Ege Journal of
Fisheries and Aquatic Sciences

www.egejfas.org

E-ISSN 2418-3140

EgeJFAS

Su Ürünleri Dergisi

Volume 41 Number 1

2024

Ege University Faculty of Fisheries

Authors Guidelines

Thank you for deciding to submit your article to the Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS). The journal welcomes the submission of articles that are of interest and high scientific quality. Authors should check the "Author Guidelines" very carefully before submitting their manuscripts. The instructions given here will ensure that your article's evaluation process (referee, publication, etc.) can proceed smoothly. Make sure your article is prepared and submitted in accordance with journal rules.

Submitted manuscripts will be checked primarily for compliance with journal subjects and rules. Manuscripts not complying with required formatting will be returned for correction. Papers outside the scope of the journal will be rejected.

GENERAL INFORMATION

Aim & Scope

Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS) is open access, international, double-blind peer-reviewed journal publishing original research articles, short communications, technical notes, reports, and reviews in all aspects of fisheries and aquatic sciences.

The journal does not charge any submission and publication fees.

All articles receive DOI, are citable, published in PDF format.

The journal focuses on interdisciplinary studies that present new and useful information to the international scientific community/readership, and contribute to scientific progress. Before submitting your article, make sure it is suitable for the journal scopes.

The main functional areas accepted into the journal are listed as follows:

Marine and freshwater fisheries, Aquaculture, Vertebrate and invertebrate aquaculture (marine/freshwater), Planktonology and plankton culture, Living resources, Management and economics, Aquaponic, Seafood processing technology, Feeding and feed technologies, Fishing technology, Fisheries management, Population dynamics, Disease and treatment, Aquatic microbiology, Biology, physiology, Macroalgae, Biotechnology, Conservation and sustainability, Environments and ecology, Biogeography, Biodiversity, Climate effects, Pollution studies.

Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS) (Su Ürünleri Dergisi) published quarterly (March, June, September, December) by Ege University Faculty of Fisheries since 1984.

The journal is published only as an e-journal since the 1st issue of 2020.

Language

Although articles in English and Turkish are accepted, priority is given to articles prepared in English in order to increase international readability and citation. Limited Turkish articles are published in each issue.

Manuscripts should comply with the standard rules of grammar and style of the language (English or Turkish) with appropriate spelling and punctuation in which they are written.

Editorial Policy and Referee Process

Manuscripts should not be copied elsewhere or submitted to another journal for parallel evaluation. Only original manuscripts are considered. It is evaluated with the understanding that the content is approved by all co-authors. Submitted manuscripts are first checked in terms of journal scope, language, presentation, and style. Manuscripts that are not suitable for these aspects will be returned without review.

In order to evaluate the appropriate articles, at least 2 or 3 external and independent referees who are experts in their fields are appointed by a member of the editorial board/section editor. Each manuscript is reviewed through a double-blind peer-review process (identities of neither authors nor peer reviewers are disclosed). Manuscripts returned to authors with referee reports should be revised and sent back to the editor as soon as possible.

Editor-in-chief/editors take the final decision (Accept, Reject) of the manuscript in line with the reviewer's opinions. All responsibility for the scientific content and expressions in the published article belongs to the authors. In accordance with the publication policies of EgeJFAS, the plagiarism report for the relevant manuscript is requested to be uploaded to the submission system by the responsible author.

Article Types

The types of articles accepted include original research articles (priority), short communications, reviews, reports, and technical notes in all aspects, focusing on interdisciplinary studies in the field of fisheries and aquatic sciences.

Original research papers: These are the article type that the Journal gives the most importance and priority. Should contain data obtained from original studies such as experimental results, field data, and/or theoretical studies.

Short communication: It should include original results and headings, like research papers. Articles provide important new research results/methods or discoveries that do not possible to publish as a full research paper. These articles that are narrowly focused deserve to be published faster than other articles.

Review: Reviews may summarize current research areas of broad importance or provide the readers with an insightful introduction to new and groundbreaking areas of research. It should be examined and discussed in-depth and comprehensively written by the author(s) who have expertise in the subject area, not just the literature surveys. Only invited reviews (in English) are considered for publication. If you would like to submit an invited review, please contact the editor-in-chief (editor@egejfas.org) and upload a review cover letter containing the requested information. As of 2023, reviews in Turkish will not be accepted. Publication of those accepted in the previous year will be completed in 2023.

Reports

Case reports encourage the submission of reports containing feature novel findings or new management strategies. Well-written and illustrated reports are taken into account.

Brief reports are short, observational studies that report the initial results or completion of a study or protocol.

Technical notes: They are short articles that focus on a new technique, method or procedure. It should identify significant changes or unique applications for the method described.

MANUSCRIPT SUBMISSION

The manuscript, when submitted together with the Cover Letter (Submission declaration and verification) and Copyright Form signed by the corresponding author on behalf of all authors, warrants (confirms) that it is original and has not been published elsewhere, has been approved - tacitly or expressly - by all co-authors and the responsible authorities at the institute where the work was carried out. The publisher will not be held legally responsible in case of any claim for compensation.

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Authorship Contributions, Conflict of Interest Statement, Ethics Approval, Data Availability should be written in the article after Acknowledgements and Funding section.

While starting

For submission of your manuscript prepared in accordance with the guideline to EGEJFAS please click here and after logging into your account (if you don't have an account please register at https://dergipark.org.tr/en/ . Your default login ID is your email address. Use your existing account; do not create new accounts with new submissions) use the "Submit Article" button on the home page of the journal to start submission. Before submitting a manuscript, do not forget to check the Submission Checklist.

After log in, the article submission process is completed in 5 steps. Upload your article information, article file, and other necessary documents step by step correctly. There is no transition to the next step until a step is completed.

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Please see our information on Ethical Principles and Publication Policy. Before submission, do not forget to read the "Ethical Responsibilities of the Authors".

Please ensure that any manuscript you submit to this Journal conforms to the Committee on Publication Ethics (COPE) recommendations for ethics, Best Practice Guidelines and as well as to the rules of Egejfas.

PREPARATION OF MANUSCRIPTS

Papers must be clearly written in Turkish or English. Manuscripts should be typed double spaced on A4 size paper in 12-point Times New Roman font including the references, table headings and figure captions with standard margins (25 mm) all around. The author's name should appear centred under the title. Numbered (1) note should give the author's institutional address and an asterisked (*) note should indicate the corresponding author's e-mail address. Degrees and qualifications should not be included.

Line and page numbers should be given from the first page of the manuscript.

Please prepare your typescript text using a word-processing package (save in .doc or .docx).

The complete manuscript should be in a single file containing full text, references, figures and tables. Figures and tables should be inside the manuscript placed properly (not at the end of manuscript). The line number should be given to the whole manuscript.

- Research papers and reviews must not exceed 25 manuscript pages including tables and figures (except systematic checklists).
- Short communications, technical notes, and reports which are results of brief but significant work, must not exceed 10 manuscript pages including tables and figures.

Papers must be clearly written in Turkish or English. Manuscripts should be typed double spaced on A4 size paper in 12-point Times New Roman font including the references, table headings and figure captions with standard margins (25 mm) all around. The author's name should appear centered under the title. Numbered ([1]) note should give the author's institutional address and an asterisked (*) note should indicate the correspondence author's e-mail address. Degrees and qualifications should not be included.

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The complete manuscript should be in a single file containing full text, references, figures and tables. Figures and tables should be at the end of the manuscript file and the locations should be indicated in the text.

- Research papers and reviews must not exceed 25 manuscript pages including tables and figures (except checklists).
- Short communications, technical notes and reports which are results of brief but significant work, must not exceed 10 manuscript pages including tables and figures.

First Page

The title should be short concise and informative, and be a statement of the main result/conclusion presented in the manuscript. The title should not contain abbreviations. Do not forget to add English title for Turkish article. The title should be written in sentence order.

Author Names and Affiliation

The first name and surname of each author should be clearly listed together and separated by commas. Provide exact and correct author names (forenames-surnames) as these will be indexed in official archives. Occasionally, the distinction between surnames and forenames can be ambiguous, and this is to ensure that the authors' full surnames and forenames are tagged correctly, for accurate indexing online.

Present the authors' affiliation addresses should be indicated at the author's name with superscript numbers immediately after the author's name. The full postal address of each affiliation at the time of research should be listed in order: Department, institution, city with postcode, and country name.

Please clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. Provide an active e-mail address of the corresponding author. It is editorial policy to list only one author for correspondence.

ORCID numbers of all authors should be listed on the article title page as of June 2017. Authors who do not have an ORCID number are required to register their number at www.orcid.org. The orcid number is mandatory. Articles that do not have an ORCID number or are incorrect will not be evaluated.

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Abstract

English and Turkish abstracts (contributors who are not native Turkish speakers may submit their manuscripts with an English abstract only) of a maximum of 300 words should be included in all submissions. The abstract should be comprehensible to readers before they have read the full paper, and reference citations must be avoided. In the abstract, the importance of the work should be clearly stated; what, why, how it was done should be answered and the contribution of the results to the scientific world should be expressed. It should not contain undefined abbreviations.

Abstract should clearly the importance of the work described in the paper and reflect what was done, why it was done and what important results were achieved. It should not contain any undefined abbreviations and not be written in the first person.

Keywords

Below the abstract, please provide 4-6 keywords related to the study that will help to increase the discoverability of your manuscript. It is especially important to include words that are fundamental to your manuscript but are not included in the manuscript title or abstract to increase discoverability by indexing services.

Following pages

Following pages should contain the rest of the paper and should be organized into an Introduction, Material and Methods, Results, Discussion, Conclusion(s), Acknowledgements and Funding, Authorship Contributions, Conflict of Interest Statement, Ethics Approval, Data Availability, References. These should be capitalized. Please note that submissions without required documents/statements will not be accepted.

Introduction

Provide clearly and an adequate background, avoiding a detailed literature survey or a summary of the results. State the specific objective or hypothesis of the study.

Material and Methods

Provide adequate detail to allow the work/experiment to be reproduced. Methods already published should be mentioned by references. Significant modifications of published methods and new methods should be described in detail.

If the study requires "Ethics Committee Permission Certificate", be sure to report after the "Acknowledgements" section that permission has been obtained from the relevant institution. A copy of the "Ethics Committee Permission Documents" should be uploaded to the system. A detailed explanation on this subject has been made in the "Ethics Approval" heading above.

Results

Results should be clear and concise. Results for different parameters should be described under subheadings or in separate paragraph. Present your results in a logical sequence in the text, tables, and figures.

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The discussion should not repeat the results, but should provide a detailed interpretation of the data. The discussion should highlight the importance of the work and the resulting new insights. Only in exceptional cases may the results and discussion be combined with the editor's consent. Avoid extensive citations and discussion of published literature.

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This should briefly state the major findings of the study.

Acknowledgements and Funding

Acknowledgements including people, grants, funds, projects, etc. should be kept brief and placed after conclusion section. Names of contributing people should be written clearly and fully.

Examples:

"The authors are grateful to John Nare, for his friendly collaboration and hospitality during the lipid analysis."

"The authors would like to thank Ken More for language revision."

Please clearly and fully specify the relevant funding information (name) with the grant number or codes.

Financial support acknowledgwment should be written like the example given:

"This study was supported by the Turkish Scientific and Technological Research Institution (Grant number: ....)."

"This work was supported by Ege University Scientific Research Projects Coordination Unit. Project Number: …."

"Author Mary Lee has received research support from Company A."

If the research has no specific financial support, please include the following statement:

"This research has not received a specific grant, fund or other support from any funding agency in the public, commercial, or not-for-profit sectors."

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Identifying individual author contributions (CRediT - Contributor Roles Taxonomy, ICMJE-Defining the Role of Authors and Contributors, Transparency in authors' contributions) is important to reduce authorship disputes and facilitate collaboration. The publisher recommends that authors include statements of contribution stating each author's contribution to the work to promote transparency. This gives authors the opportunity to share an accurate and detailed description of their various contributions to the work. The corresponding author is responsible for ensuring that the disclosures are correct and accepted by all authors.

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Example: All authors contributed to the idea and design of the study. Material preparation and investigation were performed by [full name], [full name] and [full name]. The writing/editing was carried out by [full name] and all authors have read and approved the article.

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Full name/s: Conceptualization, Methodology, Software

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Full name/s: Supervision

Full name/s: Software, Validation

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For review article; it should be stated whose idea, who did the literature survey and data analysis, who wrote the draft, and who revised the criticisms.

For articles produced from student's dissertations or thesis, it is generally recommended that the student is listed as the principal author (A Graduate Student's Guide-APA Science Student Council 2006).

Changes to Authorship

At the time of submission, the author (s) information, the corresponding author and the order of the authors must be correct. Changing the author order, adding/deleting are not allowed during the revision phases. However, in rare cases, it can be applied when detailed and acceptable reasons are presented. All authors must agree with any addition, removal or rearrangement and the reasons for changes should be explained in detail. After the article is accepted, no changes can be made to the authorships.

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Authors should declare if they have any financial or personal relationships with any institution/organization or person that may adversely affect their work. Conflict of interest statement should be attached to the article after the Acknowledgements section.

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In the event of a potential conflict of interest, the authors must state: "The following financial interests / personal relationships may be potential competitive interests."

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All animal and human experiments conducted in the manuscript research should comply with the ARRIVE guidelines, EU Directive 2010/63/EU, The Code of Ethics of the World Medical Association (Declaration of Helsinki), and National Ethics Committee for Animal Experiments (HADMEK, HADYEK). If there is a human study in the article, it must comply with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

If the submitted article involves the use of animal (vertebrate) and human subjects, authors should prove that they have carried out the manuscript studies in accordance with the relevant laws and regulations and they have received the approval of the authorized institutional committee (s) (including the ethics committee name and reference number, if possible). If a study was granted exemption or did not require ethics approval, this should also be detailed in the manuscript.

Copies of approval should be uploaded to the system under the subheading "Ethics Committee Approval". In addition, an explanation should be added to the article with the title of "Ethics Approval" after the Acknowledgements section.

Examples:

"Approval was granted by the Ethics Committee of University B (Date.../No....)."

"This is an observational study. The ABC Research Ethics Committee has confirmed that no ethical approval is required."

"This article does not contain any human or animal studies performed by any authors."

"The authors declare that all applicable guidelines for sampling, care, and experimental use of animals in this study have been followed."

"Sampling and handling procedures of the fish were in accordance with an …… protocol approved by University of ……..".

"No specific ethical approval was necessary for this study."

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If necessary, an application should be made to the ethics committee and approval should be obtained before starting a study. Generally, retrospective ethical approval cannot be obtained. It may not be possible to consider such articles for peer review. In such cases, it is at the Editor's discretion to decide whether to proceed with the peer review.

Data Availability

Articles are open access and free to use. Published articles are archived permanently. Proper citation is required when using an article published in a journal.

In order for the datasets reflecting the results of the article should be accessible to the readers; the journal encourages that datasets may be stored in public repositories (where available and appropriate) and addressed in the article, provided in the article, or in supplementary files whenever possible, or available from the corresponding author upon request. Regarding data availability, authors can follow one of the ways described. Enquiries about data availability should be directed to the authors. This information should be placed in the text with the heading "Data Availability" after the "Acknowledgements" section of the article. See examples below:

Examples:

Data availability: All of the data summarized in the study are available in the (name) Data Repository, (link address).

Data availability: The data sets generated during and/or analysed during the current study will be provided by the corresponding author upon the request of the editor or reviewers.

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Scientific Style

In writing of systematic /biological papers, international terminology such as "International Codes of Zoological Nomenclature (ICZN), and International Code of Nomenclature for Algae Fungi and Plants (ICNAFP)(Formerly known as the International Code of Botanical Nomenclature - CBN) International Code of Botanical Nomenclature (ICBN)" must be strictly followed. The first mention in the text of any taxon must be followed by its authority including the year. The names of genera and species should be given in italics. Clearly write the full genus name at the first occurrence in the text, and abbreviate it when it occurs again. When referring to a species, do not use the genus name alone; Be careful when using 'sp' (singular) or 'spp.' (plural).

Equations and units

Please ensure that equations are editable. Leave a space on both sides of the <, ±, =, etc. equations used in the text. For units and symbols, the SI system should be used.

Abbreviations

Please define non-standard abbreviations at first use in the text with full form followed by the acronym in parentheses. Use only the acronym for subsequent explanations.

Footnotes

Footnotes should be numbered consecutively. Those in tables or figures should be indicated by superscript lower-case letters. Asterisks should be used for significance values and other statistical data. Footnotes should never include the bibliographic details of a reference.

References

Full references should be provided in accordance with the APA style. The usage of reference managers as Mendeley© or Endnote© or an online reference manager as Citefast with the output style of APA 7th edition is advised in organizing the reference list.

Please ensure that every reference cited in the text is also present in the reference list (and vice versa) and avoid excessive referencing.

In-Text Citation

In-text citation to the references should be formatted as surname(s) of the author(s) and the year of publication (also known as the author-date system).

If a specific part of a source (book, article, etc) is cited directly, a page number should also be included after the date. If the full source is used, the citation page number is not displayed.

For example: Kocataş, 1978, p. 3

Citation can be shown in two ways: Parenthetical Citation or Narrative Citation.

References to be made at the end of the sentence should be shown in parentheses. If the cited reference is the subject of a sentence, only the date should be given in parentheses. There should be no parentheses for the citations that the year of the citation is given in the beginning of the sentence.

Citation examples according to the number of authors are given below.

One author:

Consider the following examples:

-……………(Kocataş, 1978)

- Kocataş (1978) states…….

- In 1978, Kocataş's study of freshwater ecology showed that….

Two authors:

If there are two authors, the surnames of both authors should be indicated and separated from each other by "and", (Geldiay and Ergen, 1972).

Consider the following examples:

-……….(Geldiay and Ergen, 1972)

- Geldiay and Ergen (1972) states……

- Similar results were expressed by Geldiay and Ergen (1972), Kocataş (1978).

More than two authors:

For citations with more than two authors, only the first author's surname should be given, followed by "et al." –in Turkish article 'vd.'- and the date (Geldiay et al.,1971; Geldiay vd., 1971).

See below examples:

-Geldiay et al. (1971) state…….

-…………………………(Geldiay et al., 1971).

There are few studies on this subject (Geldiay et al.,1971).

Two or more works by different author:

When its needed to cite two or more works together, in-text citations should be arranged alphabetically in the same order in which they appear in the reference list and used semicolons to sparate citations.

For example: Several studies have reported similar results (Geldiay and Ergen, 1972; Kocataş 1978; Thurry 1987).

Two or more works by the same author:

If there are two or more works by the same author, list the years of publication in order, earliest first. For example: (Kocataş, 1978, 1979, 1981) or Kocataş (1978, 1979, 1981)

Citation to authors with more than one work in the same year:

The works should be cited as a, b, c, etc. after the date. These letters must be listed alphabetically according to the surname of the first author in the bibliography list.

For Example:

-Geldiay and Ergen, 1972a

-Geldiay and Ergen, 1972a, b

No authors:

If the author is unknown, the first few words of the source should be used and dated.

For example: (A guide to citation, 2017).

In some cases, "Anonymous" is used for the author, accept this as the name of the author (Anonymous, 2001). Use the name Anonymous as the author in the reference list.

No publication date:

If the publication date is unknown, write "n.d." (no date) in the in-text citation.

Example: (Geldiay, n.d.).

Citation to secondary sources:

In scientific studies, citation should be made to the original primary sources. Cite secondary sources when the original work is out of print, not available, or only available in a language you do not understand. If you want to cite a work that you can't find yourself, through a citation from another source, using the phrase "…………as cited in".

For Example:

(Geldiay and Ergen 1972, as cited in Kocataş, 1978)

Personal communication and unpublished results:

Personal communications, such as phone calls, emails, and interviews, are not included in the reference list because readers can't access them. The in-text citation is also formatted slightly differently as follow:

Example:

- Demands have been increasing lately. (A. Kale, personal communication, May 10, 2021).

General use of websites and software:

It should be showed as below.

-The website of Egejfas (www.egejfas.org) includes author guidelines.

-Statistical software SPSS (version 25) was used to analyze the data.

In References

All citations should be listed in the reference list, with the exception of personal communications and unpublished results.

All references must be written in English. If an article is written in a language other than English, give the title in English and indicate the language in which the article is in parentheses at the end of the source. Example: (in Turkish)

If the article has only an English abstract, indicate it in parentheses (English abstract) or (only English abstract)

References should be listed alphabetically ordered by the author's surname, or first author's surname if there is more than one author.

Hanging indent paragraph style should be used.

The year of the reference should be in parentheses after the author name(s).

The correct arrangement of the reference list elements should be in order as "Author surname, first letter of the name(s). (publication date). Title of work. Publication data. DOI

Article title should be in sentence case and the journal title should be in title case. Journal titles in the Reference List must be italicized and spelled out fully; do not abbreviate titles (For example; Ege Journal of Fisheries and Aquatic Sciences, not Ege J Fish Aqua Sci). Article titles are not italicized. If the journal is paginated by issue the issue number should be in parentheses.

DOI (Digital Object Identifier) information (if available) should be placed at the end of the reference as in the example. After added DOI information, "dot" should not be put. The DOI information for the reference list can be retrieved from CrossRef © Simple Text Query Form (https://doi.crossref.org/simpleTextQuery) by just pasting the reference list into the query box. After copying and pasting all the references of your article in the query box on this page, the DOI information is listed as added to the relevant reference. It is strongly recommended to provide DOI information of the references.

- For a reference with up to 20 authors, ALL authors (up to 20) are spelled in the reference list. When the number of authors is more than 21, "......" is used between the 19th author and the last author (APA 7th edition).

For example:

Bolotov, I.N., Kondakov, A.V., Konopleva, E.S., Vikhrev, I. V., Aksenova, O. A, Aksenov, A. S., Bespalaya, Y. V., Borovskoy, A. V., Danilov, P. P., Dvoryankin, G. A. Gofarov, M. Y., Kabakov, M. B., Klishko, O. K., Kolosova, Y. S., Lyubas, A. A., Novoselov, A. P., Palatov, D. M., Savvinov, G. N., Solomonov, N. M., ……..& Vinarski, M. M., (2020). Integrative taxonomy, biogeography and conservation of freshwater mussels (Unionidae) in Russia.Scientific Reports, *10*, 3072. https://doi.org/10.1038/s41598-020-59867-7

- In the reference list starting with the same surname and names (initials), works with a single author are put in chronological order first; Then, two-author works are taken into account in alphabetical order of the second author. Multi-author works are listed only chronologically.

For example:

Kocataş, A. (1978)

Kocataş, A., & Ergen, Z. (1972).

Kocataş, A., & Geldiay, R. (1972)

Kocataş, A., Ergen, Z., & Geldiay, R. (1980)

The citation of journals, books, multi-author books and articles published online etc. should conform to the following examples:

Journal Articles

Öztürk, B. (2010). Scaphopod species (Mollusca) of the Turkish Levantine and Aegean seas. Turkish Journal of Zoology, *35*(2), 199-211. DOI:10.3906/zoo-0904-23

Özbek, M., & Ulutürk, E. (2017). First record of Spongilla lacustris (Porifera: Demospongiae) from the Eastern Black Sea (Uzungöl Lake, Trabzon) (in Turkish with English abstract). Ege Journal of Fisheries and Aquatic Sciences, *34*(3), 341-346. https://doi.org/10.12714/egejfas.2017.34.3.14

Books

Parsons, T.R., Matia, Y., & Lalli, C.M. (1984). A manual of chemical and biological methods for seawater analysis. New York, Pergamon Press.

Kleiner, F.S., Mamiya, C.J., & Tansey, R.G. (2001). Gardner's art through the ages (11th ed.). Fort Worth, USA: Harcourt College Publishers.

Chapter in books

Gollasch, S. (2007). Is ballast water a major dispersal mechanism for marine organisms? In W. Nentwig (Ed.), Biological Invasions (pp. 29-57). Berlin: Springer.

E-books and chapter in e-books

Mitchell, J.A., Thomson, M., & Coyne, R.P. (2017). A guide to citation. Retrieved from https://www.mendeley.com/reference-management/reference-manager

Troy, B.N. (2015). APA citation rules. In S.T, Williams (Ed.). A guide to citation rules (2nd ed., pp. 50-95). Retrieved from https://www.mendeley.com/reference-management/reference-manager

Proceedings

Soultos, N., Lossifidou, E., Lazou, T., & Sergedilis, D. (2010). Prevalence and antibiotic susceptibility of Listeria monocytogenes isolated from RTE seafoods in Thessaloniki (Northern Greece). In Ş. Çaklı, U. Çelik, C. Altınelataman (Eds.), West European Fish Technologists Association Annual Meeting 2010 (pp. 94-98). İzmir, Turkey: Proceedings Book.

Websites

Mitchell, J.A. (2017, May 21). How and when to reference. https://www.howandwhentoreference.com

If the resource was written by a group or organization, use the name of the group/organization as the author. Additionally, if the author and site name are the same, omit the site name from the citation.

