

Avian Diversity and Parasitofauna of Waterbirds in the Réghaïa Lake Nature Reserve (Algeria): Ecological Implications and Conservation

Samia Sadaoui Yahia Cherif ¹, Wahiba Aous ² Lynda Ainouz, ^{3,4} Fatma Amira HANI ⁵, Mohamed Zaouani ⁶, Nadia Boughelit, ⁷ Abderrahmane Yahia Cherif ⁸ and Ilham Sahki Benabbas⁹

¹Laboratory of Biological Sciences, Dynamics and Biodiversity, University of Science and Technology, Houari Boumediene, BP39 El Alia, Algiers, Algeria. samia.sadaoui_fsb@usthb.edu.dz

²Laboratory of Valorization and Conservation of Biological Resources, Department of Agronomic Sciences, University of M'hamed Bougara, Boumerdes, Algeria. w.aous@univ-boumerdes.dz

³Laboratory of Food Hygiene and Quality Insurance System (HASAQ), Ecole Nationale Supérieure Vétérinaire (ENSV), Abbes Street, Oued-Smar, 16000, Algiers, Algeria. l.ainouz@ensv.dz

⁴Laboratory of Biology and Animal Physiology (LBPA), ENS Kouba, Algiers, Algeria. l.ainouz@ensv.dz

⁵Animal Health and Production Laboratory (SPA), Ecole Nationale Supérieure Vétérinaire (ENSV), Abbes Street, Oued-Smar, 16000, Algiers, Algeria. f.hani@ensv.dz

⁶Animal Health and Production Laboratory (SPA), Ecole Nationale Supérieure Vétérinaire (ENSV), Abbes Street, Oued-Smar, 16000, Algiers, Algeria. m.zaouani@ensv.dz

⁷Laboratory of Soft Technologies, Valorization, and Physico-Chemistry of Biological Materials, Department of Agronomic Sciences, University of M'hamed Bougara, Boumerdes, Algeria. n.boughelit@univ-boumerdes.dz

⁸Laboratory of Biological Sciences, Dynamics and Biodiversity, University of Science and Technology, Houari Boumediene, BP39 El Alia, Algiers, Algeria.

Yahiacheriftce08@yahoo.fr

⁹Laboratory of Biological Sciences, Dynamics and Biodiversity, University of Science and Technology, Houari Boumediene, BP39 El Alia, Algiers, Algeria.

benabbas.sahki@gmail.com

ARTICLE INFO

Received: 12 Mar 2025

Revised: 05 Sept 2025

Accepted: 15 Sept 2025

Published: 30 Nov 2025

ABSTRACT

The Réghaïa Lake Nature Reserve, located in northeastern Algeria, represents a major ecological hotspot for waterbirds. From June 2020 to May 2021, a total of 30 waterbird species belonging to seven orders and twelve families were recorded. Avifaunal diversity and community structure were evaluated using Shannon-Weaver diversity indices, evenness measures, and occurrence frequencies. Principal Component Analysis (PCA) was employed to correlate physico-chemical water parameters with species distribution. Parasitological analysis of Mallards (*Anas platyrhynchos*) revealed four endoparasite species, indicating potential environmental contamination. The results underscore the ecological richness of the site, the influence of environmental variables on avifauna distribution, and the necessity for regular ecological and sanitary monitoring to ensure effective conservation.

Keywords: wetlands, aquatic birds, endoparasites, Réghaïa Lake, Algeria, biodiversity, ecological monitoring.

Introduction

The Western Mediterranean region is recognized as one of the world's primary biodiversity hotspots, characterized by high species richness, endemism, and a mosaic of unique habitats (Quézel & Médail, 2003). Within this region, wetlands provide crucial ecosystem services, including biodiversity conservation, hydrological regulation, nutrient cycling, and refuge for migratory species (Dugan, 2005; Finlayson et al., 2017). Despite their ecological importance, Mediterranean wetlands have experienced substantial degradation, with more than 50% lost over the past century due to urbanization, agricultural intensification, and climate change (Mediterranean Wetlands Observatory, 2018).

