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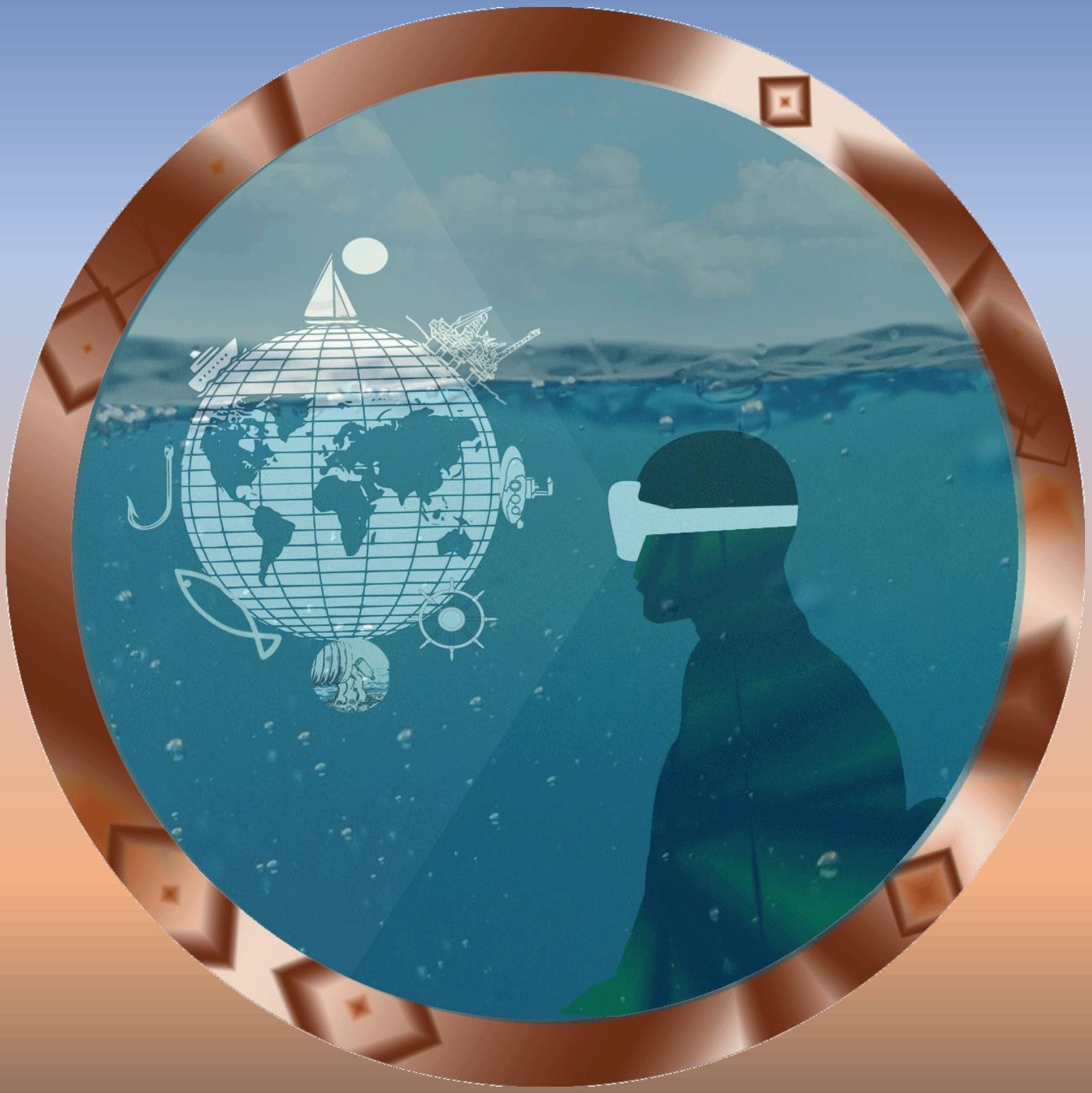

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Hampton, S., Rabagliati, H., Sorace, A., & Fletcher-Watson, S. (2017). *Autism and bilingualism: A qualitative interview study of parents' perspectives and experiences*. PsyArXiv, *Preprint*. https://doi.org/10.31234/osf.io/76xfs

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Chapter:

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Vassallo, A. I., & Mora, M. S. (2007). Interspecific scaling and ontogenetic growth patterns of the skull in living and fossil ctenomyid and octodontid rodents (Caviomorpha: Octodontoidea). In Kelt, D. A., Lessa, E., Salazar-Bravo, J. A., & Patton, J. L. (Eds.), *The Quintessential Naturalist: Honoring the Life and Legacy of Oliver P. Pearson* (pp. 945-968). 1st ed. University of California Press.

Thesis and Dissertation:

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Şimşek, E. (2018). Analysis of the factors affecting the discard fate for trawl fishery [Ph. D. Thesis, Iskenderun Technical University] (in Turkish).

Conference Proceedings:

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Institution Publication:

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Froese, R., & Pauly, D. (Eds.) (2018). FishBase. World Wide Web electronic publication. Retrieved on January 11, 2018 from http://www.fishbase.org.

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While the peer-reviewed journal literature should be accessible online without cost to readers, it is not costless to produce. However, experiments show that the overall costs of providing open access to this literature are far lower than the costs of traditional forms of dissemination. With such an opportunity to save money and expand the scope of dissemination at the same time, there is today a strong incentive for professional associations, universities, libraries, foundations, and others to embrace open access as a means of advancing their missions. Achieving open access will require new cost recovery models and financing mechanisms, but the significantly lower overall cost of dissemination is a reason to be confident that the goal is attainable and not merely preferable or utopian.

To achieve open access to scholarly journal literature, we recommend two complementary strategies.

I. Self-Archiving: First, scholars need the tools and assistance to deposit their refereed journal articles in open electronic archives, a practice commonly called, self-archiving. When these archives conform to standards created by the Open Archives Initiative, then search engines and other tools can treat the separate archives as one. Users then need not know which archives exist or where they are located in order to find and make use of their contents.

II. Open-access Journals: Second, scholars need the means to launch a new generation of journals committed to open access, and to help existing journals that elect to make the transition to open access. Because journal articles should be disseminated as widely as possible, these new journals will no longer invoke copyright to restrict access to and use of the material they publish. Instead, they will use copyright and other tools to ensure permanent open access to all the articles they publish. Because the price is a barrier to access, these new journals will not charge subscription or access fees and will turn to other methods for covering their expenses. There are many alternative sources of funds for this purpose, including the foundations and governments that fund research, the universities and laboratories that employ researchers,

endowments set up by discipline or institution, friends of the cause of open access, profits from the sale of add-ons to the basic texts, funds freed up by the demise or cancellation of journals charging traditional subscription or access fees, or even contributions from the researchers themselves. There is no need to favor one of these solutions over the others for all disciplines or nations, and no need to stop looking for other, creative alternatives.

Open access to peer-reviewed journal literature is the goal. Self-archiving (I.) and a new generation of open-access journals (II.) are the ways to attain this goal. They are not only direct and effective means to this end, but they are also within the reach of scholars themselves, immediately, and need not wait on changes brought about by markets or legislation. While we endorse the two strategies just outlined, we also encourage experimentation with further ways to make the transition from the present methods of dissemination to open access. Flexibility, experimentation, and adaptation to local circumstances are the best ways to assure that progress in diverse settings will be rapid, secure, and long-lived.

The Open Society Institute, the foundation network founded by philanthropist George Soros, is committed to providing initial help and funding to realize this goal. It will use its resources and influence to extend and promote institutional self-archiving, to launch new open-access journals, and to help an open-access journal system become economically self-sustaining. While the Open Society Institute's commitment and resources are substantial, this initiative is very much in need of other organizations to lend their effort and resources.

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The studies are sent to the referees according to their content and the expertise of the referees. The field editor examining the study may propose at least two referees from the pool of ***Marine and Life Sciences*** Advisory Board or referee pool according to their field of expertise or may propose a new referee appropriate to the field of study.

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The period given to the referee for the evaluation process is 15 days. Proposals for corrections from referees or editors must be completed by the authors within 1 month according to the "correction instruction".

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4. Evaluation and discussion: The evaluation report includes the opinion on the subject based on findings, relevance to research questions and hypotheses, generalizability and applicability.

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Marine and Life Sciences

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Marine and Life Sciences

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Marine-derived adsorption biomaterials for water treatment: Efficiency and kinetics of textile dye removal using functionalized fish bone adsorbents

Bayram Kızılkaya[1]✉

[1] Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, Department of Aquaculture, Çanakkale, Türkiye,

✉ Corresponding Author: bayram342001@yahoo.com

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A B S T R A C T

This study provides a low-cost, environmentally friendly, and biologically derived adsorbent alternative for the removal of toxic dyes commonly found in industrial wastewater. The modification of waste materials such as fish bones contributes to sustainable resource utilization while achieving effective results in reducing dye pollution originating from the textile, food, and chemical industries. The adsorption mechanism was investigated by kinetic and diffusion models; they provide important data for the design and optimization of such materials. The surface of fish bone particles was modified in two steps. Firstly, the particles (H) were silanized with 3-aminopropyltriethoxysilane (S). In the second step, modification was made by shift base reaction between the amine on the surface and 2-Ethyl-2H-pyrazole-3-carbaldehyde (A). Adsorption experiments were conducted using fuchsine solution at different initial concentrations (6.76, 3.38, 1.69, and 0.676 mg/L) and adsorption capacity (q_e), removal efficiency (%), and kinetic parameters were comprehensively investigated. The results showed a noticeable increase in adsorption capacity (0.08–0.94 mg/g) with increasing initial concentration, while kinetic analyses indicated that the adsorption process followed the pseudo-second-order kinetic model with a high degree of correlation, suggesting that chemical interactions may play a dominant role in the adsorption mechanism.

INTRODUCTION

Globally, industrial activities are leading to serious pollution of water resources, a problem that becomes especially pronounced due to dye waste originating from the textile, food, leather, and chemical industries (Markandeya and Shukla, 2022; Negi, 2025). Dyes possess high chemical stability and complex molecular structures, making them resistant to natural degradation processes and resulting in persistent pollution within aquatic ecosystems. Some dyes, in particular, exhibit toxic, mutagenic, and carcinogenic properties, posing significant risks to both human health and the environment. Therefore, the effective and economical treatment of dye-containing wastewater has become a priority research topic in environmental engineering and sustainable development policies (Lellis et al., 2019; Tkaczyk et al., 2020; Karabulut and Gürkan, 2023; Ambade et al., 2024; Dutta et al., 2025). Although conventional wastewater treatment methods such as chemical precipitation, ozonation, membrane filtration, and biological processes are commonly used, these methods often face limitations such as high operational costs, secondary waste generation, and low efficiency (Matesun et al., 2024; Sravan et al., 2024). Therefore, in recent years, there has been growing interest toward environmentally friendly, low-cost, and sustainable alternative treatment technologies. Among these technologies, adsorption has gained prominence due to its ease of application, high efficiency, and flexibility, making it

a widely preferred method, particularly for dye removal applications (Moosavi et al., 2020; Zhang et al., 2025). Traditional adsorbents used in adsorption processes include activated carbon, silica, alumina, and various synthetic polymers; however, the high production costs and environmental impacts of these materials limit their widespread use. Therefore, developing low-cost, biodegradable adsorbents derived from renewable resources has become highly important (Satyam and Patra, 2024; Akhtar et al., 2024).

In recent years, there has been a growing focus on developing low-cost and environmentally friendly adsorbent materials. Agricultural and industrial wastes as adsorbents offers a sustainable approach for both waste management and water treatment (Mo et al., 2018; Ahmad, 2023; Alvez-Tovar et al., 2025). Marine-derived biomaterials, particularly the valorization of fish industry wastes, present remarkable potential in this field. Marine-origin biomaterials stand out as innovative and eco-friendly solutions in wastewater treatment applications (Uranga et al., 2019; Rudovica et al., 2021; Chellapandian et al., 2025). With the development of aquaculture and the parallel growth of the aquaculture processing sector, the availability of fish waste has also increased (Bayraklı and Duyar, 2019; Bayraklı et al., 2019; Bayraklı, 2023). Fish bones, shells of marine organisms, and other residues from the seafood processing industry are considered suitable raw materials for the production of functional adsorbents due to their rich mineral content and porous structures. Fish bones, a significant by-product of the seafood processing industry, represent a potential raw material for adsorption applications due to their high calcium carbonate content and porous structure (Kizilkaya et al., 2010). Fish bones are natural materials with high active surface areas that are amenable to various surface modifications and can be chemically stabilized. The utilization of such waste contributes both to the production of environmentally friendly materials and to marine waste management policies (Bayraklı et al., 2019, 2024; Duyar and Bayraklı, 2023). In this study, fish bone particles were functionalized through surface modifications, and their adsorption properties were thoroughly investigated for the removal of the anionic dye fuchsine, which originates from the textile industry. The results aim to highlight the potential use of marine-derived materials in wastewater treatment technologies and to contribute to the existing literature in this field.

MATERIALS AND METHODS

Functionalization of Bone Surfaces

In this study, the surface modification of fish bone particles (H) with 2-Ethyl-2H-pyrazole-3-carbaldehyde (A) was performed according to our previous studies (Kizilkaya et al., 2016, 2018). In summary, the surface modification was carried out in two steps. In the first step, the bone particle surfaces were silanized with 3-aminopropyltriethoxysilane (S). The silanization process began by stirring the silane solution (ethanol/water 9:1) for 30 minutes. Then, 5 g of H was added and stirred at room temperature for 24 hours. The resulting suspension was centrifuged and washed five times with technical ethanol and dried at 45°C. The obtained product was named HS. Subsequently, aldehyde modification was performed on the surface using 2-Ethyl-2H-pyrazole-3-carbaldehyde. For the aldehyde modification, an aldehyde solution (in ethanol) was prepared, and HS was added; the mixture was refluxed at 70 °C for 6 hours. After cooling, the mixture was left to rest at room temperature for 12 hours. Then, the mixture was washed five times with technical ethanol by centrifugation and dried at 45°C. The final product was named HSA.

Adsorption and Removal Studies

The experiments were conducted at room temperature (23 ± 1°C). Using an adsorbent-to-solvent ratio of 1:200, after adsorption and interaction times of 30 and 24 hours, the liquid phase was taken from the solution, filtered through a 0.45 μm syringe filter, and analyzed instrumentally to complete the experiment. Fuchsine was used as the cationic dye. Measurements were performed with a PG Instruments T80-UV/VIS spectrophotometer available at our faculty. Adsorption studies in aqueous media were carried out by measuring the absorbance at the maximum wavelength (λ_{max}) of 550 nm using UV spectrophotometry. The adsorption of fuchsine dye was investigated for all obtained materials. The HSA product was treated with fuchsine solutions at concentrations of 6.76, 3.38, 1.69, and 0.676 mg/L. Experiments were completed by filtering the liquid phase from the solution through a 0.45 μm syringe filter after 24 hours of adsorption time at an adsorbent-to-solvent ratio of 1:200. The change in absorbance of the sorption solution was analyzed by UV spectrophotometry to determine the amount of adsorbed fuchsine.

RESULTS AND DISCUSSION

Fuchsine is a synthetic dye belonging to the triphenylmethane group, widely used in the textile industry, characterized by high water solubility and vibrant colors. Its chemical structure contains aromatic ring systems and amino groups, providing bright pink and magenta hues. (Degano et al., 2019; Tamburini et al., 2024). Due to its high chemical stability and solubility, fuchsine poses a risk of persistent pollution in wastewater. When discharged into aquatic

environments, particularly from textile and dye industries, it remains dissolved for extended periods, adversely affecting ecosystems and human health. This underscores the environmental necessity of effectively removing fuchsine in wastewater treatment processes (Liu et al., 2022; Al-Qarhami et al., 2025). Studies on the adsorption-based removal of fuchsine demonstrate that biologically derived adsorbents with surface modifications can be especially effective. Fuchsine can form electrostatic interactions, hydrogen bonds, and π-π interactions with adsorbent surfaces, enhancing adsorption capacity (Rajumon et al., 2019; Mohammadzadeh Pakdel et al., 2022). Therefore, developing low-cost, sustainable, and eco-friendly adsorbents for the treatment of dyes like fuchsine is of great importance. Figure 1 shows the results of the amount adsorbed per gram (mg/g), mole (μmol/g) and percentage removal (%) of the fuchsin dye adsorption of the bone particle surface modified HSA product. When evaluating the adsorption experimental results of fuchsine dye using the surface-modified fish bone-based adsorbent, the effect of the initial concentration on adsorption capacity and removal efficiency was clearly observed. At an initial concentration (C_0) of 6.76 mg/L, the amount of dye adsorbed per gram of adsorbent (q_e) was calculated as 0.94 mg/g (2.792 μmol/g), and under these conditions, the removal efficiency reached 69.60%. When the initial concentration decreased to 3.38 mg/L, the q_e value was recorded as 0.47 mg/g (1.389 μmol/g) with a removal efficiency of 69.26%. At a further reduced concentration of 1.69 mg/L, q_e was 0.22 mg/g (0.652 μmol/g) and removal efficiency was 65.03%. At the lowest initial concentration of 0.676 mg/L, the adsorption capacity was measured as 0.08 mg/g (0.223 μmol/g) with a removal efficiency of 55.47%. These data indicate that adsorption capacity increases with rising initial dye concentration, while removal efficiency tends to decrease below a certain concentration threshold. This is particularly attributed to the limited interaction probability between dye molecules in solution and the abundant active sites on the adsorbent surface at low concentrations, leading to relatively lower removal efficiencies. It can be concluded that surface-modified fish bone-based adsorbents demonstrate a certain adsorption capacity toward anionic dyes like fuchsine and can be considered as low-cost, biologically sourced alternative adsorbents. They hold promising potential for dye removal in environmental applications.

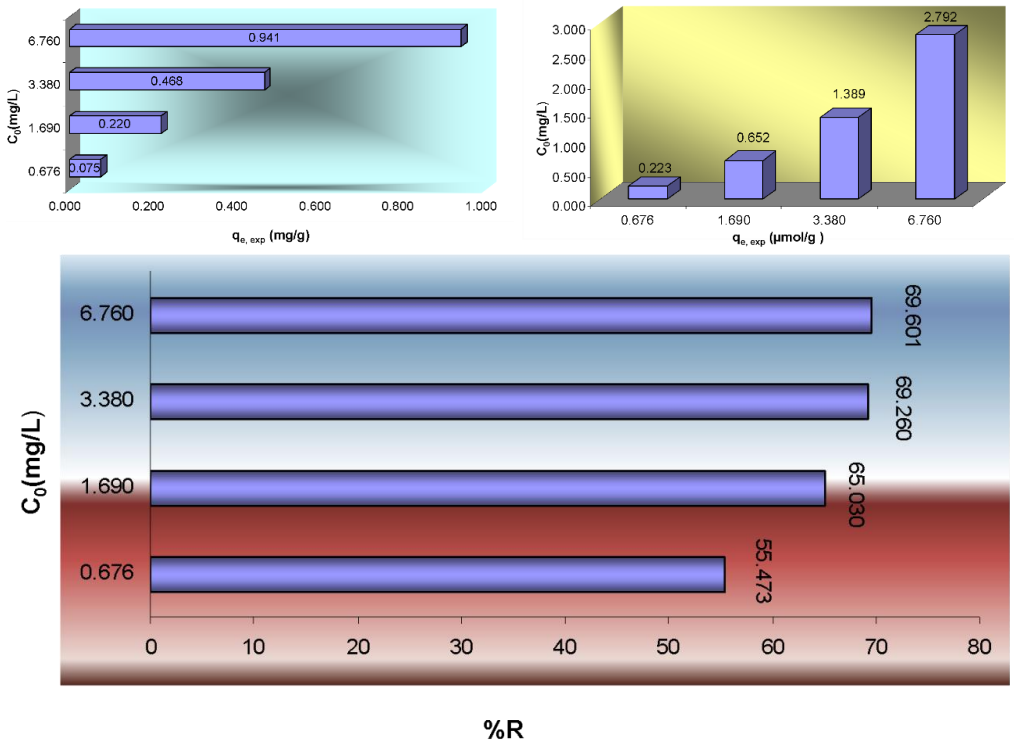

Figure 1. Results of the amount adsorbed per gram (mg/g), mole (μmol/g) and percentage removal (%) of the fuchsin dye adsorption of the bone particle surface modified HSA product

The adsorption capacities of fish bone were determined and expressed in terms of milligrams of adsorbed substance per gram of fish bone (mg/g), calculated using the relevant equation (1) (Kizilkaya et al., 2010**;** Kizilkaya and Tekinay, 2011**)**:

$$q_t = \frac{(C_0 - C_t)\cdot V}{W} \quad (1)$$

In this equation, C_0 represents the initial concentration of metal ions (mg/L), while C_t indicates the metal ion concentration at time t after adsorption (mg/L). V refers to the

volume of the metal ion solution (mL), and *W* denotes the weight of the fish bone adsorbent used in the process (g).

The kinetic behavior of the adsorption process was evaluated according to the pseudo-first-order model, applying the Lagergren equation as shown in equation (2) (El-Sikaily et al., 2007; Chairat et al., 2006; Cheung et al., 2000; Kizilkaya, 2012a):

$$\ln(q_e - q_t) = \ln q_{e,cal} - k_1 \cdot t \quad (2)$$

In the pseudo-first-order kinetic model, k_1 represents the rate constant of adsorption (h^{-1}), while q_e and q_t correspond to the amounts of metal adsorbed per gram of fish bone (mg/g) at equilibrium and at any given time *t*, respectively. A linear relationship was observed when plotting $ln(q_e-q_t)$ against *t*, confirming the applicability of the pseudo-first-order model to the adsorption process. The slope and intercept obtained from this linear plot were used to determine both the pseudo-first-order rate constant k_1 and the calculated equilibrium adsorption capacity $q_{e,cal}$.

Equation (3) was employed to represent the pseudo-second-order kinetic behavior of the adsorption process (Chiou and Li, 2003; Smičiklas et al., 2006; Kizilkaya, 2012b):

$$t/q_t = 1/k_{2q_{e,cal^2}} + t/q_{e,cal} \quad (3)$$

In the pseudo-second-order kinetic model, k_2 (g bone/mg·h) represents the rate constant of adsorption. A linear relationship was observed when plotting t/q_t against *t*, indicating that the adsorption process follows pseudo-second-order kinetics. The equilibrium adsorption capacity ($q_{e,cal}$) and the rate constant k_2) were determined from the slope and intercept of the t/q_t versus *t* plot.

The initial adsorption rate, h_i, was calculated using the rate constant k_2 derived from the pseudo-second-order kinetic model and is expressed by the following equation (4) (Chiou and Li, 2003; Chairat et al., 2006):

$$h_i = k_{2q_{e,cal^2}} \quad (4)$$

In this equation, the parameter h_i denotes the initial rate of metal adsorption, measured in milligrams of metal adsorbed per gram of bone per hour (mg/g bone·h). The constants k_2, $q_{e,cal}$ and *h* were calculated from the intercept and slope of the line obtained by plotting t/q_t against *t*.

The intraparticle diffusion (IPD) model developed by Weber and Morris is commonly used to analyze the kinetics of adsorption processes (Wu et al., 2009). Weber–Morris and Urano–Tachikawa models were employed to describe the diffusion behavior of fuchsine dye from aqueous solution. The Weber and Morris diffusion model is expressed by the following equation (5) (El-Sikaily et al., 2007; Hameed et al., 2008; Greluk and Hubicki, 2009; Kızılkaya et al., 2012b):

$$q_t = Kw.t^{0.5} + C \quad (5)$$

In this equation, *Kw* (mg.g^{-1} h$^{-0.5}$) represents the intraparticle diffusion rate constant according to Weber and Morris, while *C* is the intercept value of the plot, which provides insight into the boundary layer thickness (mg/g). The amount of adsorption at any time, q_t, is plotted against the square root of time ($t^{0.5}$) resulting in a linear relationship. The intraparticle diffusion constant (*K*w) is determined from the slope of the q_t versus $t^{0.5}$ plot. The intraparticle diffusion coefficient (*D*w) was calculated using the following equation (6) (Selatnia et al., 2004; Freitas et al., 2008; Kızılkaya et al., 2012a):

$$Dw = (\pi/8640)\left(dKw/q_e\right)^2 \quad (6)$$

In this equation, *Dw* (m^2 h^{-1}) is the diffusion coefficient in the solid and *d* (m) is the mean particle diameter.

Equation (7) was employed to describe the intraparticle diffusion model developed by Urano and Tachikawa (1991) as applied by (Freitas et al., 2008; Kızılkaya et al., 2012b):

$$-\log\left[1 - \left(q_t/q_e\right)^2\right] = 4\pi^2 D_i t/2.3d^2 \quad (7)$$

In this equation, D_i (m^2 min^{-1}) is the diffusion coefficient in the solid. D_i was calculated from the slopes of $-log[1-(q_t/q_e)^2]$ versus *t* plots.

Based on the kinetic data presented in Table 1, the adsorption of fuchsine dye using the surface-modified fish bone-based adsorbent was evaluated according to the pseudo-first-order kinetic model. The experimentally obtained adsorption capacity values ($q_{e,exp}$) were compared with the adsorption capacities calculated from the model ($q_{e,cal}$) as well as the rate constant (k_1) values. At an initial concentration of 6.76 mg/L, the experimental adsorption capacity was measured as 0.94 mg/g, whereas the model-calculated value was 0.39 mg/g, with the corresponding rate constant 0.420 h^{-1} (k_1). Under these conditions, the correlation coefficient (R^2) was 0.869, indicating a limited fit to the model. Similarly, at an initial concentration of 3.38 mg/L, the experimental q_e was 0.47 mg/g, and the model value was calculated as 0.20 mg/g. The R^2 value of 0.948 indicated the best fit, suggesting that the pseudo-first-order kinetic model better represents the adsorption process within the mid-concentration range. At lower concentrations, such as 1.69 mg/L and 0.676 mg/L, a similar trend was observed. In both cases, the experimental q_e values differed from the model

values, with R^2 values of 0.905 and 0.898, respectively. Overall, it can be concluded that the pseudo-first-order kinetic model shows a better fit in the mid-concentration range for fuchsine dye adsorption on surface-modified fish bone; however, a perfect fit across all concentration ranges was not achieved. This suggests that the adsorption mechanism is not limited to physical adsorption alone and that other processes such as chemical interactions or film diffusion may also play significant roles.

The kinetic data for fuchsine dye adsorption using the surface-modified fish bone-based adsorbent (Table 1) were evaluated according to the pseudo-second-order kinetic model. The results demonstrate that this model represents the adsorption process with high accuracy. Across all concentration ranges, the experimentally obtained adsorption capacities ($q_{e,exp}$) closely matched the model-calculated values ($q_{e,cal}$), with correlation coefficients (R^2) ranging from 0.9909 to 0.9980. An increase in adsorption capacity was observed with rising initial concentrations. For example, at an initial concentration of 6.76 mg/L, the calculated $q_{e,cal}$ was 0.95 mg/g, with a rate constant (k_2) of 3.43 g/mg·h and an initial adsorption rate (h_i) of 3.11 mg/g·h. Similarly, at 3.38 mg/L, $q_{e,cal}$ was 0.47 mg/g, k_2 was 6.37 g/mg·h, and h_i was 1.41 mg/g·h. At lower concentrations, such as 1.69 mg/L and 0.676 mg/L, $q_{e,cal}$ values were 0.22 mg/g and 0.08 mg/g, while k_2 values increased to 20.23 g/mg·h and 31.92 g/mg·h, respectively. Notably, as the initial concentration decreased, the rate constant (k_2) increased, whereas the initial adsorption rate (h_i) decreased. This indicates that adsorption occurs more rapidly at lower concentrations but with a more limited total adsorption capacity. These results reveal that the surface-modified fish bone adsorbent is effective in removing fuchsine dye and that the adsorption process follows the pseudo-second-order kinetic model. This suggests that adsorption is largely driven by chemical interactions, involving strong binding between the active sites on the adsorbent surface and the dye molecules. Considering the development of low-cost and environmentally friendly adsorbents, fish bone-based materials show promise as an alternative and sustainable option.

For the adsorption of fuchsine dye using the surface-modified fish bone-based adsorbent, both the pseudo-first-order and pseudo-second-order kinetic models were individually evaluated, and the obtained data were compared. Examination of the pseudo-first-order kinetic model revealed noticeable differences between the experimental adsorption capacity ($q_{e,exp}$) and the model-calculated adsorption capacity ($q_{e,cal}$), especially at high and low concentrations, with correlation coefficients (R^2) ranging from 0.869 to 0.948. This indicates that the pseudo-first-order model only partially represents the adsorption process of fuchsine dye. While this model is generally associated with physical adsorption processes, the results of this study suggest that physical adsorption alone cannot fully explain the mechanism. In contrast, the pseudo-second-order kinetic model results showed much closer agreement between experimental and calculated q_e values, with R^2 values ranging from 0.9909 to 0.9980. Furthermore, the rate constant (k_2) and initial adsorption rate (h_i) calculated in the pseudo-second-order model exhibited systematic changes depending on the initial concentration. This high degree of fit and systematic variation strongly indicates that the adsorption mechanism predominantly involves chemical adsorption (chemisorption), with strong bonds forming between the active groups on the adsorbent surface and the fuchsine dye molecules. In conclusion, based on the evaluation of both kinetic models, the adsorption of fuchsine dye onto the surface-modified fish bone adsorbent better fits the pseudo-second-order kinetic model. The high correlation coefficients and the close agreement between calculated and experimental values serve as significant evidence that adsorption occurs mainly through chemical interactions in the system. In this context, the study results demonstrate that surface-modified fish bone-based adsorbents offer an effective and sustainable solution, particularly for environmental applications such as dye removal.

Table 1. Pseudo first and second order kinetic constants of fuchsin adsorption of HSA product

$q_{e,exp}$ (mg/g)	Pseudo-first-order			Pseudo-second -order			
	$q_{e,cal}$ (mg/g)	k_1 (h^{-1})	R^2	$q_{e,cal}$ (mg/g)	k_2 (g/mg.h)	R^2	h_i (mg/g.h)
0.94	0.39	0.420	0.869	0.95	3.43	0.991	3.11
0.47	0.20	0.341	0.948	0.47	6.37	0.990	1.41
0.22	0.08	0.439	0.905	0.22	20.23	0.998	1.00
0.08	0.04	0.485	0.898	0.08	31.92	0.991	0.19

Table 2. Diffusion calculation results of fuchsin absorption of HSA product

Urano and Tachikawa		Weber and Morris		
D_i (m^2h^{-1})	R^2	Kw (mg $g^{-1}h^{-0.5}$)	D_w (m^2h^{-1})	R^2
9.762×10^{-11}	0.854	167.81×10^{-3}	1.1559×10^{-13}	0.972
7.706×10^{-11}	0.945	89.19×10^{-3}	1.3191×10^{-13}	0.969
1.013×10^{-10}	0.923	42.821×10^{-3}	1.3799×10^{-13}	0.831
5.57×10^{-11}	0.937	13.611×10^{-3}	1.1971×10^{-13}	0.943

The Urano and Tachikawa model is a kinetic model commonly used to investigate the effect of film diffusion in adsorption processes. Film diffusion refers to the movement of solvent or dissolved substances through a thin liquid layer that exists between the bulk solution and the adsorbent surface before the adsorbate reaches the adsorbent. This thin film can create resistance to mass transfer and may act as a rate-limiting step in the overall adsorption process. The model enables the calculation of parameters such as the film diffusion coefficient (D_i), which quantifies the rate of mass transfer through the film layer. Thus, it allows evaluation of whether film diffusion acts as a limiting step in adsorption. The Urano and Tachikawa model serves as an important tool for understanding adsorption mechanisms by helping to distinguish different mass transfer steps. It is widely used in environmental engineering and chemical process applications to optimize adsorption by improving process conditions. In summary, the Urano and Tachikawa model mathematically describes the kinetic effect of film diffusion in adsorption and quantitatively determines the magnitude of this effect (Urano and Tachikawa, 1991; Freitas et al., 2008; Yao and Chen, 2017; Lopičić et al., 2019). The Urano and Tachikawa model as the role of film diffusion in the adsorption of fuchsine dye onto the surface-modified fish bone-based adsorbent was investigated in Table 2. The obtained film diffusion coefficient (D_i) values range between 5.57×10^{-11} m^2/h and 1.013×10^{-11} m^2/h. These values indicate that mass transfer through the film layer on the modified fish bone surface is relatively slow but cannot be neglected. Additionally, correlation coefficients (R^2) vary from 0.854 to 0.945, suggesting that while film diffusion contributes to the adsorption process, it does not solely control it. Particularly in concentration ranges where R^2 values exceed 0.9, film diffusion appears to play a more significant role as a rate-controlling step affecting adsorption speed. Overall, the results from the Urano and Tachikawa model suggest that fuchsine dye adsorption onto the surface-modified fish bone adsorbent is partially controlled by film diffusion, but the adsorption cannot be fully explained by this mechanism alone. The adsorption process occurs as a combined effect of surface interactions as well as film and intraparticle diffusion steps.

The Weber and Morris model is a widely used kinetic approach to investigate the role of intraparticle diffusion in adsorption processes. This model provides important parameters to evaluate the rate of mass transfer occurring within the internal structure of adsorbent particles and whether this step acts as a rate-limiting factor (El-Sikaily et al., 2007; Hameed et al., 2008; Greluk and Hubicki, 2009; Wu et al., 2009; Chu et al., 2025). The results presented in Table 2 include values for Kw (intraparticle diffusion rate constant), D_w (intraparticle diffusion coefficient), and R^2 (correlation coefficient). The Kw values range from 13.6 to 167.8×10^{-3} $mg\cdot g^{-1}\cdot h^{-0.5}$. As an indicator of the intraparticle diffusion rate, higher Kw values suggest faster intraparticle diffusion. These results indicate variations in diffusion rates depending on adsorption conditions. Specifically, higher Kw values reflect increased kinetic facilitation at this stage and highlight the significant role of diffusion. The Dw values range narrowly between 1.16×10^{-13} and 1.38×10^{-13} $m^2\cdot h^{-1}$, indicating generally slow intraparticle diffusion. Factors such as the pore structure of the adsorbent, particle size, and surface properties strongly influence these diffusion coefficients. The low Dw values suggest that intraparticle diffusion could be a rate-limiting step, potentially slowing down the overall kinetics. Correlation coefficients (R^2) vary between 0.831 and 0.972. High R^2 values (especially above 0.97) demonstrate strong agreement between the model and experimental data, indicating that intraparticle diffusion is an important mass transfer step in the adsorption kinetics and that the model accurately represents the process. Lower R^2 values suggest that other mechanisms such as film diffusion or chemical adsorption may also contribute. Overall, the data show that intraparticle diffusion plays a significant role in the adsorption of fuchsine dye onto the surface-modified fish bone adsorbent. However, the low intraparticle diffusion coefficients indicate that the process proceeds relatively slowly, pointing to the need for optimizing the adsorbent pore structure and surface properties to enhance adsorption rates. Therefore, strategies such as increasing pore volume, improving pore accessibility, and modifying surface chemistry could be pursued to enhance both adsorption capacity and kinetics. In conclusion, the Weber and Morris model parameters reveal that

adsorption is partially controlled by intraparticle diffusion, which significantly influences adsorption performance. These insights can guide the design and application of modified fish bone-based adsorbents, contributing to the development of more effective and sustainable environmental solutions.

The kinetic and diffusion models related to the adsorption of fuchsine dye onto the surface-modified fish bone-based adsorbent were comprehensively evaluated, considering the mechanisms influencing the overall process. Within this scope, the results of the pseudo-first-order kinetic model, pseudo-second-order kinetic model, Urano and Tachikawa model, and Weber and Morris model were comparatively analyzed. The pseudo-first-order kinetic model showed limited agreement in describing the adsorption process. Deviations between experimentally obtained values and model calculations were observed, suggesting that physical adsorption alone does not sufficiently represent the adsorption mechanism. In contrast, the pseudo-second-order kinetic model exhibited very high correlation coefficients, indicating that the adsorption process is primarily chemical in nature and dominated by chemical interactions occurring on the adsorbent surface. The close agreement between experimental data and model calculations supports the dominant influence of this model on the process. The Urano and Tachikawa model, which evaluates the effect of diffusion, indicated that mass transfer from the solution to the adsorbent surface via film diffusion contributes to the adsorption process to a certain extent. However, film diffusion alone was not the rate-determining step, as reflected by lower correlation coefficients compared to the kinetic models. The Weber and Morris model highlighted the significance of intraparticle diffusion, showing that the adsorption process is partially controlled by diffusion within the adsorbent particles. The strong model fit especially points to the importance of the adsorbent pore structure and internal characteristics on the adsorption kinetics. However, the relatively low intraparticle diffusion coefficient suggests that this step could be rate-limiting. Overall, the evaluation demonstrates that the adsorption of fuchsine dye onto the surface-modified fish bone adsorbent is a multi-mechanistic process. In addition to chemical adsorption, film diffusion and intraparticle diffusion mechanisms also influence the process. The high conformity of the pseudo-second-order kinetic model underscores the dominance of chemical interactions, while diffusion models indicate that mass transfer steps cannot be neglected. This comprehensive analysis emphasizes the need to consider both surface chemistry and structural properties of the adsorbent to enhance its efficiency and performance in environmental applications.

CONCLUSION

This study holds significant importance as it offers a biologically sourced, low-cost, and environmentally friendly adsorbent alternative for the removal of toxic dyes commonly found in industrial wastewater. The modification and utilization of waste materials such as fish bones contribute to sustainable resource management while enabling the development of value-added products. Dye pollution, originating particularly from the textile, food, and chemical industries poses a serious threat to aquatic ecosystems. The effective removal of fuchsine dye in this study presents promising results for the treatment of other structurally similar anionic dyes. The findings shed light on the development of more economical and ecological solutions compared to conventional wastewater treatment methods. Moreover, the detailed investigation of adsorption mechanisms through kinetic and diffusion models provides critical information for the design and optimization of such materials. The multidisciplinary approach of this study serves as a valuable reference for researchers in environmental engineering, materials science, and chemistry. In this research, the efficacy of HSA adsorbent—obtained by chemically functionalizing fish bone waste was evaluated for the removal of fuchsine dye from aqueous solutions. Experimental results demonstrated that the modified fish bone adsorbent exhibited high adsorption capacity for fuchsine, with adsorption capacity increasing alongside initial dye concentration. Kinetic analyses revealed that the adsorption process followed a pseudo-second-order kinetic model, indicating that chemical adsorption is the dominant mechanism. Diffusion studies conducted using Weber-Morris and Urano-Tachikawa models showed that both intraparticle diffusion and film diffusion contribute to the adsorption process but neither acts as the sole rate-limiting step. Notably, a removal efficiency of 69.60% was achieved at the highest concentration tested (6.76 mg/L), proving the potential of this material as an alternative for industrial wastewater treatment. One of the key contributions of this study is providing an environmentally friendly and cost-effective solution to the waste management challenges faced by the seafood processing industry. The valorization of biological wastes such as fish bones serves as an important example in the development of sustainable water treatment technologies. While the results demonstrate the applicability of modified fish bone adsorbents particularly for treating textile and dye industry wastewater, future studies are recommended to test different dyes and real industrial wastewater samples. In conclusion, this research makes a significant contribution to the development of innovative and sustainable solutions in waste management and water

treatment technologies, offering practical insights for industrial applications.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

Generative AI (e.g., ChatGPT 4.0, DeepSeek) was used for grammatical review of the introduction and discussion sections. The author validated all outputs and assume full responsibility for the content.

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Marine and Life Sciences

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A comparative analysis of morphometric and meristic traits of endangered (*Salmo opimus* Turan, Kottelat and Engin, 2012 and *Salmo plathycephalus* Behnke, 1968) and at risk (*Salmo okumusi* Turan, Kottelat and Engin, 2014) trout species

Cemil Kara[1]✉ • Mehmet Fatih Can[2]

[1] Department of Biology, Faculty of Science, Karadeniz Technical University, Trabzon, TÜRKİYE
[2] Department of Water Resources Management and Organization, Faculty of Marine Science and Technology, Iskenderun Technical University, 31200, Iskenderun, Hatay, TÜRKİYE

✉ Corresponding Author: cemilkara67@gmail.com

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A B S T R A C T

This study examines interspecies differentiation by comparing the morphometric and meristic characteristics of two endangered trout species (*Salmo opimus* Turan, Kottelat and Engin, 2012 and *Salmo plathycephalus* Behnke, 1968) and a species with the potential to be endangered (*Salmo okumusi* Turan, Kottelat and Engin, 2014). The research was conducted between 2014 and 2016 in the upper tributaries of the Ceyhan, Seyhan, and Euphrates basins in Türkiye. A total of 25 morphometric and 24 meristic characters were examined, and the measurements influencing interspecies differentiation were analyzed using the Random Forest model. The results indicate that *S. plathycephalus* exhibits significant differentiation in metric characteristics. In particular, variables such as predorsal length, head length, and body height are key distinguishing factors for this species. Among the meristic traits, the number of red spots and black markings on the operculum are critical for species identification. This study enhances understanding of species' environmental adaptations and informs conservation strategies, laying a foundation for sustainable management. Future research should focus on habitat conservation efforts.