American Society for the Prevention of Cruelty to Animals. (2019, November 21). Justice served: Case closed for over 40 dogfighting victims. https://www.aspca.org/news/justice-served-case-closed-over-40-dogfighting-victims

Thesis

Acarli, S. (2005). Larval production of oyster. Doctoral dissertation, Ege University, Turkey.

Tables and Figures

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Corresponding Address Su Ürünleri Dergisi Ege University Faculty of Fisheries 35100 Bornova-İzmir, Turkey Phone: +90 232 311 3838 Fax: +90 232 388 3685 E-mail: editor@egejfas.org	**E- ISSN 2148-3140**

Su Ürünleri Dergisi
Ege Journal of Fisheries and Aquatic Sciences

Su Ürünleri Dergisi yılda dört sayı olarak yayınlanır. Ege Journal of Fisheries and Aquatic Sciences is published in four issues annually.

T.C. Kültür ve Turizm Bakanlığı Sertifika No: 18679
Ministry of Culture and Tourism Sertificate No:18679

Yayımlanma Tarihi **Publishing Date**
15 Mart March 15th, 2024

İletişim **Contact**
Ege Üniversitesi Su Ürünleri Fakültesi, 35100, Bornova, İzmir Ege University Faculty of Fisheries, 35100, Bornova, İzmir, Türkiye
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Su Ürünleri Dergisi

Ege Journal of Fisheries and Aquatic Sciences

Volume 41 Number 1 **ISSN 1300-1590 / E-ISSN 2418-3140**

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Published by

Ege University Faculty of Fisheries, İzmir, Türkiye

http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 1-7 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.01

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Investigations on the zooplankton distribution and composition of Işıklı Lake (Çivril-Denizli/Türkiye), with a trophic status assessment

Işıklı Gölü (Çivril-Denizli/Türkiye) zooplankton dağılımı ve kompozisyonunun trofik durum değerlendirmesi ile araştırılması

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Received date: 15.09.2023 *Accepted date: 22.11.2023*

How to cite this paper:
Apaydın Yağcı, M., Uysal, R., Yağcı, A., Yeğen, V. (2024). Investigations on the zooplankton distribution and composition of Işıklı Lake (Çivril-Denizli/Türkiye), with a trophic status assessment. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 1-7. https://doi.org/10.12714/egejfas.41.1.01

Abstract: In this study, the zooplankton distribution and composition of Işıklı Lake, located in the Inner West Anatolia region of Türkiye, were examined monthly between 2003-2005. Zooplankton samples were collected with Hydro-Bios plankton net (55 µm) at the surface and fixed in formaldehyde (4 %). Physiological parameters such as surface water temperature, pH, dissolved oxygen, and conductivity were also measured. Also, the frequency index (F %) and the *Brachionus* / *Trichocerca* ($Q_{B/T}$) were determined to assess the trophic composition of Lake Işıklı. A total of 49 species have been identified. Rotifera (55 %), Cladocera (27 %) and Copepoda (18%) were represented by the species. The maximum species was found in May 2004 (21 species), while the minimum was found in October 2003 (5 species). *Asplanchna priodonta, Keratella cochlearis, Keratella tecta, Polyarthra dolichoptera, Synchaeta pectinata, Bosmina longirostris* and *Chydorus sphaericus* are common species in the lake. The water temperature varied between 3.9-24.6 °C; pH ranged from 8.1 to 8.8; the electrical conductivity ranged from 341 µS/cm to 434 µS/cm; the dissolved oxygen values changed from 5.8 mg/L to 11.1 mg/L. According to the frequency index (F %), the most dominant species are *B. longirostris* (74 %), *K. cochlearis* (62 %), *A. priodonta* (54 %), and *C. sphaericus* (51 %). A total of 20 species are reported for the first time from the region. Newly reported species from the lake were: the rotifers, *A. priodonta, Brachionus angularis, Brachionus calyciflorus, Colurella colurus, Keratella quadrata, Lecane clostrocerca, Lecane ludwigi, Lecane luna, Lecane lunaris, Lecane ohioensis, Lecane quadridentata, Lecane* sp., *Mytilina mucronata, Notholca acuminata, Notholca squamula, Trichotria tetractis,* the cladocerans *Acroperus harpae, Daphnia cucullata,* and the copepods *Eucyclops macrurus* and *Megacyclops gigas*. Considering the *Brachionus* / *Trichocerca* ($Q_{B/T}$) ratio according to the Sládeček (1983) index, the lake showed mesotrophic features.

Keywords: Mesotrophic level, Işıklı Lake, Rotifera, Cladocera, Copepoda

Öz: Bu çalışmada Türkiye'nin İç Batı Anadolu bölgesinde yer alan Işıklı Gölü'nün zooplankton dağılımı ve kompozisyonu 2003-2005 yılları arasında aylık olarak incelenmiştir. Zooplankton örnekleri yüzeyden Hydro-Bios plankton ağı (55 µm) ile toplanmıştır ve formaldehit (% 4) içerisine sabitlenmiştir. Yüzey suyu sıcaklığı, pH, çözünmüş oksijen ve elektriksel iletkenlik gibi bazı fizikokimyasal parametreler de ölçülmüştür. Ayrıca Işıklı Gölü'nün trofik kompozisyonunu değerlendirmek amacıyla frekans indeksi (% F) ve *Brachionus / Trichocerca* ($Q_{B/T}$) belirlenmiştir. Toplam 49 tür tespit edilmiştir. Rotifera (%55), Cladocera (%27) ve Copepoda (%18) türleri tarafından temsil edilmiştir. Maksimum tür Mayıs 2004'te (21 tür), minimum tür ise Ekim 2003'te (5 tür) bulunmuştur. *Asplanchna priodonta, Keratella cochlearis, Keratella tecta, Polyarthra dolichoptera, Synchaeta pectinata, Bosmina longirostris* ve *Chydorus sphaericus* gölde yaygın olarak görülen türlerdir. Su sıcaklığı 3,9-24,6 °C arasında; pH 8,1 ila 8,8 arasında; elektriksel iletkenlik 341 µS/cm ile 434 µS/cm arasında; çözünmüş oksijen değerleri 5,8 mg/L'den 11,1 mg/L'ye kadar değişmiştir. Sıklık indeksine (% F) göre en baskın türler *B.longirostris* (%74), *K. cochlearis* (%62), *A. priodonta* (%54) ve *C. sphaericus* (%51)'dur. Bölgeden ilk kez toplam 20 tür rapor edilmiştir. Gölde yeni bildirilen türler: rotifera, *A. priodonta, Brachionus angularis, Brachionus calyciflorus, Colurella colurus, Keratella quadrata, Lecane clostrocerca, Lecane ludwigi, Lecane luna, Lecane lunaris, Lecane ohioensis, Lecane quadridentata, Lecane* sp., *Mytilina mucronata, Notholca acuminata, Notholca squamula, Trichotria tetractis*, cladocera *Acroperus harpae, Daphnia cucullata* ve copepoda *Eucyclops macrurus* ve *Megacyclops gigas*. Sládeček (1983) indeksine göre *Brachionus* / *Trichocerca* ($Q_{B/T}$) oranı dikkate alındığında; göl mezotrofik özellik göstermiştir.

Anahtar kelimeler: Mesotrofik seviye, Işıklı Gölü, Rotifera, Cladocera, Copepoda

INTRODUCTION

In freshwater and aquatic ecosystems, zooplankton is an essential component in the food web, carbon transfer, suppressing phytoplankton abundance (Bozkurt and Genç, 2018; Çolak and Alper, 2020; Karpowicz and Ejsmont-Karabin, 2021; Özdemir et al., 2021). Cladocera, Copepoda and Rotifera are the main representatives of zooplankton. While zooplankton is an essential indicator of the health of the ecosystem (Ateş and Kırkağaç, 2020), the Rotifera group is also an important indicator of the water quality, pollution and eutrophication process (Altındağ, 2000). They are also highly suitable for biological monitoring of water quality, as environmental changes strongly influence them and because of their rapid response to changes in water quality (Chalkia and Kehayias, 2013; Saler and Selamoğlu, 2020). Indeed, although zooplankton is still not included, according to the implementation of the EU Water Framework Working Directive as a biological quality indicator for aquatic ecosystems, several studies have shown its usefulness as an indicator of changes in the trophic dynamics and ecological status of lakes related to nutrient loading and climate changes (Jeppesen et al., 2011). Zooplanktonic organisms constitute the primary food source of fish in freshwater sources and they constitute the leading food of many pelagic-feeding fish species and young periods of demersal-feeding fish (Gürleyen and Ustaoğlu, 2017). Zooplanktonic organisms, which form the second food pyramid ring in fresh waters, are essential in ensuring the continuity of the material and energy cycle (Bulut et al., 2021). Rotifera group is an indicator for determining water quality and trophic status (Muñoz-Colmenares et al., 2021). Long-term limnological studies, especially research on water chemistry and zooplankton, are effective in the management of water bodies (Nandini et al., 2008). It has been stated that the rotifer community structure, which changes from lake to lake, can indicate the lake's real-time environmental health (Umi et al., 2017).

Işıklı (Çivril) Lake is within the scope of Class A wetland according to the International Ramsar Convention. It is at an altitude of about 800 m and its area is around 3500 ha. It is fed by Işıklı Springs, Büyük Menderes River, Karanlık Creek and Kufi Stream (Anonymous, 2022). When the studies carried out in Işıklı Lake are examined chronologically, the Çivril Lake limnological research project was carried out by Anonymous (1992). In addition, there are limited number of zooplankton studies that have been done before in Çivril Lake (Gündüz, 1997; Aygen and Balık, 2005; Barinova et al., 2014). This research aims to study the zooplankton species comprehensively, to present them in detail with their monthly distributions, and to compare the results with the previous state of the lake. It is thought that the studies in which Rotifera, Cladocera and Copepoda groups are presented as a whole will form an important infrastructure for future studies in ecological terms.

MATERIALS AND METHODS

Zooplankton sampling was carried out monthly from 2 stations in Işıklı Lake between 2003 (only January, September, October, November, December),2004 (all months from January to December) and 2005 (January, February, March) (Figure 1). Located in the Çivril district of Denizli province, the lake's average water level area is 64.53 km^2, and its depth is 7 m. (Uysal et al., 2006). 1st station is close to the residential area and there is no water inlet or outlet at this station. The ground is loamy and the vegetation is sparse and shallow. 2nd station is the area where irrigation gates are located. There is a partial water exchange. Gökgöl incoming water exits from the area close to the steam station. There are aquatic plants and reeds, and it is deeper than the 1st station. Zooplankton samples were taken horizontally with a plankton net (mesh size of 55 µm, diameter = 57 cm), and samples were fixed with formaldehyde (4%) immediately after collection in 250 ml bottles. Species were examined under a binocular microscope (Olympus model) and the species were determined to the species level using the keys of Kiefer (1952, 1955), Dussart (1967, 1969), Koste (1978), Negrea (1983), Smirnov (1996), Nogrady and Segers (2002). Also, a zooplankton species checklist was prepared according to Ustaoğlu (2004) and Ustaoğlu et al. (2012). Soyer's (1970) frequency index (F %) was used to define the frequency of species in the study area. Results were determined as constant (F ≥ 50%), common (50% > F ≥ 25%), or rare (F < 25%). Regardless of the Soyers index; few, abundant and most abundant indicators expressed in Table 1. The values are observed qualitatively at the stations every month. *Brachionus*/*Trichocerca* coefficient ($Q_{B/T}$) was calculated to evaluate the trophic structure of Işıklı Lake. In this formula, Sládeček (1983) stated that a quotient of 1 indicates oligotrophic conditions, while a quotient between 1 and 2 corresponds to mesotrophic conditions, and a ratio of >2 is encountered in eutrophic lakes. In the simultaneous study where fishing research was carried out in Lake Işklı; Some measurements of water quality were taken in July-December 2004 and January-March 2005. Water quality values are presented additionally for data recording in the study. Temperature and pH were recorded with a WTW electrode sentix 41 pH meter, dissolved oxygen was measured with a WTW CellOx-325 type oxygen meter, and electrical conductivity was measured using a WTW tetracon 325 type conductivity meter.

Figure 1. The study area and stations (**Stn 1:** 38°14'44.6"N, 29°55'55.1"E; **Stn 2:** 38°12'40.9"N, 29°52'15.6"E)

RESULTS

A total of 49 species, 27 from Rotifera, 13 from Cladocera and 9 from Copepoda, were identified in Lake Işıklı (Table 1). The most common group is Rotifera. The distribution of zooplankton groups by stations is shown in Figure 2.

When evaluated according to the frequency index, 4 species (F ≥ 50%) were classified as constant, 8 species (50% > F ≥ 25%) were classified as common, and 37 species (F < 25%) were classified as rare. Among these dense species, *B. longirostris* was determined with the highest frequency (74%) in almost all months.

Table 1. Zooplankton species list of Lake Işıklı (2003-2005) (+: Few; ▲: Abundant; ∗: Most Abundant)

	2003									2004																								2005						
	Jan	Sep		Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb		Mar		
	1	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	F%
ROTIFERA																																								
Asplanhna priodonta	+	+	+			+	+	▲		+				+		∗	∗	▲	▲	▲	▲				+	+						+	+	+		+	+			54
Brachionus calyciflorus						+				+									+	+																				10
Brachionus angularis																			+						+															5
Brachionus quadridentatus																										+														3
Colurella colurus																					+					+		+	+											10
Euchlanis dilatata										+						+				+	+					+							+			+		+	+	23
Keratella cochlearis	+					+	+	+		+		+		+		▲	+	+	+	∗	+					+				+	+	+	+	+	∗	∗	∗	∗	∗	62
Keratella tecta	+					+	+			+				+				+	+		+							+	+		+							+		31
Keratella quadrata	+							+		+		+		+		+	+		+	+									+		+	+	+	+	+	▲	∗	+	+	49
Polyarthra dolichoptera						+	+	+		+				+					+		+					+		+	+		+		+	+	+	+	+	+	+	46
Synchaeta pectinata	+					+	+			+																		+		+		+	+	+	▲	+	+	+		33
Testudinella patina					+											▲			+	∗				+						▲	+	+	+			+				26
Lecane bulla																				+				+	+	+				+						+				15
Lecane clostrocerca																									+	+		+		+	+					+	+			18
Lecane ludwigi																									+	+									+					8
Lecane luna																		+						+		+					+	+								10
Lecane lunaris																		+			+			+	+	+		+								+	+			21
Lecane ohiensis																										+				+	+							+		10
Lecane quadridentata																				+				+	+	+														10
Lecane sp.																													+											3
Lepadella sp.														+																										3
Mytilina mucronata	+																			+					+											+				8
Notholca acuminata														+																						+	+			8
Notholca squamula														+																				+		+	+		+	13
Trichocerca similis																		+	▲	+	+				+			+	+											18
Trichotria pocillum														+					+							+							+	+						13
Trichotria tetractis																														+					+		+			8
CLADOCERA																																								
Acroperus harpae														+					+																					5
Alona guttata																	+						+															+		8
Alona rectangula	▲					∗	▲	+		+						+				+			+			+				▲	+	+	+			+		+		38
Bosmina longirostris	∗	+	∗		∗	∗	∗	∗		+		∗				+	▲	+	▲	∗	▲		∗	∗	∗	+		▲	▲	∗	▲	+	+	+	+	+	∗	▲		74
Ceriodaphnia pulchella		▲	+			+	+												+		+			▲						+	+									23
Chydorus sphaericus	∗									+		+		+		+	▲		∗	+					+	+				+	+	+	+	+	+	∗	∗	∗	▲	51
Daphnia cucullata		+			+		+	+								+	+		+					+									+				+			26
Daphnia longispina																						+																		3
Diaphanasoma brachyurum		+	▲			+	+												+				+	▲	▲							+								23
Disparalona rostrata					+																		∗																	5
Graptoleberis testudinaria	+																																+							5
Pleuroxus aduncus	▲									+				+		+	+		+												+	+	+		+	+	+	+	+	36
Simocephalus vetulus										+																														3
COPEPODA																																								
Eucyclops macruroides										+									+																				+	8
Cyclops abyssorum						▲																														+	+			8
Cyclops strenuus	+						▲	▲		+																														10
Cyclops vicinus	+							▲		+		+										∗										+								15
Eucyclops serrulatus			+																																					3
Eucyclops speratus	+																																+							5
Eucyclops macrurus			+																																					3
Megacyclos gigas										+																														3
Canthocamptus staphylinus	+				+							+		+					+					+						+			+							21
Total species in months	**15**	**7**		**5**		**13**		**9**		**17**		**6**		**13**		**11**		**21**		**18**		**7**		**17**		**17**		**10**		**17**		**19**		**12**		**20**		**14**		

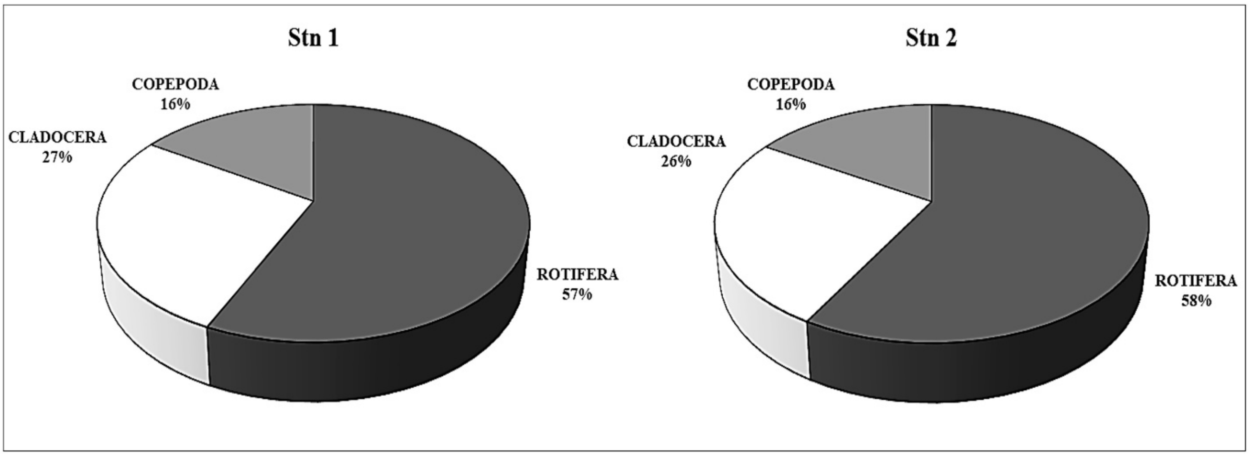

Figure 2. Distribution of zooplanktonic groups in Lake Işıklı

K. cochlearis (62%), *A. priodonta* (54 %), *C. sphaericus* (51%), *K. quadrata* (49%), *P. dolichoptera* (46%), *P. aduncus* (36%) and *S. pectinata* (33%) are other zooplanktonic organisms that are frequently seen (Table 1). The most representative Rotifera were Brachionidae (8 species) and Lecanidae (8 species). *Brachionus quadridentatus* from Rotifera was only seen at Station 1 in September 2004, *Lecane* sp. at station 2 in October 2004, and *Lepadella* sp. at station 1 in March 2004.

The rotiferans recorded only during the autumn and winter were *B. quadridentatus, Lecane* sp., *Notholca acuminata, N. squamula* and *Lecane ohiensis*. The Cyclopoidae (8 species) and Harpacticoidae (1 species) were observed between the Copepoda. Copepoda species were most abundant, mainly in the autumn and winter seasons. *Eucyclos macrurus* from Copepoda was only seen at station 2 in September 2003, and *Megacyclops gigas* was only at station 1 in January 2004. Among the Cladocera, Chydoridae (7 species) and Daphniidae (4 species) were the richest families. In addition, *Daphnia longispina* from Cladocera was found only at station 1 in July 2004, and *Simocephalus vetulus* was found only at station 1 in January 2004 (Table 1). When some physicochemical measurements between July 2004 and March 2005 were evaluated, it was determined that the conductivity was maximum in December 2004, the water temperature was maximum (24.6 °C) in August 2004, and the dissolved oxygen was low (5.8 mg/L). Monthly average values of the stations in water quality measurements are given in Table 2.

Table 2. Some physicochemical parameters of Işıklı Lake (average values of the first and second stations)

Months	Temperature (°C)	Dissolved oxygen (mg/L)	Conductivity (µS/cm)	pH
July-2004	22.5	7.6	341	8.7
August-2004	24.6	5.8	356	8.5
September-2004	19.3	9.3	356	8.7
October-2004	15.8	9.0	348	8.8
November-2004	5.0	11.1	357	8.6
December-2004	3.9	9.0	434	8.3
January-2005	5.7	12.2	414	8.3
February-2005	8.4	9.6	413	8.1
March-2005	10.5	10.4	389	8.2

DISCUSSION

In the previous study in Işıklı Lake, some Cladocera species (4 species) (Gündüz, 1997) were reported. In addition, there are studies published on Cladocera and Copepoda fauna (28 species) in 2005 (Aygen and Balık, 2005), and on some zooplankton groups (25 species) in 2014 (Barinova et al., 2014). 49 species were identified in this study, the Rotifera group being the dominant group of 55%. Compared to the study of Barinova et al. (2014), 10 Rotifera species were similar to the research results, while 5 Rotifera species were not found in this study. However, 17 Rotifera species were identified for the first time in this study. While 7 species from Cladocera were similar to those of Barinova et al. (2014), and 6 Cladocera species were identified for the first time in this study. *C. quadrangula* and *D. lacustris* species were reported only in Gündüz (1997). While *M. gigas* from Copepoda was detected only in this study, *M. albidus, M. viridis*, and *A. robustus* species were found only in Gündüz (1997) (Table 3).

Sládecek, (1983) Rotifera index (QB/T) was studied in different lakes. For example, Çaygören Reservoir (Balıkesir/ Türkiye) QB/T=1.5 (Çelik et al., 2019); Kemer Dam Lake (Aydın- Türkiye QB/T=1 (Tuna and Ustaoğlu, 2016); River Haraz (Northeast Iran) QB/T=1.5 (Jafari et al., 2011); Paraná River (Brazil) QB/T=1.3 (Golec-Fialek et al., 2021); Egirdir Lake (Isparta, Türkiye) QB/T=1.3 (Apaydın Yağcı et al., 2014) studies showed mesotrophic status in terms of zooplankton. This research showed a uniform situation with the examples given above QB/T=2.

Some zooplankton species identified in this study (*A. priodonta, K. quadrata, K. cochlearis, D. cucullata, C. abyssorum*) were determined in the study conducted in Kemer Dam Lake (Tuna and Ustaoğlu, 2016) with pH values of 7.97-8.83, dissolved oxygen values varied between 7.5-10.5 mg/L, water temperature values varied between 9.8-27.7 °C, and conductivity values varied between 206-601 $\mu S_{25°C}$. In addition, in the study conducted in Çaygören reservoir (Çelik et al., 2019), *A. priodonta, K. cochlearis, B. longirostris, E. speratus, C. vicinus, C. pulchella, D. longispina* species; It has been determined that they live in the pH range of 8.2-11.1 and temperature range of 4-26.6°C. In this study, the mentioned species had pH 8.1-8.8, dissolved oxygen values 5.8-12.2 mg/L, temperature 3.9-24.6 °C, and electrical conductivity values between 341-434 µS/cm. As seen in the Işıklı Dam lake, most lakes and dam lake ecosystems are dominated by Rotifera, followed by the Cladocera and Copepoda groups (Tuna and Ustaoğlu, 2016; Tugyan and Bozkurt, 2019; Golec-Fialek et al., 2021; Bulut et al., 2021). Calanoid and cyclopoid copepod species are important criteria in defining water resources' quality and trophic status (Muñoz-Colmenares et al., 2021). It has been reported that Cyclopoid copepod predation may be effective in hypertrophic waterbodies (Sarma et al., 2019). Among determined species *P. dolichoptera, K. cochlearis, B. quadridentatus, B. angularis, B. calyciflorus, B. longirostris, C. sphaericus, G. testudinaria* are the most well-known indicators of mesotrophic-eutrophic waters (Frutos et al., 2009; Apaydın Yağcı et al., 2014; Tuna and Ustaoğlu, 2016; Macêdo et al., 2019).

