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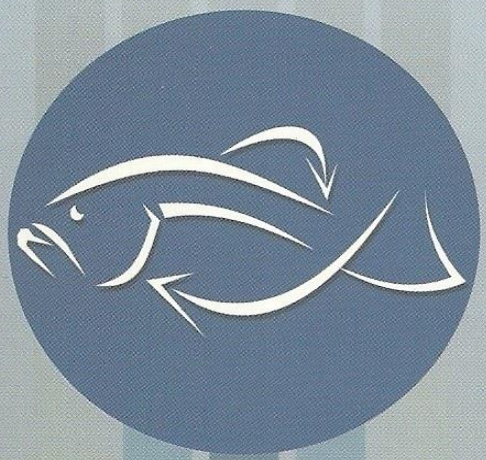

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YAZIM KURALLARI

Yazılar, dergiye yalnızca çevrimiçi gönderi sistemi ile elektronik versiyonda aşağıdaki talimatlara göre gönderilmelidir.

Yazı gönderi tipleri
Araştırma makaleler, derleme makaleler, kısa notlar ve raporlar, editöre mektup.

- Araştırma makaleler; Daha önce yayınlanmamış olan ve 7500 kelimeyi veya 25 sayfayı geçmemesi gerekir. Orijinal tam metin araştırma makaleleri (tablolar ve resimler dahil)
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- Editöre Mektuplar; güncel konulara dahil edilmeli ve 2000 kelimeyi veya tablolar ve şekiller dahil 10 sayfayı geçmemelidir.

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Derginin yayın ücreti yoktur.

Yazıların Hazırlanması
Çalışmalar Türkçe veya İngilizce hazırlanmalıdır. Metninizi bir kelime işlemci yazılımı kullanarak hazırlayın ve ".doc" veya ".docx" formatlarında kaydedin. Yazılar aşağıdaki sırayla hazırlanmalıdır;

- **Başlık sayfası**
  - o Başlık (Kısa ve bilgilendirici. Kısaltmalardan ve formüllerden kaçının)
  - o Yazar isimleri ve üyelik adresleri (Tam isimler verilmeli, kısaltma yapılmamalıdır. İlgili yazar bir yıldız işaretiyle belirtilmelidir. Her üyelik adresi kurum, fakülte / okul, bölüm, şehir ve ülkeyi içermelidir)
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  - o Materyal ve Yöntemler
  - o Bulgular
  - o Tartışma (Uygunsa Bulgular bölümü ile birleştirilebilir)
  - o Sonuçlar
  - o Etik Standartlara Uyum
    - a) Yazarların Katkıları
    - b) Çıkar Çatışması
    - c) Hayvanların Refahına İlişkin Beyan
    - d) İnsan Hakları Beyanı
  - o Kaynaklar
  - o Çizelge(ler) (metinde uygun konumda)
  - o Şekiller (metinde uygun konumda)
  - o Ekler (varsa)

Makale Formatı
Makale boyunca A4 boyutundaki kağıdın tüm kenarlarında çift aralıklı ve 25 mm kenar boşluklu referanslar, tablo başlıkları ve şekil başlıkları dahil olmak üzere 12 puntoluk bir yazı tipi kullanın (Times New Roman). Sayfanın bütün yönlerinde 25 mm'lik kenar boşlukları kullanın. Metin tek sütun formatında olmalıdır Yazarların şablon dosyalarını aşağıdaki bağlantılardan indirmeleri önerilir:

• Her sayfa Arap rakamları ile numaralandırılmalı ve yazının başından sonuna kadar satırlar sürekli olarak numaralandırılmalıdır.
• Vurgu için italik kullanın.
• Yalnızca SI (uluslararası sistem) birimlerini kullanın.
• Ondalık basamaklar için "nokta" kullanın.
• Tür adı için italik kullanın.

Etik Standartlara Uyum
Sorumlu yazar, kaynak listesinden önce ayrı bir bölümde makale metnine bir özet açıklama ekleyecektir. Aşağıdaki açıklama örneklerine bakın:

a) Yazarların Katkıları
Lütfen makale için yazarların katkılarını sağlayın. Ad ve soyadlarının ilk harflerini kullanın (örneğin; Yazar MO çalışmayı tasarladı, MF makalenin ilk taslağını yazdı, AF istatistiksel analizleri gerçekleştirdi ve yönetti. Tüm yazarlar son makaleyi okudu ve onayladı.).

b) Çıkar Çatışması
Mevcut herhangi bir çıkar çatışması burada verilmelidir. Çatışma yoksa, yazarlar şunları belirtmelidir:
Çıkar Çatışması: Yazarlar çıkar çatışması olmadığını beyan ederler.

c) Hayvanların Refahına İlişkin Beyan
Çalışmada hayvan kullanılmışsa; Araştırma için kullanılan hayvanların refahına saygı gösterilmelidir. Hayvanlar üzerindeki deneyleri bildirirken, yazarlar aşağıdaki ifadeyi belirtmelidir:
Etik onay: Hayvanların bakımı ve kullanımı için geçerli tüm uluslararası, ulusal ve / veya kurumsal yönergelere uyulmuştur.
Veya geriye dönük çalışmalar için; makale metninde bir özet beyan aşağıdaki şekilde yer almalıdır:
Etik onay: Bu tür bir çalışma için resmi onay gerekli değildir.

d) İnsan Hakları Beyanı
İnsan katılımcıları içeren çalışmaları bildirirken, yazarlar aşağıdaki ifadeyi eklemelidir:
Etik onay: Çalışmalar, uygun kurumsal ve / veya ulusal araştırma etik komitesi tarafından onaylanmış ve 1964 Helsinki Bildirgesi ve daha sonra yapılan değişiklikler veya karşılaştırılabilir etik standartlarda belirtilen etik standartlara uygun olarak gerçekleştirilmiştir. Veya geriye dönük çalışmalar için; makale metninde aşağıdaki gibi bir özet beyan yer almalıdır:
Etik onay: Bu tür bir çalışma için resmi onay gerekli değildir.

KAYNAKLAR

Metinde Alıntı;
Lütfen metinde geçen her bir atıfın kaynaklar listesinde de sunulduğundan emin olun. Metindeki literatürü kronolojik olarak, ardından bu örnekler gibi alfabetik sırayla belirtin "(Elp vd., 2018; Biswas vd., 2016; Elp ve Osmanoğlu, 2019)". Atıfta bulunulan kaynak bir cümlenin konusuysa, parantez içinde yalnızca tarih verilmelidir. Bu örnek gibi biçimlendirilmiştir: “Durmaz (2007) .... etkinliğini araştırmıştır”.
• Tek yazar: yazarın soyadı ve yayın yılı (Elp, 2017)
• İki yazar: hem yazarların soyadları hem de yayın yılı (Adem ve Elp, 2017)

• Üç veya daha fazla yazar: birinci yazarın soyadı ve ardından "ve diğerleri". ve Elp et al., 2018 yayın yılı)

Kaynaklar Listesinde Alıntı;
Kaynaklar önce alfabetik olarak sıralanmalı ve daha sonra makalenin sonunda kronolojik olarak sıralanmalıdır. Aynı yazar (lar) dan aynı yıl içinde birden fazla kaynak yayın tarihinden (2016a) sonra yerleştirilen a, b, c vb. Harflerle belirtilmelidir. Çevrimiçi olarak yayınlanan makalelerin, kitapların, çok yazarlı kitapların ve makalelerin alıntıları aşağıdaki örneklere uygun olmalıdır:

Makale:
Adem, S. S., & Elp, M. (2017). Muscle spindle and comparison of fish muscle spindle with other vertebrates. Alinteri Journal of Agriculture Sciences, 32(2): 113-117

Durmaz, Y. (2007). Vitamin E (alpha-tocopherol) production by the marine microalgae Nannochloropsis oculata (Eustigmatophyceae) in nitrogen limitation. Aquaculture, 272(4): 717-722.

Elderwish, N., M., Taştan, Y. & Sönmez, A. Y., (2019). Türkiye'nin batı karadeniz kıyı sularındaki ağır metal birikimin mevsimsel olarak incelenmesi. Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi, 5(2): 1-8.

Elp, M., Osmanoğlu, M. İ., Kadak, A. E., & Turan, D., (2018). Characteristics of Capoeta oguzelii, a new species of cyprinid fish from the Ezine Stream, Black Sea basin, Turkey (Teleostei: Cyprinidae). Zoology in the Middle East. 64(2): 102–111. https://doi.org/10.1080/09397140.2018.1442295

Sönmez, A. Y., Kale, S., Özdemir, R. C. & Kadak, A. E. (2018). An adaptive neuro-fuzzy inference system (ANFIS) to predict of cadmium (Cd) concentration in the Filyos River, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, 18(12): 1333-1343. https://doi.org/10.4194/1303-2712-v18_12_01

Kitap:
Brown, C., Laland, K. & Krause, J. (Eds.) (2011). Fish Cognition and Behavior. 2nd ed. Oxford, UK: Wiley-Blackwell. 472p.

Kitap bölümü:
Langston, W. J. (1990). Toxic effects of metals and the incidence of marine ecosystems, pp. 102-122. In: Furness, R. W. (Ed.), Rainbow Heavy Metals in the Marine Environment. New York, USA: CRC Press. 256p.
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).pp. 945-968. 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. 1st ed. Berkeley, CA, USA: University of California Press. 981p.

Tez:
Elp, M. (2002). Koçköprü baraj gölü'nde (Van) yaşayan siraz *(Capoeta capoeta*, Guldensteadt, 1772) ve inci kefali (*Chalcalburnus tarichi*, Pallas, 1811) populasyonları üzerine bir araştırma. Ph.D. Thesis. İstanbul University, İstanbul, Turkey.

Konferans bildirimleri:
Notev, E. & Uzunova, S. (2008). A new biological method for water quality improvement. Proceedings of the 2nd Conference of Small and Decentralized Water and Wastewater Treatment Plants, Greece, pp. 487-492.

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

Rapor:
FAO. (2018). Report of the ninth session of the Sub-Committee on Aquaculture. FAO Fisheries and Aquaculture Report No. 1188. Rome, Italy.

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

TurkStat. (2019). Fishery Statistics. Retrieved on December 28, 2019 from http://www.turkstat.gov.tr/

Çizelge(ler)
Arapça olarak numaralandırılmış çizelgeler, üstte kısa bir açıklayıcı başlık ile ayrı sayfalarda yer almalıdır. Dipnotları çizelge gövdesinin altındaki tablolara yerleştirin ve bunları küçük harflerle (veya anlamlılık değerleri ve diğer istatistiksel veriler için yıldız işaretleriyle) belirtin. Dikey kurallardan kaçının. Çizelgelerde sunulan veriler, makalenin başka bir yerinde açıklanan sonuçları tekrar etmemelidir.

Şekil(ler)
Metinde tüm resimler 'Şekil' olarak etiketlenmeli ve ardışık Arapça rakamlarla, Şekil 1, Şekil 2 vb. İle numaralandırılmalıdır. Bir şeklin panelleri etiketlenmişse (a, b, vb.), Metinde bu panellere atıfta bulunurken aynı durumu kullanın. Şekillerin PNG, JPEG gibi elektronik formatlarda olması önerilir. TIFF (min. 300 dpi) de mevcut boyutlarda düzenlenmelidir. Tüm şekiller veya tablolar metin içinde sunulmalıdır. Yazı tipi boyutları 9 ila 11 punto arasında olmalıdır.

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Manuscripts must be submitted to the journal in electronic version only via online submission system according to the guidelines below:

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- Research articles: original full-length research papers which have not been published previously and should not exceed 7500 words or 25 manuscript pages (including tables and figures)
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This journal has no page charges.

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  - o ORCID number and e-mail addresses for all authors.
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  - o Number of tables
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o Introduction
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o Results
o Discussion (Can be combined with Results section if appropriate)
o Conclusion
o Compliance with Ethical Standards
  a) Authors' Contributions
  b) Conflict of Interest
  c) Statement on the Welfare of Animals
  d) Statement of Human Rights
o References
o Table(s) with caption(s) (on appropriate location in the text)
o Figure(s) with caption(s) (on appropriate location in the text)
o And appendices (if any)

Manuscript formatting
Use a 12-point Times New Roman font, including the references, table headings and figure captions, double-spaced and with 25 mm margins on all sides of A4 size paper throughout the manuscript. The text should be in single-column format. The authors are encouraged to download the template files from the links below:

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• Use italics for emphasis
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The corresponding author will include a summary statement in the text of the manuscript in a separate section before the reference list. See below examples of disclosures:

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REFERENCES

Citation in text;
Please ensure that each reference cited in the text is also presented in the reference list. Cite literature in the text in chronological, followed by alphabetical order like these examples "(Elp et al., 2018; Biswas et al., 2016; Elp and Osmanoğlu, 2019)". If the cited reference is the subject of a sentence, only the date should be given in parentheses. Formatted like this example: "Durmaz (2007) investigated the efficacy of…".

• Single author: the author's surname and the year of publication (Elp, 2017)
• Two authors: both authors' surnames and the year of publication (Adem and Elp, 2017)
• Three or more authors: first author's surname followed by "et al." and the year of publication Elp et al., 2018)

Citation in the reference list;
References should be listed first alphabetically and then further sorted chronologically at the end of the article. More than one reference from the same author(s) in the same year must be identified by the letters a, b, c, etc. placed after the year of publication (2016a). The citation of articles, books, multi-author books and articles published online should conform to the following examples:

Article:
Adem, S. S., & Elp, M. (2017). Muscle spindle and comparison of fish muscle spindle with other vertebrates. Alinteri Journal of Agriculture Sciences, 32(2): 113-117

Durmaz, Y. (2007). Vitamin E (alpha-tocopherol) production by the marine microalgae Nannochloropsis oculata (Eustigmatophyceae) in nitrogen limitation. Aquaculture, 272(4): 717-722.

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Book:
Brown, C., Laland, K. & Krause, J. (Eds.) (2011). Fish Cognition and Behavior. 2nd ed. Oxford, UK: WileyBlackwell. 472p.

Chapter:
Langston, W. J. (1990). Toxic effects of metals and the incidence of marine ecosystems, pp. 102-l22. In: Furness, R. W. (Eds.), Rainbow Heavy Metals in the Marine Environment. New York, USA: CRC Press. 256p.

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Conference Proceedings:
Notev, E. & Uzunova, S. (2008). A new biological method for water quality improvement. Proceedings of the 2nd Conference of Small and Decentralized Water and Wastewater Treatment Plants, Greece, pp. 487-492.

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

Report:
FAO. (2018). Report of the ninth session of the Sub-Committee on Aquaculture. FAO Fisheries and Aquaculture Report No. 1188. Rome, Italy.

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

TurkStat. (2019). Fishery Statistics. Retrieved on December 28, 2019 from http://www.turkstat.gov.tr/

Table(s)
Tables, numbered in Arabic, should be in separate pages with a short descriptive title at the top. Place footnotes to tables below the table body and indicate them with superscript lowercase letters (or asterisks for significance values and other statistical data). Avoid vertical rules. The data presented in tables should not duplicate results described elsewhere in the article.

Figure(s)
All illustrations should be labelled as 'Figure' and numbered in consecutive Arabic numbers, Figure 1, Figure 2 etc. in the text. If panels of a figure are labelled (a, b, etc.) use the same case when referring to these panels in the text. Figures are recommended to be in electronic formats such as PNG, JPEG. TIFF (min. 300 dpi) should be also arranged in available dimensions. All figures or tables should be presented in the body of the text. Font sizes size should be from 9 to 11 points.

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İÇİNDEKİLER / CONTENS

ARAŞTIRMA / RESEARCH

DERLEME / REVIEW

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Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2021; 7(2): 77-89 Araştırma Makalesi/Research Article

Effectiveness and Impact of Artificial Reef Project in Tigbauan, Iloilo, Philippines: A case study

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Abstract

Artificial reefs (ARs) are one of the most popular and important management approaches to enhance fishery production, especially in overfished areas. However, poor site selection and lack of monitoring to some AR projects are common to this matter. Hence, in this paper, a case study was conducted to determine the effectiveness and impact of the AR project in Tigbauan, Iloilo, Philippines, through a qualitative field survey research approach. ARs used in the study are jackstone-type designs made-up of concrete that were constructed by the local fishers. Findings revealed that while other fishers reported that AR improved longline catch, on the contrary, fishers who used gill nets did not experience any catch changes; rather, it sometimes entangled and damaged their nets. Despite initial monitoring showing the presence of benthic organisms like sponges and soft corals after 6 months of installation and gradually attracting fish to aggregate, lack of follow-ups to the present date brings the AR project impact imperative. While most respondents claimed that water quality in the installed site was maintained after 4 years, the targeted objective to increase fish species abundance was not achieved. Furthermore, some respondents reported that installed ARs were buried due to natural calamities. Thus, this study suggests that the AR project in the installed site did not meet the expected output due to a lack of monitoring and poor site selection.

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INTRODUCTION

Artificial reefs (ARs) are well-known and have been used for a long time around the world and have served many purposes such as habitat restoration (Clark & Edwards 1994; Komyakova et al., 2019), fish stock enhancement (Pickering et al., 1999), aquaculture (Fabi & Fiorentini, 1996), tourism or recreation which serve as diving site (Tynyakov et al., 2017), fisheries management (Fabi et al. 2015; Becker et al. 2016; Florisson et al. 2018) and research areas (FAO, 2015). Thus, it became an important and popular resource enhancement technique (Bohnsack and Sutherland 1985) and can be considered as a management intervention (Munro and Balgos 1995) to recover and/or improve natural habitats, increase productivity, and concentrate or enhance populations of living marine resources (FAO, 2015) by concentrating fishes and by increasing the natural production of biological resources (Bohnsack & Sutherland, 1985). According to RA 8550, or the Philippine Fisheries Code of 1998, as amended by RA 10654, ARs are defined as any structure, natural or man-made materials, placed on a body of water below the sea surface (Lokesha, 2013) to mimic some functions of a natural reef (FAO, 2015; Wu et al., 2019) that affect the local biological community (Seaman & Jensen 2000; Svane & Petersen, 2001). It also has served as habitat replacement for destroyed corals (Waltemath & Schirm, 1995) that functions as part of the natural ecosystem with no destruction to the existing environment (FAO, 2015) or supplement existing natural reefs (Miller & Hobbs, 2007). Furthermore, ARs are also used to prevent any active fishing gear operations, such as bottom trawling (Komyakova et al., 2019) and dredging activities, especially in municipal waters. Thus, ARs' definition is broad and not limited to structures developed as reefs and intentionally submerged to benefit human activities (Tynyakov et al., 2017). Instead, the benefits are for the ecosystem as a whole.

A large number of ARs have been deployed in coastal regions worldwide over the past three decades (Yang et al., 2019). AR structures had been deployed in over 50 countries worldwide by 2011 (Fabi et al., 2011). This is done primarily in areas where fishery resources have been overexploited or are rebuilding (Pitcher & Seaman 2000; Brickhill et al., 2005). In the Philippines, together with other Asian countries like Indonesia, Malaysia, Cambodia, and Vietnam (FRA, 2010), ARs are widely used mainly for fishing and fisheries management (Waltemath & Schrim, 1995) to improve fishery resources (FRA, 2010)

because fishing is a major source of food, income, and export earnings in these areas (EEPSEA, 2017). It enables fishers to reduce fishing effort in terms of time and fuel by attracting a great abundance of fish. However, overfishing and degradation have been threatening the country's fishery sector for many years (EEPSEA, 2017), which leads to a debate as to what are the ARs' purpose should be. Mcmanus (1995) claimed that the coastal waters of the Philippines are generally overfished to the point of having higher fishing pressure than the maximum potential harvest. To address such issues and problems, the establishment of ARs was done as one of the fishery management tools (EEPSEA, 2017).