INTRODUCTION

Türkiye is located at the intersection of three major biogeographic regions Caucasus, Mediterranean, and Iran, Anatolia which results in a high level of species richness and endemism (Şekercioğlu, 2011; Noroozi et al., 2019; Kara and Bozali, 2024). The diversity of naturally occurring trout species in Anatolia has been identified based on morphological and genetic characteristics (Behnke, 1968; Turan et al., 2010, 2011, 2012, 2017, 2020, 2021, 2022; Kaya, 2020). Extensive research has revealed the presence of 17 Salmo species with natural distribution in Türkiye (Turan et al., 2024). Among these, *Salmo opimus*, *Salmo okumusi*, and *Salmo plathycephalus* have been reported to originate from the Adriatic lineage (Turan et al., 2024).

Previously identified as *Salmo trutta macrostigma* (Alp et al., 2003; Alp and Kara, 2004; Geldiay and Balık, 2009), *Salmo okumusi* was reclassified by Turan et al. (2014). This species has been reported in the upper tributaries of the Euphrates River and Göksu (Kara et al., 2011). *S. okumusi* can be distinguished from other trout species by the presence of red spots on its adipose fin and distinctive body coloration. Commonly referred to as "Mercan Alası" by locals, this

species has been subjected to excessive fishing due to the belief that it has medicinal benefits and its highly valued taste. Consequently, its populations have significantly declined, leading to a complete ban on fishing throughout the year. However, the conservation status of *S. okumusi* on the Red List remains undetermined.

Trout populations found in the upper tributaries of rivers flowing into the eastern Mediterranean, which were previously reported as *S. trutta macrostigma* (Alp et al., 2003; Alp and Kara, 2004; Geldiay and Balık, 2009), were reclassified by Turan et al. (2012) as *Salmo opimus* based on morphometric and molecular characteristics. Locally known as "Ceyhan Alası" or "Red-Spotted Trout," *S. opimus* is primarily found in the inland waters of Kahramanmaraş and inhabits only the first 15-20 km of streams from their source (Alp and Kara, 2004). This species exhibits a few black spots and numerous red parr marks along its lateral body surface. Its primary food source, *Gammarus* sp., is believed to be responsible for the red pigmentation observed in its body and flesh (Kara and Alp, 2005). Due to excessive fishing, *S. opimus* populations have drastically declined, and the species has been classified as endangered (Endangered, EN) (Freyhof, 2019a).

S. plathycephalus, endemic to the Seyhan River, was first described as a new species in 1968 (Behnke, 1968). It is predominantly found in the Zamantı River, an upper tributary of the Seyhan Basin. This species differs from other trout species in terms of scale count, gill raker count, pyloric caeca count, and other morphological characteristics. Unlike other trout species, *S. plathycephalus* lacks distinct red spotting, and its body coloration is irregularly distributed (Kara et al., 2011a). This species reproduces between October and January, with individuals laying approximately 5,000 eggs per kilogram of body weight (Kara et al., 2011b). Excessive and illegal fishing, along with habitat degradation, pose major threats to this species. Consequently, *S. plathycephalus* is also classified as endangered (Endangered, EN) (Freyhof, 2019b).

This study aims to assess the degree to which certain morphometric and meristic traits contribute to interspecies differentiation among two endangered trout species (*S. opimus* and *S. plathycephalus*) and one species with a potential risk of endangerment (*S. okumusi*). The findings of this research are expected to contribute scientifically to the development of conservation strategies and sustainable management plans for these species. Additionally, understanding interspecies adaptation strategies and providing a foundation for future biodiversity studies are among the key objectives of this study.

MATERIALS AND METHODS

This study focused on the *Salmo opimus*, *Salmo okumusi*, and *Salmo plathycephalus* trout species found in the streams of the Ceyhan, Euphrates, and Seyhan basins, respectively (Figure 1 and Figure 2). The research was conducted between April 2014 and June 2016. Fish samples were collected using electro-shocker, cast nets, and gill nets. In this context; n: 19 *S. okumusi*, n: 15 *S. opimus* and n: 19 *S. plathycephalus* samples were caught. The captured specimens were preserved in a 4% formaldehyde solution and transported to the laboratory for further analysis. The length measurements of the fish were performed using a digital caliper with a precision of 0.01 mm.

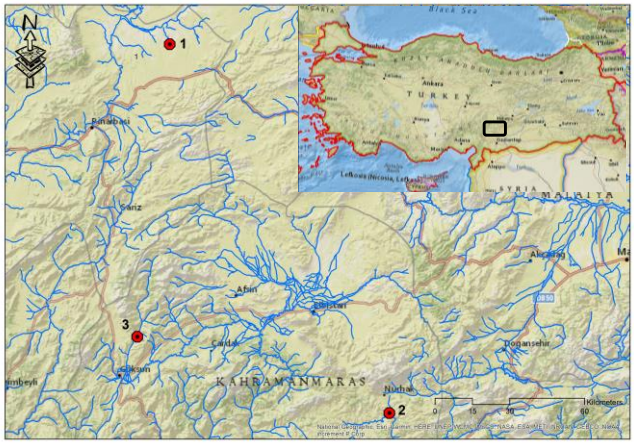

Figure 1. Localities of trout specimens: (1) Upper Seyhan River (Zamantı Stream, Şerefiye), (2) Upper Euphrates (Nurhak, Eskiköy), and (3) Upper Ceyhan River (Kömür Stream)

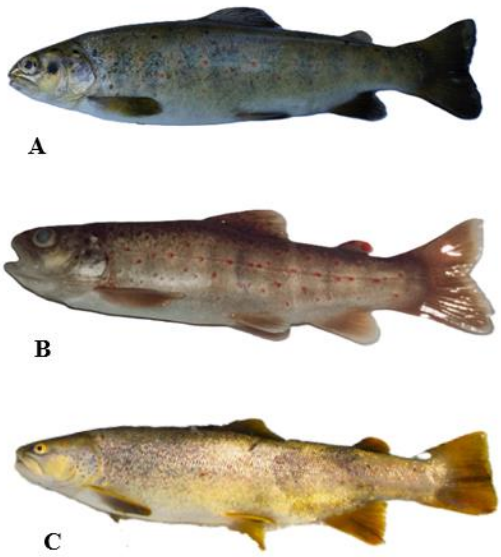

Figure 2. (A) *Salmo opimus* specimen from Kömür Stream, Ceyhan River; (B) *Salmo okumusi* specimen from Upper Euphrates River, Nurhak (Eskiköy, Kahramanmaraş); (C) *Salmo plathycephalus* specimen from Zamantı Stream, Seyhan River (Şerefiye)

Morphometric and Meristic Traits

In the laboratory, a total of 25 morphometric measurements and 24 meristic counts were recorded for each fish (Figure 3, Table 1).

Morphometric measurements were taken from the left lateral aspect and measured to the nearest 0.01 mm using a digital caliper. All meristic characters were counted twice on the same day by the same observer to ensure accuracy. Descriptive statistics of the morphometric and meristic characteristics of the sampled fish are presented in Table 2 and Table 3, respectively.

Table 1. Morphometric and meristic traits analyzed in this study

Morphometric traits (mm)		Meristic traits	
Trait	**Acronym**	**Trait**	**Acronym**
Upper jaw depth	X1	Operculum, black spot; big	Y1
Snout length	X2	Operculum, black spot; small	Y2
Orbital diameter(horizontal)	X3	Red color on the adipose	Y3
Head depth	X4	Red spots on line lateral	Y4
Orbital diameter(vertical)	X5	Red spots on the line lateral dorsal	Y5
Length of maxilla	X6	Red spots on the line lateral ventral	Y6
Upper jaw length	X7	Pyloric ceaca	Y7
Lower jaw length	X8	Gill rakers	Y8
Pectoral fin length	X9	Lingual teeth	Y9
Body depth (dorsal fin)	X10	Lower jaw teeth	Y10
Dorsal fin length	X11	Upper jaw teeth	Y11
Pelvic fin length	X12	Maxilla teeth	Y12
Body depth (anal fin)	X13	Number of red spots on the dorsal fin.	Y13
Adipose fin length	X14	Line lateral scales	Y14
Anal fin length	X15	Line lateral dorsal scales	Y15
Caudal peduncel length	X16	Line lateral abdomen scales	Y16
Caudal pedeuncle depth	X17	Dorsal fin (spine)	Y17
Length of upper caudal fin lope	X18	Dorsal fin (soft)	Y18
Length of middle caudal fin ray	X19	Anal fin (spine)	Y19
Length of lower caudal fin lobe	X20	Anal fin (soft)	Y20
Predorsal length	X21	Caudal fin	Y21
Head length	X22	Pelvic fin(spine)	Y22
Premaxilla length	X23	Pelvic fin(soft)	Y23
Prepelcic length	X24	Pectoral fin (soft)	Y24
Preanal length	X25		

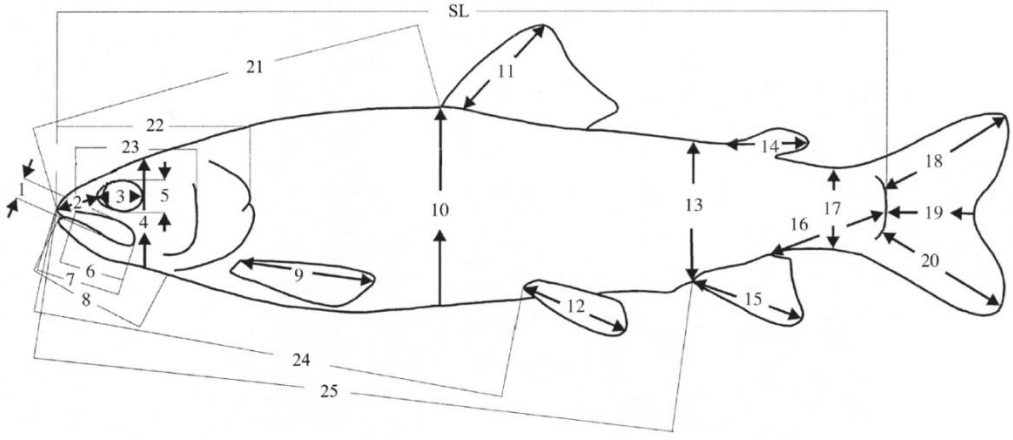

Figure 3. Measurements taken on Salmo specimens

1: upper jaw depth, as largest depth of the maxilla and supramaxilla; **2:** snout length, from symphysis of premaxilla to osseous orbit margin; **3:** orbital horizontal diameter, between osseous orbital margin; **4:** head depth, just posterior to orbit; **5:** orbital vertical diameter, between osseous orbital margin; 6: length of maxilla, from premaxillad end to posterior end of maxilla; **7:** upper jaw length, from symphysis of premaxilla to posterior end of maxilla; **8:** lower jaw length, from symphysis of dentary to retroarticulare; **9:** pectoral fin length, from base of first ray to tip of longest ray; **10:** body depth, at level of origin of dorsal fin; **11:** dorsal fin length, from base to tip of longest ray; **12:** pelvic fin length, from base of first ray to tip of longest ray; **13:** body depth, at level of origin of anal fin; **14:** adipose fin length, from origin to tip; **15:** anal fin length, from base of first ray to tip of longest ray; **16:** caudal peduncle length, from end of anal fin to middle base of caudal fin; **17:** least depth of caudal peduncle; **18:** length of upper caudal fin lobe, from base to tip of longest ray; **19:** length of middle caudal fin ray, from base to tip of shortest ray; **20:** length of lower caudal fin lobe, from base to tip of longest ray; **21:** predorsal length from upper jaw symphysis to origin of dorsal fin; **22:** head length, from upper jaw symphysis to posterior tip of operculum; **23:** premaxilla to preoperculum length, from premaxilla end of maxilla to posterior margin of preoperculum; **24:** prepelvic length, from upper jaw symphysis to origin of pelvic fin; **25:** preanal length, from upper jaw symphysis to origin of anal fin; **SL:** standard length (SL), from upper jaw symphysis to middle base of caudal fin (Modified from Delling, 2002)

Table 2. Descriptive statistics of the morphometric characteristics of the sampled fish

		X1		X6		X11		X16		X21	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	4.72	0.63	10.68	1.34	22.96	2.72	24.43	3.42	53.42	7.41
S. opimus	15	3.77	0.77	9.63	1.19	20.11	3.34	20.27	3.41	50.28	14.01
S. plathycephalus	19	12.22	1.58	22.24	2.11	42.44	5.52	51.39	7.93	121.25	12.40
		X2		X7		X12		X17		X22	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	8.24	1.55	14.61	1.79	17.84	2.28	13.28	1.80	31.50	3.69
S. opimus	15	6.45	0.95	12.45	1.90	22.20	23.59	11.32	1.66	27.67	3.84
S. plathycephalus	19	19.13	2.03	32.05	3.08	36.78	3.13	28.51	2.63	65.73	5.44
		X3		X8		X13		X18		X23	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	7.19	0.61	16.56	2.10	21.95	3.39	20.15	2.62	23.37	2.88
S. opimus	15	6.56	0.37	14.86	2.76	18.92	3.58	16.12	2.27	20.09	2.86
S. plathycephalus	19	11.50	0.82	37.58	4.04	51.38	5.63	38.08	3.22	50.28	4.17
		X4		X9		X14		X19		X24	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	16.68	2.30	24.57	2.64	11.36	1.58	12.09	1.38	63.50	8.05
S. opimus	15	15.72	2.51	21.47	2.54	8.93	1.84	10.24	1.30	51.63	13.54
S. plathycephalus	19	34.15	3.60	47.71	3.92	22.66	3.84	26.31	2.63	140.62	12.09
		X5		X10		X15		X20		X25	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	6.86	0.70	28.71	4.21	20.11	2.49	20.31	2.57	86.36	10.88
S. opimus	15	6.06	0.46	25.75	4.70	16.71	2.30	15.84	2.00	76.08	11.92
S. plathycephalus	19	10.23	0.93	69.94	8.71	41.78	4.29	37.09	2.90	196.95	19.47

Table 3. Descriptive statistics of the meristic characteristics of the sampled fish

		Y1		Y7		Y13		Y19	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	1.00	0.00	23.42	1.61	14.95	1.54	2.00	0.00
S. opimus	15	1.00	0.00	26.67	4.81	0.00	0.00	3.00	0.00
S. plathycephalus	19	0.00	0.00	27.95	4.47	0.00	0.00	2.84	0.37
		Y2		Y8		Y14		Y20	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	9.26	1.52	18.89	0.32	118.68	1.42	8.89	0.46
S. opimus	15	10.73	1.49	17.80	1.70	116.93	4.62	8.33	0.49
S. plathycephalus	19	19.05	1.35	23.84	1.07	114.32	3.02	8.68	0.75
		Y3		Y9		Y15		Y21	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	4.00	0.00	8.00	0.00	24.11	1.24	21.89	0.32
S. opimus	15	0.00	0.00	8.00	0.00	28.33	2.72	22.00	0.00
S. plathycephalus	19	0.00	0.00	9.26	0.99	19.68	1.60	20.21	0.63
		Y4		Y10		Y16		Y22	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	12.95	1.51	16.26	0.81	20.21	1.81	1.00	0.00
S. opimus	15	6.60	2.35	16.20	0.41	19.87	2.13	1.47	0.52
S. plathycephalus	19	0.00	0.00	23.37	1.07	18.63	1.26	1.00	0.00
		Y5		Y11		Y17		Y23	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	15.26	5.13	60.42	3.53	3.00	0.00	7.89	0.32
S. opimus	15	16.27	7.30	59.67	2.02	3.00	0.00	7.80	0.56
S. plathycephalus	19	0.00	0.00	66.05	5.22	3.00	0.00	7.89	0.32
		Y6		Y12		Y18		Y24	
	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
S. okumusi	19	15.53	3.94	11.00	1.29	10.11	0.57	11.79	0.42
S. opimus	15	14.33	3.62	11.00	1.51	10.13	0.64	11.20	1.01
S. plathycephalus	19	0.00	0.00	10.11	0.99	11.47	0.70	11.89	0.32

Morphometric and Meristic Traits

Because fish exhibit allometric growth, a common issue with morphometric data is the high correlation of all measurements with length. To analyze fish shape independently of size, it is necessary to remove the size factor from the data. In this study, the Random Forest model was used as the statistical method. Unlike linear models, which can suffer from multicollinearity, Random Forest effectively handles correlated features (Thakur 2020). Additionally, to minimize errors arising from differences in fish size, all morphometric measurements taken from each specimen were standardized by their standard length (SL). All statistical analyses were conducted using R (R Core Team, 2025).

RESULTS

Figure 4 and Figure 5 illustrate the interspecies morphological differences in terms of morphometric and meristic characteristics, respectively, using t-Distributed Stochastic Neighbor Embedding (t-SNE) with Random Forest embeddings. These figures provide a two-dimensional visualization of the differentiation among species based on their metric and meristic traits.

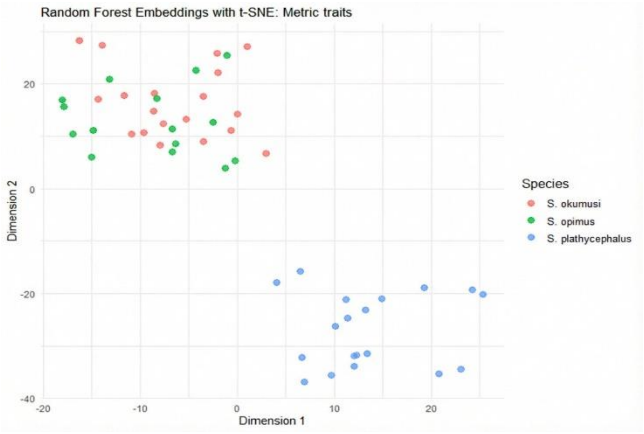

Figure 4. Differentiation of species based on morphometric (metric) characteristics

In terms of morphometric characteristics, *S. plathycephalus* individuals are distinctly clustered separately from the other two species in the Dimension 1 and Dimension 2 space (Figure 4). This indicates that *S. plathycephalus* possesses a significantly different morphometric profile compared to *S. okumusi* and *S. opimus*. However, no clear distinction is observed between *S. okumusi* and *S. opimus*, suggesting that these species may share common phenotypic traits or that the analyzed characteristics may not be sufficient to differentiate them.

Conversely, *S. okumusi*, *S. opimus*, and *S. plathycephalus* exhibit distinct structural differences in meristic characteristics (Figure 4). The pronounced differentiation among species in terms of meristic traits suggests that these features may play a crucial role in biological classification.

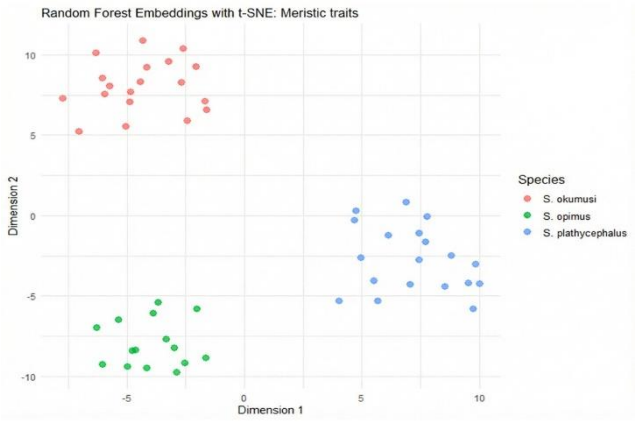

Figure 5. Differentiation of species based on meristic traits

Figures 6 and Figure 7 present the relative importance of variables influencing interspecies differentiation for morphometric and meristic characteristics, respectively, using the Mean Decrease Gini metric from the Random Forest model. A higher Gini value indicates that the corresponding variable contributes more significantly to the decision tree splits, thereby improving the model's predictive performance.

For morphometric characteristics, the variable X3 (Orbital diameter horizontal) has the highest Gini value, making it the most critical feature for species differentiation. X9 (Pectoral fin length) and X5 (Orbital diameter vertical) rank second and third, respectively, highlighting their significant roles in interspecies differentiation. On the other hand, X19 (Length of middle caudal fin lobe) has the lowest Mean Decrease Gini value, suggesting that this trait has a limited impact on distinguishing the species (Figure 6).

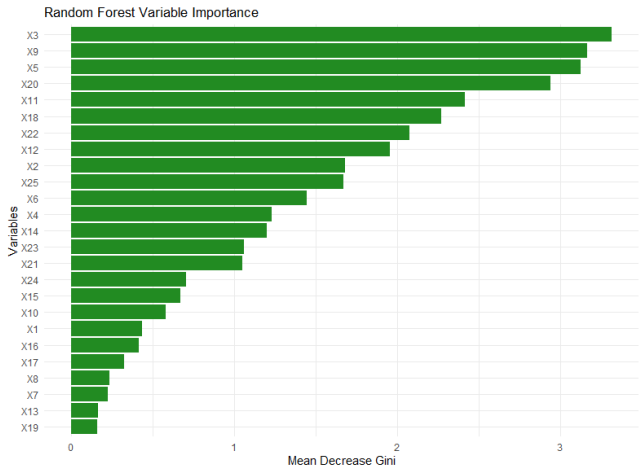

Figure 6. Importance rankings of features influencing species differentiation based on morphometric characteristics

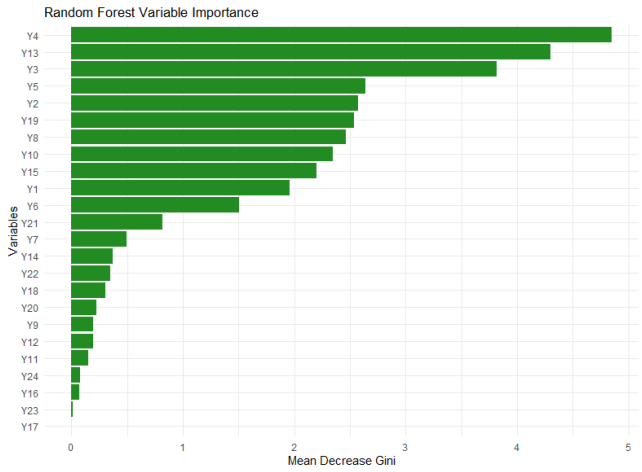

Figure 7. Importance rankings of features influencing species differentiation based on meristic traits

DISCUSSION

In this study, the morphometric and meristic differences among the endangered species *S. opimus* and *S. plathycephalus*, as well as *S. okumusi*, were examined in detail. The obtained data indicate that *S. plathycephalus* is distinctly separated from the other two species in terms of morphometric characteristics. For instance, significantly higher measurements of predorsal length (X21), head length (X22), prepelvic length (X25), body height (X10), and adipose fin length (X14) suggest that this species possesses a larger and structurally different morphology. These findings support the morphological variations observed in the Ceyhan and Seyhan basins, as reported by Alp et al. (2003) and Kara and Alp (2004).

On the other hand, while *S. okumusi* and *S. opimus* generally exhibit similar morphometric traits, certain parameters, such as X5 (orbital diameter vertical), X9 (pectoral fin length), X15 (anal fin length), and X20 (caudal fin lower lobe length), indicate partial phenotypic differentiation between these two species. This finding is consistent with the morphological similarities reported by Turan et al. (2012) and also suggests that the selected metrics might have limited power in distinguishing these two species. Additionally, the identification of X3 (orbital diameter horizontal) as the most critical parameter in species differentiation, based on its highest Mean Decrease Gini value in the Random Forest analysis, underscores the importance of morphometric characteristics in taxonomic classification (Turan et al., 2024).

Regarding meristic traits, the effects of habitat differences on morphological adaptation become evident. While red spots on the body, prominent black parr marks on the operculum, and vibrant color patterns on the dorsal fins were observed in specimens from the Ceyhan and Euphrates basins, *S. plathycephalus* individuals from the Seyhan basin exhibited less distinct spotting and more irregular color distribution. Notably, the presence of one or two red spots (parr) on the adipose fin of *S. okumusi* specimens from the Euphrates basin suggests a connection between environmental factors and the species' adaptive responses (Kara et al., 2011a; Kara et al., 2011b).

These morphological differences highlight the influence of physical and chemical properties of trout ecosystems such as water temperature, flow rate, and habitat structure in shaping species' morphology. As noted by Balık (1988) and Dorofeeva et al. (1986), these environmental factors can result in variations in growth rates, pigmentation patterns, and fin morphology. Additionally, Sušnik et al. (2004) reported that environmental pressures in specific habitats shape the adaptive morphological traits of species, influencing their ecological niche differentiation.

Furthermore, trout farming activities in the study areas and the introduction of non-native species like Oncorhynchus mykiss into natural populations may negatively impact local genetic structure and morphological diversity. As highlighted by Kara and Alp (2005) and Geldiay and Balık (2009), such genetic admixture is one of the critical factors disrupting adaptation processes in native species and complicating conservation efforts. Additionally, the recent proliferation of hydroelectric power plants (HPPs) without sufficient consideration of environmental impacts has led to habitat degradation, posing a serious threat to the sustainability of natural trout populations (Alp et al., 2020).

CONCLUSION

The present study's findings clearly demonstrate significant morphometric and meristic differentiation among the three endemic trout species *S. opimus*, *S. platycephalus*, and *S. okumusi*. Notably, *S. plathycephalus* exhibits a distinctly larger and different morphometric profile setting it apart from the other two trout. These pronounced phenotypic distinctions have important taxonomic and evolutionary implications. They affirm that each population represents a distinct species, highlighting the utility of detailed morphometric and meristic data in trout classification. The variation in traits across different river basins also underscores the role of environmental adaptation in driving divergence; for example, *S. plathycephalus* in the Seyhan basin shows reduced red spotting and more irregular coloration compared to the more vividly spotted *S. opimus* and *S. okumusi* from the Ceyhan and Euphrates basins. Such patterns are consistent with the notion that local habitat conditions (e.g. water temperature, flow rate, and habitat structure) can shape phenotypic traits over time, as observed

in other trout populations. Therefore, the study indicates that species differences arise from an interplay of genetic lineage and adaptive responses to unique environmental pressures in each habitat. Recognizing this environmental influence is crucial for taxonomy and conservation, since it suggests that preserving the distinct habitats of each trout is integral to maintaining their phenotypic and genetic identity.

From a conservation perspective, delineating these species' unique characteristics is essential for guiding management efforts. Both *S. opimus* and *S. platycephalus* are currently listed as Endangered (EN) and have suffered severe population declines largely due to overfishing and habitat degradation. *S. okumusi*, while not yet officially Red-Listed, has similarly experienced drastic declines, prompting a complete fishing ban to prevent its extinction. The insights from this study provide a valuable scientific basis for developing targeted conservation strategies and sustainable management plans for each species. In practice, this means that management can be tailored to each trout's specific needs and vulnerabilities for instance, protecting the cold, upper stream habitats that *S. opimus* requires, or enforcing stricter fishing and habitat restoration measures in the Seyhan River for *S. platycephalus*. Mitigating anthropogenic threats is also a high priority: measures such as enforcing fishing regulations, preventing genetic introgression from non-native trout (e.g. hatchery-reared *O. mykiss*), and curbing environmentally destructive activities (like unregulated hydropower development) are vital for the long term survival of these trout populations. By addressing these threats and incorporating the species specific knowledge of morphological and ecological requirements, conservation efforts can more effectively halt declines and promote recovery. Finally, the study highlights the need for continued research to support and refine these conservation initiatives. High priority should be given to genetic studies detailed molecular analyses can clarify the genetic differentiation and diversity among *S. opimus*, *S. platycephalus*, and *S. okumusi* which would complement the morphological evidence and inform management of their genetic resources. Such analyses could detect hidden structure among populations or identify any hybridization and introgression from introduced trout, an issue already flagged as a risk to the genetic integrity of native stocks. Equally important is research focused on habitat conservation and monitoring: long-term ecological studies should examine how habitat restoration, improved water quality, and protection of critical headwater spawning grounds affect population trends and adaptive traits over time. This will help evaluate the effectiveness of conservation actions and allow adaptive management as environmental conditions change. In summary, a multidisciplinary approach that integrates morphology, genetics, and ecology is essential for understanding the adaptive processes shaping these endangered trout and for guiding effective conservation strategies to ensure their persistence in native Anatolian waters.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

The study was conceived and designed by Cemil Kara and Mehmet Fatih Can. Cemil Kara and Mehmet Fatih Can were in charge of collecting data and conducting research. The manuscript was drafted by Cemil Kara and Mehmet Fatih Can. The manuscript was reviewed and revised by Cemil Kara and Mehmet Fatih Can. The final manuscript was read and approved by all authors.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Ethical Approval

In this study; it was found "appropriate" by Kahramanmaraş Sütçü İmam University, Faculty of Agriculture Animal Experiments Local Ethics Committee (KSÜZİRHADYEK) with the decision dated 28.02.2014 and numbered 2014/1.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

Generative AI was not used in this research paper.

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Azerbaycan denizcilik ve lojistik sektörleri konulu yayınların bibliyometrik analizi

Leyla Cafarova [1] • Yasemin Nemlioğlu [2]✉

[1] Azerbaycan Devlet İqtisad Universiteti, Keyfiyyat Teminatı Şubesi, Bakü, AZERBAYCAN
[2] İstanbul Üniversitesi, Deniz Bilimleri ve İşletmeciliği Enstitüsü, 34134, İstanbul, TÜRKIYE

✉ Corresponding Author: yasemin.n@istanbul.edu.tr

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Ö Z E T

Uluslararası ekonominin ve ticaretin temel unsurlarından biri olan ulaştırma ve lojistik, bilimsel araştırmaların da öncelikli konularından biri haline gelmiştir. Dünyanın en önemli ulaştırma projelerinden biri olan İpek Yolu'nun canlandırılması kapsamında Azerbaycan'da denizcilik ve lojistik sektörleri dikkat çekmektedir. Azerbaycan'da stratejik hedefler doğrultusunda Hazar Denizi limanlarıyla bağlantılı lojistik merkezlerin kurulması planlanmaktadır. Ülkede ulaştırma altyapısı ve lojistik sektörünün geliştirilmesine yönelik yapılan yatırımların verimliliğinin belirlenmesi, bakış açılarının ve sorunlarının analiz edilmesi gerekliliği bu alandaki bilimsel araştırmalara duyulan ihtiyacı da artırmaktadır. Bu çalışmanın amacı, Azerbaycan denizcilik ve lojistik sektörleri üzerine yapılmış yayın ve çalışmaları ortaya koymak, yayınları bibliyometrik analiz yöntemiyle incelemek ve değerlendirmektir. Yapılan araştırmada 115 makale ve 15 yüksek lisans tezine ulaşılmış, bu yayınlar çeşitli parametreler üzerinden bibliyometrik yöntemle analiz edilmiştir. Yayınların en fazla Rusça ve Türkçe dillerinde hazırlandığı, araştırmalarda nitel yöntem kullanıldığı, konuların Tek Kuşak Tek Yol Projesi (OBOR) çerçevesinde Bakü Uluslararası Limanı'na odaklandığı ve doktora tez çalışmasının bulunmadığı belirlenmiştir. Azerbaycan denizciliği ve lojistiği üzerine sınırlı yayın bulunduğundan bu çalışma, alandaki çalışmalara katkı sağlamakta ve boşluğu doldurmakta, gelecekte yapılacak çalışmalar için temel oluşturmakta ve karar vericilere kaynak sağlamaktadır.

Bibliometric analysis of publications on Azerbaijan maritime and logistics sectors

Keywords:
Azerbaijan
Bibliometric Analysis
Maritime
Logistics

A B S T R A C T

Transportation and logistics are one of the basic elements of international economy and trade. They have also become one of the priority topics of scientific research. Within the scope of the revitalization of the Silk Road, one of the most important transportation projects in the world, the maritime and logistics sectors in Azerbaijan, attract attention. In line with this, it is planned to establish logistics centers connected to the Caspian Sea ports in Azerbaijan. The necessity of determining the efficiency of investments made for the development of transportation infrastructure and logistics sector in the country together with analyzing the perspectives and problems necessitates the need for scientific research in this field. The aim of this study is to reveal the current state of Azerbaijan maritime and logistics sectors by examining previous publications with bibliometric analysis method. In the research, 115 articles and 15 master's theses were reached, and these publications were analyzed. It is determined that the publications were mostly prepared in Russian and Turkish languages, mostly used qualitative methods, focused on the Baku International Port within the framework of One Belt One Road Project (OBOR) and there was no doctoral thesis. Since there are limited publications on Azerbaijan maritime and logistics, this study contributes to the studies in the field and completes the gaps, provides the basis for future studies and resources for decision-makers.

GİRİŞ

Denizcilik sektörü, dünya ülkeleri arasında karşılıklı ekonomik ilişkilerin ve mal alışverişinin geliştirilmesinde önemli bir rol oynamaktadır. Küresel taşımacılıkta önemli yer tutan deniz yolu taşımacılığı günümüzde ulusal bir sektör olmanın ötesine geçerek uluslararası iş bölümünde büyük bir boyut ve maddi karakter kazanarak dünya üretiminin ve ticaretinin büyümesinde giderek daha fazla yer tutmaktadır. Dünya ticaretinde taşınan yüklerin hacmindeki artışın yanı sıra yapısal bileşim de sürekli değişmektedir; uluslararası yüklerin yaklaşık %70'ini hazır tüketim ürünleri, %30'unu ise hammadde yükleri oluşturmaktadır. Ham petrol ve petrol ürünleri ise deniz yolu yüklerinin neredeyse yarısını oluşturmaktadır (Yadigarov, 2021). Günümüzde 5.000'den fazla yük limanında, 70.000'den fazla ticari gemiyle yılda yaklaşık 12 milyar ton yükün taşındığı denizcilik sektörü küresel ticaretin en önemli itici gücüdür (Esmer, 2020).

1990'lı yıllar itibariyle Çin'in küresel bir üretim merkezi haline gelmesiyle, dünya deniz ticaret rotaları Uzak Doğu'ya kaymıştır. Çin, küresel üretim kapasitesinin yanı sıra deniz ticaret filosu ve limanlarıyla da dünyanın en önemli denizcilik ülkelerinden biri haline gelmiştir. Ayrıca Tek Kuşak Tek Yol (One Belt One Road-OBOR) projesini 2013 yılında dünyaya duyurmasıyla, kara ve denizde ulaştırma ağlarını geliştirmeyi ve gelecek 30 yılda da küresel üretim ve ulaştırmanın merkezi olma konumunu sürdürmeyi planladığı görülmektedir (World Bank, 2019). Bu kapsamda dünyanın en önemli ulaştırma projelerinden biri haline gelen İpek Yolu'nun canlandırılması, bu projeye dahil olan ülkeleri de doğrudan etkilemektedir. Kuzey-güney ve doğu-batı olmak üzere ulaştırma koridorlarının kesişim noktasında yer alan Azerbaycan'da denizcilik ve lojistik sektörleri bu projeyle gelişecektir. Ülkedeki uluslararası ticaret hacminin ve transit ticaretten elde edilen gelirin arttırılması amacıyla 2016 yılında hazırlanan "Ülke Ekonomisi ve Ekonominin Ana Sektörleri için Stratejik Yol Haritası" doğrultusunda denizcilik ve lojistiğin geliştirilmesine yönelik stratejik hedefler ortaya konmuştur (Azerbaycan Cumhuriyeti'nde Lojistik ve Ticaretin Geliştirilmesi İçin Stratejik Yol Haritası, 2016). Bu hedeflerden biri de Azerbaycan'da Hazar Denizi limanlarıyla bağlantılı lojistik merkezlerinin kurulmasıdır. Bu bağlamda, Alat'ta 2018 yılında açılan Bakü Uluslararası Limanı, uluslararası ticaret hacminin artırılması için lojistik merkezler arasında öne çıkmaktadır.

OBOR ve İpek Yolu'nun canlandırılması projelerine yönelik birçok bilimsel çalışma yapılmış olmasına rağmen, Azerbaycan'da denizcilik ve lojistik sektörlerinin yeri ve önemi hakkında yapılan sınırlı analiz çalışmalarında Azerbaycan özelinde bibliyometrik inceleme bulunmamaktadır. Bu çalışmanın amacı Azerbaycan'ın denizcilik ve lojistik sektörlerine yönelik ulusal ve uluslararası literatürdeki yayınların bibliyometrik analiz yöntemi kullanılarak çeşitli parametrelerle analiz edilmesi ve değerlendirilmesidir. Bölgeye yönelik artan politik ve ekonomik ilginin sonucu olarak, bilimsel alanda sistematik bilginin taranması ve değerlendirilmesi bu konuda yapılacak yeni çalışmalara ve araştırmalara katkı sağlayacaktır. Aynı zamanda akademik literatürün geliştirilmesi ilgili alanda politik ve ekonomik hedeflerin belirlenmesinde karar vericilere yol gösterecektir.

Denizyolu Taşımacılığı, Temel Unsurları ve İşletmeleri

Taşımacılık sektörü bir hizmet sektörüdür ve sektörün tamamı dikkate alındığında pazar büyüklüğüne göre turizm sektöründen sonra gelmektedir (Esmer, 2020). Taşımacılık deniz yolu, hava yolu, kara yolu, demir yolu ve boru hattı gibi alt dallara ayrılmaktadır.

Modern ekonomide deniz yolu taşımacılığının rolü, uluslararası ticaretin gelişmesi ve deniz yolu yük hacminin artmasıyla giderek daha fazla önem kazanmaktadır. Denizyolu taşımacılığına yapılan yatırımlar, hızlı ekonomik büyüme için koşullar yaratmakta, iç ve dış ticaretin etkinleştirilmesini sağlamakta, bu da mevcut ve gelecekteki sosyo-ekonomik kalkınma hedeflerine ulaşılmasını mümkün kılmaktadır (Smirnov, 2017).

Denizyolu taşımacılığı, maliyet etkinliği ve uzun mesafelerde büyük miktarlarda yük taşıma özelliği nedeniyle küresel ticaret ve taşımacılıkta çok önemli bir rol oynamaktadır. Deniz taşımacılığının temel unsurları, süreci şekillendiren ve etkileyen faktörler olup, gemi filosu, limanlar, deniz yolu rotaları, lojistik, emniyet ve güvenlik, teknolojidir. Tüm bu unsurlar denizcilik sektörünün temelini oluştururken sektörün verimli ve güvenli işleyişini de belirlemektedir.

Gemi sahipleri ve gemi işletmeleri deniz yolu taşımacılığının ve ticaretinin ana ve temel işletmeleridir. Düzenli (Liner) taşıma, belirli limanlar arasında önceden belirlenmiş tarifelerle ve taşıma koşullarında düzenli olarak deniz yolu taşımacılığı hizmeti sunan gemi işletmeleridir. Düzensiz (Tramp) taşıma, ise yüke bağlı olarak tarifesiz deniz yolu taşımacılığı hizmeti sunan gemi işletmeleridir. Denizyolu taşımacılığında yer alan taraflar aşağıdaki gibi gruplandırılabilir:

- Denizyolu taşımacılığında temel işletmeler: gemi sahipleri ve gemi işletmeleri
- Taşıma hizmeti alan müşteri ve kullanıcılar: yük sahipleri, taşıtanlar, taşıyanlar
- Aracı işletmeler: gemi yönetim işletmeleri, gemi

acenteleri, gemi ve yük brokerleri, forvarder işletmeleri

- Destekleyici-kolaylaştırıcı işletmeler ve kuruluşlar: Gemi Klas ve Sörvey Kuruluşları, Deniz Sigorta Kuruluşları, Limanlar, Yük Elleçleme Müteahhitleri, Bankalar
- Tedarikçi işletmeler ve kuruluşlar: tersaneler, personel sağlayıcı kuruluşlar, danışmanlık şirketleri
- İlgili otorite ve resmi kurumlar (Cerit ve ark., 2016).

Azerbaycan'da Denizcilik Sektörü

Azerbaycan'da ulaştırma, sosyo-ekonomik kalkınmayı karakterize eden önemli altyapı sektörlerinden biridir. Azerbaycan'ın dünyanın çeşitli ülkelerine kara, hava, deniz ve demir yoluyla erişimi vardır. Uluslararası ekonomik ilişkilerin kurulması ve uluslararası ticari işlemlerin yürütülmesi her türlü ulaşım aracı kullanılarak sağlanmaktadır. Ulaştırma sektörü Azerbaycan'ın makroekonomik göstergeleri üzerinde bir bütün olarak önemli bir etkiye sahiptir ve Azerbaycan ekonomisinin %6'sını oluşturmaktadır (Bagırov, 2023). Ülkenin uluslararası ilişkilerinin genişlemesi, Avrupa-Kafkasya-Asya ulaştırma koridorlarının önem kazanması ve projelerin hayata geçirilmesiyle ulaştırma sektörü son yıllarda istikrarlı bir şekilde gelişmektedir. Ülkede taşımacılık ve ulaştırma sektörleri köklü bir şekilde yeniden yapılandırılıp ve dünya standartlarına uygun hale getirilmektedir. Çoğunlukla transit yüklerin taşındığı bölgede, Avrupa-Kafkasya-Asya ulaşım koridorunda taşınan yüklerin en az %10'unun Azerbaycan üzerinden aktarılacağı tahmin edilmektedir (Samadzade, 2020).

Azerbaycan ekonomisinde denizcilik sektörü, yolcu taşımacılığında, petrol ve gaz ithalat-ihracatına yönelik taşımacılıkta önemli rol oynamaktadır. Azerbaycan'da denizciliğin gelişimi petrol endüstrisinin ortaya çıkışı ve gelişmesiyle yakından bağlantılıdır. 19. yüzyılda Bakü'de petrol üretiminin hızla artması, Hazar Denizi'nde taşımacılığın gelişmesini sağladı. Pirallahi, Gürgan, Çilov Adası, Neft Taşları, Azeri, Çırak, Kepez ve Güneşli yataklarının işletilmesi dünya ülkelerinin Azerbaycan'a olan ilgisinin artmasına neden oldu (Yadigarov, 2018).

