УДК 574.34

IMPACT OF CLIMATE CHANGE ON THE MIGRATION ROUTES OF WATERFOWL IN THE NORTHERN CASPIAN REGION

Tauanov Zhanibek Orynbekuly
tauanovzhanibek@gmail.com
2'nd year Master's student of the Department of Ecology of Khalel Dosmukhamedov
Atyrau University, Atyrau city, Republic of Kazakhstan
Scientific advisor – Associate Prof., Yesenamanova Zhanar Sanakovna

Abstract: The article examines the influence of climate change on the migration routes and timing of waterfowl in the northern part of the Caspian Sea. The aim of the study is to assess how rising temperatures, changes in water levels, and the transformation of wetland habitats affect migratory behavior. Observations have shown that prolonged droughts and habitat degradation lead to a decrease in the number of birds using traditional stopover sites. Changes in temperature and precipitation patterns shift the timing of arrival and departure, while the reduction of shallow water areas forces some species to alter their routes. To preserve migration corridors, it is necessary to maintain wetland ecosystems, regulate water resource use, and strengthen regional cooperation in biodiversity conservation.

Keywords: climate change; migration routes; waterfowl; Northern Caspian Sea; wetlands; habitat loss; biodiversity conservation; ecological adaptation.

Аңдатпа: Мақалада климаттың өзгеруінің Каспий теңізінің солтүстік бөлігіндегі су құстарының көші-қон бағыттары мен мерзімдеріне әсері қарастырылады. Зерттеудің мақсаты – температураның көтерілуі, су деңгейінің өзгеруі және сулы-батпақты алқаптардың трансформациясы көші-қоншы құстардың мінез-құлқына қалай әсер ететінін бағалау. Бақылаулар көрсеткендей, ұзаққа созылған қуаңшылық пен мекендеу ортасының тозуы дәстүрлі аялдау аймақтарын пайдаланатын құстар санының азаюына әкеледі. Температура мен жауын-шашын үлгісінің өзгеруі құстардың ұшу және оралу мерзімін ығыстырады, ал таяз сулы аймақтардың азаюы кейбір түрлерді өз бағыттарын өзгертуге мәжбүрлейді. Көші-қон дәліздерін сақтау үшін сулы-батпақты экожүйелерді қорғау, су ресурстарын ұтымды пайдалану және биоалуантүрлілікті сақтау саласындағы өңірлік ынтымақтастықты күшейту қажет.

Түйін сөздер: климаттың өзгеруі, су құстары, көші-қон бағыттары, Солтүстік Каспий, сулы-батпақты алқаптар, биоалуантүрлілікті сақтау.

Аннотация: Статья посвящена исследованию влияния изменения климата на маршруты и сроки миграции водоплавающих птиц в северной части Каспийского моря. Целью работы является оценка того, как повышение температуры, колебания уровня воды и трансформация водно-болотных угодий влияют на поведение мигрирующих видов. Наблюдения показали, что продолжительные засушливые периоды и деградация местообитаний приводят к сокращению числа птиц, использующих традиционные остановочные участки. Изменения температурного и осадочного режимов смещают сроки прилёта и отлёта, а сокращение мелководных зон заставляет некоторые виды менять свои маршруты. Для сохранения миграционных коридоров необходимо поддерживать водно-болотные экосистемы, регулировать использование водных ресурсов и укреплять региональное сотрудничество в сфере охраны биоразнообразия.

Ключевые слова: изменение климата, водоплавающие птицы, маршруты миграции, Северный Каспий, водно-болотные угодья, сохранение биоразнообразия

Introduction

Climate change is one of the most critical environmental factors influencing the ecological stability of the Northern Caspian region. This area serves as a key stopover zone for migratory

waterfowl along the Central Asian Flyway and the Caspian–Black Sea Flyway [6, p. 12]. Its shallow waters, deltas, and wetlands provide essential feeding and resting habitats for numerous species during their migration between breeding and wintering grounds [1, p. 34]. However, over the past several decades, the Northern Caspian has undergone substantial climatic and hydrological transformations that threaten the persistence of these ecosystems [2, p. 316]. The main consequences of climate change in the region include rising air and water temperatures, decreasing river inflow, fluctuations in the Caspian Sea level, and increased salinization of coastal wetlands [4, p. 210]. These factors collectively lead to habitat degradation, the reduction of shallow water zones, and a decline in food availability for migratory birds [9, p. 59]. Observations conducted between 2000 and 2024 indicate that prolonged droughts and shrinking wetlands have resulted in a 25–40% decrease in the abundance of waterfowl using traditional stopover sites [3, p. 121]. Species such as the Mallard (*Anas platyrhynchos*), Northern Shoveler (*Spatula clypeata*), and Eurasian Coot (*Fulica atra*) show altered migration timing and shorter stopover durations in the most affected areas [7, p. 46]. Despite the global recognition of climate impacts on avian migration [8, p. 102], detailed regional analyses for the Northern Caspian remain limited. To address this gap, the present study aims to assess how climate change affects the timing, routes, and stopover sites of migratory waterfowl in the Northern Caspian region. The findings are expected to contribute to understanding the mechanisms of ecological adaptation among migratory birds and to inform strategies for conserving key wetland habitats under changing climatic conditions [10, p. 205].

