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Review Article

The Smart Sea concept and its application for ocean management in a changing climate

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ABSTRACT

Global environmental change is a defining issue of our time. The ocean is a key component of the Earth system, and yet, in-depth understanding of its roles in sustaining life has not received the attention which it deserves. Humanity must develop a new relationship with the ocean characterized by protection, sustainable production, and prosperity. Society has too much to gain by implementing sustainability solutions and too much to lose by ignoring them. Our actions or inaction now will have far-reaching implications for future of all life on Earth. Ocean blueprint that calls for enforcing 30% Marine Protected Areas by 2030 requires real transformative action. This paper contains new ideas for combining the efforts of natural and social scientists, and traditional users of sea, and explores the potential of modern technologies to assist in this campaign. 'Smart Sea' concept introduced in this paper envisages synergies among the problem-solving approaches including digital tools, and eco-engineering and eco-mimicry solution options. Knowledge gaps have been highlighted and relevance of new knowledge systems emphasized together with enabling conditions to address the uncertainties associated with the ocean ecosystem. The ocean has a central position in actions towards preventing global warming of 1.5°C but measures to achieve it should consider that the ocean carbon sink is dynamic and is adversely affected when excessive carbon dioxide produces acidification. The selected measures are likely to have trade-offs, requiring analysis of multiple dimensions, for ensuring sustainable outcomes. The prevailing ocean health and urgency to mitigate it calls for combining global and local solutions, technologies and actions driven by safe and innovative solutions, and wherever possible, based on proof-of-concept. Deviating from the on-going incremental data collection systems to new forms of data-sharing using modern technological tools will contribute to addressing the glaring vacuum in knowledge of the ocean and facilitating a concerted global action for maintaining its ecosystem services. An attempt has been made in this paper to consolidate different opinions and experiences in moving from generalities to specifics for sustainable solutions that support economies, food security and the society.

Introduction

The Ocean, covering almost 71% of the Earth's surface, creates the primary life-support system of the planet. It is home to a rich biodiversity and plays a significant role in food security, global economy, and climate regulation. This vital ecosystem faces unprecedented challenges due to human and environmental pressures. Much of the life on Earth depends on the invaluable marine ecosystem functions and services. Ocean health is central to the delivery of these roles, especially oxygen generation, climate regulation, biodiversity conservation, food security, income, and livelihood. Any significant progress in the 'Building Back Better' (BBB) paradigm which is currently being advocated by The Organization for Economic Co-operation and Development to protect the natural capital and accelerate progress in sustainable

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development is inconceivable without shifting our attention to the ocean. In this context, an integrated outlook of ocean health and human health should be at forefront of global attention. It emerges from the intricate nature of the two that our actions toward the ocean will have a strong bearing on the future condition of the whole planet and health of the societies around the world (Borja et al., 2020). The increasing anthropogenic pressures driving the degradation of marine ecosystems and their services are being increasingly highlighted by scientists in the recent years (Pecl et al., 2017). Concern is growing about the sustained and cumulative pressures such as pollution, habitat loss and overfishing, and their consequences for the communities (Depledge et al., 2019). Undoubtedly, the restoration and preservation of coastal and marine ecosystems, and mitigating the effects of climate change at this critical time for the global environment (de Groot et al., 2013; Pueyo-Ros et al., 2018; Pouso et al., 2019) will support the BBB goals.

Scientific and technical assessments assert the need for an interdisciplinary and multi-actor framework to protect and restore ocean health. Despite the urgency, achieving marine conservation and protection remain challenging on account of ever-increasing environmental threats, technical planning, shortage of environmental management personnel, limited financial resources and inadequate decision-support. Expenditure in employing large numbers of marine park rangers and mobilizing costly navigational assets is high and this constrains the enforcement efforts. The Strategic Plan for Biodiversity, including the Aichi Biodiversity Targets (2011-2020) under the Convention on Biological Diversity, required at least 10% of coastal and marine areas to be conserved for protecting marine biodiversity. The UN Sustainable Development Goals (SDGs), 2016-2030, identified 'Target 14.5' that reiterated support for this call for action. However, at present, only 2.7% of the ocean is effectively protected (Sala et al., 2021). The Decade of Ocean Science for Sustainable Development (Ocean Decade), as proclaimed by the United Nations with a timeframe of 2021-2030, requires taking actions to reverse the cycle of decline in ocean health using scientific knowledge and integrated research. It calls for going far beyond the Aichi Target and bringing 30% of the total area of the world's exclusive economic zones under conservation as a Marine Protected Area (MPA) by 2030. The message being widely used is "30x30 Blueprint" for the ocean. This initiative is in the interest of the social-ecological pathways since decline in the ocean will eventually reduce its capacity to perform functions and provide ecosystem services to sustain humanity. The sequence of events is straightforward: direct and indirect impacts on the ocean pose a threat to its ecosystem stability which undermines the ecosystem services, leading to a decline in the well-being of people relying on these services. In addition to protection and restoration of marine biodiversity, the conservation measures are anticipated to harness the benefits of blue economy. The limited success in MPA enforcement is due to lack of adequate actors and stakeholders' participation (Mascia et al., 2010; McCay and Jones, 2011; Levine et al., 2015). This problem can be addressed by integrating the socio-spatial dimension of management with the geospatial tools.

Conservation of designated marine areas supports resilience of vulnerable coastal and marine organisms and critical habitats and protects biodiversity that tend to maintain ecosystem services (Cooney et al., 2019; IUEP, 2018). Several studies have provided evidence of conservation interventions contributing to the health of the ecosystem resulting in benefits to the communities. Lester et al. (2009) have suggested measuring biomass and numerical density referring to the mass of living organisms and the number or density of individuals of a targeted species, respectively in a given area at a given time. A practical approach to measuring density is determination of catch per unit effort (CPUE). Even a record of the size of a marine animal is used in quantifying the beneficial effects of different levels of conservation efforts in MPAs (FAO, 2018).

Curtailing biodiversity loss and restoring ecosystem functions and services are among the key dimensions of the BBB approach. These are fundamental to the economy and human welfare (Mustafa et al., 2020; OECD, 2020). There are many challenges in understanding the true nature of marine biodiversity. The ocean is home to millions of species (Mustafa & Saad, 2021). The World Register of Marine Species contains a record of 240,000 living species that have been identified and described until 2021. If the trend of marine biodiversity loss in several parts of the world is any indication, the number of species appears to be declining (EASAC, 2005). Over 70% of the Earth's surface is ocean, yet more than 80% of it remains unmapped, unobserved, and unexplored (NOAA, 2020). This condition can be characterized as the 'Triple U' ocean paradox! Even with the knowledge so far gained, it is evident that as much as 87-90% of the global ocean is impacted by human activities (Halpern et al., 2015; Jones et al., 2018). The abundance of marine fish has declined by 38% since the 1970 levels (Hutchings et al., 2010), global coverage of marine critical habitats (seagrasses, mangroves, and coral reefs) has decreased by 30–35 % (IOC, 2017), the percentage of overfished resources has increased to 34.2 (SOFIA, 2020), and as many as 500 oceanic dead zones now cover 245,000 square kilometres (IOC, 2017). Furthermore, the ocean acidification is mounting an increasingly serious challenge to marine life (Worm & Lotze, 2016). Having absorbed about one-third of all the carbon dioxide emissions in the past 200 years, the average pH of ocean surface has decreased by 0.1

unit-from 8.2 to 8.1, and this trend will lead to further decrease of 0.2-0.3 units by the end of the century (Orr et al., 2005; OF, 2020). Mechanisms governing the ocean's dynamic equilibrium appear to be unique in the face of the changing nature of impacts, interdependencies, and non-linearities between the causes and effects but there are limits beyond which natural oceanic processes are vulnerable. All these ocean attributes and conditions demand a different type of human-ocean relationship, new theoretical constructs, novel methodologies, participatory approaches, and translational studies to mitigate the current and anticipated ecological and social challenges.

A precautionary approach in conservation planning is necessary even though 80% of the ocean remains unexplored. Action cannot be delayed for this reason. In the vastly unknown ocean where there is a scientific uncertainty of the effects of direct and indirect human actions, common-sense perspectives and compelling reasons can be used for managerial actions. The current level of verifiable evidence, historical trends, and synthesis of knowledge about the problem-solving measures provide a basis for marine conservation planning in response to the prevailing and anticipated challenges. In this context, this article introduces a new perspective, the 'Smart Sea Concept' (SSC)- that can significantly contribute to implementing the global agenda for marine conservation, especially for enforcement of MPAs. SSC should obviously support marine biodiversity and blue carbon stocks of mangroves, sea grasses and other habitats to strengthen the ability of marine life to capture the biological carbon and remain the biggest carbon sink. While the ocean is emerging as an important element of climate policy, more efforts need to be invested in enforcing measures to reduce greenhouse gas (GHG) emissions. Reasons for urgency to act in this matter are obvious from the climate model simulations, new data analyses and more accurate methods of integrating scientific evidence that show that oxygen levels have dropped in many ocean regions and acidification has increased faster than at any time before and global mean sea level increase amounted to 3.7 mm year-1 between 2006-2018 (IPCC, 2021). It will be difficult for many ocean ecosystems, especially coral reefs, and vulnerable marine animals to adapt to such a rapid change. Mitigation measures can be prioritized keeping in view that ocean carbon sinks have more capacity to take up progressively larger amounts of carbon emissions in absolute terms, but the proportion of emissions absorbed reduces under high emissions scenarios, leaving the carbon dioxide in the atmosphere which in turn accelerates climate change. Under such a situation, enhancing ocean's blue carbon stocks should be accepted as a matter of priority.

The Smart Sea concept

There is much discussion on potential actions that can be undertaken to protect and restore marine ecosystems. Among the multiple options, nature-based solutions are considered as practically feasible and low-cost, and without any apparent risks. Thus, measures such as conservation and rehabilitation of seagrass beds, mangroves and coral reefs deliver many biodiversity and ecosystem functions and services while producing no adverse consequences. Nature Based Solutions (NBS) envisage making use of natural capital in reducing human impacts, but the problems confronting the ocean are so enormous that these require exploring synergies among many different solutions, including those intended for mitigating the effects of global warming and climate change.

In this context, the SSC is being introduced. It is designed to be inclusive and adaptable to deliver conservation goals as well as societal impacts. Key components of SSC include generation of scientific knowledge (incremental, transformative and what emerges from retrospective data for prospective use), technology (existing, disruptive comprising eco-engineering tools as well as next generation biotechnology), traditional practices under a co-management system, and lastly, policy support. The entire approach is based on the following three main strategies:

1. Deploying the digital technologies of the Fourth Industrial Revolution (IR.4) to harness the power of scientific knowledge and discoveries.
2. Synergizing eco-engineering and other complementary approaches that can improve the operationalization of marine conservation measures and produce payoff.
3. Valuing sustainability of traditional practices in a society-centric approach and refining them via biomimicry ideas.

SSC provides pathways to fast-tracking progress in achieving the goals of marine conservation and sustainable development. Akin to the 'smart city' campaign, the SSC envisages using modern technologies but is more inclusive of activities that optimize coastal zone management, seek habitat restoration, promote biodiversity, control illegal activities at the sea, and facilitate knowledge-sharing for sustainable blue economic growth and a better quality of life for the society.

With technological innovations monitoring of the ocean from remote locations is entirely possible. A variety of platforms may be used from which equipment and sensors can be deployed to measure ocean conditions. Satellite data can help in tracking "Illegal, Unreported and Unregulated" (IUU) fishing, movement of illegal fishing vessels, facial recognition to identify culprits, and drones to warn off poachers and intruders. Ending IUU that currently amounts to 20% of the global fish catch worth US$ 23.5 billion (FAO, 2017; WEF, 2017) is the target 14.4 of the UN SDG. Artificial Intelligence particularly holds the promise of helping in electronic surveillance and enforcement regulations and creating enabling conditions to achieve more with less resources. Fernandes-Salvador et al. (2022) have highlighted the practical importance of applying artificial intelligence techniques to capture fisheries, especially for improving traceability of fishery products, fishing gears and good practices. These authors have outlined the potential of such technology applications for employment opportunities for skilled professional such as fresh graduates.

However, unlike the smart city, the SSC is based on green recovery and continued investment in blue-green development shaped by the sustainability paradigm. This necessitates a fundamental system-wide transformative change in management across biological, ecological technological, economic, and social factors from local to global level to have an actionable impact (IPBES, 2019). However, without supporting policies and commitments it will be difficult to achieve the milestones, goals and trajectories by 2030 and beyond.

Ocean-based developments happen to coincide with the ground-breaking innovations that offer emerging technologies in areas of fifth-generation wireless communications and connectivity, 3D printing, sophisticated sensors, Internet of Things (IoT), Big Data analytics, robotics, nanotechnology, and biotechnology in addition to artificial intelligence. Relevance of some of these tools in specific applications in marine monitoring have been recently demonstrated by earlier studies (Watnabe et al., 2019; Xu et al., 2019). Adoption of these advanced technologies will pave the way for increased digitalization and machine-to-machine communication for automation and improvement of efficiency and productivity. However, in view of the slow pace of progress in meeting the target set for conserving 10% of the marine environment, it is unlikely that the world will be able to effectively protect 30% of the sea without a path-breaking approach provided by these emerging technologies. This is a vast sea area to effectively monitor in real-time. Thus, the technological interventions should supplement the conservation efforts through nature-based solutions and not replace them, by offering more efficient means of monitoring and enforcement through significantly enhanced capabilities. BBB strategy can guide the deployment of technologies to a faster recovery and strengthen the resilience in the MPAs covering 30% of the global ocean. Ways in which this can be achieved are summarized in Table 1.

Table 1. Application of IR4.0 technologies to address challenges associated with the ocean. Green represents ongoing implementation of the technologies. Grey refers to early stages of trial involving the technologies. Adapted with permission (WEF, 2017).

IR4.0 technologies	Application areas				
	Sustainable fishing	Pollution control	Habitat protection	Species protection	Ecosystem resilience
Advanced sensors					
Drones & autonomous vehicles					
Artificial intelligence					
Internet of Things					
Robotics					
Computing & data analytics					
Advanced materials					
3D printing					
Biotechno-logies					
Blockchain					

Application of some of these technologies will take time as many countries need to invest financial resources and develop human capital. Use of sensors for measurement of physical and chemical variables and conditions is becoming more popular since marine management systems require real-time monitoring for environmental quality. The oceanographic buoy using sensors record salinity, temperature, dissolved oxygen, among other variables. Sendra et al. (2015) have reviewed the use of low-cost sensors in collection and processing of actionable marine environmental data by wireless connection of the buoys to base stations. Optical sensors are a new addition to the growing list of sensor types. These are particularly useful in monitoring fishing operations and state of the ocean habitats. Because of their zoom capabilities, resolving images even when visibility is low, for detecting activities at the sea, especially IUU, discharge of waste, capture of endangered species can be controlled. MPAs, especially the marine biodiversity spots that are considered eco-regions such as tropical seagrass meadows and coral reefs require rigorous monitoring to maintain their ecological communities and functional links. Cusack et al. (2021) have reviewed the range of applications of modern technologies in managing the ocean resources. Monitoring of enforcement measures is critical in evaluating their effectiveness and deciding further improvement strategies.

Blending of BBB-IR4.0 can also assist restructuring of economic recovery packages focussing on conservation of marine natural capital, especially biodiversity, and sustainable benefits to the society. Investment in NBS for marine ecosystems as outlined in an earlier communication (Mustafa et al., 2019) have provided a roadmap for implementing practical means of improving resilience in marine ecosystem services. The world is lagging in valuing the marine natural capital which is important for integrating the cost-benefit analysis in decision-making. Progress in NBS through BBB-IR4.0 synergy can contribute a great deal to building resilient coastal communities and strengthening the blue economy while at the same time advancing the goals of the Paris Climate Agreement for a low-carbon future.

Climate change and environmental variability are important factors in the BBB approach. Actions should, therefore, be taken holistically across several dimensions, particularly including long-term policies for reducing GHG emissions, protecting marine biodiversity and restoring marine ecosystems.

Ocean health is a fundamental attribute for resilience of marine critical habitats and species. Products or benefits derived from the sea should not be viewed only as a commodity but a vital ecosystem service for the long-term benefit of human society. A fish harvested from the sea and processed into a dish has been a part of the ecosystem and has used the ecosystem services before it was caught. Currently, there are no structured mechanisms for mainstreaming marine natural capital in sustainable development of ocean resources. There is an urgent need to pay attention to this matter as highlighted by Mustafa et al. (2021), rather than delaying and risking future tipping points in resources such as small pelagic fisheries that provide sustenance to many coastal communities around the world.

Addressing climate change requires strategies for mitigation as well as adaptation. Mitigation measures envisage interventions to reduce the GHG emissions and to enhance carbon sinks. Adaptation involves adjustment in natural or human systems to the effects of climate change to reduce risks and to make use of the opportunities available (IPCC, 2021). There is no denying the fact that measures taken for climate change mitigation benefit the marine ecosystem and the society. This has been documented in specific cases (EF, 2018) in terms of: a) Increased biodiversity and productivity, b) Increased resilience of marine ecosystem services, c) Fisheries spill-over that enhanced catch per unit effort, d) Benchmarking of environmental health by providing controls against which the effects of human activity and regulatory measures could be evaluated, e) Protection of geological features or processes, f) Maintenance of cultural values associated with the ecosystem services, g) Improved opportunities for recreation and eco-tourism, and h) Greater avenues for environmental educational and scientific observations. The significance of adaptation strategies for the communities benefitting from the natural capital has been highlighted by Metcalf et al. (2015). It is evident from their work that success in reducing the vulnerability of coastal communities to marine climate change requires some intrinsic capacity of the people to adapt. The process of adaptation can be assisted by removing barriers and developing enablers to adaptation. However, knowledge of communities, especially their socio-economic status, resource dependence, familiarity with prevailing issues and willingness to accept change are among the important factors. It is easier to bring the communities on board if measures do not restrict the opportunities for livelihood and income generation (Adger et al., 2009). Managing trade-offs in such matters is crucial for a long-term implementation of strategic plans. Limiting pressure on a marine ecosystem service or resource should, therefore, be accompanied by supporting aquaculture that is more resilient to climate change, earns premium price to the producers, finds lucrative market and improves the earning capacity of the community. Metcalf et al. (2015) have presented synergies and trade-offs in adaptation strategies and showed how increased employment and income through aquaculture reduced the dependence on the natural capital of the ocean. It also lessened the potential vulnerability of the coastal communities to the impacts of climate change on livelihoods and social-ecological systems. While aquaculture can be practiced as a sustainable source of income, its significance increases when regulations require closure of fishing operations during brief periods such as the breeding season that will result in long-term increase in the catch per unit effort.

Exclusive Economic Zones and MPAs provide sovereign rights to countries to redouble their efforts to direct the resources needed for conservation of marine natural stocks through regulations and their enforcement to mitigate the effects of climate change. This must go together with adaptation strategies for natural systems as well as specific social-ecological systems. These strategies can focus on climate change impacts such as ocean acidification and warming, sea-level rise, geographical shifts in species distribution, oxygen deficit, decreased productivity, and increase in the frequency and intensity of extreme weather events confronting communities at the seafront. The adaptation benefits will become more evident when human welfare resulting from managed marine ecosystems is compared from the unmanaged ones.

Often, the policymaking and enforcement institutions develop measures for implementation that are not backed by any structured system of monitoring and reporting. In particular, the marine enforcement is a victim of this anomaly. Monitoring methods should be integrated in the whole regulatory framework to assess whether additional measures or adaptations of action plans are required, and to evaluate which measures are effective under the prevailing situations. Monitoring systems are improving, and if implemented properly, they can deal with the complex and dynamic nature of the marine ecosystems. For example, the 'Global Fishing Watch' is a platform that uses cutting-edge technology to visualise and track fishing activity in real-time and offers free data sharing. 'Marine Ecological Research Management Aid' (MERMAID) is the online-offline platform that enables scientists worldwide to collect, analyse and share data from coral reef surveys. The 'Spatial Monitoring and Reporting Tool' (SMART) has been developed for marine enforcement and IUU control. On a local area basis, marine buoys are a practical device for real-time monitoring of marine water condition. Marine observations and data integration are now much easier with Light Detection and Ranging (LiDAR), Infrared Acoustic (IRA) and Automatic Identification System (AIS) technological tools.

A leading example of deployment of disruptive green technologies is Canada's Ocean Supercluster initiative (COS, 2021). It is a national development-oriented cluster focussing on growing the ocean economy digitally and in sustainable ways. These programs include transformation of fisheries, aquaculture, and marine bioactive compounds among other sectors. Based on intensive uses of sensor technology and real-time analytics, this ocean initiative is intended to harness the benefits of blue economy in multiple areas. Of particular interest is sustainable protein production and aquaculture feeds on a commercial scale without any significant impact on the environment. The inclusiveness of the program facilitates a broader participation of stakeholders to support start-ups, scale-ups and all enterprises that can link up in the value chain. It is already driving cross-sectoral cooperation and fostering an innovation ecosystem that will propel the ocean economy of Canada on an unprecedented scale.

Since the time for transformative actions is limited, breakthrough ideas that can generate in an innovation ecosystem are urgently needed. The sixth assessment report of IPCC (2021) recommends action to be taken this decade to steadily reduce GHG emissions from now onward until 2030 and accelerate progress towards net-zero emissions by 2050. Without actions on this matter, the ongoing average warming of 1.1°C over the pre-industrial levels will reach the 1.5°C threshold, leading to catastrophic situations (IPCC, 2021). The innovation ecosystems should remain focused on new ways of building resilience in coastal blue carbon stocks with multiple co-benefits, engineering solutions consistent with ecosystem-based adaptations, conservation and rehabilitation of marine critical habitats and leveraging marine biodiversity to provide healing touch to the condition of the ocean. An important area that deserves attention is institutional linkages with society through new and effective arrangements that can lead to the blending of experience and scientific knowledge in a participatory process. Meaningful cooperation that will so ensue will make a real difference to the ocean ecosystem.

Knowledge gaps and uncertainties

Since most of the ocean remains unexplored, it is the least understood ecosystem of the Earth. There are vast knowledge gaps across marine biophysical systems and many uncertainties related to the impacts of climate change such as ocean acidification, warming and deoxygenation, redistribution of biodiversity, adaptive capacities of different forms of life in the sea and the trophic web of life.