Azerbaycan Hazar Deniz Taşımacılığı (CJSC), devlet denizcilik şirketi olarak, yük taşımacılığı, petrol ve gaz endüstrisine yönelik özel deniz yolu taşımacılığı hizmetleri, gemi bakım-onarımı, denizcilerin eğitimi ve sertifikalandırılmasını sağlamaktadır. Ayrıca petrol filosu ve deniz yolu taşımacılığı filosuna, 2 gemi onarım tesisine, Azerbaycan Devlet Denizcilik Akademisi ve Eğitim Merkez'lerine sahiptir. Ülkede uluslararası deniz yolu yük taşımacılığı CJSC filosuna ait 21 tanker, 13 feribot, 14 kuru yük gemisi, 2 Ro-Ro gemisi, 2 Ro-Pax gemisi olmak üzere 52 gemi tarafından gerçekleştirilmektedir (ASCO, 2024).

Ülkenin ihracat yapısında petrol ve petrol ürünleri toplam ihracatın %80'ini oluşturmaktadır. Azerbaycan Cumhuriyeti Devlet Petrol Şirketi (SOCAR) Hazar Denizi'ndeki toplam petrol ve gaz üretiminin %89'unu gerçekleştirmektedir. Hazar Denizi Petrol Filosu gemileri, SOCAR'ın tesislerinde yük ve yolcu taşımacılığı, su altı sondaj ve boru döşeme, yükleme-boşaltma, jeolojik araştırma ve deniz tesislerinin güvenliği görevlerini yerine getirmektedir (Yadigarov, 2021).

Avrupa ve Asya'nın sınırında yer alan Hazar Denizi, Orta Asya ve Kafkasya'yı birbirinden ayırmaktadır. Batı Orta Asya'da demir yolu hatları Türkmenbaşı-Türkmenistan ve Aktau-Kazakistan şehirlerinde son bulur. Kuzey Kafkasya'nın ana hatları deniz kıyısına Bakü-Azerbaycan ve Mahaçkale-Rusya Federasyonu'na kadar ulaşmaktadır. Bu bölgeler arasındaki ekonomik bağlantılar, en kısa ulaşım yolu olan Hazar Denizi'nden geçen deniz yolu taşımacılığıyla gerçekleştirilmektedir (Yadigarov, 2018).

Bakü, Hazar Denizi'nin en büyük liman şehridir ve Azerbaycan denizcilik sektörü başkentte toplanmaktadır. Bakü'den Astrahan'a, Mahaçkale'ye, Orta Asya ve İran'ın Anzali limanına düzenli seferler yapılmaktadır. Hazar Denizi okyanusa erişimi olmayan en büyük su kütlesi olmasına rağmen, Azerbaycan Hazar Denizi'nden Volga-Don Kanalı ile Azak Denizi'ne, Volga-Baltık Kanalı ile Baltık Denizi'ne, Belamor-Baltık Kanalı ile Kuzey Buz Denizi'ne ve Atlantik Okyanusu'na ulaşmaktadır (Garayeva, 2016). Uluslararası deniz yolu taşımacılığında Bakü-Astrahan, Bakü-Mahaçkala, Bakü-Anzali, Bakü-Bekdaş, Bakü-Türkmenbaşı, Bakü-Aktau hatları çalışmakta olup, son 3 hatta demir yolu bağlantıları bulunmaktadır. Bakü-Astara, Bakü-Salyan, Bakü-Lenkeran, Bakü-Çilov Adası hatlarında küçük kabotaj taşımacılığı yapılmaktadır (Novruzova, 2020). Bakü Uluslararası Limanı/Alat, Azerbaycan'ın ticari ve ekonomik olarak uluslararası entegrasyonunun gerçekleşmesinde özel bir öneme sahiptir. Liman, kuzey-güney ve doğu-batı ulaştırma koridorlarının kesiştiği ve Bakü gemi inşa endüstrisinin bulunduğu Alat'ta yer almaktadır. Toplam 400 hektar alana, 35.000 m² açık ve 9.400 m² kapalı depo alanına sahip olan Bakü Uluslararası Limanı/Alat'ta 1. aşama çalışmaları 2019 yılında tamamlanmıştır. Elleçleme kapasitesi 15 milyon ton yük ve 100.000 TEU konteyner olup, Ro-Ro, feribot ve yük terminali olmak üzere 3 terminali, 13 iskelesi bulunmaktadır. 2022 yılında Bakü Uluslararası Limanı/Alat'ta elleçlenen toplam yük hacmi 2021 yılına göre %14 artarak 6,3 milyon tona, elleçlenen konteyner sayısı %16 artışla 52.276 TEU'ya ulaşmıştır (PORTOFBAKU, 2024). Limanın kuzey-güney ve doğu-batı ekonomik koridorlarının kesiştiği noktada yer alması ve Azerbaycan'ın ana demir ve kara yolu ağına

bağlantısının bulunması limanın potansiyelini arttırmaktadır (Gunashov ve ark., 2023). Bölgede hayata geçirilen önemli projelerden biri de modern bir lojistik merkez ve Alat'taki Serbest Ekonomik Bölge'dir. Alat Serbest Ekonomik Bölgesi, uluslararası deniz yolu taşımacılığı ve Avrasya lojistik zincirlerinde öncü rol oynamak, yerel üretimi teşvik etmek amacıyla kurulmuştur.

Ülke ekonomisinin temel hedeflerinden biri petrol dışı sektörlerin de geliştirilmesidir. Bu bağlamda, taşımacılık sektörü ve özellikle transit taşımacılık petrol dışı sektörlerin önde gelen alanlarından biri olarak kabul edilmektedir (Khasiyev, 2018). Ülkenin elverişli coğrafi konumu ve uluslararası ortaklıkları, diğer ulaşım yollarına göre kısa mesafe yük taşımacılığı avantajı sağlamaktadır. Araştırmalar ve veriler, 2018-2023 yıllarında bu ulaştırma koridoru üzerinden yük taşımacılığının arttığını göstermektedir. Yıllara göre Azerbaycan yük taşımacılığında ulaşım modlarının payları taşınan yük miktarları Tablo 1 ve Tablo 2'de gösterilmektedir.

Tablo 1. Azerbaycan yük taşımacılığında ulaşım modlarının payları (%) (DSK, 2024)

Table 1. Shares of transport modes in Azerbaijani freight transport (%) (DSK, 2024)

	2018	2019	2020	2021	2022	2023
Demir yolu	6	6.5	7.8	7.8	8.6	7.9
Deniz yolu	3.6	2.5	3.2	2.8	3.4	3.9
Hava yolu	0.1	0.1	0.2	0.3	0.2	0.2
Kara yolu	64.9	66.0	59.1	58.0	57.6	58.4
Boru hattı	25.4	24.9	29.7	31.1	30.2	29.6
Petrol boruhattı	18	16.5	18.4	18.1	17.3	17.3
Gaz boruhattı	7.4	8.4	11.3	13	12.9	12.3

Tablo 2. Avrupa-Kafkasya-Asya ulaşım koridorunda Azerbaycan'da taşınan yük miktarları (Bin ton) (DSK, 2024)

Table 2. Amounts of cargo transported in Azerbaijan on the Europe-Caucasus-Asia transport corridor (Thousand tons) (DSK, 2024)

	2018	2019	2020	2021	2022
Taşınan yük	52.674	52.762	38.491	39.627	51.421
Demir yolu	12.564	13.327	12.820	13.463	16.841
(Bakü-Tiflis-Kars)	7	111.5	224.4	477.4	412.5
Deniz yolu	6.875	4.824	5.015	4.558	6.613
Kara yolu	33.235	34.611	20.656	21.606	27.967
Taşınan transit yük	9.345	8.077	8.382	8.826	13.635
Demir yolu	3.045	3.796	4.132	4.585	7.478
(Bakü-Tiflis-Kars)	5.3	99.9	217	428.9	341.1
Deniz yolu	6.300	4.281	4.250	4.241	6.157

Azerbaycan'da en az yük hava yoluyla, en fazla yük boru hattıyla taşınmaktadır. Transit yükler ise 2018-2023 yılları arasında %46 oranında artmıştır ve taşımacılıkta demir yolu yüksek bir pay almasına rağmen, deniz yolu taşımacılığının da payı giderek artmaktadır. Boru hattı taşımacılığı dışında, doğu-batı ulaştırma koridorlarındaki transit yüklerin neredeyse tamamı deniz yolu ve demir yoluyla taşınmaktadır. Azerbaycan, Hazar Denizi üzerinden Orta Asya ile Avrupa'yı birbirine bağlayan önemli bir lojistik merkez hâline gelirken deniz yolu taşımacılığı ve limanlar, ülkenin petrol dışı ekonomiyi güçlendirme stratejisinde kilit rol oynamaktadır. Ülkede transit taşımacılık hizmetlerinin düzenlenmesi sürecinde potansiyel fırsatlar bulunmaktadır ve deniz yolu taşımacılığı oranlarındaki artış bu alandaki büyüme potansiyelini göstermektedir. Bu amaçla "Azerbaycan Cumhuriyeti'nde Lojistik ve Ticaretin Geliştirilmesi İçin Stratejik Yol Haritası"nda uzun vadeli stratejiyle lojistik ve ulaştırma altyapısının önemli ölçüde iyileştirilmesi hedef olarak belirlenmiştir (Azerbaycan Cumhuriyeti'nde Lojistik ve Ticaretin Geliştirilmesi İçin Stratejik Yol Haritası, 2016). Bakü Uluslararası Limanı/Alat, Zengezur Koridoru ve Bakü-Tiflis-Kars demir yolu gibi projeler Azerbaycan'ın ticaret kapasitesini ve taşımacılık bağlantılarını arttırmaktadır.

Yadigarov'un (2021) makalesinde, Azerbaycan Hazar Deniz Taşımacılığı Kapalı Anonim Şirketi'nin 2014-2019 yıllarındaki ekonomik faaliyetleri, yük taşımacılığının mevcut durumu, gelir-gider, kâr, vergi miktarları analiz edilmekte ve değerlendirilmektedir. Makalede, Bakü Uluslararası Limanı/Alat ve CJSC tarafından gerçekleştirilen iş ve hizmetler için hesaplanan ve ödenen vergiler karşılaştırılmakta, vergilerin devlet bütçesi gelirleri üzerindeki etkisi EViews programı kullanılarak analiz edilmektedir.

Gunashov ve ark. (2023) tezlerinde, Çin tarafından başlatılan OBOR'un Azerbaycan'ın ekonomi, ticari ve liman gelişimi üzerindeki olası etkilerini incelemişlerdir. Çalışmada Azerbaycan'ın açık denize kıyısı olmayan bir ülke olması ve Hazar Denizi'nin uluslararası sulara doğrudan erişiminin olmaması gibi doğal engeller vurgulanarak, ekonominin büyük ölçüde petrol ve gaz sektörüne bağımlı olmasına çözüm olarak petrol dışı sektörlerin geliştirilmesi amacıyla Bakü Uluslararası Limanı/Alat'ın kurulması ve geliştirilmesi, OBOR projesinin Azerbaycan ekonomisine ve ticaretine yaratacağı katkı incelenmiştir.

Heydarova (2008) tezinde, TRACECA Projesi kapsamında Hazar Denizi'nin bir transfer merkezine dönüştürülmesi için bölgede önemli yatırımlar yapıldığını belirtmiş, Demir İpek Yolu olarak bilinen Bakü-Tiflis-Kars demir yolu ile yüklerin Orta Asya ülkeleri üzerinden Çin'e taşınması için Hazar Denizi'nde yapılması planlanan aktarma terminali hakkında açıklamalar yapmıştır.

Garayeva (2016) tezinde Hazar bölgesindeki ülkelerin yaptığı işbirlikleri ve projeler kapsamında Azerbaycan'ın konumunu değerlendirmiş, TRACECA Projesi kapsamında Hazar Denizi'nde yürütülen deniz yolu taşımacılığının mevcut durumunu ortaya koymuştur. Deniz yolu taşımacılığının geliştirilmesi konusunda demir yolu bağlantılarının sağlanması, Büyük İpek Yolu'nun Azerbaycan bağlantılarının geliştirilmesi ve Hazar Denizi kıyısında planlanan Bakü Uluslararası Limanı/Alat hakkında tespit ve önerilerde bulunmuştur.

Novruzova (2020) makalesinde, genel olarak uluslararası deniz yolu taşımacılığının durumu incelenmiş ve özel olarak Azerbaycan deniz yolu taşımacılığının yapısını ve gelişimini analiz etmiştir. Çalışmada, ülkede deniz yolu taşımacılığı üzerinden ekonomik önerilerde bulunulmuştur.

Bagırov (2022) makalesinde Azerbaycan'da deniz yolu taşımacılığının gelişim özelliklerini incelemiştir. Makalede ülkenin deniz yolu taşımacılığındaki mevcut durumu ve yenilikçi teknolojilerin sektörde uygulanmasına yönelik temel özellikler açıklanmaktadır. Teknolojik yeniliklerin çeşitli deniz araçlarında uygulanmasına ilişkin örneklere de yer verilmektedir.

Manafov'un (2021) makalesinde, Hazar bölgesi ulaşım koridorlarının gelişimindeki eğilimler ele alınmaktadır. Makalede İpek Yolu, kuzey-güney ulaşım koridorları, Bakü-Tiflis-Kars demir yolu hattı ve Zangezur koridorunun geleceği, hatların teknik kapasiteleri incelenmiş ve ulaşım koridorlarının geliştirilmesi için öneriler sunulmuştur.

Arlı ve Jafarova'nın (2022) makalelerinde, Azerbaycan'da deniz yoluyla taşınan konteyner miktarı ile makro değişkenler GSYİH-KBDG arasındaki ilişki açıklanmaktadır. Bu kapsamda 2000-2020 yılları arasında Azerbaycan'da taşınan konteyner miktarıyla GSYİH-Manat ve Dolar arasındaki ilişki incelenmiştir.

Borodulina ve Bagırov'un (2017) makalelerinde, Azerbaycan'da deniz yolu taşımacılığının gelişim göstergeleri incelenmiştir. Araştırmacılar, 2005-2015 yılları için yapılan analizlere dayanarak farklı sonuçlara varmışlardır.

Hasanlı ve Mansimov (2021) makalelerinde, Lojistik Performans Endeksi (LPI) parametreleri ve Azerbaycan'ın bu endeksteki puanı, Bakü Uluslararası Limanı/Alat, Bakü-Tiflis-Kars demir yolu gibi altyapı projeleri kapsamında özellikle Çin'den Avrupa'ya yük (konteyner) taşımacılığının hacmini ve bölge ülkelerinin gelişmişlik endekslerini incelemişlerdir.

İbrahimov'un (2016) makalesinde, Azerbaycan'ın elverişli konumu nedeniyle ekonomik gelişim için belirlenen sektörlerden birinin ulaşım olduğu, dünya pazarlarına sınırsız erişim sağlayacak alternatif sürdürülebilir ulaşım yollarının geliştirilmesi gerekliliği vurgulanmıştır. Makalede Azerbaycan'da ulaşım hatlarının oluşturulması ve ülkenin bölgesel işbirliğinin geliştirilmesinde ulaşım sektörünün rolü anlatılmaktadır.

İsmailzade ve Babayev (2020) makalelerinde, Hazar bölgesindeki mevcut ulaşım ve enerji ağlarını incelemiş, kapasitelerini değerlendirmiş ve Hazar bölgesi ulaşım-enerji ağlarını güçlendirebilecek potansiyel projelere dikkat çekmişlerdir. Ayrıca, yazarlar Hazar bölgesinin stratejik ve ticari avantajlarını vurgulayarak, Azerbaycan'ın Doğu'yu Batı'ya bağlayan en önemli uluslararası ulaşım ve enerji merkezlerinden biri olduğunu savunmaktadır.

Memmedov ve Hasanoğlu (2023) makalelerinde, projenin tam olarak hayata geçmesi ile birlikte Güney Kafkasya, Hazar Havzası, Doğu Akdeniz ulaşım ağlarının Bakü'de birleşerek, bölgenin ulaşım, entegrasyon, ticaret noktası olacağını belirtmişlerdir.

Rahmanov ve ark. (2022) makalelerinde küresel lojistiğin ulaştırma altyapısının yönetiminin yeri ve beklentilere ilişkin bilimsel çalışmaları özetlemektedir. Çalışmanın temel amacı, bölgelerin jeopolitik ve ekonomik özelliklerine uygun olarak ortak bir ulaştırma altyapısıyla birleşen küresel lojistik kümelerinin varlığını doğrulamaktır. Çalışmada, 2006-2020 yılları arasında 45 Avrupa ve Asya ülkesi için veriler Dünya Bankası ve Ekonomik İşbirliği ve Kalkınma Örgütü'nün veri tabanlarından veriler alınarak gruplandırılmıştır. Sonuçların, küresel lojistiğin ulaşım altyapısını yönetmek için hizmet sağlayan kamu yetkilileri ve uluslararası kuruluşlar için yararlı olabileceği öngörülmüştür.

Ünal (2023) tarafından yapılan makalede, konteyner limanları ile ilgili ulusal ve uluslararası yayınlar bibliyometrik analizle incelenmiştir. Bu kapsamda toplam 22 adet ulusal makaleden elde edilen veriler yıllara göre dağılım ve araştırma alanları analiz edilmiştir. Ayrıca makalelerin öz, başlık ve anahtar sözcükleri içerik analiziyle incelenmiştir. Konuyla ilgili uluslararası yayınlar Web of Science (WoS) veri tabanından elde edilmiştir. 1109 yayına ulaşılmış ve elde edilen veriler kapsamında yayınların yıllara göre dağılımı, belge türü, ülkelere göre dağılımı ve araştırma alanları incelenmiştir.

Jović ve ark. (2022), deniz yolu taşımacılığı ve limanlarda dijitalleşmenin bibliyometrik, içerik ve tematik analizlerini yapmışlardır. Araştırma aşamasında 8178 yayın incelenmiş, son olarak çalışmaya 280 makale dahil edilmiş ve bibliyometrik içerik analizi yapılmıştır. Araştırmada, veri tabanları, anahtar sözcükler, konular, araştırma alanları ve diğer kriterler incelenmiştir.

Çelik ve Özer Çaylan (2021) 21. Yüzyıl Deniz İpek Yolu ile ilgili makaleleri bibliyometrik analizle incelemişlerdir. Literatür taraması Scopus, Science Direct, Web of Science ve SpringerLink web sitelerinden yapılmıştır. 224 makaleden 45'i çalışmanın ana hedeflerine yönelik olarak seçilmiştir. Makaleler ulaştırma altyapısı, Deniz İpek Yolu'nun zorlukları ve fırsatları, deniz güvenliği, liman ağı, ulaştırma bağlantısı, çevre sorunları gibi konuları kapsamaktadır. Çalışmanın temel katkısı, seçilen Deniz İpek Yolu makalelerini konularına göre gruplandırmak ve makalelerin genel noktalarını açıklamak, araştırmacılara Deniz İpek Yolu girişimiyle ilgili konular hakkında fikir vermektir.

Yorulmaz ve Baykan (2022) Türkiye'de limanlar konusunda yapılan yüksek lisans ve doktora tezlerini bibliyometrik analiz yöntemiyle incelemişlerdir. Konuyla ilgili YÖK Ulusal Tez Merkezi'nden 264 tez alınmış, yayınlar ana bilim dalı, veri yapısı, dil ve araştırma konuları, yöntem kriterlerine göre analiz edilmiştir. Çalışmada liman işletmeciliği alanında eksik konular belirlenmiş ve araştırmacılara yapılacak çalışmalar için önerilerde bulunulmuştur.

Fışkın ve Cerit (2020) Science Citation Index-Expanded (SCI-Expanded) ve Social Sciences Citation Index (SSCI) veri tabanlarında yer alan deniz yolu taşımacılığı/nakliye yayınlarının bibliyometrik analizini sunmaktadırlar. Analizler bibliyometrik haritalama kullanılarak gerçekleştirilmiştir. Beş yıllık bir dönemde denizcilik/gemi inşa literatürünün karşılaştırmalı analizi yapılmıştır. Araştırma sonuçlarında ana araştırma alanları, önde gelen ülkeler, kuruluşlar, dergiler ve önde gelen yazarların yorumları, deniz yolu taşımacılığı/gemi mühendisliği literatüründe ekonomik çalışmaların sayısının azaldığı ve operasyonel çalışmaların sayısının arttığı görülmüştür.

Saral ve Sanrı (2022) makalelerinde, Covid-19'un deniz lojistiği ve limanlar üzerindeki etkisini ortaya koymak amacıyla 2020-2021 yıllarında alanda yapılan yayınları bibliyometrik analizle incelemişlerdir. Analiz Web of Science veri tabanı üzerinden gerçekleştirilmiş ve toplam 29 yayına ulaşılmıştır. Literatür taramasında yayın yılı, dil, erişilebilirlik, yayın türü kriterleri göz önünde bulundurulmuştur (Tablo 3).

Azerbaycan denizcilik ve lojistik sektörleri yeterince araştırılmamış bir alandır ve yapılan sınırlı sayıda çalışmanın da kapsam ve analiz derinliği açısından yeterli olmadığı anlaşılmaktadır. İlgili yayınlar genel olarak değerlendirildiğinde literatürün çoğunlukla OBOR çerçevesinde Bakü Uluslararası Limanı'na odaklandığı, Azerbaycan'da deniz yolu taşımacılığı, liman altyapısı, lojistik koridorlar alanlarında toplandığı görülmektedir. Literatürde Azerbaycan denizcilik sektöründe teknoloji ve dijitalleşme, çevre ve sürdürülebilirlik, liman performansı ve verimlilik, insan kaynakları, iş gücü ve eğitim alanlarında herhangi bir çalışma bulunmamaktadır ve bu konular gelişime açık, potansiyel çalışma alanlarıdır. Bununla birlikte ilgili konu kapsamında bibliyometrik açıdan çalışmaların sistematik analizinin yapılmadığı da görülmektedir. Bu alandaki çalışmaların sınırlı olmasının nedeni yetersiz sayıda yayın ve sınırlı veri bulunmasıdır. Ancak Azerbaycan'ın ulaştırma altyapısının, lojistik ve denizciliğinin geliştirilmesine yönelik artan ilgiyle birlikte bu alandaki araştırmaların genişlemesi ve derinleşmesi beklenmektedir.

Tablo 3. Literatür örneklerinin sınıflandırılması

Table 3. Classification of literature examples

Yöntem	Amaç	Kaynak
Bibliyometrik Analiz	Denizcilik ile ilgili yayınların içerik ve bibliyometrik analizi	Saral ve Sanrı (2022) Fışkın ve Cerit (2020) Yorulmaz ve Baykan (2022) Çelik ve Özer Çaylan (2021) Jović ve ark. (2022) Ünal (2023)
Belge ve veri analizi	Azerbaycan deniz taşımacılığı ve altyapı Gelişimi	Arlı ve Jafarova (2022) Hasanlı ve Mansimov (2021) Yadigarov (2021) Novruzova (2020) Bagırov (2022) Bagırov (2023) Borodulina ve Bagırov (2017) İbrahimov (2016)
Belge ve veri analizi	Hazar Bölgesi jeopolitik projeleri, OBOR, TRACECA	Rahmanov ve ark. (2022) Hasanlı ve Mansimov (2021) Manafov (2021) Yadigarov (2018) Heydarova (2008) İsmailzade ve Babayev (2020) Gunashov ve ark. (2023) İbrahimov (2016) Memmedov ve Hasanoğlu (2023) Samadzade (2020) Garayeva (2016)
İstatistiksel analiz	Ekonomik etkiler ve ilişkiler	Arlı ve Jafarova (2022) Bagırov (2023) Hasanlı ve Mansimov (2021) Rahmanov ve ark. (2022) Yadigarov (2021)

MATERYAL VE YÖNTEM

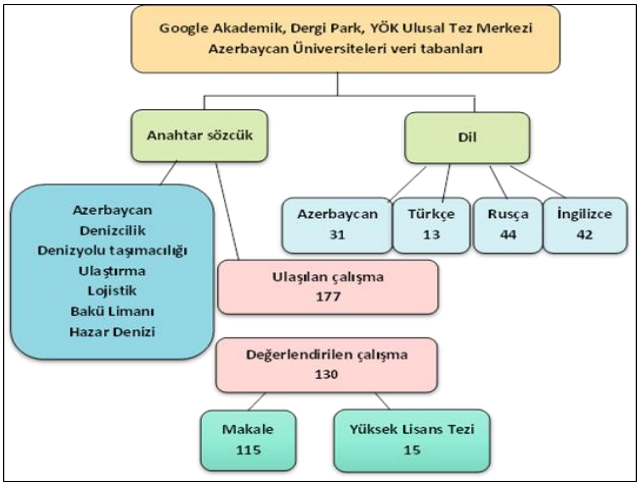
Bibliyometri (Yunanca biblion-kitap, metron-ölçü, metroo-ölçme) yeni bir bilimsel terim olarak ilk kez 1967'de İngiliz bilim adamı Pritchard tarafından tanımlanmıştır. "Bibliyometri" sözcüğünü ilk kez "İstatistiksel bibliyografya ya da bibliyometri" adlı eserinde tanımlamış ve bir araştırma alanının zaman analizini çoklu disipliner bir bakış açısıyla inceleyerek bilimsel literatüre dahil etmiştir (Turgut, 2023). Bibliyometri, matematiksel ve istatistiksel yöntemlerin uygulanması yoluyla kitapların, süreli

yayınların ve diğer bilgi taşıyıcılarının, bilgi materyallerinin incelenmesidir. Yerleşik yöntemler yardımıyla bilimsel alanların etkinliği hakkında bilgi toplamak ve gelişimlerini tahmin etmek amacıyla birincil ve ikincil bilgi kaynaklarının istatistiksel analizine dayalı belgelerin incelenmesi bilim alanıdır (Hacıyeva, 2014). Bibliyometrik analiz yöntemlerinin kullanıldığı araştırmalarda farklı parametrelere göre örneğin yazar, ülke, konu ve kurumlar arasındaki sosyal ve yapısal ilişkiler analiz edilebilmektedir (Donthu ve ark., 2021). Bibliyometrik analiz yöntemi, ilgili konuda politika oluşturma ve uygulama açısından öneme sahiptir (Aria ve Cuccurullo, 2017).

Literatürde, Azerbaycan'da kütüphanecilik, edebiyat çalışmaları, yazılım mühendisliği alanlarıyla ilgili bibliyometrik araştırmalar bulunmaktadır. Bununla birlikte Azerbaycan'da elektronik bibliyometrik veri tabanı bulunmamaktadır. Bu eksikliği gidermek amacıyla ulusal bir analitik bilgi sistemi oluşturularak, yerel yazarların yayınları ve bu yayınlara yapılan atıflara ilişkin bilgiler bir araya getirilebilir. Bu sistemin oluşturulması güncel bibliyografik bilgilerle bilimsel araştırmalara katkı sağlamakla kalmayacak, aynı zamanda bilimsel dergilerin etkililiğini, üretkenliğini ve düzeyini değerlendirmek için güçlü bir araç da olacaktır (Hacıyeva, 2014).

Bu çalışmanın amacı Azerbaycan denizciliği ve lojistiği ile ilgili bilimsel yayınları bibliyografik ve niceliksel olarak analiz etmek ve değerlendirmektir. Analizin, denizcilik ve lojistik alanındaki araştırmaların güncel konularını ve yönlerini göstererek gelecekteki araştırmacılara yol gösterebileceği düşülmektedir. Ayrıca, araştırmacıların mevcut araştırma durumunu anlamalarına, kilit araştırma alanlarını belirlemelerine ve araştırmaların zaman içindeki gelişimini izlemelerine yardımcı olabilir. Genel olarak amaç, Azerbaycan'da denizcilik ve lojistik araştırmalarının ilerlemesine katkıda bulunmak ve araştırmacılar, akademik alanda bilgi sağlamaktır.

Bu çalışmada "Google Akademik", "Dergi Park", Yüksek Öğretim Kurulu (YÖK) "Ulusal Tez Merkezi" ve Azerbaycan Üniversiteleri'nin veri tabanları/kütüphaneleri üzerinden 2000-2024 yılları arasında ulusal ve uluslararası literatürde "Azerbaycan Denizciliği ve Lojistiği" alanlarında yayınlanan 115 bilimsel makale ve 15 yüksek lisans tezi çeşitli parametreler üzerinden bibliyometrik analiz yöntemiyle incelenmiştir. Buna göre, elde edilen veriler Microsoft Excel programıyla grafiklendirilmiş, anahtar sözcüklerin analizi sözcük WordArt bulut tekniği kullanılarak oluşturulmuştur. Literatürde "Azerbaycan" "Denizcilik", "Denizyolu Taşımacılığı", "Lojistik", "Ulaştırma", "Bakü Limanı", "Hazar Denizi" sözcükleri Azerbaycan, Türkçe, Rusça, İngilizce dilleri kullanılarak araştırılmıştır. Çalışmada konuyla ilgili veri toplama aracı olarak "Google Akademik", "Dergi Park", YÖK "Ulusal Tez Merkezi" ve Azerbaycan Üniversiteleri'nin veri tabanları/kütüphaneleri kullanılmıştır. Azerbaycan'da bibliyometrik veri tabanının bulunmaması çalışmayı sınırlamaktadır ve bu nedenle tarama yalnız açık erişimli veri tabanları ve Azerbaycan Üniversiteleri'nin kütüphaneleri üzerinden yapılmıştır. Şekil 1' de görüldüğü üzere, veri toplama ve analiz süreci dört aşamadan oluşmaktadır. Akış doğrultusunda makale ve tezler "yazım dili", "yıl", "anahtar sözcük", "sayfa sayısı", "kaynak sayısı", "araştırma yöntemi", "veri toplama tekniği", "dergi", "üniversite", "yazar sayısı", "anabilim dalı" ve "danışman ünvanı" parametrelerine göre sınıflandırılmış ve değerlendirilmiştir ve Tablo 4'te çalışmada kullanılan tarama alanları ve bibliyometrik parametreler görülmektedir.



Şekil 1. Çalışmanın akış şeması
Figure 1. Flowchart of the study

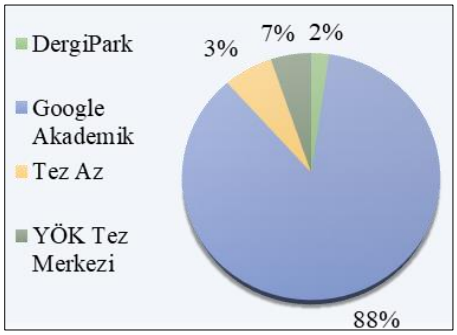
Tablo 4. Çalışmada kullanılan tarama ve bibliyometri parametreleri

Table 4. Scanning and bibliometric parameters used in the study

Veri tabanları	Diller	Anahtar Sözcükler	Yıl Aralığı	Parametreler
Google Akademik	Azerbaycan	Azerbaycan	2000-2024	Sayfa Sayısı
DergiPark	Türkçe	Denizcilik		Kaynak Sayısı
YÖK Ulusal Tez Merkezi	Rusça	Deniz yolu Taşımacılığı		Yayınlandığı Üniversite
Azerbaycan Üniversiteleri	İngilizce	Lojistik		Araştırma Yöntemi
		Ulaştırma		Veri Toplama Tekniği
		Bakü Limanı		Yazar Sayısı
		Hazar Denizi		Yayınlandığı Yıl
				Anahtar Sözcük
				Yayınlandığı Dergi
				Anabilim Dalı
				Danışman Ünvanı

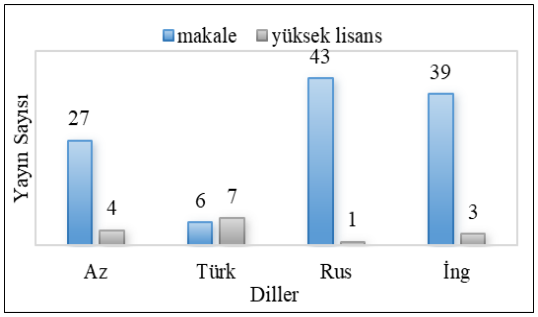
BULGULAR VE TARTIŞMA

Tarama sonucu yayınlardan 115 bilimsel makale ve 15 yüksek lisans tezi çeşitli parametreler üzerinden bibliyometrik analizle değerlendirilmeye alınmıştır. Şekil 2'de görüldüğü gibi, yayınların veri tabanlarına göre dağılımında 114 yayınla Google Akademik %88; 3 yayınla Dergi Park %2; 9 yayınla YÖK Ulusal Tez Merkezi %7 ve 4 yayınla Azerbaycan Üniversiteleri veri tabanlarının payı %3'tür.



Şekil 2. Yayınların veri tabanına göre dağılımı
Figure 2. Distribution of publications by database

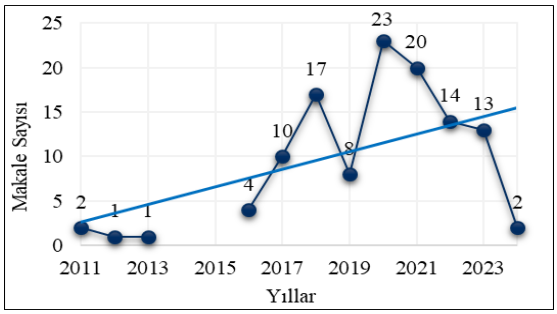
Şekil 3'te görüldüğü gibi, yayınların diline göre dağılımında 115 makaleden 27 makale Azerbaycan, 6 makale Türkçe, 43 makale Rusça, 39 makale İngilizce dillerinde yazılmış; 15 tezden 4 tez Azerbaycan, 7 tez Türkçe, 1 tez Rusça, 3 tez İngilizce dillerinde yazılmıştır. Buna göre en fazla makale Rusça, en fazla tez Türkçe olarak yayınlanmıştır.



Şekil 3. Yayınların yazım diline göre dağılımı
Figure 3. Distribution of publications by language

Makalelerin Yıllara Göre Dağılımı

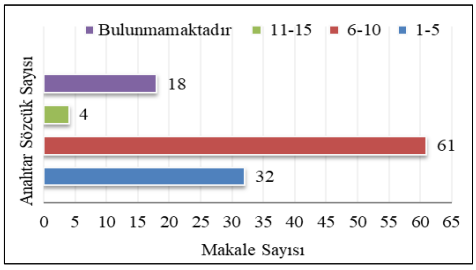
Tarama sonucunda Azerbaycan denizciliği ve lojistiği hakkında 115 bilimsel makaleye ulaşılmıştır. Veri tabanlarında 2000-2024 yıllarına göre tarama yapılmış olmasına rağmen elde edilen makaleler 2011-2024 yıllarını kapsamaktadır. Yayınların yıllara göre dağılımı incelendiğinde 2011-2016 yılları arasında az sayıda makalenin yayınlandığı, 2017 yılından sonra yayın sayısının artığı görülmektedir. Bu artışın nedeni 2015 yılında "Azerbaycan Cumhuriyeti Transit Yük Taşımacılığı Koordinasyon Konseyi" ve 2016 yılında "Azerbaycan Cumhuriyeti'nde Lojistik ve Ticaretin Geliştirilmesi İçin Stratejik Yol Haritası"nın hazırlanması ve ülkede lojistiğin geliştirilmesine yönelik önemli etkinliklerin düzenlenmesidir. En fazla yayın 23 makaleyle 2020 yılında yapılmıştır. Bunun nedenlerinden biri de Sumgayıt şehrinde "Azerbaycan'ın Transit Potansiyelinin Ekonomik Kalkınmadaki Rolü" konulu ülkenin transit potansiyelini gündeme getiren bilimsel konferansın düzenlenmiş olmasıdır. Bu durum, akademik üretimde ulusal politikaların ve etkinliklerin doğrudan etkili olduğunu göstermektedir. İlgili yıllar arasında araştırmalarının yıllık ortalama büyüme oranı %35,43 olup, yayınların yıllara göre dağılımı Şekil 4'te verilmiştir.



Şekil 4. Makalelerin yıllara göre dağılımı
Figure 4. Distribution of articles by years

Makalelerin Anahtar Sözcüklere Göre Dağılımı

Anahtar sözcükler, yayınların içeriğini özetleyip daha görünür hale getirmelerinin yanı sıra, yayınlanan alanla ilgili sık bahsedilen konu ve kavramlara da karşılık gelir. Sözcük bulutu, sık kullanılan sözcükler hakkında fikir edinilmesine katkı sağlamaktadır. Bu amaçla, makalelerin anahtar sözcüğe göre dağılımı WordArt kullanılarak sözcük bulutu tekniğiyle oluşturulmuştur. Azerbaycan denizciliği ve lojistiği alanında incelenen 115 makalenin anahtar sözcüklerine göre dağılımında "Ulaştırma", "Lojistik", "Bakü Limanı", "Transit", "Liman" sözcükleri yayınlarda en çok kullanılan sözcükler olarak belirlenmiştir. Şekil 5 ve Şekil 6'da görüldüğü gibi en fazla anahtar sözcük 61 makaleyle 6-10 aralığındadır ve 18 makalede anahtar sözcük kullanılmamıştır.

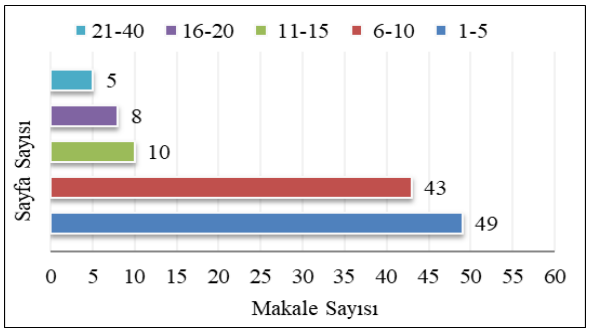


Şekil 5. Makalelerin anahtar sözcük sayısına göre dağılımı
Figure 5. Distribution of articles by number of keywords

Şekil 6. Sözcük bulutu
Figure 6. Word cloud

Makalelerin Sayfa Sayısına Göre Dağılımı

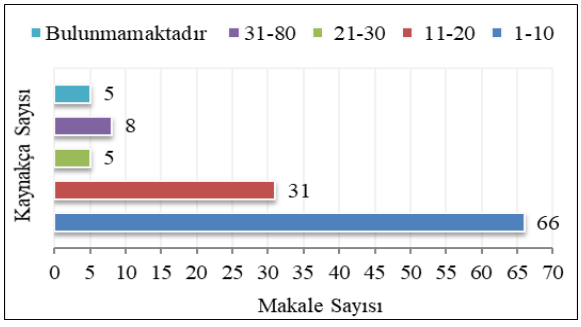
Bibliyometrik analiz parametreleri çerçevesinde makalelerin sayfa sayısına göre dağılımı incelendiğinde ortalama sayfa sayısı 8; sayfa sayısı en fazla yayın 49 makaleyle 1-5 sayfa aralığında, en az yayın 5 makaleyle 21-40 sayfa aralığında görülmektedir. Sayfa sayısına göre dağılım Şekil 7'de görülmektedir.



Şekil 7. Makalelerin sayfa sayısına göre dağılımı
Figure 7. Distribution of articles by number of pages

Makalelerin Kaynak Sayısına Göre Dağılımı

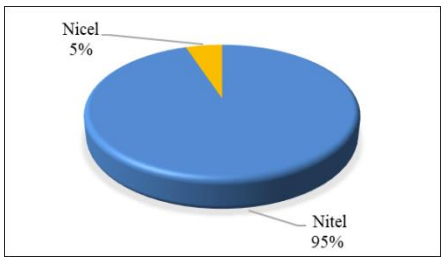
Makalelerin kaynak sayısına göre dağılımı incelendiğinde ortalama kaynak sayısı 12; kaynak sayısı en fazla yayın 8 makaleyle 31-80 kaynak aralığında, en az yayın 66 makaleyle 1-10 kaynak aralığında görülmektedir. 5 makalede ise kaynak bulunmamaktadır. Kaynakların ulusal ve uluslararası olarak dağılımına bakıldığında 17 makalede ulusal kaynak bulunmazken, 60 makalede 1-5 aralığında ulusal kaynak kullanımı belirlenmiştir. Kaynak sayısına göre dağılım Şekil 8'de görülmektedir.



Şekil 8. Makalelerin kaynak sayısına göre dağılımı
Figure 8. Distribution of articles by number of references

Makalelerin Araştırma Yöntemine Göre Dağılımı

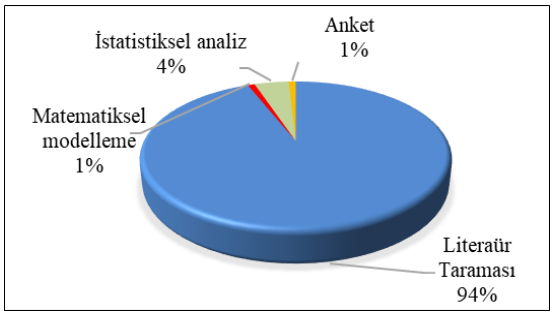
Şekil 9'da görüldüğü gibi yayınlarda en çok nitel araştırma yöntemi kullanılmıştır. İlgili konu doğrultusunda yapılan çalışmaların genelinde 109 makaleyle %95 oranında nitel, 6 makaleyle %5 oranında nicel araştırma yöntemi kullanılmıştır.