The municipality of Tigbauan in Iloilo, Philippines, specifically Barangay Baguingin, is one of the recipients to have ARs installed in the country. This is one of the coastal resource management projects of the municipality, which was established way back in 2015 (Pers. Comm with Municipal Fisheries Officer). Tigbauan is a second-class municipality located in the Southern part of the Province of Iloilo with 10 coastal barangays. These ten coastal communities considered fishing as one of the significant livelihoods for each household in the community. AR project was initiated and conceptualized by the Local Government Unit (LGU) of Tigbauan in consultation with the municipal fisherfolk of Barangay Baguingin and in coordination with the Bureau of Fisheries and Aquatic Resources (BFAR) Region VI and the Provincial Capitol of Iloilo. Parties responsible believed that implementing the AR Project along the coastal waters of Tigbauan would help minimize active fishing operations that would protect critical marine habitats and soft-bottom communities. Implementers concerned have willingly and jointly pledged to extend full support and cooperation in implementing the project in support of fisheries conservation and resource enhancement towards achieving food security and poverty alleviation program of the government. Target beneficiaries are the municipal fishermen in the area. The AR project was provided with a total amount of Php306, 820.00 (approximately US$6, 100) for the construction of 250 units of ARs. Obligations were divided among parties.

The management and operation of this AR project were the primary responsibility of the fisherfolk organization and LGU. Together with other local partners, the project implementers formulated a management plan for the proper management of the ARs. The management plan made was adapted by the LGU to become the official policy of the municipal government. Hence, municipal fisherfolks were completely aware of the project and responded positively with full support prior to implementation and installation. Furthermore, LGU, in cooperation with the Provincial Office and BFAR Region VI, successfully disseminated the importance and benefits of the AR to the target beneficiaries. The target number of ARs that should be deployed was 250 units. However, according to the survey, fishers in the area who were responsible for the management and operation of the ARs claimed that there were only an 100 units of ARs successfully deployed. The problem is that not all the materials provided by BFAR were utilized for the construction of ARs. This may be due to lack of funding for the labor from LGU. Another was the repair of the bridge at that time, which is situated near where the ARs were being constructed. There was no coordination with the contractor and fishermen regarding the start of the bridge repair; hence, ARs under the bridge were damaged and could no longer be used. ARs in the area had been deployed four years ago, and yet updates regarding its benefits to the target beneficiaries are quite vague up to this point of time.

Understanding how artificial reefs can be integrated into a more general marine resource management framework is a critical element in promoting the importance of ARs in the long run. However, the ability to evaluate the performance of ARs is quite challenging. AR projects have been criticized for lack of planning in the development of adequate monitoring programs that will provide fisheries scientists and managers with the information required to test their inherent purposes despite significant developments in construction and design (Claudet & Pelletierm 2004). ARs can potentially provide a wide range of benefits towards ecosystem as claimed by different authors. However, the extent to which they achieve their goals has received less attention. There are limited publications available as to which this management strategy is effective or not. Lack of monitoring and awareness towards community with regards to the project is quite common. Moreover, financial funds and effort from the government are being utilized; hence, a return to the community is necessary on this matter. Thus, this study aimed (1) to evaluate the level of awareness of the fishers in the community on the installed artificial reefs; (2) to assess the status and impact of installed ARs based on the fishers' perspective; (3) to determine the issues and concerns regarding the installed artificial reef; and (4) to assess also whether a four-year ago installation of ARs could have a felt impact to fishers' life.

MATERIALS AND METHODS

Study Site and Duration

The study was conducted to evaluate the effectiveness of the artificial reef installed at the municipality of Tigbauan, Iloilo, Philippines. Tigbauan is a second-class municipality located in the southern part of the province of Iloilo. This area is bounded by the Iloilo Strait to the south and the municipality of Leon to the northwest, Oton to the northeast, and Guimbal to the east. It is located 22.85 km from the city of Iloilo, and it lies at approximately 10.7283°N, 122.3788°E. Tigbauan has 52 component barangays, 10 of which are situated along the coast, with a coastline of 8 km. ARs are installed specifically in Barangay Baguingin (Figure 1), which is one of the coastal barangays of Tigbauan, Iloilo, Philippines. This study was done for a week towards the end of November 2019.

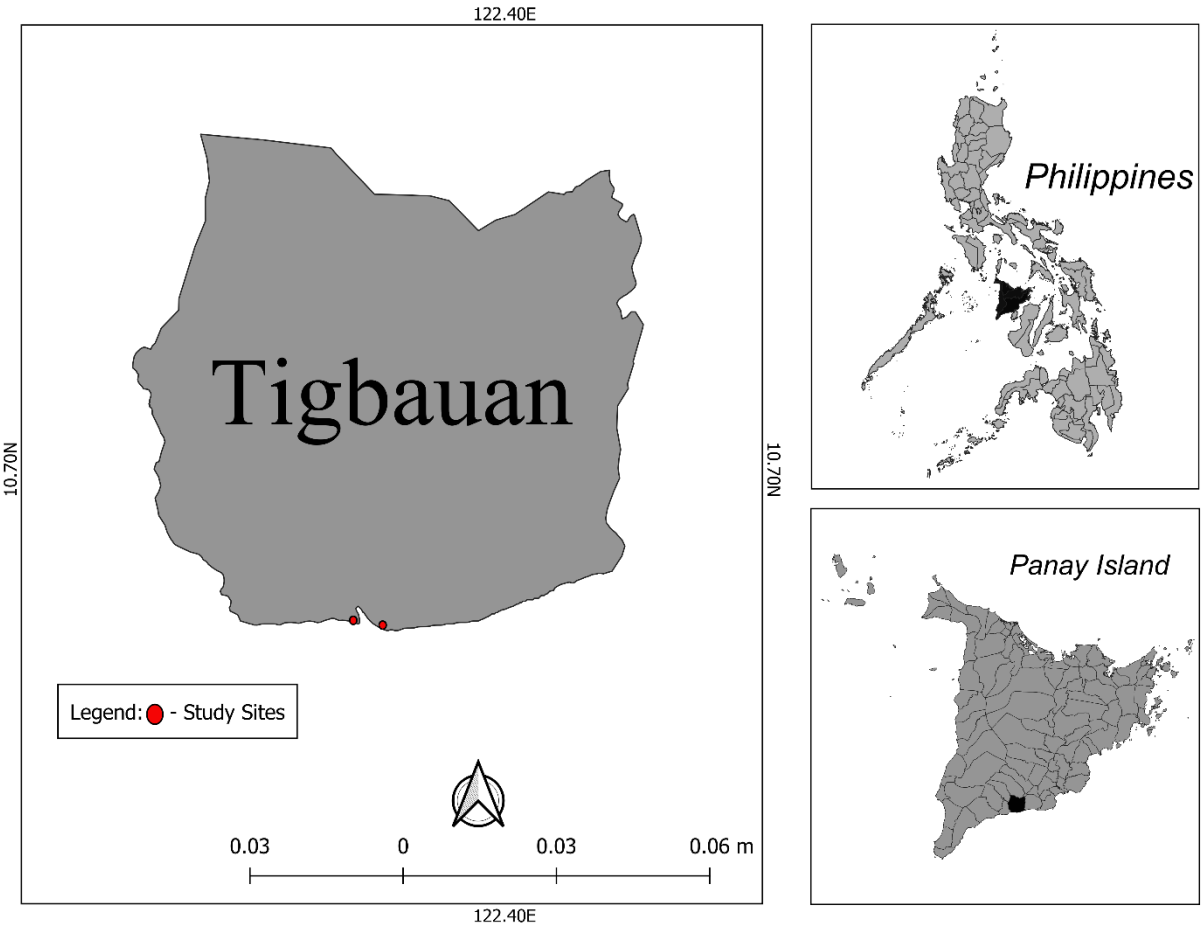

Figure 1. Map showing the study site.

Criteria for Site Selection

The criteria of site selection for ARs as provided by the Joint DENR-DA-DILG-DND Memorandum Order No. 1 Series of 2000 are as follows: (1) site where ARs are to be installed should not be less than 1 km away from existing natural reefs, if present, or 500 me away from existing ARs; (2) site should be near an alternative food sources (i.e. seagrass beds)' constructed on a flat, barren area of relatively good visibility and at depth protected from wave action but still accessible to members of the association for possible monitoring (i.e. 15-25 m away from the shoreline); (3) site should be outside designated navigational sea lanes and does not obstruct traditional navigational route of local fishers going to and from the fishing ground or pose a navigational hazard to ships and other sea crafts; (4) water current must be moderate so that plankton can stay in the vicinity; (5) site should have a rocky or sandy substrate with flat to gradually sloping bottom; (6) site should be free from pollution; and (7) site should have a water depth ranging from 6 to 12 fathoms.

The LGU was responsible for selecting the site as to where ARs are to be installed and Barangay Baguingin was chosen as the recipient. However, no prior scientific study was done on this. The only consideration was that the area chosen is adjacent to mangroves which are, for them, essential to be protected, which defeats the purpose of the mangrove in the coastal ecosystem as to help in reducing wave energy and protecting our coasts against natural hazards such as storms, tsunamis, and coastal erosions, limiting erosion and shielding coastal communities from the destructive forces of tropical storms (Spading et al., 2014). Another is the future plan of making the place a fish sanctuary or a marine protected area (MPA). According to the Aquaculturist of Iloilo Provincial Capitol, who was assigned for the pre-assessment at that time prior to ARs installation, the area has a sandy-muddy bottom with no coral reef present, making the place a good choice for the ARs to be built to help promote aggregation of fish and to help fishers gather more catch.

Design for ARs Used in the Municipality

The AR design chosen was of "jackstone-type" made up of concrete cement having a length of 1 m and a square dimension of 5x5 in (Figure 2). The decision regarding the choice of the design was accordingly originated from BFAR. This design is included in BFAR's package of technology. No concrete scientific explanation was presented. According to the consultations made with the concerned agencies, the design does not matter. All types of AR designs serve the same purposes (i.e., promote fish aggregation, spawning ground, etc.). This statement may be due to the sparse evaluation of artificial structure performance which was noticed by Becker et al. (2018). Implementers focused on proper deployment manner and desired depth instead.

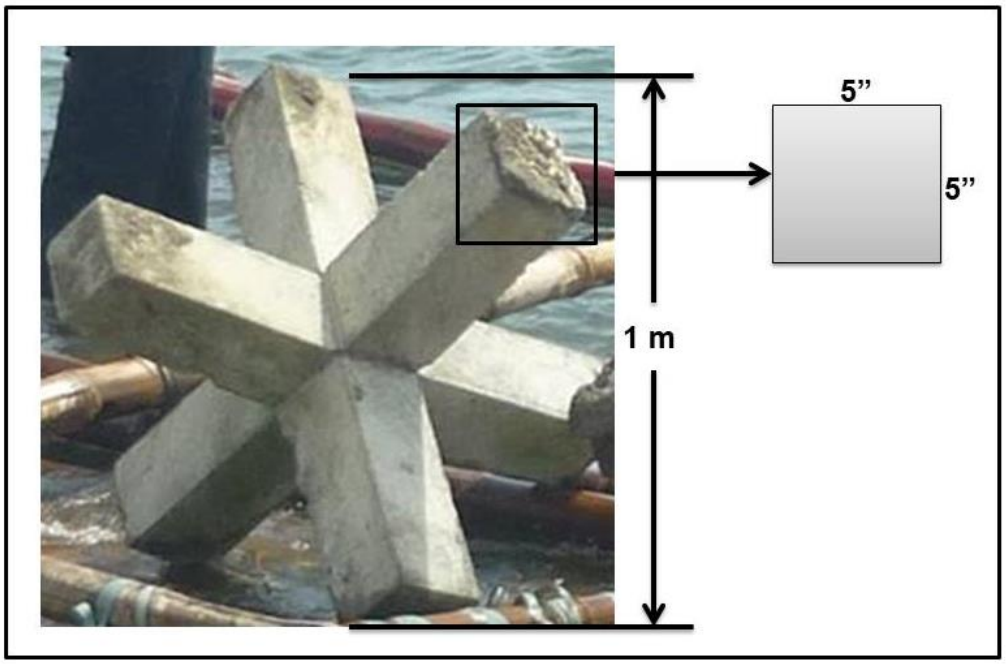

Figure 2. Specifications of AR deployed in Barangay Baguingin, Tigbauan, Iloilo, Philippines (Photo taken from Ariel S. Tentia, Tigbauan Municipal Bantay Dagat Member).

Deployment of AR units

Deployment of ARs in Barangay Baguingin was done in 3 days by the municipal fisherfolks in coordination with the LGU. ARs were carried by municipal fisherfolks to the shoreline and were loaded to the bamboo raft locally known as *balsa* for deployment. Upon arrival to the desired area, ARs were dropped down one by one from the raft to the water surface until it sunk to the bottom without the proper guidance of deployment by a diver due to the unavailability of a skilled person to do the task (Figure 3).

Figure 3. Deployment of ARs at Barangay Baguingin, Tigbauan, Iloilo, Philippines: (a) ARs were carried by municipal fisherfolks to the shoreline; (b) ARs were loaded to bamboo raft; (c) ARs were brought to the desired area of deployment; and (d) ARs were manually pushed to the water (Photo taken from Ariel S. Tentia, Tigbauan Municipal Bantay Dagat Member).

The target number of ARs that should be deployed was 250 units. However, according to the survey, fishers who were responsible in the area claimed that approximately 100 units were only successfully deployed. The problem is that not all the materials provided by BFAR were utilized for the construction of ARs. This may be due to a lack of funding for the labor from LGU. Another was the repair of the bridge at that time, which is situated near where the ARs were being constructed. There was no coordination with the contractor and fishermen regarding the start of the bridge repair; hence, ARs under the bridge were damaged and could no longer be used. ARs were deployed 200 meters away from the shoreline with a depth of 8 meters at low tide and 10 meters at high tide, which fits the site's criteria in terms of desired depths that could avoid obstruction of navigational paths for municipal fishers. As a result, fisherfolks in the barangay did not experience any hard time in their travel to their desired fishing ground.

Ideally, upon deployment, ARs should be guided by a diver to put it in the correct manner (Figure 4a) to have its best benefits as stated in the Joint DENR-DA-DILG-DND Memorandum Order No. 1 Series of 2000. However, this was not what had happened in Barangay Baguingin. Under the circumstances, there was no available diver to guide the ARs. Hence, municipal fishers tended to scatter the ARs (Figure 4b), defeating its purpose in the long run.

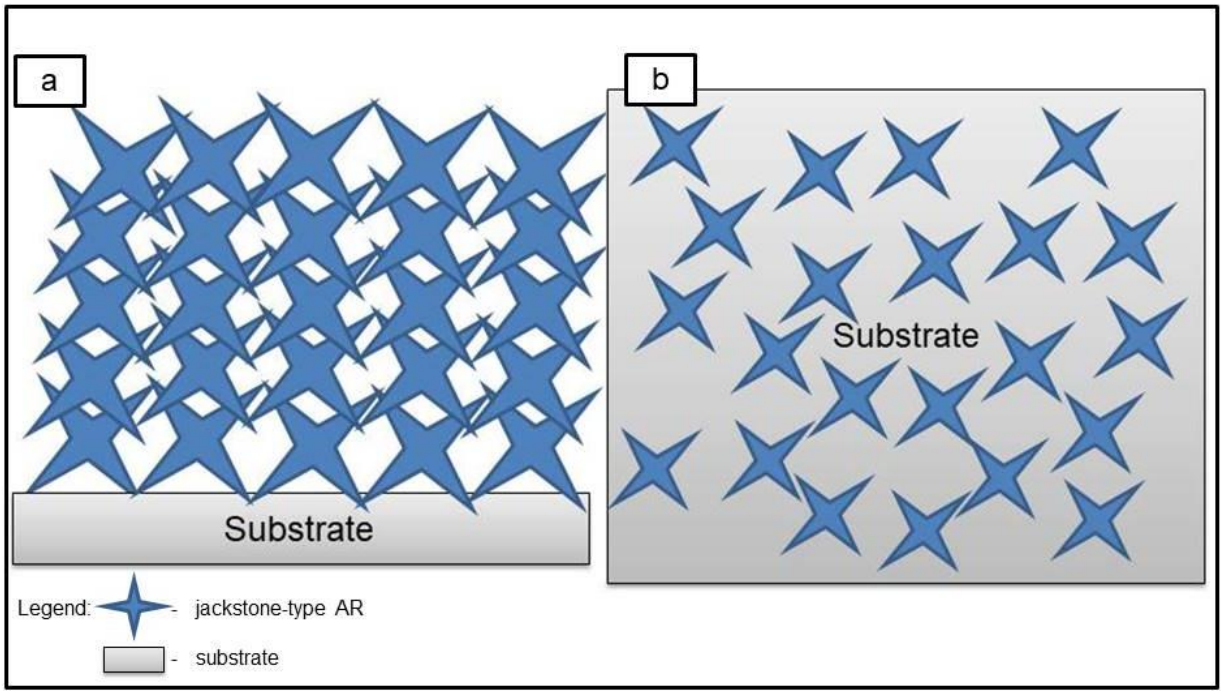

Figure 4. Manner of deployment of AR: (a) ideal and proper deployment of ARs; and (b) manner of deployment of AR done by municipal fisherfolks at Barangay Baguingin, Tigbauan, Iloilo, Philippines.

Data Gathering

This study employed a purely qualitative field survey research approach, where data were collected majorly through qualitative techniques during the fieldwork that took place in the study area.

Data sources had included both primary and secondary data. Primary data were gathered through interviews with the use of questionnaires. Key informant interview (KII) (see Appendix A for the questionnaire) with the Municipal Agriculture Officer of the Municipality of Tigbauan, President of the BFARMC and Barangay Captain in Barangay Baguingin, Training Specialist of Bureau of Fisheries and Aquatic Resources (BFAR) and Provincial Aquaculturist II of Iloilo Provincial Capitol was done to have an overview of the artificial reef installed in the area. The level of awareness of each fisher as to the implementation of the AR project and its effectiveness and impact were assessed through a household (HS) survey after KII. A list for the household survey respondents was based on the registered fisherfolks in the barangay and was acquired from the Municipal Agriculture Office. A semi-structured questionnaire (Appendix B) was used during the interview.

The secondary data collected and used in this study included reports and detailed plan of the project from Local Government Unit (LGU) of the municipality. In addition, local ordinances related to artificial reef installation were collated, analyzed, and used in this study. These secondary data contained the exact location and other important information with regards to the implementation of the said management strategy and have served as basis for the researcher to start the study.

Data Analysis

Qualitative data were analyzed using descriptive statistics, and mean scores were derived for all quantitative results using SPSS v. 20.

RESULTS

Effectiveness and Impact of Installed ARs

A total of 42 respondents were surveyed to assess the effectiveness and impacts of the AR Project established in Barangay Baguingin, Tigbauan Iloilo, Philippines, in 2015. Table 1 shows the profile of the respondents in Barangay Baguingin, Tigbauan, Iloilo. Majority of the respondents were males (88.1%) who were registered municipal fisherfolk of the recipient barangay. Females, 11.9% of the total respondents, interviewed were the wives of the fishers. This was due to the unavailability of their husbands during the field survey. Large number of fisher population in the area has more than 30 years of experience in fishing. However, the ages of fishers ranged from 22 to 59 years old. No formal education among municipal registered in the barangay is high, with a total percent composition of 88.1%. They all varied in the type of fishing gears used with gillnet (57.1%) followed by skimming net (16.7), longline (11.9%), crab pot (11.9%), and beach seine (2.4%).

Table 1. Respondent's profile in Barangay Baguingin, Tigbauan, Iloilo, Philippines.

