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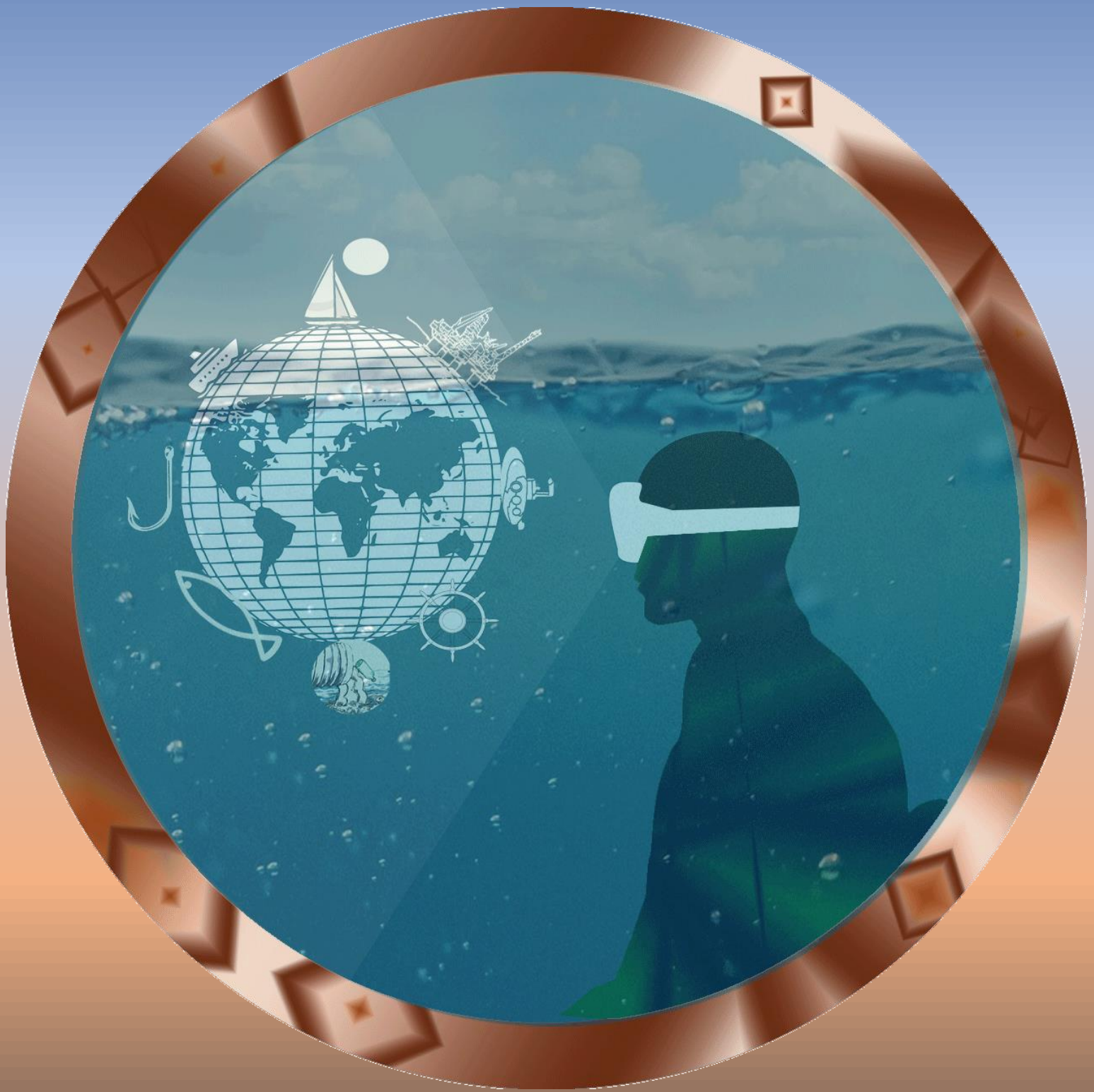

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M A R I N E A N D L I F E S C I E N C E S

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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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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:

FAO. (2016). *The State of World Fisheries and Aquaculture: Contributing to food security and nutrition for all*. Rome. 200 pp.

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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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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.

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Innovative application of marine biomaterials in microwave and antenna technologies: The study of *Monodonta turbinata*

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A B S T R A C T

This study investigates to use electromagnetic properties of *Monodonta turbinata* shells as a sustainable biomaterial for microwave and antenna applications. Shells were collected from Iskenderun Bay, Türkiye, and processed by washing, drying, and grinding to obtain fine powders. These powders were calcined at 800°C, 1000°C and 1200°C to produce samples. The calcined powders were then analyzed for their complex dielectric properties within the 1 GHz to 20 GHz frequency range. The dielectric measurements revealed significant changes in the electromagnetic properties with varying calcination temperatures, highlighting the potential of *M. turbinata* shells as tunable dielectric materials. The materials were further used as substrates in traditional patch antenna simulations. The results showed excellent behavior in terms of the S11 parameter, with a notably wider bandwidth compared to conventional dielectric substrates (i.e. FR-4 and RT-5880). These findings demonstrate the feasibility of using *M. turbinata* shells as eco-friendly and cost-effective materials for advanced microwave and antenna technologies. The study not only suggests a novel application of marine biomaterials but also provides insights into the potential of sustainable alternatives in the development of broadband communication systems.

INTRODUCTION

Monodonta turbinata, a marine gastropod, is widely distributed across the rocky intertidal zones of the Mediterranean Basin, including the Aegean, Tyrrhenian, Ionian, Adriatic, and Cretan Seas (Alyakrinskaya, 2010; Conti et al., 2006). This species thrives in challenging environments, exhibiting remarkable resilience to extreme conditions such as prolonged drought, high temperatures, wave impacts, and water pollution (Conti et al., 2006). *M. turbinata* primarily feeds on algae and plant residues scraped from rocks, playing a critical ecological role in maintaining the balance of marine ecosystems (Alyakrinskaya, 2010). Its shell, composed predominantly of calcium carbonate ($CaCO_3$) in aragonite form, exhibits a natural hierarchical structure that enhances its mechanical strength and durability, making it an attractive candidate for engineering and material science applications.

Till date, studies on *M. turbinata* have primarily focused on biological and ecological aspects, including its role as a bioindicator of heavy metal pollution, nutritional properties, chitin and chitosan production from shells and population dynamics (Uğurlu, 2024; Duysak and Ersoy, 2014; Alyakrinskaya, 2010; Boucetta et al., 2008; Conti et al., 2017, 2006; Belhaouari and Boutiba, 2009). Despite its abundance along Mediterranean coasts, particularly in Iskenderun Bay, and its lack of economic significance, limited attention has been given to its potential as a biomaterial for advanced technological applications. The exploration of marine shells as functional materials has gained traction in recent years, with particular emphasis on their electromagnetic properties. For example,

Alyakrinskaya (2010) noted that the compositional uniformity and resilience of gastropod shells make them promising candidates for industrial applications such as bone implants, cement additivies, catalysts and adsorbents.

Recent studies have demonstrated the potential of marine biomaterials for electromagnetic and microwave technologies. Uğurlu et al. (2023) investigated the dielectric properties of *Diadema setosum* shells, demonstrating their suitability as substrate layer for microwave and radome applications. Their work highlighted how thermal treatment processes could optimize the dielectric behavior of such shells, paving the way for their use in high-frequency systems. Similarly, Raman et al. (2023) used biomaterials for microwave applications by using Arecanut palm leaf. These studies underscore the growing interest in natural biomaterials for electromagnetic applications, driven by their eco-friendliness, cost-effectiveness and tunable properties.

The dielectric properties of marine biomaterials have been a focal point in advancing wireless communication technologies (Kaidarova et al., 2023). For example, Wang et al. (2022) studied the marine polysaccharide-based electromagnetic absorbing and shielding materials and its design principles. Bedi et al. (2022) explored biosensor fabrication which is marine biological macromolecules as matrix material. Moreover, Sun et al. (2022) explored the enhancement of triboelectric performance in chitosan-based materials. showing their potential in environmentally friendly and wearable triboelectric nanogenerators for multi-modal sensing applications (i.e including motion, pressure, and humidity detection). Sahin et al. (2023) demonstrated that polyaniline based composites with different Cu contents exhibit high microwave shielding effectiveness in the 0-8 GHz range, and this effectiveness can be adjusted by varying the amount of polyaniline. Wang et al. (2025) have analyzed a novel carbothermal shock method for synthesizing carbon-supported nanoscale high-entropy alloys, achieving efficient electromagnetic wave absorption through tailored electron migration modes, anisotropic dipole polarization, and ultra-thin composite designs. Rupčić et al. (2024) evaluated the electromagnetic radiation absorption efficiency of biomaterial-based harvest residues, revealing that factors like thickness, moisture, and frequency significantly influence transmission reduction, with soybean straw achieving a maximum attenuation of 43.80 dB at 4.93 GHz.

The aim of the study wasto bridge the literatüre gap by investigating the electromagnetic properties of *Monodonta turbinata* shells and their applications in microwave and antenna technologies. *M. turbinata* shells were chosen due to their natural abundance, biocompatibility, and unique microstructure, which creates for tunable dielectric behavior when subjected to different calcination temperatures. Unlike conventional materials such as FR-4 and RT-5880, *M. turbinata* shells offer a sustainable and cost-effective alternative with promising electromagnetic performance across a wide frequency range. By analyzing their dielectric properties and integrating them as substrates in microwave equipment, this study explores their feasibility for high frequency systems. The findings not only contribute to the development of eco-friendly materials for advanced communication systems but also provide a new perspective on the utilization of marine biomaterials in engineering applications. This work represents a significant step toward the broader adoption of renewable biomaterials in modern electromagnetic technologies.

MATERIAL AND METHODS

Monodonta turbinata, a marine biomaterial, was collected from the rocky coastal areas of Iskenderun Bay, Türkiye, using a sharp knife to carefully extract the shells from the marine environment. This area was chosen due to its rich biodiversity and the availability of shells suitable for this study. Once the shells were collected, the soft tissues inside were removed manually to ensure that only the shell material was used in subsequent processes. The cleaned shells were then subjected to a two-step washing procedure. Initially, they were washed with tap water to remove any surface debris and salts. Following this, the shells were further washed with bidistilled water to eliminate any remaining contaminants, ensuring the purity of the material for further analysis.

After the washing procedure, the shells were dried in an oven set to 70°C for 24 h. This drying step is crucial to reduce the moisture content of the shells and prepare them for grinding, as excess moisture could affect the subsequent processing and analysis. Once completely dried, the shells were ground into a fine powder using a grinder, making them suitable for various material characterizations, including electromagnetic testing. The powdered shells were then stored at +4°C in sealed containers until further analysis, ensuring that they remained stable and uncontaminated during storage (Figure 1).

Following the methodology adapted from Park et al. (2007), the dried *M. turbinata* shell powders were calcined at three different temperatures to evaluate the effect of thermal treatment on their properties. The calcination process was performed in a muffle furnace (Protherm-Furnaces) with a precise heating rate of 5°C/min. The powders were calcined at temperatures of 800°C, 1000°C and 1200°C for 1 h. These temperatures were selected to explore the impact of

different calcination conditions on the electromagnetic properties of the shell material. The choice of calcination temperatures was based on previous studies and theoretical models suggesting that higher temperatures would lead to enhanced crystallization and potentially improve the material's dielectric properties (Figure 1).

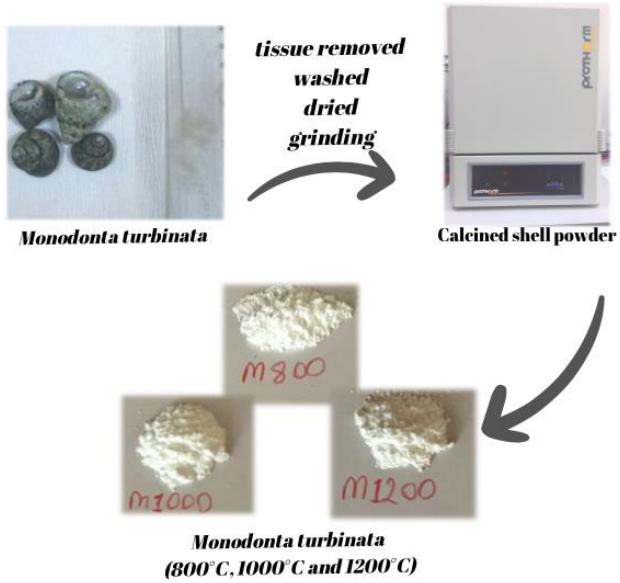

Figure 1. Calcination process in *M. turbinata* shells

Once calcined, the shell powders were carefully stored in a desiccator to maintain their dryness and prevent any absorption of moisture from the air, which could alter their dielectric characteristics. Each batch of calcined material was labeled according to its treatment temperature: M1 for the 800°C sample, M2 for the 1000°C sample, and M3 for the 1200°C sample. The labeled powders were then transferred to sealed falcon tubes, ensuring they remained isolated from environmental factors and ready for the next phase of the study. These samples were prepared specifically for use in experiments designed to measure their complex dielectric properties in microwave analysis. After completing the preparation steps, the samples underwent detailed microwave testing to investigate their electromagnetic behavior, forming the core of the study.

Microwave Analysis

In the microwave analyses, precise calibration was performed to ensure accurate measurements of the complex dielectric parameters of the materials under test (MUT). This calibration process is essential for minimizing measurement errors and ensuring reliable data. The setup used for these measurements is shown in Figure 2.a, where a dielectric probe is used to measure both the real and imaginary parts of the material's dielectric characteristics over the frequency range of 1 GHz to 20 GHz. This dielectric probe is specifically designed for use with a variety of materials, including liquids, semi-liquids, and powders, which enables a comprehensive characterization of their electromagnetic properties. Figure 2.b illustrates the first step of the calibration process, where measurements are in an open-air condition. This step provides a reference data by using for environmental factors that could influence the accuracy of the measurement. Moreover, Figure 2.c shows the use of a shorting probe as part of the calibration. The shorting probe is crucial for setting the reference impedance and provides that any discrepancies caused by the probe's interaction with the sample are corrected. This step guarantees that the system can accurately measure the material's properties without interference from the measurement setup itself. Figure 2.d illustrates the final calibration step, where a distilled water is used as a reference material. Distilled water, with well-known and stable dielectric properties, serves as an ideal calibration standard. By measuring its known dielectric response, the system can further adjust for any remaining errors in the probe or measurement system. Once these calibration steps are complete, the dielectric probe kit is ready to accurately measure a wide range of materials, from liquids to powders, it shows the characterization of their complex dielectric parameters.

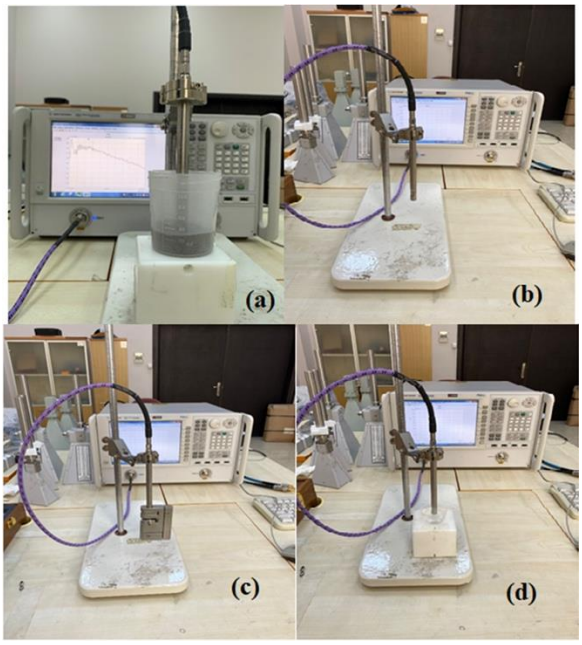

Figure 2. Complex dielectric measurement setup by a coaxial dielectric probe kit a) during measurement, b) open-air measurement, c) shorting probe for calibration and c) calibration by distilled water

RESULTS AND DISCUSSION

Figure 3 presents a comprehensive analysis of complex dielectric constants and their impact on antenna performance of *Monodonta turbinata* samples. Subfigures (a) and (b) illustrate the real and imaginary parts of the permittivity across a wide frequency range, including the

target frequency of 10 GHz. The data shows that *M. turbinata*, a novel dielectric material, exhibits tunable permittivity properties depending on its heating temperatures 800°C, 1000°C, and 1200°C. The real permittivity (a) indicates enhanced values compared to air, with a clear increase as heat temperature rises, suggesting stronger polarization capabilities. In contrast, the imaginary permittivity (b), which correlates with energy loss or dissipation, also varies with heat temperature, that indicates the material's potential for controlled dielectric loss applications. At 10 GHz, the properties appear well-suited for effective antenna performance, balancing polarization strength with minimal energy loss.

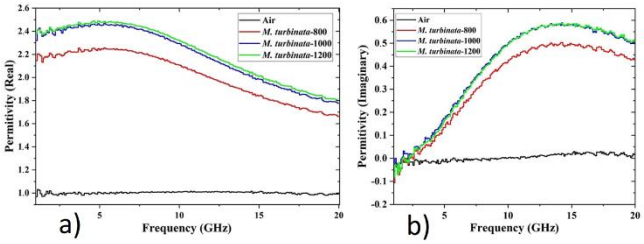

Figure 3. Experimentally measured a) real part and b) imaginary part of the prepared *M. turbinata* samples by using coaxial probe kit

Figure 4 shows a patch antenna designed using *M. turbinata* at a heating temperature of 1000°C, explains how this material integrates as a substrate in an antenna system. The use of a dielectric substrate is critical in determining antenna characteristics such as impedance matching and radiation efficiency. The unique properties of *M. turbinata*, as highlighted in the permittivity data, likely optimize the antenna's bandwidth and operating frequency. By focusing on 10 GHz, a key frequency for modern wireless communication systems, the design indicates the material's dielectric behaviour to achieve enhanced performance in a compact and efficient form factor.

In the S-parameter diagram in Figure 4 deeply illustrates the performance metrics of the antenna. Moreover, this S11 characteristic provides the reflection coefficient comparison between antennas with "*M. turbinata* 1000°C", FR-4, and RT-5880 substrates. The "*M. turbinata* 1000°C" substrate achieves better impedance matching near 10 GHz than FR-4, with performance approaching the premium RT-5880 substrate. As illustrated in Figure 4, *M. turbinata* has wider band characteristics and has relatively acceptable good radiation gain as 8.09 dBi. As given, FR-4 and RT-5880 has narrow bands and 7.06 and 8.62 dBi gain characteristics, respectively. This result underscores the material's suitability as a cost-effective alternative for high frequency applications. Another figure demonstrates the radiation pattern at 10 GHz, which presents a well distributed gain profile. The maximum gain, indicated by the colour scale, confirms that *M. turbinata* facilitates effective electromagnetic wave propagation, essential for reliable wireless communication. This combination of dielectric analysis and practical antenna application highlights the promising role of *M. turbinata* in advanced antenna technologies.

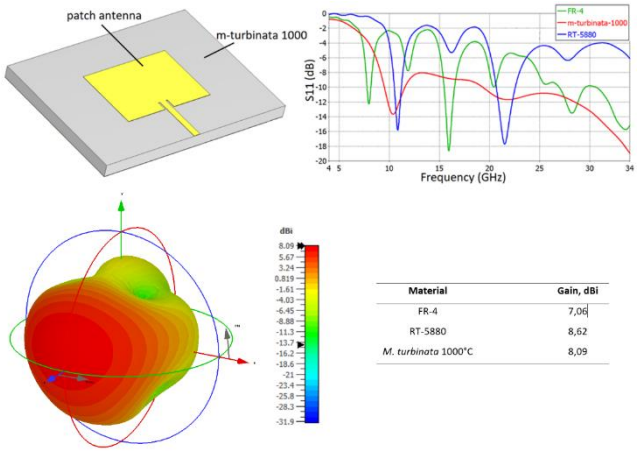

Figure 4. Designed patch antenna for ultra-high frequency application based on *M. turbinata* substrate

Furthermore, the constitutive parameters of "*M. turbinata* 1000°C", FR-4 and RT-5880 are given in Table 1. With its high loss level, "*M. turbinata* 1000°C" creates ultra-wide bandwidth characteristics in communication frequencies especially for 5G.

Table 1. Constitutive parameter comparisons at 10 GHz

Material	Loss tangent ϭ	Reel part of ε
FR-4	0,025	4,3
RT-5880	0,002	2,28
M. turbinata 1000°C	0,21	2,35

Based on the findings of this study, future research should explore several key aspects to further establish the viability of *M. turbinata* shells as a sustainable biomaterial for microwave and antenna applications. Firstly, a more extensive frequency range, extending beyond 20 GHz, should be investigated to assess the suitability of these calcined shells for applications in millimeter-wave and terahertz technologies, which are critical for next-generation wireless communication and imaging systems.

Additionally, alternative calcination methods, such as rapid thermal processing or controlled atmosphere calcination, could be explored to fine tune the dielectric properties with greater precision. The incorporation of different shell integrated composites, such as polymer matrix or ceramic matrix composites, could also be examined to enhance mechanical durability while preserving favourable electromagnetic characteristics.