Şekil 9. Makalelerin araştırma yöntemine göre dağılımı
Figure 9. Distribution of articles by research method

Makalelerin Veri Toplama Tekniğine Göre Dağılımı

Şekil 10'da görüldüğü gibi, yayınların veri toplama tekniğine göre dağılımında 108 makaleyle %94 oranında literatür taraması, 5 makaleyle %4 oranında istatistiksel analiz, 1 makaleyle %1 oranında matematiksel modelleme, 1 makaleyle %1 oranında anket tekniği kullanılmıştır.



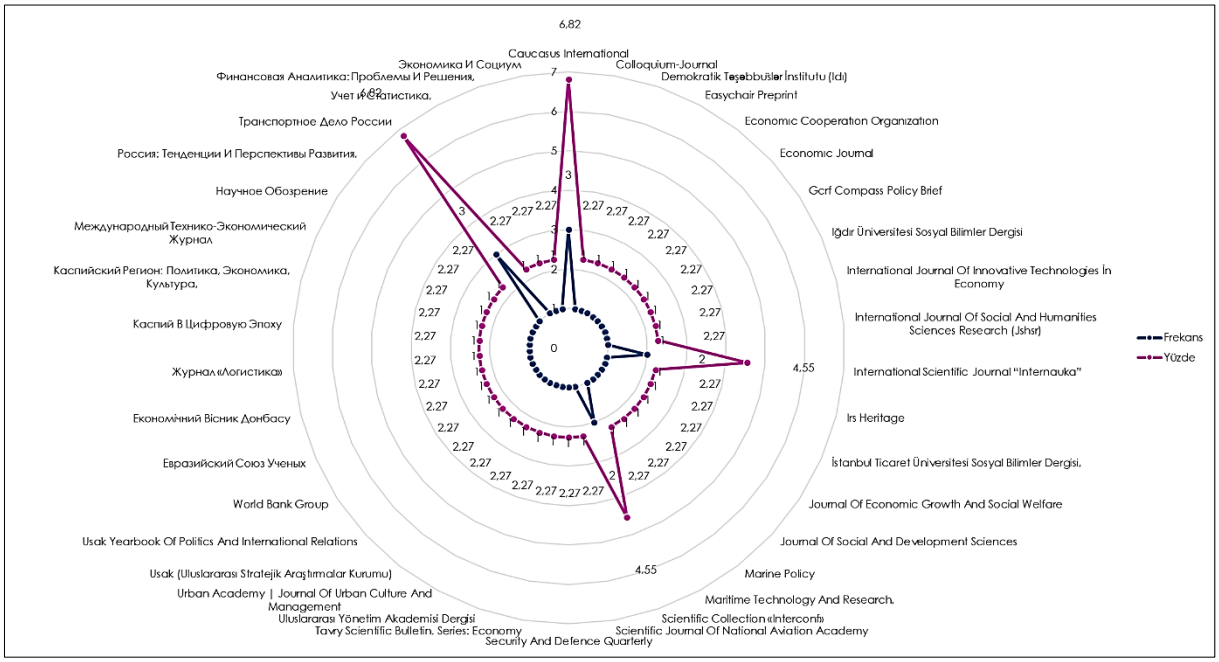
Şekil 10. Makalelerin araştırma yöntemine göre dağılımı
Figure 10. Distribution of articles by research method

Makalelerin Yayınlandığı Dergiye Göre Dağılımı

Çalışma kapsamında ele alınan makalelerin yayınlandıkları dergilere göre dağılımında 38 makaleyle %33'ü akademik dergilerde, 77 makaleyle %66'sı konferans/sempozyum kitaplarında yayınlanmıştır. Şekil 11'de görüldüğü gibi Caucasus International, Transportnoe Delo Rosii, International Scientific Journal Internauka, Scientific Collection Interconf dergileri en fazla yayının yapıldığı dergilerdir.

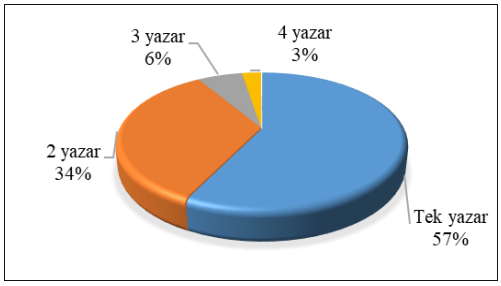
Makalelerin Yazar Sayısına Göre Dağılımı

Araştırma kapsamında incelenen yayınların yazar sayısına göre dağılımı Şekil 12'de gösterilmiştir. Yayınların 66 makaleyle %57 oranında "tek yazarlı", 39 makaleyle %34 oranında "iki yazarlı", 7 makaleyle %6 oranında "üç yazarlı", 3 makaleyle %3 oranında "dört yazarlı" olduğu görülmektedir. Yazarların yerli ve yabancı dağılımına



Şekil 11. Makalelerin yayınlandığı dergiye göre dağılımı
Figure 11. Distribution of articles by research journal

bakıldığında 14 makalenin yabancı, 101 makalenin yerli yazarlar tarafından yazıldığı belirlenmiştir.



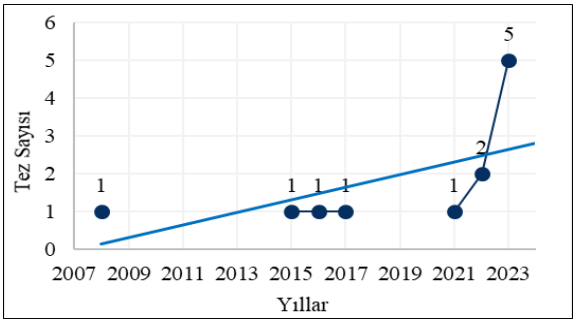
Şekil 12. Makalelerin yazar sayısına göre dağılımı
Figure 12. Distribution of articles by number of authors

Tezlerin Yıllara Göre Dağılımı

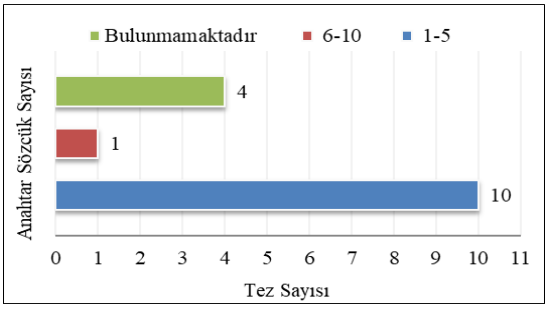
Azerbaycan denizciliği ve lojistiği ile ilgili sınırlı sayıda tez çalışması vardır. Tarama sonucunda 15 teze ulaşılmıştır. Tezlerin araştırılmasında 2000-2024 yıllarına göre tarama yapılmış olmasına rağmen, yayınların 2008-2024 yıllarında yapıldığı görülmüştür. Yayınların yıllara göre dağılımı incelendiğinde 2008 yılında 1 tez çalışmasının yapıldığı, 2009-2014 yılları arasında ise tez çalışmasının bulunmadığı, 2023 yılında ise 5 tez çalışmasının yapıldığı görülmektedir. Tezlerin türüne göre dağılımı incelendiğinde 15 yüksek lisans tezinin bulunduğu, doktora tezinin ise bulunmadığı belirlenmiştir. İlgili yıllar arasında araştırmalarının yıllık ortalama büyüme oranı %16,66 olup, yayınların yıllara göre dağılımı Şekil 13'te verilmiştir.

Tezlerin Anahtar Sözcüklerine Göre Dağılımı

Tez çalışmalarının anahtar sözcüğe göre dağılımı WordArt kullanılarak sözcük bulutu tekniğiyle oluşturulmuştur. Azerbaycan denizciliği ve lojistiği alanında incelenen 15 tezin anahtar sözcüklerine göre dağılımında "Lojistik", "Ulaşım", "Taşımacılık", "Dış Ticaret", "BRI (Belt and Road Initiative)", "Petrol", "Uluslararası Ticaret" sözcükleri çalışmalarda en çok kullanılan sözcükler olarak belirlenmiştir. Şekil 14 ve Şekil 15'te görüldüğü gibi en fazla anahtar sözcük 10 makaleyle 1-5 aralığındadır ve 4 makalede anahtar sözcük kullanılmamıştır.



Şekil 13. Makalelerin yazar sayısına göre dağılımı
Figure 13. Distribution of articles by number of authors

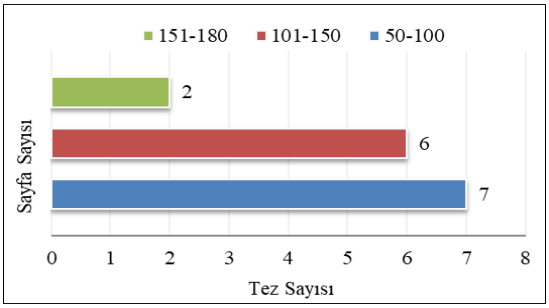


Şekil 14. Makalelerin anahtar sözcük sayısına göre dağılımı
Figure 14. Distribution of articles by number of keywords

Şekil 15. Sözcük bulutu
Figure 15. Word cloud

Tezlerin Sayfa Sayısına Göre Dağılımı

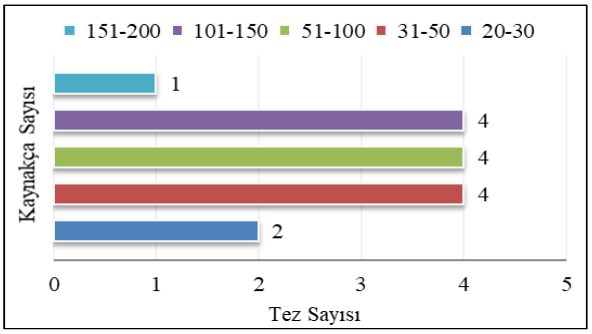
Bibliyometrik analiz parametreleri çerçevesinde tezlerin sayfa sayısına göre dağılımı incelendiğinde ortalama sayfa sayısı 108; sayfa sayısı en fazla yayın 7 tezle 50-100 sayfa aralığında, en az yayın 2 tezle 151-200 sayfa aralığında görülmektedir. Sayfa sayısına göre dağılım Şekil 16'da görülmektedir.



Şekil 16. Tezlerin sayfa sayısına göre dağılımı
Figure 16. Distribution of theses by number of pages

Tezlerin Kaynak Sayısına Göre Dağılımı

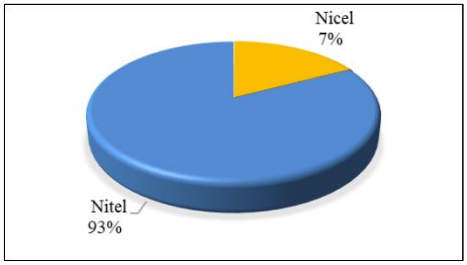
Tezlerin kaynak sayısına göre dağılımı incelendiğinde ortalama kaynak sayısı 76; kaynak sayısı en fazla yayın 1 tezle 151-200 kaynak aralığında, en az yayın 2 tezle 20-30 kaynak aralığında görülmektedir. Kaynakların ulusal ve uluslararası olarak dağılımına bakıldığında 2 tezde ulusal kaynak bulunmazken, 5 tezde 20-50 aralığında ulusal kaynak kullanımı belirlenmiştir. Kaynak sayısına göre dağılım Şekil 17'de görülmektedir.



Şekil 17. Tezlerin kaynak sayısına göre dağılımı
Figure 17. Distribution of theses by number of references

Tezlerin Araştırma Yöntemine Göre Dağılımı

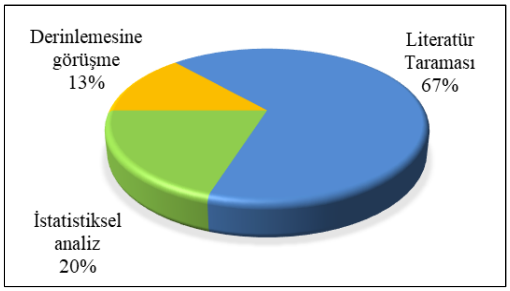
Şekil 18'de görüldüğü üzere yayınlarda en çok nitel araştırma yöntemi kullanılmıştır. İlgili konu doğrultusunda yapılan çalışmaların genelinde 14 tezle %93 oranında nitel, 1 tezle % 7 oranında nicel araştırma yöntemi kullanılmıştır.



Şekil 18. Tezlerin araştırma yöntemine göre Dağılımı
Figure 18. Distribution of Theses by Research Method

Tezlerin Veri Toplama Tekniğine Göre Dağılımı

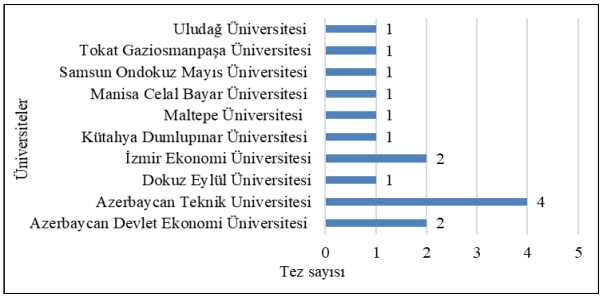
Şekil 19'da görüldüğü gibi, yayınların veri toplama tekniğine göre dağılımında 10 tezle %67 oranında literatür taraması, 3 tezle %20 oranında istatistiksel analiz, 2 tezle %13 oranında derinlemesine görüşme kullanılmıştır.



Şekil 19. Tezlerin veri toplama yöntemine göre dağılımı
Figure 19. Distribution of theses by data collection method

Tezlerin Yayınladığı Üniversitelere Göre Dağılımı

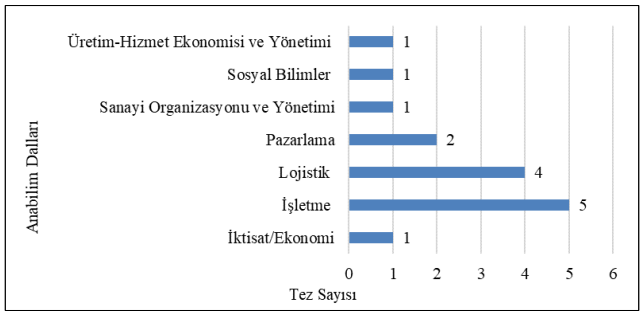
Çalışmada ele alınan tezlerin yayınlandıkları üniversitelere göre dağılımında 4 tezle Azerbaycan Teknik Üniversitesi, 2 tezle Azerbaycan Devlet Ekonomi Üniversitesi, 2 tezle İzmir Ekonomi Üniversitesi öne çıkmaktadır. Şekil 20'de görüldüğü gibi ilgili konuda Azerbaycan üniversitelerinde 6 tez, Türkiye üniversitelerinde 9 tez yapılmıştır.



Şekil 20. Tezlerin yayınlandığı üniversitelere göre dağılımı
Figure 20. Distribution of theses by universities

Tezlerin Anabilim Dallarına Göre Dağılımı

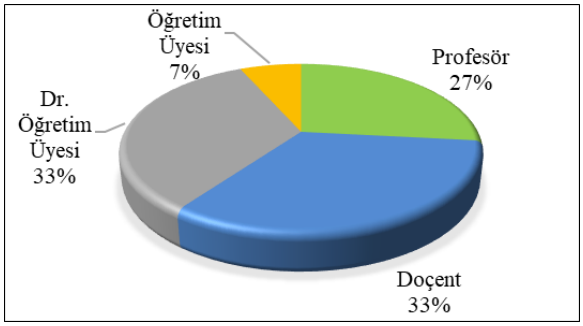
Analiz kapsamında tez çalışmaları incelendiğinde en fazla tezin 5 çalışmayla "İşletme" anabilim dalında, 4 çalışmayla "Lojistik" anabilim dallarında yapıldığı görülmektedir. Şekil 21'de tezlerin anabilim dallarına göre dağılımı yer almaktadır.



Şekil 21. Tezlerin anabilim dallarına göre dağılımı
Figure 21. Distribution of theses by departments

Tezlerin Danışman Ünvanlarına Göre Dağılımı

Araştırma kapsamında incelenen yayınların danışman ünvanlarına göre dağılımı Şekil 22'de gösterilmiştir. Yayınların 4 tezle %27 oranında profesör, 5 tezle %33 oranında doçent, 5 tezle %33 oranında Dr. öğretim üyesi, 1 tezle %7 oranında öğretim üyesi akademisyenler danışmanlığında hazırlandığı görülmektedir.



Şekil 22. Tezlerin danışman ünvanlarına göre dağılımı
Figure 22. Distribution of theses by advisor titles

Araştırmada 115 bilimsel makaleye ve 15 yüksek lisans tezine ulaşılmış ve değerlendirmeye alınmıştır. Makalelerin en fazla Rusça, tezlerin ise en fazla Türkçe dillerinde hazırlandığı belirlenmiştir. Rusça yayınların ağırlığı, bölgenin akademik üretiminde Rusya etkisini göstermektedir. Ancak İngilizce yayınların görece düşük olması, uluslararası görünürlükte bir sınırlılık yaratmaktadır. Türkçe tezlerin fazla olması ise son yıllarda Azerbaycanlı öğrencilerin Türkiye'de yüksek eğitim almasına bağlanabilir. Araştırmalarda çok yüksek oranda nitel yöntem kullanıldığı ve literatür taraması tekniğiyle veri toplandığı belirlenmiştir. Bu durum konuyla ilgili sayısal verilere ulaşmada güçlük çekildiğini gösterirken, alandaki ölçme ve değerlendirmenin yoruma dayalı ve yüzeysel kalmasına neden olmaktadır. Bibliyometrik analiz sonucu elde edilen bulgulara göre makaleler 2011-2024, tez çalışmaları ise 2008-2024 yıllarını kapsamaktadır. En fazla makalenin 2020, en fazla tezin ise 2023 yılında yayınladığı görülmektedir. Burada Azerbaycan'ın ulaştırmadaki rolüne ve transit potansiyeline ilişkin düzenlenen bilimsel konferans ve çalışmaların etkili olduğunu göstermektedir.

Makalelerde en çok kullanılan anahtar sözcüklerin "Ulaştırma", "Lojistik", "Bakü Limanı", "Transit", "Liman" sözcükleri olduğu belirlenmiştir. Makalelerin ortalama sayfa sayısı 8 olmak üzere, en fazla 1-10 sayfa aralığında hazırlandığı; ortalama kaynak sayısı 12 olmak üzere, en fazla 1-10 aralığında kaynak kullanıldığı görülmektedir. Genel olarak tek yazarlı ve Azerbaycanlı yazarlar tarafından hazırlanan makalelerde, çoğunlukla uluslararası kaynak kullanımı söz konusudur. Makalelerin en fazla Caucasus International, Transportnoe Delo Rosii, International Scientific Journal Internauka, Scientific Collection Interconf dergilerinde yayınlandığı görülmektedir.

Yayınlanan tezlerin tamamı yüksek lisans tezi olup, konuyla ilgili doktora çalışması bulunmamaktadır. Tezlerde en çok kullanılan anahtar sözcüklerin "Lojistik", "Ulaşım", "Taşımacılık", "Dış Ticaret", "BRI", "Petrol", "Uluslararası Ticaret" olduğu belirlenmiştir. Tezlerin ortalama sayfa sayısı 108 olmak üzere, en fazla 50-100 sayfa aralığında hazırlandığı; ortalama kaynak sayısı 76 olmak üzere, en fazla 51-100 aralığında kaynak kullanıldığı, kaynakların ulusal kökenli olduğu görülmektedir. Tezlerin en fazla Türkiye üniversitelerinde; lojistik ve işletme anabilim dallarında, en fazla profesör ve doçent ünvanlı akademisyenler danışmanlığında yapıldığı görülmektedir. Bu durum 31 Ekim 2017 tarihinde imzalanan "Türkiye Cumhuriyeti Yükseköğretim Kurulu ile Azerbaycan Cumhuriyeti Eğitim Bakanlığı Arasında Yükseköğretim Alanında İşbirliğine Dair Mutabakat" (RG: 2018/12/11 Karar No: 438) sonrasında Azerbaycanlı öğrencilerin son yıllarda Türkiye'de lisansüstü eğitim almasına bağlanabilir.

SONUÇ

Bu çalışmanın amacı Azerbaycan denizcilik sektörünün önemini ortaya koymak, bu alandaki sınırlı bilgiyi, yapılan az sayıdaki çalışmayı ve erişilebilirliğin sınırlarını belirlemektir. Çalışmada Azerbaycan denizciliği ve lojistiği alanlarında ulusal ve uluslararası literatürde yer alan yayınlar ilgili veri tabanlarında araştırılmış ve bibliyometrik analiz yöntemiyle incelenmiştir.

Bibliyometrik analiz sonuçlarına göre Azerbaycan denizciliği ve lojistiği alanlarında ilgili araştırmaların sayısının yetersiz olduğu belirlenmiştir. Konuyla ilgili literatürde sınırlı sayıda çalışma vardır ve bu çalışmaların

çoğu kapsam ve analiz derinliği açısından sınırlıdır. Var olan çalışmalarda nicel analizlerin sınırlı olmasının sektörel veriye erişim güçlüğünden kaynaklandığı düşünülmektedir. Bu durumda ileride yapılacak çalışmalarda büyük veri ve istatistiksel yöntemlerin kullanımının önemi yapıyı belirleme adına öne çıkmaktadır. Bulgularda öne çıkan genel eğilim, Azerbaycan'da denizcilik ve lojistik alanının uluslararası yayınlarda görünürlüğünün artırılması gerektiğini göstermektedir. Denizcilikle ilgili konuların, son zamanlarda bölgedeki jeopolitik ve ekonomik gelişmeler nedeniyle Azerbaycan için güncel konulardan biri haline geldiği görülmektedir. Azerbaycan Devleti, birbiriyle yarışan alternatif rotaların oluştuğu bir dönemde, ulaştırma ve lojistik altyapısının inşası için büyük miktarda kaynak ayırmış ve çeşitli projeleri devreye sokmuştur. Bu bağlamda OBOR ve İpek Yolu'nun canlandırılması projesi çerçevesinde Doğu-Batı Koridoru'nun Azerbaycan'a açtığı fırsatların ve yapılan çalışmaların, elde edilen başarıların ve çözüm bekleyen sorunların değerlendirilmesi önemlidir. Bu alandaki konular yerli ve yabancı yazarların ilgisini çekmektedir. Ayrıca, Azerbaycan Cumhuriyeti'nde Lojistik ve Ticaretin Geliştirilmesi İçin Stratejik Yol Haritası'nın, Azerbaycan'dan geçen uluslararası taşımacılık koridorlarının transit potansiyelinin arttırılması ve transit yük taşımacılığının teşvik edilmesine ilişkin 2024-2026 Eylem Planı ve ülkede bu sektörün geliştirilmesine yönelik önemli etkinliklerin düzenlenmesi son zamanlarda bu alanda araştırma yapacak yazarlara kaynak ve ilgi alanı sunmaktadır. Bu doğrultuda 2017 yılından itibaren hem yerli hem de yabancı yazarlar tarafından yapılan yayınların sayısında artış görülmektedir.

Azerbaycan denizcilik sektörü küresel entegrasyona açık, stratejik konuma sahip, altyapı yatırımlarını artıran, petrol dışı ekonomiye yönelen, bilimsel temelli kararlar alma eğiliminde bir görünüm sergilemektedir, dolayısıyla bu alanda akademik bilgiye ve araştırmaya ihtiyaç duyulmaktadır. Azerbaycan denizciliği ve lojistiği üzerine yapılan yayınlarda herhangi bir bibliyometrik analiz yapılmadığından çalışmanın literatüre, bibliyometrik temalı çalışmaların yaygınlaşmasına ve bu alanda yapılacak araştırmalara katkı sağlayacağı, ayrıca ilgili konuların yeterince araştırılmadığını ortaya koyarak gelecekteki araştırmalara yol göstereceği düşünülmektedir. Gelecek araştırmalarda bibliyometrik analizlerin atıf analizi, işbirliği ağları ve tematik haritalama gibi yöntemlerle zenginleştirilmesi yararlı olacaktır. Azerbaycan denizciliği ve lojistiği ile ilgili akademik araştırmaların bibliyometrik analizinin yapıldığı bu çalışmanın ilgili araştırmaların önünü açabileceği düşünülmektedir. Çalışmada yer alan makale ve tezlerin sayfa sayısı, kaynak sayısı, yöntemleri gibi özelliklerine bakılarak bu alandaki araştırmacılara çalışma içeriğinin yeterli olup olmadığı konusunda da bilgi verecektir. Azerbaycan denizcilik ve lojistik alanlarında bilimsel araştırmalara, doktora ve yüksek lisans tez çalışmalarına duyulan ihtiyacın altı çizilmektedir. Çalışma, ulusal politikalar ve etkinliklerde akademik üretimin önemini ve etkisini vurgulamakta, politika yapıcıların bu durumu göz önüne alarak ilgili alanlara destek vermesi gerekliliğini ortaya koymaktadır.

Etik Standartlara Uygunluk

Yazarların Katkısı

Yazarlar LC ve YN çalışmanın tasarlanmasında, LC makalenin ilk taslağının hazırlanmasında, LC ve YN istatistiksel analizlerin toplanması ve işlenmesinde, LC ve YN makaleyi yazımında ve yorumlanmasında yer almıştır. Tüm yazarlar makalenin son halini okuyup onaylamıştır.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını beyan ederler.

Etik Kurul Onayı

Yazarlar resmi onam gerekmediğini beyan etmektedir.

Finansman

Bu araştırma, hiçbir hibe, fon veya başka bir finansman desteği almamıştır.

Veri Kullanılabilirliği

Çalışmanın bulgularını destekleyen veriler talep üzerine sorumlu yazardan temin edilebilir.

Yapay Zeka Açıklaması

Bu araştırma makalesinde üretken yapay zeka kullanılmamıştır.

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Variability of total suspended solids, turbidity, temperature, pH, salinity and dissolved oxygen in Qatar's coastal waters

Hammam Osama Tawfik Abdelghafar[1] • Wisnu Prayogo[2] • Saleem Mustafa[3] • Abentin Estim[3]✉

[1] Department of Monitoring and Environmental Inspection, Ministry of Environment and Climate Change, Doha, QATAR
[2] Department of Civil Engineering, Universitas Negeri Medan, Medan, INDONESIA
[3] Borneo Marine Research Institute, Universiti Malaysia Sabah, Jalan UMS, Kota Kinabalu, Sabah, MALAYSIA

✉ Corresponding Author: bentin@ums.edu.my

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A B S T R A C T

The coastal waters of Qatar are vital for the environment, economy and health but they are impacted by anthropogenic and natural factors. Among other parameters, Total suspended solids (TSS), turbidity, temperature, pH, salinity and dissolved oxygen (DO) are important parameters in the determination of quality of coastal waters. This study aims to determine the spatial and temporal variations in these parameters in coastal waters of Qatar. The observations were conducted monthly between 2022 to 2023 and focused on selected sites, using multiprobe sensors to record temperature, pH, turbidity and salinity. The results showed that there were no significant differences ($P<0.05$) between the seven study sites with respect to temperature and TSS. The mean temperature range across all sites was 27.22±5.96°C to 28.40±5.97°C, while the mean TSS range was 4.64±3.32 mg/L to 6.64±6.15 mg/L. Results also suggested that there were significant differences ($P<0.05$) in salinity, pH, DO and turbidity across these study sites. There were significant seasonal differences ($P<0.05$) in water quality parameters. Temperature and salinity levels were highest during the fall and summer seasons, while pH and DO levels were highest during the spring season. Turbidity was highest during winter. There are complex relationships between water quality parameters and changes in one parameter could impact others. These results have implications for the management of coastal resources in Qatar, as they highlight the need to consider multiple factors when assessing the water quality. This study suggests that the water quality parameters are influenced by multiple factors, including proximity to some Arabian Gulf regions, urbanization and coastal erosion. These observations highlight the need for comprehensive management strategies to address the pertinent issues and protect the coastal water quality in Qatar.

INTRODUCTION

The coastal waters of Qatar are a vital component of its ecosystem, providing numerous benefits to the environment, economy and human health. However, these waters are also vulnerable to various anthropogenic and natural factors (Sankaran et al., 2023; Yao et al., 2023). TSS and turbidity are two important parameters that reflect the clarity and transparency of coastal waters (Colley and Smith, 2007; Cheng et al., 2017; Ekhlas & Bary, 2018). In this article, TSS refers to the weight of suspended particles in a unit volume of water, whereas turbidity measures the cloudiness or

haziness of water caused by suspended particles (Colley and Smith, 2007; Sankaran et al., 2023).

Turbidity, a critical indicator of water quality, can significantly influence aquatic ecosystems. Elevated turbidity levels impede the visibility and monitoring of aquatic organisms, whereas lower turbidity reflects clearer waters that are more favorable for both ecosystem health and recreational activities such as swimming and snorkeling (Colley and Smith, 2007; Alhaja et al., 2017; Cheng et al., 2017; Sankaran et al., 2023). Additionally, high TSS levels have been linked to decreased water clarity, which can lead to increased risk of disease transmission through waterborne pathogens (Al Mamoon et al., 2019;UNEP GEMS, 2008; Sankaran et al., 2023; Yao et al., 2023).

Temperature, pH, salinity, and DO are critical parameters that affect the overall health of coastal waters (UNEP GEMS, 2008; Sankaran et al., 2023; Yao et al., 2023). Temperature regulates biological processes, while pH influences nutrient availability for aquatic organisms (El-Magharaby et al., 2008; Rivers et al., 2019; Cheng et al., 2023; Xue et al., 2024). Salinity affects the distribution and abundance of marine life, particularly in areas with limited freshwater input (Ibrahim et al., 2020; Aloui et al., 2023), and DO serves as a key indicator of water quality, with low concentrations potentially reducing biodiversity and increasing mortality rates (El-Magharaby et al., 2008; Rivers et al., 2019; Cheng et al., 2023).

Comprehensive data on TSS, turbidity, temperature, pH, salinity and DO in Qatar's coastal waters remain limited, hindering effective coastal management. This study addresses this gap by evaluating the spatial and temporal variations of these key water quality parameters, providing critical insights to support sustainable management and conservation of coastal ecosystems.

MATERIALS AND METHODS

Study sites

The description of sites selected for this study follows the order of north, east, south and west instead of numeral order as described in Table 1. The sampling was carried out near the coast in proximity to initial bearings because drifts were caused by surface currents. Meanwhile, the seabed was generally flat with 1 to 2 degree incline. Therefore, the water depth remained constant.

North of Qatar lies Ras Rakan, an islet located 0.8 km from shore (Table 1). It was not completely accessible, especially by boats because the waters were shallow and almost near flat (1–2 degree incline) terrain. Generally, this T-shaped islet has seagrass meadows in both western and eastern intertidal zones and both sections are separated by an inundated seabed that is approximately 1 km long from the mainland (Figure 1). The main activity in this region is fisheries because it opens to the Arabian Gulf. In addition, a commercial fishing boat dock was in the area. Ras Imlaiji (Table 1) is an industrial hamlet on the northeast shore of Qatar. This location is approximately 3 m above sea level and could be relevant for sea outfall monitoring due to its strategic location for sea transport and in the vicinity of medium to large manufacturing and production industries.

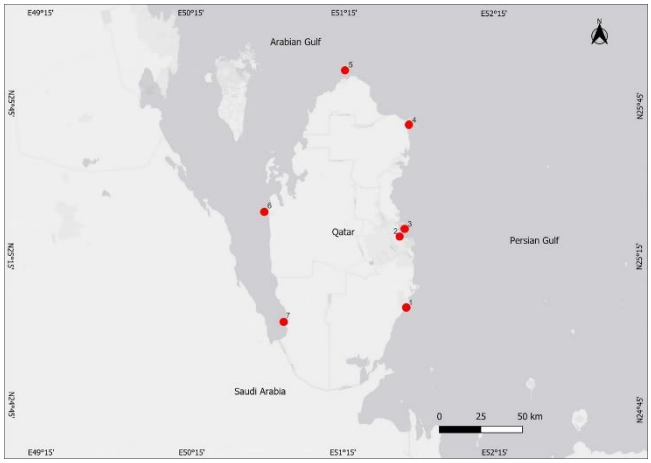

Figure 1. Depicts a map of seven study locations in Qatar's coastal waters between the Arabian Gulf and the Persian Gulf

Al Safliya Island located approximately 3 km off Qatar's eastern coast (Figure 1), is predominantly sandy and hosts clusters of seagrass meadows in the intertidal zone (Table 1). The island remains largely undisturbed with only 35 public pergolas, ensuring minimal contamination from domestic waste such as sewage or solid debris. In contrast, Doha Bay situated about 5 km from Al Safliya is characterized by high population density, a landfill and a shipping port, making it a potential source of elevated pollution and a suitable site for investigating marine outfalls (Table 1).

Sealine Beach (Table 1) is generally positioned at the southeast shores of Qatar, but for this study, the location could be considered as south (Figure 1). The main activity on this beach is tourism, and it is supported by services such as accommodation and recreational facilities. Besides, a mangrove patch is in its vicinity, and this location could be associated with a nature reserve. Due to tourism, Sealine Beach has the potential to be a point source for introduced pollutants and contaminants associated with human activities.

Salwa Beach located in the southwestern region of Qatar (Figure 1) was also selected for this study. The area is characterized by rocky shores, mangrove vegetation and sandy beaches. It is primarily used for nature tourism and winter sunbathing and generally experiences lower

contamination levels compared to Sealine Beach. Consequently, Salwa Beach was chosen as a reference site for seawater quality (Table 1).

Another study site is Dukhan (Table 1, Figure 1), a town historically developed around oil extraction since the 1940s. Dukhan hosts the largest oil reserves in Qatar and its coastal waters may be impacted by hydrocarbon deposits or outfalls. Consequently, the shores of this area represent a potential point source of hydrocarbon-associated contaminants, which may differ in composition and concentration from those in tourism or urban areas.

Sample collection and experimental design

The field visits were carried out monthly from May 2022 to April 2023. Surface seawater samples were collected 300 m and 500 m from shore. Data was recorded using a multi-probe sensor (for temperature, pH, turbidity and salinity). The complete list of assessed parameters is shown in Table 2.

Data management and statistics

The data were tabulated in Microsoft Excel to develop database sheets. These sheets were processed for statistical analysis using IBM Statistical Package for Social Science v.22. Kruskal-Wallis tests were used to compare between study sites and seasons. Spearman's correlation was used to determine relationships among the seawater parameters.

Table 1. Description of seven study sites of Qatar coastal waters

Site no.	Location	Depth (m)	Geographical coordinates	Coastal area description
1	Sealine Beach	15	24°53'03.54"N 51°33'38.10"E	Tourism area. Nature reserve. Proximity to Mesaieed Industrial Area
2	Doha Bay	3	25°18'05.54"N 51°31'30.16"E	High socio-economic importance. Intense activities along the coast and in the sea in the capital Doha. Fishing, shipping, ports, navigational passage
3	Al Safliya Island	3	25°20'07.38"N 51°34'24.07"E	Tourism activities
4	Ras Imlaiji	5	25°51'04.00"N 51°36'01.10"E	Proximity to oil and gas industries. Port operations
5	Ras Rakan	1.5	26°11'54.84"N 51°13'33.96"E	Commercial activities and fishing port in the area
6	Dukhan	3	25°24'52.00"N 50°45'05.00"E	Recreational beach and nearby oil and gas. Plants and other industrial activities
7	Salwa Beach	4	24°47'58.00"N 50°51'15.00"E	Recreational beach and tourism destination. Nature reserve

Table 2. Seawater quality attributes obtained and evaluated in the current study

Parameters	Unit(s)	Technique
Temperature	°C	Multi-probe sensor
pH	-	Multi-probe sensor
Salinity	PSU	Multi-probe sensor
Turbidity	NTU	Multi-probe sensor
DO	mg/L	APHA 4500 (with slight modifications recommended by Shriwastav *et al*. (2017)
TSS	mg/L	The method of total suspended solids followed the protocol of Hansen *et al*. (2021)

RESULTS AND DISCUSSION

The values of temperature, salinity, pH, DO, turbidity, and TSS at seven study sites are presented in Table 3. The Kruskal-Wallis test showed no significant differences ($P>0.05$) between the seven study sites in temperature and TSS. The temperature ranged from 27.22±5.96°C at Salwa Beach to 28.40±5.97°C at Ras Imlaiji, and TSS varied from 4.64±3.32 mg/L at Ras Rakan to 6.64±6.15 mg/L at Salwa Beach (Table 3). This lack of variation in temperature could be attributed to the geographical location of Qatar, which is a small peninsular country with limited site-to-site variations (Cheng et al., 2017; Ekhlas and Bary, 2018). The results suggest that the study sites are experiencing similar environmental conditions that are strongly influenced by the country's desert climate (Aloui et al., 2023; Khan et al., 2023; Cheng et al., 2017). The lack of significant variation in TSS could be attributed to the fact that Qatar is a coastal country

Table 3. Mean±S.D. of physico-chemical seawater properties at seven study sites during the four seasons of Qatar

Study sites	Season	N	Temp. (°C)	Salinity (PSU)	pH	DO (mg/L)	Turbidity (NTU)	TSS (mg/L)
Sealine Beach (Site 1)	Spring	9	24.23±2.43	40.78±0.23	8.25±0.18	6.28±0.29	1.05±0.08	6.80±5.41
	Summer	9	32.51±1.60	37.98±2.25	8.20±0.16	6.30±0.97	0.91±0.27	3.33±0.55
	Fall	6	33.57±1.45	45.95±0.49	8.23±0.06	7.40±0.20	0.90±0.11	2.01±1.10
	Winter	12	23.66±4.58	42.32±4.48	8.11±0.34	6.27±0.60	1.68±1.43	7.12±4.94
	Total	36	27.67±5.42	41.45±3.80 [c]	8.19±0.24 [a,b]	6.47±0.73 [b,c]	1.20±0.89 [a]	5.24±4.38
Doha Bay (Site 2)	Spring	9	25.55±0.37	38.60±0.31	8.38±0.26	5.79±0.34	2.86±0.69	6.23±2.08
	Summer	9	31.92±1.67	36.24±2.08	8.17±0.06	5.63±1.01	1.40±0.28	2.53±0.94
	Fall	6	33.26±1.81	41.05±0.27	8.21±0.09	6.68±0.13	1.99±0.85	2.51±0.55
	Winter	12	23.66±4.53	36.36±1.53	8.16±0.06	6.18±0.75	2.40±0.15	8.01±6.29
	Total	36	27.80±4.92	37.67±2.25 [a]	8.23±0.16 [a,b,c]	6.03±0.76 [a]	2.20±0.73 [b]	5.28±4.44
Al Safliya (Site 3)	Spring	9	25.22±0.96	38.40±0.32	8.29±0.10	6.39±0.29	1.49±0.21	5.26±1.37
	Summer	9	31.60±2.12	36.34±2.15	8.18±0.04	6.38±1.11	1.42±0.32	3.43±0.53
	Fall	6	33.18±1.71	42.20±0.88	8.18±0.04	7.22±0.12	1.22±0.05	2.50±0.55
	Winter	12	23.46±4.60	36.48±1.56	8.16±0.02	6.45±0.78	2.79±1.96	8.13±6.46
	Total	36	27.56±5.01	37.88±2.55 [a]	8.20±0.08 [a,b]	6.55±0.77 [c]	1.86±1.30 [b]	5.30±4.32
Ras Imlaiji (Site 4)	Spring	6	23.72±2.37	38.20±0.13	8.40±0.20	6.29±0.16	1.26±0.07	7.50±4.93
	Summer	9	33.99±2.89	35.43±1.96	8.37±0.25	6.05±0.55	0.99±0.12	3.26±1.29
	Fall	6	33.65±0.38	41.71±0.33	8.29±0.10	7.30±0.33	1.33±0.37	6.00±1.09
	Winter	12	23.91±4.52	38.52±3.66	8.15±0.09	6.24±0.58	1.41±0.47	6.92±4.63
	Total	33	28.40±5.97	38.20±3.18 [a, b]	8.28±0.19 [c]	6.39±0.64 [b,c]	1.25±0.36 [a]	5.86±3.82
Ras Rakan (Site 5)	Spring	6	23.04±0.72	38.92±0.53	8.34±0.14	6.55±0.18	1.19±0.05	7.25±4.11
	Summer	9	33.39±2.01	36.29±1.52	8.31±0.15	5.20±0.98	2.99±3.42	3.40±1.90
	Fall	6	32.86±2.05	49.35±6.74	8.14±0.04	6.44±0.24	1.00±0.12	3.05±0.06
	Winter	9	23.11±4.19	36.34±2.25	8.16±0.05	5.89±1.18	3.29±3.08	5.20±4.08
	Total	30	28.13±5.76	39.44±6.03 [b]	8.24±0.13 [b,c]	5.92±0.98 [a]	2.32±2.63 [b]	4.64±3.32
Dukhan (Site 6)	Spring	9	23.47±2.26	49.40±0.40	8.22±0.17	6.08±0.41	0.98±0.08	6.50±4.16
	Summer	9	34.16±1.62	43.49±6.91	8.17±0.03	5.89±0.81	0.75±0.08	3.80±1.34
	Fall	6	32.88±1.86	56.45±0.17	8.14±0.04	7.24±0.40	0.89±0.06	3.55±1.69
	Winter	12	23.35±4.90	51.87±5.77	8.11±0.05	5.88±0.56	1.19±0.29	7.83±5.05
	Total	36	27.67±6.02	49.92±6.38 [d]	8.16±0.10 [a]	6.16±0.75 [a,b]	0.98±0.25 [a]	5.78±4.03
Salwa Beach (Site 7)	Spring	9	25.12±2.74	50.99±0.40	8.27±0.19	5.64±0.39	1.06±0.05	7.00±5.27
	Summer	9	33.58±2.35	47.46±2.64	8.14±0.03	6.00±0.67	0.80±0.08	2.76±1.33
	Fall	6	31.62±1.08	59.10±0.11	8.29±0.11	7.12±0.23	0.83±0.02	4.50±3.83
	Winter	12	21.82±4.88	49.91±1.63	8.11±0.05	6.13±0.61	1.09±0.20	10.36±7.89
	Total	36	27.22±5.96	51.10±4.16 [d]	8.19±0.13 [a,b]	6.14±0.70 [a,b]	0.97±0.18 [a]	6.64±6.15
Mean	Spring	57	24.44±2.03 [b]	42.56±5.32 [b]	8.30±0.18 [c]	6.12±0.43 [a]	1.43±0.70 [a]	6.57±3.96 [b]
	Summer	63	33.02±2.20 [c]	39.04±5.31 [a]	8.22±0.15 [b]	5.92±0.93 [a]	1.32±1.44 [a]	3.22±1.22 [a]
	Fall	42	33.00±1.58 [c]	47.97±7.27 [c]	8.21±0.09 [b]	7.06±0.42 [b]	1.16±0.51 [a]	3.44±2.05 [a]
	Winter	81	23.29±4.49 [a]	41.88±7.03 [b]	8.14±0.14 [a]	6.16±0.73 [a]	1.93±1.55 [b]	7.74±5.76 [b]
	Total	243	27.76±5.53	42.36±6.89	8.21±0.16	6.24±0.78	1.52±1.25	5.55±4.44

**The different alphabetical superscripts within a row have significantly different (P < 0.05).*

with limited freshwater sources (Aloui et al., 2023; Alhaja et al., 2017). This implies that most of the water quality parameters are affected by various factors. The results suggest that the seven study sites could be exposed to pollution transported from offshore or adjacent marine areas, such as suspended sediments, wastewater discharge or other anthropogenic inputs carried by tidal currents and circulation patterns. These external influences from the open sea may contribute to the observed variability in TSS levels at the coastal sites (Ibrahim et al., 2020; El-Magharaby et al., 2008; Cheng et al., 2017; Ekhlas and Bary, 2018). However, it is important to note that this result does not necessarily mean that there are no variations in water quality parameters across the different study sites. Other factors, such as anthropogenic activities, urbanization and land use changes, could also affect the water quality at these sites (Aloui et al.,

2023; Yao et al., 2023; Ibrahim et al., 2020; UNEP GEMS, 2008).

