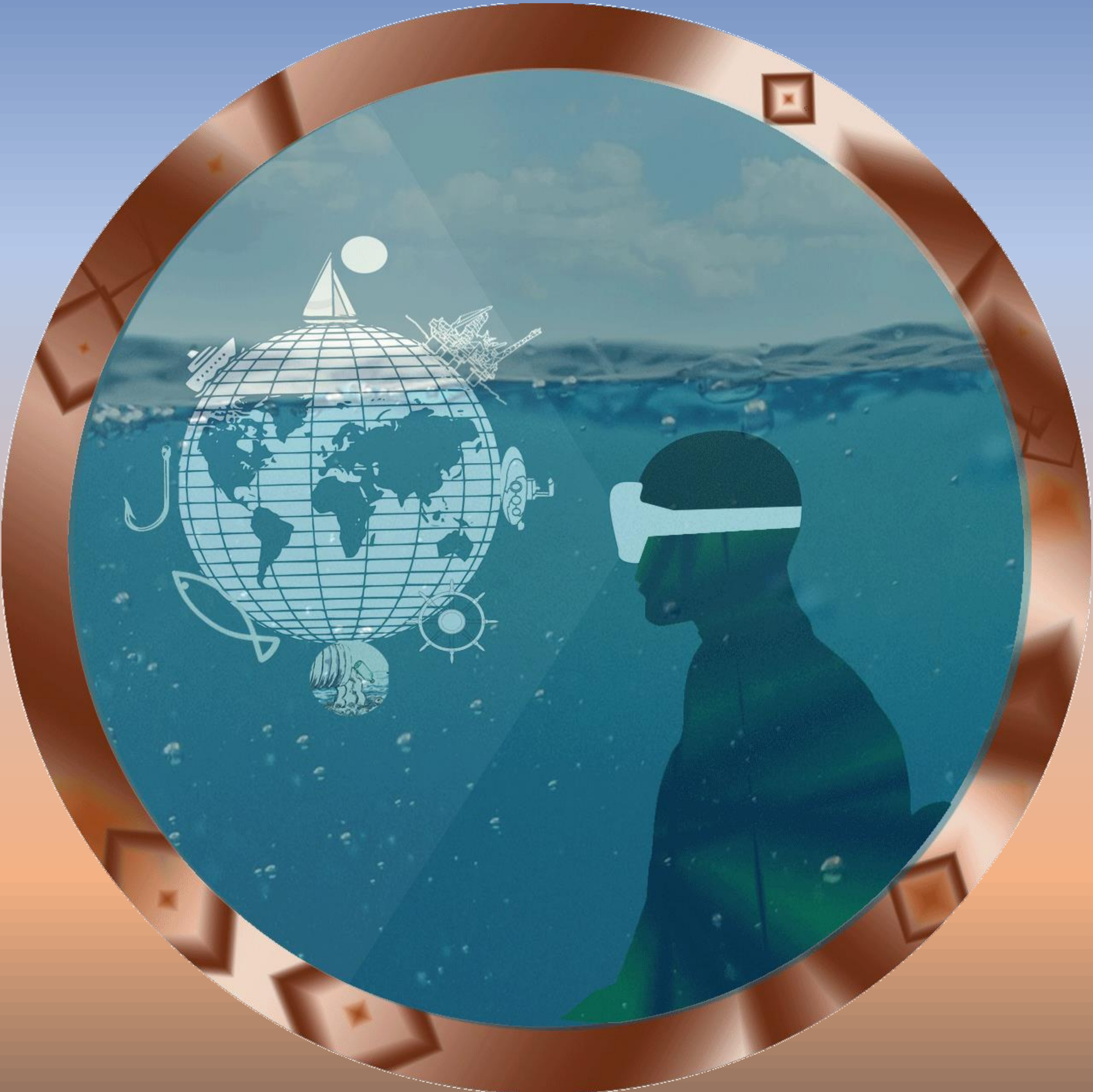
E-ISSN: 2687-5802

Marine and Life Sciences



YEAR 2023 • VOLUME 5 • ISSUE 1

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Karaağaç Övündük Mah. Uğur Mumcu 9. Cad. 14. Blok 310K/12, Arsuz, Hatay, TÜRKİYE
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Hampton, S., Rabagliati, H., Sorace, A., & Fletcher-Watson, S. (2017). *Autism and bilingualism: A qualitative interview study of parents' perspectives and experiences*. PsyArXiv, *Preprint*. https://doi.org/10.31234/osf.io/76xfs

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

Thesis and Dissertation:

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

Conference Proceedings:

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

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

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2. Pre-Evaluation Process

In the pre-evaluation process, the field editors examine the studies, introduction and literature, methods, findings, results, evaluation and discussion sections in detail in terms of journal publication policies, scope and authenticity of study. Study which is not suitable as a result of this examination is returned to the author with the field editor's evaluation report within four weeks at the latest. The studies which are suitable for the journal are passed to the referee process.

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

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

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Marine and Life Sciences

Journal Homepage: https://dergipark.org.tr/en/pub/marlife

Year 2023 **Volume: 5** **Issue: 1** **E-ISSN: 2822-3500**

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Please cite this paper as follows:
Keskin, B. A., & Gürkan, Ş. (2023). İzmir ve Kuşadası Körfezi'nde dağılım gösteren Sardalya balığında (*Sardina pilchardus* Walbaum, 1792) bazı biyolojik indekslerin mevsimsel değişimlerinin izlenmesi. *Marine and Life Sciences*, 5(1), 1-7. https://doi.org/10.51756/marlife.1241686

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi: 24.01.2023
Kabul Tarihi: 14.02.2023
Online Yayınlanma: 13.10.2023

Anahtar Kelimeler:
Beyin ağırlığı
Ege Denizi
Fulton-kondisyon
Gonadosomatik indeks
Hepatosomatik indeks
Visseral indeks
Vücut kitlesi

Ö Z E T

Bu çalışma, Ege Denizi'nin balıkçılık faaliyeti yapılan belli başlı iki önemli körfezi olan İzmir ve Kuşadası Körfez'lerinde dağılım gösteren Sardalya balıklarının *Sardina pilchardus* (Walbaum, 1792) bazı biyolojik indekslerinin (Hepatosomatik indeks, Mide doluluk indeksi, Gonadosomatik indeks ve Visseral indeks, Fulton kondisyon) 2022 yılı boyunca mevsimsel değişimlerini belirlemek ve karşılaştırmak amacıyla gerçekleştirilmiştir. Bu kapsamda her iki körfezden toplam 302 adet balık örneği, ticari balıkçılardan doğrudan temin edilmiştir. Hepatosomatik indeks (HSİ) değeri İzmir Körfezi'nde en yüksek kış mevsiminde, en düşük değeri yaz mevsiminde gösterirken, Kuşadası Körfezi'nde ise en yüksek sonbaharda en düşük ilkbahar mevsiminde belirlenmiştir. HSİ değerlerindeki mevsimsel değişimlerin, değişen mevsimsel su sıcaklığına göre balıkların metabolik faaliyetleri ile yüzme faaliyetleri üzerindeki etkisine bağlı olduğu düşünülmektedir. Bu durum mide doluluk indeksi (Fİ) ile de öngörülmektedir. Gonadosomatik indeks değerleri (GSİ), her iki körfezde de en düşük yaz mevsiminde, en yüksek kış mevsiminde hesaplanmıştır. GSİ değerlerindeki bu mevsimsel değişim sardalya popülasyonun Ege Denizi için tipik üreme döngüsü ile uyum göstermektedir. İzmir Körfezi'ndeki sardalya popülasyonun iç organ indeks değerleri (VSİ) Kuşadası körfezindeki popülasyondan yüksek olmakla birlikte, İzmir Körfezi'nde türün daha yüksek enerjili zooplanktonik av grupları ile beslendiklerini düşündürmektedir. Aynı şekilde, Fulton kondisyon değerleri de İzmir Körfezi'nde daha yüksektir. Körfezler arasında mevcut kondisyon değerleri arasındaki farklılığın Ege Deniz'inin kuzeydoğu merkez alanlarının önemli yüzey ve dip sularının yer değiştirdiği (upwelling) sahaları bulundurması ve önemli besin girdisi sağlamasıyla ilişkilendirilmektedir. Bu çalışma Ege Denizi'ndeki iki farklı körfezdeki sardalya popülasyonuna ait biyolojik indeks değerlerinin mevsimsel olarak planktonik kommunite ve çevresel değişimlerden etkilendiğini göstermiştir.

Monitoring of seasonal changes of some biological indexes of Sardine (*Sardina pilchardus* Walbaum, 1792), distribuited in İzmir and Kuşadası Bay

Keywords:
Aegean Sea
Brain weight
Body mass
Fulton-K condition
Gonadosomatic index
Hepatosomatic index
Vicceral index

A B S T R A C T

This study was carried out seasonally in 2022 in order to determine and compare the seasonal changes in some biological indexes (Hepatosomatic index, Fullness index, Gonadosomatic index, Visseral index and Fulton-K condition) of Sardine *Sardina pilchardus*, (Walbaum, 1792) fish, which are distributed in the two main fishing bays of the Aegean Sea (İzmir and Kuşadası Bay). For this purpose, a total of 302 fish samples from both bays were obtained directly from commercial fishermen. While the Hepatosomatic index (HSI) value determined the highest value in the winter season and the lowest value in the summer season in İzmir Bay, the highest value in Kuşadası Bay was in autumn and lowest in spring. It is predicted that seasonal changes in HSI values depend on the effect on the metabolic activities and swimming activities of fish according to the changing seasonal water temperature. This situation is predicted to be possible with the stomach fullness index (FI). Gonadosomatic index values (GSI) were calculated in the lowest summer and the highest winter in both gulfs. This seasonal variation in GSI values is consistent with the distinctive reproductive cycle of the sardine population for the Aegean Sea. Although the Vissceral index values (VSI) of the sardine population in İzmir Bay are higher than the population in Kuşadası Bay, it suggests that the species feeds on higher energy zooplanktonic prey groups in İzmir Bay. Likewise, Fulton-K condition values are higher in İzmir Bay. The difference between the current condition values between the bays is associated with the fact that the northeast central areas of the Aegean Sea have upwelling areas and provide important nutrient input. This study showed that the index values of sardine populations in two different gulfs in the Aegean Sea are affected by seasonal planktonic community and environmental changes.

GİRİŞ

Türkiye deniz balığı türlerinin arasında avcılık yoluyla elde edilen en önemli ticari pelajik türü olan Hamsi'den sonra ikinci sırada gelen ve Ege Denizi'nin en önemli av potansiyeline sahip Sardalya'nın *Sardina pilchardus* (Walbaum, 1792) ülkemiz su ürünleri avcılık verilerine katkısı oldukça büyüktür. 2021 yılında ülkemizde total avcılık miktarı 262 bin 297 ton iken bu av miktarı içinde sardalya türünün katkısı 15.800 ton olarak gerçekleşmiştir (TUİK, 2021). Denizel ortamdaki her balık türü gibi sardalya popülasyonları da birçok biyotik veya abiyotik şartlardan (iklimsel koşullar, besin varlığı, avcılık, kirlilik, vs.) zaman içinde etkilenmektedir. Bu etki aynı zamanda sardalya balıklarını avlayan diğer pisivor balık türlerinin stoklarına da yansımaktadır (Dalkılınç, 2021).

Balıklarda beslenme faaliyeti, ömür boyu gerçekleşen önemli bir metabolik ve fizyolojik faaliyet olduğu için balıkların büyüme ve hayatta kalmalarında doğrudan etkilidir (Hernández ve ark., 2019). Gerek sıcaklık derecelerinde gerekse besinsel verimlilikteki mevsimsel dalgalanmalar yavru ve ergin balıkların besinin bulunabilirliğini ve kalitesini etkilemektedir (Rodrigues ve ark., 2013). Her balık türü farklı fizyolojik özelliklere sahiptir ve besinden faydalanma düzeylerinin farklı olması o türün büyümesinde, üreme organlarına olan desteklerinde farklı şekilde etki göstermektedir (Hernández ve ark., 2019). Bu amaçla türlerin gonad gelişimlerine bağlı olarak karaciğer ölçümleri, lipit içerikleri ve bazı morfolojik indekslerin belirlenebileceği bilinmektedir (Hismayasari ve ark., 2015). Nunes ve ark. (2011)'e göre, Portekiz kıyılarındaki sardalya balıklarının kondisyon ve ağırlık gibi somatik ve hepatosomatik indeks ve depolanan yağ miktarlarına ait değerlerin üreme sezonuna bağlı olarak, ilkbaharda arttığı, güz ve kış sezonunda ise azaldığı ifade edilmektedir. Ayrıca balıkların mide içeriğindeki av gruplarının içerdiği yağ miktarının, balığın iç organlarında zamanla yağ birikimine neden olması visseral indeks (VSİ) değerlerinin artmasına neden olmaktadır (Korkut ve ark., 2007). Mide doluluk indeksi (Fİ) ise, balıkların gelişim süreçlerinin önemli bir parçasıdır. Ouakka ve ark. (2017)'a göre genç balıkların, erginlerine göre daha yoğun beslenme aktivitesi göstermesinde büyüme amacına bağlı olarak fizyolojik ihtiyaçlarının daha fazla olması gösterilmektedir. Beslenme aktivitesi veya yoğunluğu aynı zamanda yıl içinde denizel ortamdaki besin bolluğundaki değişimlerle doğrudan ilişkilidir (Garrido ve ark., 2008).

Doğal bir besin kaynağı olan ve insan gıdası olarak son derece önemli olan sardalya türünün Ege Denizi'nde yerel ve yabancı araştırmacılar tarafından yapılan başta üreme, büyüme, beslenme, avcılık kayıtlarını gösteren bazı araştırmaların yanında (Cihangir, 1991; Mater ve Bayhan, 1999; Sever ve ark., 2005; Sarmasik ve ark., 2008; Erdogan ve ark., 2010; Taylan ve ark., 2019; Şenbahar ve ark., 2020), Ege Denizi'nde bazı biyolojik indislerinin mevsimsel değişimleri üzerine yapılmış çalışmalar oldukça sınırlıdır. Bu konuda yapılan en önemli araştırma Gurkan ve ark. (2021) tarafından yapılan, ticari değeri oldukça büyük olan dil balıklarının (*Solea solea*) Ege Denizi'ndeki biyolojik indekslerinin belirlendiği çalışmadır.

Bu araştırma ile, sardalya balıklarının Visserosomatik indeks, Hepatosomatik indeks, Fullnes indeks ve Gonadosomatik indeksi ve kondisyon dinamiklerinin İzmir ve Kuşadası Körfez'lerindeki mevsimsel sonuçlarının detaylı şekilde belirlenmesi hedeflenmiştir.

MATERYAL VE YÖNTEM

Bu çalışmada, Sardalya balığına ait 302 adet balık örneği 2022 yılı boyunca İzmir ve Kuşadası Körfez'lerinde avcılık yapan ticari balıkçılardan mevsimsel olarak temin edilmiştir. Örneklerin değerlendirilmesinde balıkçı ağının seçiciliği göz ardı edilmiştir. (Şekil 1). Elde edilen örnekler laboratuvar ortamına getirildikten sonra boyları balık ölçüm cetveli (TL, cm) ile ölçülmüş, ağırlıkları (W, g) 0,01 g hassasiyete sahip AND marka Fz-5000i model hassas terazi ile tartılmıştır. Daha sonra balıklar kesilerek mide, gonad, beyin ağırlığı ve iç organ ağırlıkları ayrı ayrı belirlenmiştir. Eşey tayini gonadların mikroskobik olarak incelenmesiyle belirlenmiş ancak indeks değerleri eşeylere göre belirlenmemiştir.

Şekil 1. İzmir ve Kuşadası Körfez'lerinin genel görünümü
Figure 1. General view of İzmir and Kuşadası Bays

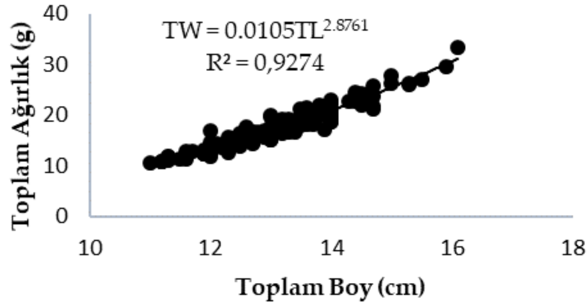
Sardalya balıklarının tüm bireyleri için hesaplanan boy-ağırlık ilişkisinde $W=aL^b$ eşitliğinden faydalanılmıştır (Froese, 2006). Burada W; gr cinsinden vücut ağırlığı, L; cm olarak boy değeri a; kesişme noktası ve b; eğim ifade etmektedir (b<3: negatif allometri, b: isometrik; b>3: pozitif allometri). İndekslerin hesaplanmasında önemli eşitliklerden faydalanılmıştır. Bunlar; HSİ= 100×Karaciğer W(g)/W(g) (Sulistyo ve ark., 2000), Fİ = mide W(g)/W(g) × 100 (Hureau, 1969), GSİ = GonadW/W(g) × 100 (Nunes ve ark., 2011), Fulton-K= 100 × W(g)/TL^3 (Ricker, 1979), VSİ= İçorgan W (g)/W(g) × 100 (Bicudo ve ark., 2010), EQ= Beyin W(mg)/ $(W)^{2/3}$ (Pauly ve ark., 2011) olup; indekslerin körfezler arasındaki fark bulunup bulunmadığı t-testi ile belirlenmiştir. Ayrıca verilerin değerlendirilmesinde ANOVA ve regresyon analizlerinden de yararlanılmıştır.