Respondents (n=24)	Frequency	Percentage Composition (%)
Sex		
Male	37	88.1
Female	5	11.9
Total	42	100
Years of Residence (years)		
11 - 15	2	4.8
21 – 25	2	4.8
26 – 30	1	2.4
>30	37	88.1
Total	42	100
Religion		
Roman Catholic	42	100
Civil Status		
Single	2	4.8
Married	38	90.5
Widowed	2	4.8
Total	42	100
Educational Attainment		
Elementary level	4	9.5
Elementary graduate	2	4.8
High School level	7	16.7
High School graduate	24	57.1
College level	2	4.8
College graduate	2	4.8
Vocational course	1	2.4
Total	42	100
Respondent Type		
Fisher	37	88.1
Fisher's wife	5	11.9
Total	42	100
Fishing Gears Used		
Gillnet	24	57.1
Longline	5	11.9
Crab pot	5	11.9
Skimming net	7	16.7
Beach seine	1	2.4
Total	42	100

Respondents claimed that the area where ARs were installed was in good condition and still in good condition after these were installed (Table 2). There were no indications of improvement. They have noticed no progress or any changes in the area prior to the objectives which were set and aimed by the project. However, fishers who used the longline as their fishing gears experienced a good catch after 6 months of establishing ARs. Species caught increased in terms of quantity, and species present also improved. However, other fishing gears used in the area, such as the gill net, which is the major gear used in the barangay, did not experience such an increase in the catch. Fishers claimed that it sometimes damaged their nets when entangled accidentally in the installed ARs. This happened during the time when buoys (markers) installed were washed out by strong waves brought by typhoons that passed the area. On the other hand, this is in contradiction with the study of Santos & Monteiro (1997). They both identified that ARs contributed to an improved value of artisanal fishery based on a fishing survey by gill nets in the Algarve coast, the southernmost region of continental Portugal. The reason might be Barangay Baguingin installed the ARs are too closed from the shoreline (i.e., 200 m away), and gillnetters mostly fished in farther areas to catch more target

species.

Table 2. Respondent's perception of the condition of the area before and after the installation of ARs in Tigbauan, Iloilo, Philippines.

Condition	Respondent's Perception on the Site Condition Before AR Installation		Respondent's Perception on the Site Condition After AR Installation	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Poor	1	2.4	9	21.4
Not Good, Not Bad	14	33.3	0	0
Good	27	64.3	33	78.6
Total	42	100	42	100

Monitoring was done after 6 months of installation by the provincial aquaculturist through an underwater visual survey. It was noticed that there was already presence of sponges and soft corals that are starting to grow in the installed ARs. Fishes tend to aggregate slowly. However, this was the only monitoring that was done, and no follow-ups until the present date. Beneficiaries and concerned agencies do not have updates and/or ideas on the actual state of deployed ARs 4 years ago. Respondents claimed that ARs were buried after a year. Only less than half a meter remained due to the typhoons that have passed, and accordingly, the area is exposed to stronger waves during this period. The presence of the river nearby also contributed to the phenomena whenever heavy rainfall happens, and there are rapid run-offs coming from the upland.

After 4 years of AR installation, respondents claimed that the water quality of the place was maintained and there was no increase of contaminations (Table 3). One of the main objectives of the project, which is increasing the target species for the fishers to have more catch and more income, was not achieved. Majority (88.1%) claimed that the catches were still dependent on the seasonality of the species and not because of the establishment of the ARs. In the study of Bohnsack et al. (1994), they have gathered equivocal evidence that the increase in biomass was likely due to aggregation rather than increased production from studies around the world. It was pointed out that ARs can serve purely as an aggregation device without any increase in biomass. Therefore, the effectiveness of ARs still remains up for debate on attraction versus production (Lee et al., 2018). The ecological, social, and economic goals of this project were in a dilemma.

Table 3. Respondent's perception of the condition of the area after the installation of ARs in Tigbauan, Iloilo, Philippines.

Questions	Respondent's Perception After the Installation of AR		
	Yes	No	No Idea
1. Is water quality maintained?	100%	0%	0%
2. Is the structural integrity and stability of the AR infrastructure maintained over time?	73.80%	16.70%	9.50%
3. Is there an increase of contaminants in the water?	0%	100%	0%
4. Is the occurrence of target fish increases?	11.90%	88.10%	0%
5. Are the ecological, social and economic goals of AR achieved?	26.20%	73.80%	0%
6. Is navigational safety maintained?	100%	0%	0%

DISCUSSION

All the respondents were positive and supportive as the project was introduced by concerned agencies. However, the main objective that connects to the main problem or concern among fishers was not addressed directly by the project. Entangling of nets used by gillnetters in the barangay is a minor problem since the area where ARs were deployed was provided with buoys as a marker. Hence, fishermen could avoid setting gill nets near the ARs. They were also fully aware of the presence of AR structures in their place. Joint DENR-DA-DILG-DND Memorandum Order No. 2000- 01 stated that registered fisherfolks who use longline fishing gear were the only allowed fishing practice along with established ARs. Trawling, dredging and/or dragging are the main illegal activities that affect much the fishers. The ARs only cover approximately 100 m^2. The area available for illegal fishers is still much larger, leading to damage of the area and collecting all possible organisms on their way. Another is the nature of the bottom where the ARs were deployed. As mentioned earlier, the area has a sandy-muddy bottom is situated near the river mouth. Whenever heavy rainfall or typhoons happen, the sedimentation rate is high, leading to the ARs being borrowed. According to some of the respondents, less than half a meter of these deployed ARs was visible. Site selection should have been considered seriously so that the projected benefit could be achieved utmost. Although the LGUs set specific rules with regards to this matter, Lemoine et al. (2019) stated, on the hand, that deployment of ARs should be based on the predetermined objectives conceptualized by the managers or implementers. This would serve as their baseline in the implementation of the project to avoid failure in the future. Moreover, the improper manner of deployment, which makes the project ineffective and inefficient.

Moreover, numerous studies (Scarratt, 1973; Spanier, 1991; Fabi, 1996; Jensen & Collins, 1996 cited from Lee et al., 2018) claimed that the effectiveness of ARs still remains up for debate in terms of increasing biomass because it depends on the design of AR structure, in particular, whether it meets specific habitat requirements of individual species and age groups.

AR project is beneficial to fishers if properly deployed. However, fished ARs have the potential to lead to overfishing if they increase the aggregation or attraction of existing stocks without increasing the overall size (Jebreen 1995; Bohnsack & Sutherland, 1985). Such an outcome would counter their inherent purposes. Moreover, the major issue they are currently facing is the rampant dragging activities in the fishing ground, which destroys the habitat, catches all species present, does not leave the small ones, and damages their fishing gears. For instance, crab pots were soaked for 24 hours prior to hauling. Dragging activities usually happen at night time. Whenever trawl or dredge passes by the deployed crab pots, these will be dragged and nowhere to be found, contributing to the loss of income of crabbers. Municipal fisherfolks suggested enforcing the existing ordinance strictly, i.e., bans of using trawl and active gears in municipal waters. AR project quite lessens the illegal activity; however, it covers only a small area which gives the illegal practices larger area to their illegal activities. Serious consultation with different stakeholders must be conducted to come up with a more effective management plan. CRM Plans in the municipality should address the fishers' main problems, or issues currently face to gain more positive results and supports.

The results of this case study will give baseline information that can provide ideas to the local government authorities on the current status of the installed artificial reef in Tigbauan, Iloilo, Philippines, and its impacts on the fishers. Information from the study can contribute to policymakers, and coastal resource managers in decision making as to AR projects are necessary to be implemented. Improved management measures can be formulated as well to lessen its failure in the future.

CONCLUSION AND RECOMMENDATIONS

Tigbauan, Iloilo, Philippines, specifically Barangay Baguingin, is one of the LGU recipients of the AR Projects conducted nationwide in the Philippines. Monitoring is scarce in the area, thus leading to limited knowledge about the status of the installed ARs underwater. Proper deployment manner and site selection of ARs are essential and necessary to focus on to avoid failure of the projects. Barangay Baguingin failed to follow such factors, and therefore expected benefits were not achieved. Although Baguingin fishers are fully supported and are optimistic about the AR Project to provide good services for them and the ecosystem, the AR structures ultimately did not meet the fishers' expectations.

This study strongly recommends that monitoring of the implemented projects must be done to have an update on the status of the project and if whether it is feasible in the area. Different stakeholders should be involved in the monitoring process so that realizations would be met and efforts invested were not be wasted if possible. Furthermore, prior to any projects that are planned to be implemented should have a scientific basis to avoid any disappointments in the long run.

COMPLIANCE WITH ETHICAL STANDARDS

Author contributions

All authors contributed equally to the writing of the manuscript.

Conflict of interest

Authors declare that they have no conflict of interest.

Animal welfare statement

No animals were used in this study. Human rights statement Official approval is not required for this type of study.

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Appendix A

Effectiveness and Impact of Artificial Reef Project in Tigbauan, Iloilo, Philippines: A Case Study

Key Informant Interview (KII) Survey Form

Date of Interview: _____

I. Respondent Informed Consent Statement

Research conducted by:
Maria Liza T. Farquerabao and Eddie R. Domingo
MS Fisheries Biology Students
University of the Philippines Visayas

As an informed participant in this research, I understand and acknowledge that:

I have been duly informed that my responses will be kept anonymous, and my personal details and those of any other people or organizations.

I have been properly informed that the details I provide will be used for the completion of the study entitled "Effectiveness and Impact of Artificial Reef Project in Tigbauan, Iloilo, Philippines: A Case Study" and may also be used as material for books or journal articles.

I have been duly informed that I may choose to end my participation at any time without consequence.

Any questions that I had about this research have been satisfactorily answered.

_____
Signature Over Printed Name

Name of Respondent: _____
First Name Middle Name Last Name

Position/Occupation: _____

II. Overview of Installed Artificial Reef

1. What type of artificial reef was installed? State the specifications of the design.
2. Why chose that design/type?
3. Who are the target beneficiaries of this project?
4. Are there ordinances related to the installation of an artificial reef in this municipality?
5. Why Barangay Baguingin was the only recipient among the coastal barangays in Tigbauan, Iloilo?
6. When was the installation done?
7. How many were installed? Specify the area covered.
8. Who are the responsible agencies initiated the project?
9. Why come up with the projects? Are there scientific studies prior to implementation? State the reasons for installing the artificial reef.
10. Was there a consultation meeting with the fishermen or community regarding the installation? Was any information drive done in the area?
11. What were the responses of the people prior to the implementation of the project?
12. Who are responsible for the construction of the artificial reef? Are the people in the community/fishermen involved?
13. How much is the total cost of the project?

III. Effectiveness of Artificial Reef Installed

1. Is there monitoring or assessment done after the artificial reef installation?
   ___ Yes ___ No
   If yes, answer the questions below.
   - How is monitoring done? Do you have tools and methods to follow?
   - Who are responsible?
   - How were the findings recorded and stored, i.e., data management?
   - What are the challenges encountered in monitoring and regulatory activities?

Questions	Yes	No	Comments/Remarks
a. Is water quality maintained?			
b. Did the structural integrity and stability of the reef infrastructure is maintained over time?			
c. Is there an increase of contaminants in the environment (water and sediments)?			
d. Is the occurrence of pests and/or other invasive species minimized?			
e. Are the ecological, social, and economic goals of the reef achieved?			
f. Is navigational safety maintained?			
g. Are the objectives of the projects being met at the least possible cost?			
h. Does the monetized value of the project's benefits exceed the project's costs?			

If no, answer the following questions.

a. Why no monitoring or assessment had been done after the installation?
b. Any updates regarding the status of the reef and its impact on the fishermen in the area?

IV. Issues/Concerns regarding the artificial reef installed

V. Any plans for the artificial reef installed?

VI. Any future CRM plans in the municipality?

Appendix B

Effectiveness and Impact of Artificial Reef Project in Tigbauan, Iloilo, Philippines: A Case Study

Household Survey Interview Form

Household Number: _____ **Date of Interview: _____**

I. Respondent Informed Consent Statement

Research conducted by:
Maria Liza T. Farquerabao and Eddie R. Domingo
MS Fisheries Biology Students
University of the Philippines Visayas

As an informed participant in this research, I understand and acknowledge that:

I have been duly informed that my responses will be kept anonymous, and my personal details and those of any other people or organizations.

I have been properly informed that the details I provide will be used for the completion of the study entitled "Effectiveness and Impact of Artificial Reef Project in Tigbauan, Iloilo: A Case Study" and may also be used as material for books or journal articles.

I have been duly informed that I may choose to end my participation at any time without consequence.

Any questions that I had about this research have been satisfactorily answered.

_____
Signature over Printed Name

II. Personal Background

1. Name of Respondent: _____
   First Name Middle Name Last Name
2. Age: _____ years old
3. Gender: _____ Male _____ Female
4. Years of residency in Tigbauan, Iloilo
   ___ <1 year ___ 1-5 years ___ 6-10 years ___ 11-15 years
   ___ 16-20 years ___ 25-30 years ___ >30 years
5. Highest Educational Attainment:
   ___ No formal schooling ___ Elementary level
   ___ Elementary graduate ___ High school level
   ___ High School graduate ___ College level
   ___ College graduate ___ Vocational Courses
6. Religion: ___ Roman Catholic ___ Other: _____
7. Civil Status: ___ Single ___ Married ___ Widowed ___ Separated
8. Number of Household Members: _____

9. Are you a fisherman? ___ Yes ___ No
   If yes, specific gear used: _____
10. Years of Engagement in Fishing: _____
11. Major Source of Income: _____
12. Other Source of Income: _____

III. Level of Awareness

1. Are you aware of the installation of the artificial reef in your area?
   ___ No Awareness ___ Limited Awareness
   ___ Moderate Awareness ___ Extensive Awareness
   ___ Complete Awareness

2. Did you remember when was it installed? ___ Yes ___ No
   If yes, what date? _____
   If no, why? _____

3. Was there an information drive done by LGU prior to the installation?
   Is it well explained? ___ Yes ___ No
   If yes, explain what information did he/she understand.
   _____
   If no, state reason/s why. _____
4. What was your reaction to the project?
5. What was your contribution as a fisherman?
6. Are there monitoring done by LGU or any other government agencies?
   _____ Yes _____ None
   If yes, did you participate during the monitoring? _____

IV. Effectiveness of Artificial Reef Installed

1. Rate the following conditions.

1 – Very Poor, 2 – Poor, 3- Not Good Not Bad, 4 – Good, and 5 – Excellent

Questions	Rating	Comments
1. How was the status of the area before the installation of the artificial reef?		
2. How is the status now, three years after the installation?		

2. Check the answer. Provide any perceptions of the fishermen in the comment box.

Questions	Yes	No	Comments
1. Is water quality maintained?			
2. Is the structural integrity and stability of the reef infrastructure maintained over time?			
3. Is there an increase of contaminants in the environment (water and sediments)?			
4. Is the occurrence of target fish increasing?			
5. Are the ecological, social, and economic goals of the reef achieved?			
6. Is navigational safety maintained?			

3. In your own perspective, was it necessary to install the reef in your area?
   ___ Yes ___ No. Why? _____
   _____
4. Did you already feel the impact in three-year time? ___ Yes ___ No
   If yes, how? _____
   _____
   If no, why is it so? _____
   _____
5. Any issues or problems encountered regarding the presence and installation of the artificial reef?
   _____
   _____
6. Do you have a suggestion for the concerned LGU to improve the project?
   _____
   _____
7. Any other concerns/issues in the area that needs to be addressed immediately regarding your coastal area?
   _____
   _____
8. If given a chance, what message do you want to tell the fishery managers to improve the fishery resources at the same time improving your status as a fisher?
   _____

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Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2021; 7(2): 90-95 Araştırma Makalesi/Research Article

Indoor Growth Performance of *Chlorella* sp. Production at Tubular Photobioreactor

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Abstract

Microalgae are known as a source of valuable biomolecules which are used in various industrial fields such as aquaculture, food, feed, pharmaceuticals, bio-fertilizers and bioenergy. *Chlorella* sp. is one of the common microalgae, cultured in the world. In this study, it was examined that growth rate and pigment contents of *Chlorella* sp. in lab-scale tubular photobioreactor at in-door conditions. Highest cell number and highest specific growth rate were determined as 155 x 10^6 cells.mL^{-1} and 0.79, respectively. Highest dry weight was measured as 4.19±0.059 g.L^{-1} and mean dry weight was found as 3.56±0.079 g.L^{-1}. Highest chlorophyll-*a* content was found at 40th day as 106.7±0.079 µg.mL^{-1}. Highest total carotenoids was 15.87±0.033 µg.mL^{-1} at the day 22. Also, 983.8 g of total biomass was harvested in last 45 days, after the exponential phase. According to the results of this study, in-door production of *Chlorella* sp. Was provided more reliable sustainability. Also, *Chlorella* sp. is photoautotrophically producible at high amounts throughout the year.

Tübüler Fotobiyoreaktörde *Chlorella* Sp. Kültürünün İç Mekanda Büyüme Performansı

Makale Bilgisi

Alınış tarihi:
16/12/2021
Kabul tarihi:
22/12/2021

Anahtar Kelimeler:
- Mikroalg
- *Chlorella* sp.
- Fotobiyoreaktör
- Klorofil
- Pigmentler

Öz

Mikroalgler sahip oldukları değerli biyomoleküller ile akuakültür, gıda, yem, farmasötik, gübre ve biyo-enerji gibi farklı endüstriyel alanlarda kullanılan bir kaynaktır. *Chlorella* sp., dünyada kültürü yapılan en yaygın mikroalglerden biridir. Bu çalışmada *Chlorella* sp.'nin laboratuvar ölçekli tübüler fotobiyoreaktörde kapalı alan kültüründe büyüme ve pigment değerleri araştırılmıştır. En yüksek hücre sayısı ve spesifik büyüme oranı 155 x 10^6 hücre.mL^{-1} ve 0.79 olarak ölçülmüştür. En yüksek kuru ağırlık 4.19±0.059 g.L^{-1} ve ortalama kuru ağırlık 3.56±0.079 g.L^{-1} olarak belirlenmiştir. En yüksek klorofil a miktarı 40. günde 106.7±0.079 µg.mL^{-1} olarak ortaya çıkmıştır. En yüksek toplam karotenoid değeri ise 15.87±0.033 µg.mL^{-1} olarak 22. gün gerçekleşmiştir. Ayrıca üstel fazın ardından, son 45 gün içerisinde 983.8 gram toplam biyokütle elde edilmiştir. Çalışma, *Chlorella* sp.'nin kapalı alan üretiminin daha güvenilir bir sürdürülebilirlik sağladığını göstermiştir. *Chlorella* sp., yıl boyunca yüksek miktarlarda fotoototrofik olarak üretilebilirdir.

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INTRODUCTION

Sustainability become much more important than ever in last recent years. Need of higher amounts of raw materials and depletion of natural resources are the main reasons of that result. However, certain organisms such as microalgae, might be the solution of this problem. High productivity, sustainability and valuable metabolites make these organisms unique resources (Gouveia and Oliveira, 2009; Ruiz et al., 2016).

Microalgae are used as resources in various industrial applications such as aquaculture, food industry, agriculture, cosmetics, feed and bioenergy (Yaakob et al., 2014; Sirakov et al., 2015; Mourelle et al., 2017; Palabıyık et al., 2018; Durmaz et al., 2020). Essential and polyunsaturated fatty acids, high amounts of protein and pigments make microalgae biomasses and their products more demanded raw materials. *Chlorella* sp. is one of the most produced microalgae species after *Spirulina*. Their

cellular composition, high productivity and ability of heterotrophic and mixotrophic growth are the main reasons related with this high demand.

Microalgae are single cell photosynthetic, microscopic organisms which are consume CO_2 as a carbon source. Flasks, bags, ponds, photobioreactors (PBRs) and fermenter systems are used for cultivation of these microorganisms. Every cultivation system has both advantages and also disadvantages. For instance, while ponds require low installation and operational advantages, photobioreactors provide higher yields and reliable sustainability. Also, outdoor and in-door production systems varies by each other with advantages/disadvantages such as illumination costs. Outdoor production benefits from sunlight and no need artificial illumination and therefore electricity costs may be lower than the other systems. However, this production is highly dependent on environmental conditions. Consequently, sustainable production of microalgae requires fully controlled cultivation environment and production process (Olaizola, 2003). Through this, in-door production emerges as the optimum solution for year round sustainable production of microalgae. In this study, in-door production of *Chlorella* sp. at laboratory scale tubular PBR was investigated.