Significant differences (P<0.05) in salinity, pH, DO and turbidity were evident among the study sites when the data was processed through the Kruskal-Wallis test. The highest salinity was recorded at Salwa Beach (51.10±4.16 PSU) and Dukhan (49.92±6.38 PSU). Salinity was lower at Sealine Beach (41.45±3.80 PSU), Ras Rakan (39.44±6.03 PSU), Ras Imlaiji (38.20±3.18 PSU) and Al-Safliya (37.88±2.55 PSU). The lowest salinity was observed at Doha Bay (37.67±2.25 PSU) (Figure 2). The highest pH was 8.28±0.19 at Doha Bay and the lowest was 8.16±0.10 at Dukhan (Figure 2). DO and turbidity were lower at Ras Rakan (5.92±0.98 mg/L) and at Salwa Beach (0.97±0.18 NTU), respectively. While the highest was recorded at Al Safliya (6.55±0.77 mg/L) and Ras Rakan (2.32±2.63 NTU), respectively (Figure 2).

The high salinity values at Salwa Beach and Dukhan may be attributed to their proximity to the Arabian Gulf open water, where salt concentration is higher due to its limited freshwater sources (Yao et al., 2023; Engel et al., 2021; El-Magharaby et al., 2008; UNEP GEMS, 2008). This is consistent with previous studies that have found high salinity levels in coastal waters adjacent to the Arabian Gulf (El-Magharaby et al., 2008; UNEP GEMS, 2008; Ibrahim et al., 2020).

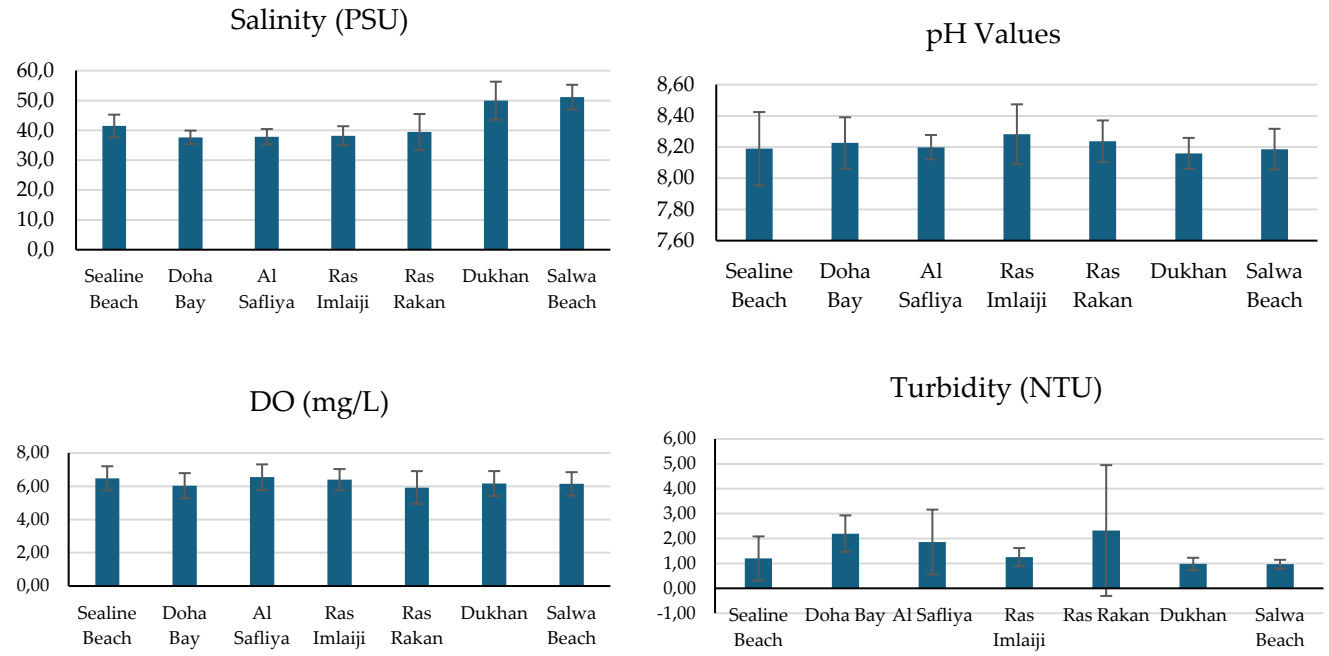

Figure 2. Comparisons of Means (± S.D.) Salinity, pH, DO, and Turbidity between the Seven Study Sites of Coastal Waters in Qatar

In addition to salinity, significant differences were also observed in pH, DO and turbidity between the study sites. The highest pH value recorded at Doha Bay may be attributed to the influence of urbanization, which can lead to an increase in anthropogenic activities that alter the local water chemistry (Afzal et al., 2023; Ibrahim et al., 2020; El-Magharaby et al., 2008). These observations are consistent with previous studies indicating that elevated pollutant levels and nutrient-rich runoff from urban areas contribute to alterations in water quality in Doha Bay (UNEP GEMS, 2008; Al Mamoon et al., 2019). The current findings suggest that such anthropogenic inputs may be a key driver of the observed spatial variations in water quality parameters, highlighting the influence of urbanization on coastal ecosystem health. The lowest DO and turbidity values recorded at Ras Rakan may be attributed to the presence of coastal erosion (Rajendran et al., 2021). Coastal erosion can lead to increased sedimentation, which can reduce DO levels and increase turbidity (Rajendran et al., 2021). This is consistent with a study that found a significant correlation between coastal erosion and changes in water quality parameters in Ras Rakan (Engel et al., 2021; Khan et al., 2023; Sankaran et al., 2023).

Furthermore, the results of this study suggest that the water quality parameters are influenced by multiple factors, including proximity to the Arabian Gulf, urbanization and coastal erosion (Engel et al., 2021; Khan et al., 2023; Sankaran et al., 2023). This highlights the need for comprehensive management strategies to address protection of water quality in Qatar's coastal waters.

The Kruskal–Wallis test revealed significant seasonal differences (P<0.05) in temperature, salinity, pH, DO, turbidity and TSS (Figure 3). Seasonal values of these parameters are shown in Table 3. Evidently, the highest temperature was recorded during the fall and summer

seasons, while the lowest temperature was recorded during the winter and spring (Figure 3). For the salinity and DO, it was obvious that the peak values were obtained during the fall season, while the lowest was during summer (Figure 3). The pH level was higher during spring and the lowest in winter (Figure 3). Turbidity and TSS were recorded higher during the winter season, while during the fall season, turbidity and TSS were recorded lower during summer (Figure 4).

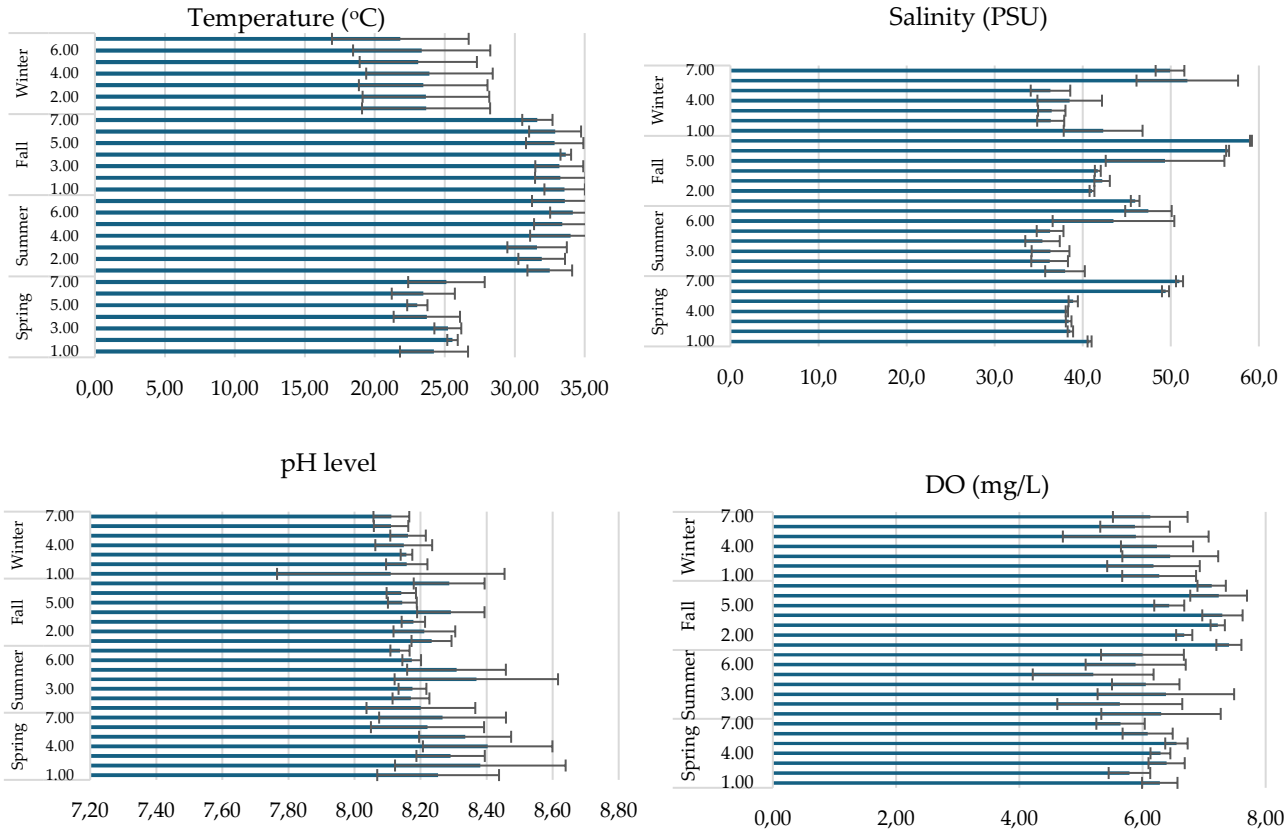

Figure 3. Mean (± S.D.) temperature, salinity, pH, and DO across seven study sites in Qatar over four seasons, with seasons and stations on the y-axis and measured values on the x-axis

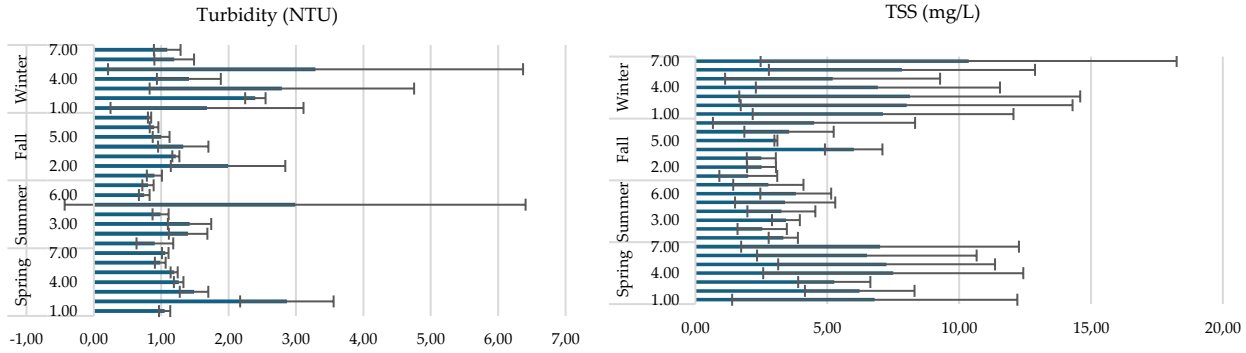

Figure 4. Mean (±S.D.) turbidity and TSS across seven study sites in Qatar over four seasons, with seasons and stations on the y-axis and measured values on the x-axis

The highest temperature was recorded during the fall and summer seasons, while the lowest temperature was during the winter and spring. This is in accordance with previous studies on the climate conditions of Qatar, which show that the country experiences a hot desert climate with very little rainfall (Paparella and Burt, 2024; Ekhlas and Bary, 2018; Cheng et al., 2017).

The highest salinity levels were recorded during the fall season, while the lowest levels were observed during the summer. This may be attributed to the increased evaporation rates during the fall and summer months, leading to an increase in salt concentration in the water (Alhaja et al., 2017; Ekhlas and Bary, 2018; Paparella and Burt, 2024). The pH level was highest during the spring season and lowest during

the winter. This could be due to changes in the concentration of dissolved gases, especially carbon dioxide, which influences the pH of seawater (Rivers et al., 2019).

The highest DO levels were recorded during the fall season, while the lowest levels were observed during the summer. This may be attributed to increased photosynthesis rates during the fall and summer months, leading to an increase in DO levels (Rivers et al., 2019; Paparella and Burt, 2024). Turbidity was highest during the winter season, while it was lowest during the summer. This could be due to increased sedimentation during the winter months, leading to higher turbidity levels (Rivers et al., 2019; Paparella and Burt, 2024).

Spearman's correlation analyses of temperature, salinity, pH, DO, turbidity and TSS are shown in Table 4. It shows that temperature is correlated with pH, turbidity and TSS, while pH is correlated with salinity only. Salinity shows a correlation with pH, DO, turbidity and TSS. On the other hand, DO has correlations with salinity and TSS. Turbidity is correlated with temperature, salinity and TSS, while TSS has a correlation with temperature, salinity, DO and turbidity. These findings demonstrate that the seawater quality in the study sites has distinct relationships with multiple parameters.

Table 4. Spearmans's correlation analyses of temperature, salinity, pH, DO, turbidity and TSS of Qatar

		Spearman's rho Correlations					
		Temperature	**pH**	**Salinity**	**DO**	**Turbidity**	**TSS**
Temperature	**Correlation Coefficient**	1.000	.206**	-.067	-.022	-.318**	-.637**
	Sig. (2-tailed)	.	.001	.301	.733	<.001	<.001
	N	243	243	243	243	243	243
pH	**Correlation Coefficient**	.206**	1.000	-.173**	-.030	.014	-.032
	Sig. (2-tailed)	.001	.	.007	.646	.824	.615
	N	243	243	243	243	243	243
Salinity	**Correlation Coefficient**	-.067	-.173**	1.000	.194**	-.455**	.194**
	Sig. (2-tailed)	.301	.007	.	.002	<.001	.002
	N	243	243	243	243	243	243
DO	**Correlation Coefficient**	-.022	-.030	.194**	1.000	-.048	.266**
	Sig. (2-tailed)	.733	.646	.002	.	.455	<.001
	N	243	243	243	243	243	243
Turbidity	**Correlation Coefficient**	-.318**	.014	-.455**	-.048	1.000	.180**
	Sig. (2-tailed)	<.001	.824	<.001	.455	.	.005
	N	243	243	243	243	243	243
TSS	**Correlation Coefficient**	-.637**	-.032	.194**	.266**	.180**	1.000
	Sig. (2-tailed)	<.001	.615	.002	<.001	.005	.
	N	243	243	243	243	243	243

***. Correlation is significant at the 0.01 level (2-tailed)*

Temperature was found to be correlated with pH, turbidity and TSS, suggesting that variations in temperature may influence these seawater parameters. For instance, elevated temperatures can reduce pH levels by enhancing the dissolution of carbon dioxide in seawater (Cheng et al., 2023; Xue et al., 2024). pH was found to have a correlation only with salinity. This is consistent with previous studies that have shown that pH and salinity are related parameters (Rivers et al., 2019; Cheng et al., 2023; Xue et al., 2024). Temperature and salinity were found to play a significant role in shaping multiple water quality parameters in Qatar's coastal waters. Temperature was correlated with pH, turbidity and TSS, suggesting that variations in temperature can impact these parameters. For instance, elevated temperatures may reduce pH by enhancing the dissolution of carbon dioxide in seawater (Cheng et al., 2023; Xue et al., 2024). Similarly, salinity influences dissolved gases, such as carbon dioxide and was correlated with pH, DO, turbidity and TSS, reflecting that salinity fluctuations can significantly alter water quality. Elevated salinity can reduce DO due to decreased gas solubility, while changes in TSS and turbidity further affect oxygen availability (Rivers et al., 2019; Cheng et al., 2023; Xue et al., 2024). These results highlight the interconnected nature of coastal water quality variables and their potential ecological implications. Overall, understanding these relationships is essential for predicting the response of coastal waters to environmental changes and for informing effective management and conservation strategies.

CONCLUSION

Qatar's coastal water quality is governed by complex interactions among multiple environmental parameters. In this study, temperature and TSS showed no significant spatial variation across the seven sites, suggesting relatively

uniform conditions for these parameters. In contrast, salinity, pH, DO and turbidity exhibited significant seasonal fluctuations, which can directly influence the chemical, physical and biological characteristics of coastal ecosystems. These findings provide essential baseline data for future monitoring and enhance understanding of the environmental drivers shaping water quality in the region. By highlighting the interconnections among key water quality parameters, the study emphasizes the need for integrated, multi-parameter approaches to support sustainable management and effective conservation of Qatar's coastal resources.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

HOTA contributed to writing the original draft, investigation, methodology, data curation, and funding acquisition. **AE** and **SM** contributed to conceptualization, supervision, formal analysis, data curation and writing (review and editing). **WP** contributed to data analysis, methodology and writing (review and editing). All authors have read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Ethical Approval

For this type of study, formal consent is not required.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

AI-assisted technology was not used in the preparation of this work, except for grammar and spelling checks.

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Water quality and plankton biodiversity of a flood retention lake in Benin City, Nigeria

Emeka Donald Anyanwu[1]✉ • Flora Ebaimoh Mukah[2] • Precious Chizaram Okani[2] • Amarachi Grace Stephen[1]

[1] Department of Zoology and Environmental Biology, College of Natural Sciences, Michael Okpara University of Agriculture, 440109, Umudike, NIGERIA
[2] Department of Plant Science and Biotechnology, College of Natural Sciences, Michael Okpara University of Agriculture, 440109, Umudike, NIGERIA

✉ Corresponding Author: ekadon@yahoo.com

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A B S T R A C T

Increased risk of flooding in many cities and regions has necessitated the inclusion of flood retention lakes in flood control systems. Man-made water bodies can provide significant ecological benefits. The water quality and plankton assemblage of a flood retention lake was assessed using two stations in dry and wet seasons. A total of ten water quality variables and phytoplankton and zooplankton diversity were examined using standard analytical and identification techniques. The lake's richness and trophic status was also evaluated. The range of water quality parameters such as water temperature (24.00-28.00°C), pH (6.10-7.20), electrical conductivity (221.00-560.00 µS/cm), total dissolved solids (113.00 - 279.00 mg/L), turbidity (0.30-2.50 NTU), dissolved oxygen (1.80-3.80 mg/L), biochemical oxygen demand (1.50-4.40 mg/L), phosphate (0.04-0.09 mg/L) and nitrate (0.08-0.29 mg/L) were presented. Dissolved oxygen and biochemical oxygen demand values did not conform to limits while station 2 and dry season had higher values. A total of 50 phytoplankton species comprising 1696 individuals and zooplankton with 35 species comprising 980 individuals were recorded. Shannon-Weiner and diversity index was varied from 3.484 to 3.750 for phytoplankton and from 3.056 to 3.360 for zooplankton. Margalef index fluctuated between 5.159 and 7.314 for phytoplankton and between 4.014 and 5.541 for zooplankton whereas Evenness index ranged from 0.8296 to 0.9057 for phytoplankton and from 0.7815 to 0.8224 for zooplankton. Nygaard indices were Myxophycean (0.72), Chlorococcales (1.84), Diatoms (0.14), Euglenophycean (0.32) and Compound Quotient (4.09) while Rotifera, Cladocera, Copepoda (RCC) index was 39.09%. The presence of some pollution tolerant species was an indication that the lake was tending towards eutrophic condition. The general condition of the lake could be due its design and anthropogenic activities. In conclusion, the lake is still suitable to support plankton and fishery development.

INTRODUCTION

Increased risk of flooding being experienced in many cities and regions are majorly caused by climate change and unplanned rapid urbanization. Unpredictable weather events especially rainfall and rapid modification of land-use patterns has posed serious challenge to most existing flood control facilities in cities around the world (Yulianti and

Prasetyo, 2024). Benin City, Nigeria is not an exception; large number of properties were inundated and lost to flood in the Government Reserved Area (GRA) until recent flood control intervention by Edo State Government. The intervention includes among other things, the construction of retention ponds in strategic locations within the reserved area (Nigerian Observer, 2023).

Retention lakes are designed to hold excess rainwater and runoff before being released into drainage basin, thereby reducing flood risks (Amalia et al., 2023; Yulianti and Prasetyo, 2024; Saputra et al., 2025). It is now a common practice in modern urban flood control systems globally (Brink and Kamish, 2018). Since retention lakes hold water permanently, stable aquatic ecosystems capable of supporting local biodiversity and removing pollutant naturally are created (AAA Paving, 2024).

Waterbodies provide habitats for diverse aquatic life and the deterioration of water quality poses a significant risk to ecosystem stability (Qu and Peng, 2025). Anthropogenic activities have been implicated in the major changes in water quality conditions of most freshwater bodies and aquatic biota in turn (Anyanwu et al., 2019; Antakil and Umaru, 2025). Among aquatic organisms, plankton plays a fundamental role in maintaining ecological integrity. Plankton are microscopic and made up of phytoplankton (plant-like organisms) and zooplankton (animals) at different developmental stages. They are important members of the aquatic ecosystems because they are vital food sources to other aquatic biota (Kumar and Veerwal, 2024). The plankton community stability is influenced by changes in environmental conditions and can exhibit varying interactions that can manifest in community structure patterns that are complex (Arab et al., 2019). Abiotic factors such as nutrients, physicochemical parameters, availability of light and level of pollution structure the plankton community organization (Jia et al., 2020; Geng et al., 2022).

Species composition, abundance and diversity has been used to define local plankton community structure and it can change spatially and temporally within the same natural aquatic ecosystem as a result of temporal or local differences in the nutrient concentrations (Di Carvalho and Wickham, 2020; Zhikharev et al., 2023). Biodiversity refers to the number of species in an ecosystem (richness) and their distribution pattern (evenness) and a number of indices have been developed to determine the biodiversity status of different ecosystems. For example, Shannon-Wiener Index considers species diversity and spread of individuals within a community. On the other hand, Margalef Index concentrates only on species richness and normalizes the number of individuals to determine the number of species while Evenness reveals the distribution of individuals among species (Margalef, 1958; Shannon, 1948; Pielou, 1975). Plankton has also been used to determine the trophic status of lentic water bodies. Trophic status is a criteria for assessing the level of nutrients (particularly phosphate and nitrate) in the aquatic ecosystems and their effects (ST-Gelais et al., 2020). Consequently, water bodies are usually classified as oligotrophic (low nutrient level), mesotrophic, eutrophic (high nutrient level) and hypertrophic (nutrient overload). Trophic indices were applied to ascertain the status of the lake. The indices are Nygaard's Trophic Status index (Nygaard, 1949) and Rotifera, Cladocera, Copepoda (RCC) index (Kozuharov et al., 2013).

Man-made water bodies, especially reservoirs created from impoundment of lotic systems have been extensively studied in Nigeria (Yusuf, 2020; Asibor and Adeniyi, 2022; Omoboye et al., 2022; Adejuwon et al., 2025). However, this flood retention lake (officially known as Retention Pond 2) was constructed by excavating a piece of land within the Government Reserved Area (GRA), Benin City in 2021 (Nigerian Observer, 2023). It was later ponded by rains, floodwater and runoffs channeled into it through the inlet canal. It was connected in a loop to other flood retention lakes before discharging into nearest river basin. Use of flood retention lakes is not common in Nigeria. To the best of our knowledge, no study has been carried out or reported in such flood retention lake in Nigeria. Therefore, this study is aimed at assessing the water quality and plankton biodiversity of a flood retention lake in Benin City, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in a flood retention lake in Benin City, Edo State, Nigeria, constructed by excavating a piece of land between two high tension electricity transmission lines in Government Reserved Area (GRA) of Benin City (Figure 1). It is part of the Edo State government flood control programme in the reserved area (Nigerian Observer, 2023). Flood water and runoffs from sections of Ugbor and Abuja quarters (GRA), Oko and Irhirhi areas of Benin City are discharged in the lake. The lake was built with a volume of 95,383 m^3 while the surface area and depth are 4.1 Ha and 6.8 m respectively. It has common features of a natural lake except for the presence of inlet and outlet channels to prevent overtopping. The study area is characterized by persistently high temperatures (25-30 °C) and humidity levels (>60%) throughout the year; exhibiting a tropical monsoon climate (Köppen Am). There is notable seasonal variation with the period between July and September having reduced sunshine and increased rainfall (Floyd et al., 2016; Daramola et al., 2017).

Figure 1. Picture of the Lake in GRA, Benin City, Nigeria

Station 1 (N6° 17′ 20.2″, E5° 36′ 4.1″) is located around Abuja Quarter (Figure 2). There is a rapidly growing squatter camp around this station with associated beehive of commercial activities and poor sanitary conditions. Human activities observed around station 1 include indiscriminate solid waste disposal and extensive open defecation around the lake.

Station 2 is about 388.18 m away from station 1, situated in Irhirhi area (N6° 17′ 17″, E5° 35′ 51.9″). There is a smaller squatter camp around this station; with a cattle shed on the edge of the lake. Human activities here include grazing and watering of cattle, fishing, swimming and minimal solid waste disposal.

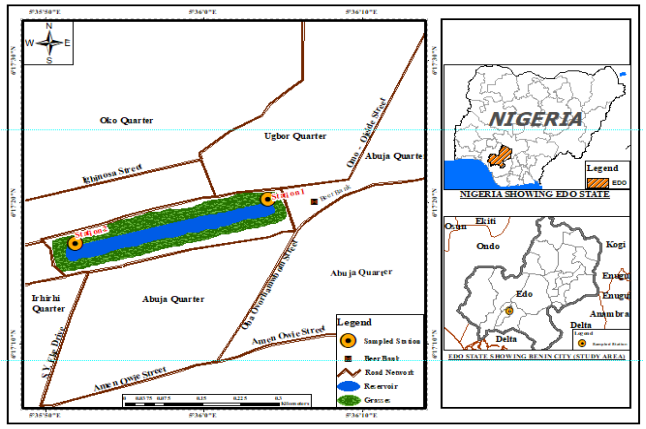

Figure 2. Map of the lake in Benin City, Edo State, Nigeria

Samples Collection

Water samples and analyses

Water samples were collected from the lake once per month in two seasons-wet season (May-July 2024) and dry season (November 2024-January 2025). The water samples for physicochemical analysis were collected from the surface and stored in 500 ml plastic containers. However, samples for biochemical oxygen demand determination were collected in amber-coloured reagent bottles and wrapped immediately with aluminum foil. All samples collected were transported in an ice-filled chest to the laboratory for analysis.

Water temperature (WT) was determined with Mercury-in-glass Thermometer, dissolved oxygen (DO) (DO meter), electrical conductivity (EC)/Total Dissolved Solids (TDS) (Digital Electrical Conductivity/TDS Meter), pH (Jenway 550 Portable pH meter) and turbidity (Tur) (Jenway 6035 Portable Turbidimeter) in the field while biochemical oxygen demand (BOD) (Winklers Method), phosphate (PO4) (Stannous Chloride Method) and nitrate-nitrogen (NO3) (UV Spectrophotometric Method) were determined in the laboratory based on American Water Works Association (2017) methods.

Plankton sampling and identification

Filtration method was used for the plankton sample collection. Total water (100 litres) was filtered through the plankton net (55µm). The net content was washed out into plankton bottles of 100 ml size and preserved in 4% formalin solution. The samples concentration was done in the lab by centrifugation. There was a complete mixing of the concentrate after the supernatant was discarded. A sub-sample (1 ml) was put on the Sedgwick-rafter counting chamber and viewed under a light binocular microscope (Nikon 400 binocular microscope) using several magnifications (x10, x100, x200 and x400). The plankton was sorted into different taxonomic group and the cells per ml were counted. The following materials-Jeje and Fernando (1986); Janse van Vuuren et al. (2006) and Dang et al. (2015) were used in the identification of the plankton to the lowest practicable taxonomic level. Biodiversity indices-Margalef (D) (Margalef, 1958), Shannon-Weiner (H) (Shannon, 1948), and Pielou's Evenness (J) (Pielou, 1975) were used to determine species richness and diversity of the plankton. The equations for the indices were:

$$\text{Margalef Index (D)} = \frac{S-1}{\text{nlog } N} \quad (1)$$

$$\text{Shannon-Wiener Index (H)} = -\sum_{i=1}^{S} pi \,\text{nlog}\, pi \quad (2)$$

$$\text{Pielou's Evenness (J)} = \frac{H}{\text{nlog } S} \quad (3)$$

Where, S = number of species, pi = proportion of individuals in species K, N = total number of individuals and n = the natural logarithm.

Statistical Analysis

The results were summarized with Microsoft Excel 2010 (Microsoft Corporation, 2010). Students t-test was used to determine significant variations ($P < 0.05$) in the spatial and seasonal mean values of physicochemical parameters. Correlation analysis was used to determine the relationships between the plankton and physicochemical parameters spatially and seasonally. All statistical analysis were carried out with PAST Statistical (version 4.03) (Hammer et al., 2001).

Trophic Status Assessment

Nygaard's trophic state index (Nygaard, 1949) and Rotifera, Cladocera, Copepoda (RCC) index (Kozuharov et al., 2013) were used to evaluate the trophic status of the lake. Nygaard's indices for different algal groups were determined using equations 4-8:

$$\text{Myxophycean} = \frac{\text{Myxophyceae}}{\text{Desmideae}} \quad (4)$$

$$\text{Chlorococcales} = \frac{\text{Chlorococcales}}{\text{Desmideae}} \quad (5)$$

$$\text{Diatoms} = \frac{\text{Centric Diatoms}}{\text{Pennates Diatoms}} \quad (6)$$

$$\text{Euglenophycean} = \frac{\text{Euglenophyceae}}{\text{Myxophyceae+Chlorococcales}} \quad (7)$$

$$\text{Compound Quotient (CQ)} = \frac{\text{Myxophyceae+Centric Diatoms+ Chlorococcales+Euglenophyceae}}{\text{Desmideae}} \quad (8)$$

The Rotifera, Cladocera, Copepoda (RCC) index is based on the quantitative proportion between the main zooplankton groups. This index is the ratio of the sum of the numbers of Copepoda and Cladocera groups to the sum of the other zooplankton groups (Rotifera, Cladocera and Copepoda) and calculated with equation 9:

$$\text{RCC (\%)} = \frac{\sum(N_{cl}+N_{cop})}{\sum(N_{cl}+N_{cop}+N_r)} * 100 \quad (9)$$

where, Nr represents the number of Rotifera, Ncl represents the number of Cladocera while Ncop represent the number of Copepoda. The index value ranges between 0 and 100; with higher values indicating decreasing trophic state. The scale is numerical and describes changes in the trophic status of stagnant water bodies with sensitivity (Kozuharov et al., 2013).

RESULTS

Physicochemical Parameters

The physicochemical parameters are presented in Table 1. Water temperatures were moderate and ranged between 24.00 and 28.00°C. The least temperature values were in stations 1 and 2 while the highest was in station 1. Station 1 was significantly ($p<0.05$) higher than station 2. The least and highest water temperatures (24.67-26.00°C) were recorded in the wet season but not significantly ($p>0.05$) different from the dry season.

The pH values varied between 6.10 and 7.20; the least and highest spatial values were recorded in station 2 while the least and highest seasonal values (6.57-6.80) were recorded in the dry season. There were no significant differences ($p>0.05$) in the spatial and seasonal values.

The electrical conductivity values were high (221.00-560.00 µS/cm); the least and the highest spatial values were recorded in station 2. The least seasonal value (308.67 µS/cm) was in the wet season while the highest (426.33 µS/cm) was in the dry season. Total dissolved solids values were 113.00-279.00 mg/L. It followed the same spatial and seasonal trend with electrical conductivity. No significant spatial and seasonal differences ($p>0.05$) were observed in both parameters.

Turbidity values ranged between 0.30 and 2.50 NTU. The least and highest values were observed in station 1. The least seasonal value (0.63 NTU) was in the wet season while the highest (1.27 NTU) was in the dry season. No significant spatial and seasonal differences ($p>0.05$) were observed in turbidity.

Dissolved oxygen (DO) values were low and ranged between 1.80 and 3.80 mg/L. The least DO values were in stations 1 and 2 while the highest was in station 2. The least seasonal value (2.20 mg/L) was in the dry season while the highest (2.90 mg/L) was in the wet season. No significant spatial and seasonal differences ($p>0.05$) were observed in dissolved oxygen content.

Biochemical oxygen demand ranged between 1.50 and 4.40 mg/L. The least value was recorded in station 2 and the highest in station 1. The least seasonal value (2.43 mg/L) was in the dry season while the highest (4.07 mg/L) was in the wet season. Station 1 was significantly ($p<0.05$) greater than station 2 while there was no significant seasonal variation ($p>0.05$).

Low phosphate concentrations (0.04 – 0.09 mg/L) were observed. The least and highest values were observed in station 2. The least and highest seasonal values (0.062-0.073 mg/L) were observed in the dry season. There were no significant spatial and seasonal variations ($p>0.05$).

The concentrations of nitrate were also low (0.08-0.29 mg/L). The least and highest values were also observed in station 2. The least seasonal value (0.12 mg/L) was in the wet season while the highest (0.20 mg/L) was in the dry season. The dry season values were significantly ($p<0.05$) greater than the wet season values while there was no significant spatial difference ($p>0.05$).

Plankton Composition, Abundance, and Distribution

A total of 1696 phytoplankton individuals/L belonging to 50 species of 6 divisions were encountered during the study period (Table 2). Baccillariophyceae was the dominant division (806 individuals/L, 47.52%), followed by Chlorophyceae (563 individuals/L, 33.20%) while the least was Chrysophyceae (13 individuals/L, 0.77%). *Scenedesmus acuminatus* (Chlorophyceae) with 85 individuals/L (5.01%),

Cylotella comta (Baccillariophyceae) with 78 individuals/L (4.60%) and *Odontella aurita* (Baccillariophyceae) with 76 individuals/L (4.48%) were the dominant species. The least dominant species, *Amphora ovalis* (Baccillariophyceae) was recorded only in the wet season. Spatially, station 1 recorded 847 individuals/L (49.94%) while station 2 had 849 individuals/L (50.06%) and seasonally, wet season recorded 812 individuals/L (47.88%) and dry season recorded 884 individuals/L (52.12%). There were no significant spatial and seasonal variations in abundance of the phytoplankton ($p>0.05$).

The phytoplankton community structure showed that the taxa (species) number ranged between 48 (station 2) and 49 (station 1). On the other hand, the wet season had 50 species and was significantly ($p<0.05$) higher compared to 36 species recorded in dry season. The Shannon-weiner diversity index (H) was between 3.684 (station 2) and 3.716 (station 1). Seasonally, it varied between 3.484 (dry season) and 3.750 (wet season). On the other hand, Margalef Species Richness (D) index was between 6.969 (station 2) and 7.120 (station 1). Seasonally, it varied between 5.159 (dry season) and 7.314 (wet season). Evenness Index (E) was highest (0.8384) in station 1 and least (0.8296) in station 2 while dry season value (0.9057) was higher than the wet season (0.8502).

A total of 35 species of zooplankton comprising 980 individuals/L representing 3 Phyla such as Protozoa, Rotifera and Arthropoda (Cladocera and Copepoda) were recorded during the study period (Table 3). The dominant taxonomic group was Rotifera (522, 53.27%), followed by Copepoda (210 individuals/L, 21.43%) and least was protozoa (123 individuals/L, 12.55%). *Centropyxis aerophila* (Protozoa) and *Gastropus stylifer* (Rotifera) were the dominant zooplankton species (67 individuals/L, 6.84%). *Brachionus caudatus* was the least dominant species (4, 0.41%); recorded only in the wet season. Spatially, station 1 recorded 518 individuals/L (52.86%) while station 2 had 462 individuals/L (47.35%) and seasonally, wet season recorded 473 individuals/L (48.27%) and dry season recorded 507 individuals/L (51.73%). There were no significant spatial and seasonal variations in abundance of the zooplankton ($p>0.05$).

The zooplankton community structure showed that the taxa number (species) ranged between 33 (station 1) and 35 (station 2). On the other hand, the wet season had 35 species and dry season had 26 species, which was significantly different ($p<0.05$). The zooplankton individuals was from 462 (station 2) to 518 (station 1). On the other hand, the wet season recorded 473 individuals/l while the dry season had 507 individuals/l. Shannon-Weiner diversity index (H) was between 3.295 (station 1) and 3.360 (station 2). Seasonally, it varied between 3.056 (dry season) and 3.309 (wet season). Margalef Species Richness (D) index, on the other hand, was between 5.120 (station 1) and 5.541 2(station). Seasonally, it varied between 4.014 (dry season) and 5.520 (wet season). Evenness Index (E) was highest in station 2 (0.8224) and least in station 1 (0.8171) while dry season value (0.8171) was higher than the wet season (0.7815).

Relationship Between Physicochemical Parameters and Plankton

Correlation analysis coefficient (r) showed that there were moderate to high significant ($r_{(9, 0.05)}=0.602$) negative and positive relationships between the physicochemical parameters and plankton spatially and seasonally (Table 4).

