water column, which enable these primary producers to produce proteins, fats, lipids, carbohydrates and essential vitamins that form the foundation of the aquatic food web. One essential natural food source is plankton which supports higher trophic levels in the ecosystem and acts as the main source of food for fish larvae and adults. In the lake ecosystem, three main phyla i.e. Rotifera, Copepoda, and Cladocera were found in zooplankton communities. There were different numbers of these species at various sampling locations and seasons. Such findings demonstrate Drigh Lake's eutrophic character, where a wealth of plankton communities boost biological productivity and show how susceptible the lake is too environmental sifts.

Table 3. Phytoplankton and algae (%) recorded from Drigh Lake

S. No.	Genera	Spring (Feb–Apr)	Summer (May–Jul)	Autumn (Aug–Oct)	Winter (Nov–Jan)
	Chroococcus	4	3	0	5
	Microcystis	0	8	15	10
	Merismopedia	10	9	10	10
	Anabaena	3	1	0	15
	Nostoc	0	1	5	0
	Oscillatoria	6	6	10	16
	Lyngbya	7	2	2	0
	Calothrix	0	5	8	0
	Spirulena	4	0	2	2
	Arthrospira	6	0	3	4
	Oocystis	9	8	8	6
	Scenedesmus	2	7	4	12
	Pediastrum	9	3	5	3
	Tetraedron	6	4	2	6
	Closterium	4	1	8	3
	Cosmarium	1	6	7	2
	Euglena	14	13	3	1
	Navicula	12	8	5	3
	Gyrosigma	3	8	2	2

	Cyclotella	0	7	1	0
	Total (%)	100	100	100	100

This table shows the seasonal distribution (%) of phytoplankton and algae genera in Drigh Lake during 2010–2013.

Table 4. Plankton composition of Drigh Lake

(a) Phytoplankton

Group	Dominant Genera	Ecological Indication
Cyanophyta	Microcystis, Anabaena, Oscillatoria	Eutrophic conditions and organic pollutants
Chlorophyta	Scenedesmus, Pediastrum, Oocystis	Rich in nutrients
Euglenophyta	Euglena	High levels of biological matter
Bacillariophyta	Navicula, Cyclotella	Waters that are moderate to eutrophic

(b) Zooplankton

Group	Common Genera	Indicator Significance
Rotifera	Brachionus, Keratella	Eutrophic circumstances
Copepoda	Mesocyclops, Diaptomus	Stability of the food web
Cladocera	Bosmina, Moina	Seasonal productivity

Table 5. Zooplankton (%) recorded from Drigh Lake

S. No.	Genera	Spring (Feb–Apr)	Summer (May–Jul)	Autumn (Aug–Oct)	Winter (Nov–Jan)
	Brachionus	13	17	2	0
	Keratella	3	6	0	0
	Lecane	0	2	0	0
	Monostyla	5	1	9	2
	Phylodina	7	0	17	5
	Alona	4	0	6	0
	Bosminopsis	0	0	8	0
	Bosmina	1	7	5	6
	Ceriodaphnia	8	4	0	0
	Diaphanosoma	0	1	7	0
	Ilyocryptus	0	1	5	0

Moina	5	2	8	0
Macrothrix	7	0	0	7
Mesocyclops	23	36	12	19
Diaptomus	22	3	12	26
Herpactoid	2	8	9	35
Total (%)	**100**	**100**	**100**	**100**

This table shows the seasonal percentage composition of zooplankton genera in Drigh Lake during 2010–2013. Aquatic Macrophytes and Fish Assemblages The diversity of macrophyte species, including emergent types like Typha domigensis and Phragmites vallatoria, floating varieties such as Eichhornia crassipes and Nelumbo nucifera, and submerged plants like Hydrilla verticillate and Najaz major, reflected the presence of nutrient-rich conditions and eutrophic propensities. Fish groupings included both native and introduced species, such as major craps (Catla catla, Labeo rohita), catfish (Wallago attu), snakeheads (Channa striatus), and tilapia (Oreochromis mossambicus). During the study period, catch quantities were drastically reduced due to worsening water quality and habitat degradation caused by human activity. However, importance of Aquatic biota as bioindicators of environmental stress was emphasized by the ecological assessment of Drigh Lake, which showed sustainable relationships between biological communities and water quality measures.