Only research can address these knowledge gaps and address the uncertainties. There are technological constraints and enormous costs in exploring the complex ocean environment, especially the deeper part. However, research is progressing with the help of more sophisticated underwater vehicles, sonar, robots equipped with artificial intelligence and sensors and other tools of disruptive technologies. Such research poses questions, aims at answers and evaluates their degree of certainty to make sure that they are well-grounded (NASEM, 2019). In the case of the ocean, a major challenge is to accurately predict its future conditions in order to be able to devise interventions. This process can be accelerated through innovation and by changing the fundamental rules or procedures, or evolution of new enabling technologies to achieve reliable results so fast that was not possible by previously established research protocols. Technologies are needed for rapid progress in ocean exploration and the search for solutions. A recent example is the remarkable work done by a group of researchers on marine environmental DNA (eDNA) (Ames et al., 2021). Their assumption that organisms living in the ocean leave behind traces containing their eDNA which is detectable in water samples collected from the sea was experimentally verified. It is a great leap forward in detecting the unseen and unknown millions of ocean species from the small bits of DNA filtered out of water and identified from the next generation sequencing. Such innovative research is not only relevant to marine biodiversity cataloguing but a solution to many problems such as identifying endangered and invasive species, marine conservation, fisheries, and developing jellyfish warning systems in areas where jelly stings frequently occur.

The power of innovation in the realm of ocean science cannot be overstated in search of discoveries needed to mitigate the enormity of impacts that this ecosystem has been subjected to. The most formidable of these is climate change. The ocean has absorbed more than 90% of the heat accumulated in the Earth's atmosphere and 25% of the carbon dioxide released from the fossil fuel consumption, resulting in seawater becoming warmer and 30% more acidic since the industrial revolution, and the formation of 500 'dead zones' where oxygen deficit has reached a level that most marine species cannot survive (Jones, 2019). Reversing the major shifts in ocean temperature, acidification, deoxygenation, and current pattern demands serious management actions and harvesting the potential of innovations. The global community has forged agreements on reducing the emissions and decarbonization that will help the health of the ocean. The scope of this article is limited to discussion about the enforcement of 30% of the global ocean in 10 years from now in smart ways so that the oceanic habitats such as seagrasses, mangroves and coral reefs, and their associated communities and food webs can contribute more effectively to carbon sequestration and biodiversity, and the reckless exploitation of fisheries resources is brought under control. Most of the oceanic data currently available supports a knowledge-based approach to management even as the scientific community explores new ways of generating additional information of significance in predicting ecosystem changes. The important next step is data mining and extracting evidence needed to model the dynamics of ocean ecosystem and predicting consequences of management interventions to chart a pathway to a sustainable future ocean. This entails a fundamental change in the methods of knowledge creation and testing its validity to be able to influence decision-making. Retrospective examination of scientific data and projections to verify existing conditions can test the accuracy of prospective scenarios and bolster the confidence and certainty in current methods for projecting models of future conditions and extrapolations. Using models based on the past 10-30 years of data to compare with the prevailing ocean condition will provide a comparative basis for testing the predictive validity of the models. Convergence of the outcomes generated by the models should change the rules of the game in favour of decisions and actions in real time. Although in a somewhat different context, the views expressed by Bean et al. (2017) are supportive of this suggestion. These authors proposed that studies on the ocean over the last century have resulted in a critical scientific understanding of this ecosystem and the changes that human impacts have brought about. By leveraging the advancements in technologies and methodologies in recent years this vast volume of data can be categorised and organized to generate integrative models, regional and global portals, and decision-support systems. These models built on marine monitoring data are useful for assessment of the state of the ecosystem (de Jonge et al., 2006), vulnerability to climate change and predicting potential adaptation and mitigation strategies. This has been amply demonstrated in the monitoring of marine biodiversity and ecosystem function in the European Union, leading to adoption of the modelling approach as an instrument of policy performance and review (Hyder et al., 2015; Lynam et al., 2016).

We believe that integrated assessment models of the ocean condition resulting from various pressures, particularly climate change, will continue to improve over time with more focused research. There are, obviously inherent complexities in balancing the trade-offs among the sustainable development requirements, but the solution will continue to examine the nature of driving forces and inclusion of stakeholder interests into the modelling process. Exclusion of any of the dimensions of sustainability or underestimation of the participatory processes in managing the coastal zone and inshore areas will adversely impact the model outcomes and their relevance (Doukas and Nikas, 2020).

Due to sustained impacts ocean biodiversity and ecosystem have degraded to a level that requires not just the intensification of incremental fundamental and applied research but also path-breaking 'disruptive' and all-inclusive approaches to conservation and restoration. Modelling of marine biodiversity scenarios and effects of environmental variability through the tools of predictive analytics can yield information of practical importance (Coll et al., 2020). It is better to continue investing in research to strengthen the knowledge-data matrix in the interest of more effective conservation measures and outcomes. With more than 99% of the habitable area of the ocean remaining without even basic data on biodiversity, the use of new technologies will help in bridging the glaring knowledge gaps (UNESCO-IOC, 2021). The BBB goal is worth pursuing through carefully planned strategies for sustainably managing the ocean in the face of 21st century challenges. Blending disruptive technologies with multiple sources of knowledge in supporting the BBB is the way forward in conserving and restoring the ocean and its natural capital as an adaptive process and not as a destination bound by timelines. This could be a game changer in creating enabling conditions for enforcement of marine conservation targets by 2030 as a milestone and continuing beyond it with additional targets. The Paris Agreement aimed to limit the increase of global average temperature to 1.5ºC and attain net-zero carbon dioxide emissions by 2050 to be able to protect not just the oceans but the entire planet from devastating consequences. There is a need to exercise caution in implementing marine conservation based on the theories especially those pertaining to species and marine ecosystems that are not supported by data metrics, and to inculcate an unwavering quest for knowing the unknown of the ocean.

Eco-engineering solutions and the living coastline

In order to open avenues to a broader section of society to take part in ocean solutions, the SSC encourages the application of biological and ecological principles and indigenous practices to engineering designs. This is beginning to yield products that are proving helpful in marine ecosystem protection and restoration. Since the problems are examined holistically through interdisciplinary perspectives, alternatives are considered so as to be able to select the best practical option. The scope for innovation in this area is unlimited. Eco-engineering is unlike geoengineering that envisages large-scale interventions in the Earth systems, including oceans, with the aim of reducing the effects of climate change but without supporting scientific evidence and proof-of-concept.

Many artificial structures can be seen along the coastlines. The most common are the sea walls (vertical or sloping), breakwaters, groynes and jetties, rock revetments and rocky outcrops or artificial headlands. Such structures are developed for specific purposes of society, but most are detrimental to marine critical habitats. Turning these so-called ‘grey’ structures into ‘green’ structures will contribute to a gradual process of partial transformation into ‘living coastlines.’ This can happen by eco-designed tiles along the seawalls or other structures or by appropriately designed objects for placing at the sea floor. Many marine species can establish substrate connectivity with the hard grey structures and reduce the erosional influence of seawater movement caused mainly by currents. The habitat mosaic that so develops supports marine biodiversity and abundance while prolonging the lifespan of the physical structures. The significance of three-dimensional artificial microhabitats for fish through experimental trials has been observed by Arsin et al. (2018) and the need for living coastlines is discussed in a recent article (Mustafa et al., 2020). Quantitative data on how topographic complexity drives species diversity published recently (Bradford et al., 2020; Strain et al., 2020) provide support for the use of 3D-printed structures mounted on hard surfaces. These eco-designed tiles enhanced biodiversity as well as abundance, and the performance was further increased when these structures were seeded with oysters. The role of living shoreline in improving water quality, providing habitat, and increasing biodiversity has been outlined in an earlier communication (NOS, 2021). Living shorelines also provide many other benefits, including naturally adaptive coastal protection, building of defence systems as sea level rises, and increasing marine habitat and spawning areas. The 3D printed coral reefs have opened a new dimension to restoration of marine ecosystem (Klinges, 2018; Mustafa, 2021). These structures can be moulded into complex shapes resembling coral reefs to support new growth of corals and associated marine communities.

Eco-engineering can contribute to solutions against the effects of sea-level rise which is a problem with wider implications that include coastal erosion and inundation of coastal habitats, flooding of wetlands, saltwater intrusion in aquifers, soil salinization, and loss of critical habitats for some species of plants and terrestrial animals. Impoverished coastal communities are adapting by using traditional methods of stabilization of coastline or shifting to higher grounds.

While the solutions inspired by the roles of mangrove and reefs are well-known due to conspicuous features of these marine critical habitats, other designing options that are recently emerging are based on the structural attributes and functions of species like oysters. Structures built from hard materials with design features resembling oysters (BI, 2021) are not only helping in the proliferation of oyster populations but also protection of shoreline from erosion and inundation. Erosion can reduce land elevation and increase inundation, and the stabilization of coastlines by the above-mentioned means can help adapt to local or relative sea level rise. Biomitigation measures or living coastlines reduce land subsidence and counter mechanical forces on the shore to protect the adjoining land even as the world continues to implement long-term measures to control GHG emissions and warming that cause thermal expansion of water and melting of glaciers. A commonly seen adaptation measure is a concrete or stone-stabilized seawall. However, nature-based solutions in the form of mangroves and seagrasses are more cost-effective and long-term solutions that can be supplemented by 3D structures that facilitate growth of shelled organisms capable of resisting the hydrodynamic forces.

Eco-designing is a dynamic area and as research intensifies in this field, a wide range of options will continue to emerge. However, repeated field trials and a long-term monitoring program are necessary to provide quantitative data on the specific benefits of these structures. Selection of materials and design should consider hydrodynamic conditions of the area, chemical properties of water (salinity and pH) and biological features in and around the area for possible settlement and colonization of marine species. In view of a general paucity of information on the exact nature of influence of these structures, deploying them as a substitute to natural habitats or to providing a ‘healing touch’ to the ecosystem will depend on results of the trials.

Nature-based solutions, sustainable cultural practices, and eco-mimicry

NBS and certain traditional practices that use marine resources for food and sustenance without negatively impacting the environment and depleting the natural capital of the ocean should be promoted. Indigenous communities must be assisted to enjoy better dividends as an incentive for them to remain committed to sustainable marine practices. In this context, it should be emphasized that seaweed farming produces 32.4 million tons per year, contributing 51.3% of the total production of marine and coastal aquaculture (Chopin and Tacon, 2021). A method used some by Indigenous communities in Borneo uses a unique buoy comprising wasted plastic bottles and kayaks (canoe) to harvest this seafood. Since 99.5% of the global supply of seaweed comes from Asia (Chopin and Tacon, 2021), this is a significant activity that benefits food security and tends to offset the effects of climate change on the ocean ecosystem.

Indigenous communities have been fishing for thousands of years. They have relied more on traditional ecological knowledge gained through a direct contact with the marine environment rather than on technology. Some of the primitive tools and methods that are still in use have limited capacity for capturing fish, thereby sparing enough fish in the sea to recruit and replenish the fished stock. Indigenous communities are less selective of the species fished and they have hunted different species at different times of the year which gives the stocks a recovery time. This is due to the seasonal cycles of aggregation, spawning migration to inshore areas, flow of juveniles from estuaries to deeper waters, schooling behaviour of small pelagic species such as sardines and mackerels, and the behaviour of predatory species like tuna and ribbon fish chasing the prey (Hickey, 2006; Friedlander et al., 2013), Generally, Indigenous communities have customary rules embedded in their inherited traditions. The fisheries conservation elements in their practices can be incorporated into a co-governance system as a reconciliation process (Atlas et al., 2021) allowing them to continue harvesting in return for their cooperation in management. There are successful case studies worldwide where conservation and habitat restoration efforts in a co-management arrangement have resulted in stock rebuilding, improved harvests, and socio-economic benefits. The findings reported by Chen et al. (2020) based on their work in China, Samoa and Vietnam suggest that what is good for the marine ecosystems is also good for society.

Achieving 30% effectively enforced MPAs will be a significant contribution to restoring and conserving marine critical habitats and biodiversity, and ocean functioning and hence sustainability. The potential benefits are estimated to be six times more sustainable seafood harvest by 2050, 15 million new jobs by 2030, forty times more renewable energy by 2050 and US$ 15.5 trillion from sustainable ocean investments by 2050 (Stuchtey et al., 2020).

Working with traditional communities wherever possible and blending new designs inspired by nature (biomimicry) offer locally effective simple solutions, albeit on a small scale, to the complex problem of trade-off analysis in marine ecosystem services that requires the application of scientific, economic, and social approaches and devices. Considering the heterogeneity of marine ecosystems and geographical disparities in socioeconomic conditions, this analysis will be time-consuming and challenging but our actions must be guided by logic and reason. There is a growing interest in emulating systems, processes, models, or other elements of nature for the sake of solving complex problems. While presenting insights into the importance of putting nature's lessons into practice we must visualize nature in three ways suggested by Benyus (2009): a) as a model for inspiration for designs and processes aimed at problem-solving outcomes, b) as a measure based on biological and ecological events, parameters and metrics to evaluate the relevance of the innovation, and c) as a mentor for observing and valuing nature. Practically, there are cases where biomimicry based on ocean ecosystem is proving successful. Some case studies reported earlier (BI, 2021) can be mentioned here to support the argument. 'ECOncrete' is a three-dimensional design that facilitates biogenic activity and imparts strength to the structure. There can be many adaptations according to beach or rocky shores. Interestingly, the biomimicry concept can be adapted using simple methods or advanced technology tools according to the local capacities. Thus, the production of 'Biotextile fibers' as an alternative to petroleum-based synthetic fibers uses DNA technology to reflect the pathways in Discosoma, a coral relative. This can potentially reduce more than a billion tons of CO_2 equivalent yearly in the manufacture of dyes and the large volume of waste that it generates. Likewise, observations on mantis shrimp that uses its chitin-enforced appendages to crack open the hard-shelled prey without damaging its own structures are used in developing light-weight underwater structures and saving fuel economy for developing turbines. Other examples are pollution-sensing robotic fish and 'robolobster' for designing underwater robots and models of a self-sustained jellyfish-like ocean city. In this context, we need to create pathways for systematically organizing and applying fundamental and applied knowledge based on exploratory principles and verifiable means.

Enabling conditions

It is easy to appreciate the benefits of effective marine conservation, but many countries lack the means of offering alternative livelihoods, mechanisms and trained human resources for deployment of modern devices and tools of management. International cooperation in capacity-building programs is a key to reshaping ocean management consistent with the 21st century challenges. The significance of information exchange and cooperation cannot be overemphasized, especially in identifying knowledge gaps, addressing pertinent questions, advancing the action research agenda based on available scientific evidence, experiences, perspectives and reflections on issues and conservation priorities. There are appropriate bodies within the ambit of the United Nations that can support international cooperation and technology transfer as well as promoting a shared vision of knowledge capacity-building across the regions and worldwide at cheaper and faster rates through digital technologies and real-time connectivity. When countries see benefits accruing from collaboration, they will be more inclined to review and reprioritise their national policies and invest in bridging the digital divide, improving transparency, and creating opportunities for new careers and employment in multiple fields. In this context, it is necessary to emphasize that the knowledge generated thus far provides a strong basis for linking marine biodiversity and geodiversity with different types of impacts and establishing trends. The power of predictive analytics that is growing in recent years from data science tools, computer simulations, statistical modelling and machine learning can be leveraged to generate future scenarios pertaining to marine biodiversity and ecosystems. With the inclusion of multiple parameters and 'Big Data' technology, the analysis of new or recurring trends or outcomes is now much easier compared to that in the past and the processed data can be utilized in conservation and restoration policies and practices. However, there is a certain amount of unpredictability caused by the effects of climate change that may require making strategic modifications, but marine management systems are inherently adaptable to incorporate changes as and when needed in advancing the scope and effectiveness of actions.

Data analytics and simulation modelling can generate enhanced understanding and help in evaluating complex systems to project scenarios with a greater degree of accuracy and confidence. To illustrate the effectiveness of these models, even one or two- decade-old data on marine ecosystem condition or a geospatial biodiversity case scenario can be processed to generate models which can be compared to the existing condition. This will provide a direct and concrete proof of accuracy of the simulation approach. It is a new form of generating scientific information and is not tantamount to acting without evidence. In fact, it will facilitate translation of precautionary approaches into managerial actions by capturing the common-sense notions backed by scientific reasoning in support of a precautionary approach. Precautionary measures have yielded positive outcomes for localized fisheries, biodiversity, and rehabilitation of marine critical habitats (Vander Zwaag, 2018). It does not reverse the burden of scientific proof but places the onus on contradictory approach (Vander Zwaag, 2018). With the review mechanisms that are generally integrated into environmental management structures, adaptive management can be accepted as a part of the whole strategy for sustainable ocean solutions.

Institutions of higher education can take advantage of the world's focus on the ocean sustainability in the current decade by cultivating links with the agencies that offer training and capacity-building. This will be a major step in harnessing the power of knowledge through partnerships to produce impacts. The key steps in this endeavour will be to create mechanisms for examining self-capabilities and reviewing existing research programs focused on topics that value ocean health, support the blue economy, and influence policies consistent with the aims and objectives of SDGs and the Ocean Decade. Important research and development areas requiring invigoration include digital ocean mapping, ocean observation systems, ocean dynamic equilibrium, data-sharing mechanisms, early ocean hazard warning, ocean in earth observing systems, technology transfer and capacity-building, science and policy interface, and research and development aligned with the blue economy. Some of these have been mentioned previously (Ryabinin et al., 2019).

New forms of international agreements are needed for meaningful results and tangible outcomes since there are vast knowledge gaps in our understanding of the ocean, and the disparities among countries in their scientific priorities and capacities to acquire oceanic knowledge are also glaring. This issue must be addressed if the world is to act collectively to move towards global change. SDG17 (Partnerships for the Goals) makes it abundantly clear that global partnerships and cooperation are vital for realizing the objectives and targets of all the SDGs. The key steps are access to science and technology, knowledge-sharing, and innovation. There is a need to establish facilitation mechanisms for this purpose involving realistic and productive international cooperation. Many tropical countries do not possess the necessary technological capacity but have a treasure trove of marine biodiversity and ecosystem services that deserve attention. An outstanding example is the 'Coral Triangle', a marine area of enormous size (5.7 million km2) at the equatorial confluence of the Pacific Ocean and Indian Ocean (Green et al., 2011). It is shared by 6 countries- Indonesia, Malaysia, Philippines, Timor-Leste, Papua New Guinea, and the Solomon Islands, and is a marine biodiversity hotspot, with many endemic species unique to the region. There is an increasing interest in marine bioprospecting and studying the effects of climate change in the Coral Triangle, but these require advanced technologies through international cooperation with countries that have made progress in applying IR4.0 technologies. There could be a 'win-win' situation if agreements are reached on benefit-sharing, intellectual property rights and mutually developing this sector of blue economy through open access (Worm et al., 2006; Mustafa et al., 2019). The Ocean Decade envisions intensifying scientific knowledge, building infrastructure and nurturing international cooperation for a sustainable and healthy ocean. In fact, progress in all the actions outlined below is required under the Ocean Decade depends on this fundamental requirement:

1. Mobilizing scientific research on critically important topics related to the ocean for the Agenda 2030 and Vision 2050.
2. Collecting and synthesizing existing research data and documentation, defining trajectories and trends, and identifying knowledge gaps deserving priority for future research.
3. Generating evidence and developing user-centric solutions.
4. Undertaking new research and nurturing cooperation within and across the world oceans.
5. Bridging science, policy and societal dialogues through data-sharing, and information and communication tools.
6. Developing new co-designed research approaches, methods, and strategies.
7. Enhancing coastal resilience for marine ecosystems and people relying on the resources of the sea for livelihoods.

Since the Ocean Decade is designed to be a participative and transformative process, the framework of agreements should be structured with clear goals and targets agreed upon among the agencies involved in development cooperation. With supporting national policies, international cooperation will proceed without constraints. There should be mechanisms for real-time data sharing and monitoring of progress in the implementation of agreed frameworks. There are, of course, integrated online platforms to advance the flow of information and to prevent unnecessary obstacles to cooperation. Accountability mechanisms should also include clauses for physical verification of progress in beneficiary countries by the supporting agencies, and for the consequences arising from default. Without such mechanisms, knowledge gaps among nations will expand further since disruptive technologies are rapidly advancing in industrialized countries while resource-rich nations remain reluctant in granting access to marine biodiversity in their exclusive economic zones.

Conclusion

Conserving and restoring ocean health is a global responsibility that cannot be ignored. Protection of 30% of the global ocean through MPAs by 2030 is needed to safeguard marine biodiversity, prevent collapse of fisheries, and build resilience in marine life to help it adapt to changing climate and assimilate other impacts. It is an enormous task that can only be delivered using a plurality approach, especially advanced technologies. The potential of new strategies should be explored for actions that can make a real difference by capitalizing on the growing familiarity and significance of digital technologies. Human impacts on the ocean are enormous and without major interventions there is a real concern about the tipping points for many ecosystem components, leading to a situation where the world risks seriously suffering from loss of vital marine ecosystem functions and services. The potential of oceans as a source of solutions should be explored by applying new ideas and perspectives. In this context, the SSC becomes increasingly relevant since it seeks to mobilize multiple approaches, namely the traditional sustainable practices, eco-engineering inspired by biomimicry designs and disruptive technology with a policy support to deliver enduring solutions. New ways of generating knowledge for managing a largely unexplored ocean are suggested as a way forward. Preserving the biodiversity and ecosystem functions of MPAs benefits marine areas globally through the so-called ‘spill-over’ of larvae and other biological gains accruing from enforcement. While the resilience of ocean ecosystems is remarkable and their ability to adapt to environmental change is significant, these attributes have limits. We must move consistently and congruently towards transformative action in ways that integrate natural and human (social-ecological) systems so that marine ecosystem processes continue to function, and socio-economic services continue to flow in a co-management framework and dynamics. Most of the ocean remains unexplored but whatever knowledge is available provides a basis for rational actions. This can be supplemented by action research, participatory efforts, and new methods of generating knowledge.