Finally, a comparative literature review is given in Table 2 with details. Different materials have varying dielectric properties, which makes these materials useful for microwave applications. Coal (2.216 GHz) and materials like Teflon, wood, and corn (2.4-2.5 GHz) have narrow application bands. In contrast, apple pulp waste (3-18 GHz), rice-based materials (1-20 GHz), and polybutylene succinate (2.3-11.7) show wider frequency ranges, which are in use across different applications in microwaves. Furthermore, this study shows that *M. turbinata shells* (1-20 GHz) have advanced properties, as explained it is suitable for microwave substrate applications. These findings suggest *M. turbinata* could be a sustainable option for microwave applications.

Table 2. Literature comparison

Material	Frequency (GHz)	Application	Reference
Coal	2.216	Not specified	Marland et al., 2001
Apple pulp waste	3-18	Microwave absorbers	Baltacıoğlu et al., 2021
Teflon, wood, paper, white corn, yellow corn, sorghum	2.4-2.5	Not specified	Hernández-Gómez et al., 2014
Rice husk, rice straw, sugar cane bagasse and banana leaves	1-20	As a substrate material in microwaves	Zulkifli et al., 2017
Polybutylene succinate (PBS)	2.3-11.7	Antenna substrate	Habib Ullah et al., 2015
***M. turbinata* shells**	**1-20**	**Microwave substrate**	**This study**

Moreover, the scalability of this biomaterial for industrial applications should be evaluated by developing standardized processing techniques and testing the long term stability of the calcined shells under various environmental conditions, including humidity, temperature fluctuations, and mechanical stress. Further studies could also investigate the potential of integrating *M. turbinata* substrates into flexible and conformal antenna designs, particularly for wearable and biomedical communication applications.

From a sustainability perspective, future research should address the environmental impact and life cycle assessment of processing *M. turbinata* shells. In addition, interdisciplinary collaborations incorporating materials science, computational electromagnetics, and environmental engineering could lead to novel applications and optimizations, which paves the way for the widespread adoption of marine biomaterials in modern communication systems. Future studies could also explore the scalability of *M. turbinata* shell processing to meet industrial demands. Investigating the long-term stability and performance of these biomaterials under varying environmental conditions would be valuable for practical applications. Furthermore, developing cost-effective and eco-friendly processing techniques could enhance the feasibility of large scale implementation.

CONCLUSION

This study highlights the potential of *M. turbinata* shells as an innovative and sustainable biomaterial for microwave and antenna applications. By systematically processing the shells through washing, drying, grinding, and calcination at varying temperatures (800°C, 1000°C, and 1200°C), the electromagnetic properties of the resulting samples were thoroughly characterized. The dielectric measurements revealed that the calcination temperature significantly influences the real and imaginary components of the permittivity, which creates a property for the material to exhibit tuneable dielectric behaviour. This tunability, particularly at 10 GHz, positions *M. turbinata* shells as a viable candidate for applications requiring precise control over electromagnetic properties. The incorporation of *M. turbinata* derived substrates in patch antenna designs demonstrated promising results. The antenna using the M2 substrate (calcined at 1000°C) achieved superior impedance matching and bandwidth performance at 10 GHz, outperforming traditional FR-4 and closely approaching the performance of RT-5880, a high-grade substrate material. The S11 parameter and radiation pattern analyses further underscored the material's potential to enhance antenna efficiency, gain, and overall electromagnetic performance, making it a cost-effective alternative for high frequency communication systems. From a practical perspective, the use of *M. turbinata* shells as a dielectric substrate provides a sustainable and economical solution for the development of advanced antenna technologies. This approach not only reduces dependence on synthetic and petroleum-based materials but also promotes the utilization of renewable marine resources. The demonstrated dielectric tunability enables the design of reconfigurable antennas, which are crucial for emerging applications such as 5G, 6G, and radar systems requiring adaptable electromagnetic responses. Overall, this study not only establishes the feasibility of using *M. turbinata* shells as eco-friendly and cost-effective materials for microwave and antenna technologies but also contributes to the advancement of sustainable alternatives in modern communication systems. By providing the unique electromagnetic properties of marine biomaterials, this research paves the way for future studies focused on the

integration of renewable resources in advanced electronic and communication applications.

Compliance with Ethical Standards

Authors' Contributions

All authors contributed to the study conception and design. The article was written by E.U and F.Ö.A. with the contributions of all authors. The collection of seashell samples and material production were conducted by E.U. and Ö.D., while the measurement of complex dielectric parameters was carried out by M.K. and F.Ö.A. Each author contributed critical feedback and played a significant role in the research, analysis, and development of the manuscript. All authors read and approved the final manuscript.

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.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

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Morphometric and meristic differentiations of *Garra turcica* (Karaman, 1971) from the various branch of the Ceyhan River System, Türkiye

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A B S T R A C T

This study was conducted to determine metric and meristic differentiations of *Garra turcica* (Karaman, 1971) inhabiting different branches of the Ceyhan River System. Individuals sampled from 13 branches of the Ceyhan River System were examined for 11 metric and 8 meristic traits. Principal Component Analysis (PCA) and Linear Discriminant Function Analysis (LDFA) identified both for metric and meristic traits among the different branches of Ceyhan River system. SIMPER (Similarity Percentage) test showed that the most important contributions to this differentiation from metric measurements were caudal peduncle length (71.50%), dorsal fin height (8.04%) and body depth (5.23%), and from meristic traits were scales on lateral line (41.65%), scales above lateral line (20.09%) and pectoral fin rays (8.55%). It is known that, in inland waters, compared to marine areas, the rate of genetic and morphological differentiation is higher for closer geographical areas, especially due to the inability to migrate and environmental factors. However, it remains a question that needs to be answered as to why the metric and meristic features determined for this species are the ones that are the most influential in the differentiation. In addition, it should be investigated whether the morphological differentiation detected in the current study also occurs at the genetic level. In this case, it may be possible to define a subspecies for this species.

INTRODUCTION

According to Menon (1964) and Goren and Ortal (1999), the *Garra* genus is reported to have spread from the Himalayas to the west and east. *Garra rufa*, on the other hand, is of Asian origin and is distributed throughout all of south western Asia, Africa, and Southeast Asia (Goren and Ortal, 1999). Geldiay and Balık (2009) report that there are two species of *Garra* genus in Türkiye: *G. rufa* and *Garra variabilis*. Recent studies in Türkiye have indicated that *G. caudomaculata* is an endemic species of the Asi River, *Garra culiciphaga* is found in the Seyhan, Ceyhan, and Asi River systems, and *G. turcica* is a synonym for *G. rufa* (Bayçelebi, 2020; Kara, 2023). In addition, the presence of endemic species such as *Garra kemali* and *Garra menderesensis* has been reported in Türkiye (Çiçek et al., 2018). *G. rufa* is distributed in the Aras River, Tigris-Euphrates system, Ceyhan and Seyhan river basins and Iran (Geldiay and Balık, 2009; Koyun, 2011; Kara and Can, 2023). It is reported that *G. rufa* individuals are found in the Ceyhan River system and they have a wide range of habitats from 126 m to 1233 m altitude (Kara and Alp, 2005; Kara et al., 2010). These fish are used for the treatment of some skin diseases (Psoriasis) in the "Balıklı Kaplıca" in Kangal district of Sivas (Demirci at al., 2016). Moreover, they are also demanded in the aquarium fish sector because they eat the algae that form in the aquarium environment (Aydın and Akman, 2020). *G. turcica* was reported by Karaman (1971) as a subspecies of *G. rufa* from the Ceyhan River due to its morphological differences.

Later, it was evaluated as a synonim of *G. rufa* by various researchers (Krupp, 1985; Bostancı, 2006; Ergüden and Göksu, 2012). Bayçelebi et al. (2018) redefined *G. turcica*, stating that it differs not only morphologically but also at the molecular level. According to this definition, it is distinguished from *G. rufa* by having a thinner body, a blunt snout and a generally short rostral head (Bayçelebi et al., 2018). *G. turcica* is found in benthopleagic, non-migratory, slow-flowing rivers, small pools and lakes, and in ecosystems with stony, gravelly, sandy and muddy bottoms (Krupp and Schneider, 1989). This species has a high tolerance to environmental conditions, capable of thriving in a wide temperature range and easily adapting to anthropogenically modified habitats (Çiçek et al., 2021). This environmental resilience of *G. turcica* is an important characteristic, both ecologically and for biodiversity studies. However, the variations of this species in different river systems and the underlying causes of these variations have not yet been sufficiently researched.

Morphometric and meristic variations, when the same species displays different characteristics in different river branches, are crucial for understanding these variations and evaluating the taxonomic and ecological relationships of the species. These variations can arise due to various factors such as genetic drift, natural selection, environmental factors, migration, and hybridization (Sing et al., 2021). Identifying these variations is an important step in understanding the status of the species' populations in local ecosystems, and such knowledge plays a critical role in the conservation of local biodiversity. In this context, studying the differences in the morphometric and meristic characteristics of *G. turcica* populations across different branches of the Ceyhan River system will provide important data for the development of conservation strategies for this species.

The aim of this study is to identify the morphometric and meristic differences among *G. turcica* populations in the different river branches of the Ceyhan River System. The methodological approaches used in this study will facilitate a better understanding of the taxonomic relationships and ecological differences between species. This research includes statistical analyses, particularly Principal Component Analysis (PCA) and Linear Discriminant Function Analysis (LDFA), to better understand the differences between river populations. These methods aim to deeply analyze the data and reveal the morphological and genetic differences of the species. Furthermore, this methodological approach is of great importance for regional biodiversity studies, as it will help in understanding the effects of environmental and genetic factors on variations between species.

MATERIAL AND METHODS

Sample Collections

This study was conducted on *G. turcica* (Figure 1) found in 13 streams (Figure 2, Table 1) located in the middle and upper Ceyhan River basin between April 2014 and May 2016. The body of *G. turcica* individuals is roundish and covered with large scales. The snout is blunt and the mouth is ventrally positioned and crescent-shaped. There are two pairs of very short barbels around the mouth. The dorsal fin starts in front of the ventral fin and has a straight free margin. There is a well-developed sucker attached to the lower lip. The color is usually brown with irregular light black markings (Figure 1). A total of 90 specimen were caught by electroshocking were brought to the laboratory in plastic containers containing 4% formaldehyde. The sampled fish number and total fish length ranges were given by river branches in Table 1. As explained in statistical analysis section, to enhance sample size and to explain variability more reasonable, a principal component analysis-PCA was applied to data, resulting to grouping of river branches.

Figure 1. An original photograph of *G. turcica* from studied area, Hemite Stream (Total length: 10.60 cm).

Table 1. River branches where samples were taken and their grouping according to PCA.

River branch	Code	No.	Total length range (mm)	Sample Groups
Körsulu Stream	KO	13	(70.80-130.40)	Group-1 N= 23
Pörnek Stream	PO	10	(70.80-120.80)	
Fırnız Stream	FI	6	(99.41-126.24)	Group-2 N=18
Zeytin Stream	ZE	6	(66.43-122.26)	
Hemite Stream	HE	6	(45.65-120.80)	
Aksu Stream	AK	8	(98.57-125.85)	Group-3 N= 22
Karasu Stream	KA	5	(63.85-113.75)	
Yarpuz Stream	YA	4	(99.11-123.93)	
İmalı Stream	IM	5	(84.79-109.36)	
Sabun Stream	SA	5	(92.55-108.32)	Group-4 N=27
Savrun Stream	SAV	8	(95.31-126.25)	
Afşin-Yazıdere Stream	AFYD	7	(64.46-95.90)	
Homzan Stream	HO	7	(66.25-92.83)	

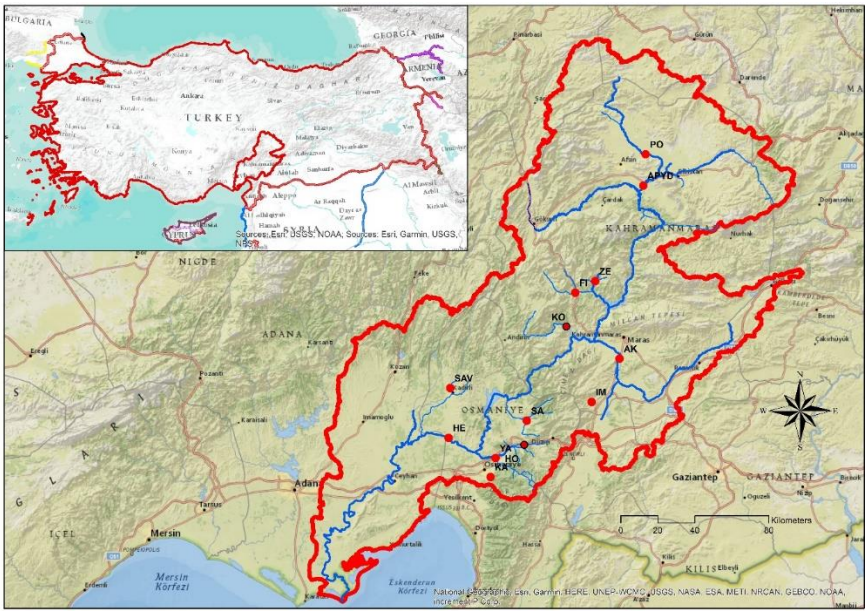

Figure 2. Sample sites with coodinates [Körsulu Stream (KO: 36° 38' 35.34'' E, 37° 37' 47.72'' N), Pörnek (PO: 37° 01' 55.62'' E, 38° 17' 37.92'' N), Fırnız Stream (FI: 36° 41' 18.48''E, 37° 45' 19.55''N), Zeytin Stream (ZE: 36° 46' 44.75''E, 37° 48' 22.20''N), Hemite Stream (HE: 36° 04' 22.50''E, 37° 11' 52.81''N), Aksu Stream (AK: 36° 54' 24''E, 37° 30 15''N), Karasu Stream (KA: 36° 16' 37''E, 37° 02' 50.82''N), Yarpuz Stream (YA: 36° 17' 45''E, 37° 07' 11''N), İmalı Stream (IM: 36° 17' 45''E, 37° 07' 11''N), Sabun Stream (SA: 36° 27' 29''E, 37° 15' 40''N), Afşin-Yazıdere Stream (AFYD: 37° 00' 34.04''E, 38° 10' 9.40''N), Homzan Stream (HO: 37° 26' 21.21''E, 37° 10' 26.17''N)].

Morphometric and Meristic Traits

In the laboratory, a total of 11 morphometric measurements and 8 meristic counts were recorded for each fish (Table 2). Morphometric measurements were taken from the left lateral aspect, and measured to the nearest 0.1 mm using a digital caliper. All meristic characters were counted twice on the same day by the same observer.

Statistical Analysis

Because fish have allometric growth, a common problem with morphometric data is that all measurements are highly correlated with length. In order to analyze the shape of the fish regardless of size, the size factor must be removed from the data. One of the most accurate ways to do this is to use Burnaby's (1966) method (Klingenberg, 1996). In this study total length (TL) was considered as size factor to be transformation base to other morphometric characters. Prior to transformation, almost all of the morphometric characters showed high correlations with total length (TL), whereas after transformation all the characters showed non-significant relationship with TL (Table 3).

Table 2. Morphometric and meristic traits of *G. turcica* used in this study.

Traits	Description	Acronym
Morphometric measurements:		
Total length	Tip of the upper jaw to the caudal end of the caudal fin	TL
Snout length	From symphysis of premaxilla to osseous orbit margin	SL
Caudal peduncle length	From end of anal fin to middle base of caudal fin	CPL
Dorsal fin height	From base to tip of longest ray	DFH
Orbital horizontal diameter	Between osseous orbital margin	OHD
Dorsal fin length	From base to tip of longest ray	DFL
Head length	From upper jaw symphysis to posterior tip of operculum	HL
Head depth	Just posterior to orbit	HD
Caudal peduncle depth	The minimum depth of the caudal peduncle	CPD
Predorsal length	Front of the upper lip to the origin of the dorsal fin	Pre-DL
Body depth	The maximal depth of the body	BD
Meristic counts:		
Pectoral fin rays	Number of thorns in the pectoral fin	PcFR
Radius pectoral fin	Number of cartilages found in the space between thorns in the pectoral fin	RPcF
Radius anal fin	Number of cartilages found in the space between thorns in the anal fin	RAF
Radius dorsal fin	Number of cartilages found in the space between thorns in the dorsal fin	RDF
Radius ventral fin	Number of cartilages found in the space between thorns in the ventral fin	RVF
Scales on lateral line	Number of scales on the lateral line	SLL
Scales above lateral line	Number of scales above the lateral line	SALL
Scales below lateral line	Number of scales below the lateral line	SBLL

Table 3. Correlation coefficients between total length (TL) and each of the other morphometric characters, r(TL~), prior and after transformation.

Morphometric character	Prior to transformation r(TL~)	After transformation r(TL~)
BD	0.909	0.000
HL	0.970	0.000
OHD	0.869	0.000
SL	0.752	0.000
DFL	0.923	0.000
DFH	0.882	0.000
Pre-DL	0.978	0.000
CPL	0.745	0.000
HD	0.955	0.000
CPD	0.959	0.000

Morphometric traits are continuous and more susceptible to the environmentally induced variability, while meristic traits are discrete and fixed early in development. Therefore, separate statistical analyses were conducted on morphometric (continuous) and meristic (discrete) data. All statistical analyses were performed for combined sexes since all morphometric measurements were transformed and the effect of size removed (Simon et al., 2010). Cross-correlations between transformed meristic and non-transformed metric traits, and also, each of distribution of individual trait were given in Figure 3.

Although 13 streams tributaries were sampled in the research, as can be seen in Table 1, the sample size does not seem to be sufficient for statistical evaluation at each river branches. Therefore, with the PCA analysis based on metric and meristic properties, the sample points were brought together into 4 groups (Figure 4) based on a combination of explained variance, Scree plot, and Eigenvalue approaches (Larose, 2015) (Table 4)

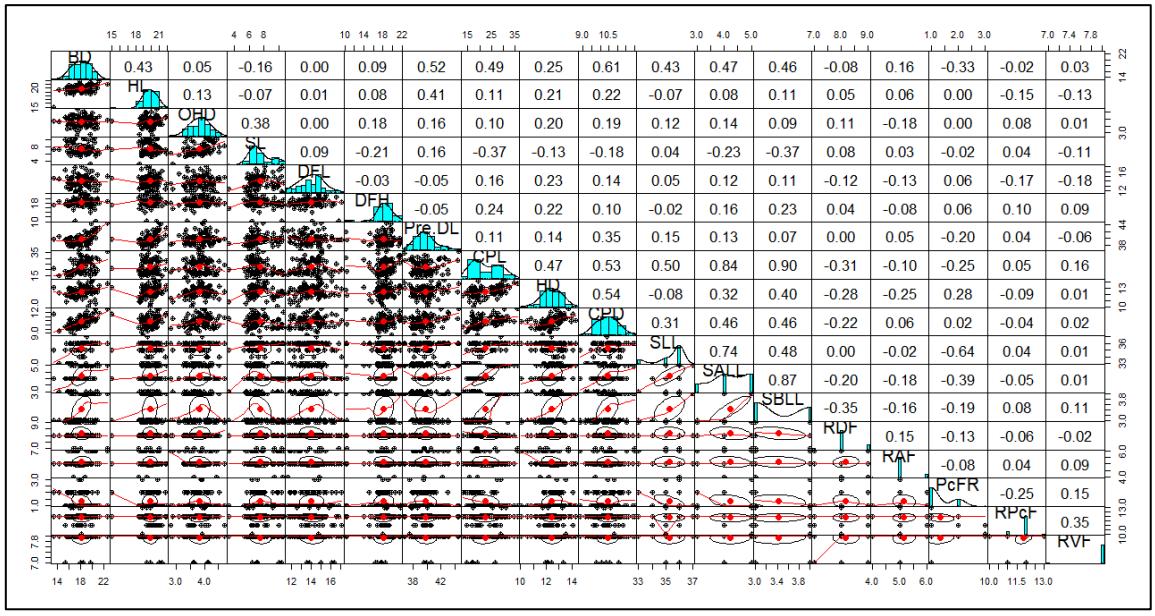

Figure 3. Distribution of each trait and cross-correlations between transformed meristic and non-transformed metric traits

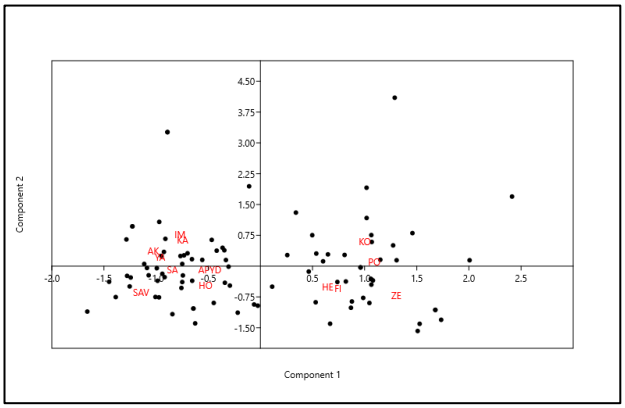

Figure 4. Allocation of river branches based on the PCA

Table 4. Eigenvalues, explained variances, and cumulative variance by each component resulted from PCA.