BULGULAR

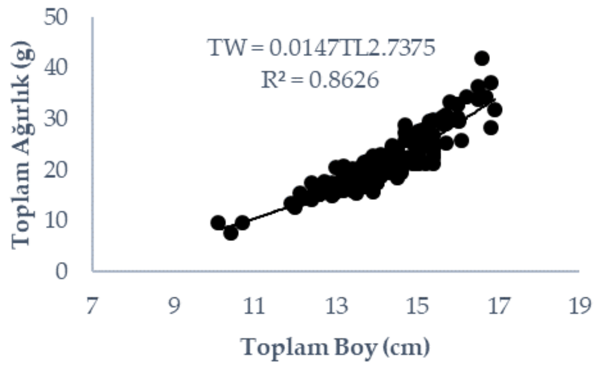
Balık örnekleri, İzmir ve Kuşadası Körfez'lerinde ticari balıkçılık yapan teknelerden dört mevsim boyunca satın alma şeklinde elde edilmiştir. Toplamda İzmir Körfezi'nden 140 adet Kuşadası Körfezi'nden 162 adet olmak üzere toplam 302 balık örneği değerlendirilmiştir. Dişi/Erkek 1:1,2 (İzmir Körfezi), 1:1,4 (Kuşadası Körfezi) olarak belirlenmiştir. Her iki körfezden elde edilen sardalya örneklerinin boy-ağırlık ilişkisi; İzmir Körfezi için; $W=0{,}0105TL^{2.876}$ $R^2=0{,}93$, Kuşadası Körfezi için $W=0.014TL^{2.737}$ $R^2=0{,}86$ olarak belirlenmiştir. Buna göre her iki körfezdeki sardalya balıklarının yıl boyunca negatif allometrik büyümeye sahip oldukları saptanmıştır (Şekil 2 ve Şekil 3).

Sardalya balıklarında morfolojik indislerinden mide doluluk, hepatosomatik, visseral, kondisyon, gonadosomatik ve beyin kitle indekslerinin İzmir ve Kuşadası Körfez'lerinde tespit edilen sonuçları Tablo 1'de verilmiştir.

Her iki Körfezde dağılım gösteren sardalya balık popülasyonlarının biyolojik indeksleri arasındaki farklılıklar t-testi ile belirlenmiştir ($p<0.05$). Buna göre ortalama HSİ değerleri bakımından İzmir Körfezi'ndeki popülasyonun daha yüksek indekse sahip olduğu belirlenmiştir ($t_{(201)}$:-6,232, p:0,00001, $p<0{,}05$). VSİ açısından iki körfez alanı arasında fark söz konusu olduğu, buna göre İzmir Körfezi'ndeki ortalama VSİ değerin Kuşadası Körfezi'ndeki değerden daha büyük olduğu görülmüştür ($t_{(140)}$:-5,837, p:0,000001, $p<0{,}05$) Fulton-K değerleri bakımından popülasyonlar arası farkın varlığı değerlendirildiğinde, yine İzmir Körfezi sardalya popülasyonun daha avantajlı durumda olduğu anlaşılmaktadır ($t_{(201)}$:-2,366, p:0,018, $p<0{,}05$). Bu indeksler arasında sadece Fİ ve EQ değerlerinin Kuşadası sardalya popülasyonunda daha yüksek seyrettiği anlaşılmaktadır (sırasıyla; $t_{(201)}$:-8,029, p:0,0000001 $p<0{,}05$; $t_{(202)}$: 3,207, p:0,00146 $p<0{,}05$).



Şekil 2. İzmir Körfezi'nde dağılım gösteren sardalya bireylerinde boy-ağırlık ilişkisi
Figure 2. Length-weight relationship in sardine individuals distributed in İzmir Bay



Şekil 3. Kuşadası Körfezi'nde dağılım gösteren sardalya bireylerinde boy-ağırlık ilişkisi
Figure 3. Length-weight relationship in sardine individuals distributed in Kuşadası Bay

Tablo 1. Sardalya balıklarının İzmir ve Kuşadası Körfezi'ndeki biyolojik indeksleri Ort±SH).
Table 1. Biological indexes of sardine fish in İzmir and Kuşadası Bay (Mean±SE).

Biyolojik İndeksler	İzmir Körfezi	Kuşadası Körfezi	p
Mide doluluk İndeksi (Fİ)	2,00±0.17	3,05±0,22	*p<0,05
Hepatosomatik İndeks (HSİ)	0,76±0,06	0,51±0,04	*p<0,05
Visseral İndeks (VSİ)	9,32±0,79	8,08±0,57	*p<0,05
Beyin kitle İndeksi(EQ)	80,78±0,17	94,95±0,22	*p<0,05
Gonadosomatik indeksi (GSİ)	4,29± 0,58	2,72±0,27	*p<0,05
Fulton- K	0,77±0,07	0,78±0,05	*p<0,05

**p<0,05: istatistiksel fark*

Tablo 2. İzmir ve Kuşadası Körfez'lerindeki sardalya balıklarının mevsimlere göre indeksleri (Ort.±SH)
Table 2. Seasonal indexes (Mean±SE) of sardine individuals in İzmir and Kuşadası Bays

	VSİ		HSİ		GSİ		Fİ		Fulton-K	
	İzmir	**Kuşadası**	**İzmir**	**Kuşadası**	**İzmir**	**Kuşadası**	**İzmir**	**Kuşadası**	**İzmir**	**Kuşadası**
İlkbahar	11,718±2,13	8,069±1,41	0,86±0,15*	0,38±0,07*	3,91±0,75	3,68±0,38	2,093±0,32	2,605±0,36	0,798±0,15*	0,740±0,13
Yaz	10,842±1,97	7,910±1,26	0,52±0,09	0,40±0,06	3,11±1,35*	1,82±5,88*	2,671±0,24*	4,22±0,29	0,767±0,14	0,794±0,13*
Sonbahar	12,94±2,31	8,191±0,92	0,65±0,11	0,62±0,07	3,45±1,18	2,88±1,23	1,796±0,38	3,275±0,46	0,753±0,13*	0,777±0,09
Kış	15,33±2,19	8,069±1,13	0,92±0,13	0,51±0,07	5,94±0,74	8,23±0,32	1,670±0,49*	2,060±0,67*	0,759±0,11	0,670±0,09*
P	*p>0,05*	*p>0,05*	**p*<0,05	**p*<0,05	**p*<0,05	**p*<0,05	**p*<0,05	**p*<0,05	**p*<0,05	**p*<0,05

Tablo 2'de Sardalya balıklarında mide doluluk (Fİ), hepatosomatik (HSİ), visseral (VSİ), kondisyon (Fulton-K), gonadosomatik (GSİ) indekslerinin İzmir ve Kuşadası Körfez'lerindeki mevsimsel sonuçları verilmiştir. EQ değerleri mevsimsel olarak değişmediğinden hesaplanmamıştır.

Sardalya balıklarının incelenen indekslerinin mevsimlere göre değerlendirmesi yapıldığında; Her iki Körfez'de HSİ değerlerinin Bahar mevsiminde Kış periyodundan daha düşük düzeyde seyrettiği ve istatistiksel açıdan da farklı olduğu anlaşılmaktadır (İzmir; $t_{(30)}$=3,130, p:0,003; Kuşadası; $t_{(32)}$= -3,69, p:0,0003, p<0,05). Her iki Körfez'de en yüksek GSİ değerlerine kış mevsiminde rastlanırken, en düşük yaz mevsiminde elde edilmiştir. Dolayısıyla bu indeks değeri mevsimsel olarak değişime uğramamaktadır (İzmir; ($t_{(30)}$: 2,111, p:0,039, p<0,05; Kuşadası; ($t_{(32)}$:2,420, p:0,018, p<0,05)). VSİ değerlerinin her iki körfezdeki sardalya popülasyonlarında tüm yıl boyunca fazla değişim göstermeden devam ettiğini göstermektedir (p>0,05). Kondisyon değerlerine göre ise, İzmir Körfezi'nde en yüksek Bahar, en düşük güzde rastlanmıştır ($t_{(30)}$:3,396, p:0,0012, p<0,05). Oysaki Kuşadası Körfezi'nde bu indeks değeri yazın en yüksek, kışın en düşük değerdedir ($t_{(32)}$=6,0785, p:0,00001, p<0,05). Fİ değerleri hem İzmir hem Kuşadası Körfezi'nde en yüksek değere yaz periyodunda, en düşük değere kış periyodunda rastlanmıştır. Dolayısıyla yaz periyodu her iki körfezde gösterdiği yüksek değerden dolayı istatistiksel açıdan farklılık arz etmektedir (İzmir; $t_{(30)}$:-2,585, p:0,012, p<0,05; Kuşadası: ($t_{(40)}$:-7,203, p:0,000001, p<0,05).

TARTIŞMA VE SONUÇ

Bu araştırmada elde edilen örneklere ait sonuçlar dünyada ve ülkemizdeki çalışmalarla karşılaştırılmıştır. Buna göre, 4 mevsim boyunca elde edilen sardalya balıklarının tüm bireylerinde b değerinin gerek İzmir Körfezi'nde ve gerekse Kuşadası Körfezi'nde negatif allometrik büyüme şeklinde ilerlediği görülmüştür. Ege Denizi'nde farklı bölgelerden elde edilen sardalya populasyonlarının büyüme parametrelerinin zaman içinde dalgalanma yaşadığı kimi zaman negatif kimi zaman pozitif yönde ilerlediğine dair çalışmalar mevcuttur (Mater ve Bayhan 1999; Erdogan ve ark., 2010; Taylan ve ark., 2019). Bulgularımız bu araştırmacıların çalışmalarıyla benzerlik göstermektedir. Balıklarda zamana bağlı olarak farklı büyüme değerlerine rastlanması; besinden yararlanma durumu, üreme zamanı, av zamanı, avcılık tipi, örnek sayısı, balığın cinsiyeti, yaşı, mevsim ve mevsimsel koşullarca etkilendiğini göstermektedir (Ricker, 1975; Bagenal ve Tesch, 1978).

Bilindiği üzere vücut iç organları arasında depo organı olan karaciğer, balıklarda iki loplu kan şekerini glikojene çeviren temel organdır. Ton (Scombridae) ve ringa (Clupeidae) balıkları gibi bazı pelajik balıkları glikojeni kasları arasında depo etmektedir (Timur, 2006). Mevsimsel HSİ değerlerindeki değişimlerin, poikiloterm canlılar olan balıkların iki körfezde seyreden metabolik faaliyetlerine ve yüzme faaliyetlerine etkisi olduğu anlaşılmaktadır. Nunes ve ark. (2011)'a göre Portekiz kıyılarındaki sardalya balıklarının mevsimlere göre HSİ değişimlerinin, tüketilen besinin üreme dönemi öncesinde gonadal yatırıma hizmet ettiği, sonrasında ise büyümeye devam etmeleri için kullanıldığı yönündedir. Buna göre bulgularımız bu görüşü desteklemektedir.

Ege Denizi'nde sardalya balıklarının total boy ağırlık ilişkisi için hesaplanan b değerleri çoğunlukla 3,09 (Pešić ve ark., 2010) ve 2,97 (Taylan ve ark., 2019) arasında değişim gösterdiği görülürken, araştırmamızda bu değerin mevcut çalışmalarla uyumlu olduğu görülmektedir. Sardalyalar çoklu yumurtlayan balık türü olup üreme dönemi, sonbahardan başlayarak ilkbahara kadar devam etmektedir (Cihangir, 1991). Çalışmamızda iki körfezdeki en düşük GSİ değeri yaz mevsiminde, en yüksek GSİ değeri kış mevsiminde olduğu belirlenmiştir. Dolayısıyla bulgularımız Ege Denizi'nde yapılan diğer çalışmalarla (Akyol, 1996; Mustać ve Sinovčić, 2011; Taylan ve ark., 2019) uyumlu olup sardalya popülasyonun Ege Denizi için tipik üreme döngüsü ile paralellik göstermektedir. Elbette ki dişi ve erkek bireylerin ayırımı bu noktada önem arz etmektedir.

Visseral indeks değerlerindeki değişim, balığın beslendiği besin grubunun yağ kompozisyonuyla ilişkilidir (Kumar ve ark., 2010). Besin içerisindeki yağ miktarı balığın iç organlarında yağlanmaya neden olmaktadır (Korkut ve ark., 2007). İzmir Körfezi'ndeki sardalya balıklarının ortalama VSİ değerleri Kuşadası Körfezi'ndeki bireylerinkinden yüksektir. Costalago ve Palomera (2014)'e göre, karbon içeriği açısından decapod larvalarının Akdeniz'de en çok tüketilen av grubu olduğu verilmiştir. Küçük pelajik tür olan sardalya balıklarının İzmir Körfezi'nde daha yüksek enerjili zooplanktonik av gruplarıyla (kopepod, dekapod krustase larvaları gibi) çokça beslendikleri (Sever ve ark., 2005) ve mevcut enerjiyi yüzme faaliyeti ve avlanmada harcamakta oldukları anlaşılmaktadır.

Araştırmamızda İzmir Körfezi'ndeki sardalyaların kondisyonu ele alındığında en yüksek değere ilkbaharda, en düşük değere sonbaharda rastlanmıştır. Kuşadası Körfezi'nde bu yaz mevsiminde en yüksek, kış mevsiminde en düşüktür. Burada en önemli nokta ortamdaki besinin varlığına bağlı olarak beslenme aktivitesinin ilkbahardan itibaren artması, sonbahardan itibaren suların soğuması ve besinin artık gonad gelişimleri için kullanılmasına bağlı olarak kondisyon değerlerindeki değişimlerdir. Keza Oukka ve ark. (2017)'e göre beslenme aktivitesi ve kondisyon değerlerinin yaz mevsiminde daha iyi olması besinin o mevsimde bulunabilirliği ile ifade edilir. Portekiz sularında sardalya balıklarının ilkbahar ve yaz mevsiminde fitoplanktonik canlılarla, kış mevsiminde ise balık yumurtalarıyla beslendiği gösterilmektedir (Garrido ve ark., 2008). Lion Körfezi'nde yapılan bir çalışmada ise sardalyaların yazın cladoserle, kışın diatomla beslendikleri verilmektedir (Costalago ve Palomera, 2014). Sardalya balıklarının beslenme alışkanlıklarında mevsimsel açıdan en belirgin fark, yaz ve sonbahar arasında olduğu ve bu farkın temelinde balık yumurtalarının yaz aylarında çok yüksek bollukta olması, sonbahar mevsiminde ise krustase larvalarının ve kopepodların bol olmasıyla gösterilmektedir (Zorica ve ark., 2016). Ege Denizi'nde sardalya türünün temel besin kaynaklarını kopepod, dekapod krustase, bivalv larvaları ve balık yumurtaları oluşturmaktadır (Sever ve ark., 2005; Dalkılınç, 2021). Kopepodlara, güney Ege kıyılarında tüm mevsim boyunca rastlanırken, bivalv larvaları ve balık yumurtaları ise ilkbahar ve yaz mevsiminde önemli besin olarak tüketilmektedir (Dalkılınç 2021). Kondisyon, balıklarda sağlıklı büyümeyi ifade eden önemli bir unsurdur. Çalışmamızda İzmir Körfezi'ndeki sardalya populasyonun kondisyon değerleri, Kuşadası Körfezi'ndeki popülasyondan daha yüksek bulunmuştur. Sonuçlarımızı benzer çalışmalarla karşılaştırdığımızda İzmir Körfezi sonuçlarımızın Mater ve Bayhan (1999)'a ait çalışma sonuçlarından (1,0-1,2) düşük, Erdogan ve ark. (2010)'ın sonuçlarıyla uyumlu olduğu anlaşılmaktadır. Kuşadası Körfezi'nde elde edilen kondisyon değerlerimiz, Mater ve Bayhan (1999) ile Karayiş ve Toğulga (2000)'a ait sonuçlarından (0,99-1,1) düşük olup, Erdoğan ve ark. (2010)'in değerleriyle (0,7-2,1) uyumludur. Bunun başlıca nedeni, Ege Denizi'nin kuzeydoğu merkez alanlarının besin girdisi açısından önemli upwelling sahalarını içermesi dolayısıyla önemli balıkçılık alanlarını sahip olması gösterilmektedir (Tokaç ve ark., 2010). Kondisyon değerleri arasındaki farklılıkların belirlenmesinde türün besinini oluşturan sucul ortamdaki planktonik canlıların yani besinin varlığına; su sıcaklığı, mevsim, kirlilik, balık yaşı ve cinsiyeti, gonad gelişimi gibi birçok faktör etkilidir (Rodrigues ve ark., 2013). Buna göre, İzmir ve Kuşadası Körfezi'nde sardalya popülasyonlarının kondisyon değerlerinin normal seyrettiği düşünülmektedir.

Mevsimler açısından ise, her iki körfezde VSİ değeri en yüksek yaz mevsiminde (İzmir Körfezi: 2,67; Kuşadası Körfezi: 4,22), en düşük kış mevsiminde (İzmir Körfezi: 1,67; Kuşadası Körfezi: 2,06) tespit edilmiştir. Ouakka ve ark. (2017)'e göre yıl boyunca bu balıkların planktonik besinlere olan ihtiyacı, mevcut besinlerin mevsimsel ritmi ile doğrudan ilişkili olduğu verilir. Görülmektedir ki, sardalya populasyonlarıda beslenme yoğunluğunu planktonik canlıların mevsimsel bolluğuna göre şekillendirmektedir. Köfezler açısından bakılırsa, Kuşadası Körfezi'ndeki VSİ değeri İzmir Körfezi'nden yüksektir. Bu durum körfezde dağılım gösteren planktonik canlıların bolluğunu etkileyen besin girdilerini işaret etmektedir. Kondisyon değerleri, yaz mevsiminde en yüksek, kış mevsiminde ise en düşüktür. Burada da en önemli nokta ortamdaki besinin varlığına bağlı olarak beslenme aktivitesinin ilkbahardan itibaren artışa geçmesi, buna karşın sonbahardan itibaren suların soğumasıyla birlikte sardalya balıklarının tükettikleri besini gonad gelişimleri için kullanması sonucunda kondisyon değerlerinde gerçekleşen değişimlerdir. Körfezlerin kondisyon yönünden karşılaştırılmasında, Ege Denizi'nin kuzeydoğu merkez alanlarının önemli upwelling sahalarına sahip olması besin girdisinin önemli olduğunu ifade etmektedir. Bu nedenle İzmir Körfezi'ndeki sardalya populasyonun kondisyon değerleri daha yüksek seyretmektedir. Mide doluluk indeksinin etkilendiği temel faktörler balığın olgunluk durumu (ergin veya juvenil), eşey durumu, balık boyu ve mevsimler olarak gösterilir (Ouakka ve ark., 2017). Buna göre, indeks sonuçlarının işaret ettiği başlıca noktalar; juvenillerin erginlerine göre daha fazla besine olan ihtiyacı, dişilerin gonad gelişimleri için yine daha fazla besine ihtiyaç duyması ve planktonik canlıların mevsimsel ritmlerinin sürekli değişmesi gösterilebilir.