Algeria hosts over 1,200 wetlands, 52 of which are recognized under the Ramsar Convention for their international importance (Beghdadi, 2017; Samraoui & Samraoui, 2008). Among them, Réghaïa Lake, positioned at the interface between continental and marine environments, comprises a heterogeneous landscape of reed beds, lagoons, coastal dunes, and halophilous thickets, providing habitats for numerous aquatic and terrestrial species (Boumaza et al., 2019). The site has recorded over 203 bird species, including 82 waterbird species, several of which are categorized as vulnerable or threatened (BirdLife International, 2022).

Waterbird distribution and community dynamics are strongly influenced by environmental variables such as water temperature, salinity, depth, and food availability (Green & Elmberg, 2014). Furthermore, these birds host a variety of parasites, whose prevalence and diversity are affected by ecological factors such as host density, microclimate, habitat quality, and seasonal variations (Poulin, 2007; Bush et al., 2001). Understanding these interactions is essential for implementing effective conservation strategies.

Objectives

The main objectives of this study were to comprehensively characterize the Réghaïa Lake wetland, focusing on its habitat diversity and ecological attributes, to analyze the spatial and temporal dynamics of its waterbird communities, to identify the key physico-chemical parameters influencing the distribution of avifauna, and to investigate the associated parasite communities in order to assess their ecological implications.

Materials and Methods

Study Site

Réghaïa Lake ($36^{\circ}42'N$, $3^{\circ}13'E$) is located in northeastern Algeria, near the Mediterranean coast. The wetland encompasses a combination of shallow lagoons, reed beds, open water, and adjacent terrestrial habitats. These varied habitats support high avian biodiversity but are subjected to anthropogenic pressures, including urban expansion, agriculture, and industrial activities (Boumazza et al., 2019).

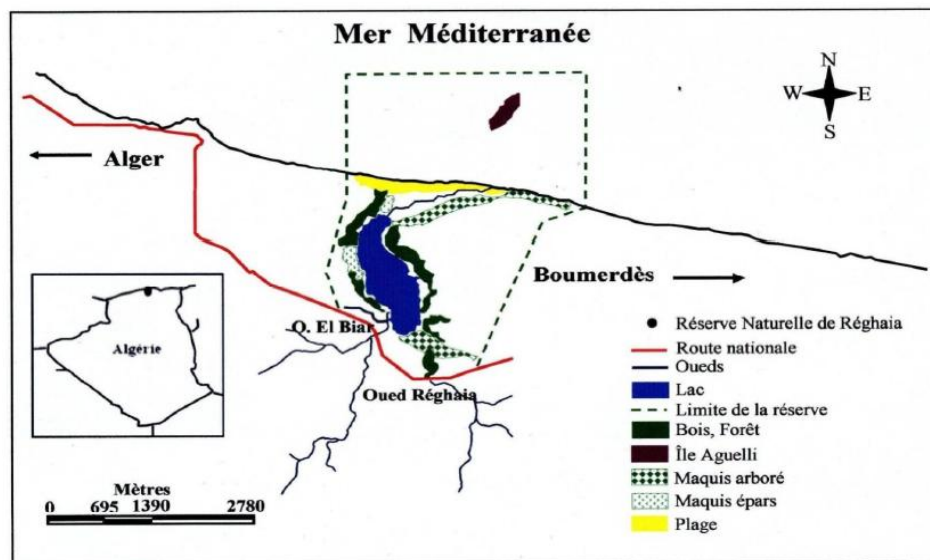


Figure 1. Spatial location and delineation of the Réghaïa Lake Nature Reserve, based on the 2005 D.G.F. cartographic database (modified).



Figure 2. View of Réghaïa Lake (Original photograph, 2019).

Avifaunal Survey

Monthly surveys were conducted from June 2020 to May 2021. Waterbirds were identified and counted using binoculars (10×42) and field guides (del Hoyo et al., 1992). Community composition was analyzed using:

- Species richness (S): total and mean species per month.
 - Occurrence frequency (OF): proportion of months in which a species was recorded.
 - Centesimal frequency (CF): proportion of individuals per species relative to total bird counts.
- Community structure was assessed using Shannon-Weaver diversity index (H') and evenness (E) (Magurran, 2004).