PC	Eigenvalue	Variance, %	Cumulative variance, %
1	33.70	71.11	71.11
2	4.33	9.13	80.23
3	3.63	7.65	87.89
4	2.05	4.33	92.21
5	1.38	2.91	95.13
6	0.95	2.01	97.14
7	0.63	1.32	98.46
8	0.49	1.03	99.49
9	0.15	0.33	99.82
10	0.08	0.18	100.00

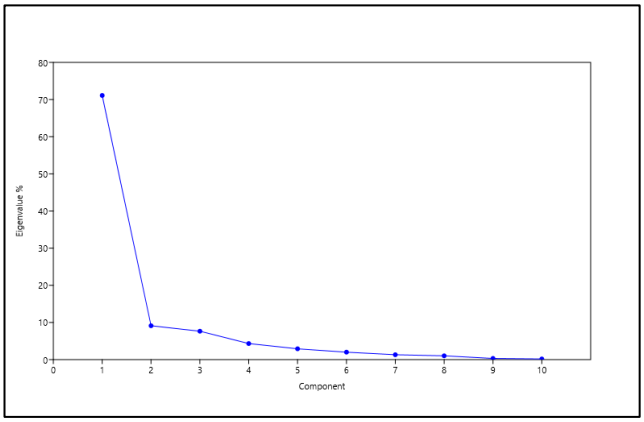

Figure 5. Scree plot from Principal Component Analysis

After the transformation (only for morphometric characters) and PCA, Discriminant Function Analysis (DFA) and SIMPER (Similarity Percentage) and were carried out on the data, respectively. Discriminant analysis is a statistical tool that is specifically designed to detect differences between two or more groups (Xanthopoulos et al., 2013). Therefore, it was applied to compute the classification success the grouping of river branches by PCA, based on confusion matrix. SIMPER (Similarity Percentage) was used for assessing which characters are primarily responsible for an observed difference between groups of samples quantitatively (Clarke, 1993).

All calculations and statistical analysis were conducted using MS Excel, PAST software (Hammer et al. 2001) and R (R Core Team, 2021).

RESULTS

Morphometric Traits

Percentage separations of four groups achieved by the first discriminant function (ld1) was 79.30%, second (ld2) was 18.74%, and third (ld3) was 1.96%. Stacked histograms of morphometric traits for ld1 discriminant function by groups were given in Figure 6. It's clearly evident that no overlaps between second and third, and between second and fourth, and between first and third groups. But some overlap observed between the first and fourth groups. In general, supporting to the PCA results, four groups can be identified from DFA. But histogram based on lda2 showed almost overlapping of each of groups with other (Figure 7).

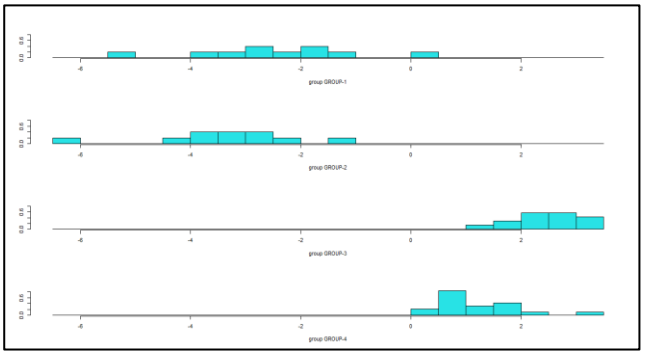

Figure 6. Stacked histograms based on ld1discriminant function

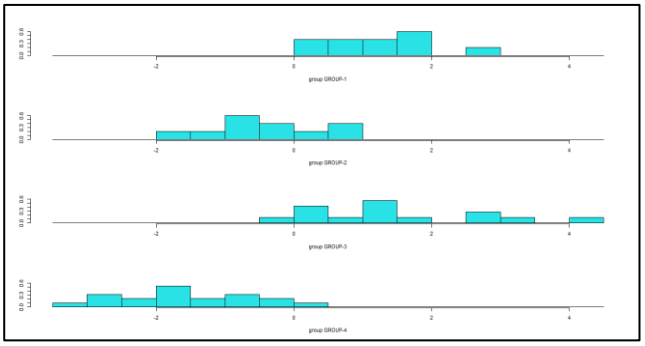

Figure 7. Stacked histograms based on ld2 discriminant function

In Figure 8, the placement of the groups according to the first and second discriminate functions based on linear DFA and the most morphometric features that affect the differentiation of the groups from each other were given as biplot vector vectors. The most important three traits leading to differentiation were caudal peduncle length-CPL (71.50%), dorsal fin height-DFH (8.04%) and body depth-BD (5.23%) (Figure 8 and Table 5).

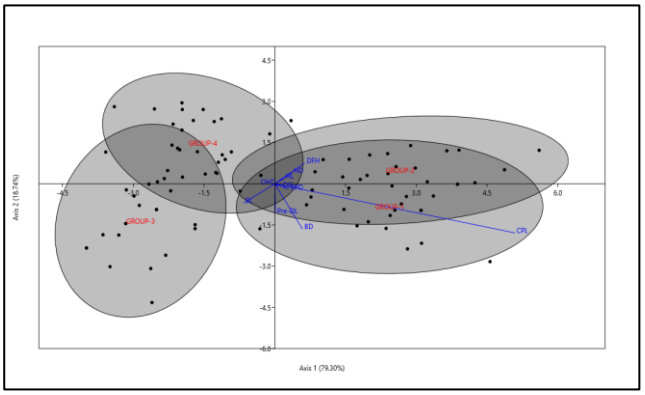

Figure 8. Four groups with 95 % confidence limits in ellipse form. Axis-1(ld1) and Axis-2 (ld2) explained 98.04 % of total variation based on the DFA for metric traits.

Table 5. Detailed SIMPER analysis results (Average dissimilarity, individual contribution, and cumulative contribution), based on Euclidean distance measure, of each morphometric traits to differentiation among groups.

Morphometric trait	Av. dissim	Contrib. %	Cumulative %
CPL	81.17	71.50	71.50
DFH	9.12	8.04	79.54
BD	5.94	5.23	84.77
Pre-DL	5.14	4.52	89.30
SL	4.79	4.21	93.51
DFL	3.10	2.73	96.24
HL	1.76	1.55	97.79
HD	1.40	1.23	99.02
CPD	0.84	0.74	99.76
OHD	0.27	0.24	100.00

For meristic traits, the DFA managed to assign correctly 87.78% of the fish to the groups after cross-validation. The high classification success provides support for the metric traits differences between the groups (Table 6).

Table 6. Classification results (confusion matrix) of discriminant function with 87.78 % success for metric traits

	Group-2	Group-1	Group-3	Group-4	Total
Group-2	17	1	0	0	18
Group-1	6	16	1	0	23
Group-3	0	0	20	2	22
Group-4	0	0	1	26	27
Total	**23**	**17**	**22**	**28**	**90**

Meristic traits

The first (ld1), second (ld2), and third (ld3) discriminant functions explained the separations between groups as 91.18%, 6.75%, and 2.07%, respectively. Stacked histograms based on ld1 and ld2 for groups were given in Figure 9 and Figure 10. Considering the ld1 discriminant function, there were exact differentiation between first and third, and between first and fourth groups, and in some degree but not clear between second and fourth groups. However, the histograms of each group based on lda2 overlapped on each other.

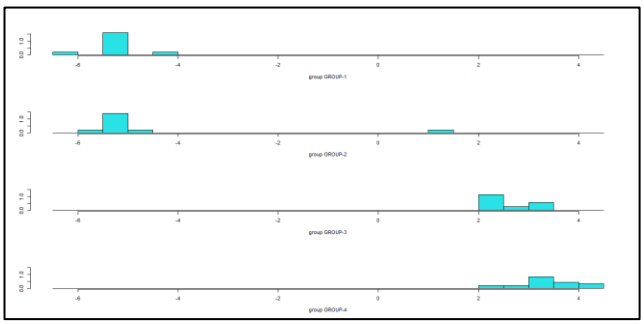

Figure 9. Stacked histograms for meristic traits based on ld1 discriminant function with 91.18 % explanation power

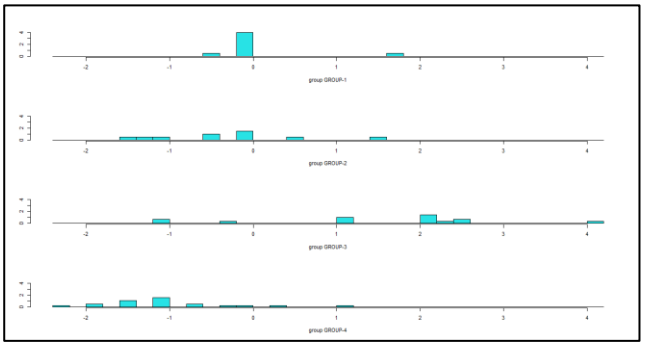

Figure 10. Stacked histograms for meristic traits based on ld1 discriminant function with 6.75% explanation power

The explanation percentages of the first and second discriminant functions on the differentiation of the groups and the biplot vector representation of the meristic features affecting the differentiation are given in Figure 11. After cross-validation, samples were correctly assigned to their group with an 80% classification success (Table 7). The most important four meristic traits leading to differentiation were scales on lateral line-SLL (41.65%), Scales above lateral line-SALL (20.09%), Number of scales below the lateral line-SBLL (9.39%), and Number of thorns in the pectoral fin-PcFR (8.55%) (Table 8).

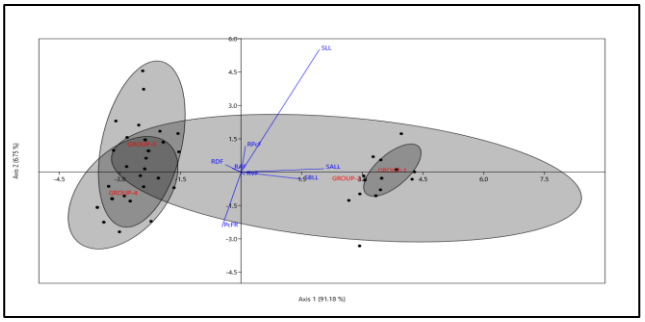

Figure 11. Graphical representation of DFA results for meristic traits. Axis-1(ld1) and Axis-2 (ld2) explained 97.93% of total variation.

Table 7. Classification results (confusion matrix) of discriminant function with 80% success for morphometric traits

	Group-2	Group-1	Group-3	Group-4	Total
Group-2	7	8	2	1	18
Group-1	0	23	0	0	23
Group-3	0	0	19	3	22
Group-4	0	0	4	23	27
Total	**7**	**31**	**25**	**27**	**90**

Table 8. Average dissimilarity, individual contribution, and cumulative contribution of each meristic traits to differentiation among groups by SIMPER analysis, based on Euclidean distance measure

Morphometric Traits	Av. dissim	Contrib. %	Cumulative %
SLL	2.84	41.65	41.65
SALL	1.37	20.09	61.74
SBLL	0.64	9.39	71.13
PcFR	058	8.55	79.68
RDF	0.47	6.94	86.62
RPcF	0.46	6.68	93.30
RAF	0.35	5.18	98.48
RVF	0.10	1.52	100.00

DISCUSSION

Morphometric and meristic variations within the same fish species across different branches of a river may arise due to various factors such as genetic drift, natural selection, environmental influences, migration, and hybridization. These factors are often interrelated and tend to operate in conjunction, generating complex dynamics within fish populations, particularly in fragmented or geographically isolated ecosystems (Liam et al., 2022).

Genetic drift refers to the random fluctuation of allele frequencies over time within a population, and it becomes particularly pronounced in small and isolated populations. Over successive generations, genetic drift can lead to significant divergence in traits, even when those traits do not confer any adaptive advantage (Frankham, 2005). This phenomenon is of particular importance in populations inhabiting isolated habitats, such as river branches separated by natural or anthropogenic barriers. In such environments, reduced or absent gene flow e.g., due to dams can accelerate genetic drift and contribute to the emergence of morphometric and meristic differences (Liam et al., 2022). Over time, these changes in allele frequencies may lead to distinct sets of physical traits within each population, even in the absence of direct selective pressures (Sing et al., 2021).

Natural selection, on the other hand, acts on heritable traits that confer a survival or reproductive advantage. In fish populations, characteristics such as body shape, fin morphology, and behavioral traits may be shaped by natural selection, as individuals better adapted to their environment tend to survive and reproduce more successfully (Monk et al., 2021). In the case of *G. turcica*, it is likely that morphometric differences such as caudal peduncle length (CPL), dorsal fin height (DFH), and body depth (BD) are influenced by environmental conditions specific to each river branch. These traits can play critical roles in vital functions such as swimming efficiency, predator avoidance, and foraging success.

Environmental factors, including temperature, water quality, and food availability, also significantly influence morphological and meristic traits in fish populations. For example, variations in water flow and habitat structure across different branches of a river can impose differential selective pressures, resulting in pronounced adaptations in body shape and fin morphology. Populations in slow-flowing waters may evolve different body forms compared to those in fast-flowing streams, as body depth and fin configuration influence a fish's ability to maneuver against currents. Furthermore, changes in water temperature can affect metabolic rates and growth patterns, thereby contributing to interpopulation differentiation (Franssen et al., 2013). In this study, the observed differences in body shape and fin structure across branches of the Ceyhan River system are likely driven by such environmental factors.

Migration or its absence also plays a critical role in the development of morphometric and meristic variation. Migration introduces new genetic material into a population, enhancing genetic diversity and altering trait distributions. However, when migration is limited, as is often the case in river systems fragmented by dams, populations become more isolated, leading to faster local adaptation. This isolation reduces gene flow and fosters both genetic and morphological differentiation. The observed differences among *G. turcica* populations may therefore result from both isolation and adaptive responses to local environmental conditions, as migration between these fragmented habitats is likely infrequent.

Hybridization, the interbreeding between distinct species or populations, may give rise to novel combinations of morphometric and meristic traits. This phenomenon is more likely in systems where multiple fish species or populations share the same habitat. In the context of the Ceyhan River, hybridization may have contributed to the observed differentiation in *G. turcica*; however, verifying this hypothesis would require genetic analyses.

In this study, the morphometric traits contributing most to differentiation among river branches were identified as caudal peduncle length (CPL) (71.50%), dorsal fin height (DFH) (8.04%), and body depth (BD) (5.23%). These traits are crucial in assessing the fish's adaptation to its environment and its overall functional capacity. For instance, CPL plays a central role in swimming efficiency, as a longer caudal peduncle is associated with stronger propulsive force, which is essential in river systems with variable current regimes. DFH and BD may influence maneuverability and stability against currents. The pronounced differences in these morphometric traits across groups suggest that local selective pressures such as water flow, habitat structure, and predator-prey dynamics are shaping *G. turcica* populations

in distinct ways. Seçer et al. (2025) stated that phenotypic flexibility increases in body shape variations in species belonging to the *Garra* genus in geographically distant populations, which is similar to our research findings.

Regarding meristic traits, the most significant contributors were the number of scales along the lateral line (SLL) (41.65), scales above the lateral line (SALL) (20.09%), and scales below the lateral line (SBLL) (9.39%). Meristic traits are generally more stable over time and less influenced by environmental factors, which makes them valuable indicators of genetic differentiation. For example, the number of scales along the lateral line is associated with the overall health and development of fish populations, as it relates to sensory function and habitat suitability. Differences in these meristic features may reflect unique adaptations of fish populations to local environmental conditions such as water temperature, current velocity, or food availability within different branches of the river.

Statistical analyses based on mean, standard deviation, and coefficient of variation support the existence of significant differences among river branches. In particular, the coefficient of variation within groups was low for key morphometric traits such as CPL, DFH, and BD, indicating limited variation within each group. However, statistically significant differences were observed between groups for these traits ($p < 0.05$). The difference in CPL was particularly pronounced, contributing the most to observed differentiation. This finding highlights the crucial role of swimming efficiency and body shape in the divergence of *G. turcica* populations within the Ceyhan River system. To fully understand the causes of these morphological differences and to determine whether they result from local adaptation, genetic drift, or other evolutionary processes further research, particularly incorporating genetic analyses, is necessary.

The mean, standard deviation, and coefficient of variation values for the most significant metric and meristic features responsible for the differentiation between river branches are presented in Table 9, and Figures 12-14. These values are categorized by river branch groups, and box plots and graphs displaying pairwise comparisons are also provided.

Table 9. Mean, standard deviation (SD) and coefficient of variation (cv, %) values of CPL, DFH and BD metric traits according to groups

	CPL			DFH			BD		
	Mean	**SD**	**cv**	**Mean**	**SD**	**cv, %**	**Mean**	**SD**	**cv**
GROUP-1	28.30^{a}	2.68	9.47	18.61^{ab}	1.60	8.60	19.55^{a}	1.02	5.22
GROUP-2	27.70^{a}	3.41	12.32	19.47^{a}	1.81	9.30	18.11^{b}	0.92	5.07
GROUP-3	17.46^{b}	1.92	11.01	17.49^{b}	2.10	12.01	18.33^{b}	1.74	9.47
GROUP-4	18.15^{b}	1.94	10.67	18.15^{b}	0.91	5.04	17.05^{c}	1.21	7.07

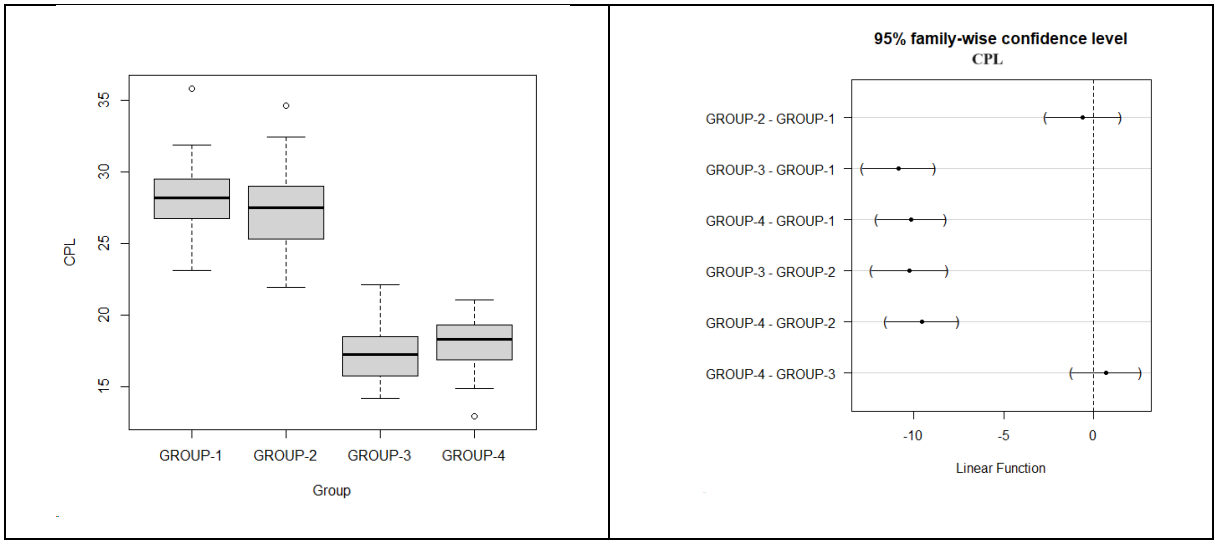

Figure 12. Box plots and pairwise comparison of means for caudal peduncle length-CPL (mm) of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p>0.05$), GROUP-3 and GROUP-1 ($p<0.05$), GROUP-4 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-2 ($p<0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p<0.05$).

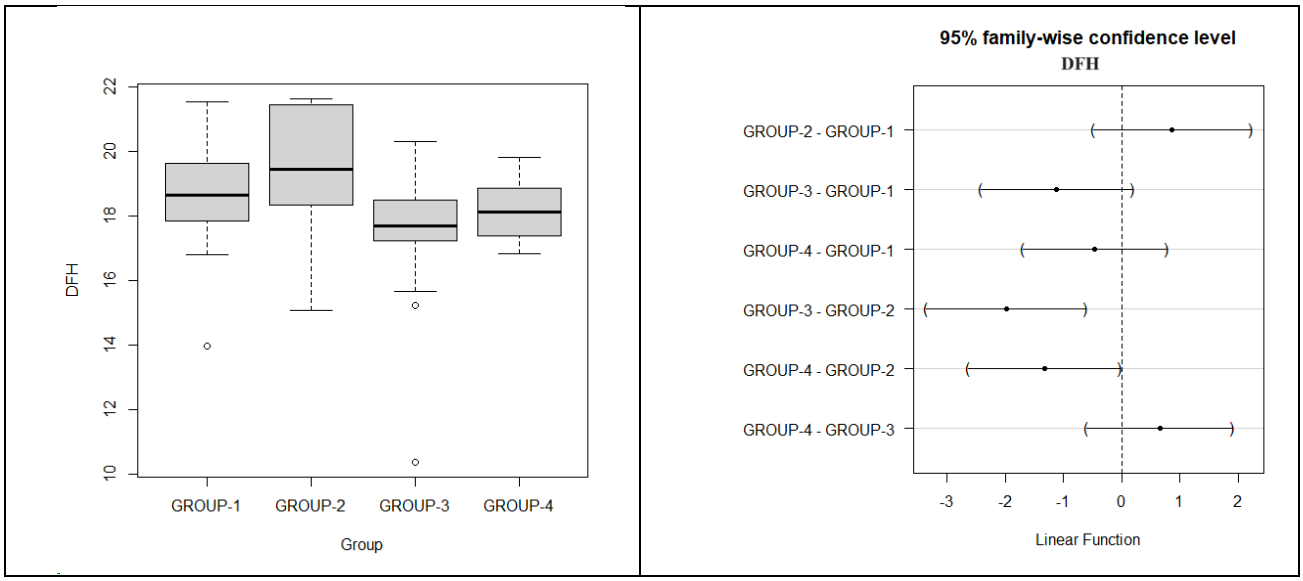

Figure 13. Box plots and pairwise comparison of means for dorsal fin height-DFH (mm)of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p>0.05$), GROUP-3 and GROUP-1 ($p>0.05$), GROUP-4 and GROUP-1 ($p>0.05$), GROUP-3 and GROUP-2 ($p<0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p>0.05$).

