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Assessment of Eutrophication Risks in Strategic Stagnant Ecosystems of the Marmara Basin via Modified Biodegradable Pollution Indices

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Abstract

Lentic and enclosed aquatic systems are inherently vulnerable to organic enrichment and accelerated eutrophication due to their limited flushing capacities. Manyas and Uluabat Lakes, two ecologically significant freshwater resources in Northwestern Türkiye, serve as vital habitats and migratory corridors for diverse avian populations. Despite their high conservation status, these ecosystems face mounting pressures from intensified agricultural runoff, industrial effluents, and domestic wastewater. This research evaluates the eutrophication potential and organic pollution levels of Manyas Lake and Uluabat Lake utilizing a suite of Modified Biodegradable Contamination Indices (MBCI) based on regional environmental standards. During the winter of 2025, critical limnological parameters were measured to calculate the index values. The analytical outcomes revealed a significant divergence in the ecological health of the two systems; Manyas Lake demonstrated a substantially higher eutrophication risk compared to Uluabat Lake. According to the applied MBCI results, Manyas Lake was characterized as highly polluted with an advanced eutrophic status, whereas Uluabat Lake exhibited moderate pollution levels and a non-eutrophic character. These findings emphasize the urgent necessity for targeted management strategies to mitigate organic loading and preserve the ecological resilience of these strategic wetland habitats.

Keywords: *Eutrophication Index, Organic Pollution, Manyas Lake, Uluabat Lake, Nutrient Enrichment, Marmara Basin*

Introduction

Organic contaminants, including nutrients from agricultural runoff and wastewater, induce algal blooms in lacustrine habitats (Atıcı et al., 2018; Ustaoğlu et al., 2022; Tokatlı et al., 2023; 2024; Muhammad et al., 2025). These blooms, marked by rapid algal growth, disrupt aquatic ecosystems by depleting oxygen, blocking sunlight, and altering food webs. Additionally, organic contamination contributes to hypoxic zones with significantly reduced oxygen levels. Such hypertrophic and hypoxic conditions severely challenge the survival of aquatic organisms, leading to mass mortality among fish and invertebrates (Howarth et al., 2011; Borrell et al., 2019; Mia et al., 2023). Evaluating organic contaminants is crucial to understand their cumulative impacts on aquatic biodiversity, water quality, and ecosystem health (Isiuku and Enyoh, 2020; Varol and Tokatlı, 2023; 2024; Yazman et al., 2024; Yüksel et al., 2025). Holistic approaches provide a comprehensive understanding of aquatic ecosystem health and inform effective management strategies. Practical indicators for assessing eutrophication risks and the synergistic effects of organic contamination include the nutrient pollution index (NPI), organic pollution index (OPI), and eutrophication index (EI) (Tokatlı and Varol, 2021; Varol et al., 2022; Muhammad et al., 2024).

Uluabat Lake, located near Bursa Province of Türkiye, is a shallow freshwater lake with a surface area ranging from 135 to 160 km², depending on water levels, and a maximum depth of 3 meters. It is fed by the Mustafakemalpaşa River and drains into the Marmara Sea via the Susurluk River. The lake is recognized as a Ramsar Wetland of International Importance and supports extensive white water lily beds and significant populations of endangered pygmy cormorants. Manyas Lake is also known as Bird Lake and this nutrient-rich freshwater lake, with an average depth of 3 meters, is fed by groundwater and four streams, forming extensive marshes and reed beds. It is a crucial site for breeding and wintering waterbirds, including the vulnerable Dalmatian pelican, and is designated as a Ramsar site. These significant lakes face significant pollution risks and key pollutants include nitrogenous and phosphorous compounds. Therefore, both lakes require urgent measures to mitigate pollution and protect their ecosystems (https:// www.livinglakes.org/; https:// www.marmara.gov.tr/; Tokatlı et al., 2025). This study evaluated and compared the eutrophication threat for the Manyas Lake (ML) and Uluabat Lake (UL) by means of some modified biodegradable contamination indices (MBCI) using Turkish Standards.