MATERIALS and METHODS

Cultures

Chlorella sp. strain was provided from Ege University, Faculty of Fisheries (Izmir, Turkey). Stocks were cultured in 5 L flasks with BG-11 medium. Cultures were maintained at room temperature (20-22 °C) and illuminated by fluorescent lamps with 70 $\mu mol.m^{-2}.s^{-1}$. BG-11 medium was used for both stocks and tubular PBR experiment. Medium was prepared at Kastamonu University, Faculty of Fisheries (Kastamonu, Turkey) (Table 1 & 2).

Table 1. BG-11 medium

Solution 1	**0.5 L**
$NaNO_3$	75.0 g
Solution 2	**0.5 L**
K_2HPO_4	2.0 g
$MgSO_4.7H_2O$	3.75 g
$CaCl_2.2H_2O$	1.80 g
Citric acid	0.30 g
Ammonium ferric citrate	0.30 g
$EDTANa_2$	0.05 g
Na_2CO_3	1.00 g

Table 2. Trace elements solution of BG-11 medium

Trace elements solution	**1 L**
H_3BO_3	2.86 g
$MnCl_2.4H_2O$	1.81 g
$ZnSO_4.7H_2O$	0.22 g
$Na_2MoO_4.2H_2O$	0.39 g
$CuSO_4.5H_2O$	0.08 g
$Co(NO_3)2.6H_2O$	0.05 g

Properties of Tubular PBR

Tubular PBR system (Model, Producer, City, Country) consists of 2 parts; transparent tubes and the reservoir tank. Total system volume is 140 L. System was illuminated by fluorescent lamps (45 $mmol.m^{-2}.s^{-1}$) between the tubes and also low CRI led lights with 130 $mmol.m^{-2}.s^{-1}$ were placed in front of the tubular system (4 x 100 W) for supporting the illumination (Figure 1). Light intensities were measured by Apogee MQ-620 quantum meter. System was operated at room temperature (20-22 °C) during the experiment period. System pH and temperature were tracked by sensors of JBL ProFlora pH/CO_2 controller. Also, system pH was controlled by the same device with automatic injection of pure CO_2 gas and was held at 8.00±0.05.

Figure 1. *Chlorella* sp. production at tubular PBR

Tubular PBR system was disinfected by adding sodium hypochlorite. After first 24 hours, sodium thiosulfate was added into the system for neutralization of the chloride. Then, *Chlorella* sp. Stocks were inoculated to the Tubular PBR system.

Growth and Dry Weight

Cell density was determined under microscope by using Neubauer haemocytometer. Growth rate was calculated with the formula given below.

$$\mu = \frac{\ln(N_t) - \ln(N_0)}{t - t_0}$$

0.45 µm filter papers were dried in the oven at 105 °C for 2 hours and were weighted. After that, 5 mL samples were filtered and were dried in the oven at same temperature until there was no change at weights (Zou and Richmond, 1999).

Pigment Analysis

Chlorophyll-*a* and total carotenoid contents were determined spectrophotometrically. 5 mL of samples were centrifuged, and supernatant was discarded. After that, 5 mL methanol and glass beads were added to the samples and mixed by vortex. Mechanical agitator was used for cell disruption. After this step, samples were placed into the ultrasonic bath. Lastly, samples were centrifuged, and supernatants were taken to determine absorbance values at defined wave-length by using a spectrophotometer (Hach DR 6000). Chlorophyll *a* and total carotenoids were calculated according to the Equation 1 and 2, respectively (Sanchez et al., 2005; Zou and Richmond, 2000);

Chlorophyll *a* (µg/ml) = 13.9 A_{665}^{*} (Eq. 1)

$^{*}A_{665}$; absorbance value at 665 nm

Total carotenoids (µg/ml) = 4.5 A_{475}^{*} (Eq. 2)

$^{*}A_{475}$; absorbance value at 475 nm

RESULTS

Starter cell density of tubular PBR experiment was 0.925 x 10^6 cells.mL^{-1}. Cells were profilirated rapidly and cell number was reached to 41 x 10^6 cells.mL^{-1} at 13th day. Specific growth rate was calculated as 0.316 in that growth phase. After that, culture cell number was varied between 93.5-155 x 10^6 cells.mL^{-1} until the end of the experiment. Highest cell number was determined as 155 x 10^6 cells.mL^{-1} while highest specific growth rate was calculated as 0.79. Mean cell number and specific growth rate were calculated as 93.2 x 10^6 cells.mL^{-1} and 0.078 (Figure 2).

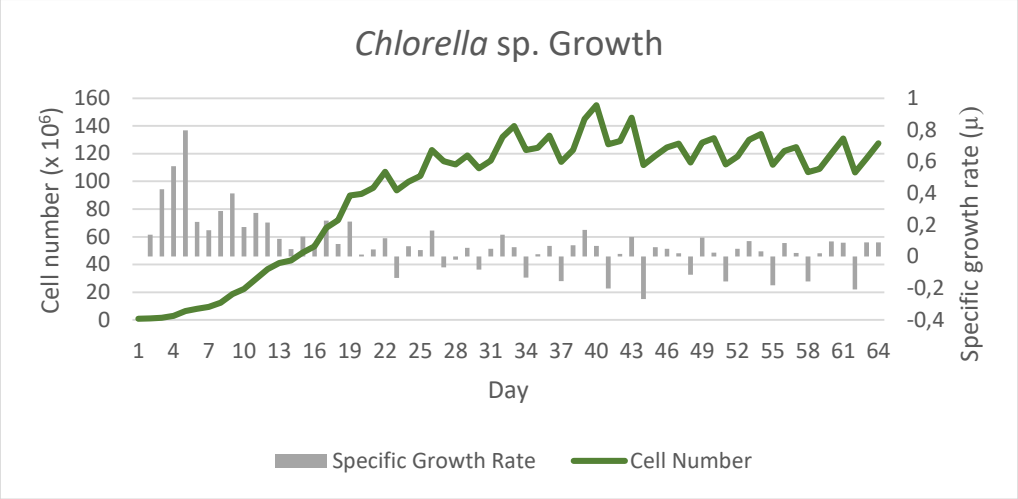

Figure 2. *Chlorella* sp. cell numbers and specific growth rates at lab scale indoor tubular PBR.

Harvest regimen was started at 5th day between 5% and 15% harvested regimes in the total culture. 275 L culture was harvested and 8.5 L medium was added, during the whole experiment. Highest dry weight was measured as 4.19±0.059 g.L^{-1} and mean dry weight was found as 3.56±0.079 g.L^{-1}. Totally, 983.8 g *Chlorella* sp. was harvested in 64 days of culture period (Figure 3).

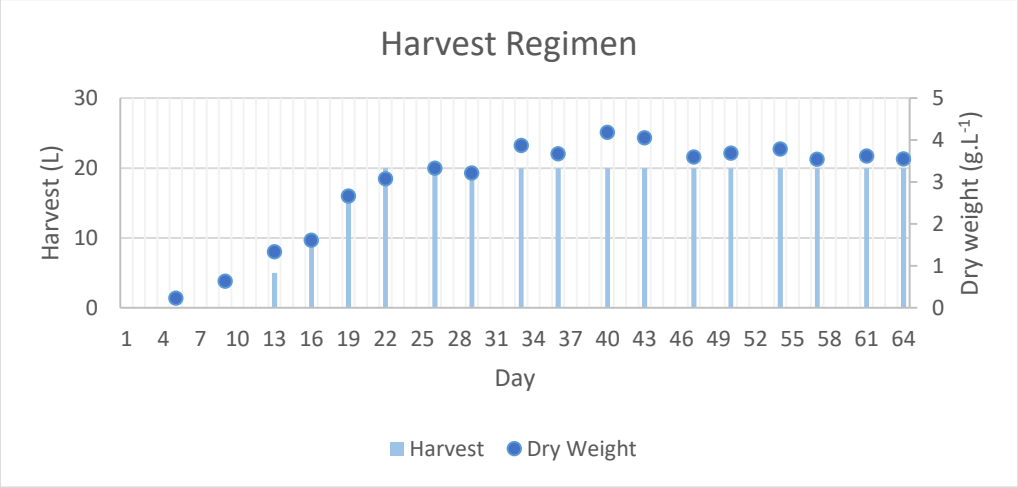

Figure 3. *Chlorella* sp. harvest amounts and dry weights at lab scale indoor tubular PBR.

Chlorophyll-*a* content of *Chlorella* sp. was 7.42±0.08 µg.mL^{-1} at 9th day. Highest chlorophyll *a* amount was found at 40th day as 106.7±0.079 µg.mL^{-1}. Lastly, mean chlorophyll *a* amount was calculated as 69.2±0.051 µg.mL^{-1} for the experiment period (Figure 4).

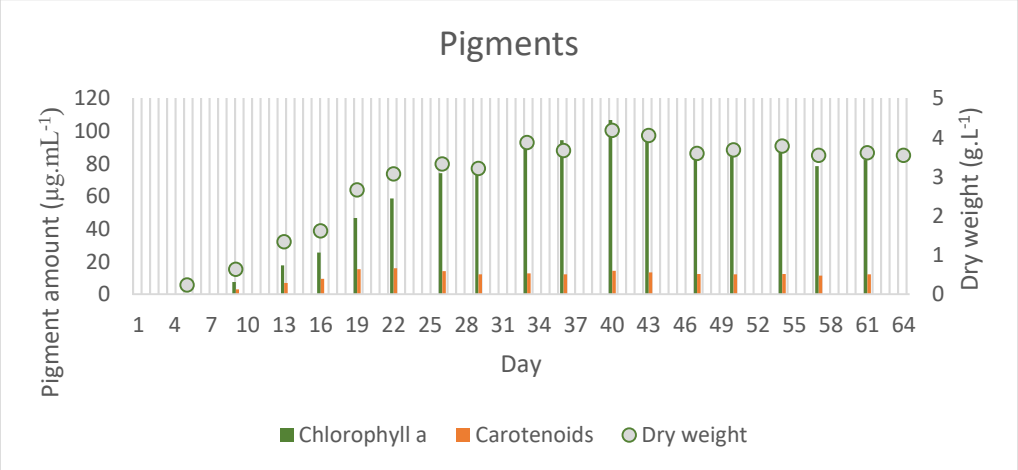

Figure 4. *Chlorella* sp. pigment amounts per mL dry weights at lab scale indoor tubular PBR.

Total carotenoid contents were also determined. According to the results, at the first measurement (day 9) total carotenoids was found as 2.91±0.009 µg.mL^{-1}. Highest carotenoid content was 15.87±0.033 µg.mL^{-1} at the day 22 and mean carotenoid content was calculated as 11.81±0.069 µg.mL^{-1} (Figure 4).

Also, cellular dry weight and cellular pigment amounts were calculated according to the dry weights, pigment amounts and cell numbers. Highest cellular dry weight was calculated for the day 5 as 36.6 pg.cell^{-1} and lowest cellular dry weight was found as 27.01 pg.cell^{-1} for the day 40. Lastly, mean cellular dry weight was found as 29.18 pg.cell^{-1}. Cellular chlorophyll-*a* amount was varied between 0.399-0.709 pg.cell^{-1}. Highest cellular chlorophyll-*a* content was found at 36th day while lowest chlorophyll *a* amount was found at the day 9. Mean chlorophyll-*a* content was determined as 0.595 pg.cell^{-1}. Total carotenoid content per cell amount was found at the highest level as 0.179 pg.cell^{-1} at 16th day. Lowest carotenoids was 0.091 pg.cell^{-1} at the day 43 and mean carotenoids was determined as 0.12 pg.cell^{-1} (Figure 5).

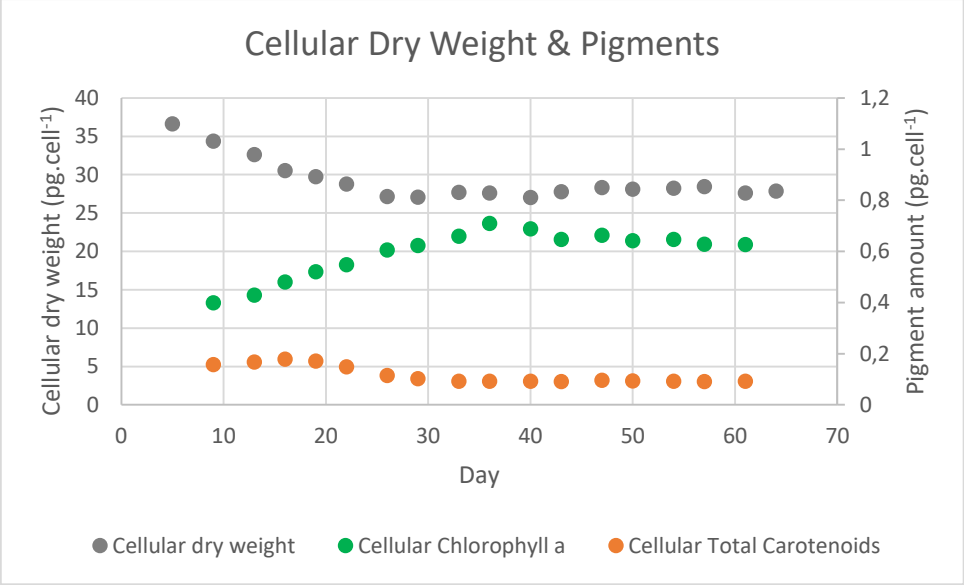

Figure 5. *Chlorella* sp. cellular dry weights and pigment amounts per cell.

DISCUSSION

In a recent study, nutrient reclamation for Chlorella vulgaris was investigated. Culture was done with artificial illumination and it was found that *Chlorella vulgaris* concentration was reached to 1.1 g.L^{-1} level (Chang et al., 2018). It is stated that maximum dry weight was 1.84 g.L^{-1} of *Chlorella vulgaris* produced at membrane PBR (Gao et al., 2019). A study shows that *Chlorella sorokiniana* was reached to 146 x 10^6 cells.mL^{-1}. Also, it was indicated that maximum dry weight was found as 3.45 g.L^{-1} with high level of NO_3 concentration (Ziganshina et al., 2020). Wong et al., (2016) was determined that *Chlorella vulgaris* may reach to 0.8 g.L^{-1} at column bubbling PBR. It was stated that 3.66 g.L^{-1} dry weight of *Chlorella vulgaris* was maximum at PW-PBR (Liao et al., 2017). In this study *Chlorella* sp. was produced at in-door lab scale tubular PBR for 2 months. According to the results, *Chlorella* can be growth in-door intensively much as 4.2 g.L^{-1}. Culture density was not fluctuated after exponential phase and mean cell number was calculated as 121.2 x 10^6 cells.mL^{-1} for stationary phase. Also, 3.63 g.L^{-1} mean dry weight was found for that period.

Chlorophyll-*a* concentration of *Chlorella vulgaris* at PBR was determined as 15.46 ± 1.05 mg.L^{-1} by Chang et al., (2018). In another study, Liao et al., (2017) was determined that highest chlorophyll-*a* accumulation of *Chlorella vulgaris* was 99.29 mg.L^{-1} at PW-PBR. Lower chlorophyll-*a* content of *Chlorella vulgaris* was found at flat-plate PBR experiment. It is stated that chlorophyll-*a* yield was 4.5 mg.L^{-1} (Lakaniemi et al., 2011). In this study, maximum chlorophyll-*a* content was determined as 106.7±0.079 mg.L^{-1}. It is concluded that culture density was the main factor of variations of maximum chlorophyll-*a* content between various studies. Cellular accumulation amounts might be more useful when tracing the changes in cellular composition. In our study, cellular chlorophyll *a* amount was increased while cellular dry weight and cellular total carotenoids content were decreased. Chlorophyll-*a* per cell increase might be the result of cellular response to culture density. It is expected that mutual shading will increase as the cell number increases. Thus, cells will have lower oppurtinity to get energy from the illumination for photosynthetic reactions. Decrease in cellular carotenoids level can be explained with low stress conditions during the experiment period. Also, decrease in cellular dry weight supports the inverse ratio between cell number and cellular dry weight was reported by Zou & Richmond, (1999).

2 months of in-door production of *Chlorella* sp. at tubular photobioreactor was done in this study. After exponential phase 3.63 g.L^{-1} dry weight was obtained without any stress conditions. Study shows that in-door production of *Chlorella* sp. provided more reliable sustainability.

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Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2021; 7(2): 96-104 Derleme Makale/Review Article

Kılıç balıklarının (*Xiphias gladius*) ilginç davranışları

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Öz

Kılıç balığı, üst çenesindeki kılıca benzer keskin ve çok uzun uzantıdan dolayı adını rostrumundan (gaga) almıştır. Görünüşü ile son derece tehlikeli ve yırtıcı bir özellik gösterir. Tehlike anında kullandığı tek silahı kılıcıdır. Bu kılıçla 30 cm kalınlığındaki ahşabı delebilen kılıç balığı, teknelere rahatlıkla saldırabilir. Kılıç balığı üzerine yapılan birçok araştırmanın derlenmesinden oluşturulan bu çalışma, kılıç balıklarının bazı ilginç davranışlarını sunmaktadır. Bunlar arasında, yatay-dikey hareketleri, beslenme, saldırı, güneşlenme ve kur yapma davranışları üzerinde durulmuştur.

Interesting Behaviours of Swordfish (*Xiphias gladius*)

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Abstract

The swordfish has got the name from its rostrum owing to the sword-like sharp and very long extension on its upper jaw. It shows an extremely dangerous and predatory feature with its appearance. The only weapon that uses in moment of danger is its sword. The swordfish, which can pierce 30 cm thick wood with this sword, can easily attack even boats. From the compilation of the many studies on the swordfish, this study presents some interesting behaviours of swordfish. Among these, horizontal-vertical movements, feeding, attacking, basking and courting behaviours were emphasized.

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GİRİŞ

Büyük pelajik balıklar içerisinde yer alan kılıç balıkları (*Xiphias gladius*, L. 1758), isimlerini üst çenede uzayan kılıç benzeri rostrumundan almıştır. Kılıç balıkları ekonomik değeri yüksek göçmen balıklardır. Genellikle ılıman denizlerde bulunmalarına rağmen, yaz aylarında İzlanda gibi soğuk denizlerde de dağılım göstermektedir. Kılıç balıkları 4,5 m boya ve 650 kg ağırlığa kadar büyüyebilmektedir (Nakamura, 1986). Kılıç balıklarının Akdeniz'de üreme döneminin Haziran ayında başlayıp Eylül ayına kadar sürdüğü ve Haziran sonu ile Ağustos ayları arasında maksimum düzeye ulaştığı bildirilmiştir (Nakamura, 1985).

Kılıç balıkları, Atlantik, Pasifik ve Hint Okyanusları'nın tropikal ve ılıman kesimlerinde (50°N – 50°S) yaygın olarak bulunur (Nakamura, 1985; Sakagawa, 1989). Kılıç balığının dağılımı cinsiyete göre de değişir; daha büyük dişiler daha yüksek enlemlerde yaygındır. Erkek kılıç balıkları ise tropikal ve subtropikal sularda daha yaygındır. Yavrular ise en çok tropikal ve subtropikal sularda görülür ve olgunlaştıktan sonra daha yüksek enlemlere göç ederler (Kailola ve diğ., 1993). Genellikle 13°C'den daha sıcak yüzey sularında bulunan, ancak 5°C ile 27°C sıcaklığa tolerans gösterebilen epipelajik ve mezopelajik bir tür olarak kılıç balıkları, gözlerini ve beyinlerini sabit olarak neredeyse 28°C'de tutmalarını sağlayan özel bir "beyin ısıtıcısı"

geliştirdikleri için, günlük göçleri sırasında deniz suyu sıcaklıklarındaki ani değişikliklere tolerans gösterebilir (Carey, 1982; Tullis ve Block, 1996).