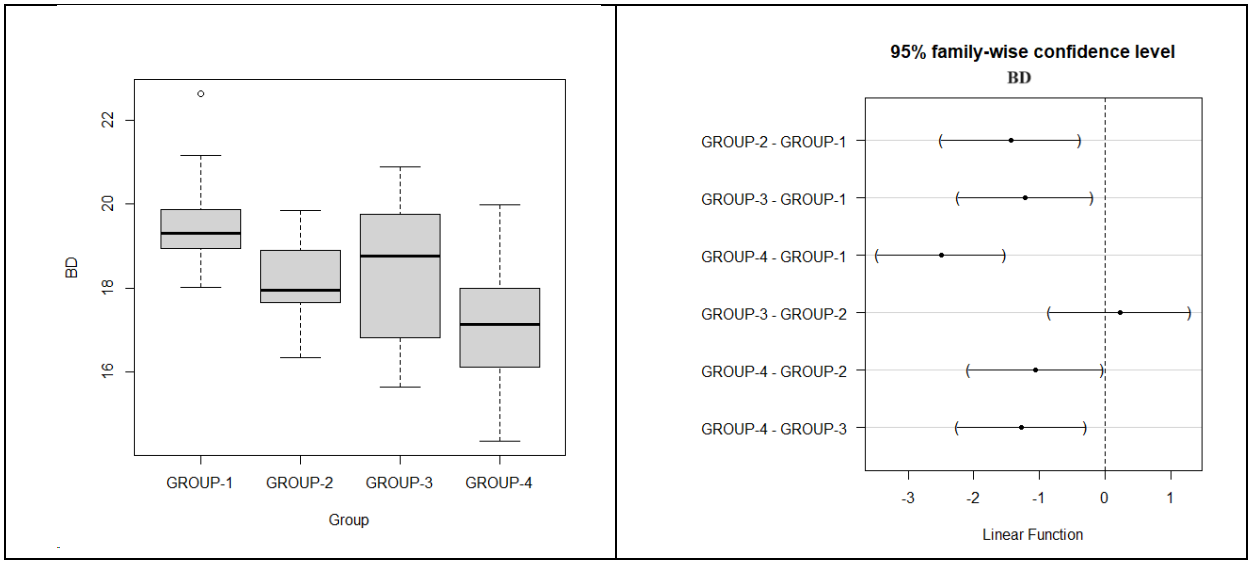

Figure 14. Box plots and pairwise comparison of means for body depth-BD (mm) of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-1 ($p<0.05$), GROUP-4 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-2 ($p>0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p<0.05$).

Considering the SLL, SALL and SBLL traits that have the most impact on differentiation in terms of meristic traits, it is seen that there was a lot of variability among the intra-group variation coefficients, especially in the SALL and SBLL traits (Table 10). When the average values were compared, it was seen that there are differences between the groups (Table 10, Figure 15-17).

Table 10. Mean, standard deviation (SD) and coefficient of variation (cv, %) values of CPL, DFH and BD metric traits according to groups

	SLL			SALL			SBLL		
	Mean	**SD**	**cv**	**Mean**	**SD**	**cv**	**Mean**	**SD**	**cv**
GROUP-1	36.00	0.30	0.84	5.00	0.00	0.00	4.00	0.00	0.00
GROUP-2	35.72	0.46	1.29	4.78	0.43	8.95	3.83	0.38	10.00
GROUP-3	35.50	1.06	2.98	3.73	0.46	12.23	3.00	0.00	0.00
GROUP-4	34.15	1.10	3.22	3.59	0.50	13.94	3.00	0.00	0.00

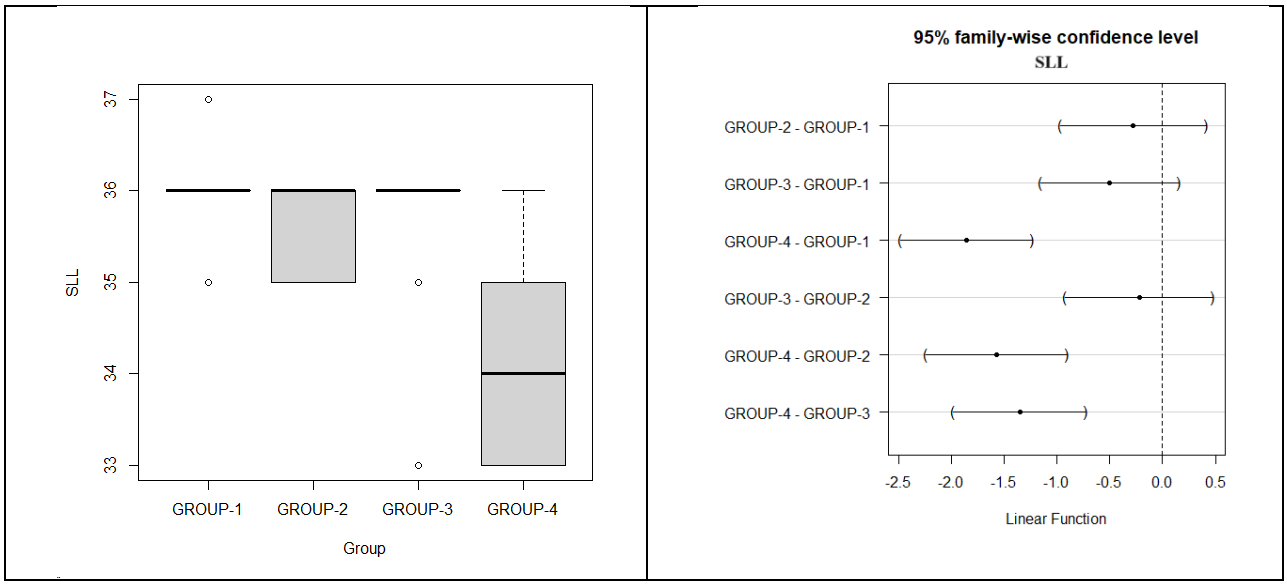

Figure 15. Box plots and pairwise comparison of means for scales on lateral line-SLL (mm)of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p>0.05$), GROUP-3 and GROUP-1 ($p>0.05$), GROUP-4 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-2 ($p>0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p<0.05$).

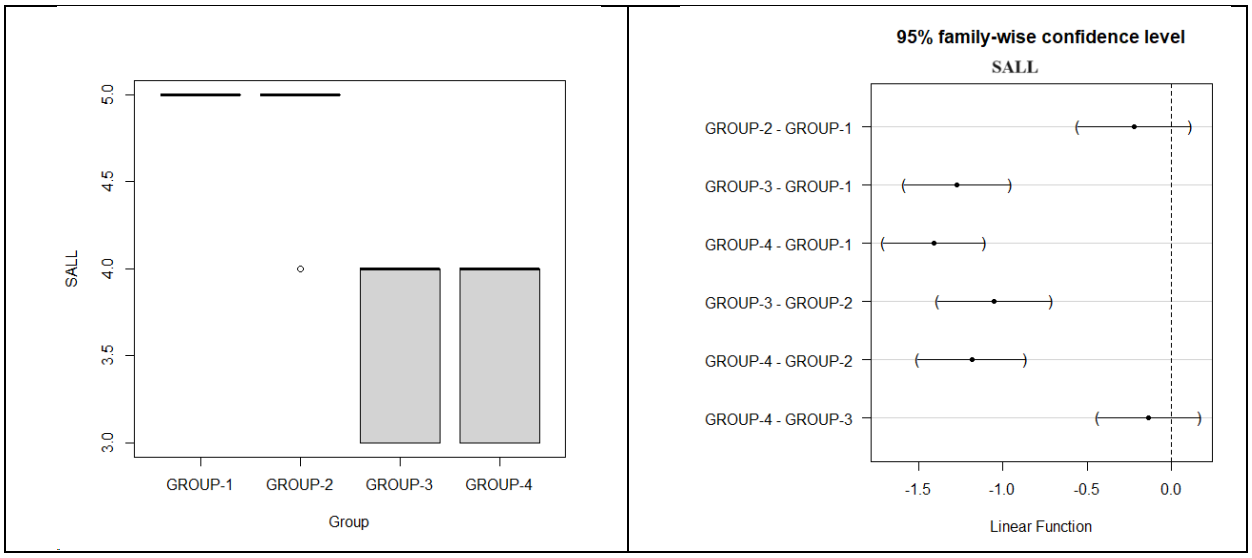

Figure 16. Box plots and pairwise comparison of means for scales above lateral line-SALL (mm) of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p>0.05$), GROUP-3 and GROUP-1 ($p<0.05$), GROUP-4 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-2 ($p<0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p>0.05$).

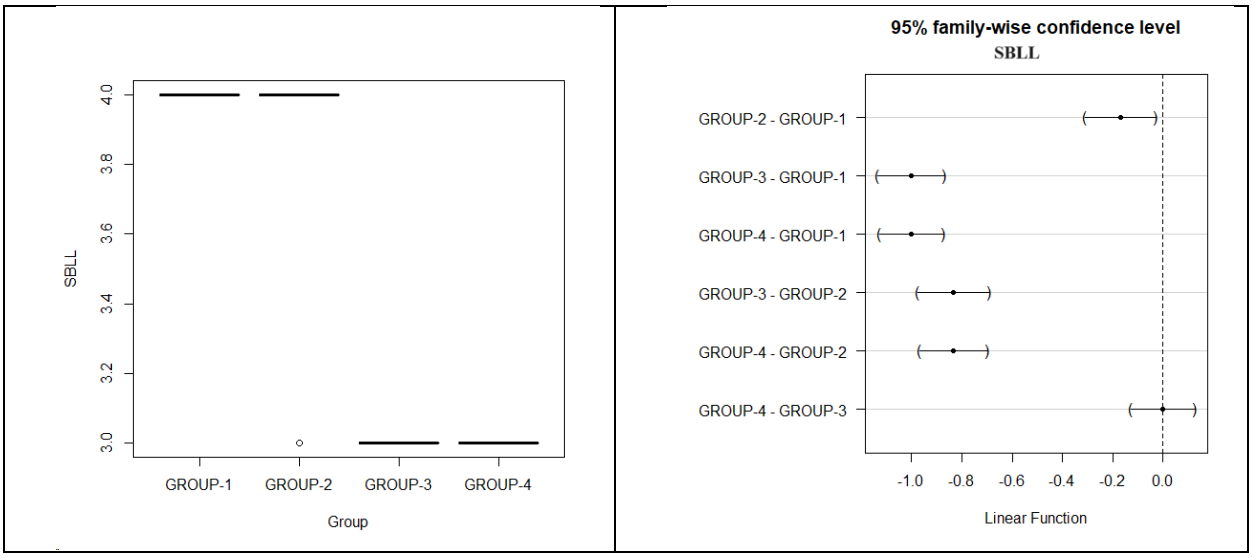

Figure 17. Box plots and pairwise comparison of means for scales below the lateral line -SBLL (mm) of the groups. Based on the one-way ANOVA, pairwise comparisons in accordance to top to bottom of the right side of graphs were: GROUP-2 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-1 ($p<0.05$), GROUP-4 and GROUP-1 ($p<0.05$), GROUP-3 and GROUP-2 ($p<0.05$), GROUP-4 and GROUP-2 ($p<0.05$), and GROUP-4 and GROUP-3 ($p>0.05$)

CONCLUSION

As shown in Figure 2, the study area spans a relatively large region within the geographical context of Türkiye. It is generally observed that, particularly in inland waters, the rate of genetic and morphological differentiation tends to be higher in geographically closer areas compared to marine environments, primarily due to the limitations on migration and the influence of environmental factors. A similar pattern is evident in the present study. However, the underlying reasons for the prominence of certain traits such as caudal peduncle length (CPL) (71.50%) among metric traits and scales on the lateral line (SLL) (41.65%) among meristic traits as the primary contributors to differentiation, remain unclear. Furthermore, it is important to explore whether this morphological differentiation is also reflected at the genetic level. Genetic evidence could potentially support the classification of this species as a subspecies.

In conclusion, the differentiation observed in *G. turcica* populations across the Ceyhan River system is likely a result of a combination of genetic drift, natural selection, environmental factors, and limited migration. These findings highlight the importance of considering both genetic and environmental factors when studying the evolution and conservation of fish populations in fragmented river systems. Future studies incorporating genetic data will provide valuable insights into the underlying causes of these morphological differences and contribute to a better understanding of the evolutionary processes shaping *G. turcica* in the Ceyhan River system.

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Compliance with Ethical Standards

Authors' Contributions

All authors contributed to the study equal. All authors read and approved the final version.

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. The study was carried out with the legal consent of the Ministry of Agriculture, and Forestry, General Directorate of Fisheries and Aquaculture (permission date 03.04.2014; permission number: 01334).

Data Availability

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

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Comparison of length-weight relationships of three economically important shrimp species in Iskenderun Bay, Northeastern Mediterranean

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A B S T R A C T

This study investigates the length-weight relationships (LWR) of three economically important shrimp species (*Farfantepenaeus aztecus, Penaeus semisulcatus,* and *Metapenaeus monoceros*) in İskenderun Bay, Northeastern Mediterranean, using data collected between October 2023 and November 2024 with trammel net. A total of 579 specimens were analyzed, with *F. aztecus* contributing the highest sample size (238 individuals), followed by *P. semisulcatus* (214) and *M. monoceros* (127). Carapace length (CL) and weight (W) measurements revealed interspecies differences. The average carapace length was 5.66±0.05 mm for *F. aztecus*, 6.63±0.06 mm for *P. semisulcatus*, and 5.08±0.06 mm for *M. monoceros*. Average weights were 32.81±1.12 g, 39.68±1.23 g, and 31.48±1.05 g, respectively. Growth patterns, determined by the parameter *b*, showed distinct gender differences. Females generally exhibited negative allometric growth, while males displayed either isometric or positive allometric growth, depending on the species. Statistically significant differences in growth types were observed, particularly in *M. monoceros* males ($p<0.05$). These results provide crucial insights into the population dynamics and ecological adaptations of shrimp in İskenderun Bay. The findings contribute to understanding the species' growth characteristics, supporting the development of sustainable fisheries management strategies in the region.

INTRODUCTION

Shrimp play a significant role in traditional small-scale fisheries worldwide, including in the Mediterranean and İskenderun Bay (Demirci et al., 2018). Their nutritional value and high economic importance make them a cornerstone of marine resources in these regions (Doğan et al., 2022; Uğurlu, 2025). Additionally, research on the catch composition and catch per unit of effort (CPUE) of penaeid shrimps in from İskenderun Bay provides insights into the species abundance and distribution, further underscoring their significance in local fisheries (Can et al., 2004). Shrimp species found in İskenderun Bay include *Penaeus semisulcatus* (Green Tiger Shrimp), *Farfantepenaeus aztecus* (Brown Shrimp), *Metapenaeus monoceros* (Speckled Shrimp), *Metapenaeus stebbingi*, *Parapenaeus longirostris* (Deepwater Pink Shrimp), *Melicertus kerathurus*, and *Metapenaeopsis japonicus* (Japanese Shrimp) (Can et al., 2004). The shrimp stocks in the region are influenced by the interaction between various migratory and native species, creating a dynamic structure that affects the biodiversity of the ecosystem and the sustainability of the stocks (Manaşırlı et al., 2018).

Length-weight relationship (LWR) studies are a necessary analytical tool for the conservation of marine ecosystems and fisheries resources, for understanding the biological characteristics of species and for developing sustainable fisheries policies. Such studies are expected to contribute to the implementation of more effective conservation and management strategies by providing

valuable information to local fisheries management authorities and related institutions (Rodríguez-García, 2023). The length-weight relationship also provides information on the population dynamics of a species (Kalaycı et al., 2007). In shrimp, length measurements are typically conducted using the carapace length. This measurement is often used in fisheries research, as it provides a reliable parameter. For most shrimp species, the carapace length corresponds to approximately half of the total body length (Silva et al., 2021). The exponential mathematical function established between carapace length and shrimp weight is widely applied in shrimp biology studies due to its accuracy and simplicity.

Gender-specific differences in growth patterns have become an increasing focus in decapod research. Variability in LWRs between male and female shrimp is often attributed to reproductive investment, energy allocation, and morphological differences. Females typically allocate more energy to gonad development, egg production, and brooding, which can suppress somatic growth and result in negative allometric growth (Li et al., 2016). In contrast, males may exhibit isometric or even positive allometric growth, depending on ecological pressures and mating strategies, including investment in structures such as the appendix masculina or petasma (Herrera et al., 2018; Schram and von Vaupel Klein, 2023).

İskenderun Bay presents a unique ecological setting where both native and invasive shrimp species co-exist, and where environmental parameters such as temperature, salinity, and fishing intensity can fluctuate widely (Demirci et al., 2020; Akar et al., 2022; Demirhan et al., 2022). These factors, in combination with species interactions, may drive differences in growth dynamics not only between species but also between sexes within the same species (Manaşırlı et al., 2018; Can et al., 2021). For this reason, updated region-specific LWR data are essential to support accurate stock assessments, estimate biomass, and guide sustainable exploitation practices for key commercial species. In recent years, the most commonly caught species in traditional fisheries in İskenderun Bay include *P. semisulcatus*, *M. monoceros* and *F. aztecus* (Demirci et al., 2023). The Atlantic-origin *F. aztecus* was first recorded in Antalya Bay in 2010 and has since rapidly spread across the Mediterranean (Gökoğlu et al., 2010; Saoud and Davis, 2003; Anderson, 2014). *M. monoceros* and *P. semisulcatus* are commercially valuable species in the eastern Mediterranean, but its population has declined due to overfishing (Bayhan, 2023; Can et al., 2021). İskenderun Bay is a critical area for studying the population structures of these species and developing sustainable fisheries management strategies.

This study aims to investigate the length-weight relationships of economically significant penaeid shrimp species (*P. semisulcatus, M. monoceros,* and *F. aztecus*) in İskenderun Bay, providing updated insights into their growth patterns and biological characteristics. What distinguishes this study from previous research is its emphasis on evaluating potential differences in growth parameters across different years, as well as assessing variations in nutritional status among species. Incorporating these aspects will enhance our understanding of temporal and ecological influences on shrimp populations, thereby supporting science-based fisheries management strategies and the sustainable utilization of regional marine resources. By highlighting interannual variability and nutritional conditions, this study aims to offer a more comprehensive perspective on shrimp ecology, aiding fisheries management authorities in making informed decisions to ensure the long-term sustainability of local shrimp stocks.

MATERIAL AND METHODS

The study was conducted in İskenderun Bay, a region renowned for its small-scale fisheries along Türkiye's eastern Mediterranean coast. Samples were collected using trammel nets between October 2023 and November 2024 from multiple locations in İskenderun Bay, including Arsuz, Dörtyol, Gölovası, İskenderun, Karataş, Konacık, and Yumurtalık. A total of 579 shrimp samples were obtained through routine fishing operations using standardized trammel nets deployed consistently across all sampling sites. The use of trammel nets ensured the unbiased capture of shrimp species, facilitating accurate comparisons of numerical abundance among the studied species. Based on the samples collected, *F. aztecus* emerged as the numerically most abundant species, followed by *P. semisulcatus* and *M. monoceros*.

Figure 1. Distribution of fishing shelters in Iskenderun Bay

The distinction between male and female in shrimps is made as follows. The female reproductive organ is called thelycum (egg-laying structure located in the lower abdomen), and the male reproductive organ is called

petesma (mating organ found near the pleopods) (Schram, and von Vaupel Klein, 2023). Thelycum is an opening in the lower abdomen where eggs are laid. This structure plays an important role in the mating and spawning processes of female shrimps. The male reproductive organ, known as the petasma, is located on the lower abdomen and near the fins. It serves as a mating organ. It is also characterized by a two-legged structure that protrudes prominently in male shrimps and separates them from female shrimps. In shrimp, weight is typically determined based on carapace length, which refers to the length of the shell covering the head part of the shrimp. This relationship is represented by the following equation: Total carapace lengths (CL) and weights (W) were measured to the nearest mm and g, respectively. The LWR of shrimp species (*F. aztecus, P. semisulcatus* and *M. monoceros*) was calculated with the parameters proposed by Ricker (1975), $W = a * CL^b$, using the log-transformation equation: $\log(W) = \log(a) + b \log(CL)$ where W is weight, L is length and a and b are constants.

where:

W represents the weight of the shrimp (in grams), measured with a precision of two decimal places, CL denotes the carapace length of the shrimp (in cm), measured using a digital caliper, a and b are constants specific to the shrimp species.

Estimation of b: The slope b is estimated from the linear regression analysis.

Standard Error of b: The standard error SE_b of the slope b is obtained from the regression analysis. This value quantifies the variability in the estimate of b.

Determination of Critical Value: The critical t-value is selected based on the desired confidence level (e.g., 95%) and the degrees of freedom.

Calculation of the Confidence Interval: The confidence interval for b is calculated using the formula: $b \pm t\ SE_b$, where:

b is the estimated slope, t is the critical t-value, SE_b is the standard error of the slope.

Interpretation: The confidence interval provides the range within which the true value of b lies at the specified confidence level. This range is used to classify the growth type as isometric, negative allometric, or positive allometric based on whether the interval includes, lies below, or lies above the theoretical value of b=3.