Physico-Chemical Parameters

Water samples were collected monthly at three representative points. Measured parameters included temperature ($^{\circ}\text{C}$), pH, biochemical oxygen demand (BOD_5 , mg/L), ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^-), and other ionic components. Multivariate analysis, specifically Principal Component Analysis (PCA), was used to examine correlations between environmental variables and bird distribution patterns (Lê et al., 2008).

Parasitological Study

Fecal samples from Mallards (*Anas platyrhynchos*) were collected monthly and analyzed for endoparasites following standard protocols (Sloss et al., 1994). Parasites were identified, quantified, and classified according to occurrence frequency. Statistical correlations were performed to assess relationships between parasitism prevalence, species diversity, and environmental parameters (Akçay et al., 2011; Qualab et al., 2019).



Figure 3. A: Pair of Mallard ducks; B: Mallard duck droppings. (Original Photos, 2019).

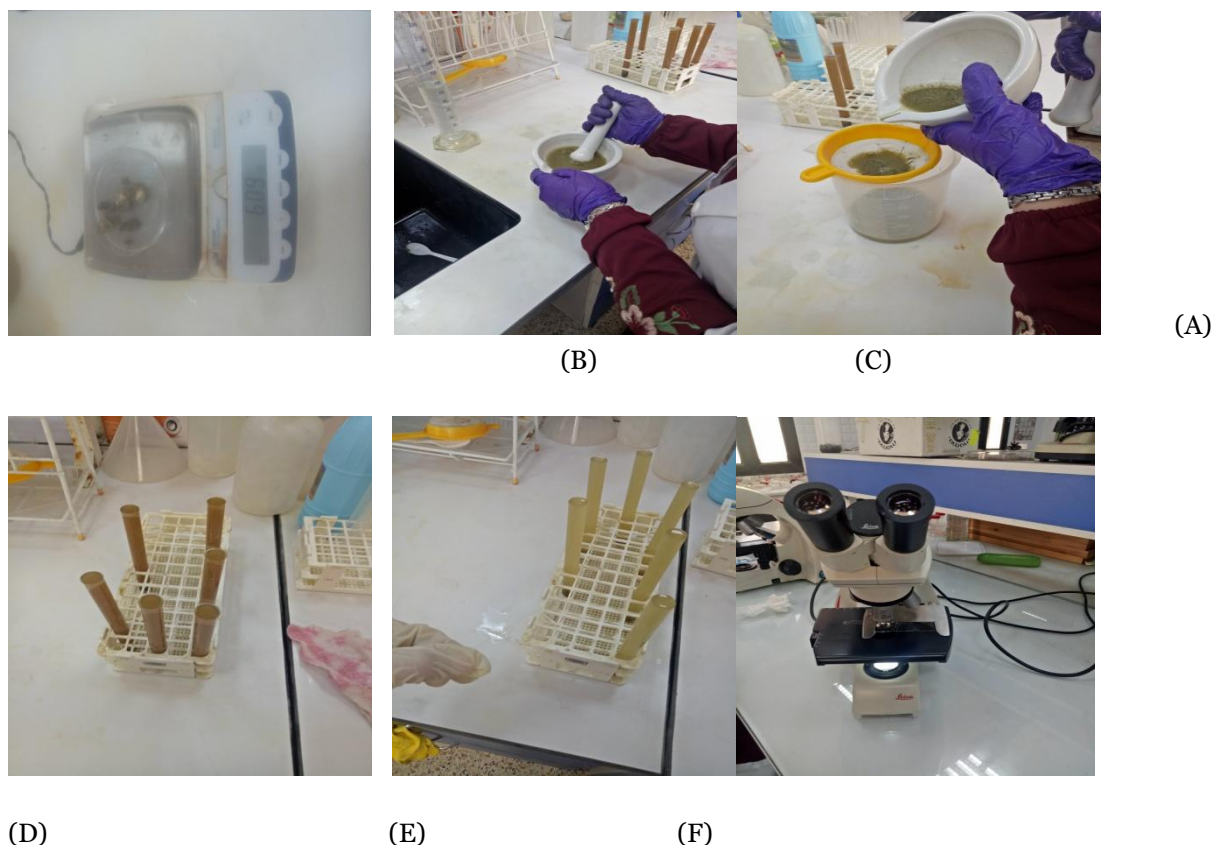


Figure 4. Flotation procedure (Original Photos, 2019).