Table 3. Chronological change of zooplankton in Işıklı Lake (●: present in the related study)

Species	Gündüz (1997)	Aygen and Balık (2005)	Barinova et al. (2014)	This study
ROTIFERA				
Asplanchna priodonta Gosse, 1850				●
Brachionus angularis Gosse, 1851				●
Brachionus calyciflorus Pallas, 1776				●
Brachionus quadridentatus Hermann, 1783			●	●
Colurella adriatica Ehrenberg, 1831			●	●
Colurella colurus(Ehrenberg, 1830)				●
Euchlanis dilatata Ehrenberg 1832			●	●
Hexarthra mira Hudson, 1871			●	
Keratella cochlearis Gosse, 1851			●	●
Keratella tecta Gosse, 1851			●	●
Keratella quadrata (Müller, 1786)				●
Lecane bulla Gosse, 1886			●	●
Lecane closterocerca (Schmarda, 1859)				●
Lecane ludwigi (Eckstein, 1883)				●
Lecane luna (Müller, 1776)				●
Lecane lunaris (Ehrenberg, 1832)				●
Lecane ohioensis (Herrick, 1885)				●
Lecane quadridentata (Ehrenberg, 1830)				●
Lecane sp.				●
Lepadella sp.				●
Mytilina mucronata (Müller, 1773)				●
Notholca acuminata (Ehrenberg, 1832)				●
Notholca squamula (Müller, 1786)				●
Polyarthra dolichoptera Idelson, 1925				●
Polyarthra vulgaris Carlin, 1943			●	
Synchaeta oblonga Ehrenberg, 1831			●	
Synchaeta pectinata Ehrenberg, 1832			●	●
Testudinella patina Herman, 1783			●	●
Trichocerca longiseta Schrank, 1802			●	
Trichocerca similis Wierzejski, 1893			●	●
Trichocerca pusilla Harring, 1913			●	
Trichotria pocillum Müller, 1773			●	●
Trichotria tetractis (Ehrenberg, 1830)				●
CLADOCERA				
Acroperus harpae (Baird, 1834)				●
Alona guttata Sars, 1862		●	●	●
Coronatella rectangula Sars, 1862		●	●	●
Alona (Biapertura) affinis (Leydig, 1860)		●	●	
Bosmina longirostris (O.F. Müller, 1785)	●	●	●	●
Ceriodaphnia pulchella Sars, 1862		●	●	●
Ceriodaphnia quadrangula (O.F. Müller, 1785)	●			
Chydorus sphaericus (O.F. Müller, 1785)		●	●	●
Daphnia cucullata (GO Sars, 1862)				●
Daphnia longispina O.F. Müller, 1785	●	●	●	●
Diaphanosoma brachyurum (Lievin, 1848)		●	●	●
Diaphanasoma lacustris (Korinek, 1981)	●			
Diaphanosoma mongolianum Ueno, 1938		●		
Disparalona rostrata (Koch, 1841)		●		●
Groptoleberis testudinaria(Fischer, 1851)		●		●
Leydigia leydigi (Schoedler, 1863)		●		
Macrothrix laticornis (Jurine, 1820)		●		
Moina micrura Kurz, 1874		●		
Pleuroxus aduncus Baird, 1850		●		●
Simocephalus vetulus (O.F. Müller, 1776)		●		●
COPEPODA				
Macrocyclops albidus (Jurine, 1820)		●		
Eucyclops serrulatus (Fischer, 1851)		●		●
Eucyclops speratus (Lilljeborg, 1901)		●		●
Eucyclops macrurus (GO Sars, 1863)				●
Eucyclops macruroides Lilljeborg, 1901		●		●
Metacyclops gracilis (Lilljeborg, 1853)		●	●	
Mesocyclops leuckarti (Claus, 1857)		●	●	
Cyclops vicinus Uljanin, 1875		●		●
Cyclops abyssorum Sars, 1863		●		●
Cyclops strenuus Fischer, 1851		●		●
Megacyclops gigas (Claus, 1857)				●
Megacyclops viridis Jurine, 1820		●		
Acanthocyclops robustus (Sars, 1863)		●		
Canthocamptus staphylinus (Jurine, 1820)		●		●

CONCLUSION

According to the results of this study, Işıklı Lake showed mesotrophic characteristics in terms of zooplankton. Compared to the previous studies in the lake, the zooplankton fauna was comprehensively studied in this study and contributed to the biodiversity fauna of Türkiye. The fact that the number of species of the Rotifera group was dominant compared to Cladocera and Copepoda and, when evaluated in terms of species, showed that the trophic structure of the lake was mesotrophic. The dominance of the *Cyclops* group, which is one of the eutrophic species, shows that the lake may progress from the mesotrophic feature to the eutrophic state.

ACKNOWLEDGMENTS AND FUNDING

We would like to express our deepest gratitude to the Fisheries Research Institute of Eğirdir-Isparta, Türkiye, for their support during the field sampling. There is no specific funding for this research.

AUTHORSHIP CONTRIBUTIONS

All authors contributed equally to the planning, execution, and field and laboratory work of this study.

CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

ETHICS APPROVAL

Ethics Committee approval certificate is not required for invertebrates. For this reason, Ethics Committee Certificate was not obtained in this study.

DATA AVAILABILITY

All relevant data is in the article.

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 8-15 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.02

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Comparative otolith morphology in two species of *Salmo* genus from Türkiye

Türkiye'den Salmo cinsine ait iki türün karşılaştırmalı otolit morfolojisi

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Received date: 26.10.2023 *Accepted date: 25.12.2023*

How to cite this paper:
Özpiçak, M., Saygın, S., & Savaş, Y. (2024). Comparative otolith morphology in two species of *Salmo* genus from Türkiye. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 8-15. https://doi.org/10.12714/egejfas.41.1.02

Abstract: In this study, the morphology of the sagittal otolith of *Salmo coruhensis* Turan, Kottelat & Engin, 2010 and *Salmo fahrettini* Turan, Kalayci, Bektaş, Kaya & Bayçelebi, 2020 from Çam Stream (Artvin) and Terme Stream (Samsun) was described by images of scanning electron microscopy. Its shape and contour were also analyzed with shape indices, elliptic Fourier coefficients and wavelet transforms. As the study material, a total of 30 *S. coruhensis* sample and 20 *S. fahrettini* sample were obtained. Interspecies differences in otolith shape and morphometry were evaluated by principal components analysis, canonical discrimination analysis, and permutational multivariate analysis of variance. The two salmonid species studied were distinguished by both morphometric and shape analysis methods. However, wavelet transform was found to be more effective than shape indices and elliptic Fourier coefficients in species discrimination, with an overall classification success rate of 80%. Our results showed that saccular otolith morphology could be an additional diagnostic character for trout species differentiation.

Keywords: Otolith, shape indices, elliptic Fourier coefficients, wavelet transform, Salmonid

Öz: Bu çalışmada, Terme Çayı (Samsun) ve Çam Deresi (Artvin)'nde yaşayan *Salmo coruhensis* Turan, Kottelat & Engin, 2010 ve *Salmo fahrettini* Turan, Kalayci, Bektaş, Kaya & Bayçelebi, 2020 türlerinin sagittal otolit morfolojileri taramalı elektron mikroskobu görüntüleri ile tanımlanmıştır. Otolit şekli ve dış hatları ayrıca, şekil indeksleri, eliptik Fourier katsayıları ve dalgacık dönüşümü ile analiz edilmiştir. Çalışma materyali olarak toplamda 30 *S. coruhensis* sample ve 20 *S. fahrettini* örneği elde edilmiştir. Otolit şekli ve morfometrisindeki türler arası farklılıklar, temel bileşenler analizi, kanonik ayrım analizi ve çok değişkenli varyans analizi ile değerlendirilmiştir. Çalışılan iki salmonid türü hem morfometrik hem de şekil analizi yöntemleriyle ayırt edilmiştir. Bununla birlikte, dalgacık dönüşümünün tür ayrımında şekil indeksleri ve Fourier katsayılarından daha etkili olduğu ve genel sınıflandırma başarı oranının %80 olduğu bulunmuştur. Sonuçlarımız sakkular otolit morfolojisinin alabalık türlerinin farklılaşmasında ek bir tanısal karakter olabileceğini göstermiştir.

Anahtar Kelime: Otolit, şekil indeksleri, eliptik Fourier katsayısı, dalgacık dönüşümü, alabalık

INTRODUCTION

Taxonomy and systematics are the cornerstone of all biological sciences. Many morphological traits, for example hard elements like otoliths, scales, and bones, are used by taxonomic investigations in ichthyology to identify species (Kontaş et al., 2020; Kikuchi et al., 2021; Akbay et al., 2022; Mejri et al., 2022; Jawad et al., 2022). These hard structures are one of the most useful anatomical features for various research of fish, leading to many practical applications (Schulz-Mirbach et al., 2019; D'Iglio et al., 2022). These studies range from ichthyology to paleontology, geology, archeology, zoogeography, and ecological analyses of predator fish.

Globally, the family Salmonidae is divided into three subfamilies: Coregoninae, Thymallinae, and Salmoninae. It is well known that species of salmonids (family Salmonidae), including those from genus *Salmo*, *Parasalmo*, *Oncorhynchus*, and *Salvelinus*, exhibit a variety of anadromous behaviors and habitat preferences (Savvaitova, 1989; Thorpe, 1994; Pavlov et al., 1999; Pavlov and Savvaitova, 2008). Genus *Salmo* is found throughout Europe, extending southeast into Africa to Morocco and eastwards into upper Amu Darya drainage of Afghanistan (Kottelat, 1997) and widespread in the almost all cold streams and rivers of (Turan et al., 2021). Trouts are economically important, therefore overfishing has a severe impact on *Salmo* populations. There are 16 species of trout described as living in Türkiye in the literature (Turan et al., 2009; Turan et al., 2014 a, b; Turan and Aksu, 2021; Turan et al., 2021). *Salmo coruhensis* Turan, Kottelat & Engin, 2010 is described from the lower and the middle part of the streams and rivers of south and southeastern Black Sea. Additionally, it is well-known in the region that is between the Çoruh drainage in the east and the Yeşilırmak drainage in the west. According to Turan et al. (2009), *S. coruhensis* is known from streams flowing to the southeastern Black Sea coast in Türkiye. For this reason, the trout species in the relevant area should be *S. coruhensis*. However, Yılmaz et al. (2021) reported *Salmo fahrettini* Turan, Kalayci, Bektaş, Kaya & Bayçelebi, 2020, an endemic fish, is distributed in the northern tributaries of the Euphrates River and from Samsun, too. Numerous taxonomic research on *Salmo* species have been realized because of Anatolia's geographic, geological, and geomorphological significance as a center of speciation.

Otoliths can be utilized to identify the species of trout, according to previous investigations (L'Abée-Lund and Jensen, 1993). However, there are limited studies in Türkiye that reveal the otolith morphology of trout species (Yıldız and Yılmaz, 2021) and examine the effectiveness of this morphology in species differentiation. Studies on the otolith morphology of trout will contribute to the issue of whether they are an additional taxonomic character in solving the problems related to the taxonomy of existing species. In this study, it was aimed to (i) describe otolith morphology of *S. coruhensis* and *S. fahrettini* (ii) contribute to the realization of species distinctions by determining the difference between the otolith morphologies of two salmonid species using otolith morphometric descriptions, Fourier and wavelet analyzes.

MATERIAL AND METHODS

Sampling

S. coruhensis (*n*= 30, mean TL±SD, 15.47 ± 3.93 cm TL) and *S. fahrettini* (*n* = 20, mean TL±SD, 13.67 ± 4.09 cm TL) individuals were collected from Çam Stream (Artvin) and Terme Stream (Samsun) using SAMUS 725 MP electroshocker, respectively. The care and use of experimental animals, sampling and analysis techniques used in this work are approved by Ondokuz Mayıs University Animal Experiments Local Ethics Committee with decree no "2017/38". For each sample, a total length (TL, nearest to 0.1 cm) was recorded. A pair of sagittal otoliths (sagitta) were extracted and cleaned with 70% ethanol to remove any additional membranes or surface residues and stored in labelled eppendorf tubes.

Otolith preparation and imaging

Because of there were no statistical differences between left and right otolith pairs (P>0.05), left sagittal otolith was chosen for analysis. Each left sagitta was positioned with the *sulcus acusticus* facing upward and the rostrum facing right. Two-dimensional digital images of the otoliths were captured with Leica DFC295 camera. High-contrast digital photos were produced using reflected light. Otoliths were captured on camera as a white silhouette against a dark background (Çöl and Yılmaz, 2022). Also, sagittal otoliths were photographed from their proximal surfaces under a scanning electron microscope for morphological identification (SEM-JEOL JSM 7001 F) (Figure 1). The morphological terminology used for the sagittal otoliths is based on Tuset et al. (2008), and Lin and Chang (2012). SEM photographs were conducted at KITAM, Ondokuz Mayıs University.

Morphometric analysis

Leica Application Suit ver. 3.8 Imaging Software was used to calculate the sagittal otolith length (*OL*), otolith height (*OH*), otolith perimeter (*OP*), and otolith area (*OA*) (±0.001 mm). Due to allometric correlations, the otolith shape indices, which are utilized as dimensionless markers of otolith form, can still be influenced by fish size. To remove the effects of fish size on otolith parameters, the following formula was used to standardize all otolith measurements:

$$Y_i^* = Y_i \times (X_0 / X_i)^b,$$

where, Y_i^* is the standardized parameter; Y_i is the original parameter; X_0 is the mean total length for all specimen (14.75 cm); X_i is the total length of each specimen; b is the slope of the regression between log Y_i and log X_i , respectively (Elliott et al., 1995; Lleonart et al., 2000).

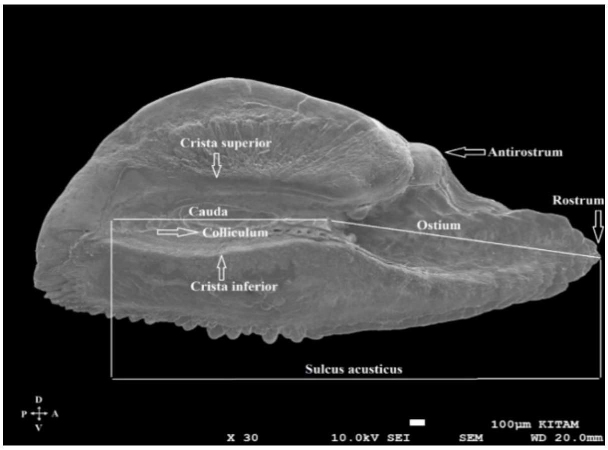

Figure 1. The proximal surface of left sagittal otolith of *S. coruhensis* (24.0 cm TL of fish), illustrates various features described in the text. D: Dorsal, V: Ventral, A: Anterior and P: Posterior

These standardized measurements were then used to calculate the following shape index parameters (SIs): aspect ratio (*AR*), form factor (*FF*), circularity (*C*), rectangularity (*REC*), roundness (*RO*) and ellipticity (*E)* according to Tuset et al. (2003) and Ponton (2006).

First of all, normality and homogeneity of variance were determined for each data set using Shapiro-Wilk and Levene's tests. An independent two-sample t-test was used to compare the otolith shape indices of *S. coruhensis* and *S. fahrettini*. Since the multicollinearity problem was detected between SIs, a principal component analysis (PCA) based on the variance-covariance matrix was performed to reduce the dimensionality of data (Sadighzadeh et al., 2014; Çöl and Yılmaz, 2022). Principal component scores (PCs) were used in a canonical discriminant analysis (CDA, Box's M test, P = 0.183) to distinguish species (Song et al., 2018). One-way PERMANOVA (Anderson, 2001) based on Euclidean distance was used for SIs comparisons between *S. coruhensis* and *S. fahrettini*.

Shape analyses

Both the wavelet transform (*WT*) and the elliptic Fourier analysis were used to assess the otolith's shape. The software Shape 1.3 (Iwata and Ukai, 2002) was operated to calculate the elliptic Fourier coefficients (EFCs) from two-dimensional otolith images. The EFCs were made to be invariant to variations in otolith size, orientation, and starting point by normalizing them in accordance with the first harmonic. The Fourier power spectrum was also employed to assess the number of harmonics necessary to effectively represent the otolith shape (Crampton, 1995). 32 Fourier coefficients were used to represent otolith shape of *S. coruhensis* and *S. fahrettini*, with the first eight harmonics accounting for 99.99% of the cumulative power. However, the first three coefficients were degenerated during the normalization procedure. Thus, the total number of EFCs was determined as 29 (4 × 8 − 3). An analysis of covariance (ANCOVA) was used to determine the effect of fish length on the EFCs. Because two EFCs (b2 and d2) were significantly different between species (ANCOVA, $P < 0.05$), these coefficients were not used in the further analysis. As two (d1 and c2) of the remaining EFCs exhibited significant linear correlation with fish size, they were standardized according to the following formula (Song et al., 2018):

$$Y_i^* = Y_i + b\,(X_0 - X_i).$$

Also, a PCA analysis was carried out to minimize the dimensionality of the data and identify the effective EFCs because multicollinearity problems were not found among the EFCs (Sadighzadeh et al., 2014; Çöl and Yılmaz, 2022). The CDA (Box's M test, $P = 0.063$) was performed using raw data to compare otolith shape variations between two salmonid species. Also, the one-way PERMANOVA was used to assess inter-species differences.

Otolith shape analysis depending the WT is based on enlarging the contour into a family of functions derived as the translations and elongations of a specific function called as a mother wavelet (Mallat, 1991). A total of 512 equidistant Cartesian coordinates of the otolith was extracted, being the rostrum the origin of the contour (Parisi-Baradad et al., 2005, 2010). Each contour generated nine wavelets depending on the degree of otolith detail. We selected the wavelet 5 as an intermediate function (Sadighzadeh et al., 2014). Wavelets were produced online using AFORO (Shape Analysis of Fish Otoliths) website (Lombarte et al., 2006). A PCA based was performed to reduce the dimensionality of the 512 data of the wavelet 5 function for each otolith without loss of information. Since it was determined that the linear correlations between the effective PCs and the total length of the fish were not significant, no standardization was applied. The CDA (Box's M test, $P = 0.021$) was performed with the building new PCA matrix and the accuracy of species identification was determined. Otolith shape variations were compared between species by non-parametric PERMANOVA. The Microsoft Excel package, Minitab 17.0, PAST 3.0 (Hammer et al., 2001), and SPSS 21.0 were used for all statistical analyses.

RESULTS

Otolith morphology

Morphological characters of sagittal otoliths of *S. coruhensis* and *S. fahrettini* are presented in Table 1. The medial surface of otoliths is fusiform to elongate convex. Antirostrum is not prominent in both species. The *sulcus acusticus* is described as median type and it opens both anteriorly and posteriorly representing a biostial sulcus type. The shape of ostium type is funnel-like and cauda type is tubular. Rostrum is extended, sharply peaked. Dorsal margin is entire for both species and ventral margin is crenate and sinuate for *S. coruhensis* (Figure 2) and *S. fahrettini* (Figure 3), respectively (Table 1).

Morphometric analysis

Standardized values of the saccular otolith shape indices for two trout species were given in Table 2. All shape indices, except rectangularity ($F = 10.79$, $P = 0.002$), were not significantly different between two species (t-test, $P > 0.05$). In the PCA, only one PC was obtained. This PC discriminate the species based on circularity ($R = 0.99$). Only one canonical discriminant function was used in the CDA ($\lambda = 0.982$, $P = 0.346$). The function 1 explained 100% of the total variance (Eigenvalue=0.019). A 58% overall categorization success rate was produced by the CDA. The percentages of classified individuals obtained with the CDA were 65% for *S. fahrettini* and 53.3% for *S. coruhensis* (Table 3). The PERMANOVA did not show significant difference between the species studied ($F = 0.887$; $P = 0.346$).

Table 1. Morphological otolith characteristics of *S.coruhensis* and *S. fahrettini*

Otolith characteristics	***S. coruhensis***	***S. fahrettini***
Otolith shape	Fusiform/Elongate convex	Fusiform/Elongate convex
Distal region	Concave	Concave
Proximal region	Convex	Convex
Anterior region	Peaked	Peaked
Posterior region	Round/oblique	Round/oblique
Dorsal margin	Entire	Entire
Ventral margin	Crenate	Sinuate
Sulcus acusticus	Median	Median
Ostium	Funnel-like	Funnel-like
Cauda	Tubular	Tubular
Antirostum	Absent/Not well expressed or small/narrow	Absent/ Not well expressed
Rostrum	Extended, broad, peaked	Extended, broad, sharply peaked
Crista superior	Well developed	Well developed
Crista inferior	Well developed	Well developed
Excisura	Moderately wide	Moderately wide

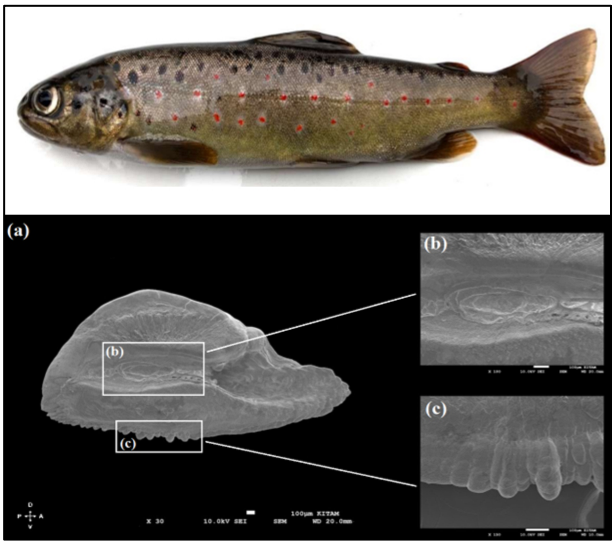

Figure 2. Original photo and otolith SEM images of *S. coruhensis* (24.0 cm TL of fish). (a) General view (SEM-30X, (b) Colliculum (SEM-100X), (c) Ventral edge (SEM-150X)

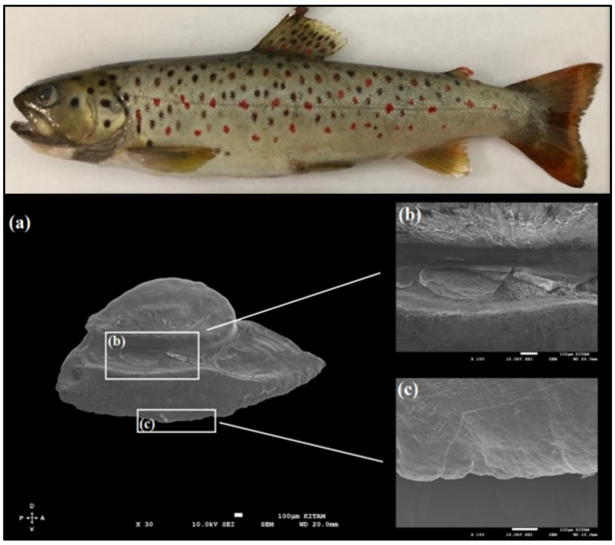

Figure 3. Original photo and otolith SEM images *S. fahrettini* (19.2 cm TL of fish). (a) General view (SEM-30X, (b) Colliculum (SEM-100X), (c) Ventral edge (SEM-150X)

Table 2. Summary of descriptive statistics of otolith shape indices and TL of *S. coruhensis* and *S. fahrettini* from Türkiye

Character	***S. coruhensis*** **(*n*=30) (Çam Stream)**		***S. fahrettini*** **(*n*=20) (Terme Stream)**	
	Min-Max	Mean±SD	Min-Max	Mean±SD
TL (cm)	9.90-24	15.47±3.93	9.60-24.10	13.67±4.09
Aspect Ratio	1.60-1.98	1.75±0.09	1.61-1.88	1.76±0.07
Form Factor	0.68-081	0.77±0.03	0.71-0.79	0.75±0.02
Circularity	15.46-18.43	16.63±0.68	15.92-17.41	16.79±0.51
Roundness	0.41-0.56	0.49±0.03	0.44-0.53	0.47±0.02
Rectangularity	0.63-0.71	0.67±0.02	0.64-0.67	0.65±0.01
Ellipticity	0.23-0.33	0.27±0.02	0.23-0.30	0.27±0.02

Otolith shape analyses

In the PCA using EFCs, only one PC was obtained, and it differentiated two species based on the coefficients d1 (R = -0.19), a2 (R = 0.49), c2 (R = 0.36), a3 (R = 0.49), b3 (R = 0.47), d3 (R = 0.19) and b5 (R = 0.19). Only one canonical discriminant function was used in the CDA (λ = 0.777, P = 0.129). This function explained 100% of the total variance (Eigenvalue = 0.287). Overall classification success for the CDA was 58%. The percentages of classified individuals based on the CDA results were 60% for *S. coruhensis* and 55% for *S. fahrettini*, respectively (Table 3). The PERMANOVA test did not indicate significant difference between two salmonid fish (F = 0.589; P = 0.613).

The PCA using wavelet 5 coefficients was created only one PC, which was employed in the CDA. Only one canonical discriminant function was used in the CDA (λ = 0.602, P = 0.000). The function 1 described 100% of the total variance (Eigenvalue=0.662). The CDA produced an overall classification success rate of 80%. The percentages of classified individuals obtained with the CDA were 90% for *S. fahrettini* and 73.3% for *S. coruhensis* (Table 3).

The PERMANOVA analysis yielded significant difference between two trout species (F = 31.76; P = 0.0001). Average decomposition of otolith contour of two salmonid species using wavelet 5 is shown in Figure 4.