RESULTS

The present study reports the length-weight relationships (LWR) of three shrimp species *F. aztecus, P. semisulcatus,* and *M. monoceros* based on 579 specimens collected between October 2023 and November 2024 from various locations in İskenderun Bay, including Arsuz, Dörtyol, Gölovası, İskenderun, Pirinçlik, Karataş, Konacık, and Yumurtalık.

According to the updated statistical analysis, significant differences in both length and weight were found between male and female individuals for all three shrimp species (p=0.05). In *F. aztecus*, based on 149 males and 89 females, highly significant differences were observed in carapace length and weight. Similarly, in *M. monoceros*, with 62 males and 65 females analyzed, both length and weight differed significantly between sexes. For *P. semisulcatus*, the analysis of 107 males and 107 females also revealed statistically significant differences in length and weight. These findings clearly indicate that male and female individuals exhibit distinct biometric characteristics across all species, supporting the necessity of analyzing data separately by sex to ensure accurate biological interpretation.

The data reveals the carapace length and weight statistics for three shrimp species. *F. aztecus* has the highest total number of individuals (238), with an average carapace length of 5.66 mm (ranging from 4.87 mm to 7.71 mm) and an average weight of 32.81 g (minimum 20 g, maximum 80.1 g). *M. monoceros* is represented by 127 individuals, showing the smallest average carapace length of 5.08 mm (range: 3.40 mm to 5.90 mm) and an average weight of 31.48 g (minimum 10 g, maximum 50.9 g). *P. semisulcatus* includes 214 individuals and exhibits the largest average carapace length of 6.63 mm (range: 4.74 mm to 7.56 mm) and the highest average weight of 39.68 g (minimum 15 g, maximum 77.3 g). These figures highlight interspecies differences in size and weight distribution (Table 1).

Table 1. Range and mean values for carapace length and weight of F. *aztecus, P. semisulcatus*, and *M. monoceros* in the İskenderun Bay of North East Mediterranean, 2023-2024.

Species	Number			Carapace Length (mm)			Weight (g)		
	Total	Male	Female	Average	Min	Max	Average	Min.	Max.
F. aztecus	238	149	89	5.66±0.05	4.87	7.71	32.81±1.12	20	80.1
M. monoceros	127	62	65	5.08±0.06	3.40	5.90	31.48±10.5	10	50.9
P. semisulcatus	214	107	97	6.63±0.06	4.74	7.56	39.68±1.23	15	77.3

Table 2 presents data on the relationship between weight and carapace length for three different species (*F. aztecus*, *M. monoceros*, and *P. semisulcatus*) in male and female individuals. The parameters "a" and "b" were provided, along with the growth type. In *F. aztecus*, negative allometric growth was observed for females (b=2.68±0.07), while isometric growth was identified for males (b=2.94±0.12), with the T-test result found to be not significant (p=0.606). For *M. monoceros*, negative allometric growth was recorded in females (b=2.68±0.74), whereas isometric growth was determined in males (b=3.09±0.26), with the T-test result deemed significant (p=0.004). In *P. semisulcatus*, isometric growth was observed in females (b=2.87±0.12), while positive allometric growth was detected in males (b= 3.31±0.1), and the T-test result was found to be significant (p=0) (Figure 2). These findings indicate that statistically significant differences were detected in certain species and between genders.

Table 2. Length-weight relationships of shrimp caught by gillnet fishing in İskenderun Bay

Species	Gender	a	b	T-Test p-value	Growth Type
F. aztecus	F	0.31	2.68 ± 0.07	0	A(-)
	M	0.19	2.94 ± 0.12	0.606	I
	F+M	0.19	2.94±0.039	0	A(-)
M. monoceros	F	0.65	2.68 ± 0.74	0.829	A(-)
	M	0.35	3.09 ± 0.26	0.004	I
	F+M	0.73	2.57 ±0.15	0	A(-)
P. semisulcatus	F	0.22	2.87 ± 0.12	0.145	I
	M	0.09	3.31 ± 0.1	0	A(+)
	F+M	0.11	3.25±0.06	0	A(+)

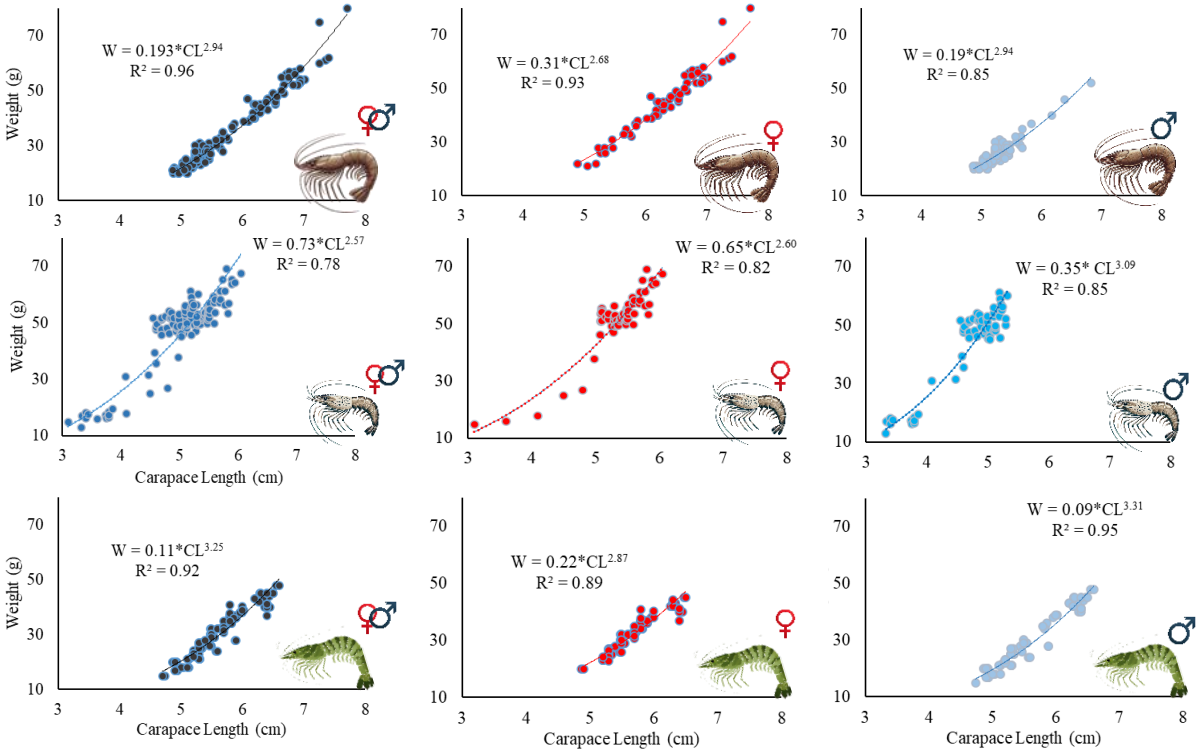

Figure 2. Length-weight relationship graphs of shrimp species caught by trammel net fishing in İskenderun Bay (:*F. aztecus* : *M. monoceros* : *P. semisulcatus*)

DISCUSSION

The dynamic and variable structure of shrimp stocks in the İskenderun Gulf is reflected in the sample sizes of this study. While *P. semisulcatus* is the most commonly caught species in the region, it has been replaced by *F. aztecus* in traditional shrimp fishing using trammel nets. The first length-weight data for *F. aztecus* in this fishing area have been presented through this research. The length-weight relationships of the *P. semisulcatus* and *M. monoceros* have also been revealed.

The notable finding in the study results is the difference in growth patterns between female and male individuals for each species. Females generally exhibit negative allometric growth, while males tend to show either isometric or positive allometric growth. The differences in length-weight relationships in female shrimp are influenced by factors such as reproductive biology, physiological requirements, and ecological adaptations. During the reproductive period, energy resources are allocated to egg production and maturation, which limits weight gain and results in negative allometric growth (Li, et al 2016). Additionally, the growth dynamics, and consequently the relationship between length and weight, are affected by the strategies females use

to avoid predators and their habitat preferences. Metabolic rates and molting processes are also identified as significant factors determining the growth rates of females. Therefore, the negative allometric growth observed in female shrimp is attributed to the distribution of energy between reproduction and growth, as well as ecological adaptations. Furthermore, the larger size of females and the tendency of smaller individuals to exhibit isometric growth are considered expected characteristics of population dynamics (Karachle and Stergiou, 2012). The growth differences between male and female shrimp are explained by variations in reproductive strategies. Female shrimp grow larger, allowing them to carry and protect more eggs, which increases reproductive success. Their abdominal structures grow proportionally (isometric growth) to support egg carrying. In contrast, male shrimp remain smaller, conserving energy and avoiding predators more effectively. Additionally, male reproductive structures, such as the appendix masculina, exhibit positive allometric growth, enhancing their mating success. The mating strategy of males prioritizes agility and the ability to locate females rather than physical size (Herrera, et al., 2018).

Table 3 presents the length-weight relationships of some shrimp species in İskenderun Bay, compared across different habitats. Studies were conducted with various genders, locations, and specific length-weight parameters. The findings of this study reveal both intraspecific and inter-habitat differences when compared to other studies. For example, the species *P. semisulcatus* displays positive allometric growth in the Red Sea (Yemen) but shows isometric growth in İskenderun Bay. This result reflects the influence of habitat conditions on the growth parameters of shrimp (Mehanna, 2000; Mohamed and El-Aiatt, 2012; Abdul-Wahab, 2014; Hussein et al., 2021).

Table 3. Comparison of length-weight relationships of some shrimp species in Iskenderun Bay with different habitats

Species	Gender	a	b	Location	References
P. semisulcatus	F+M	0.344	3.43	Yemen, Red Sea	Abdul-Wahab (2014)
	F+M	0.0065	3.07	Suez Bay	Mehanna (2000)
	M	0.175	2.97	North Sinai, Egypt	Hussien et al. (2016)
	F	0.117	3.258		
	F	0.0003	2.87	Egypt	Mohamed and El-Aiatt (2012)
	M	0.0002	2.99		
	F	0.239	2.87	İskenderun Bay	This study
	M	0.087	3.31		
F. aztecus	F	0.0164	2.73	Türkiye	Anonymous (2024)
	M	0.009	2.97		
	M	0.781	2.84	United States	
	F	0.71	2.94		
	M	0.312	2.68	İskenderun Bay	This study
	F	0.191	2.94		
M. monoceros	F	0.00927	2.92	Saurashtra, India	Dineshbabu (2006)
	M	0.00357	3.29		
	F	0.00008	2.81	Kakinada, India	Rao (1988)
	M	0.00003	3.15		
	F	0.0001	2.78	Malindi-Ungwana Bay, Kenya	Kaka et al. (2019)
	M	0.0002	3.02		
	F	0.0135	2.78	İskenderun Bay, Türkiye	Manaşırlı (2014)
	M	0.006	2.85		
	M	0.35	3.09	İskenderun Bay, Türkiye	This study
	F	0.65	2.60		

The species *F. aztecus* demonstrates various growth tendencies across the United States and Türkiye, while in İskenderun Bay, females exhibit negative allometric (NA) growth, and males display isometric (I) growth. Particularly in the United States, studies have shown positive allometric growth in females. These differences may be explained by environmental factors, fishing pressure, and habitat conditions (Anonymous, 2024).

For *M. monoceros*, studies in India found "b" values around 2.95 for females and 3.15 for males, indicating a trend of positive allometric growth. In contrast, in İskenderun Bay, females showed negative allometric growth (NA), while males exhibited positive allometric growth. These observed growth patterns among species are thought to be associated with differences in sea temperature, food availability, and habitat structure (Can et al., 2021)

In the Malindi-Ungwana Bay, studies have shown that *Penaeus monodon, M. monoceros*, and *Fenneropenaeus indicus* exhibit positive allometric growth patterns. Specifically, *P. monodon* demonstrated higher b values during the Northeast Monsoon (NEM) season (b=3.53) and the Southeast Monsoon (SEM) season (b=3.71), indicating larger sizes during these periods. Conversely, *M. monoceros* displayed negative allometric growth during the SEM season with a b value of 2.59, while *F. indicus* showed positive allometric growth at station S5 during the SEM season with a b value of 3.46 (Kaka et al., 2019).

In the waters of Maharashtra, research on species such as *Penaeus merguiensis, M. monoceros, M. affinis, M. brevicornis, Parapeneopsis stylifera, P. sculptilis,* and *Solenocerra crassicornis* revealed significant differences in length-weight relationships between males and females. For instance, in *M. monoceros,* males had a b value of 2.9064, while females had a b value of 3.0730, indicating that females tend to reach larger sizes. These findings are important for fish stock assessments and biomass estimations (Mane et al., 2019).

In the Iko River Estuary of Nigeria, studies on species including *Penaeus atlantica, Penaeus kerathurus, Penaeus setiferus, P. sculptilis, P. monodon, Nematopalaemon hastatus,* and *Macrobrachium rosenbergii* showed significant positive correlations in length-weight relationships (r^2>0.5). The growth coefficient (b) values ranged from 2.102 to 3.574, indicating allometric growth patterns. Condition factor analyses revealed that females generally had higher K values than males, suggesting that heavier individuals of the same length were in better condition (Udoinyang et al., 2016).

CONCLUSION

This study provides insights into the length-weight relationships (b-values) of *F. aztecus, P. semisulcatus,* and *M. monoceros* in the İskenderun Bay ecosystem. Observed gender-based differences in growth patterns suggest varying energy allocation strategies, with females generally exhibiting negative allometric growth and males showing isometric or positive allometric growth. These findings may reflect the influence of reproductive biology and ecological roles on growth dynamics. Differences in b-values and size characteristics among species appear to be influenced by habitat conditions and growth strategies. *M. monoceros*, being naturally smaller, demonstrates lower carapace lengths and weights, which might align with its ecological adaptations. In contrast, *F. aztecus* is noted for its faster growth rates, potentially indicative of efficient energy use and adaptability to local conditions. Meanwhile, the relatively larger size of *P. semisulcatus* could reflect favorable habitat conditions or different ecological strategies. These results highlight the importance of continuous monitoring of growth parameters to better understand the ecological dynamics of shrimp populations in İskenderun Bay.

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Compliance with Ethical Standards

Authors' Contributions

AD: Design, Data collection, Data analysis, Writing

BFÖ: Investigation, Data collection, Data analysis,

All authors read and approved the final manuscript.

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.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

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Biogenic structure of seashells: Mineralogical and surface properties of *Flexopecten glaber* (Linnaeus, 1758) collected from Bandırma Bay, the Sea of Marmara

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A B S T R A C T

The aim of this study was to determine the mineralogical structure and surface properties of sea shells belonging to the species *Flexopecten glaber* (Linnaeus, 1758) and to obtain information about their adaptation to environmental conditions. For this purpose, PZC (point of zero charge) analysis was used to evaluate the surface charge behavior, XRD (X-ray diffraction) to identify the crystalline phases, SEM-EDS (Scanning Electron Microscopy-Energy Dispersive Spectroscopy) to investigate the surface morphology and elemental composition, and FT-IR (Fourier Transform Infrared Spectroscopy) to characterize the functional groups and organic-inorganic components of the shell. As a result of the PZC analysis, the zero point charge of the shell surface was determined to be at pH 8.33, indicating that the surface carries a positive charge below pH 8.33 and a negative charge above this value. XRD analyses revealed that the crystal structure of the shells was predominantly showed as calcium carbonate ($CaCO_3$) form. EDS results showed that the shell composition contains 54.9% oxygen, 31.1% carbon, 7.5% calcium, and 6.1% nitrogen. Additionally, trace amounts of sodium (0.2%), magnesium (0.1%), and sulfur (0.1%) were detected. These data indicate that the shell structure is a complex biomaterial composed of both inorganic and organic components. The results provide important data for understanding the sensitivity of *F. glaber* shells to environmental factors and the responses of marine organisms to environmental changes. This study offers significant scientific contributions for understanding environmental adaptation mechanisms and the sustainable management of marine resources.

INTRODUCTION

Bivalves are a widely distributed group of shelled invertebrates found in both marine and freshwater environments. Species such as oysters, mussels, scallops, and clams are ecologically important, contributing to ecosystem functions like water filtration and nutrient cycling. As filter feeders, bivalves enhance water quality by removing suspended particles from the environment and also serve as a vital food source for various aquatic organisms. Although calcium carbonate is the primary structural component of bivalve shells, trace amounts of various inorganic elements are also present, varying across species. These elements can affect the physical characteristics of the shells and play a significant role in the physiological processes and life cycle of bivalves. Consequently, the study of shell composition offers valuable insights into both the biology of marine organisms and the dynamics of their ecosystems (Chakraborty et al., 2020; Mititelu et al., 2022). The shells of bivalve organisms account for a substantial proportion of their total body weight, typically ranging from 56% to 61%. Composed of approximately 94% calcium carbonate ($CaCO_3$), these shells represent highly mineralized and mechanically robust structures, reflecting their essential protective and structural functions. Marine organisms utilize their shells for both protection and structural support. These shells are formed through the aggregation of calcium carbonate ($CaCO_3$)

crystals, which are embedded within a thin organic matrix. This composite structure enhances resistance to external stressors and contributes to the overall survival and adaptability of the organisms in their natural habitats (Hamester et al., 2012; Ituen, 2015; Chakraborty et al., 2020; Mititelu et al., 2022; Kizilkaya et al., 2024a,b). Marine organisms employ a range of strategies for mineral formation, from passive processes influenced by environmental factors during organomineralization to active biomineralization mechanisms that are biochemically regulated. These processes critically influence the crystal structure, morphology, and functional properties of the minerals, enabling organisms to adapt to their environment and achieve enhanced structural durability (Louis et al., 2022; Chen et al., 2019; Qin et al., 2024). This study investigates the shell structure of the marine scallop species *Flexopecten glaber* from mineralogical and chemical perspectives, revealing how biomaterials are formed through natural processes. The results highlight the adaptation mechanisms of marine organisms to environmental conditions and emphasize the potential of these biomaterials to serve as a natural model for biomaterial research.

MATERIAL AND METHODS

Sample Collection and Preparation

In this study, *F. glaber* shells were collected from Bandırma, Türkiye. The samples were obtained from their natural marine environment and prepared for laboratory analyses. The shells were carefully washed with clean water to remove dirt, algae, and other organic residues, taking care not to damage the mineral structure during this process. After cleaning, the shells were ground into powder of appropriate sizes under laboratory conditions.

Determination of the Point of Zero Charge (PZC) in Shells

The point of zero charge (PZC) was determined by examining the behavior of homogenized and ground *F. glaber* shells under different pH conditions (Mahmood et al., 2011; Kızılkaya et al., 2024a; Kızılkaya et al., 2024b). For this purpose, solutions each with a volume of 100 mL and one gram sample containing 0.01 M KNO_3 were prepared. The initial pH values (pH_i) of the solutions were adjusted to range between 4 and 10 using 0.1 M HCl and 0.1 M NaOH. A specific amount of the modified shell sample was added to each solution with a different pH. After sample addition, the solutions were stirred for 48 hours at a constant temperature using a magnetic stirrer at 30°C and 100 rpm. At the end of the stirring period, the final pH values (pH_F) of each solution were measured and recorded. For each solution, the difference between the initial and final pH ($\Delta pH=pH_i-pH_F$) was calculated and plotted against the initial pH values (pH_i). The point where the resulting curve intersects the x-axis was accepted as the point of zero charge (PZC) of the sample. This method revealed the pH-dependent change of surface charge and allowed the determination of the PZC value, an important parameter for the shell structure.

Chemical Structure Analysis in Shells

Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) analyses were performed to determine the surface morphology and chemical composition of the samples. These analyses were conducted using a JEOL JSM-7100F SEM device located at the Central Research Laboratory of Çanakkale Onsekiz Mart University. The instrument offers a magnification range from ×40 to ×300,000 and an adjustable accelerating voltage between 0.2 and 30 kV. To increase the surface conductivity of the samples and improve image quality, a conductive coating of gold-palladium alloy (80% Au-20% Pd) was applied prior to analysis using a Quorum coating device. During the coating process, a metal film approximately 2-3 nm thick was deposited under a vacuum of 8×10^{-1} mbar/Pa with a current of 10 mA. Fourier Transform Infrared Spectroscopy (FT-IR) analysis using ATR technique was performed to determine the chemical bond structures and functional groups of the shell samples. The analyses were carried out using a Perkin-Elmer Spectrum One FT-IR spectrometer. Spectral measurements were taken within the wavelength range of 650–4000 cm^{-1}. The *F. glaber* shells used in the analysis were previously ground and homogenized, and no additional pre-treatment was applied before measurement. X-Ray Diffraction (XRD) analyses (20-90 theta) were conducted to determine the crystal structures and mineralogical compositions of the shell samples. These analyses were performed using a PANalytical Empyrean XRD device located at the Central Research Laboratory of Çanakkale Onsekiz Mart University.