A: Weighing of the sample; B: Grinding of the sample (homogeneous solution).

C: Filtering of the solution (flotation solution); D: Tubes covered with coverslips.

E: Coverslip placed on the slide for observation; F: Observation of the slides under an optical microscope.

Results

Avifaunal Inventory

A total of 30 waterbird species were recorded, distributed across seven orders and twelve families. Charadriiformes (36.7%) and Anseriformes (30%) were the most dominant orders. Among species, *Larus ridibundus* was the most abundant in summer and autumn, with centesimal frequencies of 38.91% and 36.21%, respectively. Seasonal changes in species composition reflected migration patterns and breeding activities.

Ecological Indices

Shannon-Weaver diversity (H') ranged from 2.3 to 3.2 bits, peaking above 4 bits during peak migration periods, suggesting high ecological richness. Evenness (E) ranged from 0.63 to 0.79, indicating

relatively balanced community structures without extreme dominance.

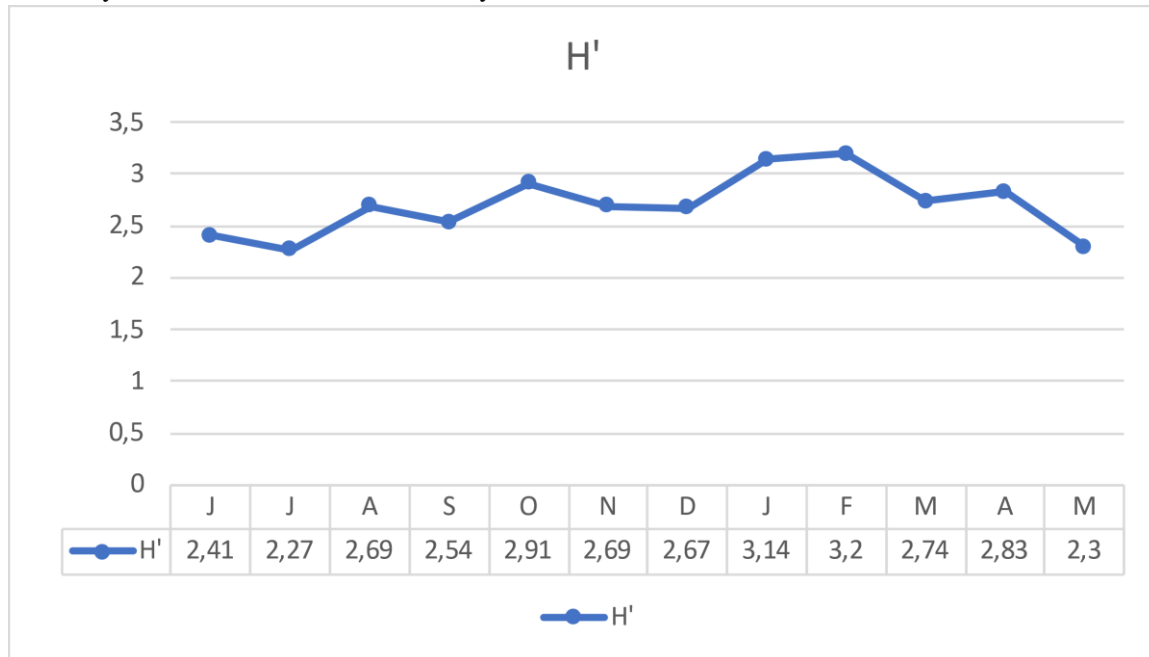


Figure 5. Monthly variations of Shannon–Weaver diversity indices of waterbirds at Lake Réghaïa