Table 1. Summary of spatial and seasonal physicochemical parameters in the flood retention lake

Parameters	Station 1	Station 2	Wet Season	Dry Season	*	**	***
Water Temp. (°C)	25.85±0.54 (24.00-28.00)	24.75±0.36 (24.00-26.00)	25.33±0.67 (24.67-26.00)	25.27±0.43 (24.83-25.70)	0.01	0.41	-
pH	6.60±0.11 (6.30-7.10)	6.73±0.15 (6.10-7.20)	6.65±0.02 (6.63-6.67)	6.68±0.12 (6.57-6.80)	0.08	0.40	6.5-8.5
Electrical Cond. (µS/cm)	362.02±40.87 (241.00-485.00	367.50±58.44 (221.00-560.00)	318.68±10.01 (308.67-328.70)	410.83±15.5 (395.33-426.33)	0.39	0.09	-
Total Dissolved Solids (mg/L)	181.67±20.43 (122.00-242.00)	184.02±29.04 (113.00-279.00)	159.18±5.15 (154.03-164.33)	206.50±7.50 (199.00-214.00)	0.40	0.08	-
Turbidity (NTU)	0.95±0.33 (0.30-2.50)	1.02±0.22 (0.50-2.00)	0.78±0.15 (0.63-0.93)	1.18±0.08 (1.10-1.27)	0.33	0.17	5
Dissolved Oxygen (mg/L)	2.38±0.19 (1.80-3.00)	2.55±0.31 (1.80-3.80)	2.63±0.22 (2.47-2.90)	2.25±0.05 (2.20-2.30)	0.33	0.18	6
Biochemical Oxygen Demand (mg/L)	3.36±0.35 (2.10-4.40)	2.68±0.33 (1.50-3.50)	3.50±0.57 (2.93-4.07)	2.55±0.12 (2.43-2.67)	0.04	0.07	3
Phosphate (mg/L)	0.07±0.00 (0.05-0.08)	0.07±0.01 (0.04-0.09)	0.07±0.00 (0.065-0.070)	0.07±0.01 (0.062-0.073)	0.37	0.48	3.5
Nitrate (mg/L)	0.16±0.02 (0.08-0.22)	0.16±0.04 (0.08-0.29)	0.12±0.00 (0.12-0.13)	0.20±0.01 (0.19-0.20)	0.33	0.03	9.1

** Spatial p-value; ** Seasonal p-value; *** NESREA (2011).*

Table 2. Spatial and seasonal distribution of phytoplankton in the flood retention lake

Division/Species	Station 1	Station 2	Wet Season	Dry Season	Total
Euglenophyceae					
Euglena acus, (O.F.Müller) Ehrenberg, 1830	12	14	7	19	26
E. ehrenbergii, Klebs 1883	15	21	18	18	36
E. viridis, (O.F.Müller) Ehrenberg, 1830	10	12	5	17	22
Trachelomonas volvocina, Ehrenberg 1834	13	16	29	0	29
Total	50(2.95%)	63(3.71%)	59(3.48%)	54(3.18%)	113(6.66%)
Cyanophyceae					
Anabaena circinalis, Rabenhorst ex Bornet and Flahault 1886	20	18	19	19	38
Gleocapsa turgida, (Kützing) Hollerbach 1936	1	9	10	0	10
Lyngbya majuscula, Harvey ex Gomont 1892	4	8	12	0	12
Microcystis viridis, (A.Braun) Lemmermann 1903	5	18	13	10	23
M. wesenbergii, wesenbergii, (Komárek) Komárek ex Komárek 2006	8	7	2	13	15
Total	38(2.24%)	60(3.54%)	56(3.30%)	42(2.48)	98(5.79%)
Chlorophyceae					
Chlamydomonas globosa, Snow 1903	18	24	9	33	42
C. reinhardtii, Dangeard, 1888	34	31	30	35	65
Closterium hunulla, Ehrenberg and Hemprich ex Ralfs 1848	15	24	25	14	39
Cosmarium crenulatum, (Ehrenberg ex Ralfs) Brébisson 1856	40	24	25	39	64
Pediastrum duplex, Meyen 1829	16	21	8	29	37
Scenedesmus acuminatus, (G.M.Smith Dedusenko 1953	36	49	43	42	85
S. dimorphus, (Turpin) Kützing 1834	14	20	14	20	34
S. quadricauda, (Turpin) Brébisson 1835	8	18	9	17	26
Schroederia setigera, (Schröder) Lemmermann 1898	6	3	9	0	9
Spirogyra dubia, Kützing 1849	25	4	29	0	29
S. porticalis, West 1907	5	10	15	0	15
Spondylosium moruloforme, P.M. Lundell 1871	12	22	20	14	34
Ulothrix tenerrima, (Kützing) Kützing 1843	15	24	14	25	39
Urococcus insignis, (Hassall) Kützing 1849	23	22	19	26	45
Total	267(15.74%)	296(17.45%)	269(15.86%)	294(17.33%)	563(33.20%)
Baccillariophyceae					
Amphora ovalis, (Kützing) Kützing 1844	5	3	8	0	8
Asterionella formosa, Hassall 1850	10	12	16	6	22
Biddulphia aurifa, (Lyngbye) Brébisson 1838	23	3	26	0	26
Caloneis amphisbaena, (Bory) Cleve 1894	25	11	13	23	36
Cyclotella meneghiniana, Kützing 1844	13	19	3	29	32
C. comta, Kützing 1849	28	50	43	35	78
Diatoma hyemale, Cleve 1953	26	6	14	18	32
Ditylum brightwelli, (T.West) Grunow 1885	17	6	23	0	23
Encyonema minutum, (Hilse) D.G.Mann 1990	20	17	12	25	37
Eucampia zodiacus, Ehrenberg 1839	25	37	9	53	62
Eunotia pectinalis, (Kützing) Rabenhorst 1864	30	38	28	40	68
Nitzschia closterium, (Ehrenberg) W.Smith 1853	11	11	10	12	22
N. radicula, Hustedt 1942	3	8	11	0	11
Odontella aurita, (Lyngbye) C.Agardh 1832	46	30	28	48	76
O. regia, (M.Schultze) Simonsen 1974	28	31	20	39	59
O. sinensis, (Greville) Grunow 1884	4	5	9	0	9
Surirella capronioides, Gandhi 1959	27	22	34	15	49
S. elegans, Ehrenberg 1843	17	21	14	24	38
Tabellaria flocculosa, Kützing 1844	29	21	23	27	50
Thalassiothrix nitzschioides, (Grunow) Grunow 1881	19	23	13	29	42
Ulnaria ulna, (Nitzsch) Compère 2001	9	17	9	17	26
Total	415(24.47%)	391(23.05%)	366(21.58%)	440(25.94%)	806(47.52%)
Dinophyceae					
Ceratium tripos, (O.F.Müller) Nitzsch 1817	26	0	12	14	26
C. furca, (Ehrenberg) Claparède and Lachmann 1859	11	9	6	14	20
C. fusus, (Ehrenberg) Dujardin 1841	17	12	3	26	29
C. hirundinella, (O.F.Müller) Dujardin 1841	8	5	13	0	13
Parvodinium africanum, (Lemmermann) Carty 2008	15	0	15	0	15
Total	77(4.54%)	26(1.53%)	49(2.89%)	54(3.18%)	103
Chrysophyceae					
Dinobryon sp.	0	13	13	0	13
Total	0	13(0.77%)	13(0.77%)	0	13(0.77%)
Grand Total	**847(49.94%)**	**849(50.06%)**	**812(47.88%)**	**884(52.12%)**	**1696**

Table 3. Spatial and seasonal distribution of zooplankton in the flood retention lake

Group/Species	Station 1	Station 2	Wet Season	Dry Season	Total
Protozoa					
Amoeba agilis, Kirk 1906	0	12	12	0	12
A. limicola, Rhumb	6	9	5	10	15
Arcella vulgaris, Ehrenberg 1832	23	6	9	20	29
Centropyxis aerophila, Deflandre 1929	47	20	19	48	67
Total	76(7.76%)	47(4.80%)	45(4.59)	78(4.90%)	123(12.55%)
Rotifera					
Ascomorpha ovalis, Bergendal 1892	12	21	13	20	33
Asplanchna priodonta, Gosse 1850	11	3	6	8	14
A. sieboldi, Leydig 1854	7	1	8	0	8
Brachionus caudatus, Barrois and Daday 1894	3	1	4	0	4
B. falcatus, Zacharias 1898	27	11	14	24	38
B. plicatilis, Müller 1786	18	15	7	26	33
Cephalodella gibba, Ehrenberg 1830	13	5	16	2	18
Colurella uncinata, Müller, 1773	13	20	8	25	33
Conochilus unicornis, Rousselet 1892	17	14	8	23	31
Gastropus stylifer, Imhof 1891	41	26	60	7	67
Keretella cochlearis, Gosse 1851	17	31	15	33	48
K. quadrata, Müller 1786	7	2	9	0	9
Platyias quadricornis, Ehrenberg 1832	32	13	7	38	45
Polyarthra dolichoptera, Idelson 1925	11	7	18	0	18
P. remata, Skorikov 1896	13	11	24	0	24
Testudinella emarginula, Stenroos 1898	22	15	30	7	37
T. reflexa, Gosse 1887	23	21	21	23	44
Tetrasiphon hydrocora, Ehrenberg 1840	5	2	4	3	7
Trichocerca similis, Wierzejski, 1893	1	10	6	5	11
Total	293(29.90%)	229(23.37%)	278(28.37%)	244(24.90%)	522(53.27%)
Cladocera					
Alona rectangula, G.O. Sars 1862	19	21	21	19	40
A. affinis, Leydig 1860	15	10	14	11	25
Alonella granulata, Brehm 1933	25	13	11	27	38
Chydorus aphaericus, O.F.Müller 1776	8	23	5	26	31
Dunhevedia serrata, Daday 1898	0	22	14	8	22
Kurzia latissima, Kurz 1875	13	10	23	0	23
Moina micrura, Kurz 1875	11	20	31	0	31
Total	91(9.29%)	119(12.14%)	119(12.14%)	91(9.29%)	210(21.43%)
Copepoda					
Cyclopoid nauplii	14	10	10	14	24
Cyclops scutifer, Sars 1863	14	15	3	26	29
C. vicinus, Uljanin 1875	3	5	8	0	8
Eucyclops agilis, Koch, 1838	21	28	5	44	49
Eudiaptomus drieschi, Poppe and Mrázek 1895	6	9	5	10	15
Total	58(5.92%)	67(6.84%)	31(3.16%)	94(5.59)	125(12.76%)
Grand Total	**518(52.86%)**	**462(47.35%)**	**473(48.27%)**	**507(51.73%)**	**980**

Table 4. Correlation coefficients (r) of the physicochemical parameters and plankton in stations and seasons

Parameters		WT	pH	EC	TDS	Tur.	DO	BOD_5	PO_4	NO_3	Phyto	Zoo
Stations	**Plankton**				**Wet Season**							
1	**Phyto**	**-0.825**	**0.747**	**0.633**	**0.617**	0.432	-0.005	**0.804**	**0.974**	0.583	1.000	-
	Zoo	-0.165	**-0.918**	0.435	0.453	**0.636**	**-0.905**	**-0.878**	-0.205	0.491	-0.421	1.000
2	**Phyto**	-0.128	-0.336	**0.841**	**0.842**	**0.917**	0.462	0.005	**0.784**	**0.904**	1.000	-
	Zoo	-0.474	**0.822**	-0.367	-0.369	**-0.977**	0.142	0.579	-0.275	-0.486	**-0.812**	1.000
					Dry Season							
1	**Phyto**	-0.122	**0.885**	0.053	0.027	**0.637**	**0.692**	**0.711**	**0.999**	0.480	1.000	-
	Zoo	0.427	0.500	0.578	0.557	**0.950**	**0.971**	0.225	**0.822**	**0.875**	**0.845**	1.000
2	**Phyto**	-0.577	**-0.961**	-0.108	-0.116	0.545	**-0.721**	**0.977**	-0.209	0.152	1.000	-
	Zoo	0.325	**-0.787**	**0.743**	**0.737**	**0.999**	0.141	**0.746**	**0.671**	**0.891**	0.585	1.000

$Df_{(9,\ 0.05)}$ = 0.602; Significant r values are boldfaced; Phyto = phytoplankton; zoo = zooplankton

Assessment of Trophic status

Nygaard's index is made up of five different indices (Table 5). The values recorded for the lake were Myxophycean index (0.72), Chlorococcales index (1.84), Diatoms index (0.14), Euglenophycean index (0.32) and Compound Quotient (4.09) while the Rotifera, Cladocera,

Copepoda (RCC) index was 39.09%.

Table 5. Nygaard Indices of the flood retention lake in relation to trophic status

Nygaard Indices	Benin Lake	Trophic Status
Myxophyceae	0.72	Eut: 0.1-3.0, Olig: 00-0.4
Chlorococcales	1.84	Eut: 0.2-9.0, Olig: 00-0.7
Diatoms	0.14	Eut: 0.0-1.75, Olig: 0.0-0.3
Euglenophycean	0.32	Eut: 0.0-1.0, Olig: 0.0-0.7
Compound Quotient (CQ)	4.09	Olig: CQ<2, Meso: 2>CQ<6, Eut: CQ>6

Olig = Oligotrophic, Meso = Mesotrophic, Eut =Eutrophic

DISCUSSION

The lake is a flood retention lake constructed on land to receive excess flood and runoff water during the wet season. Such lakes serve as one of the very effective ways of controlling flood and runoff especially in urban areas; functioning as holding basins (Amalia et al., 2023; Saputra et al., 2025). Because flood retention lakes are designed to hold water permanently, they create a stable aquatic ecosystem that can support local biodiversity and enables the natural process of pollutant removal (AAA Paving, 2024). Physicochemical parameters of waterbodies are usually assessed to determine their suitability to support aquatic life.

The water temperatures were moderate. The mean temperature value in station 1 was significantly higher than station 2. Human activities (improper solid waste disposal and open defecation) in station 1 as well as biological processes like respiration and decomposition take up oxygen and releases heat, which could result in increased water temperature locally. There was no significant seasonal variation. The temperatures were within the optimum range of 20°C - 30°C for plankton development (Mesquita et al., 2020). However, zooplankton generally survives and lives longer at lower temperatures and some cannot survive at temperatures above 25°C (Arafat et al., 2021).

The water had moderate acidic to slight alkaline pH with most conforming to limit (6.5-8.5) stipulated by Environmental Standard and Regulatory Enforcement Agency (NESREA) (2011). There were no significant spatial or seasonal variations; though, station 2 and dry season had slightly higher values. This could be attributed to accumulation of organic and inorganic substances in station 2 from the cattle stall and disposed solid wastes (Bashir et al., 2020) and increased photosynthesis during the dry season. Photosynthetic activities of microalgae can result in higher pH in the aquatic ecosystem (Zerveas et al., 2021). The pH range of 6.5-8.0 is optimum for most aquatic organisms; however, most flourish within a particular range and any slight change will affect the community composition (United States Environmental Protection Agency (USEPA), 2025).

The values of Electrical conductivity (EC) and Total Dissolved Solids (TDS) were high with similar spatial and seasonal variations. NESREA (2011) has no guidance standard for both parameters. There were no significant spatial or seasonal variations; though station 2 and dry season were slightly higher due to accumulation of organic and inorganic substances in station 2 and concentration caused by dry season effect (Anyanwu et al., 2023). High electrical conductivity and total dissolved solids are indications of pollution and eutrophication in the lake (Wu et al. 2020). Zooplankton species diversity can be negatively affected when electrical conductivity levels are high (Tavşanoglu et al., 2015). The effects and change in trophic state encourage more tolerant functional groups to dominate; leading to homogenization (Dorak et al., 2025). On the other hand, elevated EC is often associated with elevated nutrients; it can negatively affect phytoplankton because of reduction in light penetration, community structure alteration, competition and salinity-induced stress (Li et al., 2021).

The turbidity values were all low; conforming to limit (5 NTU) stipulated by NESREA (2011). This could be because the lake is a retention pond, which helped to reduce the turbidity as pollutants settle to the bottom with time (Kasco Marine, 2025). There were no significant spatial or seasonal variations, though station 2 and dry season also recorded slightly higher values. This could be attributed to the same factors observed in electrical conductivity and total dissolved solids. Elevated turbidity can negatively affect plankton communities. It can reduce light penetration and phytoplankton photosynthesis as well affect feeding efficiency, development, and abundance of zooplankton (Goździejewska and Kruk, 2022; Nunes et al., 2022).

The concentrations of dissolved oxygen (DO) were generally low and did not conform to limit (6 mg/L) stipulated by NESREA (2011). The lake receives stormwater and runoffs laden with organic and inorganic pollutants mostly during the wet season with little or nothing during the dry season. These pollutants coupled with long residence time, could deplete dissolved oxygen during degradation and lead to low concentrations in the lake. In man-made lakes, sediment oxygen demand negatively affect dissolved oxygen content during no-inflow period while during increased inflow occasioned by wet season, the pressure shift to presence of pelagic organic and inorganic substances (Wallace et al., 2016; Seetha and Chandran, 2020). Higher mean values were recorded in station 2 and wet season, though not significant. This could be attributed to minimal anthropogenic activities in station 2 and addition through in-flow during the wet season. Though minimal fishing activities occur in the lake, the DO levels were low to support

good productivity. It is recommended that DO levels above 5 mg/L are required to sustain aquatic life and good fish production (Dong et al., 2011).

Most of the biochemical oxygen demand (BOD) values exceeded the limit (3.0 mg/L) stipulated by NESREA (2011) especially in station 1. High BOD can negatively affect overall plankton species diversity; sensitive species will be eliminated due to oxygen stress while those more adapted to low oxygen conditions, will become dominant (Alprol et al., 2021). Higher values were recorded in station 1, which was significantly different from station 2 and wet season; though not significant. This could be attributed to anthropogenic activities (solid waste disposal, open defecation) around station 1 (Bhat et al., 2022; Ugada and Momoh, 2022) and degradation of organic matters and pollutants introduced through runoffs during the wet season.

The nutrients (phosphate and nitrate) values were very low. The values conformed to 3.5 mg/L for phosphate and 9.1 mg/L for nitrate stipulated by NESREA (2011). There were no significant spatial and temporal variations. The low nutrient concentration could be attributed to a number of factors within and outside the lake. Firstly, the dense littoral vegetation around the lake can prevent some of the nutrients from diffuse sources other than the inlet canal from entering the lake (Vermaat et al., 2020). Secondly, there are no agricultural activities within the area and thirdly, nutrients can be removed from the flood retention lake through processes within such as sedimentation, outflow from water discharge and volatilization (Janke et al., 2022).

Plankton diversity can be used to predict the ecosystem health of a waterbody (Kumar and Veerwal, 2024) because it is influenced by factors like water quality, season, and nutrient availability. The number of phytoplankton species in this study was higher than 38 species recorded by Yusuf (2020) in Nasarawa reservoir, Katsina State, Nigeria. However, other related studies were much higher. For example, Omoboye et al. (2022) recorded 137 species in Owalla Reservoir, Osun State, Southwest Nigeria and Asibor and Adeniyi (2022) recorded 154 species in Asejire reservoir, Southwest Nigeria. The taxonomic divisions recorded were within 5 and 7 recorded in related studies in Nigeria (Yusuf, 2020; Asibor and Adeniyi, 2022; Omoboye et al., 2022). The abundance was far lower 58,000 individuals/L recorded by Yusuf (2020) in Nasarawa reservoir, Katsina State, Nigeria and 74,925 individuals/L recorded by Asibor and Adeniyi (2022) in Asejire reservoir, Southwest Nigeria. The observed variations in related studies could be due to nature and size of the man-made water bodies and human activities. The study area was constructed on land and ponded by runoff, flashflood and rain while the others were man-made water bodies (reservoirs) created from rivers and are influenced by large watersheds.

Bacillariophyceae and Chlorophyceae were the dominant divisions, which was in line with a related study in Nigeria (Yusuf, 2020). However, dominance of Cyanophyceae and Bacillariophyceae was reported by Asibor and Adeniyi (2022) in Asejire reservoir, Southwest Nigeria and dominance of Chlorophyceae and Bacillariophyceae was reported by Omoboye et al. (2022) in Owalla Reservoir, Osun State, Southwest Nigeria.

The dominance of *Scenedesmus acuminatus* (Chlorophyceae), *Cylotella comta* (Baccillariophyceae) suggests organic pollution in the lake (Phinyo et al., 2017; Giao and Nhien, 2020). However, *Odontella aurita* (Baccillariophyceae), a marine species that have been reported in some freshwater and brackish environments in Nigeria (Akoma and Opute, 2011; Ekhator et al., 2014; George et al., 2021) are typically influenced by environmental changes. Its presence in high number in the lake is very significant because of its use as novel food (An et al., 2023; Olsen et al., 2024). Spatially, number of individuals was almost the same; suggesting relatively consistent environmental conditions influencing their growth and distribution within that lake. Seasonally, higher number of individuals was recorded in the dry season, though not significant. This could be attributed to optimal conditions created by reduced water volume, high sunlight and temperature as well as increased nutrient availability due to evaporation and mineralization (Anyanwu et al., 2021). This was in line with related studies in Nigeria (Yusuf, 2020; Asibor and Adeniyi, 2022; Omoboye et al., 2022).

The number of zooplankton species recorded was higher than 4 species recorded by Suleiman et al. (2021) in Ajiwa Reservior, Katsina State, Nigeria. The number of taxonomic groups was lower than 5 recorded in a related study (Omoboye et al., 2022). On the other hand, abundance was higher than 407 individuals recorded by Suleiman et al. (2021) in Ajiwa Reservior, Katsina State, Nigeria. The observed variations in the related study could be due to nature, size and anthropogenic activities in the water body.

Rotifer was the dominant taxonomic group as observed in related studies in Nigerian man-made lentic systems (Suleiman et al., 2021; Omoboye et al., 2022). Rotifers can adapt to different environmental conditions and capable of colonizing open systems when the conditions are right (Phan et al., 2021). The dominance of *Centropyxis aerophila* (Protozoa) suggest to organic enriched environment (Davidova and Doychev, 2025) while *Gastropus stylifer* (Rotifera) is capable of thriving in varying environmental conditions (Bhandarkar and Bansod, 2025).

As in the case of phytoplankton, spatially, the number of

zooplankton individuals was almost the same attributed to the same reason. Seasonally, higher number of individuals was also recorded in the dry season, which could be attributed to the same factors influencing phytoplankton. This trend was also observed in Omoboye et al. (2022). The community structure indices showed that the plankton community was diverse and stable; though phytoplankton was more diverse. The number of species in both phytoplankton and zooplankton in the stations respectively, was almost the same; suggesting relatively consistent environmental conditions. However, seasonally, higher number of species were recorded in the wet season that were significantly different ($p<0.05$). This trend was also observed by Abdulkarim et al. (2021) and Enawgaw et al. (2023), which was attributed to increased nutrients through runoffs, water volume as well as expansion and diversification of habitats. Shannon-Wiener index (H) values for phytoplankton and zooplankton were all greater than 3; suggesting higher diversity. High Shannon values are indications of high number of species and balanced distribution (Shannon, 1948; Zheng et al., 2007; Strong, 2016). The values were higher than 2.94-3.05 (phytoplankton) recorded by Yusuf (2020) in Nasarawa reservoir, Katsina State, Nigeria, 1.366-1.646 (phytoplankton) recorded by Asibor and Adeniyi (2022) in Asejire reservoir, Southwest Nigeria. The Margalef index values were between 4 and 7; higher value is an indication of better species diversity as determined by the total number of individuals (Kitikidou et al., 2024). However, the values were lower than 7.025-12.370 (phytoplankton) recorded by Asibor and Adeniyi (2022) in Asejire reservoir, Southwest Nigeria. Evenness index show how the number of individuals of each species are distributed; higher evenness indicates more uniform spread of the species. All the values were between >0.7 and >0.9; an indication that the water was slightly polluted or organically enriched (Zheng et al., 2007). Most of the values were close to 1; indicating that there were no dominant species in the lake.

The moderate to high significant negative and/or positive correlations observed between the physicochemical parameters and the plankton in the stations and seasons indicated the influence of some parameters on the plankton diversity (Pandya et al., 2024). This may be due to high number of particular phytoplankton or zooplankton species that were influenced by the parameter. Hence, high positive correlations with any parameter indicate that higher levels of that parameter are associated with increased plankton abundance. Likewise, high negative correlations with any parameter indicate that higher levels of that parameter are associated with decreased plankton abundance. For example, a high negative correlation was established between water temperature and phytoplankton in station 1 (wet season). Hao et al. (2024) observed that when the surface water temperature increases, the viscosity decreases, leading to rapid sinking of larger phytoplankton in the water column. Also phytoplankton had a high negative correlation with zooplankton in station 2 (wet season). This could be due to zooplankton grazing pressure on phytoplankton, or other factors like high turbidity, water volume and nutrient runoff associated with wet season that could have more negative effect on one group than the other (Waya et al., 2014). However, a high positive correlation was established between them in the dry season (station 1). Dong et al. (2022) observed that higher water temperatures with elevated nutrient levels in summer (equivalent of dry season) encourage the rapid development of phytoplankton, which in turn positively affect zooplankton growth.

The trophic status assessment indices showed that the lake was tending towards eutrophic condition. Nygaard Indices as applied has been effectively used to determine the trophic status of water bodies (Pooja, 2021). On the other hand, RCC confirmed the trophic status of the lake is tending towards eutrophic condition. Kozuharov et al. (2013) classified RCC as 0 for hypertrophic environment and 100 for oligotrophic environment. Thus, the index increases as the trophic state decreases. Kozuharov et al. (2013) recorded a range of 5 – 100; with 5 recorded at a hypertrophic swamp while 100 was recorded at an oligotrophic mountain lake.

CONCLUSION

This study has shown that the parameters were within acceptable limits except dissolved oxygen and biochemical oxygen demand. The plankton diversity was rich; though some pollution tolerant species were recorded; which point to the deteriorating condition of the lake. The biodiversity indices confirmed the richness. However, the lake was tending towards eutrophic condition which could be attributed the design and anthropogenic activities around the lake. This study has also shown the potentials of artificial water bodies to harbor rich diversity of local aquatic biota. In conclusion, the lake has provided a suitable environment to support plankton development as well as potentials for fishery development. However, the increasing anthropogenic activities within the lake need to be regulated and monitored regularly to sustain the water quality and aquatic biota.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

Conception and Supervision: EDA and FEM; Field studies: EDA, P.C.O and A.G.S; Data analysis and interpretation: EDA and FEM; Manuscript writing: EDA, FEM, P.C.O and A.G.S. All authors approved the final draft.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

The authors confirm that no generative AI was used in writing this manuscript or creating images, tables, or graphics.

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Preliminary systematic investigation of the zooplankton fauna in the streams of Gürün District (Sivas, Türkiye)

Ahmet Bozkurt[1]✉ • Mevlüt Aktaş[2]

[1] Department of Marine Sciences, Faculty of Marine Sciences and Technology, Iskenderun Technical University, Iskenderun, Hatay, TÜRKİYE
[2] Department of Aquaculture, Faculty of Marine Sciences and Technology, Iskenderun Technical University, Iskenderun, Hatay, TÜRKİYE

✉ Corresponding Author: ahmet.bozkurt@iste.edu.tr

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A B S T R A C T

A total of 34 species were detected over 5 locations in 4 distinct water bodies within the Gürün (Sivas) and Elbistan (Kahramanmaraş) districts, comprising 21 species of Rotifera, 9 species of Cladocera, and 4 species of Copepoda. Fifteen families were found, comprising ten families of Rotifera, three families of Cladocera, and two families of Copepoda. The Lecanidae and Lepadellidae families are the most diverse, each comprising five species. *Colurella adriatica* was detected at all sampling locations, whereas *Lecane closterocerca*, *Lecane lunaris*, and *Lepadella patella* were discovered at four sampling sites. In addition, in the locality where no zooplankton studies have previously been conducted, four species were classified as constant (F≥50%), six species as common (50%>F≥25%), and twenty-four species as rare (F<25%) according to Soyer's frequency index (%F).

INTRODUCTION

Zooplankton, constituting the second tier in the food chain that conveys energy from producers to consumers, are a crucial component of aquatic ecosystems (Sharma et al., 2010). These creatures are vital for the regulation and operation of aquatic ecosystems and are fundamental elements of the food web in aquatic environments (Lampert and Sommer, 1997; Moss, 1988).

Zooplankton communities purify water in natural ecosystems, enhancing various aquatic conditions and providing a crucial food source for numerous fish larvae and invertebrates (Sharma, 2020; Shurganova, 2007). The abundance and species diversity of these organisms are directly correlated with water quality and act as indicators of pollution, eutrophication, and overall water characteristics, contingent upon the trophic level of the aquatic ecosystem they inhabit (Berzins and Pejler, 1987; Gannon and Stemberger, 1978). Zooplankton are essential in the pelagic food web, facilitating the transport of photosynthetic energy to higher trophic levels. They significantly influence the regulation of yearly catch rates of commercial fish populations, especially during the initial feeding phases of fish larvae and their succeeding instars. Zooplankton play a vital role in shaping the composition and number of particles that reach the benthos, supplying nutrients for benthic species and directly regulating several ecosystem processes.

Although Türkiye is not a water-rich country, it has significant river (estimated at over 8,000 km²) and standing water (approximately 10,000 km²) resources. The zooplankton diversity of these waters has not yet been fully investigated, and further research is needed to

comprehensively assess the country's zooplankton fauna. This study, conducted at a sampling site where no previous zooplankton studies have been carried out, aimed to identify the zooplankton in the Tohma Stream, Sularbaşı Stream, Bahçeiçi Village (Tıhmın) Stream, Şuğul Valley, and Horhor Stream adjacent to Horhor Village in the Elbistan District of Kahramanmaraş Province.

MATERIALS AND METHODS

Sampling Area

The research was performed in aquatic environments located within the Gürün District of Sivas Province and the Elbistan District of Kahramanmaraş Province. Samples were collected from Sularbaşı Village Sazcağız Creek (38° 46' 59.45'' N, 37° 18' 28.53'' E), Bahçeiçi Village (Tıhmın) (38° 42' 02.72'' N, 37° 22' 12.15'' E), Tohma Stream (Bahçeiçi Village and Gürün Şuğul Valley) (38° 42' 47.11'' N, 37° 19' 55.22'' E; 38° 45' 12.19'' N, 37° 14' 07.96'' E), and Horhor Creek (38° 31' 12.06'' N, 37° 14' 32.81'' E) (Figure 1).

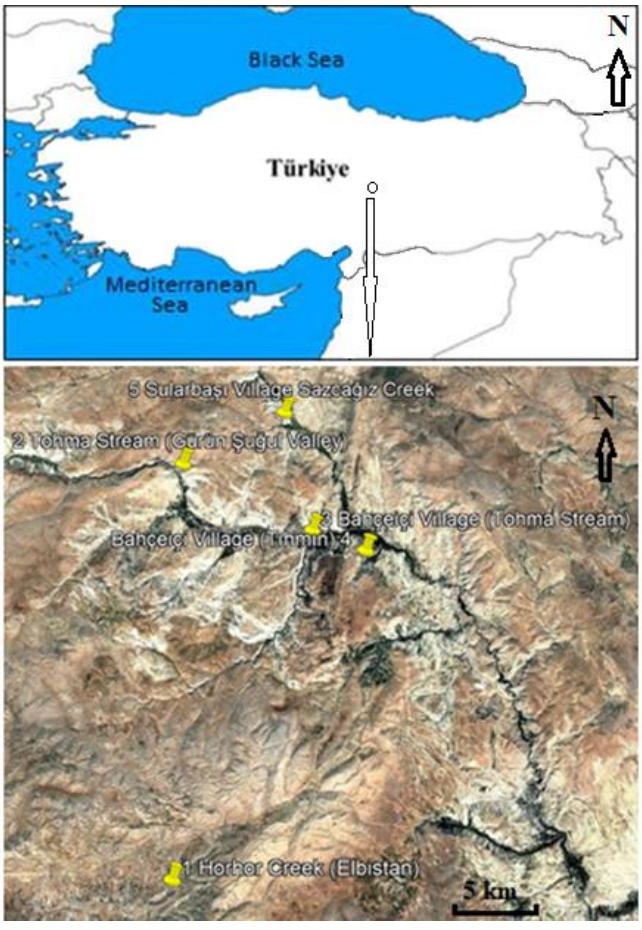

Figure 1. Map of the study and sampling stations

The Tohma Stream is a significant tributary of the Euphrates River, starting in Sivas Province and discharging into the Karakaya Dam in Malatya. The stream is created by the convergence of two principal tributaries: The Kangal Tohma, which emanates from the Dikkulak (Karatonus) Mountains near Şarkışla. The Gürün Tohma, originating in the Tahtalı Mountains, merges with the Sazcağız and Gökpınar streams inside the boundaries of the Gürün district, where both Tohma tributaries confluence near Malatya. The Tohma Stream measures around 52.5 kilometers in length (www.Malatya.gov.tr). The Bahçeiçi Village Reservoir was created by capturing the spring water from the Özdere region, previously referred to as Tıhmın, located 15 km from the Gürün district. Upon exiting the spring, the water promptly traverses a tiny stream around 2 km in length before entering the Tohma Stream. The sample was extracted from a pool created at the spring. Horhor Creek is a little watercourse situated in proximity to Horhor Village along the Gürün road. The Sazcağız Creek begins in Sularbaşı hamlet, located 13 km north of the Gürün district center, traverses the hamlet, and converges with the Tohma Stream around 7 km downstream (Figure 1).

Sampling and Evaluation

Zooplankton sampling occurred once in August 2025 at the specified coordinates. Sampling was conducted utilizing a plankton net including a 60 μm mesh size, a 30 cm mouth diameter, and a length of 1 m. Sampling was performed in the streams by maintaining the plankton net stationary while allowing water to flow through the segment for approximately 25-30 minutes. In still waters, zooplankton samples were collected by throwing the plankton net 15-20 meters away from the shore and pulling it back, and this process was repeated 10 times. Samples were contained in 500 ml plastic bottles and stored with 4% formaldehyde. Zooplankton specimens were analyzed utilizing an inverted microscope and a binocular microscope (Olympus CH40). Approximately 20 cc of subsamples were extracted from each sample, and identifications were conducted in petri dishes. This approach was employed a minimum of three times to ascertain all species present.

Zooplankton abundance was not quantified but was qualitatively assessed based on visual observations, categorized into three levels: low, abundant, and very abundant. Soyer's (1970) frequency index (%F) was employed to quantify the prevalence of zooplankton species categorized as constant (F≥50%), common (50%>F≥25%), and rare (F<25%) (Table 2). Zooplankton was identified utilizing the taxonomic keys of Scourfield and Harding (1966), Dussart (1969), Damian-Georgescu (1970), Smirnov (1974), Ruttner Kolisko (1974), Kiefer and Fryer (1978), Koste (1978), Negrea (1983), Ranga Reddy (1994), Borutsky (1964), Nogrady and Pourriot (1995), Segers (1995), De Smet (1996), and Dussart and Defaye (2001).

RESULTS

A total of 34 species were discovered, comprising 21 from Rotifera (62%), 9 from Cladocera (26%), and 4 from Copepoda (12%) (Table 1). Ten families were identified within Rotifera, with Lecanidae and Lepadellidae each comprising the highest number of species, totaling five species per family. Brachionidae, Mytilinidae, and Notammatidae constituted the second most prevalent families, each comprising 2 species. The remaining five families were represented by a single species each. Three families from Cladocera were identified: Chydoridae, which has the most species; Daphnidae, with three species; and Bosminidae, with one species (Table 1). Copepoda was represented by two families: Cyclopidae, including three species, and Ameiridae, comprising one species. *Colurella adriatica* was detected in all sampling locations, but *Lecane closterocerca*, *Lecane lunaris*, and *Lepadella patella* were identified in four sampling instances. The remaining species were few, identified in two and one samples (Table 1).

Table 1. List and abundance of zooplankton species in the sampling areas

Sampling Stations	1	2	3	4	5	F%
Rotifera						
Brachionidae						
Keratella cochlearis (Gosse, 1851)	-	-	*	-	-	**20**
Keratella tecta (Gosse, 1851)	-	-	-	*	-	**20**
Lecanidae						
Lecane closterocerca (Schmarda, 1859)	*	*	-	*	*	**80**
Lecane flexilis (Gosse, 1886)	*	-	-	*	-	**40**
Lecane lunaris (Ehrenberg, 1832)	*	*	*	*	-	**80**
Lecane stenroosi (Meissner 1908)	-	-	*	-	-	**20**
Lecane stichea Harring 1913	-	-	-	*	-	**20**
Lepadellidae						
Colurella adriatica Ehrenberg, 1831	*	+	*	*	*	**100**
Colurella uncinata (Müller, 1773)	*	-	-	-	-	**20**
Lepadella acuminata (Ehrenberg, 1834)	-	*	-	-	-	**20**
Lepadella ovalis (Müller, 1786)	-	*	-	-	-	**20**
Lepadella patella (Müller, 1773)	*	*	-	*	*	**80**
Synchaetidae						
Polyarthra dolichoptera Idelson, 1925	-	-	o	-	*	**40**
Trichocercidae						
Trichocerca weberi (Jennings, 1903)	-	*	-	-	*	**40**
Mytilinidae						
Mytilina mucronata (Müller, 1773)	-	-	-	*	-	**20**
Mytilina ventralis (Ehrenberg, 1830)	-	-	-	*	*	**40**
Euchlanidae						
Euchlanis dilatata Ehrenberg, 1832	*	-	-	-	-	**20**
Notommatidae						
Cephalodella gibba (Ehrenberg, 1830)	-	*	-	-	-	**20**
Taphrocampa selenura Gosse, 1851	*	-	-	-	-	**20**
Testudinellidae						
Testudinella patina (Hermann, 1783)	-	-	-	*	-	**20**
Asplanchnidae						
Asplanchna priodonta Gosse, 1850	-	-	o	-	-	**20**
Cladocera						
Bosminidae						
Bosmina longirostris (Müller, 1776)	-	-	+	-	*	**40**
Daphniidae						
Ceriodaphnia pulchella Sars, 1862	-	-	+	-	-	**20**
Daphnia galeata Sars, 1864	-	-	o	-	-	**20**
Daphnia longispina (Müller, 1776)	-	-	-	-	+	**20**
Chydoridae						
Biapertura affinis (Leydig, 1860)	-	-	*	-	-	**20**
Chydorus sphaericus (Müller, 1785)	-	-	*	-	-	**20**
Coronatella rectangula (Sars, 1862)	-	-	*	-	-	**20**
Disparalona rostrata (Koch, 1841)	-	-	*	-	-	**20**
Pleuroxus aduncus (Jurine, 1820)	-	-	*	-	-	**20**
Copepoda						
Cyclopidae						
Cyclops vicinus Uljanin, 1875	-	-	o	-	-	**20**
Macrocyclops albidus (Jurine, 1820)	-	-	*	-	-	**20**
Tropocyclops pracinus (Fischer, 1860)	*	-	-	+	-	**40**
Ameiridae						
Nitokra hibernica (Brady, 1880)	-	*	-	-	-	**20**

***1:** Horhor Creek, **2:** Tohma Stream –Gürün Şuğul Valley, **3:** Tohma Stream –Bahçeiçi Village, **4:** Bahçeiçi Village –Tıhmın, **5:** Sazcağız Creek –Sularbaşı Village) **-:** Absent, ***:** few (rare F<25%), **+:** abundant (Common 50%>F≥25%), **o:** very abundant (Constant F≥%50)*

The results were categorized as constant (F≥50%), common (50%>F≥25%), and rare (F<25%) species, based on Soyer's (1970) frequency index (%F). *Colurella adriatica* exhibited the highest prevalence (100%) across all samples among these several species. The prevalent species included *Lecane closterocerca, Lecane lunaris*, and *Lepadella patella* (80%), while other notable species comprised *Lecane flexilis*, *Polyarthra dolichoptera*, *Trichocerca weberi*, *Mytilina ventralis*, *Bosmina longirostris*, and *Tropocyclops pracinus* (40%) (Table 1).

DISCUSSION

This research is the first investigation of zooplankton in the Horhor Creek, Tohma Stream, Bahçeiçi Village-Tıhmın, and Sazcağız Creek, located within the Gürün District of Sivas Province and the Elbistan District of Kahramanmaraş. This research identified 34 species of zooplankton, with Rotifera comprising 62% of the overall count. Numerous studies indicate that rotifers prevail both qualitatively and quantitatively in stationary aquatic environments, including lakes, ponds, reservoirs, and wetlands (Jamila et al., 2014; Ismail and Adnan, 2016; Dorak et al., 2019). Nonetheless, despite the tested waters being flowing, rotifers were discovered to be predominant, similar to certain streams. Segers (2007) observed that rotifers inhabit nearly all varieties of freshwater environments, including big permanent lakes, small temporary ponds, intermediate and capillary waters, acidic mineral lakes, soda lakes, hyperoligotrophic mountain lakes, and sewage ponds.

Despite the presence of species recognized as effective indicators of eutrophic conditions and pollution in the study (*A. priodonta, Euchlanis dilatata, L. lunaris, K. cochlearis, K. tecta, P. dolichoptera, L. patella, T. patina, Taphrocampa selenura,* hypereutrophic *Lecane stichaea, B. longirostris, Ceriodaphnia pulchella, Coronatella rectangula, Chydorus sphaericus, D. longispina, D. galeata, P. aduncus, C. vicinus,* and *T. prasinus*) (Dussart, 1969; Voigt and Koste, 1978; Pesce and Maggi, 1983; Hansen and Jeppesen, 1992; Shah and Pandit, 2013; Heneash and Alprol, 2020; Timms, 1976; Vadadi-Fülöp et al., 2008), their minimal abundance (1-2 individuals per petri dish) indicates that the examined running waters are currently significantly distant from the risk of eutrophication. Oligotrophic lakes often display low biomass with a diverse array of species, whereas lakes in a "bloom" state, indicative of advanced eutrophy, demonstrate high biomass with reduced species diversity (Gliwicz, 1969; Odum, 1969). Moreover, Sladecek (1983) indicates that the genus *Brachionus* is predominantly located in eutrophic waters, whereas the genus *Trichocerca* demonstrates exclusively oligotrophic characteristics or resides in freshwater environments. In this study, *Lecane flexis, L. lunaris, L. clostrocerca, Lepadella ovalis, Polyarhra dolichoptera, Euchlanis dilatata, Asplanchna priodonta, Bosmina longirostris, Coronatella rectangula, Daphnia longispina, Pleuroxus aduncus, Cyclops vicinus* and *Nitokra hibernica* species were also found in Sevsak stream (Saler 2022). The study did not identify any species belonging to the genus *Brachionus. Brachionus quadridentatus* was also recorded in a survey conducted in the Mancınık Stream in the Sivas region. Besides, *L. clostrocerca* and *Biapertura affinis*, identified at stations 2 and 3 in this study, were also encountered in a survey conducted in the Mancınık Stream in the Sivas region (Apaydın Yağcı et al., 2017). The diversity of zooplankton species at stations 2 and 3 on the Tohma Stream exhibited a substantial disparity, favoring station 3. The prevalence of eutrophication indicator species and the species variation between the second and third stations is attributed to the existence of aquaculture operations in the studied streams, the streams traversing residential zones, and the confluence of smaller water bodies with the main stream.