RESULTS AND DISCUSSION

The point of zero charge (PZC) is a fundamental parameter widely used in the fields of physical chemistry and surface chemistry, and it is particularly important for understanding adsorption processes. PZC refers to the pH value at which the total electrical charge on a solid surface is zero. In other words, at this point, the positive and negative charges on the surface completely balance each other, rendering the surface electrically neutral (Kosmulski, 2002; Zuyi and Taiwei, 2003; Al-Maliky et al., 2021; Kosmulski, 2023). The electrical charges of solid surfaces vary depending on the pH of the solution. If the solution's pH is

lower than the PZC value, the concentration of hydrogen ions (H^+) on the surface will be high, causing the surface to acquire a positive charge (Kosmulski, 2002; Kosmulski, 2018; Bayram et al., 2023; Ghaedi et al., 2024; Monroyet al., 2025). This charging behavior directly affects the mechanism by which ions bind to the surface, and therefore, the PZC plays a decisive role in adsorption capacities and selectivities (Faizal et al., 2022; Bayram et al., 2023; de Moura et al., 2023). Therefore, the point of zero charge (PZC) of the surface plays a critical role in thoroughly evaluating surface-adsorbate interactions in adsorption studies (Fiol and Villaescusa, 2008; Mahmood et al., 2011). The PZC value can vary depending on the chemical nature of the material used as the adsorbent, the surface functional groups, and the ionic composition of the solution. For example, the PZC values of natural calcium carbonate-based materials are generally around neutral pH, whereas for some oxide- or carbon-based materials, this value may shift to more acidic or basic pH ranges. Therefore, a specific PZC value should be determined for each material (Khan et al., 2021; Kosmulski, 2021; Fallah et al., 2023; Alkhaldi et al., 2024). The determination of the PZC is generally carried out using potentiometric titration, the salt solution method (commonly using 0.01 M KNO_3), or zeta potential measurements (Tan et al., 2008; Cristiano et al., 2011; Bakatula et al., 2018). One of the most common methods involves adjusting the pH of an electrolyte solution with a constant ionic strength to various values and adding adsorbent samples to these solutions (Mahmood et al., 2011; Kızılkaya et al., 2024a,b). The point where ΔpH equals zero, meaning the initial and final pH values are the same, is considered the point of zero charge (PZC) of the system (Kızılkaya et al., 2024a,b).

In this study, the point of zero charge (PZC) of *F. glaber* shell particles was determined based on their surface characteristics. This analysis was conducted to understand the surface properties of *F. glaber* shell particles. The data presented in the graph illustrate how the electrical charge on the shell surface responds to changes in pH. The PZC value of *F. glaber* shells was found to be 8.33 (Figure 1). PZC refers to the pH value at which the total electrical charge on a surface is neutral, and this value can vary depending on the protonation and deprotonation of chemical groups present on the surface. When the solution pH is below the PZC, the environment contains more protons, causing the surface to attract protons and gain a positive charge. This facilitates the binding of negatively charged ions (anions) to the surface. Conversely, when the solution pH is above the PZC, the surface loses protons and becomes negatively charged, increasing the adsorption of positively charged species (cations). In this context, the shells have been shown to be effective adsorbents with the potential to retain negatively charged anions under pH conditions above 8.0. In Figure 1, the ΔpH results corresponding to different initial pH (pHi) values are presented graphically, and the PZC value determined by linear regression analysis is also indicated on the graph.

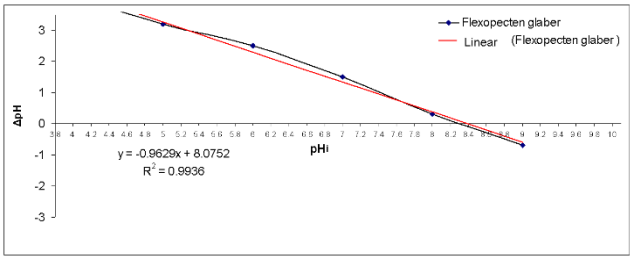

Figure 1. Graphical representation of the zero-charge point of *F. glaber* shell particles

The shells of the species *F. glaber* were analyzed using X-ray Diffraction (XRD), and the obtained data were compared with the crystal forms of calcium carbonate, specifically aragonite ($CaCO_3$). In Figure 2, the XRD spectrum of a mixture consisting of calcite (C) and aragonite (A), provided by the RRUFF project, is presented as a reference for comparison (Lafuente et al., 2015). Reference spectra facilitate the evaluation of the shells' XRD analysis results and help identify the existing structural phases. This method, used to analyze the atomic and molecular structures of shells, is based on the principle that crystals diffract X-rays in a specific order due to their unique atomic arrangements. The resulting diffraction patterns are characteristic to each crystal, acting like a fingerprint that helps distinguish one from another. Calcium carbonate, the main component of bivalve shells, is shaped through a process called biomineralization. The formation of the crystal structure is influenced by various factors such as the species' biological traits, developmental processes, and environmental conditions. In Figure 2, the most intense peak in the XRD spectra corresponds to the calcite peak. Each peak in the XRD spectrum corresponds to the diffraction of X-rays by a specific atomic plane within the mineral's crystal structure. The intensity of these peaks reflects the amount of X-rays diffracted, while the peak angles represent the planes where the diffraction occurs. Since calcite and aragonite have different crystal structures, they exhibit distinct diffraction patterns. Thus, the chemical composition and crystal structure of a mineral can be distinguished through X-ray diffraction. Examination of the XRD spectra shown in Figure 2 reveals that the shell structure of the *F. glaber* species largely consists of the aragonite form of calcium carbonate. Similarly, in Figure 2, blue color represents the analyzed samples, red represents calcium carbonate, and green indicates the aragonite phase.

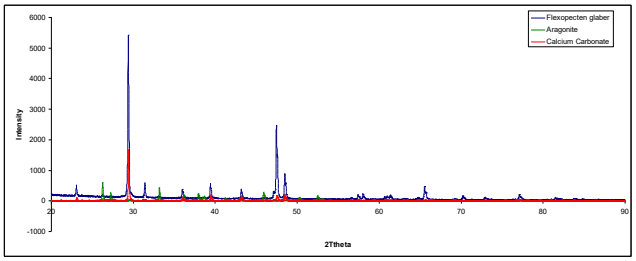

Figure 2. XRD spectra of *F. glaber* shell particles and reference calcium carbonate-aragonite (Lafuente et al., 2015)

Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Spectroscopy (SEM-EDS) is an integrated analytical technique that allows detailed examination of a sample surface structure as well as determination of its elemental composition. This method utilizes a focused electron beam directed onto the sample surface to obtain high-resolution surface images, while simultaneously enabling the identification of existing elements. Due to its capability to provide precise surface analyses, SEM-EDS is widely employed across diverse research and industrial fields, including materials engineering, geology, biology, chemistry, and environmental sciences. Its widespread preference stems from offering both morphological and chemical information, allowing a comprehensive evaluation of the sample. Figure 3 presents the SEM and EDS images of the shells. Energy Dispersive Spectroscopy (EDS) is an analytical technique used to determine the elemental composition of a material.

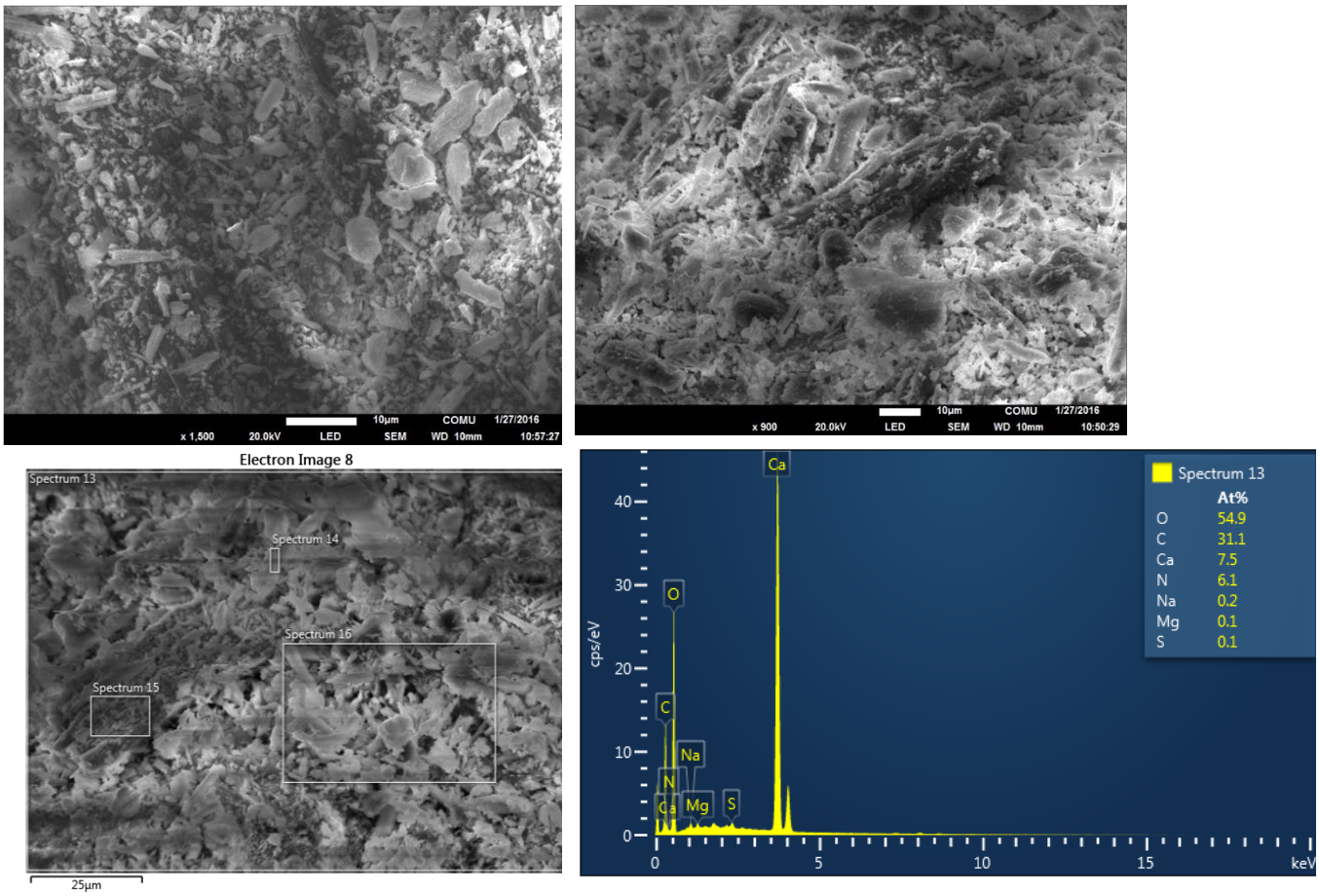

Figure 3. SEM and EDS images of *F. glaber* shell particles

The resulting spectrum from this analysis reveals the presence of elements such as carbon (C), oxygen (O), calcium (Ca), magnesium (Mg), sodium (Na), and nitrogen (N). The high intensities of calcium (Ca), carbon (C), and oxygen (O) elements, which are the main components of the $CaCO_3$ structure, indicate that the mussel shells predominantly consist of calcium carbonate. The carbon element is present both in the crystal structure of calcium carbonate and in the organic components of the shell (such as proteins). Oxygen, as an indispensable part of these inorganic structures, occupies a significant place in the spectrum, while calcium is the fundamental inorganic building block of the mussel shell's calcium carbonate. These results reveal that the mussel shells possess a complex structure rich in both mineral and organic components. In this study, the elemental composition of *F. glaber* shell particles was analyzed by Energy Dispersive Spectroscopy (EDS). The analysis results provide important information about the chemical structure of the shell and reveal the effects of environmental factors on the biomineralization process. The elements with the highest proportions in the shell chemical composition were determined as carbon (31.1%) and calcium (7.5%), confirming that the shell

primarily consists of calcium carbonate ($CaCO_3$). Calcium carbonate is the most commonly used biomineral in the shell formation of marine organisms and is generally found in aragonite or calcite crystal forms. Nitrogen, detected at 6.1%, indicates a significant presence of organic components in the shell structure. This organic matrix is considered to be conchiolin (a protein organic matrix), a structure mainly composed of proteins. The organic matrix facilitates the orderly precipitation of calcium carbonate crystals, thereby increasing the mechanical strength of the shell. Sodium (0.2%) and magnesium (0.1%) are basic components of seawater and are incorporated minimally into the shell structure. Sulfur (0.1%) may originate from sulfur-containing amino acids in the organic matrix or sulfate ions in seawater. It should be noted that EDS analysis provides surface characterization. Due to the heterogeneous nature of the sample, different compositions may be obtained in different regions. Additionally, difficulties in detecting light elements (especially hydrogen) limit the complete characterization of organic components. These findings contribute to understanding biomineralization processes and offer valuable data for pollution monitoring studies in marine environments.

Fourier Transform Infrared Spectroscopy (FT-IR) is a spectroscopy technique used to examine the chemical bonds and structural characteristics of molecules. In this method, infrared radiation is directed at the sample, and the amount of light absorbed by the molecules is measured as a function of wavelength. These measurements provide detailed information about the chemical composition and functional groups of the sample. FT-IR is widely used in various fields such as biological research, drug development, food analysis, and materials science due to the molecular-level insights it offers. In this study, FT-IR analysis was conducted to identify the main components of the shells. Figure 4 shows the FT-IR spectra of *F. glaber* shell particles. The primary component of the shells, calcium carbonate, was detected through its characteristic absorption bands. The strong band at 1411 cm^{-1} (asymmetric stretching vibration of the carbonate ion), along with bands at 875 cm^{-1} and 712 cm^{-1} (carbonate bending vibrations), indicate the presence of calcium carbonate. These findings demonstrate that the mineral portion of the shell is predominantly composed of calcium carbonate. The bands at 1652 cm^{-1}, 1540 cm^{-1} and 1238 cm^{-1} confirm the presence of a protein-rich organic matrix within the shell structure. These proteins represent the organic fraction of the shell. The broad band at 3440 cm^{-1} (O-H stretching) reflects the hydrated nature of the shell. Similar results were found in the studies of Bayraklı et al. (2024). Furthermore, traces of environmentally derived sulfate and lead accumulation were detected. These findings provide insight not only into the structural features of the shells but also into the chemical conditions of their living environment.

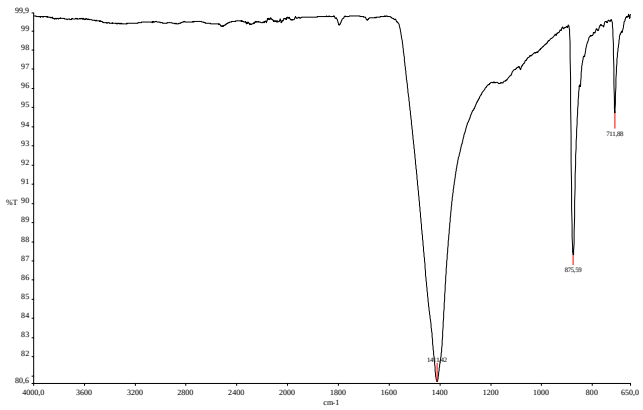

Figure 4. FT-IR spectrum of *F. glaber* shell particles

Calcium carbonate is a widely occurring mineral in nature and plays an important role for living organisms. Its crystal phases, especially aragonite and calcite, possess notable properties essential for protection and structural support of organisms. The crystalline structures of calcium carbonate, such as aragonite and calcite, contribute significantly to the formation of external skeletons and internal frameworks of organisms due to their hardness and durability. Marine shells, corals, and certain algae utilize calcium carbonate to shield themselves from external factors and provide structural integrity. These structures enhance the survival chances of organisms and help maintain balance within ecosystems. Although aragonite and calcite share the same chemical composition, they differ in their crystal structures. Aragonite has an orthorhombic crystal system, whereas calcite is trigonal. This difference influences the physical and chemical properties of both minerals. For example, aragonite is generally less stable and can gradually transform into calcite over time. However, some organisms prefer aragonite because it is thought to precipitate faster and form more complex structures. The use of aragonite and calcite forms of calcium carbonate provides energy efficiency for the organism. Biological systems expend less energy to form these structures, which is a significant advantage, especially for organisms with limited resources. Energy savings allow organisms to allocate more energy to growth, reproduction, and other vital activities, thereby increasing their chances of survival and reproductive success in competitive environments. The processes by which biological systems produce calcium carbonate are also noteworthy. Organisms control the precipitation of calcium carbonate by utilizing calcium and carbonate ions from seawater or other sources. This process is often guided by proteins and other organic molecules, enabling organisms to create calcium carbonate structures of desired shapes and sizes. In conclusion, the crystal phases of

calcium carbonate such as aragonite and calcite are crucial for protection, structural support, and energy efficiency in living organisms. These minerals enhance the survival and reproductive success of many organisms, ranging from marine shells to corals. A better understanding of the role of calcium carbonate in biological systems is important for both basic and applied sciences. In particular, comprehending biomineralization processes can inspire the design and development of new materials. Furthermore, the significance of calcium carbonate should not be overlooked in efforts to conserve marine ecosystems and achieve sustainable development goals (Reddy, 2013; Muhammad Mailafiya et al., 2019; Hossain and Ahmed; 2023).

CONCLUSION

This study examines the mineralogical and surface properties of *F. glaber* shells, shedding light on the natural optimization of biogenic materials. The shells are mainly composed of calcium carbonate ($CaCO_3$), primarily in the forms of aragonite and calcite, along with trace minerals that influence their mechanical strength and resistance to environmental factors. Factors such as temperature, salinity, and pH affect the shell's mineral composition, and *F. glaber* can modify its shell structure to adapt to changing conditions. Surface characterization identified a point of zero charge (PZC) at pH 8.33, indicating that the shell's electrostatic properties vary with environmental pH. X-ray diffraction (XRD) confirmed the dominance of aragonite crystals, while scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) revealed a multilayered surface structure and the presence of a protein-rich organic matrix. Fourier Transform Infrared Spectroscopy (FT-IR) further confirmed the composite nature of the shells, consisting of both inorganic minerals and organic compounds. Overall, the study provides valuable data on the adaptation mechanisms of marine organisms and offers a scientific basis for biomaterial research and marine conservation.

Compliance with Ethical Standards

Authors' Contributions

HY: Conceptualization, Investigation, Methodology, Writing-review & editing, Supervision, Funding acquisition, Project administration

BK: Conceptualization, Writing-original draft, Data curation, Formal Analysis, Visualization, Writing-review & editing. All authors read and approved the final manuscript.

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.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Yerel ölçekte balıkçılık yönetimi ve kooperatifçilik: Çanakkale su ürünleri kooperatiflerinin sorunları ve çözüm önerileri

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Su ürünleri kooperatifleri

Ö Z E T

Bu araştırma, Çanakkale ilinde faaliyet gösteren su ürünleri kooperatiflerinin mevcut durumunu incelemek, karşılaştıkları sorunları tespit etmek ve çözüm önerileri sunmak amacıyla gerçekleştirilmiştir. Çalışma, Çanakkale Bölgesi Su Ürünleri Kooperatifler Birliği'ne bağlı 26 kooperatifi kapsamaktadır. Nitel araştırma yöntemi kullanılarak 2024 yılında gerçekleştirilen saha çalışmalarında, kooperatif başkanları ve üyeleriyle yapılan yüz yüze görüşmelerden elde edilen veriler betimsel analiz yöntemiyle değerlendirilmiştir. Araştırma sonucunda, kooperatiflerin önemli bir kısmının idari, altyapı ve pazarlama olanakları açısından yetersiz olduğu tespit edilmiştir. Liman, çekek yeri, ağ tamir alanı, satış yeri ve soğuk hava deposu gibi temel üstyapı eksiklikleri; denetim mekanizmalarının zayıflığı; amatör balıkçılığın kontrolsüz yayılması; devlet desteklerinin yetersizliği ve yasal düzenlemelerdeki belirsizlikler, öne çıkan temel sorunlar arasında yer almaktadır. Ayrıca, pazarlama sürecinde kabzımallara olan bağımlılık, kooperatiflerin ekonomik sürdürülebilirliğini olumsuz etkilemektedir. Bu çalışma hem Çanakkale özelinde hem de Türkiye genelinde su ürünleri kooperatifçiliğinin karşılaştığı çok boyutlu yapısal sorunlara ışık tutmakta ve kooperatiflerin kurumsal kapasitelerinin güçlendirilmesine yönelik öneriler sunmaktadır. Elde edilen bulguların, balıkçılık politikalarının geliştirilmesine ve kooperatiflerin daha etkin hale getirilmesine katkı sağlaması beklenmektedir.

Local-scale fisheries management and cooperativism: Challenges and strategic solutions for fisheries cooperatives in Çanakkale

Keywords:
Fishing
Çanakkale
Coastal infrastructure
Cooperative challenges
Fisheries cooperatives

A B S T R A C T

This study aims to examine the current status of fisheries cooperatives operating in the province of Çanakkale, identify the main challenges they face, and offer viable solutions. The research covers 26 cooperatives affiliated with the Çanakkale Regional Union of Fisheries Cooperatives. Employing a qualitative research design, data were collected through face-to-face interviews with cooperative chairmen and members, and analyzed using descriptive methods in 2024. Findings reveal that a significant number of cooperatives lack adequate administrative infrastructure and physical facilities. Key deficiencies include the absence of harbors, slipways, net repair areas, sales units, and cold storage facilities. In addition, ineffective inspection mechanisms, the uncontrolled expansion of amateur fishing, insufficient state support, and legal ambiguities are among the most critical problems. The cooperatives' dependency on middlemen in the marketing process further undermines their economic sustainability. This study sheds light on the multifaceted structural problems faced by fisheries cooperatives not only in Çanakkale but also throughout Türkiye. It presents policy recommendations aimed at strengthening the institutional capacities of cooperatives and enhancing their operational effectiveness. The findings are expected to contribute to the formulation of more responsive fisheries management strategies.