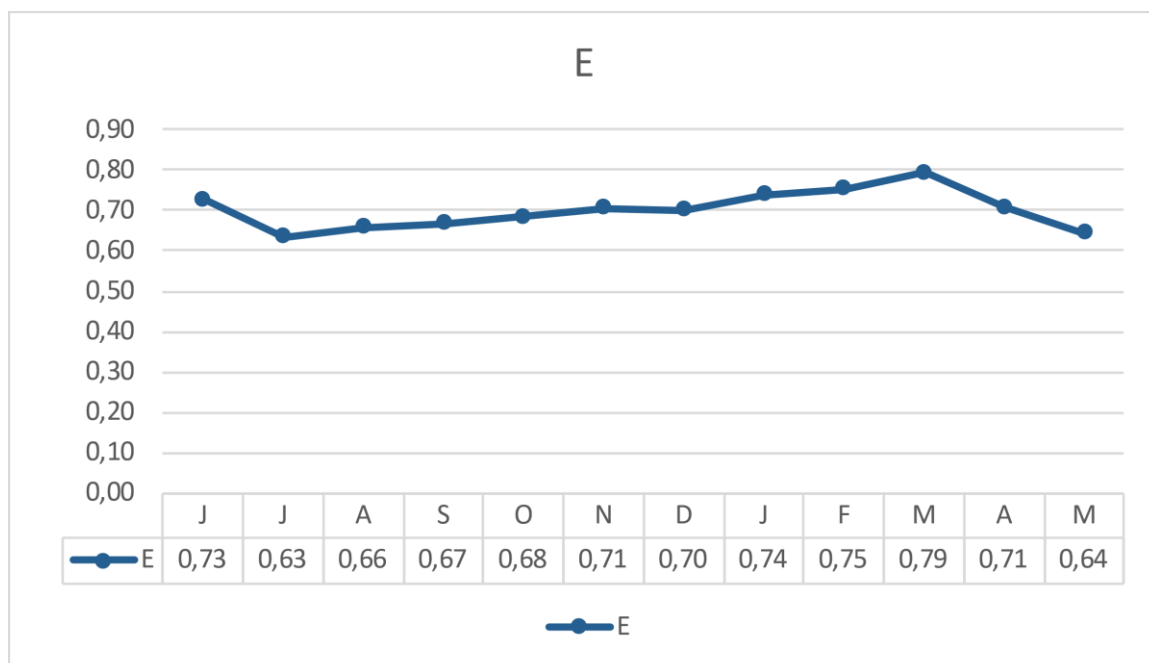


Figure 6. Monthly variations of evenness indices of waterbirds at Lake Réghaïa

Physico-Chemical Parameters

Water temperature and pH remained within expected ranges (15–28 °C; 7.2–8.3). Mean BOD₅ was 20.92 mg/L, indicating moderate organic pollution. Elevated concentrations of NH₄⁺ and PO₄³⁻ suggested a risk of eutrophication. PCA explained 57.93% of variance in bird distribution, highlighting temperature, nutrient load, and water depth as key factors shaping avifaunal composition.