Bu çalışma Ege Denizi'ndeki iki farklı körfezde dağılım gösteren sardalya popülasyonlarına ait bazı biyolojik indeks değerlerinin mevsimsel ölçekte değişimleri, planktonik kommuniteler ve çevresel değişimlerin etkisinde olduğunu göstermiştir.

Etik Standartlar ile Uyum

Yazarların Katkısı

Bu çalışma ilk yazarın "İzmir Körfezi ve Kuşadası Körfezi'nde dağılım gösteren Sardalya *Sardina pilchardus* (Walbaum, 1792) balığında bazı biyolojik indekslerin mevsimsel değişimlerinin izlenmesi" başlıklı yüksek lisans tezini içermektedir. Yazarlar eşit oranda katkı sağlamışlardır.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazarlar bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

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Mar. Life Sci. (2023) 5(1): 8-15 E-ISSN: 2687-5802

Marine and Life Sciences

Journal Homepage: https://dergipark.org.tr/en/pub/marlife

Determination zooplankton fauna of Bayındır Dam Lake (Ankara)

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Please cite this paper as follows:
Can, D. U., & Bozkurt, A. (2023). Determination zooplankton fauna of Bayındır Dam Lake (Ankara). *Marine and Life Sciences*, 5(1), 8-15. https://doi.org/10.51756/marlife.1256397

Research Article

Article History
Received: 28.02.2023
Accepted: 03.06.2023
Published Online: 18.10.2023

Keywords:
Bayındır Dam Lake
Cladoceran
Copepod
Rotifer

A B S T R A C T

Zooplankton samples were collected from four stations in Bayındır Dam Lake between April 2022 and January 2023 using a 60 µm plankton net with horizontal and vertical hauls, and some water quality parameters (water temperature, pH, dissolved oxygen, and conductivity) were determined in-situ. The annual mean water temperature, dissolved oxygen, pH and conductivity were 17.64±7.64 °C, 7.92±0.18 mgL^{-1}, 9.26±1.00 mgL^{-1}, 368.52±24.69 $\mu S\ cm^{-1}$ respectively. Water quality parameters were within normal limits for most aquatic organisms. A total of 87 species were recorded in the reservoir, including 66 rotifers (75.86%), 15 cladocerans (17.24%) and 6 copepods (6.90%). A total of 22 families from Rotifera, 5 families from Cladocera and 2 families from Copepoda were recorded. Brachionidae and Lecanidae (Rotifera) having most of the species were the richest families with 10 species each. With 8 Chydoridae species from Cladocera and 5 Cyclopoidae species from Copepoda, they were discovered to be the most numerous family. It was determined that the dam lake zooplankton consisted of widely distributed cosmopolitan and eutrophication indicator species.

INTRODUCTION

Species composition is crucial for the conservation and control of biodiversity, which is a nation's greatest natural resource (Ceballos et al., 2010). It is clear that necessary actions regarding the sustainable management, and particularly protection of ecosystems, cannot be done because of the lack of taxonomic information. It is known that our country has a very rich fauna composition, but unfortunately, there is still not enough taxonomic information about most of the living groups (Bozkurt and Genç, 2018). Turkey has a good number and length of rivers, lakes, and dam lakes (with a surface area of about one million hectares), that is negatively impacted by the ever-increasing environmental deterioration and settlements.

From the past to the present, many reservoirs have been built in Turkey for drinking water supply, irrigation, flood control, and energy production (Yuksel, 2015). However, as a result of population growth and industrialization, reservoirs are at risk of eutrophication, and the extension of eutrophic conditions could result in biodiversity loss and disruption of the food chain's balance (Brito et al., 2011). As a result, limnological and biological factors in reservoirs should be investigated and evaluated, and the results should be used to improve their water quality. Reservoir biotic and abiotic factors can influence zooplankton species diversity, density, biomass, and spatiotemporal distribution (Dorak et al., 2019).

Most aquatic organisms consume zooplankton throughout their entire lives, while others feed on zooplanktonic organisms for a certain part of their lives, especially in the larval stage (Sales, 2011). This explains the strong correlation between the variety and abundance of zooplanktonic organisms and the productivity of the aquatic environment (Brun et al., 2019).

They play an important role in aquatic environments as most zooplankton (copepod, cladoceran, and rotifer) feed on phytoplankton and rapidly convert plants into animal protein (Svanberg et al., 2022). Although zooplankton is an essential component of the food chain, some species are thought to be good indicators of eutrophication, pollution, and water quality because of their sensitivity to environmental changes (Ismail and Adnan, 2016). For this reason, lake zooplankton studies are becoming increasingly significant. Since zooplankton abundance and composition are closely related to water quality characteristics, they increase and decrease depending on the trophic status of the lakes (İpek Alış and Saler, 2016).

Characterizing the zooplankton fauna of our country, which has very rich and diverse freshwater resources, will contribute to a full understanding of Türkiye's biodiversity.

Previous studies in the dam include: Atıcı et al. (2005) on water pollution control and phytoplanktonic algae flora and Erdoğan (2015) on the taxonomic and limnoecological investigation of Rotifera fauna. No detailed records of zooplankton studies in Bayındır Dam Lake (Ankara). Therefore, this study is aimed at determining the zooplankton fauna of the dam lake.

MATERIALS AND METHODS

The study was carried out between April 2022 and January 2023 in Bayındır Dam Lake (39 ˚ 54 44.52 N, 32 ˚ 59 45.04 E) in Mamak District of Ankara province (Figure 1). Bayındır Dam Lake was built on the Bayındır Stream between 1962 and 1965 for the purpose of supplying drinking water. Body volume of the dam, which is an earth body fill type, is 553.000 m^3 and its height from the stream bed is 30 m. The lake volume at normal water level is 6.97 hm^3, and the lake area at normal water level is 0.71 km^2. It provides 7 hm^3 of drinking and utility water per year and its height above sea level is 940 m. Although Bayındır Stream feeds the dam lake to a great extent, it is also fed by other small creeks around the lake that dry up in summer and autumn.

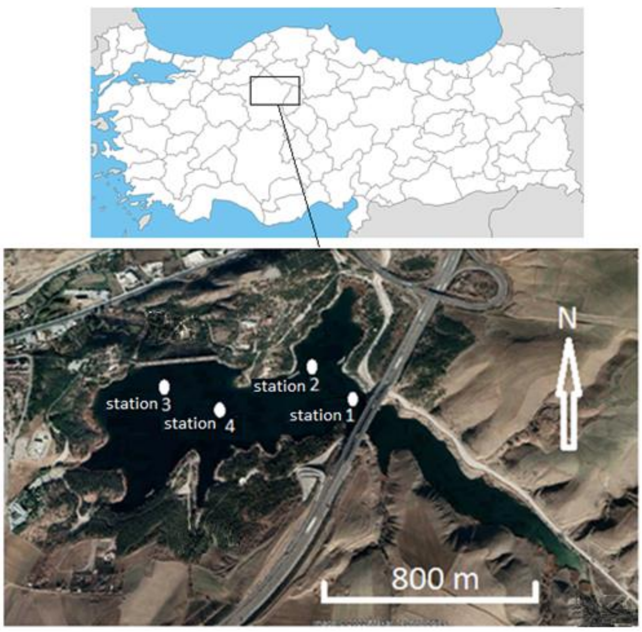

Figure 1. Bayındır Dam Lake and sampling stations

Zooplankton samples were collected seasonally from 4 different stations, three stations from the creek entrances and one station from the mixing points of the creeks, using a plankton net with a diameter of 0.30 m and a mesh size of 60 µm, with horizontal and vertical hauls. Vertical hauls were carried out from the bottom to the surface ten times while horizontal hauls were taken from the water surface for 20 minutes at about 2 mph with a motor boat. All zooplankton samples were fixed in 4% formalin. Dissolved oxygen, water temperature, and conductivity were determined insitu using digital instruments (oxygen and temperature: YSI model 52 oxygen meter; conductivity: YSI model 30 salinometer). Calculations and statistical analysis were conducting using MS Excel and PAST software (PAleontologicalSTatistics, Version 3.20) (Hammer et al., 2001).

Zooplankton species were examined and identified using an inverted microscope and a binocular microscope (Olympus CH40). The specimens were identified using Apostolov and Marinov (1988), Borutsky (1964), Damian-Georgescu (1970), Dussart (1967), Dussart (1969), Holynska et al., (2003), Karaytug (1999), Reddy (1994), Rylov (1963), Segers (1995), Scourfield and Harding (1966), Smirnov (1974) and Negrea (1983).

RESULTS

Water temperature varied between 6.64°C (winter) and 26.80°C (summer), with mean of 17.64±7.64°C (Table 1). It was determined that the pH values were close to each other between stations and seasons. The maximum, minimum, and mean pH values were 7.27 (summer), 9.10 (winter) and 7.92±0.18 respectively (Table 1). Dissolved oxygen varied between 7.00 mgL^{-1} (summer) and 10.81 mgL^{-1} (winter), with a mean of 9.26 ± 1.00 mgL^{-1} (Table 1). The conductivity value ranged from 302.4 µS cm^{-1} (summer) to 544.4 µS cm^{-1} (spring) with mean value of 368.52±24.69 µS cm^{-1} (Table 1).

Table 1. Some water quality parameters (max.-min. and seasonal mean in stations)

	Spring 2022	Summer	Fall	Winter 2023	mean
Temp (°C)	18.34-20.80 19.59±2.98	24.14-26.80 25.96±1.49	16.3-18.62 17.50±0.85	6.64-8.30 7.53±0.65	17.64±7.64
pH	7.50-8.96 8.07±0.69	7.27-8.62 7.67±0.44	7.49-8.70 7.90±0.43	7.55-9.10 8.02±0.53	7.92±0.18
DO (mgL^{-1})	9.20-10.60 9.95±0.46	7.00-8.50 7.86±0.57	8.84-9.81 9.25±0.32	9.22-10.81 9.96±0.46	9.26±1.0
EC (µScm^{-1})	302.4-544.4 392.21±75.23	329-365.4 339.51±13.71	331.2-380.2 356.83±21.82	371.6-412.8 385.54±13.87	368.52±24.69

A total of eighty-seven species were recorded out of which sixty-six (66) species were Rotifera (75.86%), 15 species were Cladocera (17.24%), and 6 species were Copepoda (6.90%) (Table 2). A total of 22 families were recorded among Rotifera with Brachionidae and Lecanidae being the richest with 10 species while Philodinidae, Conochilidae, Trichotriidae, Scaridiidae, Dicranophoridae, Habrotrochidae, and Cotylegaleatidae had 1 species each. Five families were recorded among Cladocera with Chydoridae being the richest with 8 species and least was Bosminidae, Ilyocryptidae and Macrothricidae with one species each (Table 2). Among the 2 families of Copepoda, Cyclopoidae had 5 species, and Ameiridae was represented by one species (Table 2).

The most widely distributed rotifers were recorded in all the seasons,. The rotifers recorded in three seasons were *K. longispina, K. cochlearis, A. priodonta, T. emarginula, A. ovalis, G. stylifer, F. longiseta, T. pocillum, P. dolichoptera, P. vulgaris, S. oblonga, R. rotatoria L. luna, C. adriatica, L. patella, S. stylata, D. aculeata* and *C. gibba* (Table 2).

Table 2. Seasonal indexes (Mean±SE) of sardine individuals in İzmir and Kuşadası Bays

Rotifera	Sp	Su	Fa	Wi		Sp	Su	Fa	Wi
Brachionidae					**Asplanchnidae**				
Anuraeopsis fissa Gosse, 1851	-	ııı	ııı	-	*Asplanchna priodonta* Gosse, 1850	ı	*	*	ııı
Brachionus angularis Gosse, 1851	ıı	-	-	-	*Asplanchna sieboldi* (Leydig, 1854)	ıı	-	-	ı
Brachionus quadridentatus Hermann, 1783	-	ı	-	-	**Collothecidae**				
Kellicottia longispina (Kellicott, 1879)	ııı	ı	*	ı	*Collotheca mutabilis* (Hudson, 1885)	-	*	ıı	-
Keratella cochlearis (Gosse, 1851)	ıı	ııı	ıı	ıı	*Collotheca pelagica* (Rousselet, 1893)	ı	ııı	-	-
Keratella quadrata (Müller, 1786)	ıı	*	-	-	**Testudinellidae**				
Keratella tecta (Gosse, 1851)	ı	*	-	-	*Testudinella emarginula* (Stenroos, 1898)	*	*	*	*
Notholca caudata Carlin, 1943	*	-	-	-	*Testudinella parva* (Ternetz, 1892)	-	*	-	*
Notolca squamula (Müller, 1786)	*	-	-	-	**Gastropodidae**				
Platyias quadricornis (Ehrenberg, 1832)	-	*	*	-	*Ascomorpha ovalis* (Bergendahl, 1892)	ı	*	ı	*
Lecanidae					*Gastropus stylifer* Imhof 1891	ı	ı	ı	ııı
Lecane bulla (Gosse, 1886)	-	ı	*	-	**Philodinidae**				
Lecane closterocerca (Schmarda, 1859)	-	*	*	-	*Philodina megalotrocha* Ehrenberg, 1832	-	*	-	-
Lecane flexilis (Gosse, 1886)	-	*	*	-	**Trochosphaeridae**				
Lecane ludwigi (Eckstein, 1893)	-	ı	*	-	*Filinia longiseta* (Ehrenberg, 1834)	ı	ı	ııı	*
Lecane luna (Müller, 1776)	-	*	*	-	**Conochilidae**				
Lecane lunaris (Ehrenberg, 1832)	-	*	*	*	*Conochilus unicornis* Rousselet, 1892	ıı	*	-	-
Lecane nana (Murray, 1913)	-	*	-	-	**Trichotriidae**				
Lecane pyriformis (Daday, 1905)	-	*	*	-	*Trichotria pocillum* (Müller, 1776)	*	*	*	*
Lecane quadridentata (Ehrenberg, 1830)	-	*	-	-	**Scaridiidae**				
Lecane stenroosi Meissner, 1908)	-	*	-	-	*Scaridium longicaudum* (Muller, 1786)	-	-	*	-
Lepadellidae					**Dicranophoridae**				
Colurella adriatica Ehrenberg, 1831	-	*	*	*	*Dicranophorus grandis* (Ehrenberg, 1832)	-	-	*	-
Colurella colurus (Ehrenberg, 1830)	-	*	-	-	**Habrotrochidae**				
Colurella obtusa (Gosse, 1886)	-	*	-	*	*Habrotrocha aspera* (Bryce, 1892)	*	-	-	-
Colurella uncinata (Müller, 1773)	-	ı	-	*	**Cotylegaleatidae**				
Lepadella ovalis (Müller, 1786)	-	*	*	-	*Cotylegaleata iskenderunensis* De Smet & Bozkurt, 2016	-	-	*	-
Lepadella patella (Müller, 1773)	ı	*	*	-	**Cladocera**				
Lepadella quadricarinata (Stenroos, 1898)	-	*	-	-	**Daphniidae**				
Lepadella rhomboides (Gosse, 1886)	-	*	-	-	*Ceriodaphnia pulchella* Sars, 1862	ı	*	ıı	ı
Synchaetidae					*Daphnia longispina* (Müller, 1785)	ı	*		ııı
Polyarthra dolichoptera Idelson,1925	ııı	ııı	ııı	ıı	*Scapholeberis kingi* Sars, 1888	-	*	*	-
Polyarthra vulgaris Carlin, 1943	ııı	ı	ıı	ıı	*Simocephalus vetulus* (Müller, 1776)	ı	-	*	ı
Synchaeta oblonga Ehrenberg, 1832	ııı	ıı	ııı	*	**Bosminidae**				
Synchaeta pectinata Ehrenberg, 1832	ı	-	-	-	*Bosmina longirostris* Müller, 1785	ı	-	ıı	ııı
Synchaeta stylata Wierzejski, 1893	-	*	ııı	ı	**Ilyocryptidae**				
Trichocercidae					*Ilyocryptus agilis* Kurz, 1878	-	-	ı	-
Trichocerca longiseta (Schrank, 1802)	ı	*	-	-	**Macrothricidae**				
Trichocerca pusilla (Jennings, 1903)	-	*	-	-	*Macrothrix laticornis* (Jurine, 1820)	-	ıı	ı	-
Trichocerca cylindirica (Imhof, 1891)	-	*	-	-	**Chydoridae**				
Trichocerca similis (Wierzeski, 1893)	-	ı	ıı	-	*Alona costata* Sars, 1862	-	-	*	*
Trichocerca weberi (Jennings, 1903)	-	*	-	*	*Biapertura affinis* (Leydig, 1860)	-	ı	ı	*
Notommatidae					*Coronatella rectangula* (Sars, 1862)	-	*	*	*
Cephalodella gibba (Ehrenberg, 1830)	*	*	-	*	*Chydorus sphaericus* (Müller, 1776)	ı	*	ı	*
Cephalodella ventripes (Dixon-Nuttall, 1901)	-	*	-	-	*Graptoleberis testudineria* Fischer, 1851	-	*	*	-
Cephalodella catellina (Müller, 1786)	-	*	-	-	*Pleuroxus aduncus* (Jurine, 1820)	-	*	-	-
Monommata dentata Wulfert, 1940	-	*	-	*	*Pleuroxus laevis* Sars, 1861	-	ı	-	-
Notommata copeus Ehrenberg, 1834	-	*	-	-	*Leydigia acanthocercoides* (Fischer, 1854)	-	-	ı	-
Philodinidae					**Copepoda**				
Dissotrocha aculeata (Ehrenberg, 1832)	-	*	*	*	**Cyclopidae**				
Rotaria neptunia (Ehrenberg, 1830)	ı	-	-	*	*Cyclops vicinus* Uljanin, 1875	ııı	*	-	ıı
Rotaria rotatoria (Pallas, 1766)	*	ı	ıı	ı	*Eucyclops serrulatus* (Fischer, 1851)	-	*	-	-
Mytilinidae					*Eucyclops macrurus* (Sars, 1863)	-	-	-	*
Lophocharis salpina (Ehrenberg, 1834)	-	*	*	-	*Macrocyclops albidus* (Jurine, 1820)	-	*	*	*
Mytilina mucronata (Müller, 1773)	-	*	-	-	*Paracyclops fimbriatus* (Fischer, 1853)	*	*	*	-
Euchlanidae					**Ameiridae**				
Euchlanis deflexa (Gosse, 1851)	*	*	-	-	*Nitokra hibernica* (Brady, 1880)	-	*	*	*
Euchlanis dilatata Ehrenberg, 1832	-	*	-	-	**Number of zooplankton species**	**34**	**72**	**47**	**35**

Key: (Sp: spring, Su: summer, Fa: fall, Wi: winter, - = Absent, * = very few -1/10 individuals in each petri, ı = few -10/30 individuals in each petri, ıı = abundant -30/60 individuals in each petri, ııı = very abundant -more than 60 individuals in a petri)

For the Cladocera, *C. pulchella, B. longirostris, C. sphaericus* recorded in 4 seasons, had the largest distribution range and followed by *D. longispina, S. vetulus, B. affinis* and *C. rectangula* (shown 3 seasons). On the other hand, *C. vicinus, M. albidus, P. fimbriatus* and *N. hibernica* had the largest distribution range (found in 3 seasons) among the copepods.