Bu kozmopolit balıklar, polar denizler hariç dünyanın tüm okyanuslarında yaygın olarak bulunur; ancak en büyük av sahaları Akdeniz ve Kuzeybatı Pasifik'tir (Draganik ve Cholyst, 1988). Lezzetleri nedeniyle kılıç balıklarına uluslararası yüksek bir talep vardır. Japonya'da bir deniz ürünü olarak mükemmel bir ünü vardır ve sashimi (baharat ilavesiyle soya sosuna konmuş balık dilimleri) olarak taze tüketilir (Akyol, 2018). Kılıç balıkları toplam av içerisinde ton benzeri balıkların %3,6'sını oluşturmasına rağmen, toplam pazar değerinin %12'sini oluşturmaktadır (Draganik ve Cholyst, 1988).

Oldukça güçlü ve bir o kadar hızlı olan bu heybetli balıkların dünya denizlerindeki avcılığı oltalar, zıpkın, parakete ve ağ dalyanlarla yapılmaktadır. Bunlardan farklı olarak diğer bir avlama yöntemi ise yüzer ağlarla (drift-net) yapılan avcılıktır. Bu avcılık dünya genelinde hedef dışı av oranının yüksek olması nedeniyle yasaklanmış olup, Türkiye bu yasağa 2011 yılında dâhil olmuştur. Yüzer ağların yasaklanması, en eski geleneksel av yöntemi olan zıpkın ve ayrıca parakete avcılığının artmasına neden olmuştur (Akyol, 2018).

Kılıç balıklarının kendine özgü davranışları hakkında dünya literatürüne girmiş bazı dağınık bilgiler bulunmaktadır. Bunları derli toplu bir yayında bulmak ise oldukça güçtür. Bu çalışmanın amacı, son derece güçlü vücut yapısı ve denizlerin en hızlı (>110 km) yüzeni olan kılıç balıklarının kendine has bazı ilginç davranışlarını ortaya koymaktır.

Kılıç balıklarının davranışları

Yatay ve dikey göçler

Kılıç balıkları, doğrudan gözlem için çok az fırsat sunan büyük, hızlı yüzen balıklardır ve mavi yüzgeçli orkinos (*Thunnus thynnus*), büyük gözlü orkinos (*T. obesus*) ve sarı yüzgeçli orkinos (*T. albacares*) gibi diğer büyük pelajik türlerde olduğu gibi günlük yatay veya dikey göçler yaparlar (Schaefer ve Fuller, 2002; Musyl ve diğ., 2003; Teo ve diğ., 2007; Schaefer ve diğ., 2007). Bununla birlikte, bu göç davranışlarının bazı yönleri, telemetri ile kolayca incelenebilir (Carey ve Robinson, 1981). Çalışmalar, bu balıkların gündüz mesopelajik tabakada yüzdüğünü ve geceleri ise yüzey tabakasına yükseldiğini göstermektedir (Carey ve Robinson, 1981). Yani, kılıç balıkları gündüz 200 m'den daha derinde yüzerken, gün batımından sonra ve gece muhtemelen beslenme amacıyla yüzeyde bulunmaktadırlar (Takahashi ve diğ., 2003; Abascal ve diğ., 2010).

Akustik izleme çalışmaları ise kılıç balıklarının yatay olarak gün boyunca kıyı ile açık deniz arasında günlük hareket döngüsü gösterdiğini ortaya koymuştur (Takahashi ve diğ., 2003). Hawaii açıklarında 1990 yılında gerçekleştirilen bir etiketleme deneyinde, denize bırakılan beş yüzden fazla kılıç balığından yalnızca beşi yakalanmış olmasına rağmen, balıkların döngüsel mevsimsel göç yolları gösterilmiştir (De Martini ve Boggs, 1999).

Takahashi ve diğ. (2003), kılıç balıklarının bir etiketleme denemesini, Japonya'nın doğu kıyılarında, 1999 yılının Temmuz ayında zıpkın balıkçılığı sezonunun başlarında, ticari bir zıpkın balıkçı teknesi kullanılarak gerçekleştirmişlerdir. Yapılan bu çalışmada ilk olarak, bu dönemde sıcaklık 10°C'den 20°C'ye yükseldiğinden, balıkların etiketlemeden hemen sonra güneye doğru hareket ettiğini, sonra yüksek sıcaklık ve yüksek tuzluluk ile karakterize edilen 34-36°N civarındaki Kuroshio ılık suyuna ulaşıp, orada kaldıklarını tespit etmişlerdir. Daha sonra, Ağustos ayından Ekim 1999'un başlarına kadar, 80 ve 160 m'deki sıcaklıkların 5°C ile 10°C arasında olduğu ve balığın düşük sıcaklık ve düşük tuzluluk ile karakterize edilen Oyashio su alanında bir bölgeye (40-43°N) ulaşarak kuzeye doğru hareket ettiğini bildirmiştir. Ardından balığın, karışık tabakanın yaz ve sonbaharda geliştiği Kuroshio-Oyashio geçiş bölgesinden güneye doğru hareket ettiğini ve Kuroshio uzantısının güneyindeki bölgeye, yani Ocak ayında bile su sıcaklığının yüksek olduğu subtropikal alana ulaştığını ortaya koymuştur. Mart 2000'de, balığın subtropikal alanı terk ettiği ve kuzeye doğru hareket ettiğini, Mayıs ve Haziran aylarında geçiş alanı ile Oyashio su alanı arasına ulaştığı ve daha sonra da orada kaldığını bildirmişlerdir (Takahashi ve diğ., 2003).

Günümüze kadar, 628 m derinlikte bir kılıç balığından bahseden Harbison (1987) ve akustik telemetri kullanarak kılıç balığının dikey dağılımının 617 m olduğunu gösteren Carey ve Robinson (1981) tarafından çeşitli derinliklerde dikey gözlemler bildirilmiştir. Ancak son kayıtlar kılıç balıklarının >1100 m'lere kadar indiğini kanıtlamaktadır (Abascal ve diğ., 2010). Geceleri, kılıç balıkları her zaman beslenebilecekleri ve aynı zamanda gün geçtikçe kazandıkları termal veya oksijen tükenmesinden kurtulabilecekleri karışık katmanlarda kalmaktadırlar. Geceleri ay evresiyle ortalama derinlikteki değişim, Carey ve Robinson (1981) tarafından belirlenmiştir; ancak bu yazarlar yalnızca farklı balıklardan verilerle çalışmışlardır. Verilerden geceleri maksimum derinliğe genellikle dolunaya yakın ulaşıldığı görülmektedir (Abascal ve diğ., 2010). Analizlerde bu ortalama derinlik her zaman termoklinin üzerindedir. Kesin sonuçları formüle etmek için daha fazla veriye ihtiyaç duyulmasına rağmen, termoklinin derinliği kılıç balıklarının gece dikey dağılımını sınırlıyor gibi görünmektedir. Kılıç balıkları genellikle şafaktan hemen önce derin katmanlara inmektedir. Karışık katmana döndüklerinde akşam karanlığına kadar orada kalırlar. Kaydedilen maksimum derinlik 1136 m olmasına rağmen, analiz edilen altı kılıç balığının beşinde 900 m'ye kadar dalış yaptıkları gözlenmiştir (Abascal ve diğ., 2010).

Kılıç balıkları, birkaç farklı fizyolojik adaptasyonun bir sonucu olarak bu kadar derin sulara inebilme kabiliyetine sahiptir. Yani, kafasındaki termojenik bir organ olan beyin ısıtıcısının varlığı (Carey, 1990) avlarını loş ışıkta takip etmelerine olanak sağlayan büyük gözleri, kılıç balığını anoksiye karşı diğer büyük pelajik türlere göre daha dirençli hale getirebilecek ve oldukça derinlerde yiyecek ararken oksijen birikimine olanak sağlayan büyük beyaz kas kütlesine sahiptirler (Carey ve Robinson, 1981). Ayrıca, kılıç balıklarının beyni ve gözü sudan daha sıcaktır. Göz kaslarından biri beyni ısıtan bir dokudur. Bu beyin ısıtıcısı, mitokondri ve sitokrom-c açısından zengindir ve bir vasküler ısı eşanjörü aracılığıyla kanla beslenir. Bu kılıç balığını geniş bir

sıcaklık aralığına götürebilecek günlük dikey geziler sırasında merkezi sinir sistemini hızlı soğumadan korumaktadır (Carey, 1982).

Kılıç balıkları tüm okyanusların tropikal ve subtropikal bölgelerinden ılıman sulara yatay göçler de yapmaktadır (Palko ve diğ., 1981). Kuzeybatı Atlantik'ten gelen etiket dönüş verileri, kılıç balıklarının yıl boyunca çok sınırlı göç hareketi yaptığını ve her yıl aynı beslenme alanlarına geri döndüğünü göstermektedir (Beckett, l97l). Kılıç balıklarının kat ettiği ortalama düz hat mesafesi 878 ± 750 km'dir. Kaydedilen en uzun mesafe, 62 günde 2632 km yol kat eden Küba ile Haiti arasındaki Windward Geçidi'nde bırakılan bir balıktan elde edilmiştir (Dewar ve diğ., 2011). Tüm balıklar için asgari seyahat oranı tahmini 0,2 km ile 59 km/gün (ortalama 21 ± 17 km/gün) arasında değişmekle birlikte, Kaliforniya açıklarından bırakılan bir kılıç balığın ait 19 günde 1126 km'lik yol, kaydedilen en yüksek hız olarak belgelenmiştir (Dewar ve diğ., 2011).

Beslenme

Kılıç balıklarının büyük gözleri ile gözbebekleri loş ışıkta bile hızlı hareketleri algılamaya uyum sağlamıştır ve küçük mesafelerde görsel işaretlere bağlı olarak ışıklı ortamlar esas beslenme davranışını belirliyor olmalıdır (Poisson ve diğ., 2010). Beslenme çalışmaları, kılıç balıklarının günlük hareketlerinin dikey olduğunu, gündüz saatlerce dipte iken, onun esas besini olan kalamarların gece yoğun bulunduğu yüzey sularına çıktığını açıkça göstermektedir (Romeo ve diğ., 2009b).

Kılıç balıkları, avını canlı olarak ve doğrudan doğruya kapamaz; burnunun ucunda uzanan kılıcı bunu yapmasına engel olmaktadır. Avını görür görmez, ilkin kılıcı ile çarparak onu parçalamakta, sonra sırt üstü dönerek avını yutmaktadır (Alev, 1966). Goode (1882), kılıç balığının bir balık sürüsünün altında yükseldiğini, birkaç balığı öldürene kadar sağa ve sola kılıcıyla vurduğunu ve sonra yutmaya devam ettiğini bildirmiştir. Kılıç balıklarının beslenme davranışı üzerine yapılan araştırmalar, uzun gaganın yandan kullanılarak avı öldürmek ve kesmek için yararlanıldığını ortaya koymuştur (Scott ve Tibbo, 1968). Bu durum özellikle iki veya daha fazla bölüme ayrılmış kalamar ve palaska balıklarında, gaganın neden olduğu belirgin yaralanmalara sahip mide içeriğinde bulunan av parçaları ile de kanıtlanmıştır (Stillwell ve Kohler, 1985; Romeo ve diğ., 2009a).

Kılıç balıklarının çok büyük balıklarla beslendiği görülmez; ancak, Hawaii Adaları'nın güneyinde 1955 yılında gerçekleşen ilginç bir olayda '*J. R. Manning*' adlı balıkçılık araştırma gemisinde yakalanan bir kılıç balığının tam 680 kg geldiği kaydedilmişti. Balığın midesi açıldığında henüz yenmiş 1,5 m boyunda ve 71 kg gelen bir sarı yüzgeç orkinos tespit edilmiştir. Orkinosun vücudunun her iki yanında birer kesik olduğu ve kılıcın avını başından başlayarak yuttuğu görülmüştür (Burton ve Burton, 1979). Kılıcın rakip erkeklerle savaşmak için kullanıldığına dair bir kanıt ise bulunmamaktadır (Hardy, 1959).

Kılıç balıklarının avını bölerek yediğini bilen oltacılar, baş ve kuyruktan teraziledikleri palamut veya toriği derin suya indirir ve beklerler. Balık yeme kılıcı ile hızla vurur. Bu vuruş oltacıyı haberdar eder. Balık gevşek tutulan yemi parçalayamaz. Oltacı bu yemi hemen yukarı çekerek büyük bir iğneye yaprak kesilerek takılmış ve çelik telle kalın ve sağlam bir ipe bağlanmış asıl oltayı balığın dolaştığı suya indirir. Kılıç balığı, sonradan indirilen bu yemi parçaladığı balık zannederek yutar ve iğne damağına oturtulmak suretiyle yakalanır (Üner, 1968).

Saldırı

Kılıç bir saldırı silahı olmalıdır. Balığın kılıcının bir saldırı silahı olduğu fikrini besleyen bu gaganın zaman zaman gemilerin tahtalarına saplanmış bir halde bulunmasıdır. Önünde kılıcıyla saatte 60 mil hıza çıkabilen bu balık bazen bir tekneye, bir balinaya ya da diğer iri bir objeye çarpabilmektedir. Burada aslında ilginç olan kılıcın verdiği zarar ve bunun için gereken güçtür. Amerikalı bir tabiat tarihi koleksiyoneri E. W. Gudger, kılıç balıklarının gemilere saldırmaları konusunda mümkün olduğu kadar çok hikâye toplamaya çalışmıştır. Örneğin, '*Fortuna*' adlı balina gemisinin serüveni oldukça ilginçtir: Gemi 1826'da Massachussettes'de Plymouth limanına eriştiği zaman alt kısmında bir balığın kılıcının saplı olduğu fark edilmiş. Kılıç bakır kaplamayı, 10 cm kalınlığında tahtayı, 30 cm eninde meşe döşemeyi, 6,25 cm'lik tavan kirişini ve bir yağ fıçısını delmişti. Sir James Gray, bir keresinde bir kıyaslama yapmak için saatte 10 mil hızla giden 272 kiloluk bir kılıcın bir geminin yanına vurduğu zaman her 2,5 cm^2'ye bir tonun üçte biri kadar bir güç isabet edeceğini söylemiştir. Aynı zamanda, saatte 80 mil hızla giden 272 kiloluk bir kılıç balığı, kendisine doğru yine aynı süratle gelen bir gemiyle çarpıştığı zaman her 2,5 cm^2'ye dört buçuk tonluk bir güç isabet ettiğini hesaplamıştır (Burton ve Burton, 1979).

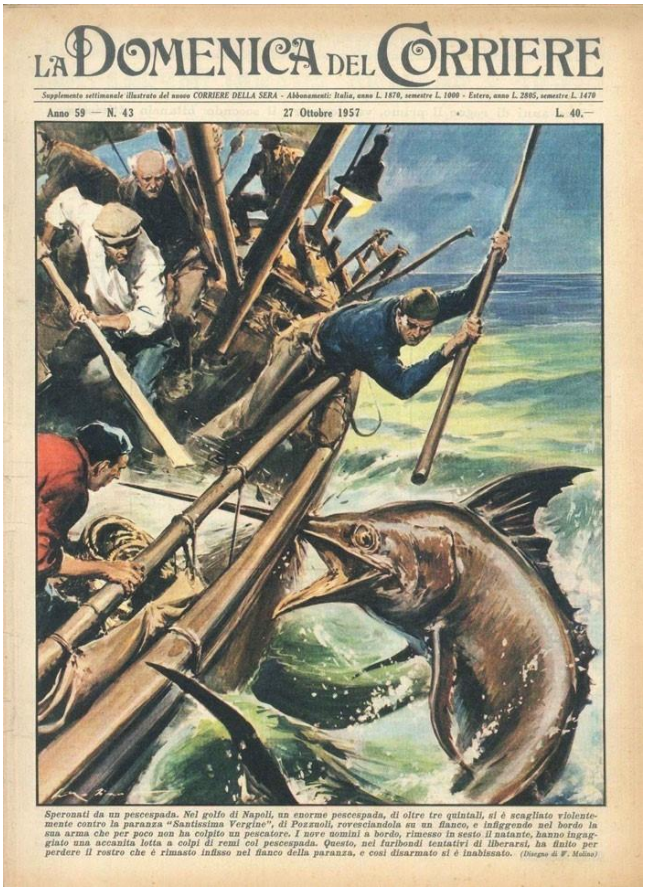
Bilim adamları kılıç balıklarının bazen adeta çıldırdıklarına ve bilerek saldırdıklarına inanmaktadır. İngiltere'de Worcester yakınlarında Severn Nehri'ne giren bir adama bir kılıç balığı saldırmış ve onu ölüm derecesinde yaralamıştır (Burton ve Burton, 1979). Okyanus sularından insanlara birkaç kılıç balığı saldırısı bildirilmiştir ve bu olaylar genellikle klinik bakış açısıyla incelenmiştir. Araştırmalar, bu balığın kışkırtıldığında veya rahatsız edildiğinde tehlikeli davranış gösterebileceğine işaret etmektedir (Romeo ve diğ., 2017). Malezya'da bir adam yüzerken kılıç saldırısıyla yaralanmış ve sonrasında ölümle sonuçlanmıştır (Gooi ve diğ., 2006). Yine, Santorini Adası'nda (Yunanistan), yüzen bir kadına muhtemelen kışkırtılmış bir kılıç balığı saldırısı vakası da bildirilmiştir (Georgiadou ve diğ., 2010). Kılıç balığı genellikle kışkırtıldığında veya eşini savunmak istediğinde saldırır ve bazı durumlarda tekneyi kılıcı ile delmeye çalışır (Romeo ve diğ., 2017). Bir balina teknesinde bir kılıç balığının gagası 35 cm kalınlığındaki sağlam tahtayı delmiştir. Diğer bir vakada ise gaganın 55 cm kalınlığındaki keresteyi delip geçtiği görülmüştür. Bu olayların bir kaza mı olduğu, yoksa balığın mahsus mu saldırdığı uzun yıllardan beri tartışılmaktadır. Ancak balığın teknelere kaza ile çarpması ihtimali daha kuvvetlidir (Burton ve Burton, 1979).

Bununla birlikte, beslenme stratejisinde kullanılan gaga, savunma amacıyla da kullanılır ve aynı zamanda büyük pelajik hayvanlara (balinalar, köpekbalıkları ve kaplumbağalar) yönelik saldırılar da bildirilmiştir (Goode, 1882; Gudger, 1938, 1940; Ellis, 2013). Ayrıca küçük denizaltılara veya batiskaflara da saldırı vakaları vardır (Romeo ve diğ., 2017). Florida'da batiskaf '*Alvin*' in yaptığı bir keşif gezisi sırasında meydana gelen bir saldırının ayrıntısı verilmiştir (Zarudski ve Haedrich, 1974); bu

olayda, bir kılıç balığı, denizaltının alt ve üst kısımlarının bir eklemine saplanmış ve denizaltı yüzeye çıktığında yakalanmıştır (Romeo ve diğ., 2017).

Kılıç balıklarının görme yeteneği, bu türün saldırgan davranışı sırasında belirli bir hedef seçmesine izin verir (Romeo ve diğ., 2017). Bildirilen birkaç vakada kılıç balıklarına zıpkın atıldığında, avcıya saldırarak misilleme yapmıştır (Romeo ve diğ., 2015). Bu gibi durumlarda saldırıların, balıkçı gemisini olası bir düşman ve/veya eşinin ölümünün ana nedeni olarak algılama eğilimini yansıttığı ve Sisci (2005) tarafından bildirildiği üzere, üreme mevsiminde erkeğin dişiye sadakati nedeniyle gerçekleştiği varsayılabilir. Zıpkın avcıları arasında dişi ve erkek kılıç balıklarının üreme döneminde genellikle yumurtlamak için yüzeye yakın yüzdükleri (Romeo ve diğ., 2009b) ve erkeklerin eşini koruma eğiliminde saldırgan hale geldiği bilinmektedir (Romeo ve diğ., 2017). Bu davranış aynı zamanda zıpkın avcıları için artan yakalama fırsatını temsil etmektedir (Romeo ve diğ., 2015). Bir çift görüldüğünde, balıkçı ilk olarak en büyük örneği (genellikle dişi) teknenin yanında suda tutarak ve erkeğin yaklaşmasını beklerken zıpkınlar. Aslında, erkek eşini terk etmez ve onu savunmaya çalışır, bu da zıpkıncıya ek bireyler yakalama fırsatını verir. Tersine dişiler genellikle erkekleri savunmaz, kaçarlar (Romeo ve diğ., 2017).