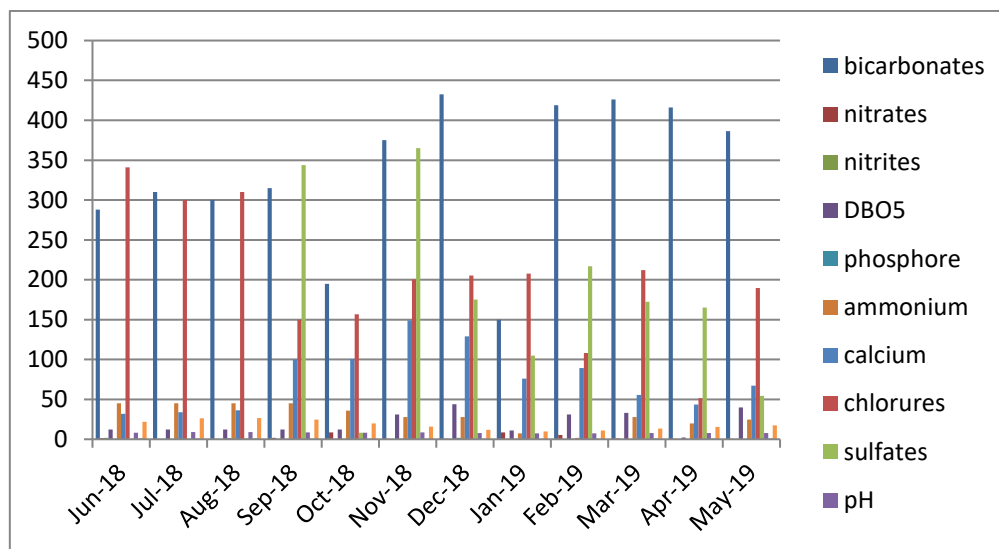


Figure 7. Monthly variations of physico-chemical parameters

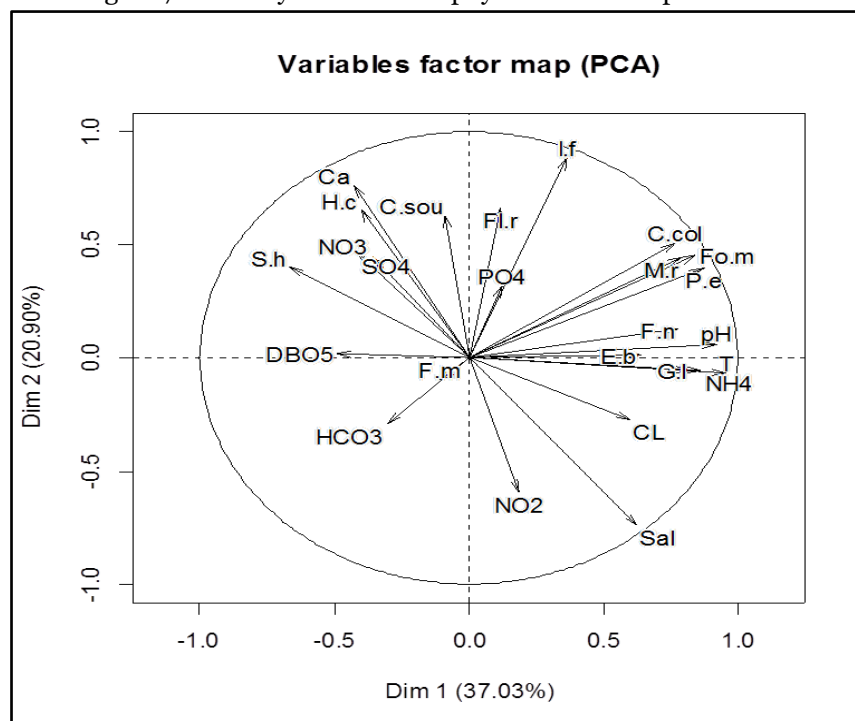
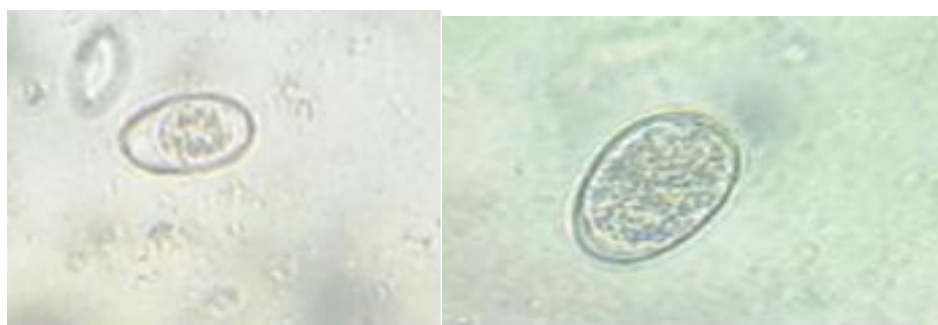


Figure 8. PCA ordination diagram (Distribution of waterbirds in relation to environmental parameters).