Some zooplankton species had limited distribution and were recorded in one season. *M. mucronata, B. angularis, B. quadridentatus, N. copeus, E. dilatata, N. caudata, N. squamula, P. megalotrocha, L. nana, L. quadridentata, L. stenroosi, S. longicaudum, D. grandis, C. iskenderunensis, C. colurus, L. quadricarinata, L. rhomboides, S. pectinata, T. pusilla, T. cylindirica, C. ventripes, C. catellina* (Rotifera), *I. agilis, P. aduncus, P. laevis, L. acanthocercoides* (Cladocera), *E. serrulatus* and *E. macrurus* (Copepoda) were recorded in one season (Table 2).

As a result of quantitative analysis, it was observed that zooplankton abundance was generally low. Out of 87 species recorded, only 23 species were very abundant (ııı) and abundant (ıı) in various seasons, while other species were fewer in number. *G. stylifer, A. priodonta, B. longirostris,* and *D. longispina* (Winter); *P. dolichoptera, F. longiseta, S. stylata, S. oblonga* and *A. fissa* (Fall); *K. cochlearis, P. dolichoptera, A. fissa,* and *C. pelagica* (Summer); *K. longispina, P. dolichoptera, P. vulgaris, S. oblonga* and *C. vicinus* (Spring) were very abundant (ııı) (Table 2).

The abundant (ıı) species were *P. dolichoptera, P. vulgaris, K. cochlearis, C. vicinus* (winter), *K. cochlearis, P. vulgaris, R. rotatoria, C. mutabilis, T. similis, B. longirostris, C. pulchella* (fall), *S. oblonga, M. laticornis* (summer), *K. cochlearis, K. quadrata, A. sieboldi, B. angularis* and *C. unicornis* (spring) (Table 2).

Most zooplankton species were recorded in summer with 72 species. This was followed by autumn with 47 species, winter with 35 species, and spring with 34 species. In terms of abundance, 5 species in spring and autumn, 4 species in summer and winter were very abundant (ııı). Zooplankton were abundant (ıı) in autumn with 7 species, in spring with 5 species, in winter with 4 species and in summer with 2 species (Table 2).

Table 3. The relationships between zooplankton and water quality parameters

	Zooplankton species number	Zooplankton abundance
Temp	R^2= 0.81	R^2= 0.95
pH	R^2= 0.98	R^2= 0.68
Con	R^2= 0.89	R^2= 0.58
DO	R^2= 0.71	R^2= 0.89

The correlation between water temperature, pH, conductivity, DO and Zooplankton species number and Zooplankton abundance is as seen in Table 3. It was determined that there was a significant relationship between temperature-zooplankton abundance (R^2= 0.95) and pH-zooplankton species number (R^2= 0.98).

DISCUSSION

Temperature affects the reproduction, nutrition and metabolic activities of aquatic organisms by increasing the biological activity in the water and accelerating the biochemical reactions and is one of the most important environmental parameters that affect and control the species diversity and zooplankton density in aquatic ecosystems (Sharma et al., 2007). Studies have shown that environmental characteristics, especially water temperature have a significant impact on zooplankton composition and abundance, and that high zooplankton abundance is associated with high water temperature (Rossetti et al., 2009; Dorak, 2013). Similar results were observed in our study, and the highest number of species (72 specimens) were found in the summer season when the average temperature was the highest (25.96±1.49). Similarly, zooplankton abundance was high in spring (19.59±2.98) and autumn (17.50±0.85) when the temperature was partially high, in accordance with the reports of Pennak (1989) and Hunt and Matveev (2005).

Conductivity is important water quality parameters that is significantly correlated with zooplankton abundance and distribution (Estlander et al., 2009). Although the change in the conductivity of a lake water depends on various factors, it varies depending on the temperature of the water, the amount of water entering the lake and precipitation. In general, while the conductivity increases with the increase of water temperature, it also increases due to evaporation when there is not enough rain or stream inflow. At the same time, pollution can also increase the conductivity of lakes and rivers, as industrial and human wastewater often have high conductivity (Wetzel, 1983). Electrical conductivity was high in spring and winter, and low in summer and autumn in the dam lake. It is not possible to comment on the seasonal variation of the conductivity due to the lack of sufficient information on precipitation amounts, the amount of water entering the lake and the pollutants. The conductivity value specified in the protocol on fisheries standards and the protection of surface water resources against pollution is between 400–1000 µS cm^{-1} (OSIB, 2015). It was determined that the conductivity values ranged between 302.4 and 544.4 µS cm^{-1}, the conductivity in all seasons was within normal limits and suitable for zooplankton life (Estlander et al., 2009).

The amount of dissolved oxygen varies according to the temperature and the trophic status of the lakes (Viet et al., 2016). The majority of zooplankton species can tolerate high amounts of oxygen, and studies have shown that low oxygen conditions can impair zooplankton growth, reproduction, and distribution. Dissolved oxygen levels below 5 mgL^{-1} in fresh water can restrict zooplankton growth (Karpowicz et al., 2020). In the study, the lowest dissolved oxygen was recorded in summer and the highest in winter, due to the fact that high temperature decreases dissolved oxygen in water, while it increases it at low temperature. The recorded dissolved oxygen levels (7.00 - 10.81 mgL^{-1}) were higher than 5 mgL^{-1}. The lake appears to be suitable for zooplankton life based on the dissolved oxygen level.

pH, which is important for the life cycle of zooplankton, can affect zooplankton abundance; Alkaline conditions associated with high primary production favor zooplankton growth and abundance (Bednarz et al., 2002; Mustapha, 2009), while low pH results in reduced zooplankton abundance, biodiversity, and extinction of some species (Ivanova and Kazantseva, 2006). It is stated in The Ministry of Forestry and Water Affairs of the Republic of Turkey (OSIB, 2015) that the pH values of fresh water to be between 6.00 and 9.00 in the regulation of Quality Criteria for Turkish Surface Water Resources. The pH values of the reservoir were between 7.27 and 9.10, its level was slightly to moderately alkaline and it was suitable for zooplankton species to live (Tessier and Horwitz, 2011).

Related studies have shown that rotifera was predominant in both qualitative and quantitative characteristics in most lenthic waters (Jamila et al., 2014; Ismail and Adnan, 2016; Dorak et al., 2019; Saler et al., 2019). Furthermore, Segers (2008) reported that rotifers are common in freshwater environments, including sewage ponds, and that they are also opportunistic in pertubed environments.

The dominant taxa recorded - *Asplanchna, Brachionus, Keratella, Notholca, Collotheca, Testudinella, Lecane, Colurella, Lepadella, Ceriodaphnia, Polyarthra, Synchaeta, Rotaria, Euchlanis, Daphnia, Scapholeberis, Simocephalus, Bosmina, Trichocerca, Alona, Coronatella, Chydorus, Pleuroxus, Cephalodella, Cyclops* and *Eucyclops* were common in inland waters of Türkiye (Ustaoğlu, 2004; Ustaoğlu et al., 2012; Ustaoğlu, 2015; Tugyan and Bozkurt, 2019). On the other hand, almost all of the zooplankton species are cosmopolitan, widespread species (Ramdani et al., 2001; Eldredge and Evenhuis, 2003) and are highly tolerant to changes in environmental conditions (Ustaoğlu, 2004; Bozkurt and Güven, 2010; Özdemir Mis et al., 2011; Bozkurt and Akın, 2012; Gaygusuz and Dorak, 2013; Saler et al., 2015; Ustaoğlu, 2015; Bozkurt et al., 2018).

Zooplankton plays a key role in indicating the degree of eutrophication and water pollution (Heneash and Alprol, 2020). Species belonging to the genus *Brachionus, Lecane,* and *Keratella*, which are important eutrophication markers (Mola, 2011) and; were widely recorded in this study. Rotifers, which are generally more abundant in eutrophic waters, respond much more quickly to environmental changes in aquatic environments and are more sensitive indicator organisms to changes in water quality (Ceirans, 2007)..

Consequently, *A. fissa, A. priodonta, B. angularis, B. quadridentatus, C. mutabilis, E. dilatata, F. longiseta, K. longispina, K. cochlearis, K. qaudrata, K. tecta, L. bulla, L. luna, L. lunaris, L. patella, N. squamula, P. quadricornis, P. dolichoptera, R. neptunia, T. cylindrica, T. pusilla, B. longirostris, C. sphaericus, C. rectangula, D. longispina, G. testudinaria, C. vicinus, E. serrulatus* recorded in this study have been reported to be eutrophic indicators (Dussart, 1969; Voigt and Koste, 1978; Pesce and Maggi, 1981; Berzins and Bertilsson, 1990; Hansen and Jeppesen, 1992; De Manuel Barrabin, 2000; Petrusek, 2002; Shah and Pandit, 2013; Apaydın Yağcı, 2016).

Some of the recorded species *A. fissa, A. priodonta, A. sieboldii, B. angularis, B. quadridentatus, C. catellina, C. gibba, C. ventripes, C. mutabilis, C. pelagica, C. adriatica, C. colurus, C. obtusa, C. uncinata, E. deflexa, E. dilatata, F. longiseta, K. longispina, K. cochlearis, K. quadrata, K. tecta, L. bulla, L. closterocerca, L. flexilis, L. luna, L. lunaris, L. nana, L. pyriformis, L. quadridentata, L. ovalis, L. patella, L. quadricarinata, M. mucronata, P. quadricornis, P. dolichoptera, S. longicaudum, S. oblonga, S. pectinata, T. emarginula, T. longiseta, T. pusilla, T. weberi* and *T. pocillum* have been reported to tolerate a wide range of conductivity (RuttnerKolisko, 1974; Herzig and Koste, 1989; Arcifa et al., 1994; De Ridder and Segers, 1997; Baribwegure and Segers, 2001; Pattnaik, 2014).

Based on some zooplankton species (especially *Brachionus, Lecane,* and *Keratella*), it can be said that the dam lake was tending towards eutrophication in line with Erdoğan (2015).

CONCLUSION

The zooplankton species were cosmopolitan and widely distributed species. Rotifera was the dominant group, followed by Cladocera and Copepoda. The dominant families were Brachionidae and Lecanidae (Rotifera), Chydoridae (Cladocera) and Cyclopoidae (Copepoda). It can be said that the lake is in tending towards eutrophication due to the dominance of Rotifera (*Brachionus, Keratella,* and *Lecane*) that were eutrophication indicators. Moreover it can be seen that most of the species recorded have ecological characteristics suitable for being in the dam where the study was conducted.

Compliance with Ethical Standards

Authors' Contributions

This study was produced from the postgraduate thesis of Deniz Ulaş Can, a graduate student. All authors have contributed equally to the work. All authors read and approved the final manuscript.

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.

Data Availability

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

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Mar. Life Sci. (2023) 5(1): 16-25 E-ISSN: 2687-5802

Marine and Life Sciences

Journal Homepage: https://dergipark.org.tr/en/pub/marlife

Feasibility of hydropower reservoirs for fish cage Aquaculture: A strategy for fish farming in drought risk areas in Kenya

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Please cite this paper as follows:
Abwao, J., Opiyo, M. A., Kyule, D., Kendi, J., Mungai, D., & Ojuok, T. M. (2023). Feasibility of hydropower reservoirs for fish cage Aquaculture: A strategy for fish farming in drought risk areas in Kenya. *Marine and Life Sciences*, 5(1), 16-25. https://doi.org/10.51756/marlife.1221254

Research Article

Article History
Received: 12.01.2023
Accepted: 27.02.2023
Published Online: 19.10.2023

Keywords:

Cage culture
ASAL
Food production
Socio-economic effects

A B S T R A C T

A significant portion of the Arid and Semi-Arid Lands rural population in Kenya suffers from social challenges linked to hunger, starvation, and malnutrition. The existing hydropower dams in these areas can be leveraged upon for fish production through the adoption of cage culture. This study sought to assess the suitability and feasibility of these dams for cage culture as a strategy for socio-economic and nutritional empowerment of the rural communities. In this study, a survey was conducted including fish farmers, fishermen, and communities who use the dam waters for domestic and agricultural purposes. The main research approaches were semi-structured questionnaires for in-depth, one-on-one interviews with participants. Descriptive and inferential statistics were used to summarize the data sets on socio-demographic indicators, such as age, economic status, education, and economic activities. The Majority of the respondents 49.6% cited fishing from the dam as the most important benefit accrued although the dams have been overfished and the harvests are dwindling from the observation. In the survey, 26.8% of the respondents identified water level fluctuation as the main challenge to cage establishment, followed by theft (25%) and wild animal menace (16.07%). Water quality analysis revealed both in situ parameters (Dissolved oxygen, temperature and pH) and nutrient concentrations as within levels acceptable for fish farming.

INTRODUCTION

Food insecurity is a major global concern while eliminating extreme poverty and hunger is the first Millennium Development Goal (MDG 1), therefore, fulfilling it is essential to achieving the other seven MDGs (Lomazzi et al., 2014). Aquaculture, often known as fish farming, is a practical and cutting-edge method for boosting food security in Kenya's drought-prone regions. Fish farming is quickly gaining popularity among other rural livelihoods, such as agriculture, due to its unexplored potential to create employment and enhance food security since it offers vulnerable households with highly nutritious animal protein and crucial micronutrients (Golden et al., 2017). Kenyans are extremely vulnerable to food insecurity due to climate change's manifestations in periodic droughts, floods, and the drying up of water resources. A significant portion of the arid and semi-arid lands (ASALs) rural population suffers from ailments linked to hunger, starvation, and malnutrition (Ngaira, 2009).

The ASALs counties of Embu and Machakos harbour great opportunities for cage culture investment for improved community livelihoods for example, the River Tana has five hydropower reservoirs in its upper watershed, with more reservoirs (including those for Karura, Mutonga, Low Grand Falls, Usheni, Adamsons Falls, Kora, and High Grand Falls) still planned downstream of the current reservoirs (Okuku et al., 2016). In other studies, small water bodies SWBs in the two counties have been found to have the highest carrying capacities with Masinga dam constituting about 51217 Tons (Aura et al., 2022). Despite these opportunities, there has never been a feasibility study conducted to assess their suitability for the venture bordering socioeconomic and ecological parameters. While it is well recognized that reservoirs have negative socioeconomic and environmental effects on the nearby riparian communities, it is crucial to establish solutions that will reduce these effects so that these hydropower projects dams can bring economic empowerment to the communities and alleviate poverty.

The concept of "blue economy," which emphasizes the valuation and wise use of resources connected to rivers, lakes, and seas holistically, is crucial for both economic growth and sustainable development (Wenhai et al., 2019). Fish plays significant role for dietary variety and nutritional security, particularly for lower-income households in both urban and rural regions. For example, fish provide 7% of all proteins and 17% of animal protein for the more than 3 billion people living in developing nations (FAO, 2022). The capture fisheries catches in Kenya has been on the decline overtime due to challenges such as climate change and variability, invasive species, overfishing, declining stocks and postharvest losses (Muringai et al., 2022). In response to this scenario, Kenya's freshwater aquaculture industry is quickly growing as a result of the nation's growing fish demand. The growth in the sub-sector, though modest, has been steady, rising from 4,452 Metric tonnes (MT) (in 2008) to a high record of 24,096 MT in 2014. Currently the national production is approximately 22000 MT (Kenya National Bureau of Statistics 2020). However, as reported by Odende et al. (2022) there is a lot of room for growth by adopting sustainable technologies and practices. Such technology would center around aquaculture systems that use less water especially in ASAL areas where due to variability in climate, poor soils structure and diverse environmental challenges, uptake of land-based aquaculture system is not possible. However, there is an opportunity for fish production through cage culture in the hydropower dams and small water bodies in these areas.

Cage culture is relatively new fish farming system which is becoming an investment choice and preference amongst the fish farmers in Kenya. The practice is more pronounced in Lake Victoria and apart from conserving the dwindling indigenous wild fish stock, cage culture has emerged as a promising new socioeconomic frontier (Aura, 2020). Kenya attempted to implement fish cage culture for the first time in Lake Victoria in 2005. Trials had setbacks, but in 2010 cage fish farming was revitalized thanks to increased research efforts and involvement from the community through Beach Management Units by the Association for Strengthening Agriculture Research in East and Central Africa (ASARECA) project (Aura et al., 2018). It has been recognized as a game-changer since then and has sporadically developed in Lake Victoria primarily involving the monoculture of *Oreochromis niloticus* (Opiyo et al., 2018).

This study was carried out to assess the feasibility of cage aquaculture in the seven folks dams particularly the Kiambere dam and Masinga in Embu and Machakos counties respectively. There is need to understand the socio economic profile of the riparian communities to the two dams as well as the Spatio-temporal physico-chemical parameters of the dam waters to determine their suitability for the culture of tilapia. The results from this study could motivate other people from different part of the country to practice cage fish farming in small water bodies and get benefits of it through improved food supply, employment, and income generation and ultimately improve the livelihood of the marginalized communities.