Everyone has a role to play in achieving ocean sustainability. Scientists can assist by providing deeper insights into the dynamics of ocean ecosystems and prioritizing actions to protect the more vulnerable critical components and collectively designing implementable short-term, medium-term, and long-term recovery plans. Scientific data of the past decades can be used to verify the accuracy of the generated models in projecting the present scenario and to convincingly model the anticipated future conditions of the marine ecosystems for remedial action proactively. Making a retrospective analysis for prospective action can serve the cause of the BBB when there are vast knowledge gaps in ocean science.

The significance of ocean-based solutions to climate change will continue to increase with the expansion of knowledge about this massive ecosystem. The issues of ocean health and climate change are interconnected. While the ocean is key to addressing climate change, mitigating climate change is also critical for the ocean's own stability. For this reason, it makes sense to focus on the problems facing the ocean, but also exploring potential solutions that the ocean offers to combat the climate change. These solutions will enable the ocean to continue to serve as a cradle for the most varied biodiversity on Earth, provide half of the world's primary production, retain its capacity as the thermostat of this planet and regulate the vital hydrological cycle.

All the stakeholders, including scientists, academics, students, policymakers, managers, thinkers, writers, journalists, and the corporate sector can create an alliance for ideas and actions to build momentum for creating a real change in the ocean's outlook as an integral component for sustainable development. This can lead to development of more organized forms of 'ocean citizen science' programs that can present scientific knowledge in a form that will be more acceptable to policy and decision-making institutions and tailored for wider audiences. It is the need of the hour to motivate all sections of the community to engage with the ocean environment and play their part in its sustainability. Awareness of how anthropogenic activities impact the ocean, and the societal consequences of the ocean's response are becoming more broadly known, but challenges remain in supporting communities take appropriate actions. In view of the non-linearity of many factors in the social-ecological systems, there is a need to develop integrated models defining geospatial and specific scenarios for strategic interventions.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

The authors contributed equally to this paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

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

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Research Article

Mean length-weight relationship and condition factor of some Cyprinid fishes in Göynük Stream, Murat River of Eastern Türkiye, Bingöl

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B. lacerta
A. marmid

ABSTRACT

The Length-weight relationships (LWRs) are very important to data for accurate estimate of populations in stock menagement. In this study, the length-weight relationships and Fulton's condition factor (K) of some fish in Göynük Stream, Murat River (Bingöl/Turkiye) were examined. The LWRs and condition factor (K) of *Cyprinon macrostomus, Garra rufa, Barbus lacerta,* and *Acanthobrama marmid* were analyzed between March 2017-February 2019. LWRs was estimated using the linear regression model. LWRs were obtained as total weight (TW) = $0.013L^{2.98}$, $0.057L^{2.40}$, $0.016L^{2.79}$ and $0.029L^{2.82}$ for *C. macrostomus, G. rufa, B. lacerta* and *A.marmid*, respectively. The b values acquired in the four fish species ranged from 2.13-2.57 (*G. rufa*-Male; Female) to 2.77-3.34 (*B. lacerta*-Female; Male). Only *B. lacerta* males had a positive allometric growth versus the males and females of all species had a negative allometric growth. The K of the fish species varied from 0.90-0.99 (*A. marmid*-Male; Female) to 1.27 (*G. rufa*-All), indicating that most of the fish were in good condition. However, *C. macrostomus* and *G. rufa* were better condition than *B. lacerta* and *A. marmid*. The study has provided baseline information on the LWR and K of the fish species in Göynük Stream. The data that would be useful to adapt the adequate regulations for sustainable fish stock estimation in the stream for fishery biologist.

Introduction

Length and weight data of fish are very important parameters for population dynamics (Krause et al., 1998), growth and death rates of the fish (Kohler et al., 1995). Also, the length-weight relationship (LWR) can also helps for stock management of the fish population (Sparre and Venema 1998, Blackwell et al., 2000). The LWR is important for calculating the present biomass of the fish population in a reservoir (Petrakis and Stergiou, 1995).

Studies of the LWR of fishes were performed for years. The LWRs has been studied by many researchers in different fish species viz., *Clarias gariepinus* (Ayo-Olalusi, 2014); *Oreochromis niloticus* (Silva et al., 2015); *Astyanax* aff. *fasciatus* (Furuya et al., 2014); *Pseudorasbora parva, Atherina boyeri, Aphanius danfordii, Tinca tinca,* and *Cyprinus carpio* (Kırankaya et al., 2014); *Capoeta umbla* (Serdar and Özcan, 2016); *Acanthobrama marmid, Capoeta trutta, Arbus luteus* and *Chalcalburnus mossulensis* (Başusta and Çiçek, 2006); *Carasobarbus luteus, Chondrostoma regium, Clarias gariepinus, Anguilla anguilla* and *Cyprinus carpio* (Özcan, 2008). In addition, the *a* and *b* values, which are the LWR parameters, allow the morphology of populations distributed in different habitats and the life processes of fish species to be compared (Yedier et al., 2019; Yılmaz et al., 2010).

Condition factor (K) is a parameter related to the body shape of the fish and serves as an important factor in understanding detailed properties of the habitat. This factor shows the nutrient

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density of the environment where fish live. Therefore, it is strongly affected by both biotic and abiotic environmental conditions (Saliu, 2001). Thus, it also provides the opportunity to compare the condition factors of fish populations of the same species in different environments. In addition, it provides an information to researchers according to sexual maturity status, population density, nutritional status and climate changes (Froese, 2006). Briefly, it is important to understanding of the quality of the ecosystem (Luff and Bailey, 2000; Anene, 2005). Condition factor has been studied for different fish species (Uysal et al., 2009; Ayyildiz et al., 2014; Emre et al., 2014; Keyombe et al., 2015; Maurya et al., 2018; Khristenko and Kotovska, 2017; Özcan, 2019; Özcan and Serdar, 2021; Alagöz Ergüden, 2021).

The Göynük Stream (Bingöl, Türkiye) has the 21 fish species (Koyun et al., 2018), but there is not a study concerning the LWR of fishes in this region. The present study aimed to find out the present status of LWR and K of some fish species in Göynük Stream. Consequently, results will contibute in the protection of natural fish stocks in this region.

Materials and Methods

Murat River is between the Tigris Euphrates Rivers and Asi Basin in Turkey and arises from hillside of Ararat Mount and carries in 2/3 of water of Euphrates River (42000 km^2). The length of Murat River is 722 km and its flow is 239.9 m^3/s (ÇDR, 2014; Kirici et al., 2016).

The fish samples (adult) were collected different location depending on fish abundant from March 2017 to February 2019 from the Göynük Stream, Murat River (Bingöl, Türkiye) using nets with different eye apertures. Caught fish were kept on ice, and delivered to the laboratory in 1 h. In the laboratory, total length (TL, cm) were measured, total weights (TW, g) were weighed. The total length and weight of each fish sample were determined to be the nearest 1 mm and 0.01 g scales, respectively. The sexes were determined by macroscopic observation of the gonads; when the gonads were thin and poorly developed the fish sex was considered as undetermined (Özcan and İspir, 2019). The sex of each specimen was determined by examining the gonads macroscopically. Chi-square ($\chi 2$) analysis was used to test the significant differences between the sex ratio. The LWR of a fish were expressed by the equation $W=aTL^b$, where W is the total weight, TL is the total length, *(a)* is the coefficient related to body form and *(b)* is an exponent indicating isometric growth when equal to 3 and allometric growth when different to 3 (the allometry is majorant if $b>3$ and minorant if $b<3$). The parameters *(a)* and *(b)* of the length–weight relationship was estimated by the least-square method, using W as the dependent variable and TL as the independent variable, $log(W)=log(a)+blog(TL)$. The b-value for each species was tested by Student t-test to verify if it was significantly different from the predictions for isometric growth (b=3) (Pauly, 1984). The relationships among the variables were identified using the regression analysis (Sparman Rank Correlation). The observed differences were evaluated statistically using STATISTICA software and t-test, independent, by groups.

The Fulton's condition factor *(K)* was calculated according to Bagenal and Tesch (1978) with the formula; $K=100W/L^3$, where K is the condition factor, W is the total body weight *(BW)*, L is the length *(L)* and 3 is a constant.

Results and Discussion

Length-weight relationship gives an information on the condition and growth pattern of fish (Bagenal and Tesch, 1978). In morphometry, it is a valuable and standart result of fish sampling programmes. The relationship is used in estimate various morphological and physicological aspects (e.g. growth rate, length, age) (Kohler et al., 1995). Weight of fish is accepted to be function of length (Weatherely and Gill, 1987). The relationship parameter was "*b*" value and generally ranges between 2 and 4 (Bagenal and Tesch, 1978), often close to 3 (Jobling, 2002). Also, *K* is used as biological parameter. *K* indicates the suitability of a spesific water body for the gowth of fish an an index of species average size (Begenal and Tesch, 1978). *K* values change depending on enviromental (e.g. nutrition condition, seasonal variation) and physicological factors of fish (e.g. age, size, disease, stress, reproduction period, gonadol development) (Doddamani et al., 2001; Welcomme, 2001; Korkut et al., 2007). The coefficient of determination *(R^2)* values explaine the proper fit of the model for growth (Datta et al., 2013). All the parameters were used in four different cyprinidae species (*C. macrostomus, G. rufa, B. lacerta, A. marmid*) from Göynük Stream, Murat River.

It is well known that the female/male ratio *(F/M)* in most species is close to 1. However, while the ratio varies considerably from species to species, it can also differ from one population to another and from year to year in the same species (Nikolsky, 1963). 42 (48.28%) females and 45 (51.72%) males a total of 87 *C. macrostomus,* 78 (48.75%) females and 82 (51.25%) males a total of 160 *G. rufa,* 35 (79.55%) females and 9 (20.45%) males a total of 44 *B. lacerta* and 11 (45.83%) females and 13 (54.17%) males, a total of 24 *A. marmid* specimens were used in the study. *F/M* ratio was the lowest in *A. marmid* (1/1.18, p=0.34) while *F/M* ratio was the highest in *B. lacerta* (1/0.26, p=0.5). There was no significant difference in *F/M* of these species from the expected 1. Generally, the males were heavier and longer than the females except for *B. lacerta* (Table 1). There were significant differences between males and females in terms of both length (F/M=1/0.95, p=0.03) and weight (F/M=1/0.84, p=0.008) of *B. lacerta* (p<0.05). However, there were not significant differences between males and females length (F/M=1/2.77, p=0.21, p>0.05) of *A. marmid* whereas there were significant differences between males and females weight (F/M=1/2.29, p=0.03, p<0.05) of *A. marmid* (p>0.05). Additionally, there were significant differences between females and males length in both of *C. macrostomus* (F/M=1/2.71, p=0.11) and *G. rufa* (F/M=1/2.15, p=0.005) (p<0.05). Similarly, there were a significant difference between males and females weight in both of them. Although, they have the same p value for weight (p=0.02, p<0.05), their *F/M* weight was different. *F/M* weight was 1/2.24 for *C. macrostomus* and 1/1.45 for *G. rufa*. We determined a negative allometry in isometric growth of all the species without distinction of sex ($b<3$, Student's t-test; $p<0.05$) LWR for *C. macrostomus* in Göynük Stream, Murat River (Table 2). "*b*" value is a parameter related to the growth pattern. The highest "*b*" value was with 2.98 in *C. macrostomus,* following *A. marmid* (b=2.82), *B. lacerta* (b=2.79) and *G. rufa* (b=2.40). *K* is a factor based on growth (Ricker, 1975). $K>1$ showes the well being of fishes fed with different diets and much robust fish (Datta et al., 2013). *K* varied between 0.94 and 1.27 for all fish specimens in our study. *K* was the highest in *G. rufa* (1.27) and *C. macrostomus* (1.20) ($K>1$) and the lowest with equal value (0.94) in *B. lacerta* and *A. marmid* (Table 2). According to the results, *C. macrostomus* and *G. rufa* were fed different and richer nutrient diets than *A. marmid* and *B. lacerta.* Therefore, we can say that *C. macrostomus* and *G. rufa* much more robust than the others fish. Additionally, Göynük Stream from Murat River had more suitable environmental conditions for *C. macrostomus* and *G. rufa* than *B. lacerta* and *A. marmid.* In the study, lowest R^2 was in *G. rufa* (0.77), whereas the highest R^2 was in with the equal value in *C. macrostomus* and *B. lacerta* (0.97) (Table 1).

Table 1. Mean length-weight relationship parameters of the species in Göynük Stream, Murat River (Türkiye) ($p<0.05$)

Species	Sex	n	$L_{min-max}$ (cm)	$W_{min-max}$ (g)	a	b	R^2
	♀	42	8.5-18.5	8.00-72.00	0.013	2.97	0.975
C. macrostomus	♂	45	9.8-18.8	10.00-87.00	0.012	2.99	0.957
	♀+♂	87	8.5-18.8	8.00-87.00	0.013	2.98	0.968
	♀	78	9.0-18.0	11.10-68.50	0.038	2.57	0.897
G. rufa	♂	82	8.1-19.0	6.50-60.00	0.011	2.13	0.606
	♀+♂	160	8.1-19.0	6.50-60.00	0.057	2.40	0.770
	♀	35	11.5-22.5	13.54-96.30	0.017	2.77	0.963
B. lacerta	♂	9	10.6-14.1	9.68-25.53	0.004	3.34	0.925
	♀+♂	44	10.6-22.5	9.68-96.30	0.016	2.79	0.966
	♀	11	12.7-19.0	21.50-72.25	0.029	2.62	0.870
A.marmid	♂	13	14.4-17.5	24.50-54.64	0.018	2.75	0.763
	♀+♂	24	12.7-19.0	21.50-72.25	0.016	2.82	0.818

Min-max total lengths and weights were between 8.5-18.8 cm and 8.0-72 g in the females of *C. macrostomus*, 9.8-18.8 cm ve 10.0-87.0 g in the males of *C. macrostomus,* respectively. The length and weight distributions of *C. macrostomus* were found as 2.50-15.50 cm and 0.43-85.21 g in the Shahpur River, Iran, and 2.80-17.70 cm and 0.51-126.15 g in the Dalaki River, Iran by Bibak et al. (2013). The length-weight relation of *C. macrostomus* was $W=0.013L^{2.97}$ for the females and $W=0.011L^{2.99}$ for the males. "*b*" had positive allometry (3.13, $b>3$) in Dalaki River and negative allometry (2.94, $b<3$) in Shahpur River for LWR for *C. macrostomus* (Bibak et al., 2013). The values of *b* in the Dalaki River were 3.27 for females and 3.02 for males in *C. macrostomus* (Sedaghat and Hoseini, 2012). We determined a negative allometry (b_{female}:2.97; b_{male}:2.99, Student's t-test; $p<0.05$) LWR for *C. macrostomus* in Göynük Stream, Murat River (Table 2). Similarly, the *b* values of both sexes were less than 3 (b_{female}: 2.95; b_{male}: 2.86) with negative allometry in Karakaya Dam Lake (Euphrates River), Türkiye (Uckun and Gokce, 2015). The mean condition factors *(K)* were 1.19 for females and 1.20 for males of *C. macrostomus*. Uckun and Gokce (2015) found that *K* was the highest 1.98 for females and 1.89 for males of *C. macrostomus*. Unlike Uckun and Gokce (2015), we found that *K* was higher in males (1.65) than females (1.38) of *C. macrostomus. K* was higher in the males (1.20) than in the females (1.19), with a slight difference. Although the research areas are in the same region, such the differences are an expected result as stated above. In the study, R^2 was 0.98 in the females while R^2 was 0.96 in the males. The regression analysis showed that male length of *C. macrostomus* had higher significant correlation than male length of *C. macrostomus* with weight ($p<0.05$, Sparman Rank Order Correlation Test) (Table 1). Length of *C. macrostomus* had a high correlation with weight of *C. macrostomus* in Dalaki River, Iran (R^2=0.98) and Shahpur River, Iran (R^2=0.997). R^2 was given as 0.88 for females and 0.87 for males of *C. macrostomus* in Euphrates River (Türkiye) by Uckun and Gokce (2015).

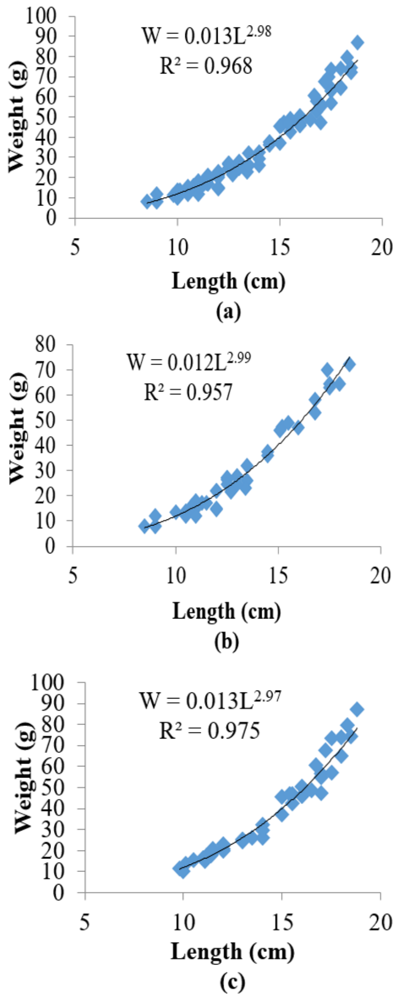

Figure 1. Mean total length-weight relationship of *C. macrostomus* for all individuals (a), male (b) and female (c) in Göynük Stream, Murat River (Türkiye)

Min-max total lengths and weights were between 9.0-18.0 cm and 11.1-68.5 g in the females of *G. rufa,* 8.1-19.0 cm and 6.5-60.0 g in the males of *G. rufa,* respectively. The total length of

G. rufa ranged from 8.5-19.1 cm in Goynuk Stream and the total weights ranged from 5.8-58.7 g (Koyun and Atici, 2021). The mean condition factor was determined as 1.126 (0.607-1.646) in the same sampling location by Koyun and Atici (2021). The length and weight distributions of *G. rufa* were found as 2.90-16.80 cm and 0.21-69.27 g in Merzimen Stream, Euphrates River by Cicek et al. (2021) and 3.00-17.10 cm and 2.00-35.00 g in the Dalaki River, Iran by Pazira et al. (2013). The maximum length were given as 16.8 cm in Merzimen Stream, Euphrates River by Cicek et al. (2021). Min-max total lengths and weights *G. rufa* were given as 3.50-17.00 cm and 4.00-35.00 g for the females and 2.00-16.50 cm and 3.00-32.00 g foor the males in Dalaki River, by Pazira et al. (2013). The length-weight relation of *G. rufa* was $W=0.038L^{2.57}$ for the females and $W=0.011L^{2.13}$ for the males with negative allometry (Student's t-test; p<0.05) (Table 2). *G. rufa* had positive allometric growth in the most the previous studies (Abedi et al., 2011; Birecikligil and Ciçek, 2011; Hamidan and Britton, 2013; Gerami et al., 2013; Ergüden, 2016; Çiçek et al., 2021). However, we found a negative allometry (b_{female}: 2.57; b_{male}:2.13, Student's t-test; p<0.05) LWR for *G. rufa* in Göynük Stream, Murat River (Table 2). Environmental conditions, existing habitat may have been effective in the difference in the results (Thoumani et al., 2006) ; Nazek et al., 2018). The values of "*b*" were between 2.63 and 3.40 in *G. rufa* collected from different rivers and basins of Iran (Keivany et al., 2015). The mean *K* were the same value with 1.27 for females and males of *G. rufa*. Similarly, Gerami et al. (2013) found almost close *K* values both of the females (1.22) and the males (1.21) in Cholvar River, Iran. Additionally, R^2 of *G. rufa* was >0.90 in the different regions in the previous studies (Keivany et al., 2015; Gerami et al., 2013; Esmaeili and Ebrahimi, 2006). However, R^2 was 0.90 in the females while R^2 was 0.61 for males in the study. The regression analysis showed that male length of *G. rufa* was weakly correlation with weight while female length of *G. rufa* was highly correlation with weight (p<0.05) (Table 1).