Materials and Methods

Selected locations and water collection

The map of the investigated lakes and selected sampling locations is presented in Figure 1. Water samples were collected during the winter season of 2025. Subsurface samples were taken using a telescopic water sampler, approximately 2.5 to 3 meters from the bank, and stored in 500 mL polyethylene bottles at 4°C (APHA, 2017). These samples were then transported to Trakya University for further chemical analysis.

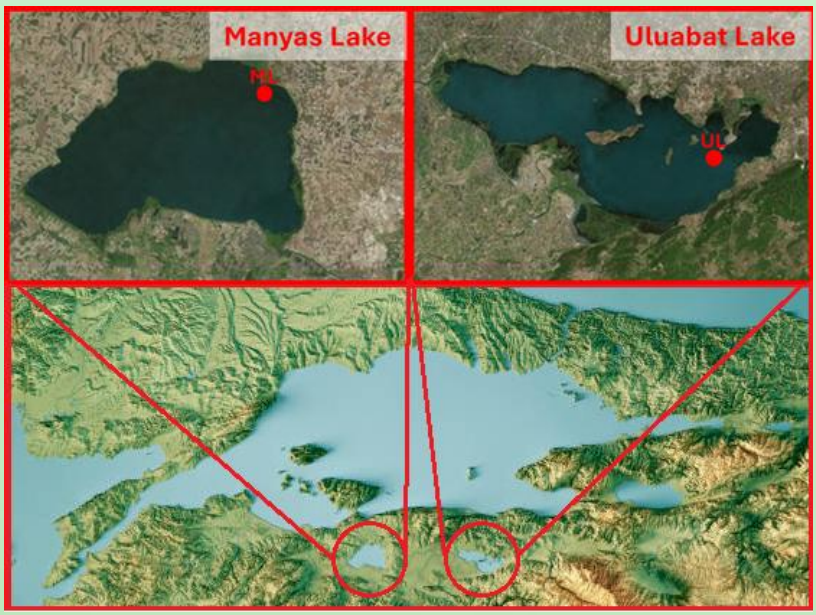

Figure 1. Study area and selected stations

Chemical analysis

Dissolved Oxygen (DO) was measured on-site in the field (APHA, 1998, 2017) using a multiparameter device (Hach Lange – HQ40D). In the laboratory, nitrite nitrogen (NO_2-N), phosphate phosphorus (PO_4-P), and Chemical Oxygen Demand (COD) levels were determined in filtered samples (using a 0.45 µm cellulose nitrate filter) (APHA, 1998) with a spectrophotometer (Hach Lange – DR3900).

Ecological indices

The details of the formulas and computation techniques of applied modified biodegradable contamination indices (MBCI) using Turkish Standards (TSWQR, 2021) are shown in Table 1 (Tokatlı et al., 2025).

Table 1. Methods of applied modified organic pollution risk assessment indices

Index	Calculation	Formula Explanations	Rating of Water Quality
NPI	$NPI = (C_N/MAC_N) + (C_P/MAC_P)$	C_N: The levels of NO_2-N in water sample C_P: The levels of PO_4-P in water sample MAC_N: The maximum limit of NO_2-N MAC_P: The maximum limit of PO_4-P	<1: No polluted 1-3: Moderate polluted 3-6: Considerable polluted >6: Very high polluted
OPI	$OPI = (COD/COD_S) + (NO_2\text{-}N/NO_2\text{-}N_S) + (PO_4\text{-}P/PO_4\text{-}P_S) – (DO/DO_S)$	COD: The chemical oxygen demand DO: Dissolved oxygen …s: Standard levels of variables	<0: Excellent water quality 0-1: Good water quality 1-2: Beginning to be polluted 2-3: Lightly polluted 3-4: Moderately polluted >4: Heavily polluted
EI	$EI = \frac{COD\ x\ NO2-N\ x\ PO4-P}{CODs\ x\ NO2-Ns\ x\ PO4-P}$	COD: The chemical oxygen demand …s: Standard levels of variables	EI > 1: Water quality is regarded as eutrophic