MATERIALS AND METHODS

Study area

The investigation was carried out amongst residents' riparian to Kiambere and Masinga Dams located in Embu and Machakos counties respectively (Figure 1). These two dams are hydropower generation projects but can still provide opportunities for cage culture to enable food security to the riparian communities in Embu and Machakos counties. The dams are located in ASALs counties which have limitations in variety of economic activities hence relegated to livestock keeping, subsistence crop farming. The demography in these areas is also associated with low population density.

Data collection

The main sampling populations included fish farmers, fishermen, and communities who used the dam waters for domestic and agricultural purposes. Key informants included staff from government organizations involved in the management of the dams, such as the Tana-Athi River Development Authority, Kenya Electricity Generating Company (KenGen), Kenya Wildlife Services (KWS), county fisheries officers (FOs), were also targeted in data collection. The sampling population was 29 respondents fewer than expected due to low population density of the target groups, characteristic of ASAL areas.

The research approaches used were semi-structured questionnaires for in-depth, face to face interviews with participants, which made it much simpler to explain non-verbal behavior (Awuor et al., 2021).

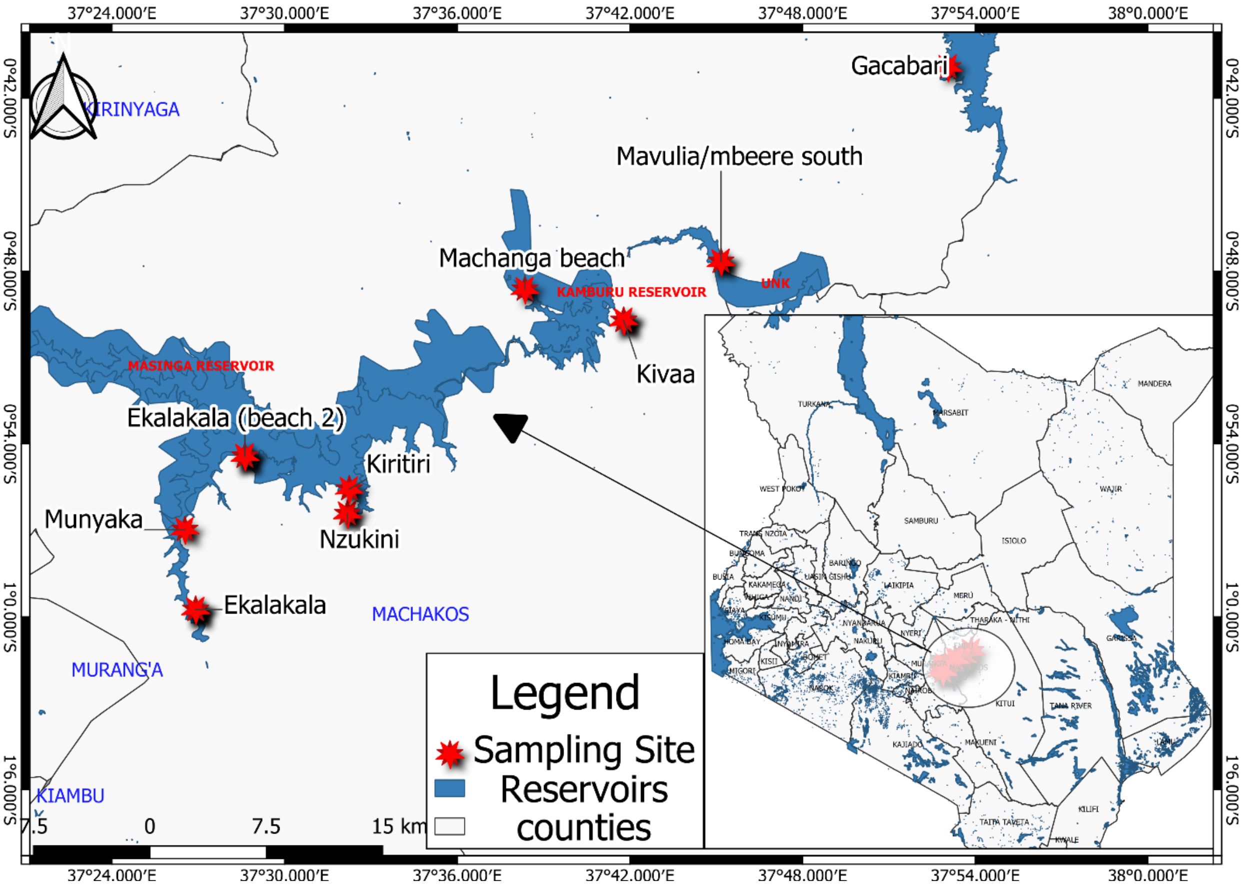

Figure 1. Data collection points amongst the respondents and stakeholders benefiting from the Masinga and Kiambere Dams.

In designing the questionnaire, the goals of the study were taken into consideration. Global positioning system (GPS) was used to mark out the data collection points in Kiambere and Masinga dams in Embu and Machakos counties respectively. Water quality parameters were recorded from specified sampling point; at the dam intake, mid areas and outflow points. Dissolved oxygen, pH, temperature, salinity and conductivity were measured in situ using YSI industries, yellow springs, OH, USA, multiparameter water quality meter while concentrations of nitrites (NO_2), ntrates (NO_3) posphates (PO_4) and ammonium concentrations were at analyzed at the Kenya Marine and Fisheries Research Institute (KMFRI), Sagana laboratory using standard methods (APHA, 2005).

Data analysis

The collected data was recorded in Microsoft Excel of Microsoft suite of 2016, coded and then transferred into Statistical Package for Social Sciences (IBM-SPSS Inc. version 23.0 IBM Corp.) and R statistical software. Both descriptive and inferential statistics were employed to determine the distribution of data and to explore relationships between variables respectively. Descriptive statistics included frequencies and percentage proportions for categorical variables such as social demographic factors while means and standard deviations were used to illustrate continuous variables such as nutrient concentrations and physical-chemical parameters. Tests of statistical significance that include chi-square tests of independence, analysis of variance and t tests were employed to determine statistical significance at 95% confidence interval or 0.05 critical alpha level. Open ended parts of the data were coded into common themes and expressed in bar graphs. Summaries were illustrated in tables while distributions were illustrated using bar graphs.

RESULTS AND DISCUSSION

Socio demographic indicators

Majority of the respondents were males (96%) Considering that majority of the respondents practiced fish farming which is male dominated (Table 1). Similar outcomes have been reported in other studies such as Aura et al. (2018), Abwao and Fonda (2019), Awuor et al. (2021). At least the respondents have some level of formal education to be able to articulate and understand cage culture technology with additional hands on training on the activities. Majority of the respondents (70%) had primary education, 26% had secondary education while only one individual had higher education. Most of the respondents were fish farmers, crop and livestock farmers due to the proximity of the communities to the dams thus benefiting from the dam waters to carry out these activities.

Table 1. Some of the socio-demographic indicators of the riparian population in Masinga and Kiambere Dams

Indicators		*n* (Proportion %)
GENDER	Female	1 (4.3%)
	Male	22 (96%)
AGE	<40	11 (48%)
	40-50	6 (26%)
	>50	6 (26%)
EDUCATION	Certificate	1 (4.3%)
	Primary	16 (70%)
	Secondary	6 (26%)
MAIN OCCUPATION	Fishing	13 (57%)
	Farming	3 (13%)
	Fishing and farming	2 (9%)
	Fish trading	3 (13%)
MONTHLY INCOME (Kenya shillings)	<20,000	10 (43.5%)
	20,000 to 40,000	10 (43.5%)
	40,001 to 60,000	2 (8.7%)
	>60,000	1 (4.3%)

**One United States dollars (USD) is equivalent to 126.5 Kenya shillings (KES) (current exchange rates)*

Some of the Socio-demographic indicators of community's riparian to Masinga and Kiambere dams is presented in Table 1. The average age for all respondents was 41 years old with a standard deviation (SD) of 10 years. The average monthly income for all the respondents was KES 26,000 while only 4.3% earned more than KES. 60,000 per month. There was no significant association between the level of education and monthly earning of the respondents (p=0.4). Therefore, reasons for low earnings per months could be related to other factors including use of traditional fishing methods which are poor and rudimentary like wooden boats with no engines and an overexploited fishery of the dams hence less earnings from the activity. This is affirmed by Martin, et al. (2013) in their assessment of the relationship between fishing, livelihood diversification and poverty in rural Laos. The study revealed that the relative household wealth was largely influenced by gear type and location of fishing.

Secondly, climate change aspects could be affecting water levels in the dams as recorded in figure 4 where water fluctuation was given as the biggest challenge to cage culture in the study areas due to aridity. This therefore leads to more expenditure in water extraction which reduces profit margins. While fishing groups in such areas at times are not extremely income poor, Simmance et al. (2022) confirms that these communities may experience multiples shock such climate variability, environmental degradation, poor regulation and marketing aspect which then erodes their wealth.

Benefits of the dams to the local community

Establishment of dams often come with negative environmental and ecological impacts which lead to secondary deprivation of the community livelihood (Okuku et al., 2016), if prior environmental and social impact assessment (EISA) is not carried out. However, in the present survey, it was realized that every respondent draws some benefits from the dams including fishing, water for irrigation, livestock and domestic use, sand harvesting and navigation as presented in Figure 2.

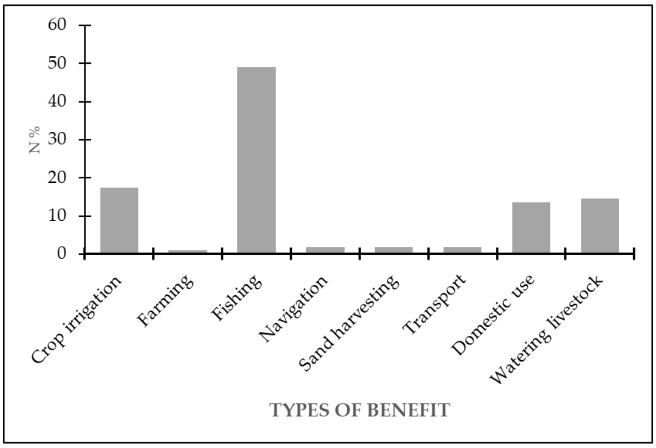

Figure 2. Benefits of Masinga and Kiambere Dams to the local communities

The majority of the respondents 49.6% cited fishing from the dams as the most important benefit accrued although the dams have been overfished and the harvests were dwindling from the observation. The riparian communities can leverage on the experiences and the nutritional benefits they get from the fish in order to establish modern fish farming systems for more fish production. At least 17.5% of the respondents used the water for crop irrigation while 13.5% each used the dam waters for domestic and livestock use.

Fish farming as an economic activity

This study sought to find out if the communities around the Masinga and Kiambere dams were already practicing aquaculture. This is due to the fact that, the Kenyan government launched the Economic Stimulus Programme (ESP) between 2009 and 2013, which identified and mapped out potential sites for pond development as part of a commitment to revive the economy (Musa et al., 2012). Fish farming was expected to contribute to greater income and food security, particularly for ASALs. However, the project did not take off in ASALs counties due to scarcity of water and poor soil structure. Some Fish farmers domiciled around the Masinga and Kiambere dams were supported in the project due to availability of the water. From the survey, 17% of the respondents were involved in fish farming while 83% were not involved in the activity. Those practicing fish farming were motivated by its role as a source of income and food for household consumption. Those not involved fish farming (83%) highlighted challenges emanating from lack of technical skills (16%), (5.3%) cited lack of startup capital and high input cost, competition from cheap fish imports from china (5.3%) and unfavorable business environment (5.3%). As reported by Ombwa et al. (2018), pond based system, in particular, require a lot of water, which makes them ineffective and susceptible to climate change, hence lowers their output. They are also characterized by both functional and technical challenges such as land scarcity, flooding menace, rapid water quality deterioration amongst others. All these factors perhaps contributed to low or lack of uptake of fish farming in areas around Masinga and Kiambere dams despite availability of water.

Aquaculture training

In this study majority of respondents 87% did not have trainings on aquaculture while 13% had been trained on pond construction, hatchery design, fish feed formulation, record keeping and enterprise budgeting (Table 2). This is linked to the low uptake of aquaculture amongst the communities' riparian to the two dams as described by Obiero et al. (2019). There was no mention on any trainings on cage culture amongst the respondents considering it is a new fish farming system, however, the knowledge gained from the pond based system could be leveraged upon to implement the cage culture investment.

Table 2. Training in aquaculture amongst the residents of Masinga and Kiambere dams

Characteristic	N = 23
RECEIVED TRAINING (Y/N)	
NO	20 (87%)
YES	3 (13%)
SOURCES OF TRAINING	
County fisheries Extension Department	2 (67%)
Private Service Provider	1 (33%)
ASPECTS OF AQUACULTURE TRAINED ON	
Pond construction and design	1 (33%)
Pond construction and design, Hatchery management practices	1 (33%)
Pond construction and design, Record keeping and Enterprise Budgeting, Fish feed formulation, storage and administration, Fish breeding and genetics	1 (33%)

Sustainable aquaculture in the ASALs will be influenced to a large extent by implementation of the best aquaculture practices. Identification of training needs as well as implementation points are important in enhancing fish productivity in these areas (Das 2019). Extension officers play important role in imparting knowledge and enhancing adoption of technology, innovation and management practices (TIMPS) to the farmers and in this survey it was revealed that 67% training and capacity building was performed by the local County Fisheries Extension Department as well as private sector players such as the local Non-governmental organization (NGOs).

Cage as an alternative culture system

In seeking to evaluate farmers' awareness and interest in the adoption of cage culture as an alternative fish production, 65% of the respondents reported interest to start cage culture while 35% did not demonstrate interest in cage culture investment (Table 3).

Table 3. Communities' interest in cage aquaculture in Masinga and Kiambere Dams

Characteristic	N = 23
INTEREST IN CAGE FARMING (Y/N)	
NO	8 (35%)
YES	15 (65%)
REASONS FOR INTEREST IN CAGE CULTURE	
As an alternative source of income	3 (13%)
Easier to manage, Assured fish catch	3 (13%)
There is low fish catch from wild	4 (17%)
To increase fish production	5 (22%)
REASONS FOR LACK OF INTEREST IN CAGE CULTURE	
There is already fish in the dams	1 (8%)
Insecurity/theft	3 (25%)
Lack of knowledge	2 (16%)
Needs high initial capital	2 (16%)

The respondents were motivated by the need to diversify income sources (13%) hence improved livelihoods, increased fish production (22%) for enhanced nutritional security while the dwindling catches from the dams (17%) triggered the need for investment in cage aquaculture as an alternative way of fish production. The 35% of the respondents that did not report interest for cage culture gave the availability of wild fish in the dam (8%), insecurity and theft (25%), and high initial capital (16%) as some of the reasons that impede the desire to start cage culture. The interest in cage fish farming in the dams by respondents in this study correspond to many affirmations by different authors on the socio economic impacts and sustainability of cage culture to improved livelihoods on the communities, (Aura et al., 2018; Ombwa et al. 2018; Abwao and Fonda 2019; Orina et al., 2021).

Other economic activities

As demonstrated in figure 3 in this survey, 25% of the respondents engaged in commercial crop farming as a source of livelihood, 20% subsistence crop farming while 11.4 % engaged in commercial livestock farming. The dominance of crop farming amongst the population is due to the availability of water for irrigation. Only 2.9 % recorded as fish traders probably due to the dwindling stock and low catch from the dams hence little fish to sell. More fish would be available for food, improving both health and wealth, if cage culture is used in the dams. Furthermore, integrating various farming endeavors with aquaculture will ensure the expansion of various commercial and non-commercial activities for better livelihoods for ASALs populations.

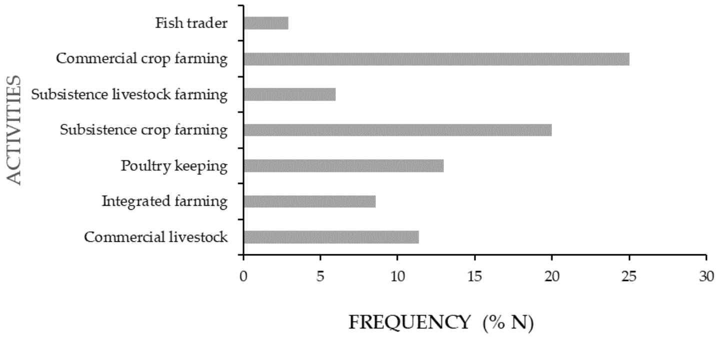

Figure 3. Other economic activities performed by the communities living around Masinga and Kiambere Dams

Challenges hindering cage culture establishment

Despite the numerous opportunities in cage culture investments, there exists several challenges to the establishment of cage culture as illustrated in Figure 4. That include insecurity, lack of technical skills and general information, lack of capital, wild animals and fluctuations in water levels.

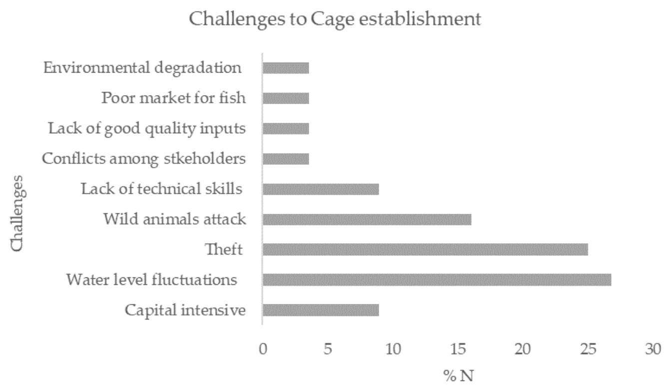

Figure 4. Challenges hindering establishment of cage culture

In this survey, majority of the respondents (26.8%) cited water levels fluctuation as a major constraint in the establishment of cages in the two dams. Fluctuation in water levels is common in the dams located in ASALs regions in Kenya due to climate change resulting from prolonged drought and reduced precipitation (AECOM, 2021). Theft of fish from cages and insecurity was mentioned as another impediment (25%), linked to the investment in cage fish culture in the dams as confirmed by Mary et al. (2021) and Charo-karisa et al. (2009) in a study on cages in lake Victoria. The authors indicated poverty as the contributing factor to the theft of fish and cages. Poverty levels are equally highest amongst the communities bordering the dams due to extreme climatic conditions.