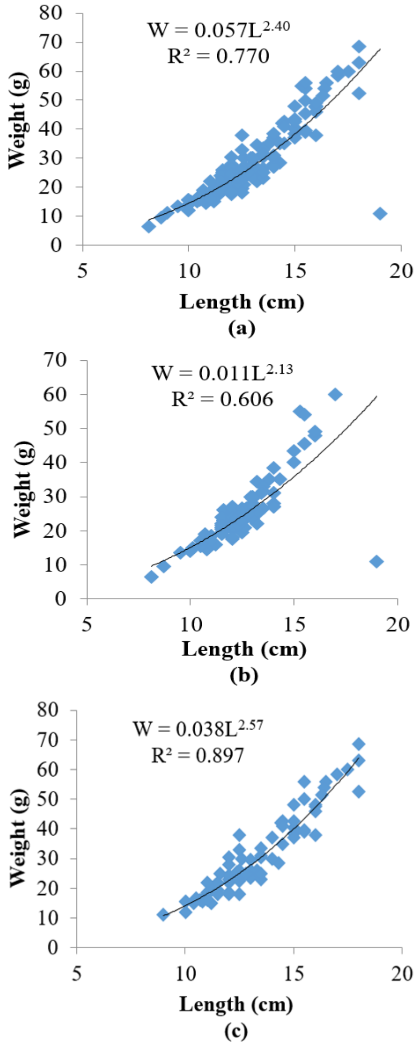

Figure 2. Mean total length-weight relationship of *G. rufa* for all individuals (a), male (b) and female (c) in Göynük Stream, Murat River (Türkiye)

Table 2. Mean total length, weight and condition factor values of the species in Göynük Stream, Murat River (Türkiye)

Species	Sex	L±SD	W±SD	K±SD	$K_{Min-Max}$	LWR*	Growth (t-test)
C. macrostomus	♀	14.33±2.77	38.89±21.58	1.19±0.11	0.95-1.38	$W=0.013L^{2.97}$	A (-)
	♂	12.88±2.66	28.87±18.47	1.20±0.15	0.84-1.65	$W=0.012L^{2.99}$	A (-)
	♀+♂	13.58±2.80	33.71±20.54	1.20±0.13	0.84-1.65	$W=0.013L^{2.98}$	A (-)
G. rufa	♀	13.27±2.13	30.97±13.65	1.27±0.2	0.90-1.95	$W=0.038L^{2.57}$	A (-)
	♂	12.60±1.73	25.92±9.86	1.27±0.2	0.16-1.67	$W=0.011L^{2.13}$	A (-)
	♀+♂	12.92±1.96	28.38±12.10	1.27±0.2	0.16-1.95	$W=0.057L^{2.40}$	A (-)
B. lacerta	♀	14.87±2.57	31.96±17.29	0.91±0.09	0.80-1.19	$W=0.004L^{2.77}$	A (-)
	♂	12.27±0.93	17.76±4.26	0.94±0.07	0.81-1.06	$W=0.016L^{3.34}$	I (+)
	♀+♂	14.34±2.55	29.66±16.54	0.94±0.09	0.80-1.19	$W=0.016L^{2.79}$	A (-)
A. marmid	♀	16.56±1.64	45.81±12.20	0.99±0.11	0.78-1.14	$W=0.016L^{2.62}$	A (-)
	♂	15.84±1.10	36.23±8.08	0.90±0.10	0.77-1.02	$W=0.018L^{2.75}$	A (-)
	♀+♂	16.17±1.39	40.63±11.07	0.94±0.11	0.77-1.14	$W=0.029L^{2.82}$	A (-)

Min-max total lengths and weights were between 11.5-22.5 cm and 13.54-96.30 g in the females of *B. lacerta,* 10.60-14.10 cm and 9.68-25.53 g in the males of *B. lacerta,* respectively. The length and weight distributions of *B. lacerta* were found as 6.0-22.6 cm and 2.14-133.0 g for the females, 5.4-25.7 cm and 2.02-158.3 g for the males in Pülümür River, Türkiye by Özcan (2019). The total length and weight distribution of *B. lacerta* was 30.4-47.4 cm and 271.8-981.6 g in Keban Dam Lake (Türkiye) (Dartay and Gül, 2013), 6.6-17.1 cm and 2.8-48.4 g in Zarrineh River (Iran) (Radkhah and Eagderi, 2015), 2.60- 23.23 cm and 0.17–123.17 g in Bibbi-Sayyedan River (Iran) (Keivany et al., 2016), 7.0-24.0 cm and 4.0-211 g (Serdar and Özcan, 2018) in the Karasu River (Türkiye). The length-weight relation of *B. lacerta* was $W=0.004L^{2.77}$ for the females with negative allometry and $W=0.016L^{3.34}$ for the males with positive allometry (Student's t-test; $p<0.05$) (Table 2). The length-weight relation of *B. lacerta* was found as positive allometric (isometric growth) both of females (b=3.11) and males (b=3.08) of *B. lacerta* by Serdar and Özcan (2018) in Karasu River. Özcan (2019) found $b<3$ in females (b=2.90) and males (2.97) of *B. lacerta*, Pülümür River. Different b values maybe depend on many factors such as number of samples, length and weight distribution of samples, sampling time and shape, ecological conditions of habitats, etc. (Yazioglu et al., 2013). The mean K were 0.91 for the females and 0.94 for the males of *B. lacerta.* $K<1$ indicated that both males and females of *B. lacerta* do not prefer mixed diets with rich nutrition and fed with diets with poor nutrient content. Similarly, Özcan (2019) found $K<1$ in both of the females (0.91) and the males (0.94) in Pülümür River. K values of *B. lacerta* were found between 1.77-2.17 in the Bibi-Sayyedan River, Iran by Dopeikar and Keivany (2015). Also, the mean K value of *B. lacerta* was determined as 1.011 in the Zarrineh River by Radkhah and Eagderi (2015) and 1.18 in Karasu River by Serdar and Özcan (2018). R^2 value was 0.94 for females and 0.96 for males of B. lacerta in Pulumur (Özcan, 2019), 0.98 for both of the females and males in Karasu River (Serdar and Özcan, 2018). Conversely, R^2 was 0.96 in the females while R^2 was 0.93 for males in the study. The regression analysis showed that length of *B. lacerta* male correlated higher with weight than *B. lacerta*'s female length correlated with weight ($p<0.05$, Sparman rank order correlations test) (Table 1).

Min-max total lengths and weights were between 12.70-19.00 cm and 21.50-72.25 g in the females of *A. marmid*, 14.40-17.50 cm and 24.50-54.64 g in the males of *A. marmid,* respectively. The length and weight distributions of *A. marmid* were found as 6.40-11.70 cm and 3.20-20.50 g for the females, 6.10-11.00 cm and 2.40-19.00 g for the males in Karasu River by Serdar et al. (2017). The length-weight relation of A. marmid was $W=0.016L^{2.62}$ for the females and $W=0.018L^{2.75}$ for the males with negative allometry (Student's t-test; $p<0.05$) (Table 2). The length-weight relation of *A. marmid* was found as positive allometric growth in both of females (b=3.25) and males (b=3.27) of *A. marmid* by Serdar et al. (2017) in Karasu River. Ünlü et al. (1994) found $b>3$ in females (b=3.40) and males (3.29) of *A. marmid*. Similarly, b was found 3.363 for females and 3.086 for males in Keban Dam Lake by Basusta (2000). Çoban and Yüksel (2013) indicated that

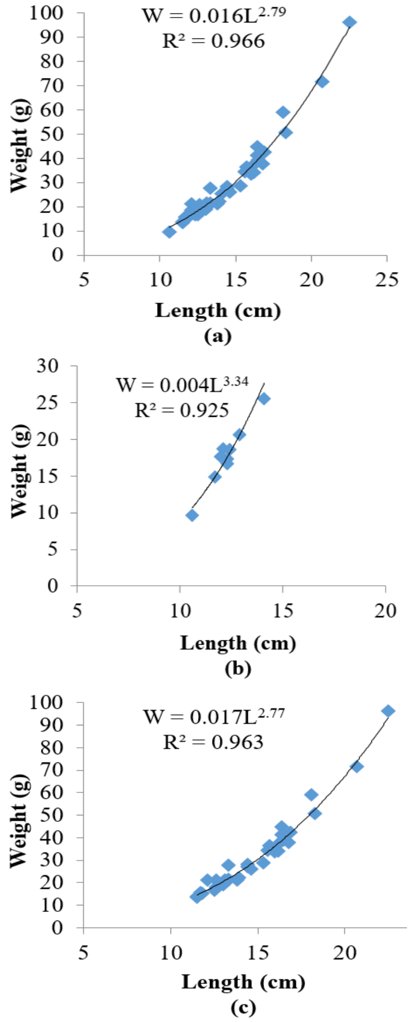

Figure 3. Mean total length-weight relationship of *B. lacerta* for all individuals (a), male (b) and female (c) in Göynük Stream, Murat River (Türkiye)

b was 2.926 for females (negative allometric) and 3.009 for males (positive allometric) in Uzuncayir Dam Lake of Eastern Türkiye. The mean K were 0.90 for the females and 0.94 for the males of *A. marmid* ($K<1$). The K values of *A. marmid* indicated that both the males and females do not prefer mixed diets with rich nutrition and fed with diets with poor nutrient content and to less favorable environmental conditions like *B. lacerta* in the Göynük Stream, Murat River. K was found between 0.77-1.14 for all *A. marmid* individuals in the study. Mean K was 0.99 (0.78-1.14) for the females and 0.90 (0.77-1.02) for the males. Similarly, Coban and Yuksel (2013) found $K<1$ in both of the females (0.23) and the males (0.24) for *A. marmid* in Uzuncayir Dam Lake. Similar results for K were found by Unlu et al. (1994) in Tigris River. K values were given as 0.69 for the males and 0.74 for the females by them. The highest K values were found in our study for *A. marmid*, compared with these studies conducted in eastern Turkey. K values of this study indicated that Göynük Stream, Murat River had more favorable environmental conditions than the others for *A. marmid.* R^2 value was 0.97 for the females and 0.96 for males in Karasu River (Coban and Yuksel, 2013). R^2 was higher (0.87) in females than the males (0.76) in the study (Figure 4). The regression analysis showed that *A. marmid's* female length correlated higher with weight than *A. marmid's* male length correlated with weight (p<0.05) (Figure 4).

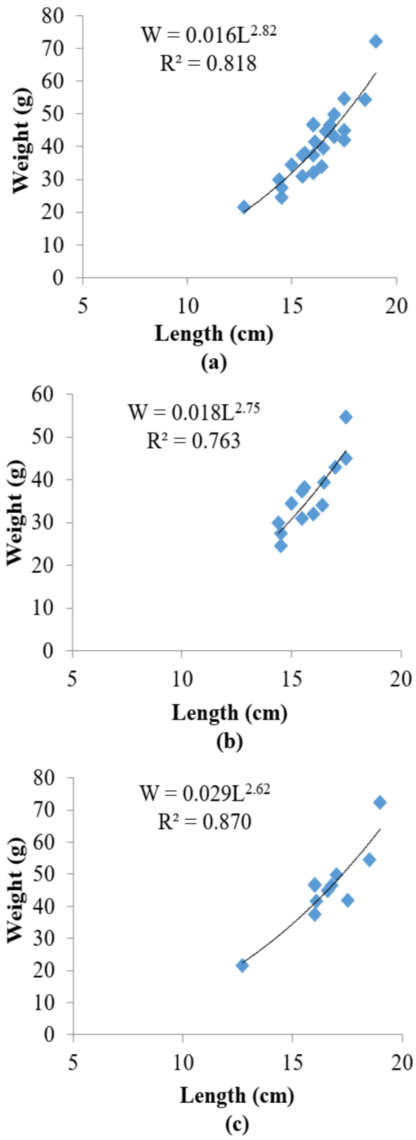

Figure 4. Mean total length-weight relationship of *A. marmid* for all individuals (a), male (b) and female (c) in Göynük Stream, Murat River (Türkiye)

Conclusion

This study included the basic information on the length-weight relationships and condition factor of *C. macrostomus, G. rufa, B. lacerta* and *A. marmid* from the Göynük Stream, Murat River that will be useful for the management of fishery resources. However, Göynük Stream, Murat River provided more favorable environmental conditions for *C. macrostomus* and *G. rufa* than *B. lacerta* and *A. marmid*. There are no data available on the species in Murat River. Thus, the study provides first informations, describing parameters related to length-weight relationships which are useful for fishery biologist in the sampling area.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

Authors contributed equally to this paper.

Conflict of Interest

The author declare that there is no conflict of interest.

Ethical Approval

Fish catching and experimental protocol was approved by Bingöl University Animal Experiments Ethics Committee (Bingöl, Türkiye). (Approval Date: 13.10.2016, Approval No: 06/5)

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Research Article

Determination of zooplankton fauna in the running waters of Arsuz District of Hatay province

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ABSTRACT

Some water quality parameters (salinity, water temperature, conductivity and dissolved oxygen) and zooplankton fauna were investigated in 4 rivers within the borders of Arsuz district of Hatay Province. Forty three (43) species of Rotifera (61.43%), 21 species of Copepoda (30%), and 6 species of Cladocera (8.57%) were recorded. In the study, 15 families from Rotifera were recorded, Lecanidae was the richest family with 12 species, Chydoridae from Cladocera represented by three families was the richest family with 4 species, and Cyclopoidae from Copepoda, represented by 10 families, was the richest family with 8 species. It was observed that *Cephalodella gibba, Colurella adriatica, Eucyclops serrulatus* and *Paracyclops fimbriatus* were the most common species recorded in all four running waters. Most species (51 species) were recorded in Arsuz Stream, followed by Gümüşkent stream with 32 species. In the study in which a total of 70 taxa were recorded, only 12 taxa were very abundant (+++) and abundant (++) levels in various seasons and rivers. Only 2 rotifer species *Brachionus quadridentatus* and *Lecane hamata* were very abundant. There was a significant and positive relationship between zooplankton species diversity, abundance, and water quality parameters.

Introduction

Zooplankton plays an important role in the integration of the energy budget into the aquatic ecosystem by controlling phytoplankton production and grazing on primary producers and organic residues in the water column, which play a key role in the food web by shaping the pelagic ecosystem (Anene, 2003). They play an important role in the aquatic food web because they provide food for many aquatic organisms. As fish depend on them nutritionally, they are useful indicators of the future of fisheries and fish health (Davies et al., 2009). Zooplankton are useful as bioindicators to help us detect pollution load, but are also useful for remediating polluted waters (Mukhopadhyay et al., 2007; Eyo et al., 2013). They are also key in determining the amount and composition of particles that sink into benthos, which provide nutrients for benthic organisms and contribute to the burial of organic compounds. What zooplankton feeds on is not always clear as it depends on life stage, season and food availability. But in general, they can be grouped into herbivores that eat only phytoplankton, omnivores that eat both phytoplankton and zooplankton, and carnivores that eat only other zooplankton, and detritivores that eat detritus and bacteria (Wetzel, 2001).

Flowing aquatic environments, such as rivers, provide a distinct, complex habitat for zooplankton and may be home to a plethora of microzooplankton (Kobayashi et al., 1998). River zooplankton assemblages can have the structure and function of rivers, as opposed to lacustrine zooplankton assemblages, which are typically dominated by larger cladocerans and copepods (Cyr and Pace, 1993).

Rivers often contain abundant plankton, although zooplanktonic organisms lack the ability to swim against currents (Hynes, 1970; Rzoska, 1978). Factors affecting plankton abundance in rivers are broadly divided into two categories: factors affecting the transport of organisms from source areas to the river and factors affecting the growth and reproduction of organisms in the river (Hynes, 1970). Plankton can be supplied to the river by stagnant waters in contact with the canal. Natural lakes and dams are obvious examples, but stagnant waters, braided channels with low flow, can be even more important in unmodified rivers. Incubation of eggs resting in river sediments may also help zooplankton populations develop in rivers (Moghraby, 1977). The fate of plankton within the river channel is largely determined by the organisms' ability to grow and reproduce. Plankton density

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increases downstream in some large rivers, indicating that populations can multiply (Greenberg, 1964). Increases, on the other hand, may vary seasonally with runoff or may not occur at all (Hynes, 1970).

Although zooplankton of stagnant waters was widely researched in Turkey, studies on rivers are relatively few. Some of these are Rotifer Fauna of Gümüldür Stream (İzmir) (Ustaoğlu et al., 1996), Rotifera and Cladocera fauna of Seyhan River (Göksu et al., 1997), Cladocera and Copepoda fauna of Gümüldür Stream (Ustaoğlu et al., 1997), rotifer fauna of Zıkkım Stream and seasonal changes (Saler and Şen, 2001), zooplankton fauna of some rivers in the Mediterranean Region (Bozkurt, 2004), Rotifera fauna of the Euphrates River basin (Akbulut and Yıldız, 2005), rotifer fauna of Seli Stream (Elazig-Turkey) (İpek and Saler, 2008), zooplankton structure in Karaman stream (Altındağ et al., 2009), Asi River (Hatay-Turkey) zooplankton succession (Bozkurt and Güven, 2010), Zooplankton of Karasu River (Erzincan) (Saler et al., 2015), Zooplankton and Variation of Murat River (Bulut and Saler, 2014), rotifer fauna of Gediz River Basin, Turkey (Ergönül et al., 2015), Rotifera Fauna and Community Structure of Tunca River (Edirne) (Güher and Demir, 2018).

This study was carried out to determine the zooplankton fauna of 4 running waters, namely Arsuz Stream, Gümüşkent Creek, Çengen Village Creek and Büyükdere Village Creek, which are between the districts of Iskenderun and Arsuz within the borders of Hatay province, where no studies have been conducted so far.

Materials and Methods

Zooplankton samples were collected from five stations located within Hatay Province, between the districts of Iskenderun and Arsuz (Figure 1). Table 1 shows the coordinates of the stations. Zooplankton samples were collected seasonally from Arsuz Stream, Gümüşkent Creek, Çengen Village Creek, and Büyükdere Village Creek in July 2021, October 2021, January 2022, and April 2022. The samples were collected using a plankton net from the water and interstitial at two stations in the Arsuz Stream and one station in each of the other streams. Samples were taken with a plankton net of 60 µm mesh size, 30 cm mouth diameter and 1 m length. Due to the fact that the river zooplankton fauna is poor in terms of quality and quantity, sampling was carried out from the flowing part of the water for approximately 25-30 minutes by keeping the plankton net constant. Interstitial samples were collected by the Karaman–Chappuis method (Delamare-Deboutteville, 1960). On the side of the stream, in sandy gravel areas under the influence of water, pits 30-40 cm deep and 50-60 cm wide (to the extent allowed) were dug and the water accumulated in them was poured into the plankton bucket with the help of a container and filtered (after the water in the pool was exhausted, it was expected to be filled again and drained). Samples taken by both methods were placed in 500 cc plastic containers and preserved in 4% formaldehyde.

While the plankton samples were taken from the water at all stations, they were also taken from the sand at the 2nd, 3rd and 4th stations. Sampling was not possible at stations 4th and 5th as there was no water summer and autumn.

Arsuz Stream is a significant stream in the Arsuz district that originates in the Amanos and grows by connecting various small running water branches to reach a length of approximately 20 kilometers. This stream contains the first and second stations. The Gümüşkent Stream is approximately 17 kilometers long, with a seasonal flow rate due to the merging of small streams originating from the Amanos Mountains, and the 3rd station is located on this stream. The Çengen Village Stream is a small running water with a length of around 5 km, which dries up in summer and autumn, and the 4th station was determined in this stream. The Büyükdere Village Stream is fed by spring water, leachate, and rain water that originates near Pirinçlik Village in Arsuz district and travels approximately 8 kilometers. Its waters drop significantly in the summer and autumn, and the 5th station is located on this stream.

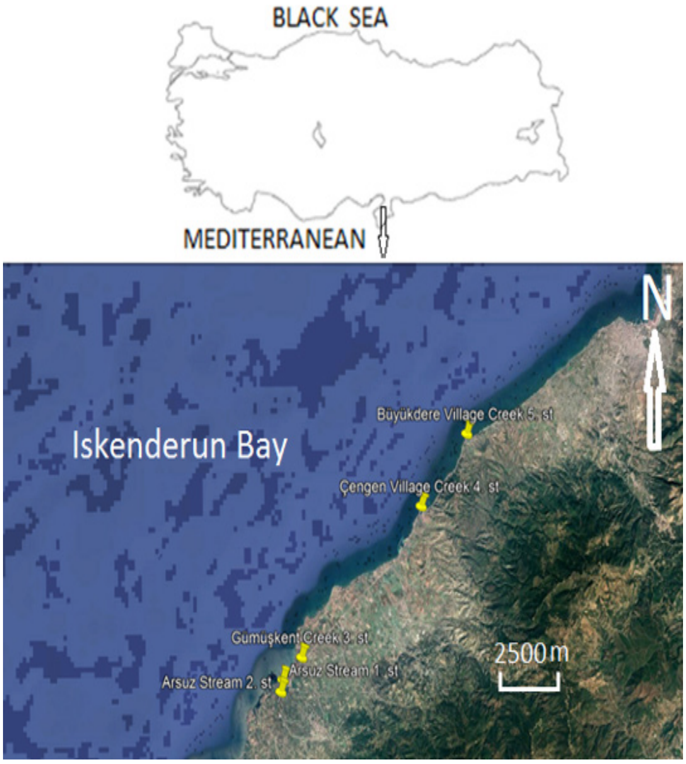

Figure 1. Sampling stations

Water temperature (°C) and dissolved oxygen (mg L^{-1}) were determined in-situ with a model YSI-52 oxygen meter, salinity (ppt) and conductivity (µS cm^{-1}) with a model YSI-30 salinometer.

Zooplankton species were examined and identified using an inverted microscope and a binocular microscope (Olympus CH40). The specimens were identified using Rylov (1963), Borutsky (1964), Scourfield and Harding (1966), Dussart (1967), Dussart (1969), Damian-Georgescu (1970), Smirnov (1974), Negrea (1983), Reddy (1994), Segers (1995), Karaytug (1999), Holynska et al. (2003) and the relevant literature.

Table 1. Sampling location and coordinates

Station	Streams	Station coordinates
1	Arsuz Stream	36° 24' 22.23" N, 35° 53' 15.09" E
2	Arsuz Stream	36° 24' 00.12" N, 35° 53' 08.58" E
3	Gümüşkent Creek	36° 25' 40.46" N, 35° 54' 16.35" E
4	Cengen Village Creek	36° 29' 39.47" N, 35° 59' 58.29" E
5	Buyukdere Village Creek	36° 31' 52.20" N, 36° 02' 12.50" E

Results

In the study, some water quality parameters such as salinity, water temperature, conductivity and dissolved oxygen were measured during the sampling in the field. Accordingly, it was determined that the highest salinity was 3 ppt in the summer and autumn at the 1st station, and the lowest was 0.2 ppt in the winter at the 1st station and the annual average was 0.79±0.88 ppt. With an annual average of 21.79±6.64 °C, the highest temperature was 32.4 °C in the spring at the fourth station and the lowest was 11.2 °C in the winter at the second station. The maximum dissolved oxygen concentration was 11.22 mg L^{-1} at station 4 in winter, while the lowest concentration was 7.60 mg L^{-1} in summer with an annual average of 8.67±0.82 mg L^{-1}. Conductivity was highly variable throughout the year. The maximum reading was 1646 μS cm^{-1} in winter at the 4th station, 360 μS cm^{-1} at the 2nd station in winter, and the annual average was 915.19±464.14 μS cm^{-1} (Table 2).

Forty three (43) species of Rotifera (61.43%), 21 species of Copepoda (30%), and 6 species of Cladocera (8.57%) were recorded in the study (Table 3). A total of 15 families were recorded among the rotifers. The family Lecanidae was the most abundant with 12 species, followed by Lepadellidae with 8 species, Brachionidae with 5 species, Trichocercidae and Notommatidae with 3 species each, and Euchlanidae and Trichotridae with 2 species each. Three families were recorded among Cladocera. Chydoridae was the richest family with 4 species (Table 3). Among the 10 families of Copepoda, Cyclopoidae had 8 species, followed by Canthocamptidae with 4 species and Ameiridae with 2 species.