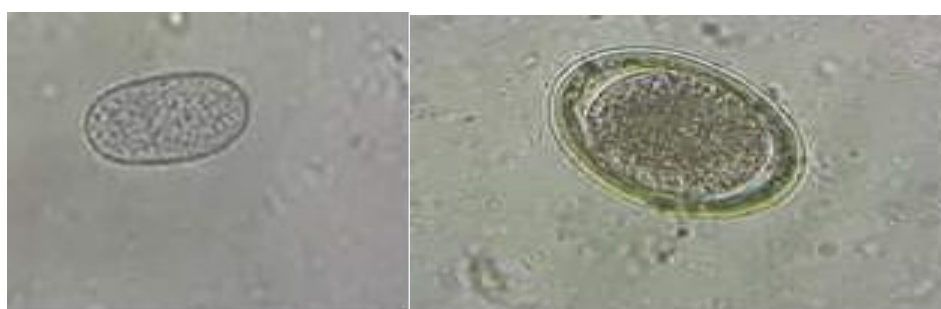
Endoparasites

Parasitological analyses identified four endoparasite species: *Eimeria* sp. (dominant), *Amidostomum anseris*, *Ascaridia* sp., and *Trichostrongylus tenuis*. Their prevalence suggests potential contamination through water, food, and soil sources, emphasizing the role of environmental quality in parasite transmission (Akçay et al., 2011; Qualab et al., 2019).



Eimeria sp

Amidostomum anseris



Trichostrongylus tenuis

Ascaridia sp

Figure 9. Parasites found in Mallard duck droppings

Discussion

Diversity and Dynamics of Waterbirds

Réghaïa Lake supports a rich assemblage of waterbirds, with high species richness and relatively balanced distribution. Seasonal fluctuations correspond to migratory influxes and local breeding activities, consistent with observations in other North African wetlands (Lahbib, 2017; Fettis, 2016). Dominance of Anatidae indicates the ecological suitability of the wetland for dabbling and diving species.

Influence of Environmental Parameters

Water quality, nutrient load, and habitat heterogeneity significantly influenced bird distribution. Eutrophication, driven by high phosphorus and nitrogen inputs, may enhance primary productivity, increasing food availability for waterbirds (Ronka et al., 2005). PCA revealed distinct seasonal groups,

illustrating how specific species associate with environmental conditions. This underlines the importance of continuous monitoring to detect habitat alterations affecting avifaunal communities.

Endoparasites and Ecological Implications

The detection of *Eimeria* and nematode species in Mallards highlights the potential for environmental contamination and pathogen transmission. Parasitism patterns are influenced by host density, habitat conditions, and seasonality (Poulin, 2007). Regular sanitary monitoring is crucial to mitigate disease risks, particularly in urbanized and ecologically sensitive wetlands.

Conclusion

Réghaïa Lake is a key wetland ecosystem in Algeria, hosting 30 waterbird species across 7 orders and 12 families, with relatively balanced diversity (Shannon-Weaver H' ranging from 2.3 to 3.5 bits) and evenness (E) from 0.63 to 0.79. The most abundant orders are Charadriiformes (36.7%) and Anseriformes (30%), with *Larus ridibundus* dominating in summer and autumn (38.91% and 36.21% of individuals, respectively). These data highlight the reserve's role as a breeding site for resident species and as a stopover for migratory species.

Physico-chemical analyses indicate that water temperatures range between 15 and 28 °C and pH between 7.2 and 8.3, with a moderate organic load (BOD₅ = 20.92 mg/L). Elevated concentrations of NH₄⁺ and PO₄⁻ indicate a potential risk of eutrophication, which may affect food availability and habitat quality. PCA revealed that 57.93% of the variance in bird distribution could be explained by these physico-chemical parameters, confirming the direct influence of environmental conditions on waterbird community structure.

The parasitofauna of Mallards (*Anas platyrhynchos*) includes four endoparasite species: *Eimeria* sp. (dominant), *Amidostomum anseris*, *Ascaridia* sp., and *Trichostrongylus tenuis*. The prevalence of these parasites reflects potential contamination of water, soil, and food consumed by birds, highlighting the close interaction between habitat quality, bird health, and sanitary risks. These observations emphasize the importance of parasitological and health monitoring to prevent disease spread and maintain the resilience of bird populations, particularly under increasing anthropogenic pressures.