GİRİŞ

Su ürünleri kooperatifleri, küçük ölçekli balıkçılığın sürdürülebilirliğini sağlamada kilit rol oynayan kurumsal yapılardır. Bu kooperatifler, özellikle küçük ölçekli balıkçılığın desteklenmesinde, kaynakların ortak kullanımı ve pazarlama faaliyetlerinin organize edilmesinde önemli rol oynamaktadır (Ünal ve Yercan, 2006; Doğan, 2015). Ancak bu kooperatifler, Türkiye genelinde çeşitli yapısal ve yönetsel sorunlarla karşı karşıyadır. Türkiye'de kooperatifçilik, özellikle su ürünleri sektöründe belirli bir örgütlenme düzeyine ulaşmış görünse de yapısal ve yönetsel sorunlar nedeniyle etkili ve sürdürülebilir bir kalkınma aracı haline gelememiştir. Türkiye genelinde toplam 31.241 ortakla faaliyet gösteren 572 su ürünleri kooperatifi ve bunların bağlı olduğu 16 bölge birliği bulunmaktadır. Ancak, bu kooperatiflerin sadece 235'i Su Ürünleri Kooperatifleri Merkez Birliği (SÜRKOOP) çatısı altında toplanmıştır (SÜRKOOP, 2025). Bu durum, örgütsel anlamda bir bütünlüğün sağlanmadığını göstermektedir. Sektörel iş gücü verileri de bu yapısal eksiklikleri destekler nitelikte olup 2006 yılında balıkçılık sektöründe istihdam edilen kişi sayısı 45.969 iken, 2024 yılı itibarıyla bu sayı 34.400'e gerilemiştir (TÜİK, 2025). İstihdamdaki bu azalma, yalnızca sektörün daralmasına değil, aynı zamanda kooperatiflerin üyelerine yeterli ekonomik katkıyı sunamadığını ve sektördeki cazibesini kaybettiğini de göstermektedir. Nitekim literatürde de bu durumun altı çizilmekte ve su ürünleri kooperatiflerinin büyük bir bölümünün kısa ömürlü olduğu ya da kuruluş amaçlarını tam anlamıyla gerçekleştiremediği ifade edilmektedir (Karademir ve Arat, 2014; Doğan, 2017). Literatürde, balıkçılık kooperatiflerinin sorunları çeşitli temalarda (örneğin; altyapı eksiklikleri (Altınışık, 2006), yasal düzenleme sorunları (Ceyhan, 2006), örgütlenme ve pazarlama yetersizlikleri (Akyol ve Ceyhan, 2010), kurumsal etkinlik düşüklüğü (Ünal ve ark., 2009) gibi) ele alınmaktadır. Bu çalışmaların çoğunda, kooperatiflerin kuruluş amaçlarını yeterince gerçekleştiremediği, kısa ömürlü olduğu ya da etkin çalışmadığı vurgulanmaktadır.

Yapılan çalışmalar Türkiye'nin farklı bölgelerinde faaliyet gösteren su ürünleri kooperatiflerinin benzer sorunlarla karşılaştığını ortaya koymaktadır. Ural ve Canpolatlı (2009), Doğu ve Güneydoğu Anadolu'daki kooperatiflerin sayıca varlık gösterse de teknik donanım ve insan kaynağı açısından sınırlı olduğunu rapor etmişlerdir. İstanbul, Giresun, Muğla, Elazığ ve Trabzon gibi illerde yapılan araştırmalarda da kooperatiflerin altyapı-üstyapı eksiklikleri, yasal düzenlemelerdeki yetersizlikler, düşük örgütlenme kapasitesi ve sosyoekonomik kırılganlıklar gibi ortak sorunlarla mücadele ettiği ortaya konmuştur (Doğan, 2010; Canpolat ve ark., 2015; Boran ve Avcı Softa, 2016; Tokmak Kırkses ve Samsun, 2020).

Özellikle kıyı balıkçılığının yoğun olduğu bölgelerde, balıkçıların sosyal güvenceden yoksun olduğu, pazarlama kanallarına erişimde zorlandıkları ve barınak gibi temel fiziksel yapılara ulaşmakta sıkıntı yaşadıkları vurgulanmaktadır (Doğan ve Gönülal, 2011; Doğan ve Alıçlı, 2018; Yücel ve Acar, 2018). Buna ilave olarak, ağ tamiri alanı, soğuk hava deposu, buz üretim tesisi gibi kritik yapıların eksikliği, avcılık sonrası tedarik zincirinin sürdürülebilirliğini de tehdit etmektedir (Akyol ve Perçin, 2006; Yıldız ve Karakulak, 2013).

Kooperatif yöneticilerinin ve üyelerinin eğitim eksikliği, kooperatiflerin profesyonelce yönetilememesine neden olurken; yasal mevzuatın uygulanmasındaki güçlükler ve yetki karmaşası da örgütsel işleyişi sekteye uğratmaktadır (Zengin ve Güngör, 2017; Akar, 2017). Özellikle amatör balıkçılık faaliyetlerinin denetimsizliği ve kayıt dışı avcılığın artması, profesyonel balıkçıların gelirlerini düşürmekte ve sürdürülebilir kaynak kullanımını tehdit etmektedir (Ceyhan ve ark., 2006).

Su ürünleri kooperatifleri konusunda Türkiye'nin birçok bölgesine ilişkin çeşitli çalışmalar yapılmış olmasına rağmen, Çanakkale ilindeki su ürünleri kooperatiflerinin tümünü kapsayan sistematik ve bütüncül bir analiz henüz gerçekleştirilmemiştir. Mevcut literatürde yalnızca sınırlı sayıda kooperatife ilişkin bölgesel değerlendirmelere yer verilmiş olup, kapsamlı ve il düzeyinde yapılmış bir çalışmaya rastlanmamaktadır (Altınışık, 2006; Ceyhan, 2006; Akyol ve Ceyhan, 2010). Oysa Çanakkale, Marmara Denizi, Ege Denizi, Çanakkale Boğazı, Saros ve Edremit Körfezleri gibi farklı denizel sistemlere ev sahipliği yapan stratejik bir konuma sahiptir. Bu çeşitlilik, bölgedeki su ürünleri kooperatiflerinin faaliyetlerinin hem biyofiziksel koşullara (örneğin deniz suyu sıcaklığı, akıntı rejimi, tuzluluk oranı, plankton dağılımı gibi doğal çevresel faktörler) hem de yönetsel uygulamalara göre farklılık göstermesine neden olmaktadır. Av sahalarının ekolojik yapısı (örneğin deniz dibi yapısı, habitat zenginliği, tür çeşitliliği ve avlanabilir stok durumu gibi ekolojik parametreler), deniz trafiği, koruma alanları ve su ürünleri yetiştiricilik alanları gibi faktörler, kooperatiflerin sorunlarını daha da karmaşık hale getirmekte olup özellikle de sit alanları, askeri yasak bölgeler ve balıkçılık dışı faaliyetlerle (deniz ulaşımı, endüstriyel atıklar vb.) çakışan sahalar nedeniyle kooperatiflerin avlanma izinleri, güzergahları ve faaliyet sürekliliği kesintiye uğramaktadır.

Bu çalışma, Çanakkale ilinde faaliyet gösteren tüm su ürünleri kooperatiflerinin mevcut durumlarını kapsamlı biçimde analiz etmeyi, yaşanan temel sorunları ortaya

koymayı ve literatürdeki bilgi boşluğunu dolduracak çözüm önerileri geliştirmeyi amaçlamaktadır. Elde edilen bulguların hem yerel hem de ulusal düzeyde balıkçılık yönetimine katkı sunması hedeflenmektedir.

MATERYAL VE YÖNTEM

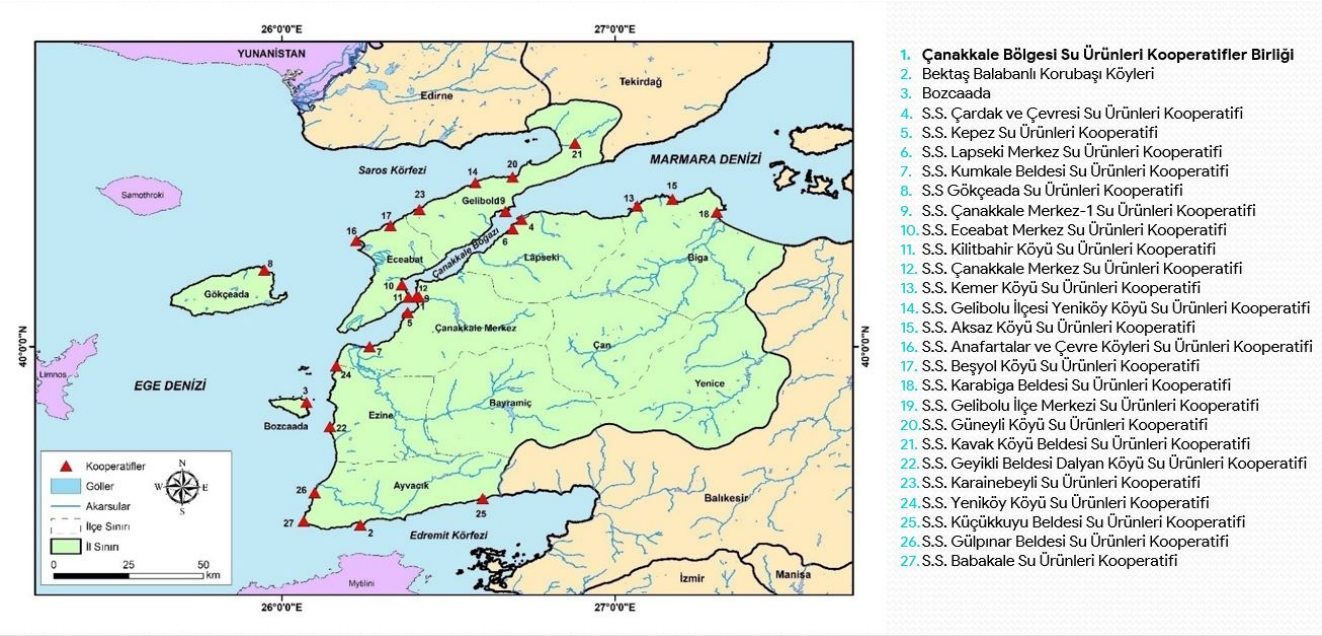
Bu çalışmanın evrenini Çanakkale Bölgesi Su Ürünleri Kooperatifler Birliği'ne bağlı olarak faaliyet gösteren su ürünleri kooperatifleri oluşturmaktadır (Şekil 1). Araştırma kapsamında aşağıdaki temel sorulara yanıt aranmıştır:

(i) Çanakkale'deki su ürünleri kooperatiflerinin mevcut yapısal ve yönetsel özellikleri nelerdir?

(ii) Bu kooperatiflerin karşılaştığı başlıca problemler nelerdir?

(iii) Belirlenen sorunlara yönelik çözüm önerileri nelerdir?

Veri toplama sürecinde öncelikle ilgili literatür incelenmiş olup Türkiye genelinde su ürünleri kooperatiflerine dair mevcut akademik çalışmalar taranarak genel eğilimler ve karşılaşılan problemler hakkında ön bilgiler elde edilmiştir. Bunu takiben, Çanakkale il sınırları içerisindeki kooperatiflere yönelik saha çalışması yürütülmüştür.



Şekil 1. Çanakkale'deki su ürünleri kooperatiflerinin konumu
Figure 1. Fisheries cooperatives in Çanakkale

Çalışmada nitel araştırma yöntemlerinden yararlanılmış olup veriler doğrudan gözlem ve yarı yapılandırılmış görüşme teknikleri ile toplanmıştır. Kooperatif başkanları ve kooperatif başkanları ile görüşme imkanı çok kısa süreli gerçekleşen bazı durumlarda kıdemli kooperatif ortakları ile yüz yüze görüşmeler gerçekleştirilmiştir. Görüşmelerde, kooperatiflerin mevcut durumu, altyapı ve üstyapı koşulları, idari ve hukuki işleyişleri, pazarlama faaliyetleri, devlet desteğine erişim ve örgütlenme kapasitesi gibi konular üzerinde durulmuştur. Görüşmelerin süresi, saha koşullarının ve kooperatif yöneticilerinin zaman kısıtlarının dikkate alınmasıyla mümkün olduğunca kısa tutulmuş, bu bağlamda Ünal vd. (2009) tarafından uygulanan yöntemlerden de yararlanılmıştır. Gözlemler sırasında elde edilen bulgular, mevcut yapıların durumu ve teknik donanımlar gibi somut göstergelerle desteklenmiştir.

Elde edilen veriler betimsel analiz yöntemiyle değerlendirilmiş; sorun alanları sınıflandırılmış ve sıklıklarına göre tablolar halinde sunulmuştur. Nicel bulgular, oranlar ve dağılımlar aracılığıyla ifade edilmiş; nitel veriler ise katılımcıların görüşlerinden elde edilen temalar doğrultusunda anlamlandırılmıştır. Şöyle ki, nitel veriler, katılımcıların görüşlerinde sıklıkla tekrar eden anahtar ifadeler ve anlam birimlerine dayalı olarak gruplandırılmış; örneğin 'altyapı eksikliği', 'pazarlama sorunları', 'yasal belirsizlik' gibi temalar tanımlanarak analiz edilmiştir.

BULGULAR

Çanakkale'deki Su Ürünleri Kooperatiflerinin Mevcut Durumu

Çanakkale Bölgesi Su Ürünleri Kooperatifler Birliği'ne bağlı olarak faaliyet gösteren toplam 26 kooperatif bulunduğu tespit edilmiştir. Bu kooperatiflerin üye sayıları 7 ile 190 arasında değişmekte olup toplamda 1072 aktif üye

bulunmaktadır. Kooperatiflerin faaliyet alanları, ağırlıklı olarak Çanakkale Boğazı, Ege Denizi ve Marmara Denizi kıyılarında yoğunlaşmaktadır (Şekil 2). Bu da bölgedeki kooperatiflerin farklı denizel ekosistemlere dayalı olarak çeşitlenen avcılık faaliyetleri yürüttüğünü göstermektedir.

Şekil 2. Çanakkale'deki su ürünleri kooperatiflerinin mevcut durumu

Figure 2. The current state of fisheries cooperatives in Çanakkale

Kooperatiflerin kuruluş yılları incelendiğinde en eskisi 1974 yılında kurulan Kemer Köyü Su Ürünleri Kooperatifi olduğu; en yeni kurulanın ise 2021 yılında faaliyete geçen Aksaz ve Gelibolu Yeniköy Köyü Kooperatifleri olduğu görülmektedir (Tablo 1). Bu çeşitlilik, kooperatiflerin zaman içinde artan balıkçılık faaliyetlerine yanıt vermek amacıyla kurulduğunu göstermektedir.

İncelenen 26 kooperatifin tamamının nakil belgesi düzenleme yetkisine sahip olduğu, ancak yalnızca iki kooperatifin doğrudan pazarlama faaliyeti yürüttüğü belirlenmiştir (Tablo 1). Bu durum, kooperatiflerin ürünlerini doğrudan son tüketiciye ulaştırmakta zorlandığını ve pazarlama zincirine yeterince entegre olamadığını göstermektedir. Öte yandan, yalnızca beş kooperatifin çalışan personeli bulunduğu, diğerlerinin ise gönüllülük esasına dayalı olduğu tespit edilmiştir.

İdari altyapı açısından değerlendirildiğinde 17 kooperatifin (%65,4) idari binası bulunduğu; geri kalan 9 kooperatifin (%34,6) ise bu olanaktan yoksun olduğu saptanmıştır (Tablo 1). Mevcut idari binaların büyük kısmı fiziki açıdan yetersiz, bakımsız ya da işlevselliği sınırlı yapılardır. İdari binalar çoğunlukla konteyner tipinde, tek odalı, ısıtma/soğutma sistemi olmayan, arşiv ve toplantı yapma kapasitesinden yoksun yapılardır. İdari birimi olmayan kooperatiflerde ise üyelerin balıkçılık faaliyetlerine dair işlemlerini liman kenarlarında ya da tekneler üzerinde gerçekleştirdiği gözlemlenmiştir. Bu durum hem verimlilik hem de kurumsal kapasite açısından ciddi bir eksikliktir.

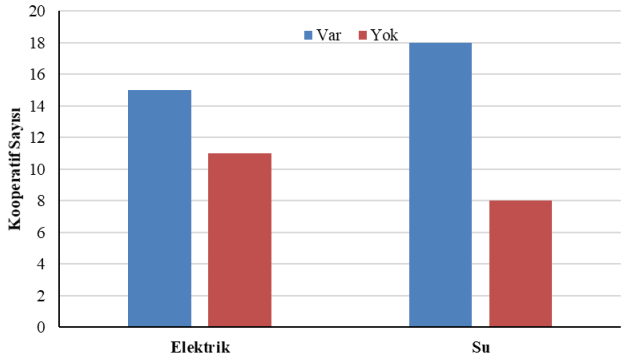
Çanakkale'deki su ürünleri kooperatiflerinin fiziksel kapasitesi incelendiğinde altyapı imkanlarının büyük ölçüde yetersiz olduğu görülmektedir (Şekil 3). Altyapı açısından yapılan değerlendirmelere göre kooperatiflerin yalnızca 15'inde (%57,7) elektrik bağlantısının bulunduğu, geri kalan 11 kooperatifin (%42,3) ise bu temel hizmetten yoksun olduğu belirlenmiştir.

Tablo 1. Çanakkale'deki su ürünleri kooperatiflerinin temel özellikleri

Table 1. Basic characteristics of fisheries cooperatives in Çanakkale

Sınırlı Sorumlu Su Ürünleri Kooperatifi	Kuruluş Yılı	Toplam Üye Sayısı	Ortak Sayısı	Fiili Avcılık Yapan Ortak Sayısı	Fiili Avcılık Yapan Balıkçı Sayısı	Kayıtlı Tekne Sayısı	Kooperatifte Çalışan Sayısı	Pazarlama Faaliyeti	Sosyal Tesis-İdari Bina	Nakil Belgesi Düzenleme
Kemer Köyü	1974	29	29	29	29	30	0	YOK	VAR	VAR
Güneyli Köyü	1975	7	7	7	7	9	0	YOK	VAR	VAR
Çardak ve Çevresi	1979	48	48	20	20	15	0	VAR	VAR	VAR
Karabiga Beldesi	1983	42	42	35	35	45	0	YOK	YOK	VAR
Bozcaada	1986	41	41	15	15	15	0	YOK	VAR	VAR
Anafartalar ve Çevre Köyleri	1986	46	46	20	20	15	0	YOK	YOK	VAR
Eceabat Merkez	1991	47	47	40	40	40	1	YOK	VAR	VAR
Bektaş Balabanlı Korubaşı Köyleri	1994	25	25	8	10	10	0	YOK	VAR	VAR
Babakale	1994	59	59	28	28	79	2	VAR	VAR	VAR
Yeniköy Köyü	1998	37	37	28	28	27	0	YOK	VAR	VAR
Gökçeada	2000	44	44	32	32	41	1	YOK	VAR	VAR
Lapseki Merkez	2002	30	30	18	18	27	0	YOK	VAR	VAR
Beşyol Köyü	2004	14	14	14	14	15	0	YOK	YOK	VAR
Kavak Köyü Beldesi	2004	21	21	9	9	9	0	YOK	VAR	VAR
Karainebeyli	2004	10	10	5	5	5	0	YOK	YOK	VAR
Küçükkuyu Beldesi	2004	57	57	25	25	95	2	YOK	VAR	VAR
Çanakkale Merkez	2005	17	17	15	15	15	0	YOK	VAR	VAR
Çanakkale Merkez Bir	2009	190	190	190	190	190	0	YOK	YOK	VAR
Kumkale Beldesi	2010	17	17	17	17	17	0	YOK	VAR	VAR
Gülpınar Beldesi	2010	20	20	7	7	20	1	YOK	VAR	VAR
Geyikli Beldesi Dalyan Köyü	2012	55	55	15	15	55	0	YOK	YOK	VAR
Gelibolu İlçe Merkezi	2014	44	44	43	43	45	0	YOK	VAR	VAR
Kepez	2016	115	60	60	60	115	0	YOK	VAR	VAR
Kilitbahir Köyü	2018	13	13	8	8	13	0	YOK	YOK	VAR
Gelibolu İlçesi Yeniköy Köyü	2021	25	25	25	25	24	0	YOK	YOK	VAR
Aksaz Köyü	2021	19	19	19	19	16	0	YOK	YOK	VAR

Su temini açısından da benzer bir durum gözlemlenmiş; 18 kooperatifte (%69,2) su altyapısının bulunduğu, 8 kooperatifte (%30,8) ise su erişiminin olmadığı tespit edilmiştir (Tablo 1). Özellikle sekiz kooperatifte hem elektrik hem de su altyapısının bulunmaması, balıkçılık faaliyetlerinin sürdürülebilirliği ve iş sağlığı açısından ciddi bir sorun teşkil etmektedir.



Şekil 4. Çanakkale'deki su ürünleri kooperatiflerinin üstyapı imkanları
Figure 4. Superstructure facilities of fisheries cooperatives in Çanakkale

Çanakkale'deki Su Ürünleri Kooperatiflerinin Karşılaştığı Sorunlar

Saha çalışmaları ve kooperatif temsilcileriyle gerçekleştirilen görüşmeler sonucunda Çanakkale'deki su ürünleri kooperatiflerinin büyük çoğunluğunun yapısal, yönetsel ve ekonomik boyutta çeşitli sorunlarla karşı karşıya olduğu belirlenmiştir. Elde edilen veriler, sorunların hem fiziki yetersizlikler hem de kurumsal işleyiş ve yerel yönetimler, kamu kurumları, pazar aktörleri ve tüketici grupları gibi kooperatif dışındaki etkileşim alanlarını kapsayan dış çevreyle ilişkiler açısından çok boyutlu olduğunu ortaya koymaktadır.