Results and Discussion

The data for calculated modified biodegradable contamination indices (MBCI) for water of UL and ML are given in Figure 2. Results showed that among the investigated natural stagnant water bodies, ML exhibits a much higher potential eutrophication risk compared to UL. According to the applied MBPI results, it was determined that the water of ML was highly polluted (NPI: 10.12 – Very high polluted; OPI: 11 – Heavily polluted) and had an eutrophic character (EI: 33.3 – Water quality is regarded as eutrophic), while the water of UL was moderately polluted (NPI: 1.82 – Moderate polluted; OPI: 1.3 – Beginning to be polluted) and had a non-eutrophic character (EI: 0.11 – Water quality is regarded as non-eutrophic).

Chemical fertilizers containing large amounts of nitrogenous and phosphorous compounds are being widely used in agricultural lands. These fertilizers and the organic pollutants they contain may be carried to the streams and rivers by irrigation, precipitation, and soil erosion (Jannat et al., 2022; Mutlu et al., 2023; Din et al., 2024). It is thought that the agricultural lands around the lakes and the domestic wastewater coming from the settlements are the main reasons for the calculated quite high ecological risk index results and eutrophication indicators.

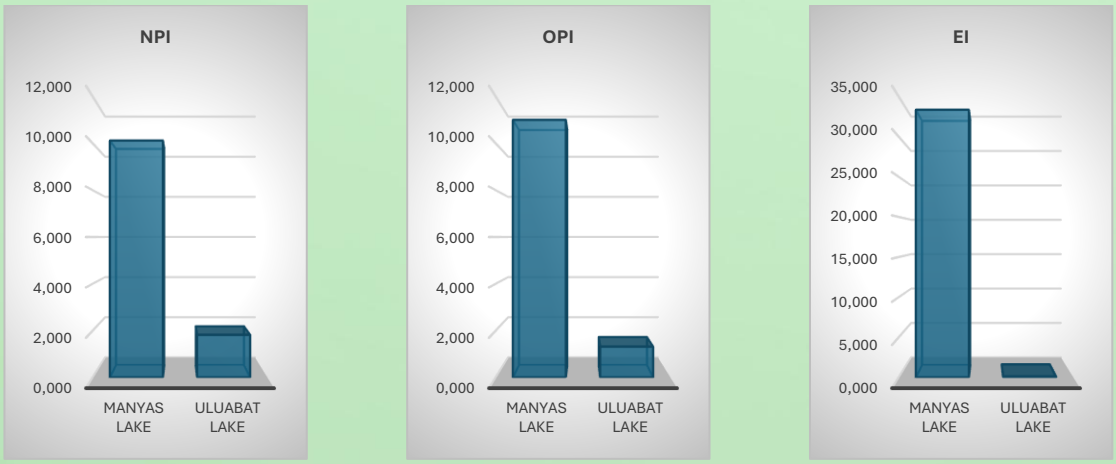

Figure 2. Results of applied MBCI in water of UL and ML

Conclusions

In this research, eutrophication threat for the Manyas Lake (ML) and Uluabat Lake (UL) were compared and evaluated by means of some modified biodegradable contamination indices (MBCI) using Turkish Standards. In conclusion, the data indicates that ML has a significantly higher potential for eutrophication and is more heavily polluted compared to UL. ML's water is classified as highly polluted and eutrophic, with very high pollution indices (NPI: 10.12, OPI: 11, EI: 33.3). In contrast, UL's water is moderately polluted and non-eutrophic, with much lower pollution indices (NPI: 1.82, OPI: 1.3, EI: 0.11). To mitigate the high eutrophication risk and pollution levels in ML, it is crucial to implement stricter pollution control measures, enhance wastewater treatment processes, reduce nutrient runoff from agricultural activities, and restore natural vegetation around the water body to act as a buffer. Additionally, promoting community awareness and involvement in pollution prevention efforts can help maintain and improve water quality over time.

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