The dams under survey are located in areas neighbouring game parks and reserves hence the interference by wildlife has a bearing on the establishment of cages. At least 16% of the respondents reported wildlife such as hippopotamus and crocodiles as a hindrance to cage culture investment. These animals can destroy cages and cause fish escapes (Charo-karisa et al., 2009). Other challenges included lack of capital (8.9%) considering investment in cage is an expensive venture, lack of technical skills (8.9%) and lack of quality inputs (3.6%) amongst other constraints. Although lack of quality inputs was ranked lowly amongst the challenges, quality seeds and feeds are very important for a successful cage fish aquaculture production (Munguti et al., 2022). Conflicts amongst the dam water users is likely to also have a considerable impediment to investment in cage culture by the riparian communities. Stakeholders such as the department of fisheries, Kenya wildlife services (KWS), Kenya Electricity Generating Company (KENGEN), Tana-Athi river development authority (TARDA) need to have an agreement with the local communities so as to mitigate on conflicts that arise from the use of the dams and reservoirs.

Water quality assessment

Fish culture systems require water as the only medium to live in and carry out all life functions such as feeding, growth, waste excretion reproduction and osmotic balance (Sibomana et al., 2022). Therefore, there is need to consider biological, chemical and physical characteristic of the water. The in-situ water quality measurements for this study are presented in Table 4. Temperature, dissolved oxygen (DO) and pH are very important parameters for fish growth and in this study, all these parameters were within optimum range for the growth of tilapia in Kiambere and Masinga dams. Temperature ranged between minimum 24.30 and maximum 28.39^{o}C, DO ranged between 5.57 and 7.71 mg/l while pH ranged between 7.44 and 8.66 According to El-Sayed and Kawanna (2008), *Orechromis niloticus* experience better performance in growth and survival at an optimum temperature of 26-30^{o}C while temperatures below 24^{o}C significantly reduce growth rate and feed utilization.

The impact of DO in culture systems cannot be over emphasized because at low level it causes mortality, susceptibility to diseases, stress, poor appetite and slow growth rate. Results recorded for the DO levels in the two dams is sufficient for fish culture as the values concur with recommendations by Abd El-Hack et al. (2022).

Table 4. Physico-chemical parameters (in situ) in Kiambere and Masinga Dams

Month	Site	Temps (^{o}C)	D.O(mg/L)	Conductivity	TDS	Salinity	pH
March	Kitui side	27.90±0.10	5.85±0.06	147.80±0.78	92.83±3.18	0.06	7.71±0.05
March	Kiambere mid	28.13±0.06	5.78±0.21	149.67±0.31	96.35±0.26	0.06	7.76±0.02
March	Kiambere Embu	27.90±0.10	5.89±0.24	146.10±0.52	88.90±0.85	0.06	7.69±0.09
March	Wamboo	28.25±0.05	7.56±0.13	136.71±0.38	83.90±0.18	0.06	8.36±0.14
June	Kitui side	28.16±0.10	5.64±0.13	146.71±0.80	94.33±3.18	0.06	7.46±0.05
June	Kiambere mid	28.39±0.06	5.57±0.21	148.67±0.31	97.85±0.26	0.06	7.51±0.02
June	Kiambere Embu	28.16±0.10	5.68±0.24	145.10±0.52	90.40±0.85	0.06	7.44±0.09
June	Kiengeli	27.27±0.34	7.55±0.12	138.14±1.77	85.79±1.07	0.06	8.38±0.29
June	Kakuku	26.77±0.10	7.71±0.33	130.79±1.11	82.25±0.00	0.06	8.60±0.17
September	Kitui side	24.35±0.05	6.67±0.35	108.77±0.23	71.50±0.00	0.05	7.76±0.04
September	Kiambere mid	24.60±0.06	7.00±0.49	109.87±0.16	71.50±0.00	0.05	8.00±0.10
September	Kiambere Embu	24.75±0.05	6.54±0.24	110.40±0.00	72.15±0.00	0.05	8.11±0.04
September	Kiengeli	24.67±0.05	6.81±0.28	122.33±2.44	80.31±1.53	0.06	8.24±0.21
September	Wamboo	24.30±0.00	7.04±0.43	101.85±1.07	66.98±0.53	0.06	7.68±0.11
September	Kiembeni	26.13±0.55	7.31±0.12	112.70±0.20	71.50±0.00	0.06	8.26±0.05
September	Kakuku	27.10±0.17	7.43±0.12	118.33±0.12	74.10±0.00	0.06	8.66±0.05
September	Thagana	24.37±0.21	7.57±0.26	107.30±1.85	69.55±0.00	0.06	8.25±0.05

Table 5. Nutrient concentration in Kiambere and Masinga Dams

Month	Site	PO_4 (µg/L)	NO_2 (µg/L)	NO_3 (µg/L)	NH_4 (µg/L)
March	Kitui side	1.69±0.03	0.67±0.03	1.11±0.04	3.72±0.16
March	Kiambere mid	1.60±0.03	0.70±0.01	0.94±0.03	3.39±0.24
March	Kiambere Embu	1.77±0.03	0.66±0.01	1.16±0.06	3.79±0.11
March	Wamboo	2.01±0.05	0.77±0.13	1.34±0.02	5.05±0.19
June	Kitui side	1.91±0.03	0.81±0.00	1.28±0.01	4.15±0.19
June	Kiambere mid	1.77±0.03	0.70±0.07	1.15±0.04	3.74±0.8
June	Kiambere Embu	1.97±0.03	0.75±0.05	1.24±0.01	4.70±0.11
June	Wamboo	2.19±0.05	0.89±0.09	1.24±0.01	3.99±0.11
June	Kakuku	2.38±0.03	0.85±0.07	1.46±0.01	4.12±0.15
September	Kitui side	2.21±0.05	0.78±0.01	1.38±0.02	3.37±0.15
September	Kiambere mid	2.38±0.03	0.85±0.07	1.46±0.01	4.12±0.15
September	Kiambere Embu	1.74±0.07	0.69±0.03	1.13±0.02	3.99±0.11
September	Kiengeli	1.93±0.03	0.61±0.02	1.00±0.01	3.47±0.11
September	Wamboo	2.30±0.07	0.62±0.01	1.22±0.02	3.47±0.04
September	Kiembeni	2.60±0.05	0.75±0.03	1.29±0.02	3.87±0.23
September	Kakuku	2.46±0.05	0.64±0.01	1.21±0.01	3.29±0.23
September	Thagana	2.26±0.03	0.75±0.01	1.32±0.01	3.84±0.09

The authors have indicated that the optimum DO level should be kept above 5mg/L to ensure good growth while pH of the water is best for the growth of tilapia at an optimum of between 7 and 8.

Nutrient concentration in the dams

Nutrient concentrations in Masinga and Kiambere Dams were analysed and presented in Table 5. Cage culture is an intensive fish farming system characterized by overuse of proteinaceous feeds and high stocking density which lead to increased loading of nitrogenous and other metabolites in the water (Ciji and Akhtar 2020). Exposure of fish to nitrites can cause adverse effects on fish health and growth. In this study, nitrite concentration ranged between 0.66 to 0.89 µg/L. Since the optimum nitrite concentration for tilapia in freshwater is 0.3 mg/L, the levels of nitrite in the two dams are minimal and have no impact on the fish's growth or physiological processes.

In intensive culture systems ammonia and nitrites are critical parameters and should be monitored regularly. This is because intensive culture systems like cage fish farming require high quality feed coupled with high stocking densities which can contribute to increased levels of unionized ammonia (NH_3) and nitrites (NO_2) (Bahnasawy et al., 2009). Analysis of nitrates (NO_3) and phosphate (PO_4) concentration is critical in aquatic system due to their contribution to primary productivity. The supply of these nutrients is affected by both enteral inputs and biogeochemical processes within the ecosystem (Howarth et al., 2021). In this study, the phosphates and nitrates ranges between 1.60 to 2.60 µg/L and 0.94 to 1.46±0.01 µg/L respectively. A proper balance of N and P is important in ensuring increased primary productivity of an ecosystem while information on the trophic status is critical in determination of the potential the dams have in accommodating cage culture (Guo and Li, 2003). The quantities of nitrates and phosphates are negligible and therefore there is need to provide the fish with high quality diet for improved growth and yields.

CONCLUSION

Adoption of cages for fish farming in the hydropower dams and reservoirs is a promising venture that can be used to transform socio-economic wellbeing of the rural communities. Cage culture is capital intensive, associated with theft of fish and also conflict with wild animals that can destroy the cages leading to losses. The government and private sector need to leverage on the opportunities existing in these dams to initiate fish farming in the ASALs areas to promote affirmative action in these marginalised communities. Proper siting of the cages and carrying capacities of the two water bodies will be an important consideration to mitigate against the effects of dam water fluctuations and quality. Community sensitization and stakeholder participation and engagement will be important in curbing arising conflicts between the riparian communities and government agencies managing the dams. Extensive services and capacity building will also ensure that cage fish farming in the dams is done based on good aquaculture practices for increased productivity, income and nutritional security.

ACKNOWLEDGEMENT

The funding for this activity was provided by Kenya marine and Fisheries Research Institute (KMFRI) through the GoK seed Research funds. Mr. Joel Gatagwu, KMFRI technologist is acknowledged for technical assistance in water quality sampling and analysis.

Compliance with Ethical Standards

Authors' Contributions

All authors have contributed equally to the work. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

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

Data Availability

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

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Mar. Life Sci. (2023) 5(1): 26-36 E-ISSN: 2687-5802

Marine and Life Sciences

Journal Homepage: https://dergipark.org.tr/en/pub/marlife

Su ürünleri yetiştiriciliğinde postbiyotik ve paraprobiyotiklerin yeri

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Please cite this paper as follows:
Aydın, F. (2023). Su ürünleri yetiştiriciliğinde postbiyotik ve paraprobiyotiklerin yeri. *Marine and Life Sciences*, 5(1), 26-36. https://doi.org/10.51756/marlife.1287544

Derleme

Makale Tarihçesi
Geliş Tarihi: 25.04.2023
Kabul Tarihi: 26.05.2023
Online Yayınlanma: 23.10.2023

Anahtar Kelimeler:
Biyoaktif bileşikler
Mikrobiyal hücreler
Metabolitler
Probiyotik
Bağışıklık

Keywords:
Bioactive compounds
Microbial cells
Metabolites
Probiotic
Immunity

Ö Z E T

Su ürünleri yetiştiriciliğinde, antibiyotiklere alternatif olarak çevre dostu yem katkı maddelerinin (probiyotik, prebiyotik, sinbiyotik) kullanımı son yıllarda hızla artmaktadır. Yeterli miktarlarda uygulandığında konakçıya sağlık açısından fayda sağlayan canlı mikroorganizmalar olarak kabul edilen probiyotik ürünlerde, üretim aşamaları sırasında ve üretimden sonra ölü hücreler ile karşılaşılabilmektedir. Buna rağmen konakçıda faydalı etkiler gösteriyor olmaları cansız mikrobiyal hücreler veya hücrelerin parçalanmasıyla oluşan hücre bileşenlerinin de etkili olabileceği 'postbiyotik ve paraprobiyotik' olarak ifade edilen tanımların kullanılmasını beraberinde getirmiştir. Bu derlemede, postbiyotik ve paraprobiyotik kavramlarının alternatif tanımları, postbiyotik ve paraprobiyotiklerin elde edilme yöntemleri ve su ürünleri yetiştiriciliğinde kullanım alanlarına dikkat çekilmiştir.

The role of postbiotics and paraprobiotics in aquaculture

A B S T R A C T

In aquaculture, the use of environmentally friendly feed additives (probiotics, prebiotics, synbiotics) as an alternative to antibiotics has been rapidly increasing in recent years. In probiotic products, that are considered as living microorganisms which provide health benefits to the host when applied in sufficient quantities. Even dead cells can be encountered during the production processes and after the production. According to the fact that they can show beneficial effects on the host before and after processes has initailly led to the use of definitions 'postbiotic and parabiotic', in which non-living microbial cells or cell components formed by the breakdown of cells can also be effective. In this review, alternative definitions of postbiotic and parabiotic concepts are discussed, the methods of obtaining postbiotics and parabiotics are evaluated and their use in aquaculture are highlighted.

GİRİŞ

Su ürünleri yetiştiriciliği balıkların gıdayı ete verimli bir şekilde dönüştürmesi ve birim alan başına yüksek miktarda biyokütle elde edilebilmesi nedeniyle karaya dayalı hayvancılık sistemlerinden ekonomik olarak daha verimlidir. Ayrıca su ürünleri yetiştiriciliği en hızlı büyüyen gıda üretim sektörlerinden biri haline gelmektedir (Khan ve ark., 2011; FAO, 2020).

Su ürünleri yetiştiriciliği sektörünün hızla büyümesi, çevresel sürdürülebilirliğin sağlanması açısından bazı istenmeyen koşulların doğmasına yol açabilmektedir. Yetiştiriciliğin yapıldığı ortamlarda yüksek stoklama oranları patojenlerin gelişebilmesi için uygun ortam hazırlarken, konakçının duyarlılığını da artırmaktadır (Bouwmeester ve ark., 2021). Yoğun yetiştiricilik yapılan işletmelerde gerekli önlemler alınmaz ise çevresel koşulların bozulması da söz konusudur. Bu durum üretim yapılan havuzlarda salgın hastalıkların görülme sıklığını da arttırmaktadır. Ayrıca, hastalıkların tedavisi dahil, su ürünleri yetiştiricilik faaliyetleri yapılırken antibiyotikler, antiparaziter ilaçlar, kirlenme önleyiciler, anestezikler ve dezenfektanlar gibi kimyasal etkenlerin yoğun kullanımı çevre üzerinde olumsuz etkiler yaratma ve çevre konusunda kaygıları arttırmaktadır (Burridge, 2010).

Su ürünleri yetiştiriciliğinde, bakteriyel enfeksiyonların tedavisinde kullanılan antibiyotiklerin birçoğu geniş spektrumlu olduğundan patojenin neden olduğu ölümleri azaltırken, diğer taraftan konakçının bağırsak mikrobiyotasında bulunan bakterilerin sayı ve çeşitliliği üzerinde olumsuz etkiye neden olabilmektedir. Antibiyotiklerin yaygın ve sistematik kullanımı, yetiştiriciliği yapılan canlının bağırsak mikrobiyotasında bulunan duyarlı mikroorganizmaları yok edebilir ve dirençli fırsatçı patojenlerin çoğalmasını kolaylaştırabilir. Ayrıca bu durum antimikrobiyal direnç sağlayan genetik materyalin, balık bağırsak mikrobiyotasında bulunan yerli popülasyonlardan fırsatçı veya potansiyel olarak patojen olan mikroorganizmalara aktarılmasına ve yetiştiricilik yapılan ortamda balık patojenlerinde antibiyotik direncin artmasına yol açabilmektedir. Su ortamında bulunan bakterilerde oluşan bu antibiyotik direnç, insan ve hayvan patojenleri dahil olmak üzere karasal ortamdaki bakterilere de yatay gen transferi yoluyla bulaşabilmektedir. Ayrıca balık eti ve balık ürünlerinde antibiyotik kalıntısı bulunma olasılığı, antibiyotik kullanımının olumsuz etkileri arasındadır. Antibiyotik kalıntısı besin zinciri yoluyla sucul/karasal hayvanlara, sucul habitatlara ulaşarak insan sağlığına ve çevreye zarar vermesi ekosistem üzerinde ciddi tehdit oluşturmaktadır (Sørum, 2005; Cabello, 2006; Navarrete ve ark., 2008; Ubeda ve Pamer 2012; Romero ve ark., 2014; Aydın ve Çek-Yalnız, 2019; Yukgehnaish ve ark. 2020; Awad ve ark., 2022; Okeke ve ark, 2022).

Günümüzde su ürünleri yetiştiriciliğinde hastalıkların yönetimi, kontrolü, balık sağlığı ve refahı konusunda çevre dostu alternatif çözüm arayışı ön plana çıkmaktadır. Bu alternatif çözümlere probiyotik, prebiyotik, sinbiyotik kullanımının yanıt verdiği pek çok araştırmada görülmektedir (Hai, 2015; Hoseinifar ve ark., 2016; Dawood ve ark, 2018; Amenyogbe ve ark., 2020; Butt ve ark., 2021; Puri ve ark., 2023).

Son on yılda, su ürünleri yetiştiriciliği ile ilgili yapılan araştırmalarda probiyotik, prebiyotik, sinbiyotik kullanımının yaygınlaşmasının ve kabul görmesinin nedeni, canlıların gastrointestinal gelişimini uyararak; beslenme, sindirim ve metabolik süreçleri düzenleme, besin alımını iyileştirme, bağışıklık sistemini güçlendirme gibi konakçı fizyolojisini, sağlığını ve hastalık yönetimini düzenlemede bağırsak mikrobiyomunun önemli rol oynamasıdır (Romero ve ark., 2014; Dahiya ve Nigam, 2023; Diwan ve ark., 2023).