Table 3. Classification matrix results of the CDA based on otolith morphometrics and different shape analyzing methods of *S. coruhensis* and *S. fahrettini* (The correct classification percentages are in bold; the number of individuals is given in parentheses)

	Predicted group memberships		
Species	**Shape Indices**	**Fourier Transform**	**Wavelet Analyses**
S. coruhensis	**53.3** (16)	**60.0** (18)	**73.3** (22)
S. fahrettini	**65.0** (13)	**55.0** (11)	**90.0** (18)

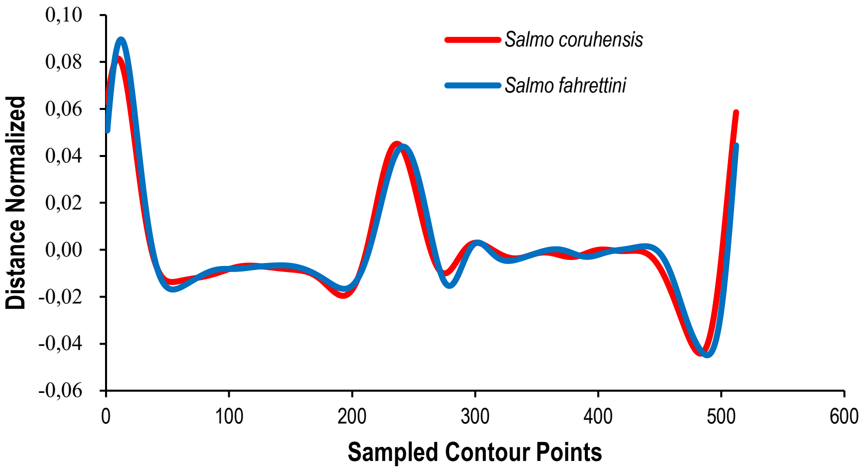

Figure 4. Decomposition of otolith contour of two salmonid species using WT 5

DISCUSSION

According to recent research, teleost fish's saccular otoliths exhibit significant inter- and intraspecies shape diversity and can be used to distinguish different fish species as well as between different stocks and populations, sexes, age groups, and reproductive variants (Mille et al., 2015; Mejri et al., 2018; Wiff et al., 2020; Sadeghi et al., 2020; Yedier, 2021; Çöl and Yılmaz, 2022; Mejri et al., 2022). In this study, we used otolith shape analysis and morphometry for the differentiation of *S. coruhensis* and *S. fahrettini*. This study offers details on the analysis of the variation in sagittal otolith shape between *S. fahrettini* and *S. coruhensis* using a variety of techniques (SIs, EFCs and WT). The attempts for the identification of salmonids have been conducted before based on several meristic, morphometric, and genetic characters (Karakousis et al., 1991; Bardakci et al., 1994; Bernatchez, 2001; Bardakçı et al., 2006; Turan et al., 2009; Berrebi et al., 2019; Delling et al., 2020; Turan et al., 2020; Guinand et al., 2021; Yılmaz et al., 2021). Phenotypic plasticity is a trait shared by individuals of several salmonid species that facilitates evolutionary adaptation. Such phenotypic adaptations, however, are not brought about by variations in the population's gene frequencies (Hutchings, 2004), though some genotypes may better endure environmental changes and leave more progeny. The adaptation based on phenotypic plasticity and genetic modifications under the influence of selection occurs at varying rates. Generic and phenotypic adaptations appear over the course of several generations. When it comes to the first scenario, adaptations should be seen as an individual's tactical response to the effects of the environment, and when it comes to the second scenario, as a population-level (gene pool) strategic response (Pavlov and Savvaitova, 2008). When evaluated in this context, otolith features are an additional very important and cheap taxonomic markers used in intra- and inter-species distinctions.

L'abèe-lund and Jensen (1993) reported otoliths as a natural tag for *Salmo* species. In addition, they evaluated the precision of intraspecific, interspecific, and intergeneric identification using the morphology of the otoliths in two species of *Salmo* and two species of *Salvelinus*. Shape indices, one of the morphometrically and morphologically important otolith characters, were reported in previous studies on *Salmo* species. Yıldız and Yılmaz (2021) were calculated shape indices (*FF* = 0.69 ± 0.05; *AR* = 1.71 ± 0.10; *C* = 18.08 ± 1.58; *RO* = 0.49 ± 0.03; *REC* = 0.65 ± 0.02; *E* = 0.26 ± 0.02) of *S. coruhensis* from Çam Stream. Also, Basçınar (2020) was reported *AR* (1.67 ± 0.15), *FF* (0.62 ± 0.07), and *RO* (1.53 ± 0.22) for *S. trutta*. Morat et al. (2008) investigated shape indices of *Salmo trutta*, too. These findings concur with those of the current investigation. In terms of shape indices, the current study shows that rectangularity is more useful for differentiating between *S. coruhensis* and *S. fahrettini*. In addition, CDA results produced 58% total successful classification rate. A series of studies confirmed that otolith shape indices could be used for inter and intraspecific discrimination of species (Tuset et al., 2003; Morat et al., 2008; Ozpiçak et al., 2018; Yedier, 2021; Akbay et al., 2022; Pavlov, 2022).

More comprehensive information on the variability of otolith shape is provided by contour analysis techniques (Tuset et al., 2021). Fourier analysis, which characterizes the general shape of the otolith, and wavelet analysis, which is useful for estimating the otolith edge, were both used in this study (Parisi-Baradad et al., 2005). The results of the elliptic Fourier analysis demonstrates that sagittal otoliths of *S. coruhensis* and *S. fahrettini* can be described with limited numbers of harmonics (total of 8 harmonics explain 99.99% of the cumulative Fourier power). Especially in the recent studies, Fourier and wavelet analyzes are mostly preferred to examine the otolith shape in different fish species (Bourehail et al., 2015; Libungan et al., 2015; Pavlov, 2022; Pavlov and Osinov, 2023). Morat et al. (2008) compared the morphological and chemical characteristics of otoliths of *S. trutta* and *Salvelinus fontinalis* with elliptic Fourier analysis and shape indices. The discrimination between the two species has a Wilks' λ of 0.18 ($P < 0.05$) and Cohen-kappa test revealed that 89% of fish were correctly classified.

Friedland and Reddin (1994) used Fourier analysis of otolith morphology in stock discriminations of *Salmo salar* population and used to calculate a complex Fourier transform and two shape indices, rectangularity and circularity. Many physiological (Mille et al., 2015; Assis et al., 2020), and environmental factors (Mahé et al., 2021; Çöl and Yılmaz, 2022) affect otolith morphology. Therefore, it is an expected result that high or low discrimination rates will occur depending on these factors in intraspecific and interspecies discrimination studies using otolith shape. Although elliptic Fourier analysis is the most popular technique (Campana and Casselman, 1993), it only approximates outline variability globally because each harmonic coefficients have no morphological significance on its own and cannot distinguish between local singularities (Tuset et al., 2021). At this stage, it has been established that wavelet analysis is a highly effective technique for highlighting morphological singularities (Lombarte and Tuset, 2015).

The discrimination between the species is higher based on wavelet transform then Fourier analysis and shape indices. Similarly, wavelet analysis (80%), one of the methods used in this study, gave a higher discrimination rate between species compared to the other two methods. Tuset et al. (2021) pointed that wavelets were a more adequate option and excellent method for the classification of species. The values of Wilks' λ range from zero to one, the closer the Wilks' λ is to zero, the better is the discriminating power of the CDA. In this study, scores of Wilks' λ calculated as 0.982 > 0.777 > 0.602 for SIs, EFCs and WT, respectively. The discrimination between the groups is higher based on wavelet transform than based on Fourier analysis and shape indices for sagittal otoliths. In the literature, there is no study using wavelet analyzes for the differentiation of *S. coruhensis* and *S. fahrettini* species. Wavelet analyses in otolith shape were employed by Koeberle et al. (2020) to distinguish *Oncorhynchus tshawytscha* population. Analysis of otolith shape (shape indices, elliptic Fourier and wavelet transform analysis) in the present study showed significant phenotypic heterogeneity between *S. coruhensis* and *S. fahrettini* from Türkiye. And also WT of otolith shape (80%) revealed a much more successful discrimination rate than the other two methods. This study was the first approach to elaborate the otolith shape of *S. coruhensis* and *S. fahrettini* using different morphological analyzing methods.

ACKNOWLEDGEMENTS

The authors are thankful to Recep YILDIZ for sampling *S. coruhensis* individuals.

AUTHORSHIP CONTRIBUTIONS

Melek Özpiçak: Conceptualization, investigation, methodology, software, validation, writing – original draft, writing – review and editing. Semra Saygın: Methodology; resources; software; validation; writing – original draft; review and editing. Savaş Yılmaz: Conceptualization; investigation; methodology; validation; writing – original draft.

CONFLICT OF INTEREST

The authors state that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICS APPROVAL

The care and use of experimental animals, sampling and analysis techniques used in this work are approved by Ondokuz Mayıs University Animal Experiments Local Ethics Committee with decree no "2017/38".

DATA AVAILABILITY

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

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 16-25 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.03

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

A preliminary study into the influence of filtration on phytoplankton dynamics in an oligotrophic marine fish farm environment

Filtrasyonun oligotrofik deniz balık çiftliği ortamındaki fitoplankton dinamikleri üzerindeki etkisine dair ön çalışma

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Received date: 10.10.2023 *Accepted date: 12.01.2024*

How to cite this paper:
Bardakçı Şener, B., & Tıraşın, E.M. (2024). A preliminary study into the influence of filtration on phytoplankton dynamics in an oligotrophic marine fish farm environment. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 16-25. https://doi.org/10.12714/egejfas.41.1.03

Abstract: Fish farms play a crucial role in meeting the escalating demand for fish in human diets, yet their nutrient releases pose potential environmental risks. This study explores the influence of a fish farm in the eastern Aegean Sea on local phytoplankton dynamics, serving as an indicator of nutrient abundance. Designing a phytoplankton bioassay near the fish farm, natural phytoplankton communities were incubated within dialysis membrane bags, creating a confined environment for accessing farm-released nutrients before dispersing into surrounding seawater. Consequently, higher growth rates within the bags were anticipated compared to the ambient seawater. However, natural interactions within phytoplankton communities involve predator-prey dynamics, influencing the net growth rates of phytoplankton. To investigate different grazing pressures on the incubated phytoplankton, five experimental groups were established. Four of these groups involved filtering seawater through various mesh sizes (40 µm, 56 µm, 100 µm, and 150 µm) and then filling the dialysis membrane bags with the filtered water. The fifth group contained seawater without any filtration. Despite the oligotrophic nature of the ambient seawater, a remarkable increase in phytoplankton growth was observed inside the bags. Variable growth rates were observed among the groups, with unfiltered and 150 µm mesh-filtered bags exhibiting the highest growth rates, suggesting copepod absence may contribute. Although the species composition within the bags differed from that of the ambient seawater, the overall species diversity remained limited. A total of 33 phytoplankton taxa were identified in the seawater samples taken from the study site, comprising 17 diatom and 16 dinoflagellate species. *Pronoctiluca spinifera* (Lohmann) Schiller 1932 was documented for the first time along the Aegean Sea coast of Türkiye. This study enhances our understanding of how fish farming can impact phytoplankton communities and underscores the necessity for further investigations into the complex interactions between aquaculture and marine ecosystems in oligotrophic environments.

Keywords: Aquaculture interactions, bioassay, growth rate variations, species composition shifts, nutrient discharges

Öz: Balık çiftlikleri, beslenmede artan balık talebini karşılamada kritik bir rol oynamakta, ancak çiftliklerden salınan nütrientler çevre için potansiyel riskler oluşturmaktadır. Bu çalışma, doğu Ege Denizi'ndeki bir balık çiftliğinin yerel fitoplankton dinamikleri üzerindeki etkisini, fitoplanktonu, nütrient varlığının bir göstergesi olarak kullanarak incelemektedir. Doğal fitoplankton toplulukları, balık çiftliğine yakın bir konumda yerleştirilen bir fitoplankton biyoanalizi tasarlanarak diyaliz membran torbalarında inkübe edilmiştir. Bu sayede fitoplanktonun salınan besinlere denizel ortamda dağılmadan önce erişebileceği içerisinde bulundukları sınırlı bir ortam oluşturulmuştur. Bu nedenle, torbaların içindeki büyüme oranlarının dışarıdaki deniz suyuna kıyasla daha yüksek olması beklenmektedir. Ancak, fitoplankton kommüniteleri av-avcı dinamiklerini içerir ve bu da fitoplanktonun net büyüme oranlarını etkilemektedir. İnkübe edilen fitoplankton üzerinde farklı otlama (grazing) baskılarını incelemek için beş deneme grubu oluşturulmuştur. Bu grupların dördü, deniz suyunu çeşitli göz açıklığına sahip ağlardan (40 µm, 56 µm, 100 µm ve 150 µm) geçirerek, diyaliz membran torbalarının bu süzülmüş deniz suyu ile doldurulması ile oluşturulmuştur. Beşinci grup ise deniz suyu filtrasyon aşamasından geçirilmeden kullanılarak hazırlanmıştır. Ortam deniz suyunun oligotrofik doğasına rağmen, çiftliğe yakın konumlandırılan diyaliz membran torbalarının içindeki fitoplankton büyüme oranlarında belirgin bir artış gözlemlenmiştir. Özellikle gruplar arasında farklı büyüme oranları gözlemlenmiş, filtresiz deniz suyu ve 150 µm göz açıklığına sahip ağ ile filtrelenmiş deniz suyu ile hazırlanan torbalarda en yüksek büyüme oranları tespit edilmiştir. Bunun nedeninin, torbaların içinde kopepodların bulunmaması olabileceği düşünülmektedir. Torba içerisindeki tür kompozisyonu ortam deniz suyundan farklılıklar gösterirken, genel tür çeşitliliği sınırlı olarak kalmıştır. Çalışma bölgesinden alınan deniz suyu örneklerinde, 17'si diatom ve 16'sı dinoflagellat türü olmak üzere toplam 33 fitoplankton taksonu belirlenmiştir. *Pronoctiluca spinifera* (Lohmann) Schiller 1932 türü, Türkiye'nin Ege Denizi kıyısında ilk kez bu araştırmada kaydedilmiştir. Bu çalışma, balık çiftliklerinin fitoplankton komünitelerine nasıl etki edebileceğini anlama konusuna katkı sağlamakta ve oligotrofik ortamlardaki akuakültür ve deniz ekosistemleri arasındaki karmaşık etkileşimlerin daha fazla incelenmesi gerekliliğini vurgulamaktadır.

Anahtar Kelime: Akuakültür etkileşimleri, biyodeney, büyüme hızı değişimleri, tür kompozisyonu değişiklikleri, nutrient salınımları

INTRODUCTION

Aquaculture plays a critical role in filling the demand gap for seafood and will continue to do so in the future (Gephart et al., 2021). However, the activities of fish farms inevitably result in various inputs into the marine environment (Navarro et al., 2008). It is well-documented that fish farms enrich the water column with organic and inorganic substances by releasing fish feces, excretion, unconsumed feed, scale and skin shedding, mucus, vitamins, and therapeutic agents (Arzul et al., 1996). Two main methods have traditionally been used to assess the effects of nutrient input from fish farms into the marine environment. The first method involves regular sampling of the water column, with subsequent measurement of nutrient values. This method has two disadvantages. Firstly, the release of nutrients varies daily depending on the feeding regime at the farms, necessitating hourly sampling to measure the nutrient discharge accurately. The second issue with this approach lies in the limited sensitivity of nutrient analyses to detect significant differences. Farms are often situated in regions with high water exchange to maximize the influx of fresh seawater into the cages and minimize their environmental impact. Significant increases in nutrient concentrations due to nutrient release are only achievable in cases where the current velocity is low (Dalsgaard and Krause-Jensen, 2006). Another proposed method for measuring nutrient input into the water column is the use of phytoplankton as an indicator. The literature suggests that the initial impact on aquatic communities due to increased eutrophication begins with changes in the abundance and species composition of phytoplankton (Sidik et al., 2008).

The impact on primary production in fish farms as a result of nutrient enrichment varies widely, ranging from significant alterations to negligible changes. Price et al. (2015) conducted a comprehensive review, revealing that numerous studies suggest a significant increase in primary production in fish farms. However, within the same work, it is also noted that certain studies found no substantial effects on primary production in fish farms. The inability to detect the impact of increased nutrient levels in the water column on phytoplankton has been attributed to factors such as rapid dilution in the water column due to strong currents and water exchange (Dalsgaard and Krause-Jensen, 2006; Pitta et al., 2009), as well as predation pressure (grazing) by organisms that feed on phytoplankton (Pitta et al., 2009).

One of the most reliable methods used to estimate the *in situ* growth rates of marine phytoplankton is incubation inside dialysis bags. The effectiveness of dialysis bag experiments is based on their ability to maintain physicochemical contact between the enclosed phytoplankton population and the surrounding environment (Furnas, 1990).

The Mediterranean Sea is typically characterized as oligotrophic, as its waters naturally contain very low nutrient concentrations (Krom et al., 1991; Mura et al., 1996). Notably, the oligotrophic nature of the marine environment where this study took place, which hosts a fish farm, theoretically provides an advantageous position for observing the effects of nutrient input. The activities of fish farms result in nutrient input into the water column, making these areas unique research sites for investigators.

In addressing the challenge of detecting the impact of increased nutrient levels from fish farming in oligotrophic environments, a bioassay was conducted at a fish farm located in Çandarlı, Denizköy (İzmir, Türkiye), where natural phytoplankton assemblages responded to nutrient releases resulting from fish farming. Utilizing dialysis bags in the bioassay provided a confined environment for phytoplankton, minimizing potential losses due to factors such as daily migrations, grazing, or drifting caused by open sea currents. As a result, higher growth rates within the bags compared to ambient seawater were anticipated, excluding factors causing losses in open water and aiming to reveal the effect of the fish farm on the water column. Inevitably, since natural phytoplankton assemblages were used as inoculum, interspecies competition and predator-prey interactions persisted within the dialysis bags. By applying various filtration treatments to the inoculum, the goal was to measure the highest growth rates inside the bags. The technique of using dialysis membrane bags for the *in situ* incubation of natural phytoplankton is applied for the first time in Türkiye in this study.

MATERIAL AND METHODS

Study area

The study site was a fish farm located in Çandarlı, Denizköy, situated in the northeastern Aegean Sea of Türkiye (38°58’33”N, 26°47’22”E; Figure 1). The farm is situated at a distance of approximately 1 km from the shore, and the water depth in the farm area ranges from 50 to 70 meters. The fish farm was established and began production 4 years before the experiment commenced. The annual production capacity of the farm is approximately 1000 tonnes of sea bream and sea bass. Fish were automatically fed once daily. The highest recorded current speed in the area was 20 cm/s. The experiment was conducted from the 20th to the 23rd of July 2020 and was based on a protocol established in a previous study by Mura et al. (1996).

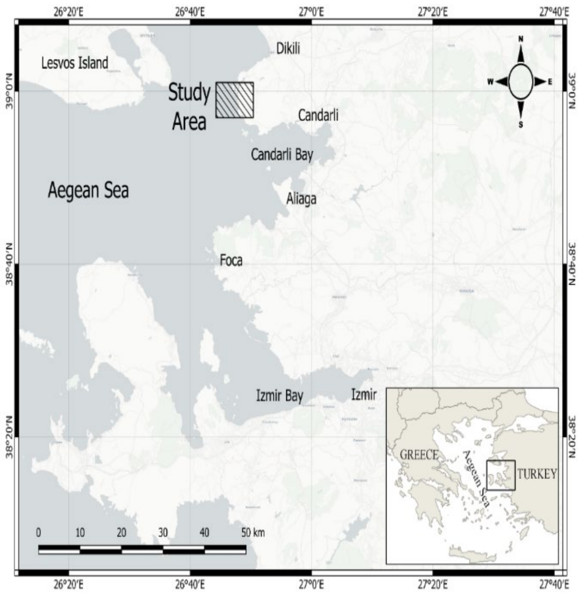

Figure 1. Location of the study area in Çandarlı (the eastern Aegean Sea)

Experimental design

The experiment was designed for the *in situ* incubation of natural phytoplankton communities within dialysis membrane bags for a duration of three days. Dialysis membrane bags facilitate the exchange of molecules smaller than proteins with the surrounding environment. The bags utilized in the experiment were constructed from Spectra/Por® 1 dialysis membrane tubing. Each bag was sealed at both ends using 110 mm Spectra/Por® closures (nylon). Each bag had a total volume of 600 mL. Seawater containing natural phytoplankton communities was collected from the 50 cm surface layer within the fish farm using a Nansen bottle. Five experimental groups were established to examine varying grazing pressures on the incubated phytoplankton. Four experimental groups were generated by filtering the seawater through meshes with different mesh sizes (40 µm, 56 µm, 100 µm, 150 µm) and subsequently filling the filtered water into the bags. The fifth group was formed using seawater that underwent no filtration. The experimental group prepared with unfiltered seawater comprised 3 bags with identical characteristics, while the remaining groups were tested using 2 bags each, resulting in a total of 11 dialysis membrane bags.

A circular PVC tubing frame with a 2-meter diameter was securely affixed to the ropes that anchored the automatic fish feeding system to the seabed of the fish farm. Using cable ties, the 11 dialysis bags were attached to a horizontal rope running along the PVC frame. Lead weights (2 kg) were strategically positioned at both ends of the rope to submerge it at a depth approximately 50 cm below the surface (Figure 2).

At the commencement and conclusion of the experiment, 1 L samples were collected from unfiltered seawater and seawater filtered through different mesh sizes (as mentioned above) to study the nutrient contents of the ambient seawater, environmental variables, and phytoplankton community in the study area.

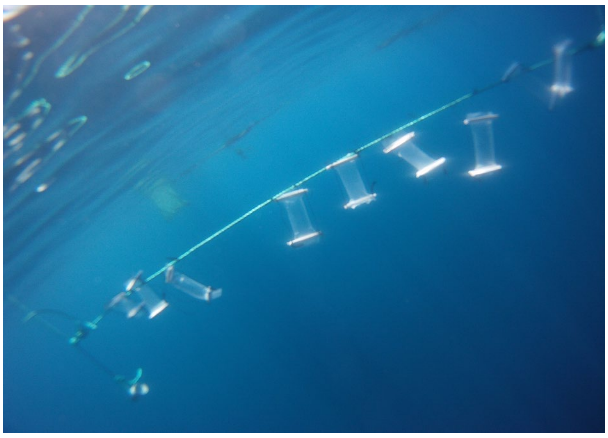

Figure 2. Photograph of the deployed experimental arrangement, 50 cm below the sea surface

Taxonomic identification and enumeration of phytoplankton species

At the end of the incubation period, water samples of approximately 200-300 mL were obtained from the bag contents. These samples, along with the seawater samples collected at the study site both at the onset and conclusion of the experiment, were used for the examination of phytoplankton. All samples underwent fixation with a 0.4% acidic Lugol's solution for this purpose. Subsequently, following sedimentation, taxonomic identification and enumeration of phytoplankton were carried out in the laboratory using an Olympus BX50 fluorescence microscope at a magnification of 100x. In order to determine the taxonomic composition of phytoplankton species, the following resources were consulted: Tomas (1997) and Gomez et al. (2010).

Nutrients and environmental variables

Samples designated for dissolved inorganic nutrients and chl *a* were prescreened through 210 µm nylon mesh to remove larger particles. After prescreening, these samples were further filtered through Whatman GF/F glass microfiber filters. The resulting filtrates were then stored at -20°C and analyzed subsequently for nitrite (NO_2), nitrate (NO_3), orthophosphate (PO_4), and reactive silica (SiO_2) using a SKALAR autoanalyzer (Skalar, De Breda, Netherlands) employing colorimetric methods adapted from the standard seawater analyses as outlined by Grasshoff et al. (1999). For analysis of chl *a*, the filters were folded and placed inside glass tubes, immediately frozen for subsequent laboratory analysis. Extraction of chl *a* was carried out using 90% acetone for a duration of 24 hours, followed by quantification using the fluorometric method described by Strickland and Parsons (1972). Seawater temperature and salinity measurements were conducted using the portable Sea-Bird 37 SM instrument (Sea-Bird Electronics Inc., Bellevue, WA, USA). Dissolved oxygen was measured using the Winkler method (Grasshoff et al., 1999). Secchi disk depth and pH were measured *in situ*.