Biapertura affinis, located in hypogean waters (Brancelj and Sket 1990), is a eurybiotic species that resides in both benthic sediments and vegetation in the peripheries of ponds, reservoirs, river floodplains, and both lowland and alpine lakes (Bledzki and Rybak 2016). *Disparalona rostrata* is prevalent in lakes and linked to rocky substrates, although it is infrequent in acidic, electrolyte-deficient waters (Shapiera et al., 2011). *M. albidus* and *T. prasinus* (Fischer, 1860) inhabit aquatic settings of varying dimensions, such as roadside ditches, pools, springs, seeps, marshes, leaf litter in rivers, streams, ponds, and other locales where an adequate food supply exists (Lee and Chang, 2007).

The majority of species examined in the study are recognized for their widespread distribution, cosmopolitan nature, and considerable tolerance to variations in water quality parameters, constituting common taxa within Türkiye's zooplankton fauna (Keppeler, 2003; Keppeler and Hardy, 2004; Segers, 2007; Ustaoğlu et al., 2012; Ustaoğlu, 2015; Koste and Shiel, 1989; De Manuel Barrabin, 2000; De Smet, 1996).

CONCLUSION

The zooplankton species in the examined streams comprise cosmopolitan, ubiquitous species that tolerate changes in environmental conditions. Rotifera constitutes the predominant group, succeeded by Cladocera and Copepoda. The predominant families are Lecanidae and Lepadellidae (Rotifera), Chydoridae (Cladocera), and Cyclopoidae (Copepoda). The limited diversity of organisms observed in the study hampers further commentary on the overall condition of the waters, except from their proximity to an oligotrophic nature. On the other hand, the data obtained from the study can guide future research.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

AB: Conception and Supervision, Data analysis and interpretation, Manuscript writing

MA: Field studies;

All authors approved the final draft.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

The authors confirm that no generative AI was used in writing this manuscript or creating images, tables, or graphics.

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Three and a half decade analysis of fish biodiversity in İzmir Bay, western Aegean Sea: Insights into fishing methods and habitat changes

Şule Gürkan[1]✉ • Bahar Bayhan[1] • Ertan Taşkavak[1]

[1] Department of Marine–Inland Waters Sciences and Technology, Faculty of Fisheries, Ege University, İzmir, TÜRKİYE

✉ Corresponding Author: sule.gurkan@ege.edu.tr

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A B S T R A C T

This study evaluates the biodiversity of fish species caught using different fishing methods in relation to habitat distribution, based on 34 length-weight studies conducted in İzmir Bay between 1990-2024. The obtained data has been analysed in terms of traditional and modern fishing methods' species distributions in coastal and offshore habitats and the state of the bay ecosystem. This study examines how fish species diversity in the bay fluctuates over time, analyzing the impact of habitat characteristics and fishing practices on these variations. In the study, data from 170,466 fish specimens belonging to 139 species were analyzed using the Biodiversity Pro program. According to Simpson's Reciprocal Index analysis, trawling is the most dominant fishing method with 20.81% in terms of number of individuals, followed by trammel net with 13.12%. While trawling, the bay's most effective fishing gear, catches 97 species, trammel net catches 28 species. The fishing method capturing the least number of individuals is fishnet with 1%. According to life forms, demersal species constitute the dominant group (18.157%) in the bay, while bathypelagic species showed the lowest diversity (1%). According to the Margalef index, the highest species richness was observed in demersal species (M: 28.265), while the lowest was in bathydemersal species (M: 43.792). According to studies between 1990-2024, fish populations with a b value above 3 comprise 68.61% in İzmir Bay. The average b value of 3.078 indicates that fish populations in the bay consist of species prone to positive allometric growth. The findings provide important contributions to understanding the ecological preferences of fishing methods and fish species. These data offer significant recommendations for sustainable fishery and species diversity management in İzmir Bay.

INTRODUCTION

The coastlines of Türkiye exhibit a highly dynamic structure in terms of fish fauna. The number of fish species identified in the Turkish seas until 2022 is 547 (Bilecenoğlu et al., 2024). In Türkiye, which has four different marine systems, particularly the Mediterranean and Aegean Seas are the regions with the highest fish species diversity. Along with the Levantine coasts, species diversity has reached its most prominent level in the Turkish Aegean coasts, with the number of species reaching 449 (Bilecenoğlu et al., 2024). The presence of numerous bays, gulfs, and islands in the coastal areas of the Aegean Sea, and the consequent narrow continental shelf, significantly limits fishing activities in the

region. The high fish species diversity in the Aegean Sea is primarily driven by nutrient input from rivers, favourable temperature and salinity conditions, and the ability of Lessepsian migrant species to locate suitable feeding and breeding grounds (Bilecenoğlu et al., 2024; Maravelias et al., 2006; Pethiakis et al., 2014; Güreşen et al., 2015).

İzmir Bay, situated in the eastern Aegean Sea within the Mediterranean basin, is one of the most significant natural bays in the region. Covering an area of 200 km² with a water volume of 11.5 million m³, it hosts intensive fishing activities (Kara and Sağlam, 2017). Typical fishing gear used in the bay consists of purse seines, gill nets, longlines, fishing lines, traps (fyke nets, pots), and fishgarth (fence, settling) (Akyol and Perçin, 2005). The bay, encompassing both natural habitats and human activities, is crucial for ecosystem health (Talas et al., 2023). Fishing in İzmir Bay not only provides a livelihood for local communities but also makes a significant contribution to the regional economy. The bay's main fishing areas, stretching from north to south, include Dikili, Çandarlı, Aliağa, Foça, Homa Lagoon, Bostanlı, Sahilevleri, Güzelbahçe, Kalabak, Urla, Özbek, Mordoğan, Karaburun, Yeni Liman, Dalyanköy, Çeşme, Sığacık, Gümüldür, Özdere (Akyol and Perçin, 2005). However, commercial and small-scale fishing activities exert significant pressure on the bay's living resources and biodiversity. These practices impact species and ecosystems, causing shifts in fish populations over time (Bilecenoğlu et al., 2024; Holmlund and Hammer, 1999). King et al. (2023) suggest that variations in catch rates due to different fishing gear and their effectiveness may result in misleading estimates of fish species abundance.

Fishing methods are one of the most important factors determining the structure of fish populations. The biological characteristics, reproductive success, and growth rates of fish species in İzmir Bay are closely linked to the types of fishing nets used. The replacement of traditional techniques with modern fishing methods has lasting effects on the marine ecosystem. Traditional gear such as gillnets and trammel nets threaten genetic diversity by leading to the capture of non-target species alongside target species (Depestele et al., 2012). In recent years, intensive fishing activities in the bay have been creating serious pressure on the ecosystem and significantly altering the population dynamics of fish species (Ulman et al., 2020).

Fishing in İzmir Bay is of great importance not only as a source of livelihood for local people but also for the regional economy. Commercial and small-scale fishing activities in the bay create pressure on the biodiversity of living resources. These pressures on fish species populations show variation over time (Holmlund and Hammer, 1999). The life patterns and behaviors of fish are directly related to environmental factors and, especially, to the fishing methods used (Wijermans et al., 2020). Fish species in İzmir Bay have a structure that maintains ecosystem functions and can adapt to environmental changes. Environmental changes and human impacts lead to changes in the life strategies of these species. The life patterns, reproductive cycles, feeding habits, and habitat preferences of fish are directly affected by overfishing. This fishing pressure reduces genetic diversity and threatens the sustainability of populations by negatively affecting species' growth rates, age distributions, and reproductive success (van Overzee and Rijnsdorp, 2015).

The biodiversity of fish species in İzmir Bay is influenced by the interaction between fishing methods and environmental factors. Several studies have documented changes in fish species diversity in the Bay since 1990. However, most of these studies are limited in duration and focus on species diversity in relation to fishing methods or habitat types (Cihangir et al., 2004; Akyol and Perçin, 2011; Tunca et al., 2022; Şenbahar et al., 2020). This study examines fish species diversity and the impact of fishing methods in İzmir Bay between 1990 and 2024. It aims to develop strategies for biodiversity conservation in the region by assessing how different fishing methods influence species distribution, growth rates, and reproductive success. Understanding fish biodiversity in İzmir Bay is crucial for ensuring the sustainability of this ecosystem. As a pioneering study on the factors affecting biodiversity in the Bay, it seeks to provide key recommendations to local and national authorities. This ecological analysis will generate critical data for safeguarding ecosystem health in the region, formulating sustainable fisheries policies, and preserving biodiversity. Consequently, this research is expected to serve as a key resource for biodiversity conservation and the long-term sustainability of marine ecosystems.

MATERIALS AND METHODS

This study analysed length-weight relationships of fish species from scientific fishing activities in İzmir Bay from 1990 to 2024 (Figure 1). This research draws upon data from 34 scientific studies retrieved via Google Scholar, encompassing 139 species and a total of 170,466 fish specimens.

The evaluation analyzed 30 years of fish sample data from İzmir Bay using nine standard fishing gear types across different habitats: trawl, beach seine, gill net, fyke net, trammel net, fish trap, handline, fish net, and purse seine. The analysis did not account for the selectivity characteristics of the fishing gear.

Figure 1 shows the coordinate data for İzmir Bay's general fishing areas where commercial fishing occurs. Given that the sampling period spans approximately 30 years, the

assessment examined the species obtained and their habitat distributions to provide a general overview.

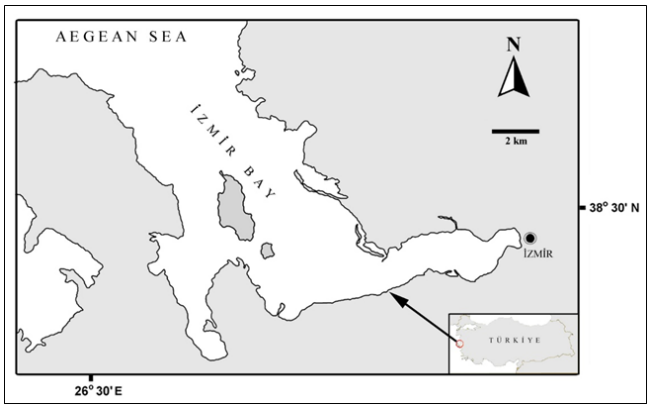

Figure 1. The map illustrates the Bay of İzmir, Eastern Aegean Sea, where scientists conducted 34 length-weight relationship studies on various fish species between 1990 and 2024

To assess the impact of fishing methods, we used Simpson's Reciprocal Index and Margalef indices (Simpson, 1949). Species composition was evaluated using Bray-Curtis Cluster analysis (Pielou, 1975). We calculated these indices using Biodiversity Pro software. We categorized fish species into four groups—demersal, benthopelagic, bathypelagic, and pelagic—to analyze their distribution patterns. Statistical differences between these groups were assessed using t-tests.

Simpson's Reciprocal Index measures the diversity of species in a community. Denoted as D, this index is calculated using the formula,

$$D = 1/\ \Sigma ni(ni-1)\ /\ N(N-1) \quad (1)$$

where ni represents the number of organisms belonging to species i and N represents the total number of organisms. Simpson's Diversity Index ranges from 0 to 1, with high er values indicating lower diversity. Because this relationship is counterintuitive, scientists often use Simpson's Reciprocal Index (also known as the Dominance Index), calculated as 1/D. With this index, higher values reflect greater species diversity. The Margalef diversity index (Gamito, 2010) is calculated using the formula,

$$Z = (S-1)/lnN \quad (2)$$

where S represents the number of species and N is the total number of individuals in the sample.

On the other hand, the Bray-Curtis index (also known as Bray-Curtis dissimilarity), which is widely used particularly in ecology and biology to compare species composition across different environments, is a statistical measure that evaluates the similarity between two datasets. Thus, the Bray-Curtis similarity index compares the relative abundances of a community across two locations. For sites i and j, with abundance vector a of length n indexed over k, this quantity is given by:

$$BCij=1-\sum nk=1|ai,k-aj,k|\sum nk=1(ai,k+aj,k)BCij=1-\sum k=1n|ai,k-aj,k|\sum k=1n(ai,k+aj,k) \quad (3)$$

RESULTS

The numbers of fish species and individuals caught from İzmir Bay vary depending on fishing methods. In 34 studies conducted in the Bay between 1990–2024, a total of 139 species and 170,466 fish individuals were examined, with an average of 1,244 individuals caught for scientific purposes. The numbers of species determined according to their habitats in the studies are as follows: pelagic: 21, demersal: 90, benthopelagic: 19, bathyodemersal: 8, and bathypelagic: 1 species. The occurrence values of fish species range between 0.0018–8.5289 (mean ± SE: 0.719 ± 0.061). While the lowest occurrence value belongs to the pelagic species *Belone svetovidovi* (0.018%), the highest occurrence belongs to the demersal species *Citharus linguatula* (8%).

According to Simpson's Reciprocal Index results, trawl nets were the most dominant fishing gear in terms of number of individuals of caught species with 20.81% (D: 0.048), followed by gill nets with 13.12% (D: 0.076). Trawl gear catches 97 species from İzmir Bay, while gill nets catch 28 species. The fishing gear that caught the least number of individuals is Fishnet with 1% (D: 1), which only caught a single species (*Hippocampus guttulatus*). When fishing gear is evaluated in terms of species richness, it is observed that the highest number of species is caught with trawl nets (M: 18.72). In contrast, the fishing gear that caught the lowest number of species is Fishnet (M: 0) (Figure 2). Both analysis results indicate that trawling is a dominant fishing gear in terms of species diversity in catching fish species in İzmir Bay.

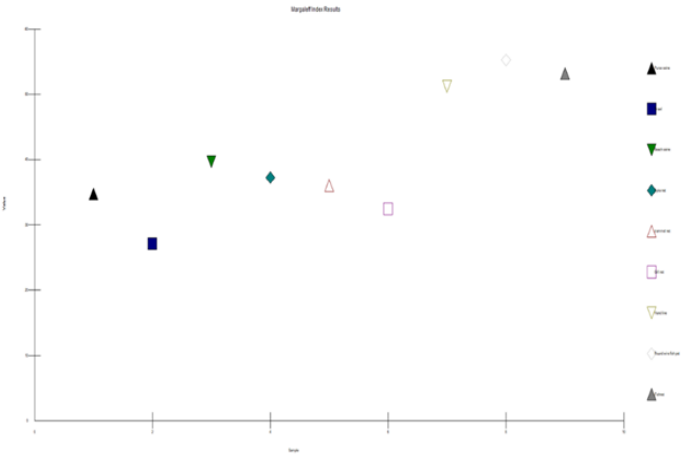

Figure 2. Distribution analysis of species caught by various fishing gears

According to the Bray-Curtis Cluster analysis, in terms of species caught by fishing methods, the highest similarity is 25.29% between trammel net and gillnet. Of the 139 species distributed in İzmir Bay, 21.58% (28 species) are caught by trammel net and 34.53% (41 species) are caught by gillnet (Table 1, Figure 3). According to Student's t-test results, no statistically significant difference was found between the number of individuals of species caught by trammel net and gillnet (t: 1.258; p: 0.210; p>0.05). Among fishing gear, trawl nets have the highest species richness (M: 18.72). Fishnet is the fishing gear where catching is specific to only one species (M: 0) (Table 2).

Table 1. Similarity results of caught fish species according to fishing methods

Step	Cluster	Distance	Similarity	Joined 1	Joined 2
1	8	74.702	25.299	5	6
2	7	82.403	17.563	3	4
3	6	83.412	16.587	1	5
4	5	84.560	15.439	1	3
5	4	89.175	10.824	1	2
6	3	90.860	9.140	1	7
7	2	94.729	5.270	1	9
8	1	94.842	5.157	1	8

Table 2. Similarity matrix of caught fish species according to fishing methods

Purse seine	**Purse seine**	**Trawl**	**Beach seine**	**Fyke net**	**Trammel net**	**Gill net**	**Roundwirefishpot**	**Fish net**
Trawl	*	1.454	3.105	5.686	10.219	16.587	1.693	0
Beach seine	*	*	0.467	1.854	6.995	10.824	0.169	0.609
Fyke net	*	*	*	17.596	10.970	8.606	0	0
Trammel net	*	*	*	*	15.439	13.326	5.157	0
Gill net	*	*	*	*	*	25.297	4.262	5.270
Hand line	*	*	*	*	*	*	1.742	0
Roundwirefishpot	*	*	*	*	*	*	0	0
Fish net	*	*	*	*	*	*	*	*

**: 0.05 signification difference*

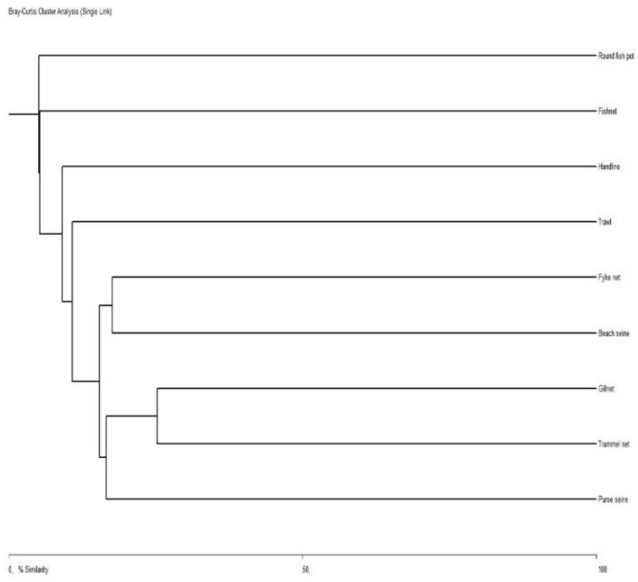

Figure 3. Similarity diagram of the captured species according to fishing methods

The number of fish species and individuals caught from İzmir Bay varies depending on their life forms. According to Simpson's diversity index results, demersal species dominated with 18.15% and 90 species in terms of number of individuals, followed by benthopelagic species with 6.69% and 25 species (Figure 4). According to the t-test results, no statistically significant difference was found between demersal species and benthopelagic species in terms of number of individuals (t:-0.296, p: 0.767, p>0.05). Bathypelagic species, represented by a single species with 1%, have the lowest number of individuals. The highest values indicating habitat diversity were obtained from demersal species. According to Margalef index results, the highest species richness in İzmir Bay was observed in demersal species with 17.47% (M: 28.27), while the lowest richness was detected in bathydemersal species with 2.13% (M: 43.79)

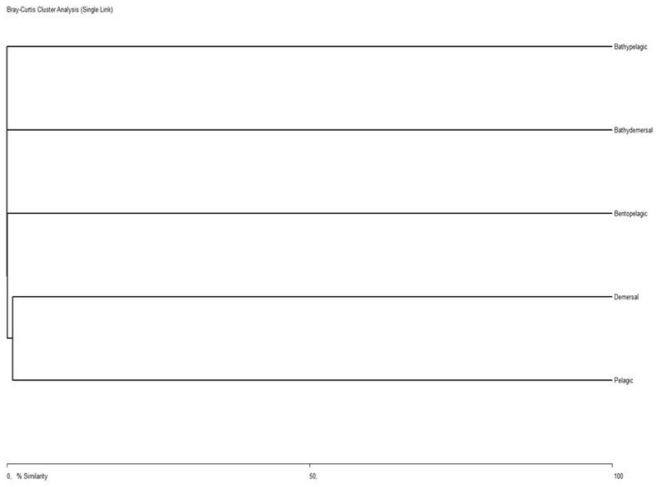

Figure 4. Similarity diagram of species' life types

In İzmir Bay, analysis of average b values for fish species caught by various fishing gear revealed that *Solea solea* had the lowest value at 1.59, while *Zeus faber* had the highest at 3.99. According to Figure 5, the b values for species caught in the bay fell into three class intervals (1.00-1.99, 2.00-2.99, and 3.00-3.99). Of the fish species distributed in the bay, individuals with b values between 1.00-1.99 comprise 0.97%

of all populations, those between 2.00-2.99 make up 30.42%, and those between 3.00-3.99 represent 68.61%. The bay's dynamics directly influence the growth parameters of fish populations.

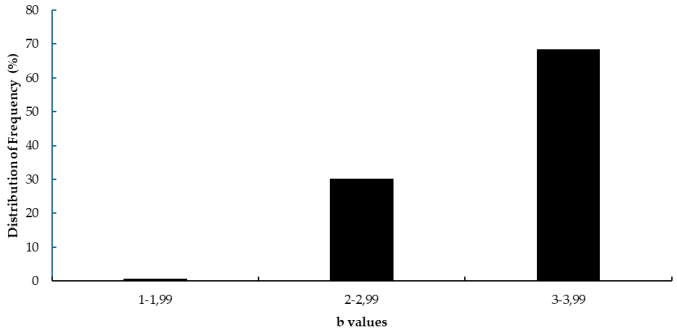

Figure 5. Similarity diagram of species' life types

According to fishing gear, the mean b value in species caught with gill nets is generally associated with individuals showing isometric growth (3.00±0.27). In contrast, the mean b value of individuals caught with fishnets is characterized by individuals showing positive allometric growth (3.50±20.23). However, it should be noted that the differences between b values are closely related to the number of individuals caught.

DISCUSSION

İzmir Bay represents one of the Aegean Sea's vital ecosystems, with its biological diversity playing a critical role in marine ecosystem sustainability. This study evaluated fish species biodiversity in İzmir Bay by examining fishing methods and fish life patterns. Our findings demonstrate that fishing techniques and environmental factors primarily determine fish population dynamics and ecosystem structure in the region.

Fishing activities significantly influence biodiversity patterns in İzmir Bay. The employed fishing techniques directly impact fish species' distribution, age structure, and reproductive capabilities (Wright and Trippel, 2009). Traditional methods-particularly gillnets and trammel nets-affect both target and non-target species, resulting in population declines and genetic diversity losses (Sadler et al., 2023). According to Gomes et al. (2014), effective fishery management requires appropriate equipment that captures target species at optimal and economical sizes while promoting sustainable harvesting and balancing resource competition with socio-ecological impacts. Recently, İzmir Bay has seen the introduction of modern fishing tools and methods aimed at increasing fishing efficiency. However, this modernization has intensified fishing pressure on local fish populations and heightened ecosystem stress.

The lifestyles and strategies of fish species are crucial for adaptation to ecosystem changes. Fish species in İzmir Bay adapt to both fishing pressures and environmental factors. Research shows that species' growth rates and reproductive success vary with seasonal and environmental changes. While some fish species have developed rapid growth strategies, others have adopted longer-lived strategies with slower growth rates (Winemiller, 2005). Larger species have longer generation times and greater vulnerability to exploitation due to their lower potential rates of population increase (Winemiller and Rose, 1992; Jennings, 2005).

In the bay, populations showing positive allometric growth (3.00-3.399) make up 68.61% of total species. The bay's dynamics directly influence fish population growth parameters. The b parameter, indicating growth value, varies over time due to several factors. Habitat conditions nutrition, sampling frequency, and fishing gear selectivity significantly influence this variation (Tesch, 1968; Wooton, 1990). Short-lived small species (r-selected) are widely distributed throughout the bay. These adaptations enhance species survival while maintaining vital ecosystem services. Increased commercial fishing affects both large, economically valuable species and smaller species crucial to the ecosystem and food chain (Crowder et al., 2008). In İzmir Bay specifically, Şenbahar et al. (2020) found that purse seine fishing shows low species diversity, with sardines dominating the catch. This finding highlights the need for regulations to ensure sustainable fishing in the region. Environmental changes and fishing pressures together test species' adaptation capabilities. Climate change, warming sea temperatures, and marine pollution are changing fish species' reproductive cycles and feeding patterns (Pankhurst and Munday, 2011). Fish species' lifestyles thus affect not only the region's ecosystem health but also its economic and socio-cultural values.

The preservation of fish biodiversity in İzmir Bay is both a scientific necessity and vital for developing sustainable fishing practices. This study demonstrates that population changes among fish species in the gulf demand a comprehensive, integrated management approach. Revising fishing policies is crucial, particularly in making fishing methods sustainable. To protect fish populations, priority must be given to regulating fishing areas, timing, and net types (Dunn et al., 2011). Local communities' and fishermen's awareness plays a key role in developing sustainable fishing strategies in İzmir Bay. Adopting eco-friendly fishing methods will help preserve biodiversity. Additionally, monitoring environmental impacts and implementing early warning systems can effectively protect fish species (Jennings 2005).

CONCLUSION

Our findings show that fishing methods and environmental factors significantly influence fish species biodiversity in İzmir Bay. Trawling captures the most species, while trammel nets and gillnets yield similar catch compositions. Demersal species show the highest diversity in terms of lifestyle patterns. Ensuring sustainable fishing requires consideration of not only fishing techniques but also species' lifestyles and ecosystem dynamics. Future research will establish a foundation for deeper analysis of these interactions and help develop sustainable fishing policies.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

Authors have contributed equally to the paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study.

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The study was not supported by any institution.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

AI Disclosure

The authors confirm that no generative AI was used in writing this manuscript or creating images, tables, or graphics.

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Türk-Amerikan teknik iş birliği bağlamında Türkiye'de balıkçılık sektörünün modernizasyonu (1950-1958)

Resul Babaoğlu[1]✉ • Celalettin Aydın[2]

[1] İzmir Kâtip Çelebi Üniversitesi, Sosyal ve Beşeri Bilimler Fakültesi, Tarih Bölümü, İzmir, 35620, TÜRKİYE
[2] Ege Üniversitesi, Su Ürünleri Fakültesi, Su Ürünleri Avlama ve İşleme Teknolojisi Bölümü, 35040, İzmir, TÜRKIYE

✉ Corresponding Author: babaogluresul@hotmail.com

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Ö Z E T

Bu makale, Amerikan diplomatik arşiv belgeleri ışığında 1950-1958 döneminde Türkiye'de balıkçılık sektörünün modernizasyon sürecini incelemektedir. Çalışma, II. Dünya Savaşı sonrası Türkiye'nin Batı ittifakına yönelmesiyle birlikte ABD'nin Türk balıkçılık endüstrisine yönelik teknik ve ekonomik müdahalelerini ele almaktadır. Araştırma, birincil kaynak olarak ABD Ulusal Arşivleri'nde yer alan diplomatik yazışmaları, konsolosluk raporlarını ve Mutual Security Agency (MSA) belgelerini kullanmaktadır. Bu belgeler, Türkiye'deki balıkçılık altyapısı, Et ve Balık Kurumu'nun faaliyetleri, konserve endüstrisi ve modernizasyon projeleri hakkında detaylı bilgiler sunmaktadır. Ayrıca dönemin Türk basını ve resmi mevzuat da destekleyici kaynaklar olarak kullanılmıştır. Çalışma, 1952 yılında kurulan Et ve Balık Kurumu'nun soğuk hava depoları, araştırma gemisi Arar ve modern avcılık teknikleriyle sektörel dönüşümü nasıl yönlendirdiğini ortaya koymaktadır. Kaliforniyalı uzman G.B. Dollar'ın hazırladığı teknik raporlar, Türk balıkçılık endüstrisinin ABD standartlarından yaklaşık 35 yıl geride olduğunu göstermektedir. MSA destekli et paketleme projesi ve FOA (Foreign Operations Administration) iş birliği, teknoloji transferi ve uzman desteğinin Soğuk Savaş dönemindeki stratejik boyutunu yansıtmaktadır. Araştırma, balıkçılık modernizasyonunun salt ekonomik değil, aynı zamanda jeopolitik bir araç olarak kullanıldığını ve ABD'nin Türkiye'yi bölgede başarılı bir modernleşme modeli olarak konumlandırma çabasını vurgulamaktadır.

The modernisation of the fishing industry in Türkiye in the context of Turkish-American technical cooperation (1950-1958)

A B S T R A C T

This article examines the modernization of Türkiye's fisheries sector between 1950 and 1958 through the lens of U.S. diplomatic archives. In the aftermath of the Second World War, Türkiye's alignment with the Western alliance opened the way for American technical and economic interventions that reshaped the country's fishing industry. Drawing on diplomatic correspondence, consular reports, and Mutual Security Agency (MSA) documents preserved in the U.S. National Archives, the study reconstructs the institutional and infrastructural transformation of Turkish fisheries. These sources, complemented by contemporary Turkish press coverage and official legislation, illuminate the development of cold-storage networks, the activities of the Meat and Fish Institution, the canning industry, and various modernization projects. The article demonstrates that the Meat and Fish Institution, founded in 1952, played a central role in leading sectoral change through the construction of cold-storage facilities, the commissioning of the research vessel Arar, and the introduction of modern fishing practices. Technical assessments by Californian expert G. B. Dollar revealed that Türkiye's fisheries lagged roughly thirty-five years behind U.S. standards. Meanwhile, the MSA-backed meat-packing initiative and cooperation with the Foreign Operations Administration (FOA) underscore the strategic dimension of technology transfer and expert assistance during the early Cold War period. By situating the fisheries modernization program within the broader context of U.S.–Turkish relations and Cold War developmentalism, the study argues that the American involvement in Türkiye's fisheries was not merely an economic enterprise but a geopolitical project aimed at presenting Türkiye as a model of successful modernization in the Middle East.

GİRİŞ

II. Dünya Savaşı'ndan sonra Türkiye'nin Batı ittifakına yönelmesi, Amerikan merkezli tercihlerle şekillenen dış politika ve siyasal yönelimler ile sonuçlanmıştır. Savaş sonrası dönemde Türkiye'nin çok yönlü bir değişim

sürecine girmesi, son asırda devam eden modernleşme/Batılılaşma gündeminden birçok bakımdan farklılıklar taşımıştır. Bu dönemde Amerika ile girilen tek yönlü bağımlılık ilişkisinin birbiriyle kopuk gibi görülen çeşitli alanlarda Anglosakson etkisinin hissedilir bir şekilde değişimin itici unsuru olması sonucunu doğurmuştur (Örnek, 2015; Erken, 2020). Sözü edilen bu değişim dalgasında Amerikan dış politikasında Türkiye'ye belirli bir ağırlık atfedildiği bilinmektedir. II. Dünya Savaşı'nın hemen ardından Amerika Birleşik Devletleri tarafından uygulanan Truman Doktrini kapsamına alına Türkiye'ye yapılan yardımlarla Sovyet Rusya'nın çevrelenmesi politikası hayata geçirilmiştir. Amerikan bakış açısına göre Sovyet Rusya'nın etki alanına girme potansiyeli taşıyan Türkiye ve Yunanistan gibi ülkeler, Truman Doktrini'nin kabul edildiği dönemde olmasa da daha sonraki süreçte kestirilemeyen şartlarda başka bir istikamete yönelebilecekleri ihtimali değerlendirilmiştir. Bu yönüyle bakıldığında Amerikan dışişleri ile Türkiye'deki elçilik yetkilileri arasında yoğun bir yazışma gerçekleştiği gözlenmektedir.

Genel itibarıyla Amerikan dışişleri bakanlığına Türkiye'deki Amerikan elçiliğinden gönderilen belgeler arasında Türkiye'de siyasal, ekonomik, idari vs. gibi birçok alanda hazırlanan raporların sayısı şaşırtıcı ölçüde fazladır. Bu yazıda ele alınan konu çerçevesinde bakıldığında, Türkiye'nin balıkçılık potansiyelinin detaylı bir şekilde analiz edilmesi ve konservecilik başta olmak üzere balık işleme tesislerinin modernleştirilmesi ve yaygınlaştırılması gibi alanlarda Amerikan menşeli kuruluşlarla iş birliği imkânlarının geliştirilmesini içine alan yazışmalardan oluşan geniş koleksiyon, Türkiye'de balıkçılık sektörünün gelişim merhalelerinin tayin edilebilmesi açısından ciddi bir değer taşımaktadır. 1950'li yıllardan itibaren Türk-Amerikan ilişkilerinin stratejik ve jeopolitik düzeyde kat ettiği mesafenin doğrudan bir uzantısı olan teknik iş birliği anlaşmaları kapsamında üretilen söz konusu diplomatik yazışmalar Türkiye'de balıkçılık sektörünün hangi aşamalardan geçerek modernleştiği ile alakalı bilgiler ihtiva etmektedir. Türkiye'deki Amerikan Büyükelçiliği ve İstanbul Konsolosluğu yetkililerinin kaleme aldıkları belgelere ek olarak Türkiye'nin balıkçılık endüstrisi alt yapısını ortaya koyan raporlar bu makalenin temel kaynaklarını teşkil etmektedir.

MATERYAL VE YÖNTEM

Bu çalışma, 1950–1958 yılları arasında Türkiye'de balıkçılık sektörünün modernizasyon sürecini Türk-Amerikan teknik iş birliği bağlamında inceleyen nitel bir tarihsel araştırma olarak tasarlanmıştır. Araştırmada, tarihsel belge analizi yöntemi esas alınmış ve birincil ile ikincil kaynaklar birlikte kullanılmıştır.

Çalışmanın temel araştırma materyalini, Amerika Birleşik Devletleri Ulusal Arşivleri'nde (U.S. National Archives) muhafaza edilen diplomatik belgeler oluşturmaktadır. Bu kapsamda, ABD Dışişleri Bakanlığı yazışmaları, Ankara Büyükelçiliği ve İstanbul Konsolosluğu tarafından hazırlanmış raporlar, Mutual Security Agency (MSA) ve Foreign Operations Administration (FOA) belgeleri incelenmiştir. Söz konusu belgeler, Türkiye'de balıkçılık altyapısı, balık işleme ve konserve sanayisi, soğuk hava depoları, Et ve Balık Kurumu'nun faaliyetleri ile Amerikan uzmanlar tarafından hazırlanan teknik değerlendirmelere ilişkin ayrıntılı bilgiler sunmaktadır. Birincil kaynaklara ek olarak, dönemin Türk basını (Akşam ve Milliyet gazeteleri), Resmî Gazete'de yayımlanan kanun ve kararnameler ile Türkiye Büyük Millet Meclisi zabıtları destekleyici materyal olarak kullanılmıştır. Ayrıca konuya ilişkin daha önce yayımlanmış akademik çalışmalar ve kitaplar, ikincil kaynaklar çerçevesinde değerlendirilmiştir.

Araştırmada nitel veri analizi yaklaşımı benimsenmiş, belgeler tarihsel bağlamları dikkate alınarak içerik analizine tabi tutulmuştur. İncelenen arşiv belgeleri; balıkçılık politikaları, teknik yardım projeleri, kurumsal yapılanmalar ve altyapı yatırımları gibi tematik başlıklar altında sınıflandırılmıştır. Belgeler arasında karşılaştırmalı bir okuma yapılarak, Amerikan teknik yardımının amaçları, uygulama biçimleri ve Türkiye'deki yansımaları analiz edilmiştir. Analiz sürecinde, belgelerin üretildiği dönemin siyasal ve jeopolitik koşulları göz önünde bulundurulmuş; Soğuk Savaş bağlamında ABD'nin kalkınma ve modernizasyon politikalarının Türkiye'de balıkçılık sektörü üzerindeki etkileri yorumlanmıştır. Bu çerçevede, Amerikan uzman raporları ile Türk resmî düzenlemeleri birlikte değerlendirilerek, teknik yardım ile ulusal kalkınma politikaları arasındaki etkileşim ortaya konmuştur.

BULGULAR VE TARTIŞMA

1950'li yılların başlarından itibaren Amerikan diplomatik çevrelerinde Türkiye'ye dönük ilginin giderek artması, iki ülke arasındaki ilişkilerin müttefiklik seviyesinde seyretmesi ile açıklanabilir (Gökatalay, 2019). II. Dünya Savaşı'ndan sonra Amerikan yöneticileri Avrupa'nın tamirinin ve modernizasyonunun finansmanı konusunda IMF, BM ve Dünya Bankası tarafından sağlanacak olan fonların yeterli olacağını düşünmekteyken kısa zaman sonra bu iyimser hava kaybolmuş ve ancak daha kapsamlı programlar yoluyla Avrupa'nın kalkındırılabileceği gerçeğine ulaşılmıştır. Bunun yanında, ekonomik ihtiyaçlar kadar stratejik gereklilikler de Avrupa'nın yeniden imarını zaruri kılmaktaydı. Bu şartlar altında gündeme gelen ve ABD Dışişleri Bakanı George Marshall'ın adıyla şekillenen ortak imar planı, Truman Doktrini'nden farklı olarak

Avrupa'nın ekonomik kalkınmasına hasredilmiştir (Erkan, 1996). Marshall Planı kapsamına alına Türkiye'ye hibe ve borç şeklinde sağlanan finansman ile canlandırılan alanlardan biri de et ve balıkçılık sektörü olmuştur (Özer, 2014). Marshall Planı ile 1948 ile 1952 yılları arasında toplam 7.640.000 dolar tutarında döviz girişi olan Türkiye'de Toprak Mahsulleri Ofisi marifetiyle balıkçılık teknolojisine yönelik malzeme alımı yapılmıştır. Balıkçılığın geliştirilmesine yönelik bu girişimler, sektörde faaliyet gösteren kesimlerce memnuniyetle karşılanmıştır (Zengin, 2023).

Türkiye'de iktisadi hayatın her alanındaki siyasal ve idari gelişmeleri konu alan Amerikan diplomatik yazışmalarının bir örneğine 29 Ağustos 1956'da Türkiye Büyük Millet Meclisi'nde 1918 sayılı kanunun bazı maddelerinin tadili konusundaki görüşmelerinin konu edildiği raporda rastlanmaktadır. Mecliste görüşülen kanunun ek 2. Maddesinde yer alan "*Karasularımızda yabancı gemilerle balık, istiridye, midye, sünger, inci, mercan, sedef vs. avlamak veya avlanmak için bu suretle karasularımıza girmek de kaçakçılıktır*" (TBMM, 1956) ifadelerinin vurgulandığı elçilik raporunda suçluların bir yıldan üç yıla kadar hapis cezasına çarptırılacağı belirtilmiştir. Ancak raporda geçen dikkat çekici yoruma göre, kanunda özel olarak belirtilmese de genel olarak Yunan ve İsrail balıkçı filosuna yönelik olduğu kabul edilmektedir. Türk makamları daha önce bu suçlamalarla Yunan ve İsrail balıkçı teknelerini yakalamış veya alıkoymuştur. Mevcut kanun bu politikanın uygulanmasına yasal dayanak sağlamakta ve büyük olasılıkla oldukça sıkı bir şekilde uygulanması beklenmektedir (NA, 1956). 1918 sayılı Kaçakçılığın Men ve Takibi Kanunu'na eklenen maddelerin kaçak avlanma ile ilgili olan kısmı elçilik yetkililerine göre Türkiye karasularında balıkçılığın geliştirilmesi amacını taşımaktadır. Kanuna uymayanların İçişleri ve Gümrük bakanlıkları tarafından yayınlanacak olan tebliğler göz önünde bulundurularak suçu işleyenlerin kaçakçılık amacıyla mı hareket ettikleri ya da ele geçirilen maddeler ve el konulan ürünlerin değeri hesaplanarak cezanın belirleneceği bilgisi raporda yer almıştır (NA, 1956).

Amerika'nın Türkiye'deki diplomatik misyonunun balıkçılık endüstrisi ve alt yapısı konusunda hazırladığı raporların oldukça detaylı bilgiler ihtiva ettiği görülmektedir. Bu konuda hazırlanmış 1958 yılına ait bir rapor İstanbul balıkçılığına hasredilmiştir. Buna göre, İstanbul'da deniz ürünlerinin pazarlanma süreci, belediye denetiminde işleyen merkezi bir sistem aracılığıyla yürütülmektedir. İstanbul bölgesinde satılan tüm deniz ürünleri Belediye Toptan Balık Müzayedesi'nden geçmek zorundadır (NA, 1958). Bu zorunluluk, denetim ve kontrol mekanizmalarının şeffaflığı ile kamu sağlığının korunmasına yönelik önemli bir adımdır. Perakendeci ve toptancılar üzerindeki kontrol ise, "imzalı makbuz talep edebilen belediye yetkilileri tarafından sağlanmaktadır. Belediye balık müzayede binası, "Galata ve Atatürk köprüleri arasında Haliç kıyısında Suriçi denilen bölgede yer almakta ve diğer belediye tesisleriyle bağlantılı bir toptan balık pazarıyla çevrilidir. Müzayedeye getirilen tüm balık ürünleri, belediye görevlileri tarafından "sınıflandırılır, derecelendirilir, tartılır ve müzayede edilir." Ürünlerin bu işlemden geçmesi hem kalite kontrol hem de fiyat istikrarı açısından önem taşımaktadır. Mevcut tesislerde soğutma, dondurma ya da depolama altyapısı bulunmamakta, bu ihtiyaçlar dış kaynaklarla karşılanmaktadır. Bununla birlikte, İstanbul Belediyesi 1957 yılında İngiltere, İskandinavya ve Almanya'daki modern balık pazarlarını incelemek üzere yapılan bir ziyaret sonrası İstanbul'a uygun modern bir tesis inşası için fikirler geliştirmiştir. Yeni kurulacak sistemin günlük 300 ton taze balık işleme kapasitesine sahip olması planlanmaktadır. Balıkların pazara ulaşımı özel sektör eliyle sağlanmakta olup, büyük firmaların sahip olduğu tekneler ön plandadır. Ayrıca, bazı bireysel balıkçılar da büyük firmalardan krediyle tekne satın alır ve sözleşmeli olarak çalışmaya devam ederler. Küçük ölçekli yelkenli ve kürekli teknelerle avlanan bağımsız balıkçılar da sistemin bir parçası olarak faaliyet göstermektedir (NA, 1958). Bu yapı, İstanbul'un deniz ürünleri sektöründe hem sağlık standartlarını hem de ekonomik verimliliği artırmaya yönelik kapsamlı bir kamu-özel sektör işleyişini temsil etmektedir. Konsolosluk raporunda bu şekilde betimlenen İstanbul balıkçılığında kooperatiflerin etkili olduğu anlaşılmaktadır. Üç farklı kooperatif ile örgütlenen balıkçılar bu yolla olta, yedek parça, yakıt ve diğer ithal malzemelerin sınırlı tedarikini de sağlamaktadırlar. 450 üyeden oluşan bir diğer kooperatif ise büyük firmalardan oluşmakta iken, üçüncü kooperatif yaklaşık 15 üyeye sahiptir ve motorlu teknesi olmayan balıkçılardan oluşmaktadır. Her üç grubunun da İstanbul'daki balıkçıların idari mekanizma ile İstanbul Belediyesi nezdinde resmi bir temsil yetkisi bulunmaktadır (NA, 1958). Bu kapsamlı belgeler, ABD'nin 1950'lerde Türkiye'nin balıkçılık sektörünü yakından takip ettiğini ve hem yasal düzenlemeler hem de endüstriyel gelişim fırsatları açısından ayrıntılı analizler yaptığını göstermektedir.