İmmünostimülanlar veya immünsakkarit olarak da isimlendirilen prebiyotikler, bağırsaktaki probiyotikler tarafından besin olarak kullanılırlar. Prebiyotikler, bağırsak bağışıklık sisteminin çeşitli bileşenlerini teşvik ederek bağışıklık yanıtının düzenlenmesi ile doğrudan; fermantasyon işlemi yoluyla faydalı metabolitler üretilmesi veya bağırsaktaki faydalı mikroorganizma popülasyonunu artırması ile dolaylı olarak, konakçı üzerinde çok sayıda faydalı etkiye neden olan sindirilemeyen bileşiklerdir (Nawaz ve ark., 2018; Martín ve Langella, 2019). Su ürünleri yetiştiriciliğinde faydalı olduğu tespit edilen, ‘oligosakkaritler’ (Fruktooligosakkaritler (FOS), Mannan oligosakkarit (MOS), Galaktooligosakkarit (GOS), Arabinoksilan-oligosakkarit (AXOS)) ve ‘polisakkaritleri’ (Inulin, β-glucan) içeren pek çok prebiyotik grubu ile ilgili araştırmalar yapılmıştır (Song ve ark., 2014)

Probiyotik bakterilerin faydalı etkileri, probiyotikler ve prebiyotiklerin bir kombinasyonu olan sinbiyotiklerin kullanımıyla arttırılabilmektedir (de Vrese ve Schrezenmeir, 2008). Su ürünleri yetiştiriciliğinde sinbiyotiklerin, konakçıda yemden yararlanma ve büyüme parametrelerinde artış ve hastalıklara karşı direnç kazanma gibi olumlu etkileri bulunmaktadır (Kaya ve ark., 2022; Oliveira ve ark., 2022; Siddik ve ark., 2022)

Probiyotikler, esas olarak organizmaların gastrointestinal sistem mikroflorasını dengelemek için kullanılan canlı mikroorganizmalardır (Bhogoju ve Nahashon 2022). Ancak son yıllarda canlı olmayan mikroorganizmaları tanımlamak amacıyla paraprobiyotik ve mikrobiyal metabolitler ile mikrobiyal hücre duvarı bileşenlerini tanımlamak amacıyla da postbiyotik kavramları kullanılmaya başlanmıştır (Cuevas-González ve ark., 2020). Güncel kaynaklar incelendiğinde, postbiyotik ve paraprobiyotik terimlerinin tanımı konusunda uluslararası ortak bir terminoljinin mevcut olmadığı ve fikir birliği sağlamasının kolay olmadığı görülmüştür.

Çalışma ile son yıllarda özellikle insan ve çevre sağlığı yönü ile öne çıkmaya başlayan postbiyotik ve paraprobiyotikler ile ilgili bilgi birikimine, terminolojik olarak tanımlarına, elde edilme şekillerine ve su ürünleri yetiştiriciliğinde kullanım alanlarına katkı sunulması amaçlanmıştır.

Probiyotikler

Probiyotik, yeterli miktarlarda uygulandığında konakçıya sağlık açısından fayda sağlayan canlı mikroorganizmalardır (FAO/WHO, 2002). Probiyotiğin, ‘yeterli miktarda uygulanması’, ‘canlı olması’ ve ‘konakçıya fayda sağlaması’ şeklinde üç özelliği öne çıkmaktadır. Ancak bu üç özellik incelendiğinde gerçekten ‘probiyotik’ bu özellikleri sağlıyor mu? sorusu güncelliğini korumaktadır.

Aşağıda bu üç temel özelliğin sağlanıp sağlanmadığını araştıran çalışmalar incelenmiştir.

Probiyotiklerde Canlılık Durumu ve Canlı Hücre Miktarı

Probiyotiklerin konakçılara sağlayabileceği fayda, uygulanan canlı mikrobiyal hücre miktarı ile son derece yakından ilgilidir. Probiyotik içeren gıda ürünlerinin etiketinde yer alan canlı mikroorganizma sayısının doğru olarak belirtilmesi gerekmektedir (Fiore ve ark., 2020). Aynı şekilde su ürünleri yetiştiriciliğinde de kullanılan probiyotik ürünlere olan güveni sürdürmek için, ürünlerdeki mikroorganizmaların raf ömürleri boyunca hayatta kaldıklarını kanıtlamak önemlidir (Wang ve ark., 2008; Awad ve ark., 2022).

Etikette, raf ömrünün sonunda mevcut olan her bir probiyotiğin canlı konsantrasyonunun belirtilmesi beklenmektedir. Burada etikette belirtilen tek doz başına mikrobiyal koloni oluşturan birim (kob) miktarı, raf ömrünün sonunda bulunması gereken minimum canlı hücre konsantrasyonuna karşılık gelmektedir (Fiore ve ark., 2020). Türk Gıda Kodeksi'ne göre, 'Probiyotik gıda: İçerisinde raf ömrü sonuna kadar yeterli miktarda canlı probiyotik mikroorganizma (en az $1.0x10^6$ kob/g) bulunduran ve bu canlılığı muhafaza eden ürün' olarak tanımlanmaktadır. Ancak probiyotik formülasyonlarında canlı olmayan hücrelere de rastlamak her zaman olasıdır. Probiyotik kullanılan ürünlerde ölü hücre sayısındaki artış, ürüne ilave edilirken olabilmektedir. Balık yemine probiyotik ilave edildiğinde, üretim sırasında aşırı sıcak ve basınç gibi etkiler nedeniyle üretim aşamaları sırasında hücreler ölebilmektedir. Bazı laktik asit bakterileri teknolojik olarak hassas suşlar olarak kabul edilmektedirler. Probiyotik içeren ürünlerdeki ölü hücre sayısındaki artış, kullanılan suş, üretim teknolojisi, paketleme, dağıtım, depolama gibi pek çok faktöre bağlı olarak değişmektedir. Bütün bu faktörler probiyotik içeren ürünün, raf ömrü süresince etkinliğinin korunmasında rol oynamaktadır (Wang ve ark., 2008; Nayak 2010 Fiore ve ark., 2020; Roy ve ark., 2022).

Das ve ark. (2013)'ları probiyotik katkılı (Bacillus amyloliquefaciens) balık yemini oda sıcaklığında (28°C) 4 hafta muhafaza ettiklerinde canlı hücrelerde ortalama %44,11'lik bir azalma olduğunu, 4°C'de 4 hafta boyunca muhafaza ettiklerinde ise canlı hücrelerde ortalama %18,61 azalma olduğunu belirlemişlerdir. Aly ve ark. (2008)'ları balık yemine ilave edilen probiyotik (*Bacillus subtilis* ve *Lactobacillus acidophilus*)'deki canlı hücre sayılarına hem 4°C hem de 25°C'de 1, 2, 3 ve 4 haftalık depolamadan sonra incelediklerinde 4°C'de saklanan probiyotik yemde, oda sıcaklığında (25°C) saklananlara göre önemli ölçüde daha fazla sayıda canlı hücre olduğunu tespit etmişlerdir. Irianto ve Austin (2002)'de benzer şekilde dört ayrı probiyotik katkılı yemi 20°C yerine 4°C'de muhafaza ettiklerinde daha fazla sayıda canlı hücre kaldığını ancak tüm probiyotiklerdeki canlı hücre sayısının 8 haftalık süre içinde azaldığını saptamışlardır.

Probiyotiğin, saklama koşulları, suşa özgü koşullar ki burada spor oluşturmayan probiyotik bakterilerin olumsuz koşullarda istenen canlılığı koruması oldukça zordur, endüstriyel üretim aşamaları, raf ömrü gibi faktörler nedeniyle canlı hücre sayısının azalması etkili dozu standardize ederken yanıltıcı da olabilir (Dash ve ark., 2015; Nayak, 2010). Yapılan çalışmalar incelendiğinde, probiyotiklerin temel özelliklerinden olan yeterli miktarda uygulanması ve canlı kalması özelliğini her zaman tam olarak karşılamadığı görülmüştür.

Probiyotiklerin Konakçıya Fayda Sağlaması

Su ürünleri yetiştiriciliğinde probiyotiklerin faydalı etkileri incelenirken probiyotiğin dozu, maruz kalma süresi, su sıcaklığı ve su kalitesi de dikkate alınmalıdır (Awad ve ark., 2022)

Probiyotiklerin büyük çoğunluğu literatürde, genel olarak güvenli (GRAS, Generally Regarded As Safe) ve sağlıklı bireyler için yararlı olarak kabul edilmektedir. Ancak bağışıklık sistemi baskılanmış, aşırı geçirgen bağırsak sendromu veya kritik hastalıklara sahip bireylerde probiyotiklerin seçiminde dikkat edilmesi gerekmektedir (Fijan, 2014). Sıklıkla kullanılan laktobasiller ve bifidobakterileri içeren birçok probiyotik suş, konakçının normal sağlıklı bağırsak mikrobiyotasında bulunduğu için sağlık açısından risk oluşturmadığı düşünülmektedir. Bu gruba ait probiyotiklerin sağlık üzerinde yararlı etkilerine dair pek çok araştırma bulunmaktadır. Bununla birlikte, uzun bir güvenli kullanım geçmişi olmayan yeni potansiyel probiyotiklerin, güvenli kabul edilebilmesi için daha fazla çalışma yapılmalıdır. (Lahtinen ve ark., 2009). Bu nedenle, yapılan araştırmalar incelendiğinde su ürünleri yetiştiriciliğinde kullanılan probiyotikler ile ilgili olarak mikroorganizma ve konakçı arasındaki etkileşimlerin anlaşılması yönünde daha fazla çalışmaların yapılmasına ihtiyaç olduğu görülmektedir.

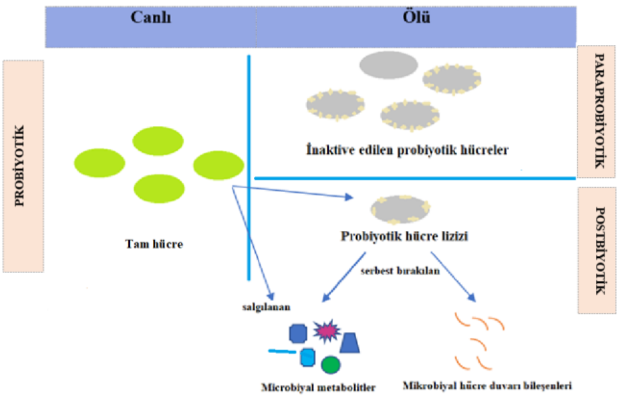
Paraprobiyotikler ve Postbiyotikler

Paraprobiyotik (hayalet/inaktive edilmiş probiyotikler) terimi ilk defa Taverniti ve Guglielmetti, (2011) tarafından literatüre eklenmiştir. Bu terimi, 'yeterli miktarlarda uygulandığında tüketiciye fayda sağlayan bozulmamış/parçalanmış cansız mikrobiyal hücreler veya ham hücre ekstraktları olarak tanımlamayı önermişlerdir. Cansız mikrobiyal hücreler elde edilirken fiziksel veya kimyasal inaktivasyon yöntemlerden etkilenmemeleri gerektiğini belirtmişlerdir. Mikrobiyal orijinli saflaştırılmış moleküller veya saf mikrobiyal hücre ürünlerini ise bu kavram içerisine dahil etmemişlerdir.

Probiyotiklerin konakçıya fayda sağlaması için canlı olmaları gerektiği belirtilmektedir. Ancak paraprobiyotik olarak isimlendirilmemiş olsa da probiyotiklerin inaktive edilerek kullanılabileceğini belirten çalışmalar bulunmaktadır (Dawood ve ark., 2015; Hai, 2015) Yapılan araştırmalar inaktive edilmiş probiyotiklerin konakçıya fayda sağladığını göstermektedir. Probiyotik mikroorganizmalar inaktivasyon işlemine maruz kaldıktan sonra hücre duvarının yırtılması, DNA filamentleri ve hücre zarının zarar görmesi gibi etkiler nedeniyle canlılıklarını tamamen kaybetmektedirler. Ancak inaktive edilmiş hücrelerin konakçıda sağlık açısından fayda sağlayabilecek aktivite gösterdikleri tespit edilmiştir. Bu nedenle parabiyotikler, konakçıya fayda sağlayan inaktive edilmiş mikrobiyal hücreler veya hücre fraksiyonları olarak da tanımlanmaktadırlar (Irianto ve Austin 2003; Kamilya ve ark., 2015; de Almada ve ark., 2016; Cerezo ve ark., 2022; Danladi ve ark., 2022).

Postbiyotikler (metabiyotikler), konakçıya olumlu etki sağlayabilen, probiyotik mikroorganizmalar tarafından salgılanan mikrobiyal metabolitler veya mikroorganizmalar parçalandıktan sonra salınan metabolitler ve mikrobiyal hücre duvarı bileşenleridir (Ang ve ark., 2020; Cuevas-González ve ark., 2020).

Probiyotik, paraprobiyotik ve postbiyotik terimlerini anlatan şematik görünüm Cuevas-González ve ark. (2020) modifiye edilmiştir (Şekil 1).



Şekil 1. Probiyotik, paraprobiyotik ve postbiyotik terimlerini anlatan şematik görünüm Cuevas-González ve ark. (2020)'den modifiye edilmiştir

Figure 1. Schematic view of probiotic, paraprobiotic and postbiotic terms, modified after Cuevas-González et al. (2020).

Postbiyotikler arasında peptitler, kısa zincirli yağ asitleri, enzimler, peptidoglikan ve lipopolisakarit, hücre yüzeyi proteinleri, teikoik asit, vitaminler, organik asitler, plazmalojenler, peptidoglikan türevli muropeptitler, endopolisakkaritler ve ekzopolisakkaritler bulunmaktadır (Ang ve ark., 2020; Barros ve ark., 2020; Goh ve ark., 2022).

Gastrointestinal sistemde bulunan mikroorganizmalar doğal süreçte prebiyotikleri kullanarak anaerobik koşullar altında postbiyotik veya biyoaktif postbiyotikler olarak isimlendirilen metabolik ürünler açığa çıkarırlar. Postbiyotikleri laboratuvar yöntemleriyle üretmek ve elde etmek de mümkündür (Aghebati-Maleki ve ark., 2021; Thorakkattu ve ark., 2022). Ancak saflaştırılmış mikrobiyal metabolitler ve aşılar postbiyotik olarak kabul edilmemektedir (Salminen ve ark., 2021; Aggarwal ve ark., 2022).

Probiyotikler için ihtiyaç duyulan soğuk taşıma zinciri parabiyotikler için gerekli olmaması ekonomik açıdan avantaj sağlamaktadır. Parabiyotikler probiyotikler gibi canlı olmadıklarından, probiyotiklere göre stabilitesi yüksek ve raf ömrünün uzun olduğu belirtilmektedir. Ayrıca paraprobiyotiklerin cansız olması nedeniyle antimikrobiyal direnç genlerinin, başka hücrelere yatay olarak aktarma riskinin muhtemelen daha düşük olacağı ileri sürülmektedir (Shripada ve ark., 2020; Goh ve ark., 2022).

Yapılan çalışmalar incelendiğinde, paraprobiyotikler cansız, tam veya parçalanmış inaktive edilmiş probiyotik mikroorganizmalar veya karmaşık kimyasal bileşime sahip ham hücresel ekstraktları içermektedirler (Taverniti ve Guglielmetti, 2011). Postbiyotikler ise canlı probiyotik mikroorganizmalar tarafından üretilen veya hücre parçalanmasından sonra salınan biyoaktif çözünür faktörler olarak da isimlendirilen ürünler veya metabolik yan ürünleri kapsamaktadırlar (Ang ve ark., 2020; Cuevas-González ve ark., 2020) (Şekil 1). Paraprobiyotikler ve postbiyotiklerin bir kısmı inaktive edilmiş mikroorganizmalardan elde edilmesi nedeniyle literatürde bu terimlerle ilgili bir netliğin olmadığı tespit edilmiştir (Salminen ve ark., 2021).

2019 yılında Uluslararası Probiyotikler ve Prebiyotikler Bilimsel Derneği (UPPBD) farklı alanlarda yer alan uzmanlarla birlikte düzenlediği panelde postbiyotik tanımını ele almışlardır. Postbiyotik 'konakçıya sağlık yararı sağlayan cansız mikroorganizmaların ve/veya bileşenlerinin hazırlanması' olarak tanımlanmıştır. Etkili postbiyotiklerin sağlık üzerinde fayda sağlayan, metabolitleri olan veya olmayan inaktive edilmiş mikrobiyal hücreler veya hücre bileşenleri içermesi gerektiğini belirtmişlerdir (Salminen ve ark., 2021).

Salminen ve ark., (2021)'ları Uluslararası Probiyotikler ve Prebiyotikler Bilimsel Birliği panelinde inaktive edilmiş mikroorganizmaları da postbiyotiklerin tanımı içerisine dahil ederek postbiyotiklerin tanımı ve konusunda fikir birliğine varıldığını ifade etmişlerdir. Ancak, 2022 ile 2023 yılındaki literatürün bir kısmı incelendiğinde; 2022 yılında;

Batista ve ark. (2022), Butera ve ark. (2022), Danladi ve ark. (2022), Goh ve ark. (2022), Li ve Tran, (2022), Lim ve ark. (2022), Michels ve ark. (2022), Tukaram ve ark. (2022); 2023 yılında; Dang ve ark. (2023), Jonesti ve ark. (2023), Luna-González ve ark. (2023), Michels ve ark. (2023), Rahman ve Dandekar, (2023), Sharma ve ark. (2023), Song ve ark. (2023), Xie ve ark. (2023)'ları olmak üzere birçok makalede inaktive edilmiş mikroorganizmaların hala paraprobiyotik olarak tanımlamalarının yapıldığı görülmektedir.

Paraprobiyotikler ve Postbiyotiklerin Elde Edilme Yöntemleri

Paraprobiyotikler, probiyotik mikroorganizmaların inaktivasyonu ile elde edilmektedirler. İnaktivasyon yöntemleri, pastörizasyon, sterilizasyon gibi ısı uygulaması, iyonlaştırıcı radyasyon, ultraviyole (UV) ışınları, yüksek basınç, sonikasyon, darbeli elektrik alanı teknolojisi gibi ısı içermeyen uygulamalar veya UV-C ışık ve ısıl işlemin bir arada olduğu uygulamaları içermektedirler (Shripada ve ark., 2020).

Parabiyotiklerin elde edilmesinde yaygın olarak kullanılan yöntemler aşağıda verilmiştir. Paraprobiyotikler 'ısı' (hücre zarı hasarları, protein pıhtılaşması, ribozom agregasyonu vb.), 'yüksek basınç' (hücre zarı hasarları, protein denatürasyonu, enzimlerin inaktivasyonu vb.), 'sonikasyon' (hücre duvarı yırtılması, hücre zarı hasarları, DNA zararları), 'ışınlama' (nükleik asit hasarları) 'ultraviyole ışınları' (protein denatürasyonu, DNA fotoürünlerinin oluşumu), kimyasal uygulama (örneğin, formaldehit) gibi farklı yöntemlerle inaktive edilebilirler (de Almada ve ark., 2016; Nataraj ve ark., 2020).