Statistical analyses

The average concentrations of each nutrient, measured in both the ambient water and the water enclosed within the dialysis bags, were compared using independent *t*-tests (Snedecor and Cochran, 1989). The population growth rates of phytoplankton within the dialysis bags and those present in the ambient water were estimated using chl *a* concentrations and cell numbers. Calculations were based on the exponential growth model (Snedecor and Cochran, 1989; Reynolds, 2006):

$$Y_t = Y_0 e^{rt}$$

Here, Y_t is the dependent variable that describes the cell numbers or chl *a* concentrations at time *t* (day). Y_0 is the initial number of cells or amount of chl *a* concentration at time t=0 (i.e., at the start of the experiment), and *r* is the specific growth rate of the phytoplankton community, either in terms of cell counts or chl *a* concentration. The growth model was linearized with logarithmic transformation, and the specific growth rate *r* was then estimated as the slope of the linear regression of the natural logarithm of *Y* versus *t* (Snedecor and Cochran, 1989; Reynolds, 2006). Moreover, an analysis of covariance (ANCOVA) was carried out to examine potential variations in the estimated *r* values among the five experimental groups, namely, the dialysis bags containing seawater subjected to four different filtration treatments and one unfiltered seawater. Changes in concentrations (chl *a* or cell numbers) within the dialysis bags after incubation were utilized to represent the gross rates (r_{gross}). Net growth rates (r_{net}) were calculated based on changes in concentrations in the ambient seawater between the start and end of the experiment and served as the control (Mura et al., 1996). The disparity between the gross and net rates was designated as the loss rates (r_{loss}).

Various indices were employed to evaluate species diversity and evenness within the phytoplankton communities. Diversity was quantified using both the Shannon-Weiner index (H') and Simpson's index (D) (Magurran, 1988; Krebs, 1999). The ratio of observed diversity (H') to maximum diversity (H_{max}), which represents the diversity achievable under conditions where all species are equally abundant, served as a measure of evenness (E) (Magurran, 1988).

$$H' = -\sum_{i=1}^{S}(p_i) \times log_2(p_i)$$

$$D = 1 - \sum_{i=1}^{S} p_i^2$$

$$E = \frac{H'}{H_{max}} = \frac{H'}{log_2(S)}$$

In the above formulations, the quantity p_i represents the proportion of the *i*th species in terms of cell numbers, and S represents the total number of phytoplankton species or species richness within each community. For a more explicit interpretation of diversity, the Shannon-Wiener index can be expressed in an alternative form using exponentiation with 2 as the base and H' as the exponent, commonly referred to as Hill's number N_1 (Krebs, 1999). Additionally, an alternative form of Simpson's index, known as Simpson's reciprocal index (D^{-1}), is used to express diversity estimates in terms of the number of species. Simpson's reciprocal index corresponds to Hill's number N_2 (Krebs, 1999). All the indices were calculated for each dialysis bag and the ambient seawater for both the start and end of the experiment. Prior to the tests, the necessary assumptions of normality and homoscedasticity were assessed using an *F*-test, the Shapiro–Wilk normality test, and normal quantile-quantile plots (Snedecor and Cochran, 1989). All statistical tests were conducted using R software version 4.1.3 (R Core Team, 2022), with a significance level set at 5%.

RESULTS

The physical properties remained unaltered throughout the duration of the experiment (Table 1). According to observations and records from the fish farm personnel, the average wave heights during the experiment were consistently low (<1 m). The nutrient concentrations, measured both in the ambient seawater and within the dialysis membrane bags, are shown in Table 2. The concentrations of nitrite + nitrate, orthophosphate, and reactive silica determined in the ambient seawater ranged from 0.08 to 0.23, 0.03 to 0.07, and 0.21 to 0.45, respectively. The nutrient concentrations measured in the bags were slightly higher than those from the ambient seawater (Table 2).

The concentrations of chl *a* and phytoplankton cell numbers, determined from both unfiltered and filtered ambient seawater, as well as from unfiltered and filtered dialysis bags, at the beginning and end of the experiment, are all presented in Table 3. Gross (r_{gross}), net (r_{net}), and loss (r_{loss}) growth rates, derived from the chl *a* values and phytoplankton cell numbers in both the ambient seawater and dialysis bags (Table 3), are displayed in Table 4. As evident from Table 3, the chl *a* concentrations and phytoplankton cell numbers in the samples collected from the ambient seawater, regardless of the filtering treatment, were very similar at the start and end of the experiment. Consequently, no significant phytoplankton growth was observed (*t*-test), and the net growth rate was zero (Table 4).

However, after three days of incubation, a substantial increase in cell numbers and chl *a* concentrations within the dialysis bags became evident (Table 3). At the conclusion of the experiment, there was an over 18-fold increase in chl *a* values observed in the bags incubated with unfiltered seawater in comparison to the ambient seawater. Likewise, for the dialysis bags incubated with filtered seawater, the observed increases were approximately 11-fold at 40 µm, 12-fold at 56 µm, 11-fold at 100 µm, and 17-fold at 150 µm filtration (Table 3). Similarly, the increases in phytoplankton cell numbers in the bags subjected to filtration were more than 9-fold at 40 µm, nearly 12-fold at 56 µm, 10-fold at 100 µm, and 16-fold at 150 µm filtration, with close to 17-fold increase in the bags incubated with unfiltered seawater (Table 3).

Table 1. Physical properties of the ambient seawater

	Physical Properties				
Days	Temperature (⁰C)	Salinity (ppt)	Dissolved Oxygen (mg L^{-1})	pH	Secchi Depth (m)
0	23.4	39.4	7.9	8.1	24.3
3	23.3	39.5	7.8	8.1	24.6

Table 2. The nutrient values measured in both the ambient seawater and dialysis membrane bags at the beginning and end of the experiment. Note that nutrient values inside the dialysis membrane bags represent averages. UF: unfiltered treatment

Medium	Nutrients	Days									
		0					3				
		40µm	56µm	100µm	150µm	UF	40µm	56µm	100µm	150µm	UF
Ambient Seawater	Nitrite+ Nitrate (µM)	0.18	0.14	0.09	0.06	0.11	0.18	0.23	0.19	0.22	0.18
	Orthophosphate (µM)	0.09	0.03	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.08
	Silicate (µM)	0.26	0.21	0.32	0.26	0.39	0.35	0.45	0.37	0.33	0.34
Dialysis Membrane Bags	Nitrite+ Nitrate (µM)	-	-	-	-	-	0.22	0.4	0.43	0.21	0.28
	Orthophosphate (µM)	-	-	-	-	-	0.03	0.05	0.07	0.07	0.05
	Silicate (µM)	-	-	-	-	-	0.52	0.58	0.35	0.42	0.46

Table 3. Estimates of chl *a* concentrations and phytoplankton cell numbers from the unfiltered and filtered ambient seawater samples, as well as from the incubated bags. Reported results for the bags represent the average values of the sampled bags for each treatment, UF representing the unfiltered treatment

Medium	Growth Variable	Days									
		0					3				
		40µm	56µm	100µm	150µm	UF	40µm	56µm	100µm	150µm	UF
Ambient Seawater	chl *a* µg L^{-1}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	Cell L^{-1}	72860	72356	71346	79823	76439	76435	78923	73265	74391	75693
Dialysis Membrane Bags	chl *a* µg L^{-1}	-	-	-	-	-	0.65	0.7	0.68	1.01	1.09
	Cell L^{-1}	-	-	-	-	-	689797	883409	703460	1221128	1292972

The ANCOVA results revealed that the bags could be categorized into two distinct groups in terms of growth rates estimated from chl *a* concentrations. The first group consisted of unfiltered bags and those filtered through a 150 µm mesh size, and they exhibited significantly higher growth rates than the second group, which comprised bags prepared by filtering through 40 µm, 56 µm, and 100 µm mesh sizes (Table 4). When growth rates were estimated from cell counts, The ANCOVA results indicated three separate groups of bags. The bags in the first group, with higher growth rates, were the same as those identified in the analysis using chl *a* contents, namely the bags filtered with a 150 µm mesh size and unfiltered bags. The second group included only the bags filtered through a 56 µm mesh size. The gross growth rate of this group was lower than that of the first group but higher than that of the third one, which consisted of the bags filtered with 40 µm and 100 µm mesh sizes (Table 4). In each of the five experimental groups, the two growth rates estimated from two different dependent variables, i.e., chl *a* concentrations and cell numbers, were comparable. The Pearson's product-moment correlation coefficient between these two measurements was 0.99.

Table 4. Gross growth rates, net growth rates, and loss growth rates estimated from chl *a* values and phytoplankton cell numbers observed both in the ambient seawater and inside the dialysis membrane bags (UF representing the unfiltered treatment)

Source	Treatment	r_{gross} (d^{-1})	r_{net} (d^{-1})	r_{loss} (d^{-1})
Estimated from chl *a* values	40µm	0.80	0.00	0.80
	56µm	0.82	0.00	0.82
	100µm	0.81	0.00	0.81
	150µm	0.95	0.00	0.95
	UF	0.97	0.00	0.97
Estimated from phytoplakton cell numbers	40µm	0.75	0.02	0.73
	56µm	0.83	0.03	0.81
	100µm	0.76	0.01	0.75
	150µm	0.91	-0.02	0.93
	UF	0.94	0.00	0.95

A total of 33 phytoplankton taxa were identified in the seawater samples taken from the study site during the experiment. Of these, 17 were diatom species, while the remaining 16 belonged to dinoflagellate species (Table 5). In the unfiltered seawater sample collected on the initial day of the experiment, *Pronoctiluca spinifera* (Lohmann) Schiller, 1932 (Family: Protodiniferaceae, Class: Dinophyceae) was found (Figure 3), (Table 5). This species had previously been reported only in the Black Sea waters of Türkiye by Öztürk (1998), and this study provides the first record of its presence on the Aegean Sea coast of Türkiye. Upon examination of the phytoplankton community composition, it became evident that diatoms dominated, especially within two prominent families: Leptocylindraceae and Bacillariaceae. In contrast, when assessing dinoflagellate abundance, the Ceratiaceae family stood out as having the highest number of individuals.

The filtration stage prevented the entry of certain taxa, notably chain-forming diatoms such as *Chaetoceros* spp., which have relatively larger cell sizes, into the dialysis bags (Table 5, Table 6). Unfiltered samples exhibited the highest species count. This pattern was similarly reflected in the species diversity indices and evenness values. Table 7 shows the number of species, diversity indices, and evenness values for both filtered and unfiltered ambient seawater samples collected on the first and last days of the experiment, as well as similar estimates for all dialysis bags collected on the final day of the experiment. In general, it was observed that with an increase in the mesh size of filtration, there was a corresponding rise in the number of species, aligning with expectations.

Figure 3. *Pronoctiluca spinifera*

Table 5. List of phytoplankton species observed in the ambient seawater samples

Classis	Family	Taxa	Days 0 40 µm	56 µm	100 µm	150 µm	UF	Days 3 40 µm	56 µm	100 µm	150 µm	UF
Bacillariophyceae	Bacillariaceae	*Cylindrotheca closterium* (Ehrenberg) Reimann & Lewin, 1964	+	+	+	+	+	+	+	+	+	+
		Nitzschia longissima (Brébisson) Ralfs, 1861	+	+	+	+	+	+	+	+	+	+
		Pseudo-nitzschia sp.	+	+	+	+	+			+	+	+
	Chaetocerotaceae	*Chaetoceros affinis* Lauder, 1864		+	+	+	+	+	+	+	+	+
		Chaetoceros decipiens Cleve, 1873							+	+	+	+
	Grammatophoraceae	*Grammatophora marina* (Lyngbye) Kützing, 1844				+	+					
	Hemiaulaceae	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882	+	+	+	+	+	+	+	+	+	+
	Leptocylindraceae	*Leptocylindrus danicus* Cleve, 1889	+	+	+	+	+	+	+	+	+	+
	Licmophoraceae	*Licmophora* sp.		+	+	+	+			+	+	+
	Naviculaceae	*Navicula* sp.	+	+	+	+	+	+		+	+	+
	Rhizosoleniaceae	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	+	+	+	+	+		+	+	+	+
		Guinardia flaccida (Castracane) H.Peragallo, 1892					+		+	+	+	+
		Guinardia striata (Stolterfoth) Hasle, 1996	+	+	+	+	+		+	+	+	+
		Pseudosolenia calcar-avis (Schultze) B.G.Sundström, 1986				+	+					
		Rhizosolenia sp.				+	+					
	Pleurosigmataceae	*Pleurosigma* sp.			+	+	+	+	+	+	+	+
	Thalassionemataceae	*Thalassionema nitzschioides* (Grunow) Mereschkowsky, 1902					+					
Dinophyceae	Ceratiaceae	*Tripos fusus* (Ehrenberg) F.Gómez, 2013		+	+	+	+	+	+	+	+	+
		Tripos furca (Ehrenberg) F.Gómez, 2013						+	+	+	+	+
		Tripos lineatus (Ehrenberg) F.Gómez, 2021					+					
		Tripos macroceros (Ehrenberg) Hallegraeff & Huisman, 2020		+	+	+	+					
		Tripos trichoceros (Ehrenberg) Gómez, 2013				+	+					
	Dinophysaceae	*Dinophysis acuminata* Claparède & Lachmann, 1859		+	+	+	+	+		+	+	+
	Oxyphysaceae	*Oxyphysis oxytoxoides* (Kofoid) F.Gomez, P.Lopez-Garcia & D.Moreira, 2011		+	+	+	+			+	+	+
	Oxytoxaceae	*Corythodinium tesselatum* (F.Stein) Loeblich Jr. & Loeblich III, 1966					+					
		Oxytoxum scolopax F. Stein, 1883		+	+	+	+	+	+	+	+	+
	Podolampadaceae	*Podolampas elegans* F.Schütt, 1895				+	+					
		Podolampas palmipes F. Stein, 1883						+	+	+	+	+
	Prorocentraceae	*Prorocentrum gracile* F.Schütt, 1895			+	+	+					+
		Prorocentrum micans Ehrenberg, 1834	+	+	+	+	+	+	+	+	+	+
	Protodiniferaceae	*Pronoctiluca spinifera* (Lohmann) Schiller, 1932					+					
	Protoperidiniaceae	*Protoperidinium depressum* (Bailey) Balech, 1974				+	+					
		Protoperidinium steinii (Jørgensen) Balech, 1974								+	+	+

Table 6. List of phytoplankton species observed inside the dialysis membrane bags

Classis	Family	Taxa	Day 3 40 µm	56 µm	100 µm	150 µm	UF
Bacillariophyceae	Bacillariaceae	*Cylindrotheca closterium* (Ehrenberg) Reimann & Lewin, 1964			+	+	+
		Nitzschia longissima (Brébisson) Ralfs, 1861		+	+	+	+
		Pseudo-nitzschia sp.			+	+	+
	Chaetocerotaceae	*Chaetoceros affinis* Lauder, 1864		+	+	+	+
		Chaetoceros decipiens Cleve, 1873					
	Grammatophoraceae	*Grammatophora marina* (Lyngbye) Kützing, 1844			+	+	+
	Hemiaulaceae	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882	+	+	+	+	+
	Leptocylindraceae	*Leptocylindrus danicus* Cleve, 1889	+	+	+	+	+
	Licmophoraceae	*Licmophora* sp.					+
	Naviculaceae	*Navicula* sp.					
	Rhizosoleniaceae	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996					+
		Guinardia flaccida (Castracane) H.Peragallo, 1892					
		Guinardia striata (Stolterfoth) Hasle, 1996					
		Pseudosolenia calcar-avis (Schultze) B.G.Sundström, 1986					
		Rhizosolenia sp.				+	+
	Pleurosigmataceae	*Pleurosigma* sp.					
	Thalassionemataceae	*Thalassionema nitzschioides* (Grunow) Mereschkowsky, 1902			+	+	+
Dinophyceae	Ceratiaceae	*Tripos fusus* (Ehrenberg) F.Gómez, 2013				+	+
		Tripos furca (Ehrenberg) F.Gómez, 2013		+	+	+	+
		Tripos lineatus (Ehrenberg) F.Gómez, 2021	+	+	+	+	+
		Tripos macroceros (Ehrenberg) Hallegraeff & Huisman, 2020					+
		Tripos trichoceros (Ehrenberg) Gómez, 2013					
	Dinophysaceae	*Dinophysis acuminata* Claparède & Lachmann, 1859					
	Oxyphysaceae	*Oxyphysis oxytoxoides* (Kofoid) F.Gomez, P.Lopez-Garcia & D.Moreira, 2011				+	+
	Oxytoxaceae	*Corythodinium tesselatum* (F.Stein) Loeblich Jr. & Loeblich III, 1966					
		Oxytoxum scolopax F. Stein, 1883				+	+
	Podolampadaceae	*Podolampas elegans* F.Schütt, 1895					
		Podolampas palmipes F. Stein, 1883					
	Prorocentraceae	*Prorocentrum gracile* F.Schütt, 1895			+	+	+
		Prorocentrum micans Ehrenberg, 1834	+	+	+	+	+
	Protodiniferaceae	Pronoctiluca spinifera (Lohmann) Schiller, 1932					
	Protoperidiniaceae	*Protoperidinium depressum* (Bailey) Balech, 1974					
		Protoperidinium steinii (Jørgensen) Balech, 1974					

Table 7. Phytoplankton species richness and species diversity observed in the unfiltered (UF) and filtered (40 µm, 56 µm, 100 µm, and 150 µm) ambient seawater as well as in the unfiltered and filtered dialysis membrane bags

Medium	Indices	Days: 0 40µm	56µm	100µm	150µm	UF	3 40µm	56µm	100µm	150µm	UF
Ambient Seawater	Species richness (*S*)	9	16	18	24	29	13	15	21	21	25
	Shannon Index (*H'*)	2.64	3.07	3.30	3.65	3.90	2.92	3.10	3.48	3.51	3.63
	Simpson's Index (*D*)	0.78	0.79	0.82	0.85	0.86	0.78	0.82	0.83	0.84	0.83
	N_1 ($2^{H'}$)	6.24	8.39	9.88	12.59	14.92	7.58	8.57	11.16	11.36	12.39
	N_2 (D^{-1})	4.61	4.82	5.59	6.73	6.91	4.63	5.53	5.73	6.14	6.18
	Evenness (*E*)	0.83	0.77	0.79	0.80	0.80	0.79	0.79	0.79	0.80	0.78
Dialysis Membrane Bags	Species richness (*S*)	-	-	-	-	-	5	7	12	16	19
	Shannon Index (*H'*)	-	-	-	-	-	0.30	0.34	0.67	0.61	0.66
	Simpson's Index (*D*)	-	-	-	-	-	0.08	0.08	0.16	0.13	0.14
	N_1 ($2^{H'}$)	-	-	-	-	-	1.23	1.27	1.59	1.52	1.58
	N_2 (D^{-1})	-	-	-	-	-	1.08	1.09	1.19	1.15	1.16
	Evenness (*E*)	-	-	-	-	-	0.13	0.12	0.19	0.15	0.16

The trend of rising species richness with increasing mesh size of filtration was also observed in the dialysis bags at the end of the experiment. While many species found in the ambient seawater were not encountered inside the bags, certain species were observed in much higher numbers than those recorded in the ambient seawater. In particular, the diatom species *Leptocylindrus danicus* Cleve, 1889 was present in exceptionally high quantities in all bags (Figure 4), contributing to the lower evenness values in Table 7 compared to the ambient seawater. Additionally, this species was seen to form chains consisting of 8-10 cells inside the bags. Overall, species diversity was notably low in all incubated bags, as evidenced by the N_1 and N_2 values presented in Table 7. The contents of all bags at the end of the incubation period comprised a total of 11 diatom species and 8 dinoflagellate species (Table 6).

Samples collected from the ambient seawater also contained microzooplankton, including ciliate protozoans and copepod nauplii, although their concentrations were very low. No adult copepod was found inside any bag, but ciliates were present in all bags (Some of the identified genera include *Favella* sp., *Eutintinnus* sp., *Strobilidium* sp., and *Mesodinium* sp.).

Figure 4. *Leptocylindrus danicus* bloom

DISCUSSION

An increase in primary production due to additional nutrient input is readily detectable in waters with oligotrophic characteristics (Pitta et al., 1999). Fish farms established in oligotrophic marine environments, such as the Aegean Sea, should serve as examples of places where such a nutrient increase can be observed. Nevertheless, in the present study, both in the ambient seawater and inside the bags, nitrite+nitrate and orthophosphate concentrations measured at the beginning and end of the experiment (Table 2) fall within the range of values defined by Ignatiades et al. (1992) as characteristic of the oligotrophic Aegean Sea. Furthermore, chl *a* concentrations of the study area were notably low, measuring approximately 0.06 µg L^{-1} (Table 3) and was consistent with the range reported for other oligotrophic regions in the eastern Mediterranean (e.g., Pitta et al., 1999). The current findings concerning the physical, chemical, and biological attributes of the water column align with a previous study investigating three fish farms in the western Aegean Sea (Pitta et al., 1999). La Rosa et al. (2002), in their study on the impact of fish farm activities on the water column in the Tyrrhenian Sea in the northwestern Mediterranean, similarly reported no significant increase in nutrient or chl *a* contents in the water column adjacent to the cages throughout the year. According to Gowen and Bradbury (1987), the dispersion of wastes released from fish farms is influenced by factors such as the farm's surface area, the settling velocity of uneaten feed, and the depth of the water beneath the cages. Moreover, strong currents can disperse phytoplankton far from the farm area (Navarro et al., 2008). Another critical factor contributing to the difficulty in detecting phytoplankton response to nutrient enrichment may be the grazing effect, as highlighted by Pitta et al. (2009).

The present study, conducted during the summer season between 20 to 23 July 2020, holds particular significance due to its timing. This period aligns with the natural seasonal patterns of the Mediterranean Sea, characterized by low production rates during the summer months (López-Sandoval et al., 2011). What makes the findings particularly noteworthy is the significant contrast observed within this oligotrophic environment. Despite the prevailing oligotrophic conditions in the study area and the absence of a discernible net phytoplankton growth rate in the ambient seawater (Table 3), the gross growth rates based on both chl *a* values and cell counts exhibited a significant increase inside the dialysis membrane bags at the end of the 3-day incubation period. This unexpected and substantial growth was a consistent observation across all treatments. Similar observations of phytoplankton blooms under low nutrient conditions were made in an *in situ* diffusion culture system by Furnas (1982).

The findings confirmed that the filtration successfully eliminated all predator species larger than 150 µm. However, the filtration treatment could not completely prevent the entry of all ciliates into the bags. The inability to completely eliminate grazers from the bags may account for the unexpected result of significantly lower growth rates observed in the bags subjected to filtration using mesh sizes between 40 and 100 µm, as compared to those estimated for the remaining bags containing seawater filtered with a 150 µm mesh size and unfiltered seawater. Some portion of phytoplankton production in the bags filtered with 100 µm mesh size and below was likely consumed by the ciliates in the medium. Pitta et al. (1999) conducted a similar experiment at a fish farm in Sitia, Crete, employing a method where half of the dialysis membrane bags were filled with seawater filtered through a 25 µm mesh size while the other half contained unfiltered seawater. After a ten-day incubation period, during which the chl *a* content of the bags was measured, they observed the highest concentrations in the filtered bags. The explanation provided for this phenomenon was the complete exclusion of ciliates from the bags. Ciliates, with sizes exceeding 20 µm, are the primary grazers of nano-sized fractions of phytoplankton (Zöllner et al., 2009).

Another possible explanation for significantly higher growth rates observed inside the unfiltered bags and those filtered with a 150 µm mesh size may be as follows: Considering that a significant portion of the phytoplankton observed in the study were of a size smaller than 150 µm, it is likely that using a 150 μm mesh size for filtration, aside from some chain-forming diatoms, did not result in a substantial difference in phytoplankton composition compared to the unfiltered bags. When designing the experiment, it was hypothesized that the presence of adult copepods in the unfiltered bags could potentially differentiate them from those subjected to the 150 μm filtration. However, no adult copepods were found inside either type of bag. This absence may account for the high phytoplankton growth rate inside the bags compared to that in the ambient seawater. Pitta et al. (1999) also suggested, that due to the limited volume of the bags, copepods were unlikely to graze on the microphytoplankton inside them. An experiment with bigger bags comprising larger volumes of seawater may be more suitable for detecting copepod grazing. Additionally, a Nansen bottle may not be the optimal tool for sampling adult copepods, and a more appropriate sampling device should be considered.

The number of phytoplankton species at the study site increased with the enlarging filtration mesh size, while unfiltered samples contained the highest species counts as expected (Table 7). A similar trend was reflected in the species diversity indices and evenness values. Likewise, species richness inside the incubated dialysis bags increased with larger filtering mesh sizes. However, species diversity inside all bags remained notably lower than those estimated for differently treated ambient water samples (Table 7). Many phytoplankton species present in the ambient water were conspicuously absent inside the bags (Table 5, Table 6). In contrast, certain species were observed in significantly higher densities than those in the ambient seawater. This resulted in generally very low N_1, N_2, and evenness values (Table 7). A similar substantial increase in cell densities for some phytoplankton species inside dialysis bags during an experiment was also documented by Mura et al. (1996). This observed phenomenon suggests that only a few taxa can tolerate experimental manipulations, and an incubation period of just three days, as in the present study, is sufficient to observe these changes.