Türkiye'de et ve balık üretimi desteklemek ve fiyat istikrarını sağlamak amacıyla 1952 yılında Et ve Balık Kurumu (EBK) kurulmuştur (Resmi Gazete, 1952a). EBK, et ve balıkla ilgili üretim, araştırma, düzenleme ve dağıtım işlevlerini üstlenen merkezi bir devlet kuruluşu olarak, tarım ve hayvancılığın yanı sıra balıkçılık sektörüne de müdahil olmuştur Bu kurumun üstlendiği önemli roller

ABD'nin İstanbul konsolosluğunun altını çizdiği hususlardan biri olmuştur. 1955 yılında Amerikan dışişlerine gönderilen bir belgede Et ve Balık Kurumu'nun faaliyetlerine son aylarda ciddi bir ilginin varlığına dikkat çekilmiştir (NA, 1955). ABD Dışişleri Bakanlığı'na iletilen rapora göre, kurumun çalışmaları o dönemde hem kamuoyunun hem de merkezi hükümetin yakın ilgisini çekmiştir. Merkezî yönetimi Ankara'da bulunan kurum, İstanbul'da operasyonel olarak ciddi bir varlık göstermekteydi (NA, 1955). Bu kapsamda kentin farklı bölgelerinde soğuk hava deposu tesisleri kurulmuş, mezbahalar inşa edilmiş ve balıkçılık araştırmaları için özel projeler geliştirilmiştir. 1954 yılında açılışı yapılan Beşiktaş Soğuk Hava Deposu, EBK'nın en dikkat çeken yatırımlarından biri olmuştur. Bu tesis, Birleşmiş Milletler Tarım ve Gıda Örgütü (FAO) desteğiyle inşa edilmiş ve Başbakan'ın da katıldığı bir törenle açılmıştır. Tam kapasiteye ulaşması beklenen bu tesisin donmuş et ve balık depolama kapasitesinin yanı sıra, buz üretimi ve sebze-meyve muhafazasına yönelik altyapısıyla da çok yönlü bir gıda koruma merkezi olması hedeflenmiştir. Beşiktaş dışında Zeytinburnu ve Haydarpaşa'da yapımı süren tesisler, hem günlük işleme kapasiteleri hem de saklama olanaklarıyla İstanbul'daki gıda lojistiği için stratejik bir önem taşımaktaydı. Bu yatırımlar, sadece iç tüketime değil, aynı zamanda dış ticaret potansiyeline de hizmet etmiştir (NA, 1955).

İncelenen konsolosluk raporuna göre, kurumun temel hedeflerinden biri de et ve balık piyasalarında yaşanan fiyat dalgalanmalarını dengelemekti. Bu amaçla EBK, üreticiden doğrudan alım yaparak arzı düzenlemeye çalışmış, ancak bazı durumlarda piyasa direnciyle karşılaşmıştır. Örneğin, kurbanlık kuzu alımlarında spekülatif fiyatları düşürme çabası, kurumun beklenenden daha az ürün satın almasıyla sonuçlanmış ve bu süreç zarar hanesine yazılmıştır. EBK, satın aldığı ürünleri mevcut ticari kanallar üzerinden daha yüksek fiyatla satışa sunmakla birlikte, gelecekte kendi mağaza ağını kurma niyetindeydi. Bu doğrultuda, dönemin yenilikçi perakende modeli olan Migros Türk ile iş birliğine gidilerek, mobil mağazalar ve self-servis marketler aracılığıyla ürün dağıtımı yapılmaya başlanmıştır (NA, 1955). Et ve Balık Kurumu'nun faaliyetleri yalnızca iç piyasayla sınırlı kalmamış, dış ticarete de yönelmiştir. 1954-55 kışında İtalya ve Macaristan'a balık ihracatı gerçekleştirilmiş, ürünlerin taşınmasında kurumun kendi soğutucu gemileri kullanılmıştır. Ayrıca İsrail'e donmuş balık, Dahran'daki Arap-Amerikan Petrol Şirketi'ne ise donmuş sığır eti satışı için müzakereler yürütülmüştür (NA,1955).

Bilimsel Araştırma ve Uluslararası Uzman Desteği

Balıkçılık alanında bilimsel kapasiteyi artırmayı amaçlayan EBK, Balıkçılık Araştırma Merkezi'ni kurarak Arar adlı araştırma gemisini devreye almıştır. Bu gemi, Almanya'da inşa edilmiş olup iki laboratuvar ve bilimsel araştırma ekipleriyle donatılmıştır. Merkezde İzlandalı ve Norveçli FAO uzmanlarının da katkısıyla Türk bilim insanlarının eğitilmesi hedeflenmiştir. Ayrıca Amerikan yapımı gırgır ağların kullanımıyla Karadeniz ve açık denizlerde balıkçılık potansiyelinin ölçülmesine yönelik seferler planlanmıştır. Bu süreçte Türk balıkçılarının modern avcılık teknikleriyle tanışmaları ve eğitilmeleri sağlanmıştır. Diğer yandan, EBK'nın yönetici kadrosunun Erzurum'a düzenlemiş olduğu bir ziyarette soğuk hava depolarının kurulması gündeme gelmiş, ayrıca Viyana'dan gelecek olan uzmanların Türkiye'de sosis üretimi için çalışmalara başlayacakları bilgisi kamuoyuyla paylaşılmıştır (Akşam, 1955). Raporda belirtildiği üzere, EBK'nn politikalarının İstanbul'daki et ve balık arzı ile fiyatlar üzerindeki etkilerini değerlendirmek için henüz erken olsa da, kurumun sahip olduğu yetkiler ve altyapı kapasitesi, piyasada belirleyici bir aktör olabileceğini göstermektedir. Bu durum, EBK'nın uluslararası düzeyde dikkatle izlenmesi gereken bir kamu kurumu olarak kabul edildiğini ortaya koymaktadır. Esasen 1950'lerden sonra Türkiye'de balıkçılık sektörünün geliştirilmesine yönelik atılan birtakım adımlar köklü birtakım değişimleri de beraberinde getirmiştir. Bu süreçte 1951 yılında Ekonomi ve Ticaret Bakanlığı tarafından gerçekleştirilen Su Ürünleri Kongresi ile sektörün temel sorunları ele alınmış ve gerekli çözümler için atılacak adımlar kararlaştırılmıştır. 1952 yılında Hidrobiyoloji Enstitüsü bünyesine dahil edilmek üzere satın alınan tekneler ile alt yapı güçlendirilmeye çalışılmıştır (Zengin, 2023).

1952 tarihli ve 871 sayılı Bakanlar Kurulu Kararnamesi uyarınca kurulan Et ve Balık Kurumu Türkiye'de et ve su ürünleri sektörlerinde hem üretim hem de piyasa regülasyonu alanlarında faaliyet göstermek üzere yapılandırılmıştır. Kararnamenin ikinci maddesinde belirtildiği üzere kurumun temel amacı, bu alanlarda üretim, ticaret ve sanayi faaliyetlerini düzenlemek, yönlendirmek ve desteklemektir. EBK, çiftlik hayvanları ve balığın yanı sıra bu ürünlerin işlenmiş biçimlerinin de iç ve dış ticaretine doğrudan katılabilmekte; aynı zamanda türlerin ıslahı, üretim tekniklerinin geliştirilmesi ve bu süreçleri destekleyecek altyapının kurulmasına yönelik faaliyetlerde bulunmaktadır. Bu kapsamda kurum, mezbaha ve soğuk hava depoları gibi işleme ve muhafaza tesislerini kurma ve işletme yetkisine sahiptir. Ek olarak, piyasalarda ortaya çıkabilecek dengesizliklere müdahale etme amacıyla, Ekonomi ve Ticaret Bakanlığı onayıyla fiyat

regülasyonu uygulayabilmekte ve hem kamu hem özel sektöre kredi mekanizmaları aracılığıyla mali destek sunabilmektedir (Resmî Gazete, 1952b). Bu dönemde EBK'nın teşekkülü basın organlarında da konu edilmiştir. 1931 yılında Toprak Mahsulleri Ofisi'ne bağlı olarak kurulmasına rağmen son iki seneden beri müstakil bir iktisadi devlet teşekkülü halinde yeniden teşkilatlanmasıyla Türkiye'de balıkçılığın inkişaf etmesinin kolaylaşacağı vurgulanmıştır. Gazete haberine göre EBK'nın balıkçılık sektörüne en önemli katkısı tanzim satışları ve Migros'un takviye edilmesiyle piyasanın düzenleneceği ve balıkların denize dökülmesi gibi durumları yaşayan üreticilerin korunması da sağlanacaktır. Kurumun Beşiktaş'taki soğuk hava deposunun ve buz fabrikasının yetersizliğine de vurgu yapılan gazete haberinde kurumun müdürü Kazım Öztürk'ün bu konudaki açıklamasına yer verilmiştir. Buna göre, bazı üreticilerin soğuk hava depolarını kiralamak istemelerine rağmen zaten son derece sınırlı olan bu depoların kiralanmasının mümkün olmadığı belirtilmiştir (Milliyet, 1955).

1950'li yılların ortalarında EBK'nın özellikle İstanbul'daki faaliyetleri dikkat çekici biçimde genişlemiş ve ABD İstanbul Başkonsolosluğu tarafından raporlanmıştır. Konsolosluk kaynaklarına göre, kurumun Beşiktaş'ta inşa ettiği FAO destekli soğuk hava deposu, dönemin en kapsamlı gıda lojistiği yatırımlarından biri olarak değerlendirilmiştir. Bu tesisin tam kapasiteye ulaşmasıyla günlük 100 ton buz üretimi, 2,000 ton donmuş balık ve 20,000 karkas et depolama kapasitesine ulaşması beklenmekteydi (NA, 1955). Kurum ayrıca Zeytinburnu ve Haydarpaşa'da yeni tesislerin inşasına başlamış ve FAO ile iş birliği içinde Türk balıkçılarının modern gırgır ağlarıyla avcılık tekniklerini öğrenmesi için eğitim projeleri yürütmüştür. Tüm bu gelişmeler, EBK'nin yalnızca bir tedarik ve dağıtım organizasyonu olmanın ötesinde, sektörler arası entegrasyonu ve yapısal dönüşümü hedefleyen bir kamu kurumu haline geldiğini göstermektedir. Konsolosluk raporunda da belirtildiği üzere, kurumun piyasa üzerindeki uzun vadeli etkileri henüz kesinleşmemiş olsa da, sahip olduğu kapsamlı yetkiler ve kurumsal kapasite dikkate alındığında yerel ve ulusal düzeyde belirleyici bir aktör olma potansiyeli taşımaktadır. EBK'nin piyasayı düzenleyici bir etkisinin olduğu, döneme dair bir gazete haberinden takip edilebilmektedir. İstanbul'da et tedariki konusunda yaşanan sorunların çözülmesi maksadıyla düzenlenen toplantıda üretim bölgelerindeki 4000 baş hayvanın kesilip sevkiyat yapılacağı ifade edilmiş, ancak daha da önemlisi İzmir Belediyesi'nin et narhının arttırılması için yapmış olduğu müracaat reddedilmiştir. Böylelikle karaborsanın ve fiyat dalgalanmalarının önlenmesine çalışılmıştır (Milliyet, 1957). Bu dönemde, balıkçılık konusunda incelemelerde bulunmak üzere ECA kapsamında Yunan balıkçılık uzmanı Türkiye'ye gelmiştir. Ankara'daki yetkililerle görüştükten sonra İstanbul'a gelişinde yaptığı açıklamada daha önce Amerikalı yetkililer tarafından sunulan raporları incelediğini ifade eden uzman, soğuk hava depoların gereken önemin verilmesi ve konuyla alakalı mütehassısların bu alandaki bilgilerini arttırmaları gerektiğini vurgulamıştır (Zengin, 2023; 120). Diğer yandan Türkiye'de balıkçılık faaliyetlerinin bilimsel bir çerçevede yönetilebilmesi ve ileriye dönük projeksiyonların yapılabilmesi için 1955 yılından itibaren balıkçılığa yönelik istatistiklerin tutulmaya başlaması ve 1967'den sonra da düzenli olarak anketlere dayalı olarak bu istatistiklerin yıllık şeklinde yayınlanması Türkiye'de bilimsel ve rasyonel bir balıkçılık sanayisi kurulmasının önünü açmıştır (Knudsen, 2009).

Soğuk Savaş Döneminde Türk-Amerikan Teknik İş Birliği: 1952-1953 Et Paketleme Projesi Örneği

1951-1953 yılları arasında faaliyet gösteren Mutual Security Agency (MSA) adlı Amerikan dış yardım kuruluşu esasen Marshall Planı'nın bir uzantısı olarak Sovyet etkilerine açık olan Avrupa ülkelerine iktisadi ve teknik yardım faaliyetlerini yürütmek amacıyla tesis edilmiştir. Daha sonra Amerika Birleşik Devletleri Uluslararası Kalkınma Ajansı (USAID)'in öncüsü olan Foreign Operations Administration (FOA)'ya dönüşecek olan MSA'nın Türkiye'deki önemli faaliyetlerinden biri de et ve balık endüstrisinin modernleştirilmesi için teknik yardım ve finansman sağlama girişimi olmuştur (Birinci, 2007). 1950'li yıllarda Amerika'nın Türkiye'ye verdiği teknik yardımların bir örneğini oluşturan et ve balık paketleme sektöründeki girişimler diplomatik yazışmalarda bütün detayları ile yer almıştır. 1952-53 yılları arasında gündeme gelen Türkiye Et Paketleme Projesi bu dönemin teknik yardım anlayışının somut bir örneğini sunmaktadır. Mutual Security Agency (MSA) yetkileri olan Macaulay ve G. H. Knutson arasında yapılan görüşmeye göre Noble Raporu'na dayalı olarak Türkiye Et Paketleme Tesisi kurulması gündeme alınmıştır (NA, 1952a). Bu konunun detaylarıyla araştırıldığı Noble Raporu'na göre Türkiye'de Toprak adıyla faaliyet gösteren mühendislik şirketi, MSA ve Ankara'daki yetkililer arasında yapılacak olan görüşmeler sonucunda bir yol haritası belirlenecekti. Rapora göre Amerikan Et paketleme Enstitüsü'nün kalifiye mühendislik firmaları için danışılması uygun olsa da Henschin, Everds&Crombie ile Smith, Brubaker and Egan adlı iki firma da tavsiye olunmaktadır. Yapılan görüşmelerde Türkiye'nin et endüstrisindeki mevcut kapasitesinin yetersizliği, hem iç tüketim hem de potansiyel ihracat açısından önemli bir darboğaz oluşturmaktaydı. Noble Misyonu'nun hazırlamış

olduğu rapora göre Türkiye'deki mevcut tesisler modern standartlara uzak olmakla birlikte verimlilik de son derece düşüktü.

MSA yetkilisi George H. Knutson'ın aktardığı bilgiye göre, Türkiye'deki tesislerin açılması için Noble Raporu'nda belirtilen beş yıllık süre oldukça uzundu, ancak buna mukabil Bay Macaulay'ın öngördüğü iki yıllık süre de oldukça kısaydı. MSA'nın yürüteceği bu teknik yardım için hatırı sayılır bir bütçe ayrılacağı belirtilmiştir. Bunun dışında Noble Misyonu'nun önerileri arasında ABD yönetimi ve işletme firmasının mühendislik firması ile iş birliği içinde çalışması ve Amerikan know-how ve ekipman için MSA tarafından bir milyon doların ayrılacağı belirtilmiştir (NA, 1952a).

Proje, Türkiye'nin dört farklı bölgesinde tesis kurulmasını öngörmekteydi. Erzurum, Doğu Anadolu'nun hayvancılık potansiyelinden yararlanmak üzere öncelikli pilot tesis olarak planlanmıştır. Bölgenin hammadde zenginliği ve stratejik konumu bu seçimde etkili olmuştur. Konya, İç Anadolu'nun tarım-hayvancılık merkezi konumundan hareketle ikincil üretim merkezi olarak tasarlanmıştır. Ankara, başkent konumu ve merkezi lokasyonunun sağladığı lojistik avantajlar nedeniyle önemli bir üretim merkezi olarak öngörülmüştür. En büyük tüketim merkezi olan İstanbul'da kurulacak olan tesis ise hem yerel pazar hem de potansiyel ihracat için stratejik konumdaydı. Projenin toplam maliyeti 400.000-800.000 dolar arasında MSA hibesi ile karşılanacaktı. Bu tutar modern et işleme ekipmanları, teknik danışmanlık hizmetleri, personel eğitimi programları ve tesis tasarım ve kurulum masraflarını kapsıyordu. MSA (Mutual Security Agency), ana finansör ve koordinatör kurum olarak projenin genel yönetiminden sorumluydu ve ajans içinde Alexis Doster'in koordinatörlüğünde multidisipliner bir ekip oluşturulmuştur. John H. Noble liderliğindeki teknik danışmanlık ekibi, Türkiye'nin et endüstrisi durumunu analiz ederek 16 maddelik kapsamlı tavsiye raporu hazırlamıştır (NA, 1952a).

Et ve Balık Kurumu, projenin ana uygulayıcı kurumu olarak teknik ve idari koordinasyonu üstlenmekteydi. Refet Artuner, Genel Müdür Yardımcısı sıfatıyla Türk heyetinin başkanı olarak müzakerelerde aktif rol almıştır. Yavuz Üstün, Makine Ekipman Departmanı Başkanı olarak teknik konularda Türk tarafının başlıca uzmanı olarak görev yapmıştır. Nail Artuner ise New York Türk Büyükelçiliği Ticari Ataşesi olarak diplomatik kanallar aracılığıyla koordinasyonu sağlamıştır. Palmer House Hotel'de 30 Ocak 1953'te gerçekleştirilen Chicago toplantısı, projenin nihai şeklini belirlemede dönüm noktası olmuştur. Noble-Barnett-Coultas Misyonu'nun 16 tavsiyesinin görüşüldüğü toplantıda, 12 madde üzerinde anlaşma sağlanırken 4 konuda anlaşmazlık devam etmiştir (NA, 1953). Uzlaşma sağlanan konular arasında temel tesis tasarımı, ekipman standartları, eğitim programları ve finansman mekanizmaları yer alırken; Ankara tesisinin zamanlaması, yönetim yapısı modeli, Amerikan uzman sayısı ve mühendislik koordinasyonu konularında anlaşmazlık yaşanmıştır. MSA merkezinde 4 Şubat 1953'te yapılan Washington görüşmelerinde, Chicago'da çözülemeyen konular ele alınmıştır. Alexis Doster'in koordinatörlüğünde gerçekleştirilen görüşmelerde, her iki taraf da pragmatik yaklaşım sergileyerek uzlaşma sağlamıştır. En önemli anlaşmazlık alanlarından biri yönetim modeli konusundaydı (NA, 1953). Amerikan tarafı projenin tamamen Amerikan şirketi kontrolünde, "anahtar teslimi" bir sistemle yürütülmesini önerirken, bu model hızlı sonuç alma ve kalite kontrolü açısından avantajlı görülüyordu. Türk tarafı ise Et ve Balık Kurumu'nun genel sorumluluğu üstlendiği, Amerikan uzmanların Türk Genel Müdür koordinasyonunda çalıştığı hibrit bir model önerdi. Uzlaşma sonucunda Türk tarafının önerisinin kabul edildiği nihai modelde, Et ve Balık Kurumu genel koordinasyonu üstlenecek, Amerikan uzmanlar teknik konularda tam yetki sahibi olacak ve teknoloji transferi ile personel eğitimi öncelik kazanacaktı. Tesisin kurulum sırası konusunda da farklı görüşler mevcuttu. Noble Misyonu önce Erzurum'da pilot uygulama ile deneyim kazanılması, başarılı sonuçlar alındıktan sonra diğer tesislere geçilmesi yaklaşımını benimserken, Türk tarafı ülkenin acil ihtiyaçları nedeniyle mümkün olduğunca eş zamanlı inşaatın başlatılmasını istiyordu (NA, 1953). Çözüm olarak Erzurum'un öncelikli statüsü korunarak, diğer tesislerin de hızlandırılmış programa alınması kararlaştırıldı. Anlaşmazlık yaşanan diğer bir konu da uzman sayısı ve niteliği idi. Türk tarafı sekiz Amerikalı uzman talep ederken, Amerikan tarafı üç uzmanın yeterli olacağını düşünüyordu. Bu konuda uzlaşma, görev tanımlarının netleştirilmesi ile sağlandı. Proje Türkiye açısından önemli kazanımlar vaat ediyordu. Modern et işleme teknolojilerine erişim, yerli uzman kadro eğitimi, istihdam yaratma ve katma değer artışı, uluslararası standartlarda üretim kapasitesi gibi faydalar öngörülüyordu. ABD açısından ise hedefler farklıydı. Türkiye'nin NATO müttefiki olarak güçlendirilmesi, Amerikan teknoloji ve ekipmanına bağlılık, diğer gelişmekte olan ülkeler için örnek teşkil etme ve Amerikan şirketleri için yeni fırsatlar yaratma gibi stratejik amaçlar güdülüyordu. Bu proje, MSA'nın 1951-1953 faaliyet döneminin son aylarında gerçekleşmiştir. 1953 yılında MSA'nın Foreign Operations Administration (FOA) haline dönüşmesi, projenin yeni kurumsal çerçevede devam etmesini gerektirmiştir.

1955 yılında ABD Dışişleri Bakanlığı'na ait bir belgede Türkiye'de et ve balık sektöründeki devlet müdahalesinin kapsamlı bir analizi yer almaktadır. 1950'li yılların ortalarında Türkiye'nin gıda sektörünün modernizasyonunda kararlı müdahalelerde bulunduğuna yer verilen belgede Et ve Balık Kurumu'nun ülke genelinde fiyat istikrarı ve et ve balık ticareti, üretimi ve endüstrisindeki tüm çalışma ve araştırmaları yürütmek üzere tasarlandığına değinilmiştir. Merkezi Ankara'da bulunan kurumun İstanbul'daki operasyonları, modern soğuk hava deposu tesisleri ve deneysel balıkçılık projelerini kapsıyordu. Belgede ayrıca yer verilen bilgiye göre, FOA desteğiyle Beşiktaş'ta kurulan soğuk hava deposu tesisi, günlük 100 metrik ton buz üretimi, 400 metrik ton buz depolama alanı, 2000 metrik ton donmuş balık ve 20.000 karkas donmuş et depolama kapasitesine sahipti (NA, 1955). Kurumun fiyat istikrarını sağlama misyonu dikkat çekiciydi. İstanbul genel müdürü, organizasyonun kuzu, sığır eti ve balık satın alarak geleneksel fiyat dalgalanmalarını azaltmaya çalıştığını, aynı zamanda balıkçılar ve çiftlik hayvanı satıcılarının çıkarlarını gözettiğini belirtiyordu. Birlik, satın aldığı ürünleri üreticiye ödenen fiyattan daha yüksek fiyata satarak kar elde ediyordu ve gelecekte kendi satış mağazalarını kurma planları vardı. Migros Türk ile yapılan anlaşma da dağıtım kanallarının genişletilmesi açısından önemliydi. Uluslararası ticaret boyutunda, Birlik geçen kış İtalya ve Macaristan pazarlarına balık satmış, kendi küçük soğutucu gemileriyle taşımacılığı üstlenmişti. İsrail'e donmuş balık ve Dahran'daki Arap-Amerikan Petrol Şirketi tesisine donmuş sığır eti satışı için müzakerelerin devam ettiği belirtiliyordu. Kurumun araştırma ve geliştirme faaliyetleri de kapsamlıydı. Yeni kurulan Balıkçılık Araştırma Merkezi bünyesinde laboratuvarlar ve 175 tonluk araştırma gemisi R/S Arar da vardı. 1952'de Almanya'da inşa edilen Arar, iki laboratuvar içeriyor ve altı bilim insanı ile on bir mürettebat üyesi barındırabiliyordu. İki FAO uzmanı genç, Türk bilim insanlarıyla çalışarak Karadeniz'in balıkçılık potansiyelini araştırıyordu. Amerika'dan getirilen California tipi gırgır ağları ve İzlandalı yapımı ağlarla deneyler yapılıyor, FOA misyonu tarafından Türk balıkçılarının eğitimi için Amerikan uzmanlar sağlanıyordu (NA, 1955).

Türkiye'de Balık Konserve Endüstrisi

Türkiye'de 1950 ile 1954 yılları arasında balık konserve endüstrisinde mevcut altyapı ve kapasite konusu Amerikan konsolosluk belgelerine yansıyan iktisadi konular arasındaydı. ABD hariciyesine sunulan raporlar, dönemin Türk balıkçılık sektörünün kapsamlı bir portresini ortaya koymakla birlikte bu sektörde hangi adımların atılabileceği konusunda da önemli bilgiler ihtiva etmektedir. ABD'nin İstanbul Konsolosluğu tarafından düzenlenen belgede 1950 yılı itibarıyla Türkiye'de faaliyet gösteren yedi balık konserve fabrikasının faal halde olduğu bilgisi yer almıştır. 21 Temmuz 1949 tarihli 63 numaralı olan Türk Balıkçılık Endüstrisi raporunda bu fabrikaların isimleri ve üretim kapasiteleri şu şekilde açıklanmıştır; 1950 yılı itibarıyla Türkiye'de yedi ana balık konserve fabrikası faaliyet göstermekteydi (NA, 1950). Bu fabrikalar İstanbul merkezli olup, günlük üretim kapasiteleri 8 saatlik vardiya başına 1000 ila 5000 kilogram arasında değişmekteydi. En büyük tesis olan Konservecilik Türk Anonim Ortaklığı günde 5000 kg kapasiteye sahipken, Marmara Konserve Fabrikası 2000 kg, İdeal Konserve Fabrikası ise 1500 kg kapasiteye sahipti. Ali Rumani, Çiftlik Konserve Fabrikası, Pişkin Konserve İmalathanesi ve Geyik Konserve Fabrikası gibi diğer tesisler ise her biri 1000 kg günlük kapasiteyle faaliyet göstermekteydi. Bu konserve fabrikalarının önemli bir özelliği, münhasıran balık konservesi üretimi yapmamalarıydı. Mevsimsel koşullara ve mevcut ham maddeye göre et, meyve, sebze ve marmelat gibi çeşitli ürünlerin konservesini de üretebilmekteydiler. Bu durum, dönemin Türkiye'de gıda sanayisinin çok ürünlü yapısını ve esnekliğini göstermektedir (NA, 1950).

1952 yılında Kaliforniyalı balık uzmanı G.B. Dollar tarafından hazırlanan detaylı rapor, Türk balıkçılık endüstrisindeki teknolojik durumu çarpıcı şekilde ortaya koymaktadır. Dollar'ın bulgularına göre, Türkiye'de kullanılan balık işleme yöntemleri ABD'deki uygulamalardan yaklaşık 35 yıl gerideydi (NA, 1952b). Bu gerilik hem üretim süreçlerinde hem de ekipman teknolojisinde kendini göstermekteydi. Balık işleme süreci oldukça ilkel yöntemlerle gerçekleştirilmekteydi. Balıklar 200-300 kg taşıyan teknelerle kıyıya getirilmekte, ardından elle işleme bölümüne taşınmaktaydı. Yıkama, baş ve kuyruk kesme işlemleri tamamen manuel olarak işçiler tarafından yapılmaktaydı. Sardalya ve diğer küçük balıkların donmuş hale getirilmesi için tuzlu su çözeltisi kullanılmakta, balıklar ahşap ve tel bez raflar üzerine yerleştirilerek güneş altında kurutulmaktaydı. Rapora göre, hava koşulları uygun olmadığında ise ahşap veya kömür ateşi ile kurutma işlemi yapılmaktaydı. Ön pişirme işlemi, rafların dikdörtgen fırına yerleştirilmesi ve buhar ile pişirme ya da kuru ısıtma ile pişirme şeklinde iki farklı yöntemle gerçekleştirilmekteydi. Dollar, hazırladığı raporda bu yöntemlerden ikincisinin daha iyi sonuçlar verdiğini belirtmiştir. Pişirme sonrasında ise balıklar soğutularak teneke kutuya yerleştirilmekte ve soğuk zeytinyağı eklenmekteydi (NA, 1952b). Mevcut üretim yöntemlerinin en kritik sorunu, tüm bileşenlerin soğuk konulması nedeniyle teneke kutularda vakum oluşmamasıydı. Bu durum, ürünün yüksek rakımlara çıkarılması halinde tenekelerin şişmesine ve bozulma ile kontaminasyon riskine yol açmaktaydı (NA, 1952b).

Sterilizasyon süreci de manuel kontrol altında yürütülmekte, sadece termometre ve basınç göstergesi bulunmaktaydı. Operatörün deneyimine bağlı bu sistem, sıcaklık ve süre hatalarına açık olup, bozulma ve kontaminasyon riskini artırmaktaydı. Teneke kutu üretimi de aynı derecede ilkel yöntemlerle yapılmaktaydı. Teneke levhalar elle metal makasla kesilmekte, gövde çekiç ile şekillendirilmekte ve alt kısım lehim ile sabitlenmekteydi. Bu manuel süreçlerde herhangi bir test yöntemi bulunmaması, doldurmadan önce ve sterilizasyon sırasında sızıntılara neden olmaktaydı (NA, 1952b).

Dollar'ın araştırması sırasında ziyaret ettiği balıkçılık merkezleri arasında Bandırma, Erdek, Marmara, Çanakkale, Lapseki, Çardak ve Gelibolu bulunmaktaydı. Bu bölgelerdeki balıkçılarla yapılan görüşmelerde, modern yöntemler ve ekipman eğitimi ile günde yaklaşık 15 ton balık sağlayabilecekleri belirlenmişti. Ancak balıkçıların karşılaştığı temel ekonomik zorluk, yakaladıkları balığı pazara götürdüklerinde uygun fiyat alamamalarıydı. Sermaye eksikliği nedeniyle müşteri bulamayan balıkçılar için önerilen çözüm, sezonun başında konserve operatörleri ile anlaşma yapabilmeleriydi. Ziyaret edilen limanların tümü modern konserve tesisi kurulumu için önemli sınırlamalara sahipti. Bu sınırlamalar arasında taze su eksikliği, yakıt sorunu, elektrik gücü yetersizliği, demiryolu taşımacılığı problemleri ve yedek parça için makine dükkanlarının bulunmaması yer almaktaydı (NA, 1952c). Modern sardalya konserve fabrikası için taze su gereksinimi kritik öneme sahipti. Dollar, kapsamlı değerlendirmeleri sonucunda Marmara Adası ve Gelibolu olmak üzere iki lokasyonu uygun bulmuştur. 1200 kişilik nüfusunun %90'ının geçimini balıkçılıktan sağladığı bir yer olan Marmara Adası, Ege Denizi ve Boğazlar üzerinden Karadeniz'e göç eden uskumru ve orkinos türü balıklar için önemli bir duraktı. Adada mevcut olan küçük Ender Konserve Şirketi'ne ait tesis, yeniden şekillendirilerek günde 10-15 ton kapasiteli modern bir fabrikaya dönüştürülebilirdi. Gelibolu ise yaklaşık 10.000 nüfuslu bir şehir olarak daha iyi ulaşım imkanlarına sahipti. Bölgede bulunan beş küçük konserve fabrikasından biri günde 15.000 adet konserve üretim kapasitesine sahip iken büyük kargo gemilerinin yanabildiği liman, lojistik açıdan da oldukça avantajlı bir konumdaydı (NA, 1952c).

Raporun hazırlandığı yıllarda henüz emekleme aşamasında olan balıkçılık endüstrisinde balık sakatatlarına (temizlenen balıktan arta kalan kısım) üretim süreçlerinin hiçbir aşamasında yer verilmemiştir. Bu nedenle, Dollar'ın raporunda yer alan konularda biri de balık sakatatları olmuştur. Dollar'a göre balık sakatatları balık yemi ya da balık yağı olarak değerlendirilmeliydi. Halihazırda balık sakatatlarının tavuk ve hindi gibi kanatlılar için hayvan yemi olarak kullanıldığına değinilmiş ve hatta bir dönemler gübre olarak kullanılan balık sakatatlarının Amerika'da oldukça pahalı bir ürün olduğuna yer verilmiştir. %60 ya da %70 oranında zengin bir protein kaynağı olan balık yeminin bu öneminin yanında balık yağı da kemik gelişimi açısından önem taşıyan D vitamini kaynağı olduğu için Türkiye'deki balık endüstri altyapısının bu yönde bir dönüşüm geçirmesi gerekmekte olduğu belirtilmiştir (NA, 1952c).

Marmara Adası'nda inşa edilmekte olan soğuk hava deposu sayesinde her türlü balık çeşidinin uygun koşullarda saklanabileceği ve orkinos ve uskumru balıklarının konserve fabrikalarında işlenmek üzere bu tesiste depolanabileceğine yer verilmiştir. Bu sayede dondurulmuş balıklar aynı zamanda yurtdışına ihraç edilebilecektir. Geleneksel bir üretim altyapısına sahip olan Ender Konservecilik adlı şirket, saatte 750 adet konserve üretim kapasitesine sahip olmakla birlikte üretim tesisindeki ekipmanlar modern makinalarla değiştirilirse daha yüksek kapasitede üretim olanağı elde edilmiş olacaktır.

Söz konusu rapor hazırlanırken Marmara Adası, Gelibolu ve Çanakkale'de yerel idarecilerin nezaretinde bölgede balıkçılarla görüşmeler gerçekleşmiştir. O tarihlerde 10 bin nüfusluk bir yerleşim yeri olan Gelibolu'da günlük 15000 adet üretim kapasiteli irili ufaklı konserve fabrikaları mevcuttu ve iyi geçen bir sezon sonunda toplam 500.000 adet konserve paketlenebiliyordu. Yapılan görüşmeler neticesinde verimli bir tesis kurulabilmesi için balık arzı, ulaştırma, balıkçılık bölgesine yakınlık, su kaynağı, atıkların bertaraf edilmesi, rahatsız edici kokular, bakım ve diğer malzemeler gibi konular gündeme gelmiştir (NA, 1952c). Raporda belirlenen lokasyonların hiçbiri bu gereksinimleri karşılamadığı ortaya konmuş, İstanbul'un ise en uygun yer olacağı ortaya konmuştur. İstanbul'u soğuk hava depolarına sahip olması ve ticaret merkezlerine olan yakınlığı ile birlikte konserve tesislerinde yer alacak olan makinaların bakım ve onarımına destek olacak elektrik, makine ve tamir imkanlarının mevcudiyeti tahmin edilen büyüklükte bir tesis için olumlu parametreler olarak değerlendirilmektedir. Orkinos dışında uskumru ve sardalya türü balıkların işleneceği konserve tesisi için gerekli olan malzeme ve inşaatın tüm detayları raporda yer almıştır. Tesis için satın alınacak ekipmanlar 126.000 USD tutarında hesaplanmıştır (NA, 1952b). Marshall Planı kapsamındaki faaliyetler 1952 yılı itibarıyla sona ermiş olsa da ABD'nin Türkiye'ye yaptığı teknik yardımlar ilerleyen yıllarda da devam etmiştir. Cumhurbaşkanı Celal Bayar'ın 1955 yılında Türkiye Büyük Millet Meclisi'ni açış konuşmasında EBK'nin üretim ve tüketim bölgelerinde 36 fabrika ve tesis ile üç et kombinası ve 50'yi aşkın soğuk hava ve buz fabrikasını meydana getirdiğini aktarmış olması

balıkçılık endüstrisindeki somut ilerlemeyi göstermektedir (Özer, 2023).

Çalışma kapsamında incelenen belgeler, 1950'li yılların başında Türkiye'nin balıkçılık endüstrisinin durumunu ve modernizasyon ihtiyacını detaylı şekilde ortaya koymaktadır. Amerika Birleşik Devletleri'nin Türkiye Sanayi Kalkınma Bankası aracılığıyla sektöre destek verme planları, dönemin uluslararası iş birliği anlayışını da yansıtmaktadır. Ancak belgelerde, önerilerin ne ölçüde hayata geçirildiğine dair bilgi bulunmamaktadır.

SONUÇ

1950'li yılların başından itibaren Türkiye'nin NATO üyeliği ve Batı ittifakına eklemlenme süreciyle birlikte, ABD'nin Türkiye'ye yönelik ilgisi ekonomik kalkınma alanında somut projelere dönüşmüştür. Bu çalışmada incelenen Amerikan diplomatik belgeleri, balıkçılık sektörünün modernizasyonunun salt teknik bir mesele olmadığını, aynı zamanda Soğuk Savaş döneminin jeopolitik stratejilerinin bir parçası olarak ele alındığını göstermektedir. ABD'nin Türk balıkçılık endüstrisine yönelik yaklaşımı üç temel eksende şekillenmiştir. İlk olarak, müttefik bir ülkenin ekonomik kapasitesini güçlendirerek Sovyet etkisine karşı direncini artırma hedefi; ikinci olarak, Amerikan teknolojisi ve ekipmanına bağımlılığı artırarak uzun vadeli ticari ilişkiler kurma amacı; üçüncü olarak ise Türkiye'yi diğer gelişmekte olan ülkeler için başarılı bir modernleşme örneği haline getirme stratejisi. Et ve Balık Kurumu'nun kuruluşu ve faaliyetleri, 1950'li yıllarda Türkiye'de devlet müdahaleciliği anlayışının balıkçılık sektöründe nasıl tezahür ettiğini ortaya koymaktadır. FOA desteğiyle kurulan soğuk hava depoları, araştırma gemisi Arar'ın devreye alınması ve modern avcılık tekniklerinin öğretilmesi gibi girişimler, kurumun sadece piyasa düzenleyicisi değil, aynı zamanda sektörel dönüşümün öncüsü rolünü üstlendiğini göstermektedir.

Kaliforniyalı uzman G. B. Dollar'ın raporu, Türk balıkçılık endüstrisinin teknik açıdan 35 yıllık bir gecikme yaşadığını ortaya koymuştur. Bu tespit, dönemin kalkınma politikalarında teknoloji transferi ve uzman desteğinin önemini vurgulamaktadır. Ancak önerilen çözümlerin İstanbul merkezli olması, coğrafi dengesizlikleri derinleştirme riski taşımaktadır. MSA (Mutual Security Agency) destekli et paketleme projesi, Amerikan dış yardım sisteminin işleyişi hakkında değerli bilgiler sunmaktadır. Chicago ve Washington'da gerçekleştirilen müzakerelerde yaşanan anlaşmazlıklar, teknoloji transferinde ulusal egemenlik ile modernleşme gerekliliği arasındaki gerilimi yansıtmaktadır.

Araştırmanın bulguları, 1950'li yılların Türk-Amerikan ilişkilerinde balıkçılık sektörünün ekonomik boyutunun yanında diplomatik bir araç olarak da kullanıldığını göstermektedir. Amerikan uzmanların hazırladığı detaylı raporlar, salt teknik analiz olmaktan öte, Türkiye'nin ekonomik potansiyelini ve yatırım fırsatlarını değerlendiren stratejik belgeler niteliği taşımaktadır. Bu dönemde başlatılan modernleşme girişimleri, Türk balıkçılık sektörünün sonraki on yıllarındaki gelişim rotasını belirlemiştir. Ancak teknoloji transferinde yaşanan bağımlılık ilişkisi, uzun vadede sektörün özgün bir gelişim çizgisi izlemesini sınırlamış olabilir. Gelecek araştırmalarda, bu dönemin modernleşme politikalarının 1960'lar ve sonrasındaki balıkçılık sektörü üzerindeki uzun vadeli etkilerinin incelenmesi, konunun daha kapsamlı anlaşılmasına katkı sağlayacaktır.

Etik Standartlara Uygunluk

Yazarların Katkısı

RB ve CA çalışmanın tasarlanmasında, makalenin ilk taslağının hazırlanmasında, yazımında ve yorumlanmasında yer almıştır. Tüm yazarlar makalenin son halini okuyup onaylamıştır.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını beyan ederler.

Etik Kurul Onayı

Yazarlar resmi onam gerekmediğini beyan etmektedir.

Finansman

Bu araştırma, hiçbir hibe, fon veya başka bir finansman desteği almamıştır.

Veri Kullanılabilirliği

Çalışmanın bulgularını destekleyen verilerin tamamı makale içerindedir.

Yapay Zeka Açıklaması

Bu araştırma makalesinde üretken yapay zeka kullanılmamıştır.

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