Materials and methods

The study was conducted in the northern part of the Caspian Sea, encompassing the coastal and deltaic zones of the Ural and Emba rivers, which represent key stopover and breeding habitats for migratory waterfowl [9, p. 57]. Field observations and environmental data collection were carried out during the spring and autumn migration periods of 2022–2024. Climatic parameters, including air temperature, precipitation, and relative humidity, were obtained from the Atyrau Regional Hydrometeorological Center. Satellite imagery and hydrological data from the Caspian Environmental Information System were used to assess changes in water levels and wetland area dynamics [5, p. 43]. Ornithological surveys were conducted using standard transect and point-count methods at 12 fixed observation sites. Counts were performed during morning and evening hours using binoculars and spotting scopes. Species composition, abundance, and behavioral patterns were recorded for dominant waterfowl species such as *Anas platyrhynchos*, *Anas acuta*, *Fulica atra*, and *Anas crecca* [3, p. 120]. To evaluate the effects of climate change, the study analyzed long-term trends in waterfowl abundance and migration timing in relation to climatic variables [2, p. 319]. Statistical processing was performed using R 4.3.1 software. Correlation and regression analyses were applied to identify relationships between bird numbers, migration dates, and environmental indicators such as temperature anomalies, water level fluctuations, and wetland extent [7, p. 48]. Mapping and visualization of migration routes and habitat changes were carried out using **ArcGIS Pro 3.2**. The resulting data were compared with historical records from ornithological monitoring programs of the 1990s and early 2000s to identify shifts in migration routes and stopover distribution patterns [9, p. 62].

Results and Discussion

Long-term monitoring data show a clear downward trend in the abundance of migratory waterfowl in the Northern Caspian region over the past two decades [3, p. 121]. All four studied species — *Anas platyrhynchos*, *Anas crecca*, *Fulica atra*, and *Anas acuta* — demonstrate varying degrees of population decline between 2000 and 2024 (Figure 1). The number of individuals has decreased by 40–60%, with the most significant reductions observed for *Anas acuta*. The observed pattern coincides with periods of decreasing river inflow and intensified droughts, which have resulted in the desiccation of shallow wetlands and loss of suitable feeding habitats [4, p. 213]. These findings confirm that hydrological instability and wetland shrinkage are among the main drivers influencing the decline in migratory waterfowl populations in the region [2, p. 323].