Probiyotiklerin suşa özgü etki mekanizmaları bulunmaktadır. İnaktivasyon yöntemlerinin hücrenin yapısal bileşenlerini farklı şekilde etkileyebilir olmaları nedeniyle paraprobiyotiklerin faydalı etkileri koruyabilen uygun inaktivasyon yönteminin seçilmesi konusunda dikkat edilmesini gerekmektedir. Çünkü her bir yöntemin yapısal hücre bileşenlerini etkileyen farklı mekanizmaları vardır. Uygun inaktivasyon yöntemi seçilmesi durumunda elde edilen paraprobiyotik, probiyotiklerin sağladığı faydalı etkilere sahip olabilmektedir (de Almada ve ark., 2016; Deshpande ve ark., 2018; Barros ve ark., 2020).

Paraprobiyotiklerin canlı probiyotiklerin sahip olduğu yararlı etkileri korudukları ancak zararlı olmalarının pek olası görülmediği belirtilmektedir. İnaktivasyon yöntemi ile elde edilen paraprobiyotiklerin uygun kültür ortamlarına ekilerek canlı olup olmadıkları kontrol edilebilmektedir (Shripada ve ark., 2020). Paraprobiyotiklerin üretiminde probiyotik inaktivasyonunu optimize ederken akış sitometri analizi kullanılarak probiyotik işlevselliğini koruyup korumadığını tespit edilebilmektedir (Barros ve ark., 2021).

Postbiyotikler bakteri üremesi sırasında ortama salgılanan ürünler veya metabolik yan ürünler gibi çözünür faktörleri içermektedirler. Ancak bazı çalışmalarda, üreme sonrasında bakteri hücrelerinin enzimler, termal, sonikasyon ve yüksek basınçlı işlemler ile veya bu uygulamaların kombinasyonu ile parçalanması sağlanmaktadır Parçalama işlemlerinin uygulanması postbiyotiklere bazı ek hücre içi metabolitlerinin ve hücre duvarı türevli maddelerin katılmasını sağlayarak işlevselliklerini arttırmaktadır (Moradi ve ark., 2021).

Postbiyotikler, çoğunlukla laktik asit bakterileri (Lactobacillus cinslerinden) ve mayalar (özelikle Saccharomyces cerevisia) tarafından gerçekleştirilen fermantasyon yoluyla elde edilir. Kısa zincirli yağ asitleri, bakteriyosinler ve organik asitler bazı postbiyotik örnekleridir. Bu bileşikler antimikrobiyal, immünomodülatör, antioksidan ve antienflamatuar aktiviteler sergilerler (Duarte ve ark., 2022; del Valle ve ark., 2023; da Silva Vale ve ark., 2023).

Su Ürünleri Yetiştiriciliğinde Postbiyotik ve Paraprobiyotiklerin Kullanılması

Su ürünleri yetiştiriciliğinde probiyotikler, bağışıklık sisteminin güçlendirme (Rodríguez ve ark., 2007), büyümeyi destekleyici (Khattab ve ark. 2005; Carnevali ve ark., 2006), patojenik mikroorganizmaların inhibisyonu (Ravi ve ark., 2007; Subharanjani ve ark., 2015) gibi pek çok konuda konakçıya fayda sağlamaktadır. Ancak probiyotik ilave edilen yemin hazırlanması ve depolanması sırasında canlı hücre sayısında azalma görülmesi istenmeyen bir durumdur. Probiyotiklerin sağladığı faydalara benzer etkiler gösteren biyoaktif bileşikleri içeren postbiyotik ve paraprobiyotiklerin kullanımı son yıllarda su ürünleri yetiştiriciliğinde yerini almaya başlamıştır. Post ve paraprobiyotiklerin su ürünleri yetiştiriciliğinde kullanılması elde edilme yöntemleri, uygulandıkları balık türleri, uygulama süreleri ve elde edilen sonuçlar kronolojik sıraya göre Tablo 1'de verilmiştir.

SONUÇ

İnsan ve hayvanlarda kullanılan probiyotik ürünlerin kalitesi ve kullanımları ile ilgili potansiyel risklerin olma ihtimali her zaman söz konusudur. Antibiyotik direnç genlerine sahip olan probiyotikler, bu direnci patojen veya patojen olmayan mikroorganizmalara aktarabilirler. Ayrıca, üretim ve depolama aşamasında probiyotiklerin canlı hücre sayısında azalma görülmektedir. Probiyotikler için etkili dozun standardize edilmesi ve stabilitesini koruması açısından bu durum sorun yaratmaktadır.

Probiyotiklerin canlılığını koruyarak biyoyararlanım düzeyini arttırmak için birçok çalışmada mikrokapsülasyon yöntemi önerilmektedir. Olumsuz koşullarda balıklarda

Tablo 1. Postbiyotik ve paraprobiyotiklerin su ürünleri yetiştiriciliğinde kullanılması
Table 1. Use of postbiotic and paraprobiotics in aquaculture

Tür adı	Postbiyotik -paraprobiyotik veya İnaktivasyon yöntemi	Uygulama süresi	Sonuç	Referans
Cyprinus carpio	*Paraprobiyotik* ve *postbiyotik* bileşiği	98 gün	Hepatosomatik indeksde azalma Büyüme performansına etkisi yok Spesifik olmayan bağışıklık artış antioksidan seviyelerinde artış Bağırsak sağlığını ve bağırsak mikrobiyota kompozisyonunu iyileştirme	Meng ve ark., 2023
Dicentrarchus labrax	*Postbiyotik,* mayadan ekstrakte edilen nükleotidler ve nükleik asitler	80 gün	Büyüme performansında artış Lipit etkinliğini iyileştirme TGF-β artış, IL-1 β azalış ile bağırsak mukozası üzerinde olumlu etki	Pelusio ve ark., 2023
Micropterus salmoides	*Paraprobiyotik* (çoklu maya fraksiyonları)	65 gün	Pamuk tohumu proteini konsantresi bazlı diyetle beslenen balıklarda bağırsak mikrobiyota düzenlemesi yoluyla karaciğer fonksiyonları üzerindeki olumsuz etkisini azaltma	Xie ve ark., 2023
Cyprinus carpio	*Postbiyotik* (*Cetobacterium somerae* ve *Lactococcus lactis*)	98 gün	Büyüme performansına etkisi yok Karaciğer ve bağırsak sağlığını iyileştirme	Yu ve ark, 2023
Micropterus salmoides	*Paraprobiyotik* (çoklu maya fraksiyonları)	65 gün	Bağışıklık ve bağırsak mikrobiyotasını düzenlemesiyle Büyüme performansında artış Düşük balık unu diyetinde maya takviyesiyle bağırsak geçirgenliği, enflamatuar ortamı düzenleme	Xie ve ark., 2022
Oreochromis niloticus	*Paraprobiyotik* (*Bacillus* sp. NP5)	30 gün	Büyüme performansını, bağışıklık yanıtı ve *Streptococcus agalactiae* enfeksiyonuna karşı dirençte artış	Aldy Mulyadin ve ark., 2021
Penaeus vannamei	*Paraprobiyotik, (Clostridium butyricum CBG01)*/sonikasyon	42 gün	Büyüme performansı, yaşama oranı ve bağışıklık yanıtında artış	Luo ve ark.,2021
Oncorhynchus mykiss	*Postbiyotik,* iki laktik asit bakterisinden elde edilen fermente ürün	28 gün	Büyüme performansına etkisi yok Bağırsaktaki bakteri çeşitliliği ve sayısında artış *Lactococcus garvieae* enfeksiyonuna karşı hastalık direncinde artış	Pérez-Sánchez ve ark, 2020
Catla catla	*Paraprobiotik, (Bacillus amyloliquefaciens FPTB16)*/ısı ile	28 gün	Oksijen radikal üretimi, serum lizozim aktivitesi, toplam serum protein, miyeloperoksidaz aktivitesi ve alkali fosfataz aktivitesinde artış	Singh ve ark., 2017
Macrobrachium rosenbergii	*Paraprobiotik, Lactobacillus plantarum*/ısı ile	90 gün	Ağırlık artışı, spesifik büyüme oranı, yem dönüşüm oranı ve protein verimlilik oranına etkisi yok Toplam hemosit sayısında artış Fenol oksidaz aktivitesinde artış Solunum patlaması aktivitesinde artış Hemolenf bakteriyel temizleme verimliliğinde artış *Aeromonas hydrophila*'a karşı hastalık direncinde artış	Dash ve ark., 2015
Pagrus major	*Paraprobiotik, Lactobacillus plantarum* (LP20) /Isı ile	56 gün	Büyüme performansı ve yemden yararlanma da artış Spesifik olmayan bağışıklık savunma sistemini güçlendirme Düşük tuzluluk stresi ve strese karşı yüksek direnç	Dawood ve ark., 2015
Litopenaeus vannamei	*Postbiyotik,* maya kültürü metabolitleri (nükleotitler, polisakkaritler, küçük peptitler, organik asitler, lipitler)/ticari ürün	61 gün	Büyüme performansında artış Lizozim ve fenoloksidaz aktivitesinde artış *Vibrio* sp. ve heterotrofik bakterilere karşı dirençte artış Karides bağırsağında endotoksinde azalış Su kalitesi ve havuz sedimentini iyileştirme	Deng ve ark., (2013)
Oncorhynchus mykiss	*Paraprobiotik, Bacillus subtilis* AB1 (Formaldehit+sonikasyon+ hücre içermeyen ekstrakt)	14 gün	*Aeromonas* sp. enfeksiyonunu önlemede etkin	Newaj-Fyzul ve ark. (2007)

mikroorganizmaların canlılığını ve etkinliğini koruyabilmek için kapsülasyon teknolojilerinde farklı yöntemler ve malzemeler kullanılmaktadır. Ancak probiyotiklerin kapsülasyonunda kullanılan yöntemlerin avantajları olabildiği gibi, probiyotik hücrelerde ısı hasarı, bakterileri üzerinde inhibitör etki gibi kullanılan malzemeden ve yöntemden kaynaklanabilecek dezavantajlarda söz konusudur. Bazı yöntemler ise ekipman, bakım ve enerji gerektirdiği için maliyetlide olabilmektedir (Saha ve ark., 2023). Su ürünleri yetiştiriciliğinde probiyotiklerin muhafazasında mikrokapsülasyonun kullanılması probiyotik içeren yemlerin maliyetini artıracak olmasından dolayı üretici açısından arzu edilmeyen bir durum oluşturur.

Su ürünleri yetiştiriciliğinde 1980'li yılların ortalarında başlayan probiyotiklerin ilk kullanımından (Banerjee ve Ray, 2017) sonra, bu yönde yapılan çalışmalar günümüze kadar artan oranda devam etmektedir. Su ürünleri yetiştiriciliğinde probiyotiklerin kullanılmasında karşılaşılabilecek pek çok dezavantajlı durum söz konusudur. Ayrıca kullanılan probiyotikler geçici olarak bağırsak mikrobiyotasının bir parçası olabilir ve sonrasında dışkıyla atılabilir. Bütün bu olumsuzluklar değerlendirildiğinde; günümüzde probiyotikler ile ilgili yapılan çalışmalarda canlı mikroorganizmaların kullanılmasından ziyade, cansız mikrobiyal hücreler (inaktif), mikrobiyal hücre duvarı bileşenleri veya mikrobiyal metabolitlerin kullanılması ile ilgili yapılan araştırmalara ilginin niçin bu kadar artığı anlaşılmaktadır. Bu yönde yapılan çalışmalarda probiyotik yerine aradaki farkın daha iyi anlaşılabilmesi ve ortak bir dilin kullanılabilmesi açısından bilimsel literatürde postbiyotik ve paraprobiyotik terimlerinin yaygınlaşması doğru bir yaklaşım olacaktır.

Su ürünleri yetiştiriciliğinde yapılan çalışmalar incelendiğinde, postbiyotik ve paraprobiyotik kullanılan türlerde, bağırsak mikrobiyotasının düzenlemesi, büyüme performansı ile yemden yararlanmada artış, bağışıklık sisteminin güçlenmesi, enfeksiyonlara karşı dirençte artış gibi birçok fayda sağladığı belirlenmiştir. Bu nedenle probiyotikler ile kıyaslandığında daha güvenli ve stabil olan bu biyoaktif bileşiklerin su ürünleri yetiştiriciliğinde önemli bir potansiyele sahip oldukları düşünülmektedir.

Etik Standartlar ile Uyum

Çıkar Çatışması

Yazar, herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazar, bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

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Marine and Life Sciences

Journal Homepage: https://dergipark.org.tr/en/pub/marlife

First occurrence of *Zu cristatus* (Trachipteridae) in the Turkish Aegean Sea (Eastern Mediterranean Sea)

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Please cite this paper as follows:

Akyol, O., & Tosunoğlu, Z. (2023). First occurrence of *Zu cristatus* (Trachipteridae) in the Turkish Aegean Sea (Eastern Mediterranean Sea). *Marine and Life Sciences*, 5(1), 37-39. https://doi.org/10.51756/marlife.1285550

Short Communication

Article History
Received: 19.04.2023
Accepted: 07.06.2023
Published Online: 23.10.2023

A B S T R A C T

This ichthyologic note presents the incidental catch of *Zu cristatus* from a commercial long-liner from the northeastern Aegean Sea. On 14 March 2023, a specimen of *Zu cristatus* was collected by a commercial deep-sea long-liner, targeting European hake at a depth of 600 m in Saros Bay on the northern Aegean coast of Türkiye. In this short report, we confirmed its occurrence in the Turkish Aegean waters of the eastern Mediterranean.

Keywords:

Scalloped ribbonfish
Long-line fishery
Incidental catch
Saros Bay

INTRODUCTION

Though Trachipteridae family are poorly known due to the scarcity of data, they are represented by ten species belonging to three well-defined genera: *Zu* (Walters and Fitch, 1960), *Desmodema* (Walter and Fitch, 1960), and *Trachipterus* (Goüan, 1770) all these genera are found to be in all oceans, and among these, the genus *Zu* comprises two species, *Zu cristatus* (Bonelli, 1819) and *Zu elongatus* (Heemstra and Kannemeyer, 1984) (Albano et al., 2022a).

Scalloped ribbonfish, *Zu cristatus* (Bonelli, 1819) is an epi and mesopelagic species that is a particular head-up swimmer and feeds on fishes, squids and other large invertebrates; its size to 120 cm total length (Golani et al., 2006; Albano et al., 2022a). They occur in wide distribution, including the southern Atlantic and throughout Indo-Pacific and are rare in the eastern Mediterranean (Golani et al., 2006). Moreover, *Zu cristatus* is a unique species of the genus that inhabits the Mediterranean Sea (Albano et al., 2022a).

Since 1918, *Zu cristatus* has been documented sporadically from the Balearic Sea and off Blanes, Palma de Mallorca and Cataluña (Spain) in the western Mediterranean; Ligurian, Tyrrhenian, Ionian and Adriatic Seas, and also Tunisian waters in the central part of the Mediterranean Sea (Albano et al., 2022b). In addition, eggs of *Zu cristatus* were described from the Adriatic Sea (Dulcic, 2002). On the other hand, a recent check-list study focused on fish spreading in the Israeli coasts has corroborated *Zu cristatus* is very rare in the eastern Mediterranean (Golani et al., 2023).

In the Aegean Sea, Bilecenoğlu et al. (2014) reported *Zu cristatus* in the Aegean fish checklist according to Geldiay (1969). However, it has been mentioned only by name as a probable invasion of the Aegean Sea (and the Mediterranean) without confirmation. Recently, Kaminas et al. (2021) reported via the citizen science contribution of *Zu cristatus* from the Dodecanese Islands and Lesvos Island (Greece), respectively.

This ichthyologic note presents the northernmost record of *Zu cristatus* from a commercial long-liner from the north-eastern Aegean Sea. At the same time, we report the first substantiated record of *Zu cristatus* from the Turkish waters of the Levantine Sea.

MATERIALS AND METHODS

On 14 March 2023, a specimen of *Zu cristatus* (Figure 1) was captured by a commercial deep-sea long-liner, targeting European hake (*Merluccius merluccius*) at a depth of 600 m in Saros Bay (40.48416°N-26.37583°E) at the northern Aegean coast of Türkiye. The bait was sardine. The fish was measured and weighed by the angler.

Figure 1. *Zu cristatus* specimen, captured from Saros Bay, northern Aegean Sea (scale bar: 100 mm) Photo credits: angler Hayri Şahin

RESULTS AND DISCUSSION

In this study, the fish was 120 cm TL and 6250 g according to the angler. Moreover, regarding the total length and weight, this fish is likely to be one of the longest and most heavy specimens, captured among the reported Mediterranean ones (*see*, Albano et al., 2022a). Also, it is close to the sample (1275 mm TL) of Palmahim on the Mediterranean coast of Israel (Golani et al., 2023). The maximum length is 118 cm SL according to Fishbase (Froese and Pauly, 2023).

The photograph is examined and all morphologic aspects and colour patterns are in accordance with the descriptions of Golani et al. (2006; 2023) and Froese and Pauly (2023). The large eye that it's a diameter of 3 times in head length and body colouration with prominent vertical dark bars, and red dorsal and pectoral fins, but no anal fin, and protrusible mouth shows that this fish is undoubtedly *Zu cristatus*. Then, we made an interview with the angler via phone for details; he said that a similar fish was caught more than ten years ago in the same area for the first time, and not retained for the examination.

This short report represents the new occurrence of an adult big-sized specimen of *Zu cristatus*, which was captured in one of the deeper zone (600 m) from the eastern Mediterranean Sea. At the same time, this report represents the third occurrence of *Zu cristatus* in the Aegean Sea.

CONCLUSION

Though this report does not reflect the true regional abundance, the occurrence of new specimens is likely to increase where deep-sea fishing is. Its biology and ecology are not well-known due to the rarity of *Zu cristatus*, so further records are needed to better understand the life cycle of *Zu cristatus* in the Mediterranean.

ACKNOWLEDGEMENT

The authors thank both Mr. Hayri Şahin, who caught the fish, for his cooperation and Mr. Akın Aşık from the Tekirdağ regional association of fisheries cooperatives for bringing the fish to our attention.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

OA: Conceptualization, Writing - original draft; Writing -review and editing. **ZT:** an interview with a fisherman, review and editing.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

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

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