Each of the other families belonging to the rotifer, cladoceran and copepod groups in the study were represented by only one species (Table 3).

When the running waters in which the research was carried out were evaluated separately, the zooplankton content of each stream was quite different, although the zooplankton fauna of all of them consisted of common species.

According to this; a total of 51 species, 36 rotifers, 12 copepods, and 3 cladocerans, were determined from the Arsuz Stream plankton and interstitial samples. While Gumuskent Stream was found in the second abundance with a total of 32 species, 22 rotifers, 8 copepods and 2 cladocerans, it was followed by the Cengen Village Stream with a total of 17 species, 9 rotifers, 6 copepods and 2 cladocerans. The least species was recorded in the Büyükdere Village Creek, where there were a total of 16 species, 7 copepods, 5 rotifers and 4 cladocerans.

The species recorded in all four streams were *C. gibba, C. adriatica* and *E. serrulatus*. Of the species found in three streams, *E. dilatata, C. rectangula, Speocyclops* sp. (Arsuz Stream, Gümüşkent Creek, Büyükdere Village Creek), *L. closterocerca, L. hamata, L. luna, K. xanthi, N. stammeri* (Arsuz Stream, Gümüşkent Creek, Çengen Village Creek), *L. ovalis* (Arsuz Stream, Cengen Village Creek, Büyükdere Village Creek), *P. fimbriatus* (Gumuskent Creek, Cengen Village Creek, Büyükdere Village Creek).

Species recorded in two streams, *B. quadridentatus, E. brachionus, L. bulla, L. furcata, L. papuana, L. pyriformis, L. patella, R. neptunia, T. patina, T. weberi, M. laticornis* (Arsuz Stream, Gümüşkent Creek), *C. colurus, T. tetractis* (Arsuz Stream, Çengen Village Creek), *L. curvicornis, M. viridis* (Gümüşkent Creek, Büyükdere Village Creek), *L. acanthocercoides, P. aduncus, M. mehmetadami* (Çengen Village Creek, Büyükdere Village Creek), *A. crassa, B. minutus* (Arsuz Stream, Büyükdere Village Creek).

Species recorded in only one stream were *C. forficula, C. uncinata, C. iskenderunensis, D. epicharis, L. flexilis, L. ludwigi, L. acuminata, L. (Heterolepadella) ehrenbergi, L. rhomboides, L. salpina, Ptygura* sp., *S. longicaudum, T. similis, T. taurocephala, T. pocillum, T. plicata, I. sordidus, C. perplexa, Ectinosoma* sp., *E. richardi, E. acutifrons, L. brevicornis, M. aestuarii* (Arsuz Stream), *B. calyciflorus, B. falcatus, B. urceolaris, Eothinia elongata, L. furcata, L. tenuiseta, M. grandispinifer, P. viguieri* (Gümüşkent Creek), *B. plicatilis, Diacyclops* sp., *D. bicuspidatus, N. kosswigi, Schizopera* sp. (Çengen Village Creek), *C. sphaericus* (Büyükdere Village Creek).

The most rotifer species were found in the 2nd station with 21 species in summer. This was followed by Station 1 with 20 species in the autumn and 19 species in the summer, and Station 2 in the autumn with 18 species. While no rotifers were recorded in the interstitial of the 3rd station in the winter and spring, 1 species was recorded in the interstitial samples of the 2nd station in the winter (Table 4). The most cladoceran was recorded in plankton samples with 3 species at station 2 in the summer and station 5 in the spring (Table 4). The most copepod species were recorded in the interstitial samples of station 2 with 9 species in the summer. This was followed by 5th station plankton samples in the winter with 6 species, 2nd station in interstitial with 5 species in the spring, 4th station plankton samples in the winter, and 2nd station in interstitial samples in the autumn (Table 4).

The most zooplankton was recorded in the 2nd station plankton samples in the summer with 25 species. This was followed by the summer and autumn 1st station plankton samples with 22 species, the autumn 2nd station plankton samples with 21 species, and the 2nd station interstitial samples in summer with 20 species. During the winter, no zooplankton was recorded in the interstitial samples of the 3rd station, but only one species was recorded in the same season in the interstitial samples of the 2nd station.

Table 2. Seasonal water quality parameters

Station	Parameter	Summer 2021	Fall 2021	Winter 2022	Spring 2022	Annual Mean
1	Salinity (ppt)	3.0	3.0	0.2	0.7	1.73±1.49
	Temp. (°C)	23.3	23.1	11.9	21.2	19.88±5.40
	Conduc. (µS cm^{-1})	1540	1602	366	960	1117±578.16
	DO (mg L^{-1})	8.00	8.26	9.10	8.65	8.50±0.48
2	Salinity (ppt)	0.4	0.3	0.3	0.3	0.32±0.05
	Temp. (°C)	28.1	25.7	11.2	24.5	22.38±7.60
	Conduc. (µS cm^{-1})	548	476	360	530	478.5±84.72
	DO (mg L^{-1})	8.40	8.80	9.10	8.45	8.69±0.33
3	Salinity (ppt)	0.7	0.3	0.6	0.5	0.53±0.17
	Temp. (°C)	24.6	29.1	13.5	22.3	22.38±6.56
	Conduc. (µS cm^{-1})	592	617	780	1046	758.75±208.86
	DO (mg L^{-1})	7.60	8.01	9.09	8.60	8.33±0.66
4	Salinity (ppt)	-	-	0.6	0.8	0.7±0.14
	Temp. (°C)	-	-	12	32.4	22.2±14.43
	Conduc. (µS cm^{-1})	-	-	1646	1630	1638±11.31
	DO (mg L^{-1})	-	-	11.22	7.95	9.585±2.31
5	Salinity (ppt)	-	-	0.5	0.5	0.5±0
	Temp. (°C)	-	-	18.21	27.6	22.91±6.64
	Conduc. (µS cm^{-1})	-	-	990	960	975±21.21
	DO (mg L^{-1})	-	-	8.92	8.49	8.71±0.30
Annual averages across all sampling sites						
Salinity (ppt)						**0.79±0.88**
Temp. (°C)						**21.79±6.64**
Conduc. (µS cm^{-1})						**915.19±464.14**
DO (mg L^{-1})						**8.67±0.82**

*-: Sampling and measurement could not be made due to lack of water.

As a result of quantitative analysis, it was observed that zooplankton abundance was generally low. In the study in which a total of 70 taxa were recorded, only 12 taxa were very abundant (+++) and abundant (++) levels in various seasons and rivers, while other species were fewer amounts. *B. quadridentatus* and *L. hamata* were recorded very abundant in plankton samples at station 3 in the summer. The abundant species was *B. quadridentatus* (summer, 3rd station, interstitial), *E. brachionus* (autumn, 3rd station, in plankton), *L. bulla* (summer 3rd station in plankton samples and interstitial, autumn in 1st and 2nd station in plankton samples), *L. closterocerca* (Summer, 1st, 2nd and 3rd stations in plankton samples), *L. hamata* (1st and 2nd stations, plankton in Summer, 1st station plankton in autumn), *L. luna* (2nd station plankton samples in summer), *L. papuana* (Autumn in 2nd station), *Lepadella patella* (Summer 2nd station, plankton samples, Autumn, 3rd station, plankton samples), *R. neptunia* (Summer, 3rd station, plankton samples), *T. tetractis* (Summer, 2nd station, plankton samples), *C. adriatica* (Spring, 4th station, plankton and interstitial) and *Speocyclops* sp. (Spring 2nd station, interstitial).

Species recorded only once at any time and station during the study period, *B. calyciflorus, L. flexilis, L. ludwigi, L. tenuiseta, Lepadella acuminata, L. (Heterolepadella) ehrenbergi, L. rhomboides, Ptygura* sp., *T. similis, Tripleuchlanis plicata, C. sphaericus, C. perplexa, D. bicuspidatus, E. acutifrons, L. brevicornis, N. kosswigi, P. viguieri*; twice recorded species were *B. urceolaris, C. iskenderunensis, L. curvicornis, L. pyriformis, S. longicaudum, I. sordidus* and *L. acanthocercoides*. While these species were not discovered in interstitial samples and were only recorded in plankton samples, *B. falcatus* and *Schizopera* sp. were only recorded in interstitial samples once (Table 4). The ecological aspects of these species have not been discussed because of their rarity. On the contrary, the species recorded more than twice in the plankton samples during the study were *C. colurus* (found 3 times), *C. uncinata* (4), *L. ovalis* (9), *Lophocharis salpina* (3), *T. patina* (3), *T. pocillum* (7), *P. aduncus* (3) which was never found in the interstitial samples (Table 4). Other species were recorded in plankton and interstitial samples according to different seasons and stations.

Identified species showed different distributions according to seasons throughout the year. *C. gibba, C. adriatica, E. dilatata, L. closterocerca, L. hamata, L. luna, Lepadella ovalis, T. pocillum,*

Table 3. Taxa in the study

Rotifera
Brachionidae
Brachionus calyciflorus (Pallas, 1766)
Brachionus falcatus (Zacharias, 1898)
Brachionus plicatilis (Müller, 1786)
Brachionus quadridentatus (Hermann, 1783)
Brachionus urceolaris (Müller, 1773)
Notommatidae
Cephalodella forficula (Ehrenberg, 1830)
Cephalodella gibba (Ehrenberg, 1830)
Eothinia elongata (Ehrenberg, 1832)
Cotylegaleatidae
Cotylegaleata iskenderunensis (De Smet and Bozkurt, 2016)
Dicranophoridae
Dicranophorus epicharis (Harring & Myers, 1928)
Epiphanidae
Epiphanes brachionus (Ehrenberg, 1837)
Euchlanidae
Euchlanis dilatata (Ehrenberg, 1832)
Tripleuchlanis plicata (Levander, 1894)
Lecanidae
Lecane bulla (Gosse, 1886)
Lecane closterocerca (Schmarda, 1859)
Lecane curvicornis (Murray, 1913)
Lecane flexilis (Gosse, 1886)
Lecane furcata (Murray, 1913)
Lecane hamata (Stokes. 1896)
Lecane ludwigi (Eckstein, 1893)
Lecane luna (Müller, 1776)
Lecane papuana (Murray, 1913)
Lecane pyriformis (Daday, 1905)
Lecane stenroosi (Meissner, 1908)
Lecane tenuiseta Harring, 1914
Lepadellidae
Lepadella acuminata (Ehrenberg, 1834)
Lepadella (Heterolepadella) ehrenbergi (Petry, 1850)
Lepadella ovalis (Müller, 1786)
Lepadella patella (Müller, 1773)
Lepadella rhomboides (Gosse, 1886)
Colurella adriatica Ehrenberg, 1831
Colurella colurus (Ehrenberg, 1830)
Colurella uncinata (Müller, 1773)
Mytilinidae
Lophocharis salpina (Ehrenberg, 1834)
Flosculariidae
Ptygura sp.
Philodinidae
Rotaria neptunia (Ehrenberg, 1830)
Scaridiidae
Scaridium longicaudum (Müller, 1786)
Testudinellidae
Testudinella patina (Hermann, 1783)
Trichocercidae
Trichocerca similis (Wierzeski, 1893)
Trichocerca taurocephala (Hauer, 1931)
Trichocerca weberi (Jennings, 1903)
Trichotriidae
Trichotria pocillum (Müller, 1776)
Trichotria tetractis (Ehrenberg, 1830)
Cladocera
Chydoridae
Coronatella rectangula (Sars, 1862)
Chydorus sphaericus (Müller, 1776)
Leydigia acanthocercoides (Fischer, 1854)
Pleuroxus aduncus (Jurine, 1820)
Ilyocryptidae
Ilyocryptus sordidus (Liévin, 1848)
Macrothricidae
Macrothrix laticornis (Jurine, 1820)
Copepoda
Cyclopidae
Diacyclops sp.
Diacyclops bicuspidatus (Claus, 1857)
Eucyclops serrulatus (Fischer, 1851)
Megacyclops viridis (Jurine, 1820)
Metacyclops grandispinifer (Lindberg, 1940)
Monchenkocyclops mehmetadami (Karaytuğ, Bozkurt and Sönmez, 2018)
Paracyclops fimbriatus (Fischer, 1853)
Speocyclops sp.
Canthocamptidae
Attheyella crassa (Sars, 1863)
Bryocamptus minutus (Claus, 1863)
Epactophanes richardi (Mrázek, 1893)
Mesochra aestuarii (Gurney, 1921)
Canuellidae
Canuella perplexa (Scott and Scott, 1893)
Ectinosomatidae
Ectinosoma sp.
Tachidiidae
Euterpina acutifrons (Dana, 1847)
Parastenocarididae
Kinnecaris xanthi (Bruno and Cottarelli, 2015)
Darcythompsoniidae
Leptocaris brevicornis (Van Douwe, 1904)
Ameiridae
Nitocrella kosswigi (Noodt, 1954)
Nitocrella stammeri (Chappuis, 1938)
Phyllognathopodidae
Phyllognathopus viguieri (Maupas, 1892)
Miraciidae
Schizopera sp.

Table 4. Plankton abundance

Sampling Time	Summer 2021					Fall 2021				
Stations	1	2		3		1	2		3	
Species	p	p	i	p	i	p	p	i	p	i
Rotifera										
Brachionus calyciflorus	–	–	–	*	–	–	–	–	–	–
Brachionus falcatus	–	–	–	–	–	–	–	–	–	*
Brachionus plicatilis	–	–	–	–	–	–	–	–	–	–
Brachionus quadridentatus	*	–	–	+++	++	–	–	–	–	–
Brachionus urceolaris	–	–	–	–	–	–	–	–	*	–
Cephalodella forficula	*	*	*	–	–	–	–	*	–	–
Cephalodella gibba	*	+	+	*	–	*	*	*	*	–
Colurella adriatica	*	*	–	–	–	*	*	–	–	–
Colurella colurus	–	*	–	–	–	*	–	–	–	–
Colurella uncinata	–	–	–	–	–	*	*	–	–	–
Cotylegaleata iskenderunensis	–	*	–	–	–	–	–	–	–	–
Dicranophorus epicharis	–	*	–	–	–	–	*	–	–	–
Eothinia elongata	–	–	–	*	*	–	–	–	*	+
Epiphanes brachionus	*	–	–	*	–	–	–	–	++	*
Euchlanis dilatata	*	*	–	+	*	–	–	–	*	–
Lecane bulla	+	+	+	++	++	++	++	+	*	+
Lecane closterocerca	++	++	–	++	+	–	+	–	–	*
Lecane curvicornis	–	–	–	–	–	–	–	–	–	–
Lecane flexilis	–	–	–	–	–	+	–	–	–	–
Lecane furcata	–	–	–	*	*	*	*	–	–	–
Lecane hamata	++	++	*	+++	+	++	+	–	+	*
Lecane ludwigi	–	–	–	–	–	*	–	–	–	–
Lecane luna	+	++	+	+	+	+	+	*	*	–
Lecane papuana	–	*	–	+	*	+	++	+	+	+
Lecane pyriformis	*	–	–	–	–	–	–	–	*	–
Lecane stenroosi	*	–	*	–	–	+	+	+	–	–
Lecane tenuiseta	–	–	–	–	–	–	–	–	*	–
Lepadella acuminata	–	–	–	–	–	–	–	–	–	–
Lepadella (Heterolepadella) ehrenbergi	–	–	–	–	–	*	–	–	–	–
Lepadella ovalis	*	*	–	–	–	*	*	–	–	–
Lepadella patella	+	++	*	+	–	–	*	–	++	*
Lepadella rhomboides	–	–	–	–	–	–	*	–	–	–
Lophocharis salpina	–	*	–	–	–	*	+	–	–	–
Ptygura sp.	–	–	–	–	–	–	–	–	–	–
Rotaria neptunia	+	–	–	++	+	–	–	–	–	–
Scaridium longicaudum	*	*	–	–	–	–	–	–	–	–
Testudinella patina	*	–	–	–	–	–	–	–	–	–
Trichocerca similis	–	–	–	–	–	*	–	–	–	–
Trichocerca taurocephala	–	*	*	–	–	–	–	–	–	–
Trichocerca weberi		*	*	*	–	+	*	*	–	–
Trichotria pocillum	*	+	–	–	–	*	+	–	–	–
Trichotria tetractis	*	++	*	–	–	*	+	*	–	–
Tripleuchlanis plicata	+	–	–	–	–	–	–	–	–	–
Total rotifer species	**19**	**21**	**10**	**15**	**10**	**20**	**18**	**7**	**12**	**8**

(p: Plankton. i: interstitial. -: Absent, *: very few (1-10 individuals in each petri), +: few (10-30 individuals in each petri), ++: abundant (30-60 individuals in each petri), +++: very abundant (more than 60 individuals in a petri))

Table 4. Plankton abundance (continued)

Sampling Time	**Summer 2021**					**Fall 2021**				
Stations	**1**	**2**		**3**		**1**	**2**		**3**	
Species	**p**	**p**	**i**	**p**	**i**	**p**	**p**	**i**	**p**	**i**
Cladocera										
Coronatella rectangula	*	*	*	–	*	–	–	–	–	–
Chydorus sphaericus	–	–	–	–	–	–	–	–	–	–
Ilyocryptus sordidus	–	*	–	–	–	–	*	–	–	–
Leydigia acanthocercoides	–	–	–	–	–	–	–	–	–	–
Macrothrix laticornis	*	*	–	+	+	–	*	–	*	–
Pleuroxus aduncus	–	–	–	–	–	–	–	–	–	–
Total cladoceran species	2	3	1	2	2	0	2	0	1	0
Copepoda										
Diacyclops sp.	–	–	–	–	–	–	–	–	–	–
Diacyclops bicuspidatus	–	–	–	–	–	–	–	–	–	–
Eucyclops serrulatus	–	–	*	–	*	–	–	–	–	–
Megacyclops viridis	–	–	–	*	*	–	–	–	–	–
Metacyclops grandispinifer	–	–	–	–	–	–	–	–	+	+
Monchenkocyclops mehmetadami	–	–	–	–	–	–	–	–	–	–
Paracyclops fimbriatus	–	–	–	–	*	–	–	–	–	*
Speocyclops sp.	–	–	*	–	–	–	–	*	–	–
Attheyella crassa	–	–	*	–	–	–	–	*	–	–
Bryocamptus minutus	–	–	*	–	–	–	–	–	–	–
Canuella perplexa	–	–	–	–	–	*	–	–	–	–
Ectinosoma sp.	–	–	*	–	–	–	–	*	–	–
Epactophanes richardi	–	–	*	–	–	–	–	–	–	–
Euterpina acutifrons	*	–	–	–	–	–	–	–	–	–
Kinnecaris xanthi	–	–	+	–	–	–	–	*	–	–
Leptocaris brevicornis	–	–	–	–	–	*	–	–	–	–
Mesochra aestuarii	–	*	*	–	–	–	–	–	–	–
Nitocrella kosswigi	–	–	–	–	–	–	–	–	–	–
Nitocrella stammeri	–	–	*	–	*	–	–	*	–	–
Phyllognathopus viguieri	–	–	–	–	–	–	–	–	–	–
Schizopera sp.	–	–	–	–	–	–	–	–	–	–
Total copepod species	**1**	**1**	**9**	**1**	**4**	**2**	**0**	**5**	**1**	**2**
Total zooplankton species	**22**	**25**	**20**	**18**	**16**	**22**	**20**	**12**	**14**	**10**

(p: Plankton. i: interstitial. -: Absent, *: very few (1-10 individuals in each petri), +: few (10-30 individuals in each petri), ++: abundant (30-60 individuals in each petri), +++: very abundant (more than 60 individuals in a petri))

Table 4. Plankton abundance (continued)

Sampling Time	Winter 2022								Spring 2022							
Stations	**1**	**2**		**3**		**4**		**5**	**1**	**2**		**3**		**4**		**5**
Species	**p**	**p**	**i**	**p**	**i**	**p**	**i**	**p**	**p**	**p**	**i**	**p**	**i**	**p**	**i**	**p**
Rotifera																
Brachionus calyciflorus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Brachionus falcatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Brachionus plicatilis	–	–	–	–	–	*	*	–	–	–	–	–	–	–	–	–
Brachionus quadridentatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Brachionus urceolaris	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
Cephalodella forficula	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cephalodella gibba	–	*	*	*	–	+	+	+	–	*	+	*	–	*	+	*
Colurella adriatica	–	*	–	–	–	–	+	+	+	+	–	+	–	++	++	+
Colurella colurus	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–
Colurella uncinata	–	–	–	–	–	–	–	–	*	*	–	–	–	–	–	–
Cotylogaleata iskenderunensis	–	–	–	–	–	–	–	–	*		–	–	–	–	–	–
Dicranophorus epicharis	–	–	–	–	–	–	–	–	*	*	+	–	–	–	–	–
Eothinia elongata	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Epiphanes brachionus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Euchlanis dilatata	*	–	–	–	–	–	–	*	*	*	–	–	–	–	–	+
Lecane bulla	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane closterocerca	–	–	–	–	–	*	–	–	*	+	*	*	–	+	+	–
Lecane curvicornis	–	–	–	–	–	–	–	*	–	–	–	*	–	–	–	–
Lecane flexilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane furcata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane hamata	–	–	–	–	–	–	*	–	–	–	–	–	–	+	–	–
Lecane ludwigi	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–
Lecane luna	–	–	–	–	–	*	–	–	+	+	*	–	–	*	–	–
Lecane papuana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane pyriformis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane stenroosi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*
Lecane tenuiseta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lepadella acuminata	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–
Lepadella (Heterolepadella) ehrenbergi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lepadella ovalis	–	–	–	–	–	–	–	*	*	+	–	–	–	+	–	*
Lepadella patella	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lepadella rhomboides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lophocharis salpina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ptygura sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rotaria neptunia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Testudinella patina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scaridium longicaudum	–	–	–	–	–	–	–	–	*	–	–	*	–	–	–	–
Trichocerca similis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Trichocerca taurocephala	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Trichocerca weberi	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–
Trichotria pocillum	*	–	–	–	–	–	–	–	+	*	–	–	–	–	–	–
Trichotria tetractis	–	–	–	–	–	–	–	–	+	+	*	–	–	–	*	–
Tripleuchlanis plicata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total rotifer species	**3**	**3**	**1**	**2**	**0**	**5**	**4**	**5**	**11**	**10**	**6**	**6**	**0**	**6**	**3**	**5**