CONCLUSIONS

Overall, the findings of this study have demonstrated that the nutrient discharge from a fish farm established in an oligotrophic marine area did not alter the prevailing oligotrophic conditions in the environment. The unexpectedly high growth rates observed inside the bags can be attributed to the confinement of phytoplankton within the bags, preventing them from drifting away with currents or being subject to daily migration or grazing, factors that would typically limit their growth in the open sea. Additionally, the phytoplankton enclosed within the dialysis membrane bags positioned close proximity to the fish farms benefit from the unique advantage of accessing and utilizing the nutrients released from the farm before these nutrients disperse and dilute within the surrounding seawater. These combined factors likely contributed to the substantial increase in phytoplankton growth observed in the study. The present work represents the first bioassay and *in situ* phytoplankton incubation experiment using dialysis membrane bags in the Eastern Aegean Sea and all other Turkish seas. The results from this research may serve as a foundation for estimating the growth rates of natural phytoplankton communities in future investigations in Turkish waters.

ACKNOWLEDGEMENTS AND FUNDING

We extend our sincere gratitude to Akvatek Aquaculture Inc. for generously permitting us to conduct the *in situ* microcosm experiment within their fish farm facilities. Our special thanks go to Dr. Güngör Muhtaroğlu for his unwavering support and for granting us access to the farm's resources throughout the study. We are indebted to Tahsin Han and Cumhur Şahin from Akvatek for their invaluable assistance in experiment design and their unwavering support during all fieldwork phases. Additionally, we appreciate the insightful discussions with Dr. Filiz Küçüksezgin and Dr. Güzel Yücel Gier. It is worth noting that the first author is submitting this paper as part of the requirements for a Ph.D. degree at Dokuz Eylül University. We are grateful for the financial support provided by Dokuz Eylül University's Department of Scientific Research Projects (Project number: 2019KBFEN017), which also included an 18-month fellowship for Author B. B. Şener.

AUTHORSHIP CONTRIBUTIONS

Betül Bardakçı Şener: Conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, writing -original draft, writing - review & editing. Eyüp Mümtaz Tıraşın: Conceptualization, formal analysis, funding acquisition, investigation, project administration, resources, supervision, writing - review & editing.

CONFLICT OF INTEREST STATEMENT

The authors affirm that they do not have any known financial interests or personal associations that might have given the impression of exerting influence over the study described in this manuscript.

ETHICS APPROVAL

This manuscript does not involve any animal studies conducted by the authors. The experimental research was carried out using natural phytoplankton communities.

DATA AVAILABILITY

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

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Ege Journal of Fisheries and Aquatic Sciences, 41(1), 26-29 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.04

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Karyological analysis of endemic *Pseudophoxinus anatolicus* (Hankó 1925) in Türkiye

Türkiye'ye endemik *Pseudophoxinus anatolicus* (Hankó 1925)'un karyolojik analizi

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Received date: 30.10.2023 *Accepted date: 16.01.2024*

How to cite this paper:
Doori, A.S.J., & Arslan, A. (2024). Karyological analysis of endemic *Pseudophoxinus anatolicus* (Hankó 1925) in Türkiye. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 26-29. https://doi.org/10.12714/egejfas.41.1.04

Abstract: The karyological characteristics of nearly half of the *Pseudophoxinus* species in Türkiye were determined. In this study, it is planned to determine the karyological characteristics of *P. anatolicus*, which is common in Beyşehir Lake, specimens were caught from the coast at Çiftlik village. The captured specimen were karyological analysed and Giemsa staining, C-banding and Ag-NOR staining were applied to the slides that obtained. The chromosome set of this species consists of 12 pairs of metacentric, eight pairs of submetacentric, two pairs of subtelocentric and three pairs of acrocentric chromosomes. Dark and slightly C-bands were observed in the centromeric regions of some chromosomes. Active Ag-NORs were detected in the telomeric region of the short arm of two pairs of chromosomes. Our results are similar to those of other *Pseudophoxinus* species except for some differences and it was determined that Anatolian minnow has a conserved karyotype like other *Pseudophoxinus* species.

Keywords: Anatolian minnow, chromosome, karyotype, C-banding, Ag-NOR

Öz: Türkiye'deki *Pseudophoxinus* türlerin yarısının karyolojik özellikleri belirtilmiştir. Beyşehir gölünde yaygın olan *P. anatolicus*'un karyolojik özelliklerini belirlemek için planlanan bu çalışmada örnekler Çiftlik köyü kıyısından yakalandı. Yakalanan bireylerin karyolojik analizleri yapıldı ve elde edilen slaytlara sırayla giemsa boyama, C-bantlama ve Ag-NOR boyama uygulandı. Bu türün kromozom seti 2 çift metasentrik, sekiz çift submetasentrik, iki çift subtelosentrik ve üç çift akrosentrik kromozomdan oluşmaktadır. Koyu ve açık C-bantlar bazı kromozomların sentromerik bölgelerinde gözlemlendi. Aktif Ag-NOR'lar iki çift kromozomun kısa kolunun telomerik bölgesinde tespit edildi. Sonuçlarımızın diğer *Pseudophoxinus* türlerinkine bazı farklılıklar hariç benzer tarafları vardır ve Anadolu yağ balığının da diğer *Pseudophoxinus* türlerindeki gibi korunmuş karyotipe sahip olduğu belirlendi.

Anahtar kelimeler: Anadolu yağ balığı, kromozom, karyotip, C-bandlama, Ag-NOR

INTRODUCTION

There are 30 known species of *Pseudophoxinus*, a genus of the Leuciscidae family, and they are generally distributed in isolated spring pools and rivers in Central Anatolia and the Levant (Küçük et al., 2012). Türkiye, which is rich in freshwater fishes, has 24 fatfish species (Çiçek et al., 2020). They are mainly distributed in lake basins and rivers in Central and Southwestern Anatolia (Küçük et al., 2016). Although sufficient studies have been carried out on the systematics of fishes, karyological studies are still not advanced. The studies on *Pseudophoxinus* species in Türkiye are not sufficient. So far, the karyological characteristics of 13 species of this genus in Türkiye have been investigated by different researchers (Ergene et al., 2010; Karasu et al., 2011; Ünal et al., 2014; Karasu Ayata et al., 2016; Ünal and Gaffaroğlu, 2016; Gaffaroğlu et al., 2022). In addition to the standard karyological characteristics of *Pseudophoxinus* species found in different rivers and lakes of Anatolia, C-banding and NOR characteristics were also investigated by these researchers. So far, there is no karyological study on *P. anatolicus*. Therefore, the aim of this study was to determine the banded karyological characteristics of *P. anatolicus* and to establish the similarities and differences with other species.

MATERIALS AND METHODS

Four *P. anatolicus* specimens were collected from the shore of Çiftlik village in the east of Beyşehir Lake with the help of an electro-shocker. The captured fish specimens were transported to the laboratory alive under suitable conditions and kept in a well-aerated aquarium until analysis. After this adaptation period, each specimen was performed karyological analysis according to the method of Bertollo et al. (2015). 0.1% colchicine was injected (1ml/100g) into each specimen for which chromosome preparations were to be prepared and kept in the aquarium for 50 minutes. After anaesthetization, the cell suspension from head kidney with 0.075 M KCl was kept in hypotonic solution. Then, fixation steps (methanol: acetic acid, 3:1) were repeated at least three times and at least 10 metaphase slides were prepared from each individual. Some slides were stained with 10% Giemsa for standard karyotype and preserved. The other slides were subjected to C-banding (CBG-banding) (Sumner, 1972) and Ag-NOR staining (Howell and Black, 1980). Well-spread metaphases of each staining were photographed under a microscope. Metaphase chromosomes were identified and karyotyped according to Levan et al. (1964). The fundamental number of autosomal arms (NF) was calculated considering the number of bidentate and acrocentric chromosomes.

RESULTS

The diploid chromosome number (2n) of four specimens (2 males, 2 females) was 50. According to karyotype analysis, the chromosome set consisted of 12 pairs of metacentric (no. 1-12), eight pairs of submetacentric (no. 13-20), two pairs of subtelocentric (no. 21-22) and three pairs of acrocentric (no. 23-25) chromosomes. The fundamental number of autosomal arms (NF) was 94 (Figure 1). Heteromorphic sex chromosomes were not detected in males and females. The karyotype of the specimens obtained by CBG banding is shown in Figure 2. Constitutive heterochromatin regions (C-bands) observed in centromeric regions of chromosomes were dark in some chromosomes and slightly in others. Active Ag-NORs were detected on two pairs of chromosomes. These were found in the telomeric region of the short arm of the largest metacentric chromosome (no. 1) and the medium-sized submetacentric (no. 16) chromosome in all specimens analyzed. One of these NORs on the largest metacentric chromosome is heterozygous and the other homozygous and neither is associated with the heterochromatin region (Figure. 3).

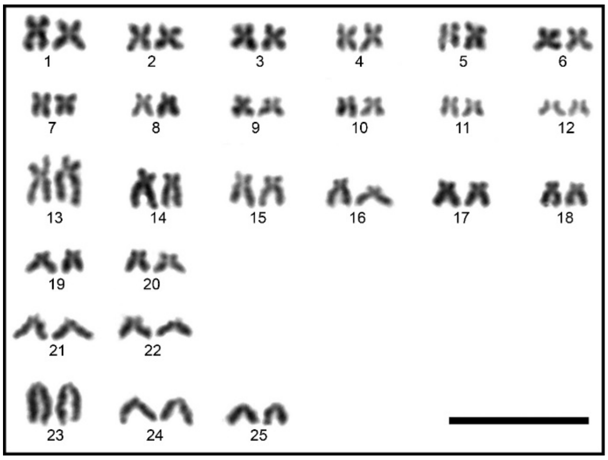

Figure 1. Standard Giemsa staining karyotype of *Pseudophoxinus anatolicus* (Scale bar = 10 µm)

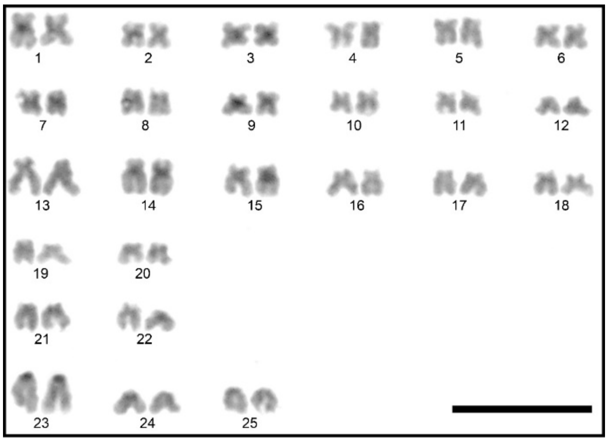

Figure 2. C-banded (CBG) karyotype of *Pseudophoxinus anatolicus* (Scale bar = 10 µm)

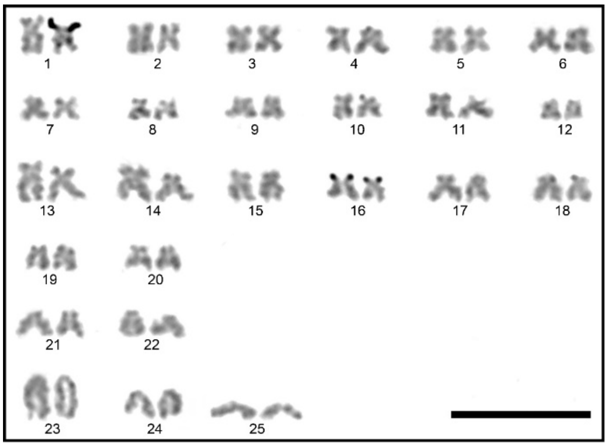

Figure 3. Silver-stained karyotype of *Pseudophoxinus anatolicus* (Scale bar = 10 µm)

DISCUSSION

The karyotype features of *P. anatolicus* were revealed for the first time in this study. The karyotype formula of this species shows a numerical dominance of meta/submetacentric chromosomes as in the basic karyotype model of leuciscines. When the total number of meta/submetacentric chromosomes of *P. anatolicus* is taken into account, it was seen that this species is similar to the majority of some other *Pseudophoxinus* species studied in Türkiye, but different from some others (Table 1). This difference may be as a result of the way the researchers determined the chromosome morphology (numerical variation of meta/submetacentric chromosomes). The fundamental number of autosomal arms (NF) value is not finalised because St and A chromosomes were not evaluated separately. Therefore, the NF value of species may be varied. When these are taken into consideration, the preserved karyotypic evolution in *Pseudophoxinus* species supports the hypothesis. In fact, in a study investigating the phylogenetic and zoogeographic characteristics of *Pseudophoxinus*, which supports this hypothesis, it was found that *Pseudophoxinus* was divided into two clades consisting of species of Anatolian (central and western) and Eastern Mediterranean (Levant) origin (Perea et al., 2010), and Küçük et al. (2012) showed that *Pseudophoxinus* has two main speciation zones, Anatolian and Eastern Mediterranean. Thus, both *P. anatolicus* and other *Pseudophoxinus* species in Anatolia have similar standard karyological characteristics and phylogenetic studies support the hypothesis of conserved karyotypic conservation in the Anatolian line.

In this study, dark and slightly constitutive heterochromatin C-bands were detected in centromeric regions some of chromosomes in *P. anatolicus*. Our C-band results are similar to those of *P. antalyae*, *P. battalgilae*, *P. burduricus* and *P. evliyae* (Ergene et al., 2010; Karasu Ayata et al., 2016). However, our results are partially similar to those of *P. egridiri*, *P. fahrettini*, *P. maeandri* (Karasu Ayata et al, 2016) and *P. zekayi* (Ünal and Gaffaroğlu, 2016), while it is different from the results of *P. firati*, *P. crassus*, *P. hittitorum*, *P. zekayi*, *P. alii* and *P. elizavetae* which have only pericentromeric C-bands (Karasu et al., 2011; Ünal and Gaffaroğlu, 2016; Gaffaroğlu et al., 2022). The interstitial C-band detected in some cyprinids (Arslan and Gündoğdu, 2016) was not detected in both species and in other *Pseudophoxinus* species.

Table 1. Chromosomal records of Anatolian *Pseudophoxinus* species

Species	Locality	2n	Karyotype	Reference
P. antalyae	Mersin	50	16M + 14Sm + 12St + 8A	Ergene et al. (2010)
P. firati	Malatya	50	38M/Sm + 12St	Karasu et al. (2011)
P. crassus	Konya	50	12M + 30Sm + 8St/A	Ünal et al. (2014)
P. hittitorum	Konya	50	14M + 26Sm + 10St/A	Ünal et al. (2014)
P. battalgilae	Konya	50	6M + 28Sm + 6St/A	Karasu Ayata et al. (2016)
P. burduricus	Burdur	50	18M + 26Sm + 6St/A	Karasu Ayata et al. (2016)
P. egridiri	Isparta	50	14M + 28Sm + 8St/A	Karasu Ayata et al. (2016)
P. evliyae	Antalya	50	14M + 30 Sm + 6St/A	Karasu Ayata et al. (2016)
P. fahrettini	Isparta	50	6M + 26Sm + 8St/A	Karasu Ayata et al. (2016)
P. maeandri	Denizli	50	10M + 32Sm + 8St/A	Karasu Ayata et al. (2016)
P. zekayi	Adana	50	16M + 26Sm + 8St/A	Ünal and Gaffaroğlu (2016)
P. alii	Antalya	50	18M + 24Sm + 8St/A	Gaffaroğlu et al. (2022)
P. elizavetae	Kayseri	50	8M + 34Sm + 8St/A	Gaffaroğlu et al. (2022)
P. anatolicus	Konya	50	24M + 16Sm + 4St + 6A	This study

All individuals of *P. anatolicus* analysed here carried Ag-NOR on metacentric chromosome 1. In addition, except for some metaphases, the submetacentric chromosome 16 was also found to have Ag-NOR. There are similarities and differences between our Ag-NOR results and previously studied *Pseudophoxinus* species, both numerically and in terms of the morphology of the chromosome in which the NOR is localised. Numerically, *P. firati*, *P. zekayi*, *P. evliyae*, *P. fahrettini*, *P. maeandri* and *P. alii* and *P. elizavetae* have active NOR on two pairs of chromosomes (M+Sm, Sm+Sm or Sm+St), while the other species have active NOR on one pair of chromosomes (Sm) (Ergene et al., 2010; Karasu et al., 2011; Ünal et al., 2014; Karasu Ayata et al., 2016; Ünal and Gaffaroğlu, 2016). Gaffaroğlu et al. (2022) also argued that they detected a higher number of Ag-NORs in some metaphases of *P. alii* and *P. elizavetae.* When evaluated in terms of active NOR-bearing chromosome morphology, *P. anatolicus* is close to *P. zekayi*. The variation in active NORs detected by silver staining in *Pseudophoxinus* species in Türkiye needs to be confirmed using molecular cytogenetic techniques. Active NORs detected by silver staining contain 18s rDNA (Diniz et al., 2009). Recently, the presence of active NORs detected by silver staining has been confirmed using 18s rDNA probes. Even inactive NORs are detected with 5s rDNA probes and the results are used to assess the relatedness between species (Bueno et al., 2014).

CONCLUSION

As a result, it was observed that the standard karyological features of this species were similar to those of some of the other *Pseudophoxinus* species studied in Türkiye, but the variations in both standard and C-banding results revealing these differences varied according to the researcher. Therefore, we believe that molecular cytogenetic methods, which are the major deficiency in the researches in Türkiye, can be used to reach more permanent results in the differentiation of species or determination of kinship relationships.

ACKNOWLEDGEMENTS AND FUNDING

This article is based on Ahmed Sadeq Jaber DOORI's PhD summarized from a part of his thesis. This study was financed with a grant from the Scientific Research Projects Coordination Board of Selçuk University (Project number: 21211009).

AUTHORSHIP CONTRIBUTIONS

The contribution of the authors is equal.

ETHICS APPROVAL

The samples in this study were collected with the permission of the TR Ministry of Forestry and Water Affairs (Permit No: E-21264211-288.04-3435924). This permission replaces the local ethics committee permission per 8/L of the regulation "On Working Procedures and Principles of Animal Experiments Ethics Committees" prepared by the Ministry of Forestry and Water Affairs and published in the Official Gazette on February 15, 2014.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY

All relevant data is inside the article.

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 30-36 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.05

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Some biological aspects of White seabream, *Diplodus sargus* (Linnaeus, 1758) from the northeastern Aegean Sea, Türkiye

Kuzeydoğu Ege Denizi'nde (Türkiye) *Diplodus sargus* (Linnaeus, 1758)'un bazı biyolojik özellikleri

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Received date: 18.10.2023 *Accepted date: 18.01.2024*

How to cite this paper:
Daban, İ.B., İşmen, A., Arslan İhsanoğlu, M. (2024). Some biological aspects of White seabream, *Diplodus sargus* (Linnaeus, 1758) from the northeastern Aegean Sea, Türkiye. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 30-36. https://doi.org/10.12714/egejfas.41.1.05

Abstract: In the study, the age, growth, mortality parameters and length-weight relationship parameters of *Diplodus sargus* (white seabream) collected by a small-scale fisherman between August 2020 and July 2021 along the northeastern coast of Aegean Sea (Türkiye coast), were investigated. *D. sargus* had a range of total length and weight from 14.3 cm to 36.7 cm and from 50.5 g to 836.5 g, respectively. The length-weight relationships (LWRs) were calculated as $W=0.02368*L^{2.881}$ for females, $W = 0.01847*L^{2.959}$ for males and $W = 0.01989*TL^{2.936}$ for both sexes. Using data from fish scales, the maximum age was determined to be 11 years. von Bertalanffy growth parameters have been calculated as follows $L\infty=39.01$ cm TL, K=0.13 year^{-1}, and t_0= -2.58 year for both sexes combined. Total (T), natural (N) and fishing (F) mortalities were defined as Z: 0.83 year^{-1}, M: 0.33 year^{-1} and F: 0.50 year^{-1} for both sexes combined. The exploitation rate (E) was calculated as 0.70, 0.44 and 0.60 for females, males and combined, respectively.

Keywords: Age, growth, mortality, length-weight relationship, white seabream, Aegean Sea

Öz: Bu çalışmada, Ağustos 2020 ve Temmuz 2021 tarihleri arasında Ege Denizi'nin kuzeydoğu kıyılarında (Türkiye kıyıları) küçük ölçekli bir balıkçı tarafından toplanan *Diplodus sargus*'un (Sargos) yaş, büyüme, ölüm parametreleri ve boy-ağırlık ilişkisi parametreleri incelenmiştir. *D.sargus*'un toplam uzunluğu 14,3 cm ila 36,7 cm ve ağırlığı 50,5 g ila 836,5 g arasında değişmektedir. Boy ağırlık ilişkisi dişiler için $W = 0.02368*L^{2.881}$, erkekler için $W = 0.01847*L^{2.959}$ ve her iki cinsiyet için $W = 0.01989*TL^{2.936}$ olarak tahmin edilmiştir. Balık pullarından hesaplanan yaş verileri maksimum yaşın 11 olduğunu göstermiştir. Belirlenen büyüme parametresi değerleri tüm bireyler için $L_\infty=39.01$ cm, K=0.13 yıl^{-1}, t_0= -2.58 yıl olarak belirlenmiştir. Toplam ölüm (Z), doğal ölüm (M) ve balıkçılık ölümü (F) tüm bireyler için Z: 0.83 yıl^{-1}, M: 0.33 yıl^{-1} ve F: 0.50 yıl^{-1} olarak belirlenmiştir. Sömürülme oranı (E) dişiler, erkekler ve tüm bireyler için sırasıyla 0.70, 0.44 ve 0.60 olarak hesaplanmıştır.

Anahtar kelimeler: Yaş, büyüme, mortalite, boy ağırlık ilişkisi, Sargos, Ege Denizi

INTRODUCTION

The white seabream, *Diplodus sargus* (Linnaeus, 1758), is an important representative of the family Sparidae with a geographical distribution ranging from the Bay of Biscay to Angola in the eastern Atlantic and from Gibraltar to the Black Sea (Bauchot, 1987; Bilecenoğlu et al., 2014). It has a shallower distribution (<70 m) and is mostly found in the same habitats. These habitats consist of rocky areas and *Posidonia oceonica* beds (Bauchot and Hureau, 1990; Lenfant and Planes, 1996). The white seabream feeds on algae, worms, gastropods, amphipods, bivalves, echinoderms, fishes and fish eggs (Maigret and Ly, 1986; Bianchi et al., 1999; Figueiredo et al., 2005).

It is known to be a common species in the northern Aegean Sea and is mainly caught in the shelf and coastal areas. The northeastern Aegean Sea is known as one of the areas where the most intensive small-scale fishing is carried out. The most preferred fishing gears are gillnets, trammel nets, longlines and hand lines. Hand lines and longlines are mainly used to catch white seabream. White seabream is more economically important than most other species in the region's fisheries. White seabream caught are exported and the approximate yield is 10 dollars per kilogram in 2021. Due to the problem of unrecorded fishing in the small-scale fisheries inTürkiye, the recorded catch rates are lower than the realised catch rates. The landed catch of white seabream is estimated at 26 tonnes according to the Turkish Statistical Institute Fisheries Report in 2022 (TUIK, 2023). The scientific knowledge on the biology of white seabream in Turkish seas is limited, although it is known as a common species of Sparidae.

Ayyıldız and Altın (2020) studied the daily growth of juvenile white seabream, Balık and Emre (2016) determined the age and growth of specimens with a total length of 13-16 cm from Beymelek Lagoon, southwest of Turkey. Some valuable literature on age, growth and feeding of white seabream has been published from Algeria, Portugal, Western and Eastern Mediterranean (Lloret and Planes, 2003; Benchalel and Kara, 2013; Al-Beak et al., 2015; Paiva et al., 2018; Boufekane et al., 2021). While the population characteristics of fish are significant factors in managing and controlling fisheries resources (Froese et al., 2008) and the mortality rates, the age distribution offers crucial insights into the size and structure of the stock. The literature currently lacks information on the age, growth, and mortality parameters of *D. sargus*, posing potential hurdles for the management of the stock due to the paucity of data on the population biology in the Eastern Mediterranean, Aegean, Marmara, and Black Seas. The objective of this study is to offer initial insight into the growth parameters of white seabream in the northeast Aegean Sea. This research holds significance as it reveals the first findings of the population parameters of *D. sargus* in the Northeast Aegean Sea.