DISCUSSION

Drigh Lake's characterization as a nutrient-rich, eutrophic wetland under growing anthropogenic stress is amply supported by the integrated Physico-chemical, biological and hydrological results, which are in line with the study objectives. Strong nutrient enrichment caused by agricultural runoff, organic loading, and evaporation effects in a closed basin system is indicated by elevated TDS, alkalinity, hardness, and persistent phosphate availability along with moderate-to-low transparency. While, similar trends have been observed in other Ramsar wetlands in Sindh, such as Haleji and Keenjhar lakes, where altered trophic dynamics and eutrophication are encouraged by decreased flushing and nutrient imports (Yaseen & Ali, 2019; Bano & Siddiqui, 2016). Although the pleasantly alkaline pH and often sufficient dissolved oxygen reflect the photosynthetic activities of thick macrophytes and phytoplankton during the day, these conditions frequently conceal the concerns of nocturnal oxygen depletion that are typical of eutrophic systems (Wetzel, 2001). As bioindicators, biological communities provide additional evidence of the deterioration of water quality. In aquatic environments, the prevalence of phytoplankton species that can withstand pollution, such Microcystis, Oscillatoria, and Anabaena, is a clear sign of both organic pollution and nutrient enrichment (Palmer, 1969; Reynolds, 2006). Although their predominance illustrates the sensitivity of phytoplankton communities as bioindicators for evaluation the ecological health and water quality of freshwater systems. Seasonal cyanobacterial blooms and the steady numerical dominance of phytoplankton over zooplankton point to a top-down imbalance and decreased grazing pressure, which are frequently seen in eutrophic tropical lakes (Jeppesen et al., 2005). Similar to this, the growth of macrophytes like Phragmites vallatoria, Typha domingensis, and Eichhornia crassipes indicates shallow-water expansion and high nutrient availability, which are frequently associated with habitat homogenization and a decline in fish and avifaunal diversity (Mitsch & Gosselink, 2015). The coexistence of hardy fish species (such as Wallago attu and Oreochromis mossambicus) with diminishing waterbird populations confirms previous findings that human disturbances, nutrient over-enrichment, and hydrological instability are the main causes of biodiversity loss in South Asian wetlands (Khan et al., 2014; Ramsar Convention Secretariat, 2018). Overall, the use of plankton, macrophytes, and fish assemblages as useful bioindicators is strongly justified by the combined Physico-chemical signals and biological response, highlighting the critical need for nutrient load management and hydrological regulation to restore Drigh Lake's ecological balance.

CONCLUSION

Drigh Lake is a highly productive yet ecologically stressed wetland where anthropogenic activity is having a growing impact on ecosystem health and water quality. Its eutrophic status characterized by excessive nutrient levels, decreased transparency and the predominance of pollution-tolerant phytoplankton and macrophytes is confirmed by integrated Physico-chemical, hydrological and biological evaluations. Fish production, habitat appropriateness, and plankton dynamics are all heavily influenced by seasonal fluctuations' cyanobacterial blooms and excessive macrophyte growth are signs of increasing ecological deterioration. These findings demonstrate the reliability of bioindicators for ecological evaluation and emphasize the lake's susceptibility to uncontrolled agricultural runoff, fertilizer inputs and hydrological disruptions, which pose a significant risk to its long-term sustainability as a Ramsar wetland.

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DECLARATIONS

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Informed Consent: Informed Consent was taken from participants.

Authors' Contributions:

Concept: MAA, MAM, SND, ARA; Design: MAA, MAM, SND, ARA; Data Collection: MAA, MAM, SND, ARA; Analysis: MAA, MAM, SND, ARA; Drafting: MAA, MAM, SND, ARA

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