Güney Tiren Denizi'nde Milazzo Körfezi'nde 1952'de ulusal bir gazete tarafından bir insana kılıç balığı saldırısı bildirilmiştir (La Domenica Del Corriere, 1957). Yayınlanan fotoğraf, bir balıkçının karnını yaralayan bir kılıç balığını göstermekteydi. Ulusal gazete "La Domenica del Corriere", 21 Eylül 1952 ve 27 Ekim 1957 tarihlerinde iki kılıç balığı saldırısı kaydı daha vermiştir. Her iki saldırı da Tiren Denizi'nde (Milazzo Körfezi ve Napoli Körfezi) meydana gelmiştir. İlk vakada, bir kılıç balığı, balık tutma faaliyeti sırasında bir balıkçının karnını yaralamış, diğer vakada ise 300 kg'dan büyük bir kılıç balığı, balıkçı teknesine saldırıp kılıcını tekneye saplamış ve kırılan gagasını kaybeden balık kaçmıştır (Şekil 1). Kılıç balığı gagasının yemleme stratejisi ve savunmada önemli bir rol oynadığı için yüksek önemi göz önüne alındığında (Scott ve Tibbo, 1968; Stillwell ve Kohler, 1985; Habegger ve diğ., 2015), gagasının kaybı balığın erken ölümüne yol açabilmektedir (Romeo ve diğ., 2017).


LA DOMENICA DEL CORRIERE

Supplemento settimanale illustrato del nuovo CORRIERE DELLA SERA - Abbonamenti: Italia, anno L. 1870, semestre L. 1000 - Estero, anno L. 2805, semestre L. 1470

Anno 59 — N. 43 27 Ottobre 1957 L. 40,—

Speronati da un pescespada. Nel golfo di Napoli, un enorme pescespada, di oltre tre quintali, si è scagliato violentemente contro la paranza "Santissima Vergine", di Pozzuoli, rovesciandola su un fianco, e infiggendo nel bordo la sua arma che per poco non ha colpito un pescatore. I nove uomini a bordo, rimesso in sesto il natante, hanno ingaggiato una accanita lotta a colpi di remi col pescespada. Questo, nei furibondi tentativi di liberarsi, ha finito per perdere il rostro che è rimasto infisso nel fianco della paranza, e così disarmato si è inabissato. (Disegno di F. Molino)

Şekil 1. Napoli Körfezi'nde bir balıkçı teknesine saldırıp kılıcını kaybeden kılıç balığının temsili resmi (La Domenica Del Corriere, 27 Ekim 1957).

Gazetenin kapağında özetle şöyle yazmaktaydı: "*Kılıç balığı tarafından çarpılmış. Napoli Körfezi'nde, dev bir kılıç balığı, kendini şiddetle ve silahını neredeyse bir balıkçıyı vuracak şekilde teknenin kenarına sapladı. Tekneyi tekrar yola koyan dokuz adam, kılıç balığıyla şiddetli bir kürek mücadelesine giriştiler. Bu, kendini kurtarmak için yapılan öfkeli girişim, trolün kenarına sıkışmış kılıcı kaybetmekle sonuçlandı ve böylece balık silahsız olarak batıp gitti (Çizim: W. Molino)*."

Zıpkın balıkçılarının tanıklığı, tüm saldırılarda net bir hedef seçimini ve gemiye doğru kılıcın agresif kullanımını vurgulamaktadır. Saldırılara her zaman bir savunma davranışı neden olmuşsa da, balığın insanları veya bir tekneyi gerçekten bir tehdit olarak algılayıp algılamadığı hala belirsizdir (Ellis, 2013).

Tüm bunlara karşın, kılıç balıklarının gerçekte munis balıklar olduğuna dair karşı görüşler de vardır. 1910 yılında İstanbul Balıkhanesi Müdürlüğüne getirilen ve '*Türkiye'de Balık ve Balıkçılık*' isimli önemli eserin yazarı Karekin Deveciyan, kılıç balıklarının ürkütücü bir şekli olduğunu, güçlü ve esnek olduklarını, balina ve köpekbalıklarına saldıracak kadar cesur olduklarına ilaveten kılıcıyla kayıkların, hatta yelkenlilerin gövdelerini delebilecek, ağlara ve dalyanlara büyük zarar verebilecek kudrette olduğunu kabul etmekle birlikte, buna mukabil, kılıç balıklarını doğanın kendisine verdiği bu gücü kötüye kullanmayacak kadar yumuşak başlı bir hayvan olarak tanımlamıştır. Bunu da bir dalyanın içinde kılıcının ucu ağın bir düğümüne takıldığı andan itibaren kaderine küsüp hareketsiz kalmasına; hatta sudan çıkarıldığı zaman diğer balıkların yaptığı gibi çırpınmamasına bağlamaktadır (Akyol, 2018).

Güneşlenme

Tipik dikey göç hareket modelinin özel durumu, güneşlenme olaylarıdır (Dewar ve diğ,. 2011). Kılıç balıkları üzerine elektronik etiketleme çalışmalarından (Carey ve Robinson, 1981; Carey, 1990; Holts ve diğ., 1994; Takahashi ve diğ., 2003; Sepulveda ve diğ., 2010) ve ayrıca dünyanın dört bir yanındaki balıkçılar tarafından güneşlenme davranışı iyi bilinmektedir (Nakamura, 1985; Brewster-Geisz ve diğ., 1997; Coan ve diğ., 1998). Kılıç balığında yüzeyde güneşlenmeyi tarif etmek için farklı tanımlar kullanılmış olsa da, bu davranış özetle derinlikten hızlı bir yükseliş, dakikalar ile saatler arasında değişen bir yüzeyde yatış periyodu ve ardından hızlı bir alçalma olarak nitelendirilebilir (Dewar ve diğ., 2011).

Güneşlenmeye ilişkin raporların çoğu, Japonya, Şili, Kaliforniya, Meksika'nın Baja Yarımadası ve Kanada'nın kıyı sularından alınmıştır (Carey ve Robison ,1981; Sakagawa 1989; Carey, 1990; Holts ve diğ., 1994; Coan ve diğ., 1998; Takahashi ve diğ., 2003; Neilson ve diğ., 2009; Sepulveda ve diğ., 2010). Kılıç balıklarının güneşlenme davranışlarının ağırlıklı olarak daha soğuk, kıyı sularında gerçekleştiğini ve daha sonra balıklar kıyıdan uzaklaştıkça azaldığı düşünülmektedir (Dewar ve diğ., 2011). Carey ve Robinson (1981), belirgin bir oksijen minimum bölgelerinde yüzeyde bir artışa dayanarak, güneşlenmenin oksijence fakir suda yiyecek aradıktan sonra anaerobik ortamdan kurtulmaya izin verdiğini öne sürmüştür. Takahashi ve diğ. (2003), balıkların daha soğuk sulara girmesinden sonraki ilk günlerde güneşlenmenin daha yaygın olduğunu bildirerek, kılıç balığının termal olarak yeniden şarj olmak için yüzeye geri döndüğünü bildirmiştir.

İlginç bir şekilde, Güney Kaliforniya Körfezi'ndeki zıpkıncılar, karaya çıkarılan kılıç balıklarının tipik olarak midelerinin dolu olduğunu bildirmişlerdir. Kılıç balıkları, sindirimi hızlandırmak için yüzeye geliyor olabilirler ve bu da yiyecek arama etkinliğinin sıklığını artırabilir (Dewar ve diğ., 2011). Zıpkın avcılığı, kılıç balıklarının genellikle daha sıcak yüzey sularında, genellikle sırt ve üst kuyruk yüzgeçleri açıkta dururken bulundukları gün boyunca yüzeye yakın görülmelerine dayanır. Bu durumda onlara yaklaşılabilir ve zıpkınlanabilirler. Bu güneşlenme davranışı balığı ısıtabilir ve daha derinlerde yiyecek ararken yakalanan avın sindirilmesine yardımcı olabilir (Carey ve Robinson, 1981).

Son çalışmalar, kılıç balıklarının normalde tek yaşarken üreme dönemlerinde çiftler oluşturup, deniz yüzeyinde bazı kur yapma davranışları gösterdiğini kanıtlamaktadır. Sicilya kıyıları ve Messina Boğazı'nda yapılan zıpkıncılık (bizim sularımızdan farklı olarak) sadece balık güneşlenirken değil, bu kur yapma faaliyetleri sırasında da gerçekleşmekte ve av sezonu Mayıstan Ağustosa dek uzamaktadır (Akyol, 2018). Atlantik ve Pasifiğin ılıman sularında, kılıç balıkları sık sık yüzeyde güneşlenir. Bu davranış tropikal sularda nadiren görülür ve ılıman sularda (yüzey suları nispeten daha sıcaktır) sindirimi kolaylaştırdığı düşünülmektedir (Palko ve diğ., 1981). Tüm bu sonuçlara rağmen, kılıç balıklarının niçin güneşlendiği sorusu tam olarak yanıt bulmuş değildir.

Kur yapma

Sicilya Adası'nın kuzeyinde Tiren Denizi'nde 2002 yılından 2005 yılına kadar üreme dönemlerinde (Mayıs - Ağustos arası) 207 çift kılıç balığının deniz yüzeyindeki yüzme davranışlarını incelenmiştir (Romeo ve diğ., 2009b). Balıkçılık filosu tarafından tanımlanan davranışlar temelinde, bunlar tek erkekler, tek dişiler ve çiftler olarak çapraz yedi kategoride sınıflandırılmıştır. Balıklar yakalandıktan sonra, her balığın cinsi olgunlukları gözle tespit edilmiş, hem dişi hem de erkeklerin Haziran ve Temmuz boyunca çok daha sık yüzeyde görüldüğü gözlenmiştir. En sık gözlenen davranış erkek tarafından yakından izlenen bir düz çizgide yüzen dişi veya yüzeye yakın yüzen iki balık ve tam dairesel dönüştür. Her iki davranış gonadların en olgun olduğu safhada görülmüştür. Bu veriler, kılıç balıklarının gonad gelişimiyle etkilenen üreme davranışı nedeniyle uzun süreli bir kur yapma gösterisi izlenimini vermiştir (Romeo ve diğ., 2009b).

Sınıflandırılmış yedi adet davranış kategorisi (Şekil 2) şöyledir (Romeo ve diğ., 2009b):

(1) Daire: tek bir balık veya bir çift balık yüzer ve yaklaşık 3-8 m çapta tek bir daire çizerek kayıtsızca saat yönünde veya tersi yönde döner. Balık çift olarak yüzüyorsa bunlar birbirine yakın en çok 5 m mesafede kalır.

(2) Daire S: dişi ve erkek balık çifti yukarıya yüzer fakat birbirine maksimum 3 m yakın iki belirgin daire çizerler.

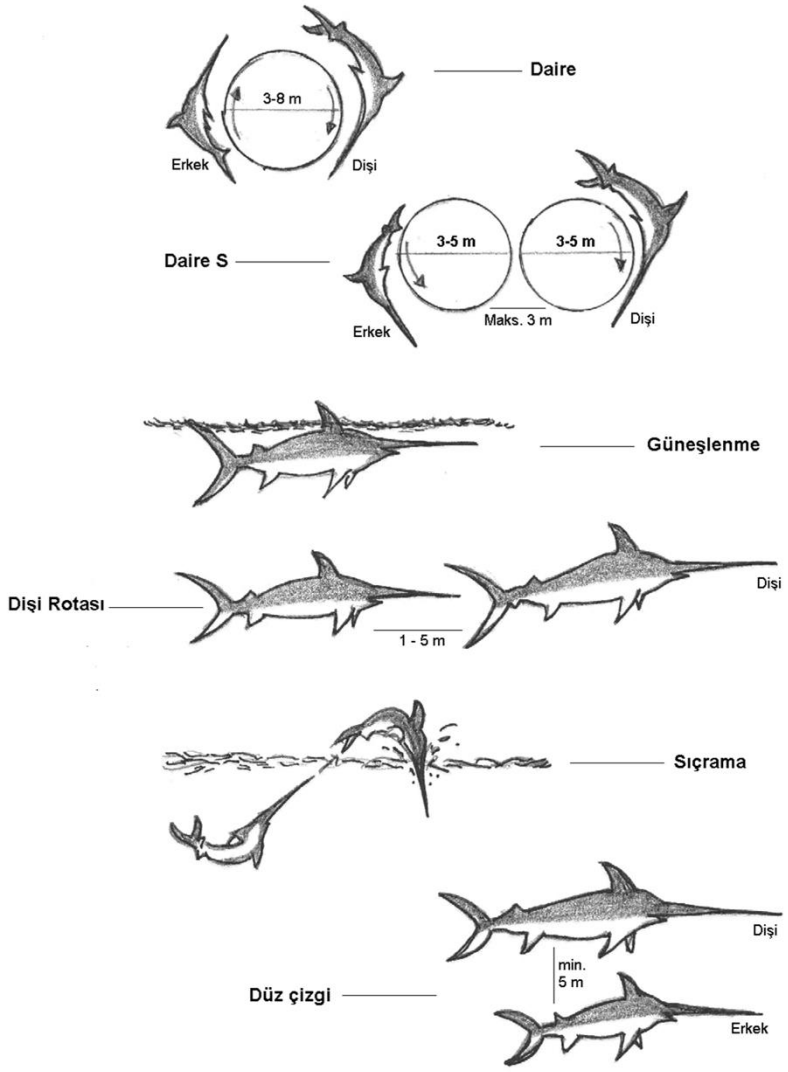
(3) Güneşlenme: tek bir birey dorsal (sırt) yüzgecini (2 cm) göstererek yavaşça yüzer veya dorsal ve kaudal (kuyruk) yüzgeçleri yüzeydedir ve deniz yüzeyinde hafif iz bırakır.

(4) Dişi rotası: bir erkeğin önünde yüzen bir dişiyle çift oluşturma; birbirine çok yakın yüzme (1 – 5 m). Dişi düz rota çizerken, erkek onu takip eder.

(5) Erkek rotası: bir dişinin önünde yüzen bir erkekle çift ve rota oluşturma.

(6) Düz çizgi: bir birey veya aynı derinlikte yüzen bir çift daima aynı yönde ilerler; balıklardan biri yüzdüğünde, birbirinden 5 m'den fazla mesafede ve rotada kalır.

(7) Sıçrama: bireyler 10 m derinlik civarında tek veya çift olarak yüzerken, hızla suyun dışarısına sıçrarlar. Deniz yüzeyine vardığında kısa süre orada kalabilirler veya hızla derin sulara dalarlar.



Şekil 2. Kılıç balıklarının davranış kategorileri (Romeo ve diğ., 2009b'den yeniden çizim)

Cinsiyete göre ayrılmış davranış da 'yüzey' ve 'derin' olmak üzere iki gruba ayrılmıştır. Birincisi balığın (daire, daire S, güneşlenme, erkek rotası, dişi rotası) 3 m derinliğe kadar yüzey sularına yakın ve uzun süre (2 saat) kalan davranışını içerir. İkincisi, 3 m derinliğin (3-10 m) altında kalan 'doğrusal' ve 'su üstüne sıçrama' davranışlarını içerir. Ayrıca 'Daire' davranışı, *Sarda chiliensis* gibi diğer pelajik balıklarda da gözlemlenen belirli bir kur yapma davranışı olabilir (Magnusson ve Prescott, 1966). Bu döngü davranışı, yalnız yaşayan balıklar için de gözlemlenmiş olup bir üreme davranışı ile de ilişkilendirilebilir. 'Doğrusal' davranış, balıkların olgunluk sergilediği bu dönemle (Ağustos) ilişkilendirilebilir ve bu gonadların gelişme aşamasında olan dişilerle temsil edildiği gonadosomatik indeks'in 1'e yakın olduğu dönemdir (Romeo ve diğ., 2009b).

Yüksek sayıda dişi kılıç balığı Haziran ve Temmuz ayları boyunca gonad gelişimiyle uyumlu olarak yüzey sularında gözlenmiştir. Bununla birlikte, güneşlenme davranışı olgun gonadlarıyla dişi veya erkek olsun yalnızca tek bireylerde gözlenmiştir. Ancak bunun çiftleşme için diğer bir balığı bekleme durumu olup olmadığı aydınlatılamamıştır. Bu davranışlar balıkçılık operasyonunu da şekillendirmektedir. Bir çift balık görüldüğünde, balıkçı genellikle daha büyük olan dişiyi yakalamayı denemektedir. Onu zıpkınladıktan sonra erkekler vurulan balık yüzeye gelene dek aynı derinlikte dişilerin etrafında dönmeyi sürdürürler. Erkeklerin sadakati dişilerin yakalanmasından sonra balığın tekneye olan saldırısıyla da gözlenmiştir (Romeo ve diğ., 2009b).

SONUÇ

Bu çalışma, kılıç balıkları üzerine yapılmış pek çok çalışmadan ve gözlemden onların ilginç davranışlarını bir araya toplayan bir derlemeyi sunmaktadır. Kılıç balıkları göçmen ve uzun gagası ile tanınan predatör ve epipelajik bir balık olup sürü oluşturmazlar ve genellikle açık denizlerin tropik ve ılıman sularında dağılım gösterirler. Denizin 600 m derinliğinde ısı 5°C'ye kadar düşmektedir ve kılıç balıkları 1000 m'den fazla derinliğe kadar inebilen, çok gösterişli bir türdür. Bu derinliklerdeki çok kısa süreli ani ısı değişikliklerinin balığın vücut fonksiyonlarında bir değişikliğe sebep olmaması için balığın 'beyin ısıtma

sistemi' adı verilen özel bir sistemle, gözleri ve beyinleri 19-28°C arasındaki bir sıcaklıkta kalmaktadır. Bu ısıtıcı sistem, balığın gözlerinin görme işlevi için gerekli ısıyı da sağlamaktadır. Görme, bir dizi kimyasal olaylar sonucunda gerçekleşir. Hava serinledikçe kimyasal reaksiyonlar daha uzun zaman alır. Bu nedenle soğukkanlı canlılar, eğer hızlı hareket eden nesneleri görmek istiyorlarsa kendilerini ısıtmak durumundadır.

Ekonomik değeri oldukça yüksek olan bu balıkların besinlerini başta kalamarlar olmak üzere sürüler halindeki pelajik balıklar oluşturur ve uzun kılıcıyla hem avını hisseder hem de onu yönlendirirken kılıcını adeta bir av aracı olarak kullanabilirler. Kılıç balıklarının gösterdikleri bir dizi davranıştan biri deniz içerisinde yatay ve dikey hareketi ve beslenme davranışıdır. Bu yatay ve dikey hareketi daha çok besin arayışı ile ilişkilidir. Çünkü kılıç balıkları gündüz mezopelajik bölgede bulunurken, geceleri beslenme amacıyla yüzeye çıkmaktadırlar. Gece boyunca yüzey sularından gündüzleri daha derin sulara günlük yatay ve dikey göçler yaparlar. Vücutlarındaki kasların hareketinden ortaya çıkan enerjiyi bir takım kimyasal reaksiyonlar sonucu gözlerinin bahsedilen görme işlevini yerine getirebilmesi için kullanırlar. Bu sayede su sıcaklığının 5°C'ye kadar düştüğü derinliklerde bile rahatlıkla görme işlevini yerine getirebilirler. Kılıç balıkları gündüz saatlerce dipte iken, gece vazgeçilmez besini olan kalamarların yoğun bulunduğu yüzey sularına çıkmaktadırlar.