MATERIALS AND METHODS

Specimens were collected from fish captured by a fisherman with a handline and longline in the northeastern coast of Türkiye between August 2020 and July 2021. During the research, 30 samples were taken every month. A total of 322 fish were examined. TL (total length) and FL (fork length) were measured to the nearest millimetre. Total weight (TW) and gonad weight (GW) were also weighed to the nearest 0.01 grams. Subsequently, the exponential regression $W = a*TL^b$ was used to estimate the length-weight relationship (Le Cren, 1951), where W represents the total weight (grams) and TL denotes the total length (centimetres). Linear least squares regression after logarithmic transformation was used to estimate the constants a and b. Growth type was determined via t-test on the value of 'b', which reflects the allometry of growth (Sokal and Rohlf, 1987). At first, age determination was assessed for both otoliths and scales, and it was concluded that the fish scales was the most appropriate method for white seabream. The age of 322 white seabream specimens was ascertained from intact scales underneath the pectoral fin's left section. The translucent zones were identified as annuli and counted. Both sets of scale ring measurements were conducted by three independent observers using a binocular microscope. For the entire dataset, we estimated growth parameters using the von Bertalanffy growth equation: $L(t)= L_\infty\ [1-\exp(-k(t-t_0))]$ where L(t) represents total length at time t, L_∞ denotes asymptotic length (cm), K indicates the growth coefficient (y^{-1}) and t_0 is the age of the fish when its size is zero (von Bertalanffy, 1938). The von Bertalanffy growth parameters were estimated using FISAT II programme. Instantaneous total mortality (Z) was determined using the age-converted catch curve method of Pauly (1984). Natural mortality (M) was calculated using Pauly's (1980) empirical formula, which includes von Bertalanffy growth parameters and mean annual seawater temperature (15.7°C; Türkoğlu, 2010). The fishing mortality rate was computed via the formula F = Z - M (Bingel, 2002). To compute the exploitation rate (E), Gulland's formula (1979) was utilised: E = F/Z. Calculating the growth performance index, ϕ, involved using this formula: $\phi = \log K + 2 \times \log L_\infty$.

RESULTS

The lengths of 322 white seabreams ranged from 14.3 cm to 36.7 cm TL. The mean TL was calculated to be 23.8 ± 0.18 cm (Table 1). Individual weights ranged from 50.5 g to 836.5 g with a mean of 232.4 ± 5.7 g. It was observed that the most common length group was 24 cm TL with 17.4% of the total individuals, and almost half of the total individuals were between 22 cm and 24 cm TL (Figure 1). Looking at the monthly variation in mean TL, the highest mean length was observed in May and the lowest in August. The length-weight relationship was calculated as $W = 0.02368*TL^{2.881}$ ($r^2 = 0.93$) for females, $W = 0.01847*L^{2.959}$ ($r^2 = 0.93$) for males and $W = 0.01989*TL^{2.936}$ ($r^2 = 0.93$) for both sexes (Table 2). The regressions showed negative allometric growth for males, females and both sexes. According to the fish scale readings, white seabream was distributed between 1 and 11 years of age (Table 3, Figure 2). The most common age groups were 5, 4 and 6 years with 27.6%, 21.1% and 16.1% of the total individuals.

Table 1. The range of total length (TL), and weight (g) of *D. sargus*

	Total Length(cm)				Weight (g)		
	N	Mean ± Sx	Min	Max	Mean	Min	Max
Male	176	23.47 ± 0.22	14.3	31.6	220.74 ± 6.53	50.46	542.12
Female	143	24.19 ± 0.28	15.9	36.7	243.67 ± 9.66	71.32	836.51
Total	322	23.83 ± 0.18	14.3	36.7	232.36 ± 5.67	50.46	836.51

Table 2. Length-weight relationships (LWRs) parameters of *D. sargus*

Sex	N	a	%95 Cl a	b	%95 Cl b	r^2	Growth type
Female	143	0.0236	0.0155-0.0360	2.88	2.749-3.013	0.93	A(-)
Male	176	0.0184	0.0125-0.0272	2.96	2.835-3.082	0.93	A(-)
Total	322	0.0199	0.0149-0.0263	2.94	2.847-3.025	0.93	A(-)

A(-) : negative allometry

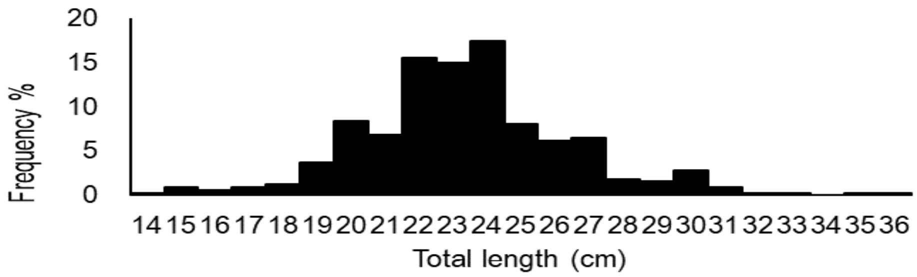

Figure 1. Frequency distribution of the length of *D. sargus*

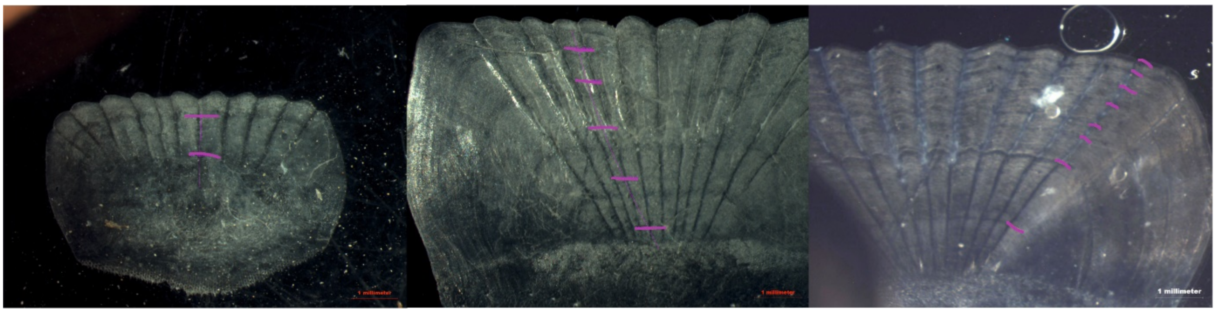

Figure 2. Annual growth rings (pink lines) on the scales in different ages of *D. sargus*

Table 3. Key to the age-total length of *D. sargus*

Total length (cm)	Age										
	1	2	3	4	5	6	7	8	9	10	11
14	1										
15		3									
16		2									
17		3									
18		2	2								
19			11	1							
20		4	19	3	1						
21			7	14	1						
22			2	34	14						
23			1	13	33	1					
24				3	29	22	2				
25					7	14	5				
26					3	7	7	3			
27					1	5	9	6			
28						1	2	3			
29						2	1	2			
30								8	1		
31									3		
32									1		
33										1	
34											
35										1	
36											1
N	1	14	42	68	89	52	26	22	5	2	1
Mean length (cm)	14.3	17.9	20.4	22.4	23.8	25.5	26.7	28.6	31.4	34.5	36.7

We employed the FISAT II programme to study the length and age data as well as the growth parameters of 322 individuals. The values of the growth parameters for the entire population were calculated as L_∞=39.01 cm TL, K=0.13 year^{-1}, and t_0=-2.58 years. Growth parameters for female individuals were determined as L_∞=37.96 cm TL, K=0.14 year^{-1}, t_0=-2.0 years. For male individuals, the growth parameters were L_∞=32.86 cm TL, K=0.19 year^{-1}, t_0=-2.0 years.

Graphs depicting von Berlanffy growth curves for females, males, and all individuals of *D.sargus* are illustrated in Figure 3. Total mortality (Z), natural mortality (M) and fishing mortality (F) were determined as Z: 0.83 t^{-1}, M: 0.33 t^{-1} and F: 0.50 t^{-1} for the combined sexes. Z, M and F were determined to be 0.64 t^{-1}, 0.35 t^{-1} and 0.29 t^{-1} for females and 0.81 t^{-1}, 0.45 t^{-1} and 0.36 t^{-1} for males. The exploitation rate (E) was calculated as 0.70, 0.44 and 0.60 for females, males and both sexes, respectively.

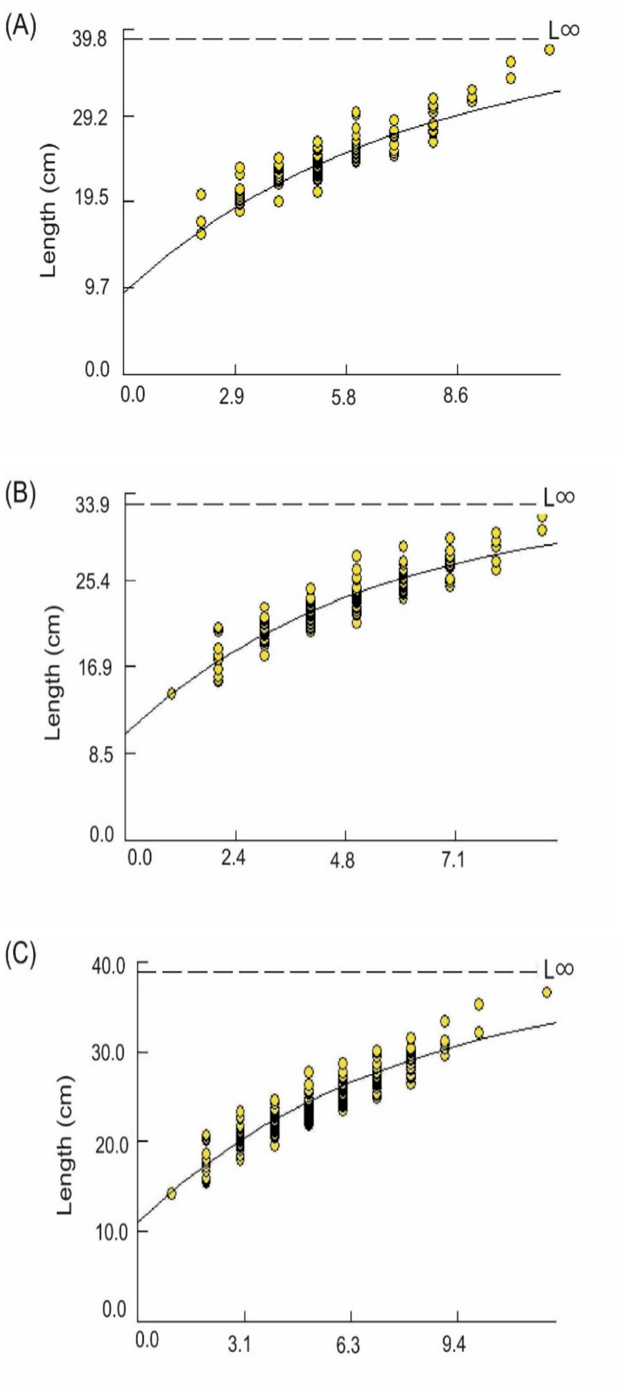

Figure 3. The growth curve of female (A), male (B) and (C) total individuals of *D. sargus*, as modelled by the von Bertalanffy equation

Mortality parameters were calculated for all individuals, yielding the following values: Z = 0.83 year^{-1}, M = 0.33 year^{-1} and F = 0.50 year^{-1} (Figure 4). Exploitation rate was ascertained at (E): 0.60. For male subjects, mortality parameters were Z: 0.81 year^{-1}, M: 0.45 year^{-1}, F: 0.36 year^{-1}, and E: 0.45. For females, the mortality parameters were calculated as Z: 0.64 year^{-1}, M: 0.35 year^{-1}, F: 0.29 year^{-1}, and E: 0.45.

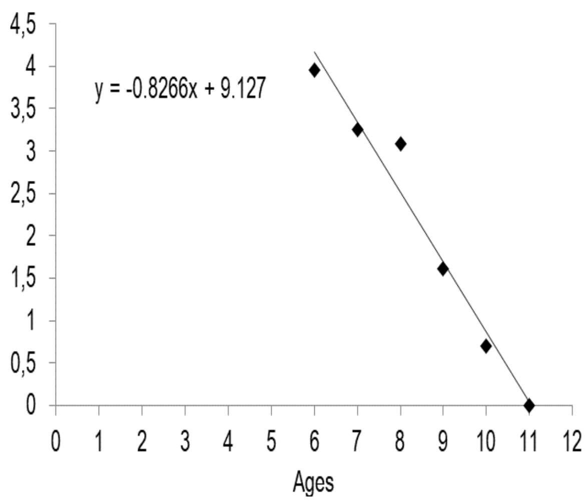

Figure 4. Total mortality-age curve of sexes combined of *D. sargus*

DISCUSSION

The b-value of the length-weight relationship for this species has been reported by various authors in different regions. Man Wai and Quignard (1982) reported a b-value of 3.123 in the Gulf of Lion, Mouine et al. (2007) found a value of 3.05 in the Central Mediterranean (Tunis), Lahlah (2004) reported a value of 2.859 in Egyptian Mediterranean waters, Mahmoud et al. (2010) found a value of 2.942 in the Abu Qir Bay of Egypt, El-Maghraby and Botros (1981) reported a value of 3.144 in the Mediterranean waters of Egypt, and Morato et al. (2003) found b value of 3.18 in the North Eastern Atlantic, Balık and Emre (2016) found that the b value is 3.1028 in the Mediterranean Sea. This study recorded b value of 2.88 in females, 2.96 in males in the Northeastern Aegean Sea (Table 4). This could be due to differences in environmental conditions, sampling methods and size range coverage. The samples primarily comprised of small individuals which could have influenced the b value of the length-weight relationship. However, our results contrast with those previously reported, which may be due to differences in the size distributions of samples taken from different habitats.

Benchalel and Kara (2013) found that the age distribution of *D. sargus* species on the east coast of Algeria ranged from 0-10 years in the length group between 12.2 cm and 34.6 cm TL, El-Maghraby and Botros (1981) found that individuals on the Egyptian coast ranged from 1-8 years of age in the length range of 6-39 cm. In this study, the TL range was 14.3-36.7 cm and the age distribution was between 1-11 years. Age distributions were similar between the studies, but it was understood that there was a smaller age distribution in the Egyptian coast in contrast to the larger length distribution. It is thought that this may be due to the difference in the method used during age reading or the faster growth on the Egyptian coast. In the study carried out in our country, Balık and Emre (2016) reported that the age distribution in the length range of 13-16 cm TL in Beymelek Lagoon was 0-3 years old. In this study, it was determined that the length of the youngest individual aged 3 years was 18.5 cm TL (Table 5). In both studies, it was observed that the majority of individuals in this length range were 2 years old. The variations of the results can be attributed to the differences in study regions, environmental variables, and the number of individuals involved. The researchers also determined the growth parameter values of the species. The discrepancy in age distribution and growth parameter values found in this study compared to other studies is attributed to the different methods employed. While many researchers used otoliths, the age determinations in this study were made from fish scales similar to Abecasis et al. (2008). The age determination from the fish scales specific to the species was easier to determine.

Table 4. The b values of length-weight relation of *D. sargus* reported for some populations living in different locations

Author	Sex	N	b	Area	Growth type
El-Maghraby and Botros (1981)			3.144	Egypt Mediterranean waters	
Man Wai and Quignard (1982)			3.123	Gulf of Lion	
Morato et al. (2003)	Male Female Total	231 446 1178	3.032 3.054 3.181	North Eastern Atlantic	I I I
Lahlah (2004)			2.859	Egyptian Mediterranean waters	
Mouine et al. (2007)	Male Female Total	37 108 247	3.129 2.994 3.051	Central Mediterranean (Gulf of Tunis)	I I A(+)
Mahmoud et al. (2010)	Total		2.942	Abu Qir Bay of Egypt	A(-)
Balık and Emre (2016)	Total	355	3.1028	Beymelek Lagoon S.W. coast of Türkiye at the Med. Sea	
This study	Female Male Total	143 176 322	2.88 2.96 2.94	NE Aegean Sea of Türkiye	A(-) A(-) A(-)

I: izometry, A(+): positive allometry, A(-): negative allometry

Table 5. The von Bertalanffy growth parameters of *D. sargus* reported for some populations living in different locations

Author	Area	Age range	Method	L_∞	K	t_0
El-Maghraby et al. (1981)	Egypt	1-8	Otolith			
Man Wai and Quignard (1982)	N/W Mediterranean	-	Otolith	46.70	0.12	-0.63
Man Wai and Quignard (1982)	Gulf of Lion	-	Otolith	45.86	0.17	-1.18
Martinez-Pastor and Villegas-Cuadros (1996)	Cantabrian Sea	1-11	Otolith	48.48	0.18	-0.06
Gordoa and Moli (1997)	N/W Mediterranean	-	Otolith	41.70	0.25	-0.08
Mann and Buxton (1997)	South Africa	-	Otolith	30.94	0.25	-1.05
Abecasis et al. (2008)	South Portugal	0-18 0-16	Otolith Scale	40.93 39.55	0.18 0.15	-0.86 -1.89
Lahlah (2004)	Egypt	-	Otolith	32.72	0.13	-1.84
Mahmoud et al. (2010)	Abu Qir Bay	0-6	Otolith	31.38	0.26	-0.73
Benchalel and Kara (2013)	Algeria	1-10	Otolith	36.39	0.15	-0.49
Balık and Emre (2016)	Mediterranean	1-3	Otolith			
This study	NE Aegean Sea	1-11	Scale	39.01		

The mortality parameters, exploitation ratio and reproductive characteristics of fishes are key elements in the consideration and control of fisheries resources. There is no data of mortality parameters and exploitation ratio of *D.sargus* in our seas. One study is represented the first sexual maturity length of the species that is 22.69 cm in females and 25.2 cm in males, respectively (Daban et al., 2023). In the communiqué issued by the Ministry of Agriculture and Forestry, which regulates commercial fishing, the minimum length of *D. sargus* species is set at 21 cm TL, that result is smaller than the first maturity length. And, in this study the mortality parameters were calculated and the exploitation rate was found as E:0.60. According to all these results it is possible to say that the species is under fishing pressure.

CONCLUSION

Understanding the biological characteristics of populations is crucial for maintaining species continuity. This research focuses on *D. sargus*, an economically important species, and investigates its age distribution, growth parameters, and mortality parameters. According to the results obtained, it is seems that the first capture length should be increased in order to ensure the continuity of the stocks. In order to reduce the fishing pressure on the species, increasing the mesh size of the gillnets, which is one of the fishing gears where selectivity can be adjusted most easily, can be effective in reducing the fishing power.

ACKNOWLEDGEMENTS AND FUNDING

This study was supported by Çanakkale Onsekiz Mart University Scientific Research Projects Commission with the project number FBA-2020-3295.

AUTHORSHIP CONTRIBUTIONS: All authors contributed to the idea and design of the study.

CONFLICT OF INTEREST STATEMENT: The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL: No specific ethical approval was necessary for this study.

DATA AVAILABILITY: For questions regarding datasets, the corresponding author should be contacted.

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Ege Journal of Fisheries and Aquatic Sciences, 41(1), 37-45 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.06

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

The list of deep-sea decapod crustaceans and new records from Sığacık Bay (Aegean Sea, Türkiye)

Sığacık Körfezi (Ege Denizi, Türkiye)'nin derin deniz dekapod tür listesi ve körfezden yeni kayıtlar

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Received date:18.10.2023 *Accepted date: 15.02.2024*

How to cite this paper:
Koçak, C. (2024). The list of deep-sea decapod crustaceans and new records from Sığacık Bay (Aegean Sea, Türkiye). *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 37-45. https://doi.org/10.12714/egejfas.41.1.06

Abstract: Decapod crustaceans were sampled monthly from May 2008 to April 2009 using a commercial trawl vessel at depths between 292 and 550 m from Sığacık Bay. 16 species were identified, of which 3 are Brachyura, 5 Caridea, 3 Dendrobranchiata, 1 Polychelida, 1 Astacidea, 3 Anomura. Of these, 4 species (*Bathynectes maravigna*, *Munida intermedia*, *Pontophilus spinosus*, and *Processa canaliculata*) are new records for Sığacık Bay. Furthermore, all of the previous studies were reviewed on the deep-sea decapod crustaceans of Sığacık Bay, depth range of each species is given.

Keywords: Decapoda, deep-sea, *Bathynectes maravigna*, *Munida intermedia*, *Pontophilus spinosus*, *Processa canaliculata*

Öz: Sığacık Körfezi'nden dekapod krustase örnekleri Mayıs 2008'den Nisan 2009'a kadar ticari trol teknesi kullanılarak 292 ve 550 m derinlikler arasından aylık olarak toplanmıştır. 3 Brachyura, 5 Caridea, 3 Dendrobranchiata, 1 Polychelida, 1 Astacidea, 3 Anomura olmak üzere 16 tür tespit edilmiştir. Tespit edilen türlerden 4'ü (*Bathynectes maravigna*, *Munida intermedia*, *Pontophilus spinosus* ve *Processa canaliculata*) Sığacık Körfezi'nden ilk kez rapor edilmektedir. Ayrıca, Sığacık Körfezi'nin derin deniz dekapod krustasea faunası üzerine daha önce yapılmış çalışmaların tümü gözden geçirilmiş, her bir türün derinlik aralığı verilmiştir.

Anahtar kelimeler: Dekapoda, derin deniz, *Bathynectes maravigna*, *Munida intermedia*, *Pontophilus spinosus*, *Processa canaliculata*

INTRODUCTION

Decapod crustaceans form an important part of the marine ecosystem because of their importance on the benthic biomass and activities in the food chain. They are one of the most dominant megafauna communities in the deep sea basin (Sarda et al.,1994).

In the most recent checklist compiled for the Turkish Seas (Bakır et al., 2014), the number of decapod crustacean species is given as 216 for the Aegean Sea coast of Türkiye and 259 in total for the Turkish Seas (given in the study *Monodaeus guinotae* Forest, 1976 is accepted as *M. couchii* (Couch, 1851) (WoRMS, 2023). The authors stated in their study that, 9 of these species (*Dorhynchus thomsoni* Thomson, 1873, *Geryon longipes* A. Milne-Edwards, 1882, *Monodaeus couchii* (Couch, 1851) (given as *Monodaeus guinotae* Forest, 1976 in the study), *Plesionika acanthonotus* (Smith, 1882), *P. martia* (A. Milne-Edwards, 1883), *Amalopenaeus elegans* Smith, 1882 (given under the name *Gennadas elegans* (Smith, 1882) in the study), *Munida tenuimana* Sars, 1872, *Richardina fredericii* Lo Bianco, 1903), also given from the Turkish Aegean Sea, were found at depths of more than 600 m.

In the Aegean coasts of Türkiye, the first study on the deep-sea decapod crustacean species (Katağan et al., 1988) recorded 13 species. In a later study by Kocataş and Katağan (2003), 7 decapod crustacean species were reported from the deep waters of Turkish Aegean Sea. Then Koçak and Katağan (2008) recorded 5 deep-sea decapod crustacean species. Besides these studies, Özcan et al. (2009a) and Gönülal et al. (2014) reported 1 and 3 species, respectively, from the region. Subsequently, an anomuran species, *Galathea bolivari* Zariquiey Álvarez, 1950, was reported from the deep waters of the Turkish Aegean by Gönülal and Dalyan (2017), although this species has been described in various studies as a species distributed in shallow waters (i.e. Geldiay and Kocataş, 1970; Noël, 1992; Falciai and Minervini, 1996; Koçak and Katağan, 2008).

Sığacık Bay located in the Central Aegean Sea is one of the most efficient trawling grounds in the Aegean Sea. The bay is an important commercial fishing area for deep-sea decapod crustaceans. The national waters of Sığacık Bay, lying between 100 and 550 m deep, are extensively fished by trawling. Shrimps are the most important bathyal resource here.

Several studies were present on the deep-sea decapod crustaceans of Sığacık Bay (Koçak et al., 2008, Özcan and Katağan 2009, Koçak, 2010, Özcan and Katağan 2011, Aydın and Aydın, 2011, Koçak et al., 2012, Oraner et al., 2018, Dereli et al., 2021). In the research area, Koçak et al. (2008) reported 1 anomuran species. In a later study by Özcan and Katağan (2009), which is the only comprehensive study to date on deep-sea decapod crustaceans of Sığacık Bay, recorded 21 species, of which 10 are Brachyura, 5 Caridea, 2 Dendrobranchiata, 1 Astacidea, 1 Polychelida, 2 Anomura. Since then, 1 Brachyura by Koçak (2010), 1 Caridea by Koçak et al. (2012), and 1 Dendrobranchiata by Dereli et al. (2021) were recorded from the same area. The goal of the present study was a faunistic study of the deep-sea decapod crustaceans of Sığacık Bay.

MATERIALS AND METHODS

Sampling surveys are performed monthly from May 2008 to April 2009 using a commercial bottom trawl (44-mm nominal mesh size, PE netting at the codend) in Sığacık Bay, Aegean Sea (from 38°05'13"N, 26°35'08"E to 37°59'27"N, 26°54'47"E) (Figure 1, Table 1). A total of 24 hauls are taken at depths between 292 and 550 m. The trawling speed fluctuated from 2.3 to 2.6 knots, depending on the nature of the substrate. Each haul usually lasted 1 hour, but several hauls lasted between half an hour to 1.5 hours (Table 1). All hauls are performed in daylight. The specimens were fixed in 5% formaldehyde. Carapace length (CL) and total length (TL) were measured with digital calipers to the nearest 0.01 mm.