In conclusion, Réghaïa Lake is a major conservation site for avian biodiversity in Algeria. Protecting and sustainably managing this site requires the integration of measures such as habitat restoration, water quality management, regular ecological and health monitoring, and stakeholder awareness programs. The combination of avian richness and parasitic diversity underscores the importance of an integrated approach that considers both biodiversity and bird health to ensure the long-term sustainability of this unique ecosystem for future generations.

References

- [1] Akcay, C., Gungor, B., & Yilmaz, R. (2011). Intestinal parasites of wild waterfowl in Turkey. *Parasitology Research*, 108(1), 221–229. <https://doi.org/10.1007/s00436-010-2095-0>
- [2] Beghdadi, S. (2017). Evaluation of wetland biodiversity in Algeria. Ministry of Environment, Algiers.
- [3] BirdLife International. (2022). Species factsheet: *Aythya nyroca*, *Marmaronetta angustirostris*, *Oxyura leucocephala*. Retrieved from <https://www.birdlife.org>

- [4] Boumaza, M., Bounif, M., & Bouchecker, A. (2019). Diversity and seasonal dynamics of waterbirds in the Réghaïa Lake wetland (Algeria). *Revue d'Écologie*, 74(2), 123–136.
- [5] Boudraa, M. (2016). Ecological assessment of the wetlands of eastern Algeria. *Mediterranean Ecology*, 12, 45–59.
- [6] Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, A. W. (2001). Parasitology meets ecology on its own terms: Margolis et al. revisited. *Journal of Parasitology*, 87(4), 575–583.
- [7] Dugan, P. (2005). Guide to Wetlands of the Mediterranean Basin. IUCN, Gland, Switzerland.
- [8] Finlayson, C. M., Davidson, N. C., Spiers, A. G., & Stevenson, N. J. (2017). *The Wetland Book I: Structure and Function, Management, and Methods*. Springer, Dordrecht.
- [9] Fettis, M. (2016). Seasonal abundance and habitat selection of migratory waterbirds in Algerian wetlands. *Ornithological Science*, 15, 97–108.
- [10] Green, A. J., & Elmberg, J. (2014). Ecosystem services of waterbirds. *Biological Reviews*, 89(1), 105–122.
- [11] Khelou, F. (2011). Ecological monitoring of wetlands in Algeria: Patterns and trends. *Wetlands Ecology and Management*, 21, 233–245.
- [12] Lahbib, F. (2017). Seasonal variation and habitat use of waterbirds in northeastern Algerian wetlands. *African Journal of Ecology*, 55(2), 224–234.
- [13] Lê, S., Josse, J., & Husson, F. (2008). FactoMineR: An R package for multivariate analysis. *Journal of Statistical Software*, 25(1), 1–18.
- [14] Magurran, A. E. (2004). *Measuring Biological Diversity*. Blackwell Science, Oxford.
- [15] Mediterranean Wetlands Observatory (MWO). (2018). *Mediterranean Wetlands Outlook 2: Solutions for Conservation and Sustainable Use*. Tour du Valat, France.
- [16] Poulin, R. (2007). *Evolutionary Ecology of Parasites* (2nd ed.). Princeton University Press, Princeton, NJ.
- [17] Quézel, P., & Médail, F. (2003). *Ecology and Biogeography of Mediterranean Basin Forests*. Springer, Berlin.
- [18] Ronka, K., Hellsten, S., & Karjalainen, K. (2005). Effects of eutrophication on waterbird communities in Finnish lakes. *Hydrobiologia*, 551, 213–224.
- [19] Samraoui, F., & Samraoui, B. (2008). Wetland birds in Algeria: Status, threats, and conservation. *Wildfowl*, 58, 71–96.
- [20] Sloss, M. W., Kemp, R. L., & Zajac, A. M. (1994). *Veterinary Clinical Parasitology* (6th ed.). Iowa State University Press, Ames, IA.
- [21] Slimani, T., & Taleb, N. (2014). Waterbird diversity in coastal wetlands of Algeria. *Journal of North African Zoology*, 8, 55–68.