Bu davranışları sergileyen kılıç balıklarının elbette dünyamızın uydusu olan ay ışığı ile birlikte olan davranışları da söz konusudur. Kılıç balıkları beslenmek için yiyecek ararken, avlarını görebilecekleri minimum ışığa ihtiyaç duymaktadırlar. Buna bağlı olarak ayın farklı evreleri onların beslenme aktivitesini uyarmaktadır. Fakat kılıç balıklarını ağlarla avlarken ise durum tam tersidir. Çünkü ağın görünürlüğünü azaltmak için aysız geceler tercih edilir. Kılıç balıkları yeni ay döneminde (karanlık dönem) aydınlık döneme göre daha fazla avlanabilmektedirler.

Sonuçta, kılıç balıkları nevi şahsına münhasır davranışlarıyla ve etinin lezzetiyle dünyada ve Türkiye balıkçılık kültüründe önemli bir yer edinmiş sembol bir balıktır (Akyol, 2018). Ekonomik önemi oldukça yüksek bu balıkların yüzyıllardır Boğaziçi yeme-içme kültüründe çok önemli yeri olduğu, saray mutfağı menülerinde yer aldığı kayıtlarda bulunmaktadır. Bu balık üzerine Türkiye'de yeterince araştırma bulunmamaktadır. Kılıç balıklarının sürdürülebilir avcılığı konusunda ileri araştırmalara oldukça ihtiyaç vardır. Kılıç balıkçılığının idamesinde balıkçılık idarecileri, akademisyenler ve balıkçılara önemli sorumluluklar düşmektedir. Ayrıca, kılıç balıklarının davranış özelliklerini iyi bilmek, etkili ve sürdürülebilir avcılık için gereklidir ve bu makale bu davranışların bir özetini sunmaktadır.

ETİK STANDARTLARA UYUM

Yazar katkıları

Yazar SK lisans tezi olarak yazmış; OA tasarlamış, özetlemiş ve son biçimlendirmeyi yapmıştır.

Çıkar çatışması

Yazarlar çıkar çatışması olmadığını beyan ederler.

Çalışmaya İlişkin Beyan

Etik onay: Bu tür bir çalışma için resmi onay gerekli değildir.

İnsan Hakları Beyanı

Etik onay: Bu tür bir çalışma için resmi onay gerekli değildir.

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Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2021; 7(2): 105-115 Derleme Makale/Review Article

Potential Role of Zeolite on Improvement of Aquaculture Sector

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Abstract

Aquaculture, which is very important in many regions of the world, attracts attention as the fastest growing sector in the livestock sector in our country. The share of our country's aquaculture production in the production of total aquatic products is increasing day by day. Studies have been carried out to solve feed problems and importance has been attached to additives that reduce cost and feed conversion ratio (FCR) to contribute to feed quality. Zeolites came to the forefront as feed additives. Due to the gap between 20 and 50 % in the structure, the molecules can be taken into the structures and they are named as molecular sieves. Zeolites are used for purposes such as controlling the pollution in pools in the aquaculture sector, increasing the growth parameters of the fish by incubation, fish transport and removal of nitrogen compounds from aquarium water, increasing ambient oxygen in aquarium and fish transport, and as feed additive. In Turkey, billions of tons of zeolite have been detected and clinoptilolite type zeolite is found mostly in the beds of Ankara-Polatlı-Mülk-Oğlakçı Region and Bigadiç, Şaphane, Gediz, Emet and Gördes Districts. We believe that the use of zeolites produced in Turkey as a local and natural product as feed additive substance in the aquaculture industry in the aquaculture sector will contribute to the production of lower cost fish as well as contribute to the development of 2 different sectors (aquaculture and mining) in interaction with each other.

Su Ürünleri Yetiştiricilik Sektörünün Gelişiminde Zeolitin Olası Rolü

Makale Bilgisi

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- Su Ürünleri
- Yetiştiricilik
- Zeolit

Öz

Dünyanın birçok bölgesinde çok büyük önem arz eden su ürünleri, Ülkemizdeki hayvancılık sektörleri içerisinde en hızlı gelişen sektör olarak dikkati çekmektedir. Ülkemizin toplam su ürünleri üretimi içerisindeki su ürünleri yetiştiriciliğinin payı da her geçen gün artmaktadır. Bu yem ile ilgili sorunların çözümüne yönelik çalışmalar yürütülmüş ve yem kalitesine katkıda bulunacak, maliyeti ve yem dönüşüm oranını (FCR) azaltıcı katkı maddelerine önem verilmiştir. Yem katkı maddesi olarak zeolitler öne çıkmıştır. Yapılarında % 20 ile 50 arasında boşluk olmasından dolayı molekülleri yapılarına alabilmekte ve moleküler elek olarak ta adlandırılmaktadırlar. Zeolitler, yetiştiricilik sektöründe havuzlarda kirlilik kontrolünün sağlanması, kuluçka, balık nakil ve akvaryum suyundan azotlu bileşiklerin uzaklaştırılması, akvaryum ve balık naklinde ortam oksijeninin artırılması ve yem katkı maddesi olarak kullanımıyla, balık büyüme parametre değerlerinin artırılması gibi amaçlar için kullanılmaktadır. Türkiye'de ise milyarlarca tonluk zeolit varlığı ortaya konmuş olup, Ankara–Polatlı–Mülk–Oğlakçı Bölgesi ile Bigadiç, Şaphane, Gediz, Emet, Gördes Bölgeleri'ndeki yataklarda çoğunlukla klinoptilolit türü zeolitin yoğun olarak bulunduğu tespit edilmiştir. Yerel ve doğal bir ürün olarak Türkiye'deki üretimi yapılan zeolitlerin yetiştiricilik sektöründe yem fabrikalarınca temelde yem katkı maddesi olarak kullanılması, daha düşük maliyetli balık üretimine katkı sağlayacağı gibi, birbirleriyle etkileşim içerisinde 2 farklı sektörün (su ürünleri yetiştiriciliği ve madencilik) gelişimine de katkıda bulunacağı kanaatindeyiz.

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INTRODUCTION

Aquaculture, which is of great importance in many parts of the world, draws attention as the fastest growing sector among the livestock sectors in our country. The share of aquaculture in the total aquaculture production in our country is

increasing day by day. According to statistical data of TURKSTAT, while the total fisheries production in 2003 was 587715 tons, the aquaculture amount was 79943 tons with a rate of 13.6%. These amounts reached 785811 tons in 2020 and the share of aquaculture reached 421411 tons with a rate of 53.62% (TUİK, 2021). While the amount of products obtained by aquaculture increased each year, the rate of increase decreased after 2007. One of the most important reasons for this is the problems experienced in the supply and quality of feed and feed raw materials. Studies have been carried out to solve these problems and importance has been attached to some feed additives that will contribute to feed quality and reduce the cost and feed conversion ratio (FCR). Among these substances, zeolites came to the fore.

Zeolites, which are one of the important raw materials of recent years, as the word "boiling stone (This name was given because it explodes when heated)"; chemically known as "hydrated alumino silicates". Zeolites are hydrated aluminosilicates of alkali and alkaline earth metals with a crystalline structure and are in the frame silicates group. Despite some changes in the Si/Al ratios in the skeletal structure and the type and amount of cations they contain, they can be expressed with the general formula $\mathbf{(M^{+}, M^{+2})\ O.Al_2O_3.9SiO_2.nH_2O}$. M^{+} is an alkali cation, usually Na^{+} or K^{+}, rarely Li^{+}. M^{+2} is an alkaline earth cation and is usually Mg^{+2}, Ca^{+2}, Fe^{+2}, rarely Ba^{+2}, Sr^{+2} (Leung, 2004; Anonymous I, 2006; Virta, 2014; Erdogan et al. 2019).

The smallest structural unit of any zeolite crystal is the SiO_4 and AlO_4 tetrahedras. Single and double ring secondary structure units and highly symmetrical parameters are formed by the combination of primary structure units formed by Si and Al tetrahedras. The zeolite skeleton with micropores emerges with the arrangement of these polyhedra and secondary structure units in three dimensions in different ways. These micropores, located between the polyhedra and the secondary structure units that connect them, combine with micro windows and form one, two or three-dimensional space systems and/or channels. The amount of space is between 20-50% of the total volume. The most important feature of zeolite minerals is these spaces, and the "molecular sieves" feature that is originated from liquid and gas molecules that can easily enter and displace these spaces, and alkaline earth ions (Mumpton, 1999; Leung, 2004; Anonymous II, 2006; Chowdhury et al., 2016).

Zeolites are of two types, natural and artificial. Today, more than 150 zeolite structures have been classified, of which about 40 are natural (the most common are analcim, cabazite, clinoptilolite, erionite, ferrierite, heulandite, laumontite, mordenite, and phillipsite), and about 110 are artificial (the most common synthetic zeolites, Zeolite A, X, Y, and ZMS-5) (Anonymous III, 2002; Virta, 2014). The most well-known of the natural type zeolites is “clinoptilolite” (Tepe et al., 2005). The molecular sieve structure of clinoptilolite and its absorption of a substance are given schematically in Figure 1. and the cation selectivity is as follows (Mumpton, 1999; Leung, 2004):

Cs > Rb > K > NH^4 > Ba > Sr > Na > Ca > Fe > Al > Mg > Li

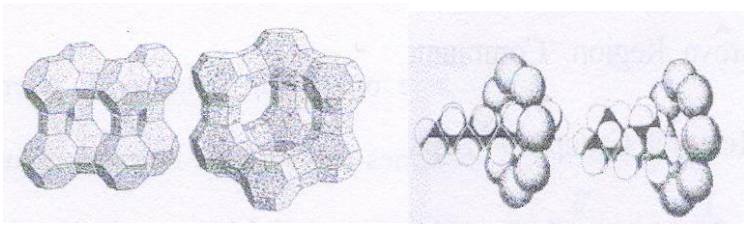

Figure 1. Molecular sieve structure of a zeolite (sodalite) for an example and schematic representation of absorption of a substance (Leung, 2004)

The main physical and chemical properties of zeolites are; ion exchange, adsorption and its sieve structure, silica content, light color in sedimentary zeolites, lightness, pore structure of small crystals, have caused zeolites to be used in a wide variety of fields (Tepe et al., 2005).

Usage Areas of Zeolites

Areas benefiting from zeolites, which have become an important industrial raw material in recent years, may be grouped under 5 main headings.

Use in Pollution Control

Soil Pollution Control: It has been determined that the use of concrete type clays and clinoptilolite type zeolites together has a positive effect on the soil and soil stabilization of the landfills, and also contributes to the formation of soil with thinner lining material. At the same time, zeolite also acts as a filter by keeping harmful ions in the water that may leak from these areas (Anonymous IV, 2005). In addition, zeolite minerals can retain isotopes such as Sr_{90}, Cs_{137}, Co_{60}, Ca_{45}, which are found in nuclear power plant wastes and are dangerous for environmental health. In this way, radioactive materials taken from wastewater are rendered harmless by being buried with zeolite minerals. For this purpose, clinoptilolite and mordenite are used because they are resistant to acids (Bish et al., 2003; Alp, 2005; Anonymous IV, 2005; Kibaroğlu, 2008; Gülen et al., 2012).

Air Pollution Control: Oxygen-rich air can be provided by utilizing the adsorbing properties of zeolite minerals (Alp, 2005; Anonymous V, 2006; Anonymous VII, 2006; Kibaroğlu, 2008). In addition, they can be used for supplying oxygen with a purity of 60% in hospitals, increasing the oxygen ratio by reducing air pollution in small units (Aybal, 2001) and adsorbing the gases coming out of the chimneys of the facilities using oil and coal. For this purpose, artificial zeolite minerals, and mordenite, clinoptilolite, erionite and chabazite from natural zeolite minerals are used (Alp, 2005; Anonymous I, 2006; Kibaroğlu, 2008; Gülen et al., 2012).

Water Pollution and Waste Water Control: Zeolite minerals are used in cleaning the pollution caused by organic wastes in lakes, ponds and rivers, and in the purification of wastewater from heavy metals, especially with N compounds (Tarasevich et al., 1997; Mumpton, 1999; Aybal, 2001; Alp, 2005; Sarioglu, 2005; Anonymous VI, 2006; Anonymous VII, 2006; Sevgi et al., 2007; Kibaroğlu, 2008; Zorpas et al., 2008; Wang et al., 2008; Sprynskyy, 2009); in adsorption of oil on the water surface in marine environments (Anonymous I, 2006). However, they can be used to clean fish pond waters and increase the oxygen rate, to control possible pollution in live fish transport and to remove the hardness of drinking water (Anonymous VIII, 2000; Hargreaves and Tucker, 2004; Örgev and İnanç, 2004; Alp, 2005; Sarioglu, 2005; Anonymous IX, 2006; Kibaroğlu, 2008; Zorpas et al., 2008; Chowdhury et al., 2016).

Use in the Field of Energy

In addition to petroleum and coal, energy needs are tried to be met from sources such as nuclear energy and solar energy, and natural zeolites are used in the conversion of these resources into energy.

Obtaining Energy from Coal: In this area, zeolites are used to produce the oxygen necessary for burning the coal underground and to clean the explosive nitrogen oxides and hydrocarbons, as well as SO_2 formed during combustion. However, their use is not common.

Purification of Natural Gases: Zeolites have been used to remove CO_2 from polluted or impure natural gases since 1969 (Anonymous IV, 2005).

Utilizing Solar Energy: Zeolites are used as a heat exchanger in the transfer of solar energy due to their ability to exchange water depending on the temperature. Clinoptilolite and chabazite are used for heating and air-conditioning of small buildings (Anonymous IV, 2005; Anonymous I, 2006).

Petroleum Products Production: Natural zeolites, which provide important information in the exploration of oil and gas-containing fields and in the determination of paleoenvironment conditions, can be used in some special applications in oil and gas production and their refining. However, synthetic zeolites are preferred due to their higher adsorption capacity and higher pore diameters. Water and CO_2 are separated from natural gases using mordenite, chabazite and clinoptilolite. In addition, catalysts that can be used in petroleum refining from natural zeolites have been produced (Anonymous IV, 2005).

Usage in Mining and Metallurgy

Exploration of Mineral Deposits: Zeolites, which are formed as a result of hydrolysis of volcanic materials, can be used in exploration as well as explaining the formation of ore deposits (Anonymous IV, 2005; Gülen et al., 2012).

Metallurgy: Waste waters resulting from mining and metallurgical activities containing some heavy metal cations that pose a danger to environmental health, can be treated by utilizing the cation exchange properties of natural zeolites (Anonymous I, 2006; Gülen et al., 2012).

Use in Agriculture and Animal Husbandry

The purposes of using zeolite minerals in agriculture and animal husbandry are tried to be summarized below.

1. Fertilizer preparation (Rehákova et al., 2004; Alp, 2005; Kibaroğlu, 2008),

2. Controlling the content of fertilizers and removing bad odours (Rehákova et al., 2004; Alp, 2005; Kibaroğlu, 2008),

3. Enabling fertilizer savings by binding NH_4^+ in environments where zeolite minerals are present and enabling this compound to be used more effectively by plants (Alp, 2005; Kibaroğlu, 2008; Zorpas et al., 2008),

4. Delaying deterioration by providing hardening during storage in fertilizers, as it can absorb water molecules in the environment (Rehákova et al., 2004; Alp, 2005),

5. Due to its high ion exchange and binding water molecules, it is mostly used for soil preparation and improvement in clay-poor soils (Dyer and White, 1999),

6. Prevention of fungal diseases that may occur in plants due to excessive irrigation in agricultural lands (Anonymous VII, 2006; Zorpas et al., 2008),

7. Removal of pesticide residues in agricultural struggle due to its high ion exchange and adsorbing capacities (Anonymous II, 2006; Anonymous VII, 2006),

8. Increasing the pH values of acidic and volcanic soils (Anonymous IV, 2005; Glisic et al., 2008),

9. Allowing more steam pressure and higher temperature to be used in pelletizing animal feeds, reducing friction and ultimately increasing production with less energy use (Anonymous VII, 2006),

10. As it was started with a study conducted in Japan for the first time in 1965, by adding to cattle, ovine and poultry feeds, reducing the feed utilization rate, which is one of the important parameters in terms of aquaculture, and increasing the growth performance. (Aybal, 2001; Alp, 2005; Kibaroğlu, 2008; Zorpas et al., 2008),

11. Controlling the pollution caused by feed and faecal wastes and preventing diseases in animal shelters such as poultry houses, pens and barns (Elekoglu and Yalcin, 2005; Tepe et al., 2005; Leung et al., 2007; Gülen et al., 2012).

Zeolite tuffs, clinoptilolite and mordenite type zeolite minerals are generally used for the above-mentioned purposes (Mumpton, 1999; Anonymous VII, 2006).

Other Usage Areas

Paper Industry: High gloss zeolite ores are increasingly used as filling material. Clinoptilolite-added paper is more tough than normal clay-added papers, can be cut easily, is lighter, and disperses ink less (Anonymous IV, 2005).

Construction Industry: Zeolithic tuff deposits are used as pozzolanic raw materials in many countries. Expanded zeolites have higher resistance to compression and abrasion, and expanded lightweight aggregates are produced. They are used as building blocks because they can be easily cut and processed and they are light (Mumpton, 1999; Anonymous IV, 2005).

Health sector: It is used as a brightening additive in clinoptilolite fluoride toothpastes, as a patented drug in the treatment of ulcers and diarrhea in Cuba, and as a powder in the treatment of cut-injured animals to prevent infection of the wound (Mumpton, 1999; Anonymous I, 2006). Natural phillipsite and certain synthetic zeolites have been found to be an effective means of removing NH_4 during hemodialysis of kidney patients (Mumpton, 1999)

Detergent Industry: Synthetic zeolites are used as additives instead of phosphate in detergents due to environmental pollution (Anonymous I, 2006).

Storage and Transport of Fruits and Vegetables: The effect of ethylene gas, which occurs during the collection of vegetables and fruits and causes deterioration, is minimized by coating the products with natural zeolite and can be stored for a longer period of time (Anonymous I, 2006).

Icing Prevention: Natural zeolites are used directly on the road or mixed into asphalt. Thus, both the environment is cleaned of chemical pollutants and damage to asphalt and vehicles such as salt is prevented (Anonymous I, 2006).

Pellet Binders: Zeolite (BRZ) allows more steam and higher heat to be used in pelletizing animal feeds, reducing friction and increasing production by 30% without the need for more energy (Anonymous VII, 2006).

Zeolite species are used for different purposes in aquaculture as well as in the feeding of different animal species.

Use of Zeolites in Aquaculture

Zeolite minerals are mainly used for four purposes in aquaculture applications. These;

1. Ensuring pollution control in ponds,

2. Removal of nitrogenous compounds from hatching, fish transport and aquarium water,

3. Increasing the ambient oxygen in aquarium and fish transport,

4. Increasing fish growth parameter values by using it as a feed additive (Pond and Mumpton, 1984; Watten and English, 1985; Dryden and Weatherley, 1989; Mumpton, 1999; Aybal, 2001; Peyghan and Azary-Takamy, 2002; Ravendra et al., 2004; Alp, 2005; Tepe et al., 2005; Anonymous X, 2006; Anonymous XI, 2006; Anonymous XII, 2006; Kaiser et al., 2006; Töre, 2006; Kanyılmaz, 2008; Danabas, 2009, Danabas and Altun, 2009; Danabas and Altun, 2011; Aksu, 2016; Chowdhury et al., 2016).

Some of the studies carried out for these purposes are summarized below.