(p: Plankton. i: interstitial. -: Absent, *: very few (1-10 individuals in each petri), +: few (10-30 individuals in each petri), ++: abundant (30-60 individuals in each petri), +++: very abundant (more than 60 individuals in a petri))

Table 4. Plankton abundance (continued)

Sampling Time	Winter 2022								Spring 2022							
Stations	**1**	**2**		**3**		**4**		**5**	**1**	**2**		**3**		**4**		**5**
Species	**p**	**p**	**i**	**p**	**i**	**p**	**i**	**p**	**p**	**p**	**i**	**p**	**i**	**p**	**i**	**p**
Cladocera																
Coronatella rectangula	+	*	–	–	–	–	–	–	+	+	*	–	–	–	–	*
Chydorus sphaericus	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–
Ilyocryptus sordidus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leydigia acanthocercoides	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	*
Macrothrix laticornis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pleuroxus aduncus	–	–	–	–	–	–	–	*	–	–	–	–	–	*	–	*
Total cladoceran species	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**1**	**1**	**0**	**0**	**2**	**0**	**3**
Copepoda																
Diacyclops sp.	–	–	–	–	–	*	*	–	–	–	–	–	–	–	–	–
Diacyclops bicuspidatus	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–
Eucyclops serrulatus	–	–	–	–	–	*	–	*	–	–	–	–	–	–	–	*
Megacyclops viridis	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–
Metacyclops grandispinifer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Monchenkocyclops mehmetadami	–	–	–	–	–	+	*	+	–	–	–	–	–	–	–	–
Paracyclops fimbriatus	–	–	–	–	–	–	–	*	–	–	–	*	*	+	*	*
Speocyclops sp.	–	–	–	–	–	–	–	*	–	–	++	*	*	–	–	*
Attheyella crassa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*
Bryocamptus minutus	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–
Canuella perplexa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ectinosoma sp.	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–
Epactophanes richardi	–	*	–	–	–	–	–	–	–	–	*	–	–	–	–	–
Euterpina acutifrons	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kinnecaris xanthi	–	–	–	–	–	–	*	–	–	*	+	–	*	–	–	–
Leptocaris brevicornis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mesochra aestuarii	–	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–
Nitocrella kosswigi	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–
Nitocrella stammeri	–	–	–	–	–	*	–	–	–	*	*	–	–	–	–	–
Phyllognathopus viguieri	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–
Schizopera sp.	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–
Total copepod species	**0**	**1**	**0**	**0**	**0**	**5**	**4**	**6**	**1**	**4**	**5**	**3**	**3**	**2**	**1**	**4**
Total zooplankton species	**4**	**5**	**1**	**2**	**0**	**10**	**8**	**13**	**13**	**15**	**12**	**9**	**3**	**10**	**4**	**12**

(p: Plankton. i: interstitial. -: Absent, *: very few (1-10 individuals in each petri), +: few (10-30 individuals in each petri), ++: abundant (30-60 individuals in each petri), +++: very abundant (more than 60 individuals in a petri))

P. fimbriatus, Speocyclops sp., *K. xanthi* and *N. stammeri* were recorded at different rates in 4 season. Species recorded in 3 seasons *C. forficula, C. colurus, E. elongata, L. patella* (summer, autumn, winter), *D. epicharis, L. stenroosi, T. weberi, T. tetractis, A. crassa, Ectinosoma* sp. (summer, autumn, spring), *C. rectangula, E. serrulatus, E. richardi* (Summer, winter, spring). Species recorded in 2 seasons *C. uncinata, E. brachionus, L. bulla, L. furcata, L. papuana, L. salpina, M. laticornis* (summer, autumn), *T. patina, M. aestuarii* (summer, spring), *P. aduncus* (winter, spring), *M. viridis* (summer, winter). *B. quadridentatus* and *R. neptunia* (summer) were recorded in only one season (Table 4).

The species showed differences in plankton and interstitial samples according to their presence. *B. quadridentatus* (2 times in plankton/once in interstitial), *C. forficula* (3/2), *C. gibba* (14/6), *Colurella adriatica* (12/2), *D. epicharis*, (4/1), *E. elongata* (3/2), *E. brachionus* (3/1), *E. dilatata* (9/1), *L. bulla* (6/4), *L. closterocerca* (9/4), *L. furcata* (3 /1), *L. hamata* (7/4), *L. luna* (10/4), *L. papuana* (5/3), *L. stenroosi* (4/2), *Lepadella patella* (6/2), *R. neptunia* (2/1)), *T. weberi* (4/3), *Trichotria tetractis* (6/4), *C. rectangula* (7/3), *M. laticornis* (5/1), *E. serrulatus* (3/2), *M. viridis* (2/1), *M. mehmetadami* (2/1), *M. aestuarii* (3/2) were recorded at different rates in both plankton and interstitial samples throughout the study but they were recorded more in plankton samples. *P. fimbriatus* (4/4) was recorded in equal numbers in plankton and interstitial samples, while *Speocyclops* sp. (3/4), *A. crassa* (1/2), *Ectinosoma* sp. (1/2), *E. richardi* (1/2), *K. xanthi* (1/5) and *N. stammeri* (2/4) were recorded more in interstitial samples (Table 4).

There was a significant positive correlation between the number of zooplankton species and temperature (R^2=0.56), conductivity (R^2=0.50), dissolved oxygen (R^2 = 0.80), and salinity (R^2=0.95) (Table 5). Similarly, a significant positive correlation was observed between the abundance of zooplankton and temperature (R^2=0.80), conductivity (R^2=0.61), dissolved oxygen (R^2=0.98), and salinity (R^2 =0.67) (Table 5).

Table 5. The relationships between zooplankton and water quality parameters

Parameter	Zooplankton species number	Zooplankton abundance
Salinity	R^2 = 0.95	R^2 = 0.67
Temp	R^2 = 0.56	R^2 = 0.80
Con	R^2 = 0.50	R^2 = 0.61
DO	R^2 = 0.80	R^2 = 0.98

Discussion

Salinity was found to be higher (3 ppt) only in the first station compared to the other stations because it was in contact with sea water. Accordingly, the relationship between salinity and the number of zooplankton species and zooplankton abundance was found to be significant. According to Gao et al. (2008), salinity affects the number of individual zooplankton species, which determines the total density of zooplankton. The biomass of zooplankton is largely determined by salinity. Similar to density, higher salt concentrations result in larger zooplankton biomass (Echaniz et al., 2012). Paturej and Gutkowska (2012) discovered a modest positive association between salinity and the number and biomass of zooplankton in the Vistula Lagoon.

Temperature influences the species diversity and density of zooplankton in aquatic ecosystems, which are among the most important environmental parameters controlled by temperature (Herzig, 1987; Sharma et al., 2007). Temperature increases the biological activity in the water, and by accelerating the biochemical reactions, it affects the reproduction, nutrition and metabolic activities of aquatic species (Taş et al., 2010). The abundance of zooplankton was affected by seasonal temperature changes (Rossetti et al., 2009). Water temperature varied between 11.2 °C and 32.4 °C and a positive significant relationship between temperature and zooplankton was observed. Similarly, Dorak (2013) recorded that environmental characteristics, particularly water temperature and nutrients, have a considerable impact on zooplankton composition and abundance, and that high zooplankton abundance is associated with high water temperature.

Conductivity was between 360 and 1646 µS cm^{-1}. Although the electrical conductivity in freshwater varies between 400 and 3000 µS cm^{-1}. High and low conductivity lakes have different zooplankton groups, and species diversity declines as conductivity rises (Tavsanoglu et al., 2015). The conductivity was found to be high in particular streams and during certain times of the year, while being close to the norms (400 µS cm^{-1} -first class waters). Conductivity is important water quality parameters that is significantly correlated with zooplankton abundance and distribution. Therefore, there was a positive correlation zooplankton diversity, abundance and conductivity (Karp-Boss et al., 1996). Determined water quality parameters, for animals in water are observed to be within the normal values.

The species identified in the study are those detected in various inland water studies (lentic and lotic) (Ustaoğlu et al., 1996; Göksu et al., 1997; Ustaoğlu et al., 1997; Saler and Şen, 2001; Bekleyen, 2003; Bozkurt, 2004; Akbulut and Yıldız, 2005; Altındağ et al., 2005; Kaya et al., 2007; İpek and Saler, 2008; Altındağ et al., 2009; Bozkurt and Güven, 2010; Bulut and Saler, 2014; Saler et al., 2015; Ergönül et al., 2015; Güher and Demir, 2018; Kaya and Altındağ, 2009; Jersabek and Bolortsetseg, 2010; İpek Alış and Saler, 2013; Güher and Çolak, 2016).

As in this study, it has been determined that rotifers are the most recorded group among all zooplankton in many studies conducted in rivers (Saunders and Lewis, 1988; Vasquez and Rey, 1989; Kim and Joo, 2000; Göksu et al., 1997; Bozkurt, 2004; Bozkurt and Güven, 2010; Bozkurt and Akın, 2012; Bulut and Saler, 2014). Ruttner-Kolisko (1974) reported that the embryonic development times of rotifer species shortened in parallel with the increase in ambient temperature, and accordingly, they multiplied rapidly in a very short time. The seasonal variation in the streams where this study was conducted showed similarities with other running waters where the zooplankton population is low in cold season and high in hot season (Saunders and Lewis 1988).

According to several studies (José de Paggi 1980; Saunders and Lewis 1988; Vasquez and Rey 1989), the volume and species variety of zooplankton in flowing water varies depending on the discharge regime, turbidity, water quality, and river upstream and downstream.

M. mehmetadami and *K. xanthi,* discovered in this study and recently added to the zooplankton fauna in inland waters of Turkey, were identified for the first time from interstitial samples from Turkey (Karaytuğ et al., 2018; Bruno and Cottarelli, 2015). *K. xanthi* was found for the second time in the Sarıseki stream and reeds (Bozkurt, 2017), and the third time in the well water in the Yayladağı district (Bozkurt, 2022). *N. kosswigi* and *N. stammeri,* which are rarely found in inland waters of Turkey, were found in the Dragon River (Bozkurt, 2017), additionally *N. stammeri* was found in the well waters of Yayladağ district (Bozkurt, 2022). *Speocyclops* found in this study was first record in well waters in Turkey by Bozkurt (2018). *E. richardi* was first found in Sarıseki Stream in Turkey (Bozkurt, 2017). *P. viguieri* was found in Turkey for the first time from Gölbaşı lake (Bozkurt, 2007), second time from Sarıseki stream (Bozkurt, 2017) and third time from Yayladağı well waters (Bozkurt, 2022). *L. brevicornis* was first reported from interstitial samples from Gölkent Lake in Turkey (Bozkurt, 2007).

If we look at the general ecological characteristics of the copepod species reported above; *L. brevicornis* lives in brackish areas of the marine littoral as well as saline and fresh inland waters (Borutsky, 1964). *E. richardi* is cosmopolitan, capable of cold stenothermic and parthenogenetic reproduction (Dole-Olivier et al., 2000), often found in semi-terrestrial habitats, wet moss, seepage and water sources (Rundle et al., 2000). *P. viguieri* is a cosmopolitan species, found in habitats ranging from the bottom sediments of lakes to compost piles, in the hyporheic zone of streams and in the seats of bromeliads. It is most common in semi-terrestrial moist soils, moss and decomposing organic matter (Glatzel and Konigshoff, 2005). *N. kosswigi* is a groundwater species and has been reported from wells and lakes in Turkey (Reid, 2001; Yağcı and Ustaoğlu, 2012). *N. stammeri* is a stygobitic species with generally limited distribution but widely distributed in coastal karst environments (fresh and anchialine waters, wells, caves). *Speocyclops,* a nearly pan-European genus, is a unique morphological, zoogeographical, and ecological unit. From the Pyrenees to the Western Caucasus, species of the genus live in the subterranean waters of the Alpine formation in South Europe. The genus *Metacyclops* is widespread in tropical and temperate regions, most of them have been recorded in different groundwater habitats, such as wells, caves, anchialine habitats (Pesce, 2015). *M. grandispinifer* is one of the 6 species of the genus found in Turkey (Bozkurt, 2021). It is the second report of the species after its first report (Lindberg, 1940) from Turkey.

According to Ceccherelli et al. (1982), *C. perplexa*, an epibenthic harpacticoid copepod, is found in brackish waters. Similarly, the cosmopolitan, coastal, neritic *E. acutifrons* are mainly coastal marine species, but are also common in brackish waters as they can tolerate a wide variety of salinity (Razouls et al., 2009). In a study, *C. perplexa* and *E. acutifrons* were found in the Kızılırmak river mouth (in brackish waters) (Deniz and Gönülol, 2014). In this study, *C. perplexa* and *E. acutifrons* were found only in station 1, which has brackish water characteristics due to the rising sea water from time to time. *Mesochra aestuarii* is characterized as euryhaline species (Remane and Schlieper, 1971) and is a brackish water species frequently seen in fresh water (Lang, 1948; Noodt, 1970; Kunz, 1971). It was reported for the first time in Turkey by Gündüz (1989) from the Bafra Fish Lake.

The genus Ectinosoma has not been reported from Turkish inland waters so far, but has been reported from marine water. A new record for Turkish inland waters, a species belonging to the genus *Ectinosoma,* was detected in station 2, where sea water could not reach.

In general, the species identified in this study were reported to be common and highly tolerant to environmental conditions in many lotic and lentic water studies conducted in Turkey (Bozkurt and Akın 2012; Bozkurt et al., 2018; Bozkurt and Güven 2010; Özdemir Mis et al., 2011; Gaygusuz and Dorak, 2013; Saler et al., 2015; Ustaoğlu, 2004; Ustaoğlu, 2015).

In this case, it can be postulated that the existence of the species in the study areas is closely related to the ecological characteristics and habitat preferences of the species.

Conclusion

The zooplankton fauna of the running water, which were mostly fed by groundwater, surface water and leachate water consists of 43 rotifer, 21 copepod and 6 cladoceran species. A total of 15 rotifer families, 3 cladoceran families and 10 copepod families were recorded. The number of zooplankton species and abundance had significant positive correlation with salinity and dissolved oxygen. *B. quadridentatus, C. adriatica, E. brachionus, L. bulla, L. closterocerca, L. hamata, Lepadella patella, R. neptunia, T. tetractis, Speocyclops* sp. were very abundant in different seasons and lothic systems, while cladocerans and copepod species were much less common in all streams and seasons. Most of the species recorded in this study are considered cosmopolitan.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

This paper was produced from master thesis of Figen Can and authors contributed equally to this paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

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

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Research Article

Çitören (Van, Türkiye) balıkçılık faaliyetlerinin iş sağlığı ve güvenliği açısından incelenmesi

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ÖZET

Balıkçılık faaliyetleri dünyada en tehlikeli meslek grupları içerisinde yer almaktadır. Son yıllarda Türkiye'de balıkçıların iş sağlığı ve güvenliği ile ilgili çalışmalarda bir artış söz konusudur. Bu çalışma Çitören'de balıkçılık faaliyetlerinin iş sağlığı ve güvenliği açısından değerlendirilmesi amacıyla Haziran 2021 - Ocak 2022 tarihleri arasında balıkçılarla yüz yüze anket uygulaması ile gerçekleştirilmiştir. Balıkçıların, avcılık faaliyetleri sırasında maruz kaldıkları riskler ve bu risklerin olası sonuçları hakkında bilgilerine başvurulmuş ve verilen cevaplara göre alınması gereken önlemelere karar verilmiştir. Mevcut çalışma Van Gölü Havzası için bir ilk olup bölgedeki sonraki çalışmalara bir referans olması ümit edilmektedir.

Anahtar Kelimeler
Balıkçılık faaliyetleri
Çitören
İş sağlığı ve güvenliği
Van Gölü Havzası

Investigation of fishing activities in Çitören (Van, Türkiye) for occupational health and safety

ABSTRACT

Fishing activities are among the most dangerous occupational groups in the world. In recent years, there has been an increase in studies on the occupational health and safety of fishermen in Turkey. This study was carried out with a face-to-face survey with fishermen between June 2021 and January 2022 in order to evaluate the fishing activities in Çitören in terms of occupational health and safety. The information of the fishermen about the risks they are exposed to during their fishing activities and the possible consequences of these risks was consulted and the precautions to be taken were decided according to the answers given. The present study is a first for the Van Lake Basin and is hoped to be a reference for future studies in the region.

Keywords
Fishing activities
Çitören
Occupational health and safety
Van Lake Basin

Giriş

Bir çalışma ortamında meydana gelen iş kazaları ve bunun doğal yansıması olan mesleki hastalıklar, oluşturdukları neticeler itibariyle ülkelerin kalkınmalarının önünde engel teşkil ettikleri için iş sağlığı ve güvenliği (İSG) konuları hem ülkemizde hem de dünyada üstünde durulan önemli konulardan biri haline gelmiştir. Meslek hastalıklarının ve iş kazalarının sonucu olarak işveren ve çalışanlar, birtakım sosyal ve ekonomik maliyetler ile yüz yüze kalmaktadır. Çalışanların maruz kalabileceği en acı olay kendilerinin veya çalışma arkadaşlarının hayatlarını kaybetmesidir. Bu can kayıpları dışında çalışan kişilerde görülen ortam koşullarından kaynaklı duygusal

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ve fiziksel sıkıntılar, gelir kaybı, işinden olma ihtimali, sigortasız çalışma gibi etkenler maruz kalabilecekleri belli başlı diğer kayıplardır. Bunların yanı sıra iş gücü kaybı, tazminat giderleri, makinaların zarar görmesi, tedavi masrafları, üretimin duraksaması, kalitenin düşmesi ve yasal yükümlülükler gibi ekonomik kayıplarla ilk önce iş sektörünün yöneticileri karşılaşmaktadır. Bu bilgilere ek olarak, işletmenin tanınırlığının zarar görmesi, müşteride oluşan memnuniyetsizlik, tecrübeli çalışanın kaybedilmesi sonucu yerine alınan kişinin eğitilmesi söz konusu maliyetler arasında düşünülmektedir (Sevinç ve ark, 2016).

İçinde yaşadığımız çağda, gerek dünyada gerekse ülkemizde, insanların çalışma hayatı her geçen gün zorlaşmakta, bu durum ise, kişiler üzerinde hem zihinsel hem de fiziksel olarak bir baskı oluşturmaktadır. Geçmişte olduğu gibi günümüzde de balıkçılık faaliyetleri birçok ülkede yüksek seviyede risk faktörleri içeren en tehlikeli meslek grubu olarak kabul edilmektedir. Sucul kaynakların avcılığı, çoğunlukla, sert deniz ve hava koşullarında yapılmaktadır. Bu durum ise oldukça fazla sayıda kaza ve bunun doğal sonucu olan yaralanmalara sebebiyet vermektedir (Kaplan ve Kite-Powell, 2000). Denizde balıkçılık faaliyetinde bulunan kişi veya kişiler hastalık, kaza ve yaralanma gibi olaylar ile yüz yüze kaldıkları durumlarda karadaki insanlar gibi sağlık hizmeti alamamakta ve karaya çıkartılana kadar teknedeki diğer insanların yardımına ihtiyaç duymaktadır. Ayrıca, balıkçılar aylık maaşları olmayıp yakaladıkları avdan pay verilmesi esasına göre geçimlerini sağlayan kişilerdir. Söz konusu durum maddi açıdan belli avantajlar oluştururken sert deniz ve hava koşullarında bile denizde kalmak istemeleri, çalışma saatlerinin uzaması sonucunda yorulmaları, balıkçıların daha fazla risk ile burun buruna gelmelerine neden olmaktadır Yukarıda da vurguladığımız gibi, bahsedilen nedenlerden dolayı balıkçılık faaliyetleri yüksek seviyede risk faktörleri içeren en tehlikeli meslek grubu olarak düşünülmektedir (Soykan, 2018).

Van İli'nde en yoğun balıkçılık faaliyetlerinin yapıldığı yerlerden biri olan Çitören'deki balıkçılara yönelik iş sağlığı ve güvenliği ile ilgili bir çalışma daha önce gerçekleştirilmemiştir. Bu çalışmada adı geçen yerde balıkçı teknelerinde çalışanların balıkçılık faaliyetleri sırasında ne türlü tehlikelere maruz kalabileceği ve bu tehlikelerin nasıl riskler doğuracağının ortaya çıkarılması amaçlanmıştır.

Materyal ve Yöntem

Van il merkezine 15 km uzakta yer alan Çitören'de bir adet balıkçılık kıyı yapısı yer almaktadır. Bu çalışma Çitören balıkçılık kıyı yapısındaki (Şekil 1, Şekil 2) balıkçıların, avcılık faaliyetleri sırasında İSG açısından ne türlü tehlikelere maruz kalabileceklerinin ve bu tehlikelerin olası sonuçlarının ortaya çıkarılması amacıyla gerçekleştirilmiştir. Araştırma evrenini 10 tane teknede çalışan balıkçılar oluşturmaktadır. Söz konusu balıkçılara Haziran 2021-Ocak 2022 tarihleri arasında yüz yüze anket çalışması yoluyla 30 tane soru yöneltilmiştir.

Şekil 1. Çitören, Van
Figure 1. Çitören, Van province

Şekil 2. Çitören balıkçılık kıyı yapısı (Fotoğraf: Adem Sezai Bozaoğlu)
Figure 2. Çitören fishing coastal structure (Photograph: Adem Sezai Bozaoğlu)

Çitören'deki balıkçılık faaliyetlerinin risk analizini çıkarmak için sahada pratik ve tüm sektörlere uygulanabilirliğinin kolay olması nedeniyle, sebep-sonuç ilişkisinin analiz edilmesinde tercih edilen *"L Tipi Matris"* metodu kullanılmıştır (Özkılıç, 2005). Bu yöntemde bir riskin/tehlikeli olayın gerçekleşme ihtimali (Tablo 1) ve bu riskin/tehlikeli olayın gerçekleştiği takdirde şiddeti (Tablo 2) 1'den 5'e kadar sayısal değerler alır. Sonrasında riskin/tehlikeli olayın gerçekleşme ihtimali ile bu ihtimalin şiddet derecesinin çarpımından risk skoru elde edilir (Tablo 3). Böylelikle, yapılacak eylemlere (kontrol önlemlerine) karar verilir.