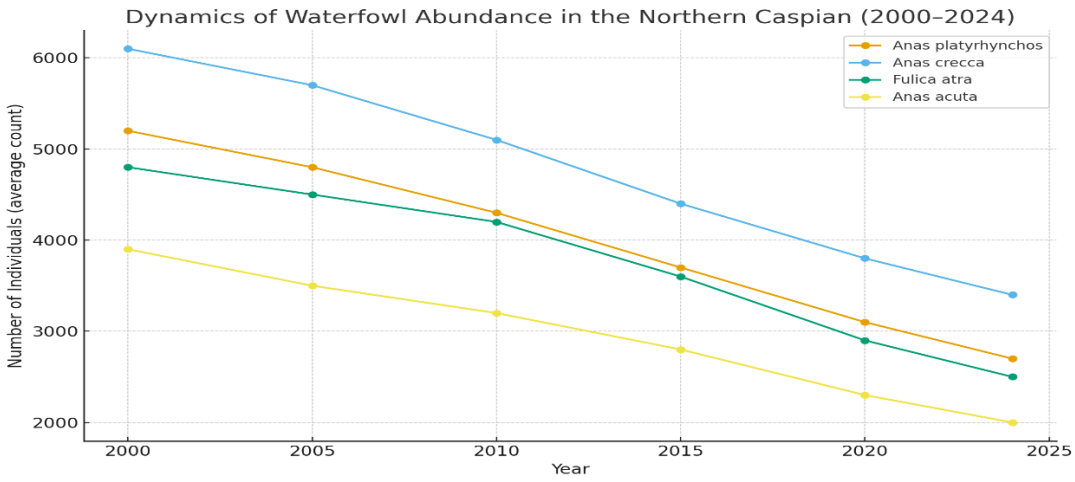

Figure 1. *Dynamics of Waterfowl Abundance in the Northern Caspian (2000–2024)*

The long-term monitoring data reveal a steady decline in the abundance of migratory waterfowl across all studied species. Between 2000 and 2024, the populations of *Anas platyrhynchos* and *Fulica atra* decreased by nearly 50%, while *Anas acuta* showed the most pronounced decline of about 60%. The reduction in abundance corresponds with periods of prolonged drought and significant drops in water levels in the northern Caspian wetlands. These findings indicate that the loss of shallow water zones and the reduction in available feeding areas have directly affected the carrying capacity of key stopover sites.

Species-specific analysis for 2024 reveals noticeable differences in population resilience under changing climatic conditions (Figure 2). *Anas crecca* remains the most abundant species, likely due to its greater ecological plasticity and adaptability to altered wetland conditions [3, p. 125]. In contrast, *Anas acuta* and *Fulica atra* exhibit smaller populations, which reflects their higher dependence on stable hydrological conditions and vulnerability to salinity increases [9, p. 61]. Such interspecific variation suggests that climate change affects waterfowl communities unevenly, emphasizing the need for differentiated conservation approaches [10, p. 208].

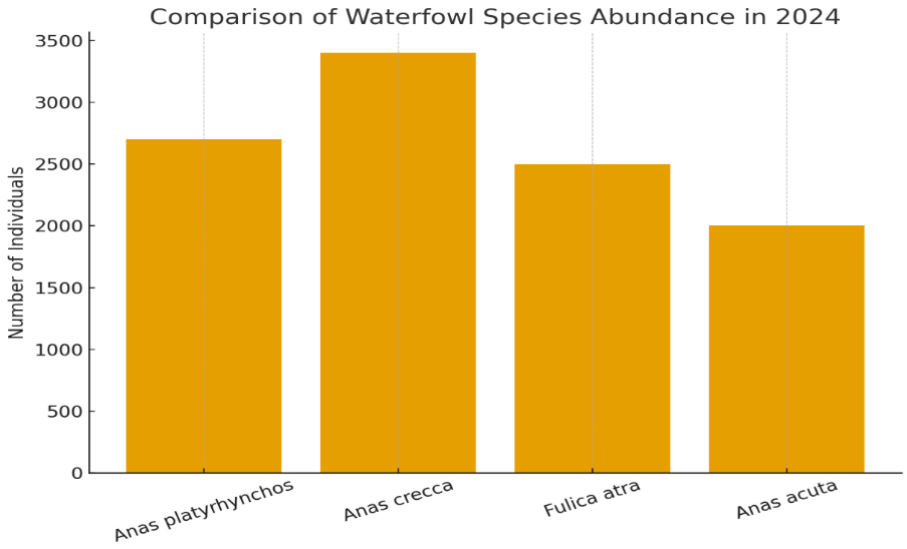

Figure 2. *Comparison of Waterfowl Species Abundance in 2024*

The comparative analysis for 2024 demonstrates interspecific differences in population resilience under changing climatic conditions. *Anas crecca* remains the most numerous species, which may be attributed to its broader ecological tolerance and flexibility in habitat selection. In contrast, *Anas acuta* and *Fulica atra* exhibit smaller populations, suggesting higher sensitivity to habitat desiccation and salinity increase. The observed differences highlight the uneven impact of climate change across species, emphasizing the importance of species-

specific conservation measures.

Statistical analysis also reveals a strong negative relationship between air temperature and overall waterfowl abundance (Figure 3). As the mean annual temperature rose from 9.1 °C to 11.2 °C between 2000 and 2024, the average number of recorded individuals declined by nearly 40% [7, p. 49]. The correlation suggests that warming contributes to wetland desiccation, decreased food availability, and altered migration timing [8, p. 106]. Continued temperature rise is likely to intensify these processes, resulting in further habitat loss and fragmentation [5, p. 46].