Water and/or waste water management becomes increasingly important issue worldwide for many animal culture as more as the aquaculture. Guo et al. (2013) reported that synthesized zeolite from coal fly ash and chemically modified zeolite (treated with MgO), respectively, were effective (up to 95% and 87%, respectively) for NH^{4+} removal of swine wastewater. However, Markou et al. (2014) used natural clinoptilolite to adsorb NH^{4+} from poultry wastewater, in which the removal efficiency was about 9 mg N $g1^{-1}$ of zeolite. Nutrient-enriched zeolites can be used to produce microbial biomass. For instance, Markou et al. (2014) used natural zeolite as a medium for the sorption of ammonia from wastewater, and subsequently as nitrogen releaser in cultures of *Arthrospira platensis*. Markou et al. (2015) reported that modified zeolite (treated with $Ca[OH]_2$) was a significant adsorbent for PO_4 in synthetic wastewater, and subsequently a P source for the cultivation of green microalga (*Chlorella vulgaris*) and cyanobacterium (*A. platensis*).

The content of ammonium ions ($NH4^+$) produced by fish metabolism is unfavourable for the fish culture including the fish breeding industry and requires frequent water change. Water pollution can be reduced by using zeolite materials capable of removing ammonium cations more efficiently than nitrifying bacteria used in biological filters (bacterial carriers). Skleničková et al. (2020) researched the three zeolite materials (Bear Blanked Clinoptilolite, Mordenite Manganese and Geopolymeric Zeolite A) in the breeding tanks of Koi carp for their ammonium cations exchange kinetics. The zeolite prolonged the water quality improvement without any negative effects. Because of zeolite Mordenite Manganese, water consumption can be decreased by almost 70 % in aquaria setting and by 40 % in fish-breeding conditions

Yu et al. (2020) used the lanthanum modified zeolite (La-Z) to adsorb chlortetracycline (CTC) from aquaculture wastewater and obtained 98.4% removal rate. Zeolites reduce ammonia and hydrogen sulphate levels in fish/shrimp lakes and increase fish/shrimp growth rates and population density (Anonymous VI, 2006; Tepe et al., 2005). In Far East Asia, zeolite is applied to shrimp ponds by sprinkling it on the water surface at a rate of approximately 200 kg ha^{-1} every month. The purpose of this zeolite application is to remove halogen sulfide and carbon dioxide by absorption, and to remove ammonium from the environment at the end of ion displacements (Tepe et al., 2005). Both zeolite and biochar are sustainable alternatives of biomedia for nitrate removal (Paul and Hall, 2021).

Aksu (2016) studied the effects of natural zeolites clinoptilolite (0 (control), 1, 2, 4 and 8 g l^{-1}) on some water quality parameters (water temperature, dissolved oxygen, pH, total hardness, ammonium, nitrite, nitrate, sulfate, phosphate, chlorine, fluorine, calcium, lithium, magnesium, potassium, sodium and bromine) and mortality rates in the crayfish (*Astacus leptodactylus* Eschscholtz, 1823) culture. In order to control the constant organic input to the experimental environment, 400 g crayfish (34.01±1.78 g) per m^2 were stocked in each tank and the zeolite was used by laying it on the ground. It was observed that there were statistical differences among the periods for all measured parameters ($P<0.05$). It was determined that there were statistical differences between the periods and groups for the analyzed parameters and mortality rates ($P<0.05$). In terms of mortality rates at the end of the trial, it was determined that all crayfish in the Control and A Group died (100%), while the B (48.15%) and C (47.83%) Groups showed the lowest statistical mortality rates.

Kaiser et al. (2006) used clove oil and clinoptilolite (20 mg/l) during 48-hour transplant of *Haplochromis obliquidens*. In this study, they found the NH_3 concentration to be 360% higher in the group that clinoptilolite were used, compared to the group that did not use clinoptilolite.

Jain (1999), in his study to determine the toxicity of $Pb(NO_3)_2$ and the protective effect of clinoptilolite in catfish (*Heteropneustes fossilis*), 20 mg l^{-1} (for 12 days) and 60 mg l^{-1} (for 35 days) Pb $(NO_3)_2$ on fish was investigated by adding clinoptilolite at a rate of 50 mg l^{-1}. As a result, in the groups that did not add clinoptilolite, growth of fish, soluble protein, glycogen and ribonucleic acid (RNA) content in their livers decreased, but cholesterol levels increased. In the group with clinoptilolite added, all findings were found to be closer to the Control Group.

James et al. (2000) investigated the effects of 5 different clinoptilolite concentrations (0, 0.5, 2, 4 ve 8 g zeolit l^{-1}) on the complete removal of Cu from the pond waters, added 2.14 mg l^{-1} Cu and growth of *Oreochromis mossambicus*, in their research for the 180 days. In the study, in the group with 0.5 g clinoptilolite added, the complete removal of Cu from the environment took 150 days, while it took 120 days in other groups added 2, 4 and 8 g. As a result, the group added 2 g of clinoptilolite gave the highest values in preventing the accumulation of Cu from body tissues, removing metal from pond water and body tissues, and improving the RNA:DNA (deoxyribonucleic acid) ratio and protein amount. Therefore, this ratio is expressed as the optimum ratio.

In the study conducted by Peyghan and Azary-Takamy (2002), 150 mg l^{-1} NH_3 and 5, 8, 10, 15 and 20 g l^{-1} clinoptilolite were added to the water of carp ponds, respectively. At the end of the experiment, the mortality rate in the first three application groups (5, 8, 10 g l^{-1}) was determined as 100, 80 and 30%, respectively, while no death was observed in the other two groups. The differences among the experimental groups and the control group mortality rates were found to be statistically significant ($P<0.05$). In addition, no difference was found in serum alanine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate

aminotransferase (AST) and lactate dehydrogenase (LDH) levels in fish blood, and the cholesterol and urea levels of groups containing 15 and 20 g l^{-1} clinoptilolite and the Control Group was found to be statistically significant ($P<0.05$). Researchers have reported that clinoptilolite can be used in the prevention of acute NH_3 toxicity.

Ravendra et al. (2004), during the transportation of 3 common carp species (*Catla catla, Labeo rohita* and *Cirrhinus mrigala*) cultured in India, zeolite (0, 7, 14, 21 and 28 g l^{-1}), tris-buffer (0.01, 0.02, 0.03 and 0.04 M), 2-phenoxyethanol (0. 0.09, 0.13, 0.18 and 0.22 ml l^{-1}) and oxyflov (0, 250, 500, 750 and 1000 mg l^{-1}) were added and evaluated the effects of these substances on fish for 48 hours. 1500 fry (30.00±0.76 mm total length (L) and 410.00±7.66 mg body weight (W)) were stocked in plastic bags each containing 3 l freshwater (pH, 7.4; dissolved oxygen, 5.4 mg l^{-1} and NH_3, 0.0012 mg l^{-1}) and 20 mg l^{-1} neomycin sulfate was added to control bacterial growth. At the end of the experiment, a 100% survival rate (SR) and 0.052±0.0008 mg l^{-1} NH_3 ratio was obtained in the group to which 7 g l^{-1} zeolite was added and and with the increase of the amount of zeolite added to the transport bags, the SR decreased and the NH_3 ratio increased. However, in the group with 0.01 M tris-buffer added, 100% SR and 0.0076±0.0003 mg l^{-1} NH_3 ratio were obtained and with the increase in the amount of tris-buffer added to the transport bags, the NH_3 ratio increased; in the other 3 groups (0.02, 0.03 and 0.04 M), all fish died. In addition, 100% SR and 0.186±0.0033 mg l^{-1} NH_3 ratio was obtained in the group to which 0.09 ml l^{-1} 2-phenoxyethanol was added. Although SR decreased with the increase of 2-phenoxyethanol ratio added to the bags, the NH_3 ratio changed and the lowest ratio was obtained from the 3rd group (0.18 ml l^{-1}). Finally, 100% SR and 0.216±0.0033 mg l^{-1} NH_3 ratio were obtained in the groups with 250 to 500 mg l^{-1} oxyflow added, and with the increase in the added oxyflow ratio, SR decreased and NH_3 ratio increased. They reported that these rates do not affect the post-trial SRs and therefore, they can be used safely during transportation of these fisf species.

When the studies conducted for fish feeding are evaluated, a feed containing 48% crude protein and added 2% zeolite was used in a pond containing 100 trouts and the fish were grown for 64 days without any health problems, and a 10% increase in the total fish biomass was obtained (Tepe et al., 2005). At the end of the trial, the average body weight was determined as 48.6 g in the Control Group and 52.3 g in the group containing clinoptilolite. A remarkable reduction in feed cost was also provided (Leonard, 1979: Pond and Mumpton, 1984; Mumpton, 1999). Lanari et al. (1996), reported that different ratios (2.5, 5.0 and 7.5%) of kuban zeolite (35% pure mordenite, 35% pure clinoptilolite) had no effect on the digestibility coefficient of rainbow trout feed and crude protein and dry matter rates from fish meat nutrient components ($P>0.05$); however, the first two ratios of supplementation had a positive effect on nutritional efficiency and fish growth compared to the Control Group.

James et al. (2000) determined that zeolite was effective in the growth of *Oreochromis mossambicus* and removal of Cu from water and increased the RNA:DNA ratio and protein amount.

Dias et al. (1998) studied the effects of three different additives (cellulose, silicate and zeolite) at different rates (0% (Control), 10 and 20%) on European sea bass (*Dicentrarchus labrax*) fry. They reported that the diets containing 10 and 20% additives did not have a significant effect on the growth performance of fries, protein digestibility and FCR values of the fish, and that the groups containing 20% additives performed a fecal excretion in a longer time compared to the Control Group. However, they stated that diluting the nutrient elements of the rations had an adverse effect on FCR and growth performance.

In a study, effects of clinoptilolite (0, 1, 2, 3, 4, 5 and 6) on the W and L values, condition factor (CF), FCR and some blood serum enzymes (ALT, AST and ALP) activity levels of rainbow trout (initial body weights; 139–140 g) were investigated (Aybal, 2001). At the end of the trial, it has been reported that the W averages of the groups were between 296 and 320 g; the mean of CF is between 1.26 and 1.38; the mean of FCR ranged between 1.33–1.56; serum ALT activities ranged between 3.28–4.94 UI l^{-1}; and the differences between the groups were insignificant ($P>0.05$). On the other hand, it was reported that only the differences between the CF averages, serum AST and ALT activities in period I was significant ($P<0.05$). As a result of the study, the highest W and L averages were obtained in the group III. While the lowest levels of serum AST in the III and IV. Groups, the highest levels also were in the Control and Group II. However, the lowest levels of ALP were in the IV and II Groups; and the highest values were in the Control and Group V.

Töre (2006) investigated the effects of water quality parameters, some blood parameters and body composition of fish in a study in which clinoptilolite and starch were used as additives in tilapia (*Oreochromis niloticus*) feed. In the trial, it has been reported that 49.54±3.83 g live weight gain in 10% starch group (NG), 48.62±3.16 g in 10% clinoptilolite group (KG), 42.36±1.28 g in 20% NG, and 41.26±2.17 g in 20% KG was achieved, and the best FCR average was obtained from 10% KG (1.17±0.08) and 10% NG (1.17±0.10%). In addition, at the end of the trial, there was no statistical differences between and within the groups in terms of protein efficiency ratio, viscerosomatic index (VSI) and hepatosomatic index (HSI) and dry matter, crude protein, crude oil and crude ash analyzes of fillet samples taken from trial fish ($P>0.05$). According to the results of cholesterol, glucose, triglyceride, and LDH blood analyzes in blood samples in the groups, the differences among the groups was found statistically significant ($P<0.05$). According to the results of the water analysis, the lowest NH_3 level is in 20% NG (0.0425±0.02 mg l^{-1}), and the highest level is in the 20% KG (0.154±0.04 mg l^{-1}). As a result, it was reported that the use of these ratios of clinoptilolite as an additive in fish feed instead of starch did not have a significant effect on growth and feed evaluation performances, and it was suggested that lower ratios should be studied.

The efficiency of chelating zeolite to counteract the toxicity of two levels of ammonium chloride (18 and 1.8 mg NH^4cl/l) was evaluated in the culture of Nile tilapia (*O. niloticus*). In this research, the addition of zeolite to ammonia in a contaminated medium is recommended to reduce ammonia concentration in aquaculture, improve growth performance and physiological function and activities in fish (Shalaby et al., 2021). However, in Nile tilapia, it was indicated that zeolite can improve the growth performance and increases fish resistance to undesired effects associated with Pb toxicity (Abbas et al., 2021). The substitution of natural zeolite (1, 3 and 5%) in Nile tilapia (*Oreochromis niloticus*) was decreased ($P< 0.05$) the amount of food per animal (9.08 to 6.50 g) and intake protein (2.95 a 2.09 g). It was proposed to continue researchers with zeolite as partial replacement of protein raw matters in tilapias feed (Llanes and Castro, 2020).

Kanyılmaz (2008) examined the effects of different ratios of clinoptilolite (0% (control) 1, 2, 3 and 4) in the common carp (*Cyprinus carpio* L., 1758) with an initial body weight average of 15.09±0.02 g on growth, body composition, some blood parameters, and intestinal mucosal morphology. In the study, W means of the groups were 73.01±2.68 g, 68.93±2.43 g, 72.51±5.01 g, 69.82±5.29 g, and 72.10±3.28 g, respectively, while the means of FCR were found 1.75±0.01, 1.82±0.04, 1.74±0.05, 1.83±0.07 and 1.76±0.04, respectively. In the trial, it was reported that clinoptilolite had no effect on the W increase, feed consumption, FCR, specific growth rate (SGR), protein efficiency ratio, VSI, carcass yield, CF, crude protein, dry matter, fat and raw ash values; and also on the intestinal surface area and the length of the digestive tract according to the findings obtained from histological examinations of samples taken from small and large intestines ($P>0.05$). However, according to the results of the blood analysis, it was reported that the glucose and blood urea nitrogen levels decreased, the hemoglobin level increased ($P<0.05$) and the cholesterol level remained unchanged ($P>0.05$).

Danabas (2009) was applied the zeolite (clinoptilolite) into the pond water (E1) (0 (Control), 1, 2 and 3 g l^{-1} ratios) and into the feed (E2) (0 (Control), 1, 2 and 3%) of rainbow trout (*Oncorhynchus mykiss*) (20.8984±0.564 g and 12.8263±0.122 cm). It was evaluated in E1, its effects on some water parameters and fish growth, and on the fish growth and body composition in E2. In E1, it was determined that the clinoptilolite ratios applied to the pond water did not affect the water and growth parameters ($P>0.05$). In E2, clinoptilolite added to the feed increased W, L, daily live weight gain (DLWG), SGR, SR, crude protein, dry matter and raw ash values ($P<0.05$); decreased the FCR and VSI ($P<0.05$); however, it did not affect CF, HSI, gonadosomatic index (GSI) and lipid values ($P>0.05$). According to these results, it was concluded that adding 1% clinoptilolite to feeds of this size of rainbow trout fry is beneficial.

Both inside and outside of the filter, the effects of zeolite on water quality and the growth of electric blue hap (*Sciaenochromis ahli*) were investigated for 3 months (Öz et al., 2021). They determined some statistically insignificant differences between weight gain, specific growth rate and feed conversion ratio ($P>0.05$) and it was suggested that low ratios as 0.35 g l^{-1} of zeolite may be used in tulle bags on floor or inside the filter to prevent ammonia rising to high concentrations.

Surmeli et al. (2020) was carried out the zeolite as feed additive (1 and 2%) to juvenile carp species (*Cyprinus carpio*). The comparative analysis of the results obtained for the morpho-productive characters (live weight, total length and maximum body height) revealed that the group fed with 2% clinoptilolite additive feed, obtained the best performances. Clinoptilolite in feed has contributed at maintaining favorable media conditions for the growth and development of fish from the controlled systems used.

Güler and Ucar (2020) fed the rainbow trout (*Oncorhynchus mykiss*) with feeds containing zeolite (1, 3 and 5%) for three months to evaluate fish growth parameters and hematological indices. The changes in growth parameters were determined ($P>0.05$), and different ratios of zeolite added diets were found to cause a change in the blood indices, of which WBC, ESR and MCV values were statistically significant ($p <0.05$).

Tekeşoğlu and Ergun (2021) performed to evaluate the effects of clinoptilolite on the growth performance and some biochemical blood parameters in juvenile rainbow trout (*Onchorynchus mykiss*). 0.5% zeolite showed the best results in final body weight, weight gain, specific growth rate, feed intake, feed conversion rate, and protein efficiency while 2.5% zeolite has negative effects. However, in terms of blood parameters, all the groups had similar values with no significance ($p>0.05$) compared to the control group. They stated that limited usage of clinoptilolite in rainbow trout diets (no higher than 1% in diets) might have beneficial effects on growth parameters.

It is stated that 75% of the total zeolite reserves in the world are found in Turkey. The Western Anatolia Region is rich in clinoptilolite deposits. The most important reserves of clinoptilolite in Turkey are Manisa-Gördes and Balıkesir-Bigadiç basins, with estimated reserves of 20 million tons and 500 million tons, respectively. Other basins for clinoptilolite with total reserves of 50 billion tons are in Emet-Yukarı Yoncaağaç, Kütahya-Şaphane, Gediz-Hisarcık, İzmir-Urla, Tuzköy-Kayseri and Amasya-Doğantepe. The country with the highest production is China (70% of the total production - 1.75 to 2.25 Mt). Turkey is only in the 4th place with a production of 100000 tons (Bahaallddin, 2010). In Turkey, on the other hand, billions of tons of zeolite have been revealed, and it has been determined that mostly clinoptilolite type zeolites are concentrated in the deposits in Ankara-Polatli-Mulk-Oglakci Region and Bigadic, Saphane, Gediz, Emet, Gordes Regions. It is one of the most important

manufacturers in the world. The price of the zeolite produced in Turkey is quite reasonable (15900 TL / 25 t). With the studies summarized above, the importance and potential of zeolite use in the aquaculture sector is evident.

Water quality is also very important in aquaculture as well as in all animal farming. Guo et al. (2013) in swine culture, Markou et al. (2014) and Markou et al. (2015) in the production of phytoplankton and cyanobacteria. reported that the using of the zeolite varieties was effective in removing ammonia from the culture environment. Skleničková et al. (2020) in the koi breeding environment; Yu et al. (2020) in the aquaculture environment; Aksu (2016) in the crayfish culture environment; and Peyghan and Azary-Takamy (2002) in improving the water quality in carp ponds, reported that the addition of zeolite gave positive results. Kaiser et al. (2006) in the transplant of *Haplochromis obliquidens* and Ravendra et al. (2004) in the transportation of common carp species, stated that positive results were obtained with the supplementation of zeolite. Dias et al. (1998) in European sea bass (*Dicentrarchus labrax*) fry; Aybal (2001), Danabas (2009), Güler and Ucar (2020) and Tekeşoğlu and Ergun (2021) in the rainbow trout (*Oncorhynchus mykiss*) culture; Töre (2006), Shalaby et al. (2021), Abbas et al. (2021) and Llanes and Castro (2020) in the tilapia species culture; Kanyılmaz (2008) and Surmeli et al. (2020) in the carp (*Cyprinus carpio*) culture; and Öz et al. (2021) in the water quality and growth parameters of electric blue hap (*Sciaenochromis ahli*) reported to provide more positive parameters with addition of different zeolite rates. Zeolites have given very effective results for purposes such as increasing of the fish growth parameters, because of controlling pollution in ponds in the aquaculture sector, of removing nitrogenous compounds from hatchery, fish transport and aquarium water, of increasing ambient oxygen in aquarium and fish transport, and of using them as feed additives. In addition, it has been considered that it will give very useful results in overcoming the problem of feed raw material and cost, which is the main problem of fish culture.

In conclusion, we believe it will also contribute that as a local and natural product, the use of zeolites produced in Turkey country as a feed additive in the aquaculture sector will contribute to the production of fish with lower costs, as well as to the development of 2 different sectors (aquaculture and mining) in interaction with each other.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' contributions

Author DD had the first idea and the design of the study, He wrote the first draft of the manuscript, MD improved the final version of manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

Statement on the welfare of animals

This manuscript is a review. So, for this type of study, formal consent is not required.

Statement of human rights

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

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