Bu çalışmada *"L Tipi Matris"* yöntemi ile risk değerlendirilmesinde kullanılmak üzere kapsamlı bir risk değerlendirme tablosu oluşturulmuştur. Örnek tablo kişisel gözlem ve deneyimler, Tantanoğlu (2016) ve Soykan (2018) baz alınarak hazırlanmıştır.

Tablo 1. Riskin gerçekleşme ihtimali
Table 1. Realization probability of the risk

İhtimal	Riskin Gerçekleştirme Sıklığı
Çok küçük (1)	Hemen hemen hiç
Küçük (2)	Çok az (yılda bir kez)
Orta (3)	Az (yılda birkaç kez)
Yüksek (4)	Sık (Ayda bir)
Çok Yüksek (5)	Çok sık (haftada bir / hergün)

Tablo 2. Riskin gerçekleştiği takdirde şiddeti
Table 2. Severity of the risk, if realized

Şiddet	Olası Sonuç
Çok hafif (1)	İş saati kaybı yok, ilk yardım gerektiren durum
Hafif (2)	İş günü kaybı yok, kalıcı etkisi olmayan ve ayakta tedavi gerektiren durum
Orta (3)	Hafif yaralanmaya sebebiyet veren, yatarak tedavi gerektiren durum
Ciddi (4)	Ciddi yaralanmaya sebebiyet veren, uzun süreli tedavi gerektiren durum, meslek hastalığı
Çok Ciddi (5)	Ölüme veya görememezliğe sebebiyet veren durum

Bu tabloda (Tablo 4) 30 tane risk ve risklerin olası sonuçları belirtilmiştir. Araştırmada, balıkçılara; a) bu risklere ve risklerin olası sonuçlarına karşı mevcut koruma önlemlerinin ne olup olmadığı; b) sonrasında bu risklerin gerçekleşme ihtimali ve eğer bu riskler ile yüzyüze gelinirse şiddeti sorulmuş ve c) böylelikle risk skoru oluşturularak mevcut koruma önlemlerinin yeterli olup olmadığına, d) yeterli olsa bile alınması gereken ek önleme (eyleme) karar verilmiştir.

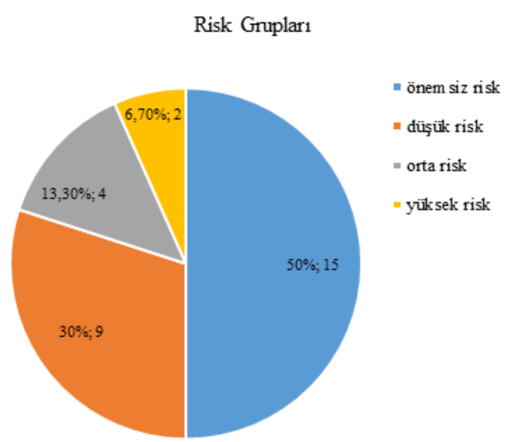
Bulgular ve Tartışma

Mevcut araştırma için Çitören balıkçılık kıyı yapısı'nda 30 tane balıkçı ile yüz yüze görüşülmüş ve balıkçıların verdiği cevaplar neticesinde Tablo 4'e ait sonuçlar bulunmuştur. Riskin olma ihtimali ve şiddeti balıkçıların verdiği sayısal değerlerin ortalamasıdır.

Tablo 3. Risk skoruna göre yapılacak eyleme karar verilmesi
Table 3. Deciding the action to be taken according to the risk score

Risk skoru	Anlam	Eylem
1	Önemsiz riskler	Belirlenen riskleri ortadan kaldırmak için önlem almaya gerek yoktur.
2-3-4-5-6	Düşük riskler	Belirlenen risklerin ortadan kaldırılması için ek önlemlere ihtiyaç duyulmamaktadır. Mevcut önlemlerin sürdürülmesi ve sürdürüldüğünün denetlenmesi gerekmektedir.
8-9-10-12	Orta riskler	Belirlenen riskleri düşürmek için acil olmamakla birlikte önlemler alınması gerekmektedir.
15-16-20	Yüksek riskler	Çalışma risk azaltılmadan başlatılmamalıdır. Riskin azaltılması için dikkate değer kaynak ayrılması gerekebilir. İşin bu riske rağmen devam etmesi gerekiyorsa acil önlemler alınmalıdır.
25	Katlanılmaz riskler	Belirlenen risk kabul edilebilir seviyeye düşünceye kadar iş başlatılmaz. Devam eden faaliyetler durdurulur.

Balıkçılarla yapılan anket sonucunda, 30 tane risk'in 15 tanesinin önemsiz risk (%50), 9 tanesinin düşük risk (%30), 4 tanesinin orta risk (%13,3) ve 2 tanesinin ise yüksek risk (%6,7) grubunda olduğu görülmüştür (Şekil 3).



Şekil 3. Risk gruplarının oransal dağılımı
Figure 3. Proportional distribution of risk groups

Bu çalışmada, "Balıkçıların ISG ile ilgili herhangi bir eğitim almamış olmaları" ve "Düzensiz ve uzun çalışma sürelerinden kaynaklanan yorgunluk" yüksek risk grubu içindedir. Bu noktadan hareketle, FAO (2001) ve Roberts (2004) yorgunluğun denizel ortamda kazaları etkileyen ana etkenlerden biri olduğunun altını çizmişlerdir. Ayrıca, Asyalı ve Kızkapan (2012) balıkçıların aşırı çalışma ve bunun sonucuda oluşan yorgunluk nedeniyle

Tablo 4. Çitören balıkçılık kıyı yapısındaki balıkçılık faaliyetlerinin risk analizinin sonuçları
Table 4. Risk analysis results of fishing activities in Çitören fishing coastal structure

Risk/Tehlikeli Olay	Olası Sonuç	Mevcut Koruma Önlemleri	Risk Seviyesi			Ek Koruma Önlemleri
			Riskin Olma İhtimali	Riskin Şiddeti	Risk Skoru	
1) Tekne ile açılmadan önce hava durumuna bakılmaması	Teknenin batması, can kaybı	Hava durumu düzenli olarak kontrol edilmekte	1	5	5	Mevcut koruma önlemi yeterli
2) Öngörülemeyen hava koşullarının oluşması	Teknenin batması, can kaybı	Tekneler balıkçı barınağına geri dönmekte	1	5	5	Mevcut koruma önlemi yeterli
3) Tekneye biniş ve iniş esnasında iskele kullanılmaması	Denize düşme, yaralanma	İskele sürekli kullanılmakta	1	3	3	Mevcut koruma önlemi yeterli
4) Teknelerin yanlarında usturmaça bulunmayışı	Teknelerin birbirine sürtünmesi sonucu oluşan zarar / maddi kayıp	Usturmaça var, ama sayısı yetersiz	2	3	6	Usturmaça sayısı arttırılmalı
5) Güvertede çalışma alanının düzenli olmayışı	Düşme olayları sonucu meydana gelen yaralanmalar, can kaybı	Çalışma alanı düzenli tutulmakta	1	4	4	Mevcut koruma önlemi yeterli
6) Güverteden sarkarak çalışma	Denize düşme, can kaybı	Sarkarak çalışılmamakta	1	4	4	Mevcut koruma önlemi yeterli
7) Güvertede ağın düzenli şekilde istiflenmemesi	Takılıp düşme sonucu yaralanma	Ağ düzenli şekilde sürekli istiflenmekte	1	3	3	Mevcut koruma önlemi yeterli
8) Balıkçıların tecrübesizliği	Yaralanmalar, iş verimini düşmesi	Yeni işe başlayan balıkçı bilgilendirilmekte	3	3	9	Bu bilgilendirilme uzman kuruluşlarca yapılmalı
9) Islak ve soğuk koşullarda çalışma	Çalışanların üşümesi, iş veriminin düşmesi	Balıkçılar içlik ve tulum giymekte	1	1	1	Mevcut koruma önlemi yeterli
10) Dümenin başıboş bırakılması	Teknenin batması, can kaybı	Kaptan olan kişi dümenin başında her zaman bulunmakta	1	1	1	Mevcut koruma önlemi yeterli
11) Denize düşme	Boğulma sonucu can kaybı	Tüm balıkçılar yüzme bilmekte	1	1	1	Mevcut koruma önlemi yeterli
12) Gürültü	Talimatları duymama	Gerektiğinde işaret dili ile kullanılmakta	1	3	3	Mevcut koruma önlemi yeterli
13) Avın/av araçlarının taşınması sonucu oluşan rahatsızlıklar	Sırt ve bel bölgesinde incinmeler, ellerde yaralanmalar	Balıkçılar birbirine yardım etmekte	4	2	8	Mevcut koruma önlemi yeterli
14) Güvertenin kaygan oluşu	Düşme olayları sonucu meydana gelen yaralanmalar	Balıkçılar tabanı kaymayan çizme giymekte	1	1	1	Mevcut koruma önlemi yeterli
15) Düzensiz ve uzun çalışma sürelerinden kaynaklanan yorgunluk	Yaralanmalar, iş verimini düşmesi	Mevcut koruma önlemi söz konusu değil	5	4	20	Balıkçılar vardiyalı çalışmalı
16) Ağ atılırken ağa dolanma	Denize düşme, can kaybı	Ağ, tecrübeli kişiler tarafından denize atılmaktadır	1	1	1	Mevcut koruma önlemi yeterli
17) Yangın	Teknenin batması, can kaybı	Böyle bir durum hiç yaşanmamış	1	1	1	Teknelerde yangın söndürücüler bulundurulmalı
18) Yeterli sayıda can kurtarma ekipmanının olmayışı	Can kaybı	Yeterli sayıda can kurtarma ekipmanı var ve görülebilecek bir yere konulmuştur	1	1	1	Mevcut koruma önlemi yeterli
19) Balıkçıların yüzme bilmemesi	Boğulma sonucu can kaybı	Tüm balıkçılar yüzme bilmektedir	1	1	1	Mevcut koruma önlemi yeterli
20) Çöp kutularının olmaması/ kontrol edilmemesi	Çevresel problemler, bulaşıcı hastalık riski, hijyenik sorunlar	Çöp kutuları var ve kıyıya her dönüşte boşaltılmaktadır	1	1	1	Mevcut koruma önlemi yeterli
21) Tekne mutfağında hijyen eksikliği	Besin zehirlenmesi	Gıda maddeleri ve mutfak düzenli olarak temizlenmektedir	1	1	1	Mevcut koruma önlemi yeterli
22) WC gibi ortak kullanım alanlarında hijyen eksikliği	Hijyenik sorunlar	Ortak kullanım alanları hergün temizlenmektedir	1	1	1	Mevcut koruma önlemi yeterli
23) Rafların sabitlenmemiş olması	Devrilme sonucu yaralanma	Raflar sabitlenmiştir	1	1	1	Mevcut koruma önlemi yeterli
24) Tatlısu gereksinimi ile ilgili sorunlar	Bulaşıcı hastalık riski, hijyenik sorunlar	Tatlısu gereksinimi ile ilgili herhangi bir sorun bulunmamaktadır	1	1	1	Mevcut koruma önlemi yeterli
25) Teknede ilkyardım dolabının olmayışı	Yaralanma	İlk yardım yönetmeliğine göre ilk yardım dolabı var	1	1	1	Mevcut koruma önlemi yeterli
26) Balıkçılar arasında ilk yardım eğitimi eksikliği	Yaralanma	Balıkçılar ihtiyaçları ölçüsündeki bilgiye sahipler	2	2	4	Mevcut koruma önlemi yeterli
27) Balıkçıların ISG eğitimlerini almamış olması	Yaralanma, can kaybı, meslek hastalığına yakalanma, maddi hasar	ISG ile ilgili bir bilgilendirme yok	5	4	20	En kısa zamanda balıkçılara İSG ile ilgili eğitimler verilmeli
28) Tekne tam olarak iskeleye yanaşmadan karaya çıkmaya çalışmak	Denize düşme, yaralanma	Mevcut koruma önlemi yok	5	2	10	Tekne limana bağlanmadan ve motorlar kapatılmadan karaya çıkılmamalı
29) Teknenin iskeleye bağlanması durumunda yetersiz haberleşme	Denize düşme, yaralanma	İletişimin uzman ve tek bir kişi tarafından yapıldığı ifade edilmektedir	1	1	1	Mevcut koruma önlemi yeterli
30) Elektrik kaçağı	Elektrik çarpması sonucu yaralanmalar, can kaybı, Yangın	Prizlerin sağlam olduğu ifade edilmektedir	2	5	10	Belli aralıklarla prizlerin kontrolleri yapılmalı

denizel ortamlarda kaza riskinin yükseldiğini ifade etmişlerdir. Bununla birlikte, Doğanyılmaz Özbilgin ve Tok (2017) uzun çalışma saatlerinin neden olduğu yorgunluktan dolayı yakılan sigaraların söndürülmeden uyumanın sonucu olarak teknede yangına sebebiyet verdiğini vurgulamışlardır. Son olarak, Mermer ve ark. (2022) balıkçılık sektörünün İSG hizmetlerinden yeterince yararlanamadığını, balıkçılar arasında iş güvenliği bilincinin oluşturulmasın önemli olduğunu, balıkçıların bu faaliyetler hakkında bilinçlendirilmesinin daha güvenli çalışma koşullarının oluşumuna katkı sağlayacağını belirtmişlerdir.

Sonuç

Ülkemizde de en tehlikeli iş kolları içerisinde yer alan balıkçılık faaliyetlerinde İSG ile ilgili farkındalığı artırmak amacıyla hem üniversitelerin hem de devletin ilgili kurumlarının ulusal çapta projeler gerçekleştirmesi her geçen gün önem kazanmaktadır. Bunun için, risk değerlendirmesi bölge bölge balıkçılık faaliyetlerinde bulunan tüm teknelere yapılmalı ve konuyla ilgili balıkçılar bilgilendirilmelidir. Balıkçıların sürekli yüze yüze kaldıkları iş kazalarının ve meslek hastalıklarının engellenmesi tüm paydaşların içinde olduğu bir sorumluluk gerektirir.

Teşekkür

Yazarlar yardımlarından dolayı İsmail Bulova'ya teşekkür eder.

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Short Com.

Occurrence of *Plotosus lineatus* (Thunberg, 1787) from the northeastern Mediterranean coast of Turkey

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ABSTRACT

A single specimen of striped eel catfish *Plotosus lineatus* (Thunberg, 1787) has been captured in August 2022 from Mersin Bay, at 3 m depth. This study reveals a new locality record from Turkish waters and the occurrence from the northeastern Mediterranean coast of Turkey. This species has been formed in this region, indicating that its trend has the potential to spread westward along the northern side of the coast of Turkey. Besides, this species is also the successive alien plotosid recorded from the Mediterranean marine waters of Turkey. All measurements and counts as well as color descriptions of *P. lineatus* agree with previous descriptions.

Keywords
Striped eel catfish
Non-indigenous species
Venomous
Expansion
Mediterranean Sea

Introduction

Since the opening of the Suez Canal in 1869, it has provided a significant and suitable pathway for the invasion of many alien species that penetrated the Mediterranean. To date, more than 600 invasive species, among them 104 fish species, have spread into the Mediterranean, establishing populations in their new habitat (Golani et al., 2020).

The striped eel fish *Plotosus lineatus* (Thunberg, 1787), belongs to the family Plotosidae that consists of 10 genera and 42 valid species (Nelson, 1994), is an inshore benthic fish species with an original distribution range of 1 to 60 m. It dwells in sandy and rocky substrate sheltered reef areas (Taylor and Gomon, 1986; Myers, 1999). Adult specimens are solitary or occur in smaller groups; on the other hand, juvenile specimens are dense ball-shaped schools that are found in coral reefs, usually in a hide under ledges during the day (Kuitar and Tonozuka, 2001), and estuary areas and tide pools (Froese and Pauly, 2022). It feeds on commonly benthic invertebrates, crustaceans, and small fish (Golani et al., 2021; Froese and Pauly, 2022). It reaches sexual maturity within 1-3 years, at a maturity length of 140 mm (Thresher, 1984). Its eggs are demersal and larvae planktonic. Adults are known to hide under cavities and ledges during the day.

P. lineatus is distributed from the Red Sea and east Africa to Japan, including Australia, and also Palau and Yap in Micronesia (Myers, 1991). It sometimes enters the freshwaters of East Africa (Lake Malawi) and Madagascar (Taylor and Gomon, 1986).

P. lineatus was previously known only from the Red Sea (Goren and Dor, 1994). This species was later recorded from Mediterranean waters (Golani, 2002; Golani et al., 2020). According to Golani (2002), *P. lineatus* was entered through Suez Canal into the Mediterranean Sea and it is recorded second alien catfish after *Arius parki* in the Mediterranean waters.

In the Mediterranean Sea, the first record of *P. lineatus* was reported by Golani (2002) and subsequently, then several specimens were collected from the Israel coasts by Golani et al. (2021) from Israel (Tel Aviv). Later, the species was recorded

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from Lebanon Bitar (2013), Egypt (Temraz and Ben Souissi, 2013), Syria (Ali et al., 2015), and Tunisia (Ounifi-Ben Amor et al., 2016). In Turkish marine waters, *P. lineatus* was firstly reported from Iskenderun Bay (northeastern Mediterranean) by Doğdu et al. (2016).

This paper, presents a second captured record as the range expansion of *P. lineatus* in Turkish marine waters. Besides, the current specimen represents a new locality record from Mersin Bay (northeastern Mediterranean), Turkey. In addition, this study elucidated that *P. lineatus* was the first plotosid species successively recorded from the Mediterranean coasts of Turkey.

Materials and Methods

A single specimen of *P. lineatus* was caught by a fishing rod at a depth of 3 m from Arpacbahsis coast, Mersin Bay (Coordinate: 36° 38' N, 34° 21'E) on 13 August 2022 (Figure 1). The morphometric measurements of the samples were taken using a digital caliper to the nearest 0.01 mm and weighed to the nearest 0.1 g for the total body.

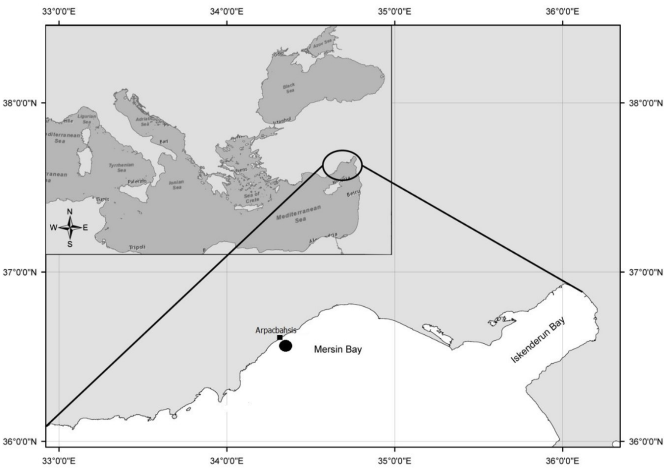

Figure 1. Map showing the capture site (●) of *P. lineatus* in the Mersin Bay (N.E. Mediterranean)

The description of the present specimen agrees with the description given by Golani (2002) and Ali et al. (2015). The specimen was stored in a deep-freezer and was deposited in the Museum of the Faculty of Marine Sciences and Technology, Iskenderun Technical University (Figure 2), (MSM-PIS/2022-1).

Results

The specimen had a total length (TL) of 127.8 mm and a weight of 11.905 g. The diagnostic features of the specimen were as follows: First dorsal fin rays I +4, Second dorsal fin rays 83, anal fin rays 66, pectoral fin rays I+ 10.

The body depth is 14.01% of TL; head length is 20.98% of TL; eye vertical diameter is 1.53% of head length; eye horizontal diameter is 1.98% of head length; pre-dorsal length is 24.52% of of TL; pre-pectoral length is 17.88% of TL; pre-pelvic length is 34.18% of TL; pre-anal length is 44.50% of TL; dorsal fin ray is 12.59% of TL; pectoral fin ray is 12.35% of TL; pelvic

Figure 2. The specimen of striped eel catfish *P. lineatus* (Thunberg, 1787), captured from Mersin Bay (Arpacbahsis), Turkey

fin ray is 8.84% of TL; anal fin ray is 57.62% of TL; first dorsal fin spine length is 6.87% of TL and pectoral fin spine length is 6.06% of TL. Its body is elongated, and smooth without scales. The head is large and broad. The eye is moderately large. Four pairs of barbels (one nasal and one maxillary barbel) extend slightly beyond the posterior borders of the eye. The dorsal and anal fins are continuous with the caudal fin. The distribution of the *P. lineatus* previous and present capture records in the Mediterranean Sea was given in Table 1.

The color of the fresh specimen was the body brown with two narrow white stripes. The second dorsal fin and anal fins are paler than the rest of the body with a black margin. The ventral side of the body was whitish and light brownish. All measurements and counts as well as color descriptions of *P. lineatus* agree with Golani (2002), Ali et al. (2015), and Doğdu et al. (2016).

Discussion

The present range expansion record represents the second observation of *P. lineatus* in the Mediterranean coasts of Turkish marine waters. The main reason why non-indigenous alien species are increasing their entry into the Mediterranean and expanding their range is considered to be the increase in water temperature caused by global warming (Turan et al., 2016).

Today, many invasive alien species entering the Mediterranean cause damage to some important marine habitats and community structures (Turan et al., 2018), it is likely that they will affect the food webs in the future, resulting in drastic changes in Mediterranean biodiversity (Arndt et al., 2018).