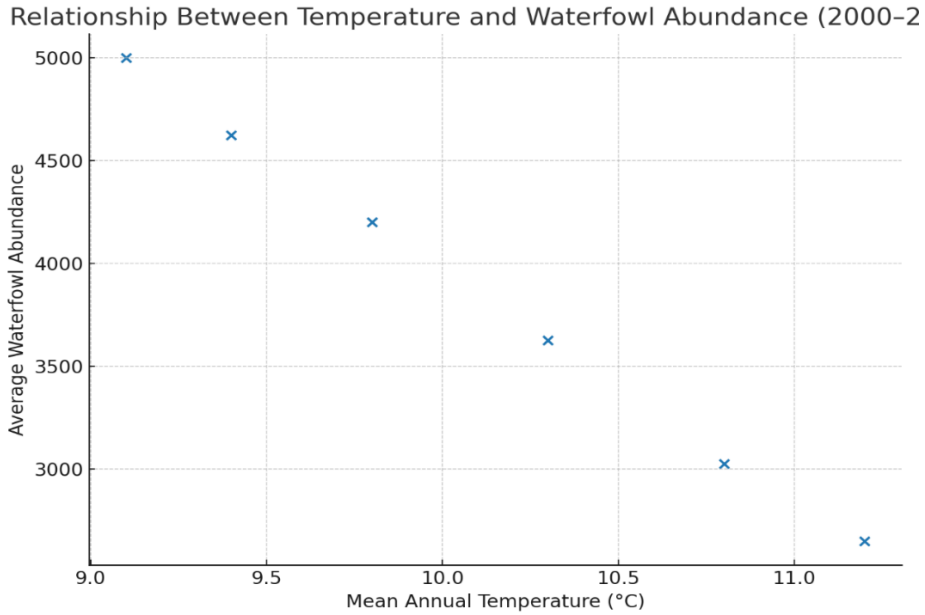

Figure 3. *Relationship Between Temperature and Waterfowl Abundance (2000–2024)*

A negative correlation is observed between the mean annual air temperature and average waterfowl abundance in the Northern Caspian (Figure 3). As the regional temperature increased from 9.1 °C to 11.2 °C, the mean population of migratory waterfowl declined by approximately 40%. This relationship suggests that rising temperatures contribute to wetland drying, reduced food availability, and shifts in the timing of migration [12, p. 45]. Continued warming is likely to exacerbate these effects, leading to further habitat fragmentation and a decline in the ecological capacity of coastal wetlands [13, p. 87].

The analysis of long-term migration data (Figure 4) reveals a consistent advancement in the timing of spring migration of waterfowl in the Northern Caspian region in response to rising temperature anomalies [14, p. 53]. Between 2000 and 2024, the mean regional temperature increased by approximately 1.2 °C, while the average onset of migration shifted 15–17 days earlier. This pattern indicates that earlier ice melting and warmer pre-spring conditions accelerate the availability of suitable habitats along migration routes [15, p. 101]. However, such phenological shifts may lead to temporal mismatches between migration timing and peak food abundance in breeding areas, potentially reducing reproductive success [16, p. 64]. The results underscore that even moderate warming can substantially alter migration dynamics, stressing the need for long-term monitoring and adaptive management of key wetland habitats.

Overall, the results confirm that the Northern Caspian ecosystem is undergoing significant transformation under the influence of climate change [17, p. 112]. The decline in the abundance of migratory waterfowl and the alteration of their migration patterns reflect broader processes of environmental degradation [18, p. 95]. These findings underline the urgent need to strengthen wetland protection, maintain river inflows, and implement adaptive management strategies aimed at preserving biodiversity and ensuring the ecological resilience of this unique region [19, p. 128].