En sık dile getirilen sorun, kooperatiflerin liman, barınak ve çekek yeri gibi temel kıyı yapılarındaki eksikliklerdir. Kooperatiflerin %88,46'sı, bu altyapıların yetersizliği nedeniyle teknelerin bağlanması, karaya çekilmesi ve korunması süreçlerinde ciddi sıkıntılar yaşadıklarını belirtmiştir. Özellikle bazı bölgelerde limanların doğal afetler (fırtına, sel, taşkın) karşısında dayanıklı olmaması veya hiç liman yapısının bulunmaması, maddi hasarlara yol açmakta ve balıkçı güvenliğini tehdit etmektedir.

Tablo 2. Çanakkale'deki su ürünleri kooperatiflerinin temel sorunları
Table 2. Main problems of fisheries cooperatives in Çanakkale

Kooperatifler	Sorunlar											
	1	2	3	4	5	6	7	8	9	10	11	12
Bektaş Balabanlı Korubaşı Köyleri	×	×	×	×	×	×	×	×			×	×
Bozcaada	×	×	×				×				×	×
Çardak ve Çevresi	×	×	×	×					×		×	
Kepez	×	×	×	×		×	×		×	×		×
Lapseki Merkez						×			×		×	
Kumkale Beldesi	×	×	×	×			×			×		
Gökçeada	×	×	×	×	×			×	×	×	×	×
Çanakkale Merkez Bir	×	×	×	×		×	×	×	×		×	
Eceabat Merkez						×		×	×	×	×	×
Kilitbahir Köyü	×	×	×	×	×	×	×	×	×	×	×	×
Çanakkale Merkez	×	×	×			×	×	×	×	×	×	×
Kemer Köyü	×	×				×				×	×	
Gelibolu İlçesi Yeniköy Köyü	×	×	×	×	×	×	×	×	×	×	×	×
Aksaz Köyü	×	×	×	×	×	×	×	×	×	×	×	×
Anafartalar ve Çevre Köyleri	×	×	×	×	×	×	×	×	×	×	×	×
Beşyol Köyü	×	×	×	×						×	×	×
Karabiga Beldesi					×			×	×	×	×	
Gelibolu İlçe Merkezi	×	×	×	×		×		×	×	×	×	×
Güneyli Köyü	×	×		×							×	×
Kavak Köyü Beldesi		×				×			×		×	
Geyikli Beldesi Dalyan Köyü	×	×	×		×			×	×			×
Karainebeyli		×	×	×		×				×	×	
Yeniköy Köyü		×		×	×		×	×	×	×	×	
Küçükkuyu Beldesi		×						×		×		×
Gülpınar Beldesi		×			×			×	×	×		
Babakale		×				×						
Oran (%)	65,38	88,46	61,54	57,69	38,46	57,69	42,31	57,69	65,38	65,38	76,92	57,69

1: Kooperatifin İşletmesi/Kiralanması, 2: Liman-Barınak-Çekek Yeri, 3: Altyapı-Üstyapı, 4: Barınma-Depo-Sosyal Alan, 5: Yasa Dışı Avcılık, 6: Av Sahaları, 7: Pazarlama, 8: Koruma-Kontrol-Denetim Hizmetleri, 9: Yasal Düzenleme Eksikliği, 10: Devlet Desteği, 11: Balıkçıların Sosyoekonomik İmkanları, 12: Yerel Yönetimlerle İlişkiler

1: Operation/Renting of Cooperative, 2: Port-Shelter-Dock Place, 3: Infrastructure-Superstructure, 4: Shelter-Storage-Social Area, 5: Illegal Fishing, 6: Fishing Grounds, 7: Marketing, 8: Protection-Control-Supervision Services, 9: Lack of Legal Regulation, 10: State Support, 11: Socioeconomic Opportunities of Fishermen, 12: Relations with Local Governments

Ayrıca, %65,38 oranında ifade edilen bir diğer sorun ise devlet desteklerinin yetersizliğiyle ilgilidir. Akaryakıt, av araçları ve bakım-onarım gibi temel ihtiyaçlar için sağlanan desteklerin güncel ekonomik koşulları karşılayamadığı, bu nedenle kooperatiflerin üretim faaliyetlerinde ciddi finansman sıkıntıları yaşadığı bildirilmiştir.

Kooperatiflerin %76,92'si, üyelerinin sosyoekonomik durumlarının zayıf olması nedeniyle üretim faaliyetlerinin sürdürülebilirliğinde zorluk yaşandığını ifade etmiştir. Artan maliyetler, devlet desteğinin yetersiz olması ve pazarlama kanallarındaki sınırlılıklar, birçok balıkçının mesleği bırakma eğiliminde olduğunu göstermektedir. Balık satışlarının genellikle kabzımallar aracılığıyla yapılması, ürün fiyatlarının kontrol edilememesine ve balıkçının düşük gelir elde etmesine neden olmaktadır. Düşük gelir, sosyal güvenlik kapsamı dışında kalma, yaşlı nüfusun ağırlığı, alternatif istihdam kaynaklarının olmayışı gibi etkenler kooperatif üyelerinin sosyoekonomik kırılganlığını artırmaktadır.

Yasal mevzuat ve kamu yönetimi ile ilgili sorunlar da öne çıkan hususlar arasındadır. Kooperatiflerin %65,38'i işletme ve kiralama hakları ile ilgili belirsizliklerin kurumsal faaliyetleri kısıtladığını belirtmiştir. Özellikle av sahalarının sit alanları içerisinde kalması, farklı kamu kurumları arasında yetki çakışmalarına ve uzun süren bürokratik süreçlere neden olmaktadır. Bu durum, özellikle yerel yönetimlerle yaşanan anlaşmazlıklarda daha belirgin hale gelmektedir. Kooperatiflerin faaliyet alanlarına ilişkin izin süreçlerinin farklı kurumlar arasında net tanımlanmamış olması; sit alanı kapsamındaki bölgelerde faaliyet yürütme belirsizlikleri de örnek olarak gösterilmiştir.

Altyapı ve üstyapı eksiklikleri (%61,54), barınma, depo ve sosyal alan yetersizlikleri (%57,69), koruma-denetim hizmetlerinin yetersizliği (%57,69), yerel yönetimlerle olan iletişim ve iş birliği sorunları (%57,69), balıkçıların mesleki tanımlarının olmaması gibi eksiklikler, kooperatiflerin kurumsal etkinliğini olumsuz yönde etkilemektedir. Pazarlama (%42,31) ve yasa dışı avcılık (%38,46) ise kooperatiflerin daha az sıklıkla bildirdiği ancak önemli görülen diğer sorunlardır. Pazarlama sorunları, kooperatiflerin finansal sürdürülebilirliğini zayıflatmakta; yasa dışı avcılık ise yasal çalışanların pazar payını daraltarak gelir eşitsizliğini artırmaktadır. Özellikle ticari olmayan, sportif ya da amatör balıkçılık adı altında yapılan ve yasal sınırların dışında gerçekleşen faaliyetler, kayıt dışı balıkçılığı artırmakta ve kooperatiflerin ekonomik sürdürülebilirliğini tehdit etmektedir. Sonuç olarak, Çanakkale'deki su ürünleri kooperatiflerinin çok boyutlu sorunlarla mücadele ettiği ve bu sorunların çözümü için kapsamlı bir kurumsal reform, altyapı yatırımı ve mevzuat güncellemesi gerekliliği ortaya çıkmaktadır.

TARTIŞMA

Bu çalışmada elde edilen bulgular, Çanakkale'deki su ürünleri kooperatiflerinin hem nicelik hem de nitelik bakımından çok çeşitli sorunlarla karşı karşıya olduğunu açıkça ortaya koymaktadır. Toplam 1072 üyesi bulunan 26 kooperatifin yapısal, yönetsel ve ekonomik kapasitelerinin oldukça sınırlı olduğu tespit edilmiştir. Altınışık (2006) tarafından bildirilen 497 üyeye kıyasla önemli bir artış kaydedilmiş olması, kooperatifleşme eğiliminde nicel bir büyümeye işaret etse de bu artışın nitel bir iyileşmeye dönüşemediği görülmektedir. Öte yandan Kale ve Zabun (2023) tarafından belirtilen 1207 üye sayısı ile karşılaştırıldığında, veriler arasında görülen farklılıklar, üyeliklerin dinamik yapısını ve her yıl yapılan genel kurul süreçlerinin bu rakamlarda etkili olduğunu göstermektedir.

Kooperatiflerin mevcut fiziksel koşulları, Türkiye'nin diğer bölgelerinde yapılan çalışmalarla karşılaştırıldığında da benzer eksiklikler göstermektedir. İstanbul'daki kooperatifleri inceleyen Yıldız ve Karakulak (2013), özellikle altyapı ve üstyapı olanaklarının kısıtlı olduğunu; örneğin yalnızca %58'inde idari bina, %35,4'ünde ağ tamir yeri, %3,2'sinde buz üretim alanı bulunduğunu bildirmiştir. Çanakkale'deki kooperatiflerle kıyaslandığında, su temini açısından daha iyi durumda olunmasına karşın, elektrik erişimi, ağ tamir alanı ve ilk yardım birimi gibi temel hizmetlerde benzer yetersizlikler olduğu anlaşılmaktadır. Öte yandan, Trabzon'daki balıkçı barınaklarında da ağ kurutma sahası ve soğuk hava deposu eksiklikleri Boran ve Avcı Softa (2016) tarafından benzer şekilde rapor edilmiştir. Bu bulgular, söz konusu altyapı sorunlarının bölgesel değil ulusal ölçekte yapısal bir mesele olduğunu düşündürmektedir.

Çanakkale özelinde dikkat çeken bir diğer önemli sorun, kooperatiflerin pazarlama süreçlerine aktif olarak dahil olamamasıdır. Birçok kooperatifin mezat alanı bulunmamakta ve bu durum, balıkçıların ürünlerini yerel kabzımallar aracılığıyla düşük fiyatlarla satmak zorunda kalmalarına yol açmaktadır. Bu sorun hem ekonomik sürdürülebilirliği tehdit etmekte hem de kooperatiflerin gelir kaynaklarını sınırlamaktadır. İstanbul ve Marmara Bölgesi'nde yapılan benzer çalışmalarda da pazarlama-satış altyapısının zayıf olması, kooperatiflerin ürün fiyatları üzerinde kontrol sahibi olamaması gibi benzer sonuçlara ulaşılmıştır (Karademir ve Arat, 2014; Zengin ve Güngör, 2017).

Kooperatiflerin devlet desteği konusundaki beklentileri de bu çalışmada net bir şekilde ortaya konmuştur. Artan üretim maliyetleri karşısında mevcut teşviklerin yetersiz kalması, balıkçıların büyük bir kısmının mesleği bırakmayı düşünmesine neden olmaktadır. Özellikle akaryakıt, av

araçları ve teknelerin bakımı gibi temel giderlerde devlet desteğinin artırılması gerekmektedir. Çımat ve Duran (2018) Muğla'da yapılan çalışmada da benzer şekilde kooperatiflerin sürdürülebilirliğinin kamu teşviklerine bağlı olduğu vurgulamıştır.

Yasal düzenlemelerle ilgili sorunlar ise sadece mevzuat eksikliğiyle sınırlı kalmamakta, uygulamadaki belirsizliklerle daha da karmaşık hale gelmektedir. Özellikle kıyı alanlarının sit alanı veya farklı kamu kurumlarının yetki alanı içerisinde bulunması, kooperatiflerin idari süreçlerinde çok sayıda kurumla muhatap olmasına ve bu durumun ciddi zaman kayıplarına yol açmasına neden olmaktadır. Altınışık (2006) da bu durumu yıllar önce dile getirmiş ve barınakların mülkiyetinin kooperatiflerde olmasına rağmen işletme haklarının verilmemesinin hizmet sunumunu engellediğini belirtmiştir. Ancak, Balıkçı Barınakları Yönetmeliği'ne göre (Anonim, 1996), barınakların mülkiyeti kamuya aittir. Oysa, bu barınakların işletme hakkı ilgili su ürünleri kooperatiflerine devredilebilmektedir. Uygulamada, bu devirlerin zaman zaman yapılmaması ya da prosedürle ilgili nedenlerle gecikmesi, kooperatiflerin hizmet sunma kapasitesini sınırlamaktadır. Mevcut bulgular, bu yapısal sorunun hâlâ çözülememiş olduğunu ortaya koymaktadır.

Kooperatiflerin av sahalarının daralması ve avcılık faaliyetlerinin kısıtlanması da önemli bir sorun alanıdır. Çanakkale Boğazı'nda artan deniz trafiği, gümrük sahaları ve 1915 Çanakkale Köprüsü gibi yeni yapılar, balıkçılar için ayrılan alanların azalmasına neden olmaktadır. Aynı zamanda amatör balıkçılık faaliyetlerinin yeterince denetlenmemesi, profesyonel balıkçıların kazançlarını olumsuz yönde etkilemektedir. Bu durum, Akyol ve Perçin (2006) ile Ceyhan ve ark., (2006) tarafından da dile getirilmiş ve amatör balıkçıların yasal sınırları aşan faaliyetlerinin kayıt dışılığı artırdığı ve ticari balıkçılığı zora soktuğu vurgulanmıştır.

Denetim ve kontrol mekanizmalarının yetersizliği, yasa dışı avcılıkla mücadelede önemli bir engel oluşturmaktadır. Sahil Güvenlik Komutanlığı ve İl Tarım ve Orman Müdürlükleri tarafından yürütülen denetimlerin personel eksikliği, yasal yaptırımların caydırıcı olmaması ve kayıt dışı avcılığın yaygınlığı nedeniyle istenilen etkiyi yaratamadığı gözlemlenmiştir. Bu bağlamda, cezaların artırılması ve amatör-ticari ayrımının netleştirilmesi önerilmektedir.

Kooperatiflerde teknik personel eksikliği, uzmanlaşmanın önünde ciddi bir engel olarak durmaktadır. Tarım ve Orman Bakanlığı tarafından 2021 yılında alınan kararla, üst birliklerde su ürünleri mühendisi istihdamı zorunlu hale getirilmiş olsa da bu uygulamanın tüm kooperatiflere yaygınlaştırılmaması, teknik eksiklikleri sürdürmektedir. Bu doğrultuda, su ürünleri mühendisi istihdamının tüm kooperatifleri kapsayacak şekilde genişletilmesi, kurumsal kapasitenin artırılması açısından büyük önem taşımaktadır.

Görüşmeler sırasında az sayıda da olsa kooperatif yöneticilerinin liyakat eksikliği, yerel güç ilişkilerine bağımlılık ve yetersiz kurumsal vizyon gibi nedenlerle sorunların çözümüne yeterince katkı sunamadığı dile getirilmiş olmakla beraber genel olarak kooperatif yöneticilerinin katkı sağlamaya çalıştıkları kooperatif ortakları tarafından belirtilmektedir. Ancak yine de bu durum, yalnızca dışsal değil, aynı zamanda içsel yönetsel sorunların da kooperatiflerin işlevselliğini olumsuz etkilediğini göstermektedir. Türkiye'de su ürünleri kooperatiflerinin kurumsal kapasiteleri ile sahadaki etkileri arasında ciddi bir uyumsuzluk söz konusudur. Bu durum, yapısal eksiklikler (yetersiz finansman, düşük eğitim düzeyi, mevzuat uyumsuzlukları) ve yönetsel zaafların (şeffaflık eksikliği, denetim sorunları, profesyonel yönetim eksikliği) Türkiye'de kooperatifçiliğin gelişimini sınırladığını ve istenilen düzeye ulaşmasını engellediğini ortaya koymaktadır.

Son olarak, su ürünleri verilerinin doğru ve sistematik biçimde kaydedilmemesi, balıkçılık yönetiminin bilimsel temellere dayanmasını engellemektedir. Özellikle karaya çıkış noktalarında yeterli veri toplanamaması ve amatör avcılığın kayıt dışı kalması, kaynakların izlenebilirliğini ve sürdürülebilir yönetimini sekteye uğratmaktadır. Zengin ve Güngör (2017) ile Doğan (2018) benzer sorunlara işaret etmiş ve balıkçılık verilerinin güvenilirliğinin artırılmasının, politika yapım süreçleri açısından kritik bir ihtiyaç olduğunu vurgulamıştır.

Nihai olarak değerlendirildiğinde, Çanakkale'deki su ürünleri kooperatiflerinin karşılaştığı sorunların büyük bölümü Türkiye genelindeki yapısal sorunlarla örtüşmektedir. Ancak, bölgenin denizel çeşitliliği, kıyı yapılarının karmaşıklığı ve tarihi-kültürel koruma alanları nedeniyle bürokratik zorlukların daha da yoğun yaşandığı görülmektedir. Bu durum, bölgesel balıkçılık politikalarının merkezi düzenlemelerden ziyade yerel dinamiklere göre şekillendirilmesi gerektiğini ortaya koymaktadır.

SONUÇ

Bu araştırma, Çanakkale ilinde faaliyet gösteren su ürünleri kooperatiflerinin mevcut durumunu kapsamlı bir biçimde ortaya koymak, karşılaştıkları temel sorunları belirlemek ve bu sorunlara yönelik çözüm önerileri geliştirmek amacıyla gerçekleştirilmiştir. Elde edilen bulgular, bölgede faaliyet gösteren 26 kooperatifin büyük

bir kısmının altyapı, örgütsel kapasite, pazarlama ve yasal düzenlemeler açısından ciddi kısıtlarla karşı karşıya olduğunu göstermektedir. Kooperatiflerin çoğunda idari yapıların yetersiz olması, ağ tamir alanı, soğuk hava deposu ve mezat yeri gibi üstyapı eksikliklerinin sürmesi, balıkçılık faaliyetlerinin sürdürülebilirliğini ve kooperatiflerin etkinliğini önemli ölçüde sınırlamaktadır. Bunun yanı sıra, denizel alanların sınırlı hale gelmesi, avlanma sahalarının giderek daralması ve amatör balıkçılığın kontrolsüz yayılması gibi dışsal faktörler de kooperatiflerin üretim ve gelir olanaklarını tehdit etmektedir. Araştırma kapsamında yapılan görüşmeler, kooperatiflerin yeterli kurumsal destekten yoksun olduğunu, pazarlama faaliyetlerinde kabzımallara bağımlı kalındığını ve balıkçılık gelirlerinin istikrarsızlaştığını ortaya koymuştur. Üyelerin sosyoekonomik durumunun zayıflığı ve artan maliyetler karşısında devlet desteklerinin yetersizliği, üretimin sürekliliğini zorlaştırmakta ve meslekten çıkış eğilimini artırmaktadır. Bu bağlamda, su ürünleri kooperatiflerinin kurumsal kapasitelerinin güçlendirilmesi, teknik personel istihdamının yaygınlaştırılması, altyapı ve üstyapı eksikliklerinin giderilmesi büyük önem taşımaktadır. Özellikle kıyı yapılarının iyileştirilmesi, liman ve çekek yeri gibi temel unsurların kooperatiflerin kullanımına tahsis edilmesi, operasyonel verimliliği artıracaktır. Ayrıca, mezat alanlarının kurulması ve doğrudan pazarlama kanallarının geliştirilmesi, kooperatiflerin ürün değer zincirine daha etkin katılımını sağlayacaktır. Yasal düzenlemelerdeki belirsizliklerin giderilmesi, kooperatiflerin kiralama ve işletme haklarının netleştirilmesi ve kamu kurumları arasındaki yetki çatışmalarının ortadan kaldırılması gerekmektedir. Aynı zamanda, denetim mekanizmalarının güçlendirilmesi ve kayıt dışı avcılıkla mücadelenin artırılması, balıkçılık kaynaklarının sürdürülebilirliğini destekleyecektir. Sonuç olarak, bu çalışma yalnızca Çanakkale'ye özgü bir değerlendirme sunmakla kalmamakta; Türkiye genelinde su ürünleri kooperatifçiliğinin karşı karşıya olduğu yapısal sorunlara da ışık tutmaktadır. Bu bağlamda geliştirilen önerilerin, ilgili kamu kurumları ve yerel yönetimler başta olmak üzere, sektördeki tüm paydaşlar tarafından dikkate alınması önem arz etmektedir. Kooperatiflerin etkinliğini artırmak, yalnızca balıkçılık sektörünün değil, kıyı topluluklarının sosyal ve ekonomik refahının da sürdürülebilirliğini sağlayacaktır.

Teşekkür

Bu çalışma ilk yazarın yüksek lisans tezinden üretilmiştir.

Etik Standartlara Uygunluk

Yazarların Katkısı

MZ: Araştırma, Yazma-orijinal taslak hazırlama, Yazma-inceleme ve düzenleme
SK: Kavramsallaştırma, Gözetim ve denetim, Yazma-inceleme ve düzenleme
Tüm yazarlar makalenin son halini okuyup onayladılar.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını beyan ederler.

İnsan Hakları Beyanı

Çalışma yüz yüze görüşmeler yoluyla gerçekleştirilmiş olup veri toplama araçları hususunda herhangi bir etik kurul onayına ihtiyaç duyulmamaktadır. Çalışmada ilgili kurumsal ve/veya ulusal araştırma etiği komitesi tarafından onaylanmış olup etik standartlara uygun olarak gerçekleştirilmiştir.

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