P. lineatus is a non-commercial venomous species. The venomous serrated spine at the beginning of the first dorsal and each pectoral fin is dangerous and causes painful and in rare cases even fatal injuries (Myers, 1991). It is also known that this species is opportunistic, possibly one of the top predators, and is able to adapt to different new ecological habitats. *P. lineatus*

Table 2. Collected records of *Plotosus lineatus* from the Mediterranean Sea covering the period 2002-2022

References	Number of Samples	Record Date	Location/Country	Sampling Gear	Depth (m)	Total Length (mm)
Golani (2002)	17	11.11.2001	Ashod and Ashqelon (Mediterranean Sea), Israel	Trawl	20	152-177
Temraz and Ben Souissi (2013)	7	10.2012	offshore Damietta coast, Egypt	Trawl	-	112-137
Rizkalla and Akel (2015)	28	09.2014	El Arish, Egypt	Trawl	51-67	80-100
	3	09.2014	Balteem, Egypt	Trawl	21	80-100
Ali et al. (2015)	2	29.10.2014	Tartus, Syria	Spear gun	3	174-181
Doğdu et al. (2016)	3	04.04.2016	Cevlik, Iskenderun Bay, Turkey	Spear gun	20	216-245
Ali et al. (2017)	4	14.05.2015	off Latakia, Syria	Bottom cage net-Beach seine	20	156.8-186.2
Present study	**1**	**13.08.2022**	**Arpacbahsis, Mersin Bay, Turkey**	**Fishing rod**	**3**	**127.8**

was also listed among the 100 worst invasive species to enter the Mediterranean by Streftaris and Zenetos (2006).

In this study, *P. lineatus* was sampled at night by scale fishermen. Although the presence of only one specimen of *P. lineatus* was reported in the study, according to the information given by the fisherman, it was stated that this species was seen many times in the region (Personal comm.). Similarly, Turan et al. (2022) reported one group of the striped eel cat fish *P. lineatus* was underwater observed from Kızkalesi and Bogsak region in the Mersin Bay. Edelist et al. (2012) stated that this species may rapidly become a dominant component of the benthic habitat. Besides, the present observation of this species strongly suggests that it has been established in the northeastern Mediterranean and could be a threat to local biodiversity by expanding its range over time.

Conclusion

In the present paper, we report the occurrence of *P. lineatus* from the Mediterranean coasts of Turkey and the new locality record from Mersin Bay. The distribution trend in this area indicates that this species may have the potential for spread along the Mediterranean and Aegean Sea coast of Turkey in the near future. Thus, further monitoring studies are needed for non-indigenous alien species and spreading in the Mediterranean.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

Authors contributed equally to this paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

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

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Research Article

Symbiotic effect of *Bacillus clausii* and Galacto-oligosaccharide on growth and survival rates in red cherry shrimp (*Neocaridina davidi*)

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ABSTRACT

The effect of probiotics (*Bacillus clausii*, commercial probiotics: Enterogermina) and prebiotics (Galactooligosaccharides, GOS) on the growth of red cherry shrimp (*Neocaridina davidi*) has been investigated for 30 days. The trial was conducted with 270 red cherry shrimps (initial weight: 0.24±0.03 g) in 27 plastic tanks (volume 0.01 m³ and area of 0.05 m²) representing 9 groups. Except for the control group, diets were supplemented with either GOS or synbiotics per kg of feed as G1 (1g GOS), G2 (2g GOS), G3 (3g GOS), G4 (4g GOS), G1P (1g GOS+ 1 ml probiotic), G2P (2 g GOS+ 1 ml probiotic), G3P (3 g GOS+ 1 ml probiotic) and G4P (4 g GOS+ 1 ml probiotic). This study showed significantly ($P<0.05$) higher growth rate indices of male and female shrimps fed with feed additives groups compared to the control group. The highest final body weight (FBW), weight gain (WG), and specific growth rate (SGR) in male shrimps were recorded from the 2 g GOS+ 1 ml probiotic and 3 g GOS+ 1 ml probiotic groups. Similarly, the highest FBW, WG and SGR in the female shrimps were found in the G1P and G2P synbiotic groups. Conversely, the lowest FBW, WG and SGR of both the female and male groups were noted in the control groups. Regarding feed conversion ratio (FCR) and survival rates of both female and male shrimps, G2P and G3P groups showed significant improvements. Our study's findings stated that 2 g GOS and 1 ml of *Bacillus clausii* (commercial probiotic: Enterogermina) dietary synbiotics can be used to improve red cherry shrimp growth rates.

Introduction

The production of crustaceans in aquaculture has increased from 7 million tons, which is about 36 billion US dollars in 2014 (FAO, 2016), to 11.3 million tons, which is estimated at 81.5 billion US dollars in 2020 (FAO, 2022). This dramatic increase, which is expected to continue growing, is not just for human consumption as crustaceans are grown for other reasons, one of which is aquarium sector (Sganga et al., 2019). The cultivation of ornamental crustaceans is an established industry that provides huge economic incentives to both small and large-scale farmers and traders. This is because crustaceans have a variety of beautiful and bright colors that have become attractive for many aquarium hobbyists (Amaya and Nickell, 2015). Red cherry shrimp (*N. davidi*) is one of the commonly used ornamental crustaceans. The species is a native of far east Asian countries such as China, Taiwan, Korea, Vietnam, and Japan, and is a member of the family Atyidae, a cosmopolitan shrimp family readily available in tropical, subtropical, and temperate regions (Yixiong, 1996). *N. davidi* can be easily kept in captivity, survive on less or minimal feeding, and can tolerate varying temperatures and higher stock densities (Pantaleão et al., 2015). Red cherry shrimp have also a short life cycle and a very good reproduction pattern producing several spawns with the same brood quality (Sganga et al., 2018).

Currently, research focuses on improving both the quantity and quality of aquaculture feeds using functional feed additives and immunostimulants. Especially the feeds formulated for crustaceans, which, unlike fish, are known to be unable to develop acquired immunity and therefore their innate immunity should constantly be stimulated with immunostimulants (Kaya et al., 2020). In addition, feeds supplemented with such feed additives improve growth, reproduction, egg quality, and shrimp welfare (Shehata et al., 2022). Some of the functional feed additives used in aquaculture are probiotics and

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prebiotics, both of which are applied in this study. Probiotics are beneficial microorganisms composed mainly of bacteria and yeast that can modulate the digestive systems of the farmed aquatic animal; prebiotics are indigestible fibres that support the growth and proliferation of probiotics. (Quigley, 2019). Among the frequently used prebiotics in aquaculture are mannan oligosaccharides (MOS), fructooligosaccharides (FOS, and galactooligosaccharides (GOS). In particular, GOS obtained from the enzymatic conversion of lactose has received significant research focus due to its various benefits (Ringø et al., 2010). Bacillus clausii has been evaluated one of the potential probiotics because of its antagonistic activity against fish pathogens (Yang et al., 2012) and it has been reported that this probiotic has a synergistic effect with prebiotics (Ye et al., 2011).

In aquaculture, both probiotics and prebiotics are used to improve aquatic animal growth, feed utilization, tissue histomorphology, disease resistance, immune response, and animal welfare. In crustaceans, prebiotics have been reported to modulate digestive enzymes, improve digestibility, growth performance, feed efficiency, enhance survival, and resistance to pathogens, and improve intestinal bacterial load and water quality of different shrimp species; whiteleg shrimp (*Litopenaeus vannamei*) (Luis-Villasenor et al., 2013; Nimrat et al., 2021; Mirbakhsh et al., 2022), giant tiger shrimp (*Penaeus monodon*) (Karthik et al., 2014; Kolanchinathan et al., 2022), giant freshwater prawn (*Macrobrachium rosenbergii*) (Mohamad et al., 2020), and fleshy prawn (*Fenneropenaeus chinensis*) (Chai et al., 2016). Similarly, many authors have also shown the beneficial effect of GOS on different shrimp (Huynh et al., 2018; Fu et al., 2019) and crayfish species (Nedaei et al., 2019). It has also been proven that the mixture of prebiotics and probiotics, called synbiotics, has a synergistic effect and can improve the biochemical and growth parameters of aquatic animals. Many studies have emphasized that the administration of prebiotics or probiotics alone is generally less effective than their combined forms (Ai et al., 2011; Lee et al., 2018). This is especially true where probiotic microorganisms face difficulties in surviving in the digestive tract, so careful selection of combined prebiotics and probiotics is considered necessary (Pandey et al., 2015). Many research articles on the effect of synbiotics on aquatic animals in general and crustaceans, in particular, have been conducted in recent years (Huynh et al., 2018; Butt et al., 2021). Nevertheless, there is a lack of information regarding the possible effects of prebiotics, probiotics, and their combinations on ornamental shrimp, particularly red cherry shrimp. In this trial, the effects of synbiotics: prebiotics (GOS) and probiotics (*Bacillus clausii*, commercial probiotics: Enterogermina, Sanofi, Istanbul, Turkey) on the growth rate indices of red cherry shrimp (*Neocaridina davidi*) were investigated.

Materials and Methods

Experimental Design

Red cherry shrimp obtained from a local producer (Eker Ornamental Prawns Production Farm, Antalya, Türkiye) was brought to Ankara in a plastic transport tank (10 L) with an aeration system. The trial was conducted in the Aquaculture Research Unit (Department of Fisheries and Aquaculture Engineering, Ankara University, Turkey). In this study, red cherry shrimps with an initial weight of 0.24±0.03 g in total 270 were used. The shrimp were allotted to the plastic tanks with a volume of 10 L (0.01 m³) and an area of 0.05 m², representing 9 groups, each of which contained 3 replicates and ten shrimps were placed in each tank. Except for the control group, diets for all shrimps were supplemented with either GOS or synbiotics. Plastic shelters and algae were used for shrimp hiding spots. To maintain good water quality siphoning of unconsumed feed and shrimp excrement was ensured. The temperature was kept at the optimum level; a warm air blower (2000W, Kumtel, Istanbul, TR) was used in case of a temperature drop, while the photoperiod was ensured to be as 12 hours of light and 12 hours of darkness. During this thirty-day experiment, dissolved oxygen, temperature, and pH were recorded on daily basis using YSI Pro20 for oxygen and temperature and YSI EcoSense pH100A for pH measurement. Further, total ammonia was also measured each week using an Iris Visible Spectrophotometer - HI801-01 and the data obtained were analyzed with SPSS. Water quality parameters were 6.4±0.3 mg/L, 26±1°C, 6.6±0.2, and 0.3±0.1 mg/L for dissolved oxygen, temperature, pH and ammonia, respectively.

Experimental diets

The basal diets (2-3 mm, Novoprawn Perlgarnelenfutter, JBL GmbH & Co. Neuhofen, Germany) contained 38.4% crude protein, 10.4% lipid, 6.9% ash, 10% moisture, and 1.9% cellulose. In the experiment, probiotics as Enterogermina (1 ml, 2 x 10^9 CFU Bacillus clausii, www.enterogermina.com.tr) and/ or the Galactooligosaccharide as prebiotics (GOS, Vivinal GOS, Friesland Foods Domo, Zwolle, The Netherlands) were added in the basal diets. The feeds of the 9 groups were supplemented with the following feed additives (per kg): control (0 g), G1 (1 g GOS), G2 (2 g GOS), G3 (3g GOS), G4 (4g GOS), G1P (1 g GOS+ 1 ml probiotic), G2P (2 g GOS+ 1 ml probiotic), G3P (3 g GOS+ 1 ml probiotic) and G4P (4 g GOS+ 1 ml probiotic). All groups were fed with these feeds twice a day until satiation (ad libitum), and faeces with remained feed were removed by siphoned from the tanks after feeding.

Growth Performance

During the experiment, the total weight of all shrimps after the shrimps are dried with paper towels was measured using a precision balance (Radwag brand PS 360.R2 model) once in two weeks intervals. Shrimp's sexual dimorphism cannot be detectable in the juvenile stage. At the end of the experiment, all the individuals reached maturity and the female and male counting and weighting were performed. 24 hours before each measurement feeding was stopped to ensure obtaining dry weights. At the experiment, a digital meter (balance accurate to 0.001 g) was used for the growth parameters. The growth indexes were determined using the below formulas:

WG (Weight gain, g): Final weight of shrimps (g)-Initial weight (g)

FCR (Feed conversion ratio): Feed given to shrimps (g)/body weight gain (g)

SR (Survival rate, %): (The number of shrimps at end of trial/ initial number of shrimps) x 100

SGR (Specific growth rate, %/day): (ln final shrimp weight)-(ln initial shrimp weight)/trial day x 100

Statistical Analysis

Data collected for growth and water quality indices after the end of the experiment were analyzed using the package program (SPSS 17.0, Chicago, IL, USA). Tukey, a post hoc ANOVA test, was chosen to examine the difference among the groups. While the P value was determined as 0.05, the findings were given as the mean ± standard deviation.

Results

At the end of the experiment, female ratio was 52.15±0.41, 51.80±0.36, 52.02±0.42, 53.01±0.45, 51.65±0.48, 52.70±0.34, 54.04±0.49, 51.80±0.21 and 52.60±0.40 for the G1, G2, G3, G4, G1P, G2P, G3P and G4P groups, respectively. The findings of growth rate indices of red cherry shrimp fed with diets supplemented with various doses of Galactooligosaccharides and Enterogermina probiotics are summarized in Table 1. In general, the growth parameters were found to be significantly higher (P<0.05) in shrimp fed with prebiotic and synbiotic supplemented feeds compared to shrimps in control, regardless of the male or female groups. The highest FBW in male groups was recorded from the groups fed with synbiotic added feeds (G2P: 0.454±0.048 g and G3P: 0.437±0.050 g), while the lowest FBW was noted from shrimp in the control (0.404±0.047 g) and G1 (0.411±0.039 g) groups. Similarly, the highest FBW in female groups was found in synbiotic groups (G1P: 0.690±0.055 g and G2P: 0.716±0.039 g) while the lowest was recorded from shrimp in the control group shrimps. In terms of WG and SGR, the highest values in both male and female groups were found in the G2P groups, while the lowest values were recorded in the control groups (P<0.05). For FCR of male groups, synbiotic supplemented shrimps (G2P: 1.820±0.072 and G3P: 1.933±0.153) depicted the lowest values (P<0.05) compared to other groups, while in female groups G2P (1.797±0.148) showed the best FCR value. Although there were no statistical differences (P<0.05) were noted among the female groups in terms of survival rate, the lowest survival rates were recorded in the control group. On the contrary, significant differences (P<0.05) were found in the male control group (73.33±23.09%) with the lowest survival rate when compared to the G2, G3, G2P, and G3P groups, which showed 100% survival rates.

Discussion

Synbiotics, a combination of probiotics and prebiotics that are often in a synergistic relationship, have recently become a magnet for many research studies focusing on the use of functional feed additives in aquaculture (Butt et al., 2021). Prebiotics, such as Galactooligosaccharides, has been proven to promote the growth and development of commensal bacteria that are distributed through the digestive enzymes of aquatic animals (Grisdale-Helland et al., 2008; Nedaei et al., 2019). The selection of probiotics is usually determined based on their ability to improve the biochemical and zootechnical parameters of aquatic animals, while the selection of prebiotics is carried out in accordance with their ability to stimulate the growth and proliferation of probiotic microorganisms (Kolida and Gibson 2011). When probiotics are selected for suitable prebiotics, many studies have reported that a combination (synbiotics) performs better than either prebiotics or probiotics alone (Merrifield et

Table 1. Dietary synbiotics applications on growth rate indices of red cherry shrimp

		Control	G1	G2	G3	G4	G1P	G2P	G3P	G4P
M	IW	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}
	FBW	0.404±0.047^{a}	0.411±0.039^{a}	0.418±0.029^{ab}	0.413±0.030^{ab}	0.408±0.034^{a}	0.428±0.037^{bc}	0.454±0.048^{c}	0.437±0.050^{c}	0.419±0.053^{ab}
	WG	0.167±0.058^{a}	0.193±0.056^{a}	0.201±0.039^{ab}	0.196±0.047^{ab}	0.171±0.048^{a}	0.243±0.044^{bc}	0.269±0.063^{c}	0.251±0.055^{bc}	0.197±0.065^{ab}
	SGR	0.885±0.293^{a}	0.996±0.287^{ab}	1.027±0.213^{ab}	1.009±0.253^{ab}	0.907±0.257^{a}	1.180±0.216^{bc}	1.263±0.283^{c}	1.204±0.245^{bc}	1.015±0.312^{ab}
	FCR	2.617±0.215^{c}	2.293±0.276^{bc}	2.247±0.514^{bc}	2.400±0.087^{bc}	2.060±0.122^{ab}	2.000±0.009^{ab}	1.820±0.072^{a}	1.933±0.153^{a}	2.050±0.050^{ab}
	SR	73.33±23.09^{a}	86.67±11.55^{ab}	100.0±0.00^{b}	100.00±0.00^{b}	93.33±11.55^{ab}	93.33±11.55^{ab}	86.67±23.09^{ab}	100.00±0.00^{b}	100.00±0.00^{b}
F	IW	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}	0.242±0.027^{a}
	FBW	0.613±0.046^{a}	0.619±0.041^{ab}	0.624±0.033^{ab}	0.622±0.053^{ab}	0.621±0.054^{ab}	0.690±0.055^{c}	0.716±0.039^{c}	0.628±0.065^{ab}	0.675±0.047^{bc}
	WG	0.371±0.064^{a}	0.377±0.053^{a}	0.382±0.050^{ab}	0.380±0.056^{ab}	0.379±0.055^{a}	0.448±0.069^{bc}	0.474±0.056^{c}	0.386±0.069^{ab}	0.433±0.065^{ab}
	SGR	1.555±0.275^{a}	1.572±0.230^{a}	1.586±0.230^{a}	1.577±0.214^{a}	1.573±0.204^{a}	1.751±0.260^{ab}	1.815±0.240^{b}	1.591±0.241^{a}	1.715±0.260^{ab}
	FCR	2.847±0.243^{d}	2.108±0.251^{ab}	1.953±0.525^{ab}	2.470±0.108^{bc}	2.393±0.361^{bc}	1.995±0.009^{ab}	1.797±0.148^{a}	2.100±0.200^{ab}	2.017±0.104^{ab}
	SR	80.00±20.00^{a}	93.33±11.55^{a}	93.33±11.55^{a}	93.33±11.55^{a}	93.33±11.55^{a}	100.0±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}	93.33±11.55^{a}

IW: Initial weight (g); FBW: Final body weight (g); WG: Weight gain (g); SGR: Specific growth rate (%/day); FCR: Feed conversion ratio; SR: survival rate (%). C (0 g), G1 (1 g GOS), G2 (2 g GOS), G3 (3g GOS), G4 (4g GOS), G1P (1 g GOS+ 1 ml probiotic), G2P (2 g GOS+ 1 ml probiotic), G3P (3 g GOS+ 1 ml probiotic) and G4P (4 g GOS+ 1 ml probiotic). Results are depicted as mean ± standard deviation. Different superscript in the same row shows a considerable difference (P<0.05).

al., 2010). In fact, many researchers argue that in the shrimp industry synbiotics are more effective than the sole application of probiotics or prebiotics (Oktaviana and Yuhana 2014; Zhang et al., 2011; Hamsah et al., 2019).

Although many studies on the effects of prebiotics and probiotics on aquatic animals have been performed in recent years, to the best of our knowledge this is the first study to determine the impacts of synbiotics (probiotics (Enterogermina probiotic- *B. clausii*) and prebiotics (GOS)) on the growth and survival of red cherry shrimp (*N. davidi*). Prebiotics such as GOS, MOS, and FOS have been combined with different Bacillus species and supplemented with various fish and crustacean species; Positive effects on growth, immunity, tissue histomorphology and gut microbiota have been reported from these studies (Daniels et al., 2010; Ai et al., 2011; Kaya et al., 2021). A recent study conducted by Modanloo et al., (2017) found that synbiotics (*B. clausii* and FOS, GOS, and MOS) improved the immune response of Japanese flounder (*Paralichthys olivaceus*).

Our results showed that, regardless of male or female red cherry shrimp, the groups supplemented with feed additives (GOS and/or synbiotics) showed improved growth rates compared to the control group. Similar results have been reported from white leg shrimp (*L. vannamei*) fed GOS-supplemented diets compared to their control counterparts in different studies (Huynh et al., 2018; 2019). We found that the highest FBW in male and female groups were recorded from the shrimp fed with synbiotic added feeds (G2P: 0.454±0.048 g and G3P: 0.437±0.050 g) and (G1P: 0.690±0.055 g and G2P: 0.716±0.039 g) respectively. This means that synbiotics have demonstrated a synergistic effect, which is consistent with the findings of Hamsah et al., (2019), who found better results in immunity and growth of white leg shrimp when fed to diets added with synbiotics (MOS and *Pfiesteria piscicida*) instead of probiotics or prebiotics alone. Furthermore, the beneficial effect of synbiotics on the growth rate parameters of different shrimp species was reported; Pacific white shrimp (*L. vannamei*) (Yu et al., 2009; Munaenı et al., 2014; Huynh et al., 2018); Kuruma prawn (*Penaeus japonicus*) (Zhang et al., 2011) and Tiger shrimp (*P. monodon*) (Bir et al., 2020). The improved growth performance of shrimp fed diets including synbiotics can be linked to increased feed utilization. According to our results, the lowest feed conversion rate (FCR) was obtained in the group the male red cherry shrimp (1.820±0.072) and in the female (1.797±0.148) in the synbiotic fed shrimp groups. Although there were no significant differences between the groups of female and male red cherry shrimp in terms of survival rates, higher values were recorded in the shrimp that were fed diets added with synbiotics. In contrast, Hamsah et al., (2019) reported that Pacific white shrimp fed with synbiotic-supplemented feeds showed significantly higher survival rates compared to their control groups. Finally, in agreement with the results of Yu et al., (2009) who noted that synbiotics improved WG and SGR of Pacific white leg shrimp, our findings indicated considerably higher specific growth rates in the red cherry shrimp which fed to diets added with synbiotics and GOS supplementation.

Conclusion

In this study, results indicated significantly higher growth rate parameters in all the red cherry shrimps which fed supplemented diets with prebiotics (GOS) and synbiotics (GOS and *B. clausii*) than the control group shrimps. Furthermore, both females and males of red cherry shrimp groups which fed with synbiotics(G2P) showed the best performance in all growth parameters, so it is better to recommend adding synbiotic (2 grams of GOS and 1 ml of probiotic Enterogermina) into feed for red cherry shrimp. Finally, more studies needed in terms of histomorphology, body composition, and pigmentation on the effect of synbiotics on red cherry shrimp (*N. davidi*).

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

Authors contributed equally to this paper.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

The authors followed all applicable international, national, and/or institutional guidelines for the care and use of animals.

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