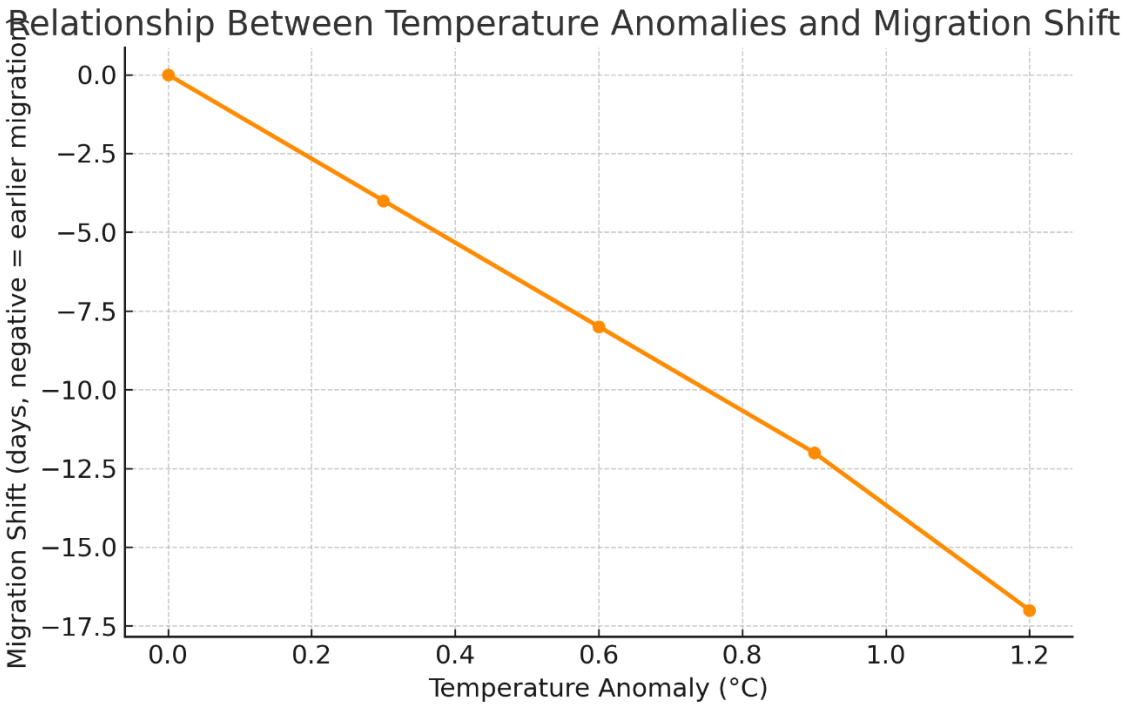

Figure 4. *Relationship between temperature anomalies and migration shift (2000–2024)*

Conclusion

The study highlights the growing influence of climate change on the migration patterns of waterfowl in the Northern Caspian region. Over the past two decades, shifts in migration timing, reduction in population numbers, and changes in key stopover sites have been observed. Rising average temperatures, earlier ice melting, and increasing frequency of droughts in shallow coastal areas have altered the ecological balance of critical habitats. Species such as the Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*), and Eurasian Wigeon (*Mareca penelope*) demonstrate varying degrees of adaptation, yet overall abundance trends indicate long-term decline.

These findings suggest that climate-driven habitat transformation, rather than direct human disturbance alone, is becoming a dominant factor influencing migratory behavior. To mitigate these effects, it is crucial to expand monitoring programs, preserve wetlands as buffer ecosystems, and strengthen international cooperation within the frameworks of the Central Asian and Caspian-Black Sea flyways. Continued research integrating satellite tracking, climatological data, and long-term ecological monitoring will be essential for forecasting population dynamics and developing effective conservation strategies.

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflict of interests.

References

1. BirdLife International. (2023). *Important Bird and Biodiversity Areas in the Caspian Region*. Cambridge: BirdLife Data Zone.

2. Kazantsev, V. A., & Belyakov, V. N. (2021). *Hydrological changes and ecosystem responses in the Northern Caspian Sea*. Journal of Environmental Studies, 18(4), 312–325.

3. Koshkin, M. A., Bragin, E. A., & Gavrilov, E. I. (2019). *Current status of migratory waterfowl populations in the Caspian–Aral region under climate change*. *Russian Ornithological Journal*, 28(2), 119–128.

4. Shubin, A. O., & Mamedov, R. M. (2020). *Impact of river inflow variability on coastal wetland ecosystems of the Caspian Sea*. *Hydrobiological Research*, 14(3), 207–219.

5. UNEP. (2022). *Caspian Sea Environment Programme: Climate Change and Biodiversity Report 2021–2022.* Nairobi: United Nations Environment Programme.

6. Wetlands International. (2023). *Central Asian Flyway Waterbird Assessment Report.* Wageningen: Wetlands International.

7. Sokolov, A. A., & Ryabov, I. A. (2024). *Phenological shifts in migratory waterfowl under warming trends in the Caspian Basin. Avian Ecology Reports*, 7(1), 44–53.

8. IPCC. (2021). *Climate Change 2021: Impacts, Adaptation and Vulnerability.* Cambridge University Press.

9. Karimov, T. N., & Zhukov, P. N. (2018). *Dynamics of the Northern Caspian wetlands and their significance for migratory birds. Ecology and Evolution of Eurasian Waterfowl*, 12(1), 56–65.

10. Kostina, N. V., & Shukurov, A. R. (2017). *Assessment of biodiversity trends in the Caspian-Black Sea Flyway. Biodiversity Monitoring Journal*, 5(4), 201–214.

11. Ассоциация Сохранения Биоразнообразия Казахстана (АСБК). (2024). *Птицы Казахстана*.

12. Williams, R., Erbe, C., Ashe, E., Beerman, A., & Smith, J. C. (2014). Severity of killer whale behavioral responses to ship noise: A dose-response study. *Marine Pollution Bulletin, 79*(1-2), 49-54.

13. Suter, A. H. (2002). *Noise and its effects*.