All decapod crustaceans are determined to species level using the studies by Zariquiey Álvarez (1968), Noël 1992, Ingle (1993), and Falciai and Minervini (1996). In addition, WoRMS (2024) is considered for synonyms of the species and also variations in the nomenclature.

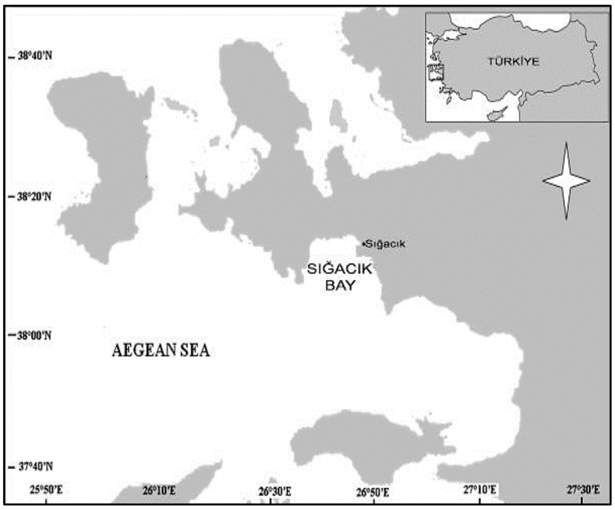

Figure 1. Map of the study area

Table 1. Information on bottom trawl surveys carried out in Sığacık Bay

Date	Depth (m)		Time		Coordinates	
	Start	Finish	Start	Finish	Start	Finish
28.05.2008	320	344	11:25	12:25	37°59'93"N 26°44'82"E	38°00'98"N 26°41'72"E
	526	550	13:45	14:45	37°55'51"N 26°40'85"E	37°55'08"N 26°43'69"E
19.06.2008	319	343	11:40	12:40	37°59'93"N 26°44'82"E	38°09'98"N 26°41'72"E
	526	500	13:55	14:55	37°55'51"N 26°40'85"E	37°55'08"N 26°43'69"E
12.07.2008	494	539	08:40	09:40	37°55'81"N 26°39'36"E	37°54'34"N26°41'11"E
	350	292	11:00	12:00	37°59'03"N 26°44'09"E	38°01'39"N 26°43'32"E
16.08.2008	316	366	09:10	10:10	37°59'83"N 26°45'54"E	38°00'57"N 26°42'19"E
	512	512	11:10	12:10	37°56'70"N 26°39'19"E	37°54'70"N 26°42'92"E
13.09.2008	310	347	09:50	10:50	37°59'84"N 26°44'96"E	38°00'63"N 26°41'48"E
	512	550	12:10	13:45	37°56'14"N 26°39'81"E	37°54'92"N 26°44'20"E
15.10.2008	530	545	07:15	08:15	37°55'28"N 26°41'38"E	37°54'86"N 26°43'75"E
	342	320	09:30	10:30	37°59'82"N 26°43'95"E	38°01'09"N 26°41'75"E
08.11.2008	520	550	06:40	08:10	37°55'11"N 26°42'35"E	37°56'31"N 26°38'25"E
	360	320	09:25	10:25	38°00'43"N 26°42'34"E	37°59'80"N 26°45'35"E
20.12.2008	495	510	09:50	10:20	37°55'10"N 26°42'74"E	37°56'00"N 26°38'65"E
	360	330	12:30	13:30	38°00'13"N 26°41'76"E	38°00'33"N 26°44'99"E
17.01.2009	520	550	07:18	08:40	37°56'09"N 26°39'73"E	37°54'96"N 26°43'65"E
	350	350	09:55	10:55	37°59'41"N 26°43'94"E	38°00'75"N 26°41'96"E
17.02.2009	520	550	07:10	08:40	37°55'07"N 26°43'06"E	37°55'99"N 26°39'12"E
	360	310	09:50	10:50	38°00'25"N 26°41'55"E	38°00'18"N 26°44'56"E
28.03.2009	500	530	12:05	13:35	37°54'96"N 26°43'23"E	37°56'10"N 26°39'70"E
	350	335	14:50	15:50	37°59'47"N 26°43'83"E	38°01'12"N 26°41'84"E
24.04.2009	350	335	08:25	09:25	37°59'99"N 26°45'84"E	38°00'00"N 26°41'71"E
	550	550	10:30	12:00	37°56'19"N 26°40'67"E	37°55'02"N 26°43'49"E

RESULTS

The bathyal trawling surveys in Sığacık Bay revealed 16 deep-sea decapod crustacean species, of which 3 are Anomura (*Pagurus prideaux* Leach, 1815*, Iridonida speciosa* (von Martens, 1878), *Munida intermedia* A. Milne-Edwards and Bouvier, 1899), 3 Brachyura (*Bathynectes maravigna* (Prestandrea, 1839), *Inachus parvirostris* (Risso, 1816), *Macropipus tuberculatus* (Roux, 1830), 1 Astacidea (*Nephrops norvegicus* (Linnaeus, 1758), 1 Polychelida (*Polycheles typhlops* Heller, 1862), 3 Dendrobranchiata (*Aristeomorpha foliacea* (Risso, 1827), *Parapenaeus longirostris* (Lucas, 1846), *Solenocera membranacea* (Risso, 1816), 5 Caridea (*Plesionika heterocarpus* (A. Costa, 1871), *P. martia* (A. Milne-Edwards, 1883), *Aegaeon lacazei* (Gourret, 1887), *Pontophilus spinosus* (Leach, 1816), *Processa canaliculata* Leach, 1815). Of these, 4 species (*M. intermedia, B. maravigna, P. spinosus, P. canaliculata*) newly recorded for the region. As a result of studies carried out in order to review the deep-sea decapod crustacean fauna of the Sığacık Bay, indicating the presence of 24 species inhabiting the Bay, of which 2 are Anomura, 6 Caridea, 3 Dendrobranchiata, 11 Brachyura, 1 Astacidea, 1 Polychelida.

The present study raises this species number, to 28, with the addition of the 4 new records.

Systematics

ANOMURA

SUPERFAMILY: GALATHEOIDEA SAMOUELLE, 1819

FAMILY: MUNIDIDAE AHYONG, BABA, MACPHERSON and POORE, 2010

GENUS: *MUNIDA* LEACH, 1820

***Munida intermedia* A. Milne-Edwards and Bouvier, 1899**

Synonyms: *Munida bamffia* (Pennant, 1777) *sensu* Bonnier, 1888 (part); *Munida bamffica* (Pennant, 1777) *sensu* Bouvier, 1940; *Munida bamffica tenuimana* Sars, 1872 *sensu* Bouvier, 1940; *Munida bamffica var. gracilis* A. Milne-Edwards and Bouvier, 1899; *Munida bamffica var. intermedia* A. Milne-Edwards and Bouvier, 1899; *Munida sarsi meridionalis* Zariquiey Álvarez, 1952

This is the first record of *M. intermedia* from Sığacık Bay. This species was recorded for the first time in Turkish seas by Katağan et al. (1988) in the Saros Bay (Aegean Sea) at a depth of 520 m in a muddy biotope. Sex was determined under a stereo microscope by observing the condition of the gonophores; in the coxa of the third pereiopod in females or the coxa of the fifth pereiopod in males.

Habitat: Muddy bottom.

Depth range: 300-400 m

Worldwide Distribution: Eastern Atlantic, Mediterranean (d'Udekem d'Acoz, 1999)

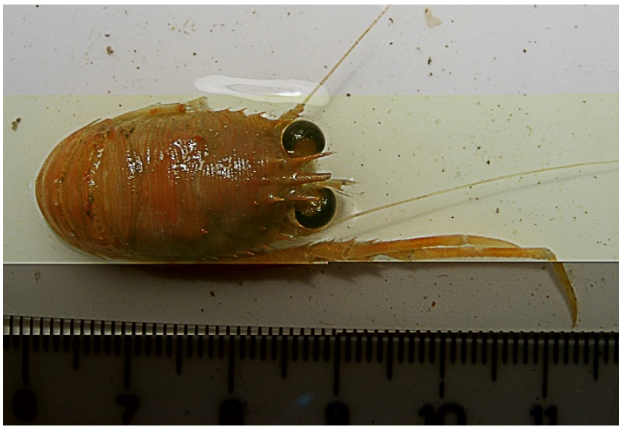

Figure 2. *Munida intermedia* A. Milne-Edwards and Bouvier, 1899 ♀, Sığacık Bay (dorsal view). CL (without rostrum): 15.3 mm

GENUS: *IRIDONIDA* MACPHERSON & BABA *IN* MACHORDOM, AHYONG, ANDREAKIS, BABA, BUCKLEY, GARCIA-JIMENEZ, MCCALLUM, RODRIGUEZ-FLORES & MACPHERSON, 2022

***Iridonida speciosa* (von Martens, 1878)**

Synonyms: *Munida iris* A. Milne Edwards, 1880 sensu A. Milne Edwards and Bouvier, 1900; *Munida iris rutllanti* Zariquiey Álvarez, 1952; *Munida rutllanti* Zariquiey Álvarez, 1952; *Munida speciosa* von Martens, 1878

This species (as *Munida rutllanti*) was reported by Kocak et al. (2008), Özcan and Katağan (2009; 2011) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Eastern Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

SUPERFAMILY: PAGUROIDEA LATREILLE, 1802

FAMILY: PAGURIDAE LATREILLE, 1802

GENUS: *PAGURUS* FABRICIUS, 1775

***Pagurus prideaux* Leach, 1815**

Synonyms: *Pagurus pridauxii* Leach, 1815; *Pagurus prideauxi* Leach, 1815; *Pagurus solitarius* Risso, 182

P. prideaux was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-300 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

BRACHYURA

SUPERFAMILY: PORTUNOIDEA RAFINESQUE, 1815

FAMILY: POLYBIIDAE ORTMANN, 1893

GENUS: *BATHYNECTES* STIMPSON, 1871

***Bathynectes maravigna* (Prestandrea, 1839)**

Synonyms: *Bathynectes superba* (Costa, 1853); *Portunus maravigna* Prestandrea, 1839; *Portunus superbus* Costa, 1853; *Thranites velox* Bovallius, 1876

B. maravigna is new record for Sığacık Bay. *B. maravigna* was recorded for the first time in Turkish seas by Kocataş and Katağan (2003) in Aegean Sea at a depth of 720 m in a silty substratum. Sex was identified by observing the characteristic shape of the abdomen (triangular in males, circular in females) and the appearance of the first two pairs of pleopods (developed into gonopods in males).

Habitat: Sandy-muddy bottom.

Depth range: 500-600 m

Worldwide Distribution: Eastern Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

Figure 3. *Bathynectes maravigna* (Prestandrea, 1839) ♂, Sığacık Bay (dorsal view). CL: 41.6 mm

GENUS *MACROPIPUS* PRESTANDREA, 1833

***Macropipus tuberculatus* (Roux, 1830)**

Synonyms: *Macropipus citrinus Cocco,* 1832; *Macropipus citrinus Prestandrea,* 1833; *Portunus macropipus Cocco,* 1832; *Portunus macropipus Prestandrea,* 1833; *Portunus tuberculatus* Roux, 1830

The species was reported by Özcan and Katağan (2009; 2011) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

SUPERFAMILY: CALAPPOIDEA DE HAAN, 1833

FAMILY: CALAPPIDAE DE HAAN, 1833

GENUS *CALAPPA* WEBER, 1795

***Calappa granulata* (Linnaeus, 1758)**

Synonyms: *Calappa tuerkayana* Pastore, 1996; *Calappa turkayana* Pastore, 1995; *Calappe granulata* (Linnaeus, 1758); *Cancer granulata* Linnaeus, 1758

C. granulata was recorded by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

SUPERFAMILY: GONEPLACOIDEA MACLEAY, 1838

FAMILY: GONEPLACIDAE MACLEAY, 1838

GENUS *GONEPLAX* LEACH, 1814

***Goneplax rhomboides* (Linnaeus, 1758)**

Synonyms: *Cancer angulata* Pennant, 1777; *Cancer rhomboides* Linnaeus, 1758; *Gelasimus Bellii* J Couch, 1838; *Goneplax angulata* (Pennant, 1777); *Goneplax rhomboidalis* Risso, 1827; *Gonoplax angulata* (Pennant, 1777); *Gonoplax rhomboides* (Linnaeus, 1758); *Ocypoda bispinosa* Lamarck, 1801; *Ocypoda unispinosa* Rafinesque, 1814; *Ocypode longimana* Latreille, 1803

It was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

SUPERFAMILY: MAJOIDEA SAMOUELLE, 1819

FAMILY: INACHIDAE MACLEAY, 1838

GENUS *MACROPODIA* LEACH, 1814

***Macropodia tenuirostris* (Leach, 1814)**

Synonyms: *Leptopodia tenuirostris* Leach, 1814; *Macropodia longipes* (A. Milne-Edwards and Bouvier, 1899); *Stenorhynchus longipes* A. Milne-Edwards and Bouvier, 1899; *Stenorhynchus longipes* A. Milne-Edwards and Bouvier, 1894

This species was recorded by Özcan and Katağan (2009) from Sığacık Bay under the name *Macropodia longipes*.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

Macropodia rostrata

Synonyms: *Cancer rostrata* Linnaeus, 1761; *Cancer rostratus* Linnaeus, 1761; *Macropodia parva* Van Noort and Adema, 1985; *Macropodia spinulosa* (Miers, 1881); *Stenorhynchus inermis* Heller, 1856; *Stenorhynchus rostratus* (Linnaeus, 1761); *Stenorhynchus rostratus var. spinulosus* Miers, 1881

M. rostrata was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-300 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

GENUS: *INACHUS* WEBER, 1795

***Inachus parvirostris* (Risso, 1816)**

Synonyms: *Doclea fabriciana* Risso, 1827; *Macropus parvirostris* Risso, 1816

The species was reported Kocak (2010) from Sığacık Bay.

Depth range: 300-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

SUPERFAMILY: DORIPPOIDEA MACLEAY, 1838

FAMILY: DORIPPIDAE MACLEAY, 1838

GENUS: *MEDORIPPE* MANNING & HOLTHUIS, 1981

***Medorippe lanata* (Linnaeus, 1767)**

Synonyms: *Cancer lanatus* Linnaeus, 1767; *Dorippe affinis* Desmarest, 1823; *Dorippe lanata* (Linnaeus, 1767)

It was recorded by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

SUPERFAMILY: PARTHENOPOIDEA MACLEAY, 1838

FAMILY: PARTHENOPIDAE MACLEAY, 1838

GENUS: *SPINOLAMBRUS* TAN & NG, 2007

***Spinolambrus macrochelos* (Herbst, 1790)**

Synonyms: *Cancer macrochelos* Herbst, 1790; *Eurynome aldrovandi* Risso, 1827; *Lambrus macrochelos* (Herbst, 1790); *Lambrus mediterraneus* Roux, 1828; *Lambrus Miersii* A. Milne-Edwards and Bouvier, 1898; *Lambrus spinosissimus* Osório, 1923; *Parthenope humbertii* Costa, 1838; *Parthenope macrochelos* (Herbst, 1790); *Parthenope miersii* (A. Milne-Edwards and Bouvier, 1898)

This species (as *Parthenope macrochelos*) was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-300 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

GENUS*: PARTHENOPOIDES* MIERS, 1879

***Parthenopoides massena* (Roux, 1830)**

Synonyms: *Lambrus (Parthenopoides) bicarinatus* Miers, 1881; *Lambrus (Parthenopoides) massena* (Roux, 1830); *Lambrus (Parthenopoides) massena* var. *atlanticus* Miers, 1881; *Lambrus (Parthenopoides) massena* var. *goreensis* Miers, 1881; *Lambrus (Parthenopoides) massena* var. *spinifer* Miers, 1881; *Lambrus hexacanthus* A. Costa in Hope, 1851; *Lambrus massena* Roux, 1830; *Lambrus rugosus* Stimpson, 1857; *Lambrus setubalensis* de Brito Capello, 1866; *Parthenope contracta* OG Costa and A Costa, 1840; *Parthenope massena* (Roux, 1830)

P. massena was reported by Özcan and Katağan (2009) from Sığacık Bay under the name *Parthenope massena*.

Depth range: 300-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

SUPERFAMILY: PILUMNOIDEA SAMOUELLE, 1819

FAMILY: PILUMNIDAE SAMOUELLE, 1819

GENUS: *PILUMNUS* LEACH, 1816

***Pilumnus hirtellus* (Linnaeus, 1761)**

Synonyms: *Cancer hirtellus* Linnaeus, 1761

The species was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 200-300 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

SUPERFAMILY: XANTHOIDEA MACLEAY, 1838

FAMILY: XANTHIDAE MACLEAY, 1838

GENUS: *XANTHO* LEACH, 1814

***Xantho pilipes* A. Milne-Edwards, 1867**

Synonyms: -

It was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 300-400 m.

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

CARIDEA

SUPERFAMILY: PROCESSOIDEA ORTMANN, 1896

FAMILY: PROCESSIDAE ORTMANN, 1896

GENUS: *PROCESSA* LEACH, 1815

***Processa canaliculata* Leach, 1815**

Synonyms: *Nika cannelata* Griffith and Pidgeon, 1833; *Nika couchii* Bell, 1847; *Nika edulis* var. *britannica* Czerniavsky, 1884; *Nika edulis* var. *mediterranea* (Parisi, 1915); *Nika mediterranea* Parisi, 1915; *Processa mediterranea* (Parisi, 1915); *Processa prostatica* Zariquiey Cenarro, 1941

P. canaliculata is recorded for the first time from Sığacık Bay. This species was recorded for the first time in Turkish seas by

Santucci (1928) from Aegean Sea. Sex was determined by the presence (males) and absence (females) of an appendix masculina on the second pleopod.

Habitat: Sandy-muddy bottom.

Depth range: 500-600 m

Worldwide Distribution: Eastern Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

Figure 4. *Processa canaliculata* Leach, 1815 ♀, Sığacık Bay (lateral view). TL: 64.2 mm

SUPERFAMILY: CRANGONOIDEA HAWORTH, 1825

FAMILY: CRANGONIDAE HAWORTH, 1825

GENUS: *PONTOPHILUS* LEACH, 1817

***Pontophilus spinosus* (Leach, 1816)**

Synonyms: *Crangon spinosus* Leach, 1816

The present report represents a new record for *P. spinosus* from Sığacık Bay. The species was recorded for the first time in Turkish seas by Adensamer (1898) from Aegean Sea. Sex determination was made by the same method as for *P. canaliculata*.

Habitat: Muddy bottom.

Depth range: 300-400 m

Worldwide Distribution: Eastern Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

Figure 5. *Pontophilus spinosus* (Leach, 1816) ♂, Sığacık Bay (lateral view). CL: 11.7 mm TL: 48.3 mm

GENUS *AEGAEON* AGASSIZ, 1846

***Aegaeon lacazei* (Gourret, 1887)**

Synonyms: *Aegeon brendani* Kemp, 1906; *Aegeon lacazei* (Gourret, 1887); *Crangon lacazei* Gourret,1887; *Pontocaris habereri* Doflein, 1902; *Pontocaris lacazei* (Gourret, 1887)

This species was reported by Özcan and Katağan (2009, 2011) from Sığacık Bay.

Depth range: 300-600 m

Worldwide Distribution: Atlantic, Mediterranean, Indo-Pacific (d'Udekem d'Acoz, 1999).

SUPERFAMILY: PANDALOIDEA HAWORTH, 1825

FAMILY: PANDALIDAE HAWORTH, 1825

GENUS: *CHLOROTOCUS* A. MILNE-EDWARDS, 1882

***Chlorotocus crassicornis* (Costa, 1871)**

Synonyms: *Chlorotocus gracilipes* A. Milne-Edwards, 1882; *Chlorotocus gracilipes var. andamanensis* Alcock and Anderson, 1899; *Chlorotocus incertus* Spence Bate, 1888; *Palemon chlorotocus* Filhol, 1885; *Pandalus crassicornis* A. Costa, 1871

C. crassicornis was reported by Özcan and Katağan (2009, 2011) from Sığacık Bay

Depth range: 300-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

GENUS: *PLESIONIKA* SPENCE BATE, 1888

***Plesionika narval* (Fabricius, 1787)**

Synonyms: *Astacus narval* Fabricius, 1787; *Nisea formosa* Risso, 1844; *Palaemon tarentinum* O.G. Costa, 1844; *Palemon pristis* Risso, 1816; *Pandalus escatilis* Stimpson, 1860; *Pandalus narwal* (Fabricius, 1787); *Pandalus stylopus* A. Milne-Edwards, 1883; *Parapandalus narval* (Fabricius, 1787)

This species was reported by Özcan and Katağan (2009) from Sığacık Bay as *Parapandalus narval*.

Depth range: 300-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

***Plesionika heterocarpus* (A. Costa, 1871)**

Synonyms: *Pandalus heterocarpus* A. Costa, 1871; *Pandalus longicarpus* A. Milne-Edwards, 1883; *Pandalus sagittarius* A. Milne-Edwards, 1883

The species was reported by Özcan and Katağan (2009, 2011), Oraner et al. (2018), and Dereli et al. (2021) from Sığacık Bay.

Depth range: 200-600 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

***Plesionika martia* (A. Milne-Edwards, 1883)**

Synonyms: *Pandalus martius* A. Milne-Edwards, 1883; *Plesionika (Pandalus) sicherii* Riggio, 1900; *Plesionika martia martia* (A. Milne-Edwards, 1883)

It was reported by Koçak et al. (2012) and Dereli et al. (2021) from Sığacık Bay.

Depth range: 400-600 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

DENDROBRANCHIATA

SUPERFAMILY: PENAEOIDEA RAFINESQUE, 1815

FAMILY: PENAEIDAE RAFINESQUE, 1815

GENUS: *PARAPENAEUS* SMITH, 1885

***Parapenaeus longirostris* (Lucas, 1846)**

Synonyms: *Penaeus bocagei* Johnson, 1863; *Penaeus lividus* Filhol, 1885; *Penaeus longirostris* Lucas, 1846; *Peneus cocco* Prestandrea, 1833

P. longirostris was reported by Özcan and Katağan (2009, 2011), and Dereli et al. (2021) from Sığacık Bay.

Depth range: 200-600 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

FAMILY: ARISTEIDAE WOOD-MASON *IN* WOOD-MASON & ALCOCK, 1891

GENUS: *ARISTAEOMORPHA* WOOD-MASON IN WOOD-MASON & ALCOCK, 1891

***Aristaeomorpha foliacea* (Risso, 1827)**

Synonyms: *Aristaeomorpha giglioliana* Wood-Mason, 1892; *Aristaeomorpha mediterranea* Adensamer, 1898; *Aristaeomorpha rostridentata* (Spence Bate, 1888); *Aristeomorpha foliacea* (Risso, 1827); *Aristeus japonicus* Yokoya, 1933; *Aristeus rostridentatus* Spence Bate, 1881 *Penaeus meridionalis* Hope, 1851; *Peneus foliacea* Risso, 1827

This species was reported by Dereli et al. (2021) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean, Indo-Pacific (d'Udekem d'Acoz, 1999).

FAMILY: SOLENOCERIDAE WOOD-MASON *IN* WOOD-MASON & ALCOCK, 1891

GENUS: *SOLENOCERA* LUCAS, 1849

***Solenocera membranacea* (Risso, 1816)**

Synonyms: *Penaeus carinatus* Otto, 1821; *Penaeus distinctus* De Haan, 1849; *Penaeus membranaceus* Risso, 1816; *Penaeus siphonoceros* Philippi, 1840; *Peneus siphonoceros* Philippi, 1840; *Solenocera philippii* Lucas, 1849

S. membranacea was recorded by Özcan and Katağan (2009, 2011) from Sığacık Bay.

Depth range: 200-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

SUPERFAMILY: PASIPHAEOIDEA DANA, 1852

FAMILY: PASIPHAEIDAE DANA, 1852

GENUS: *PASIPHAEA* SAVIGNY, 1816

***Pasiphaea sivado* (Risso, 1816)**

Synonyms: *Alpheus sivado* Risso, 1816; *Pasiphaea brevirostris* H. Milne Edwards, 1837; *Pasiphaea distincta* Guérin-Méneville, 1844; *Pasiphaea neapolitana* Hope, 1851; *Pasiphaea savignyi* H. Milne Edwards, 1837

The species was reported by Özcan and Katağan (2009) from Sığacık Bay.

Depth range: 400-600 m

Worldwide Distribution: Atlantic, Mediterranean (d'Udekem d'Acoz, 1999).

ASTACIDEA

SUPERFAMILY: NEPHROPOIDEA DANA, 1852

FAMILY: NEPHROPIDAE DANA, 1852

GENUS: *NEPHROPS* LEACH, 1814

***Nephrops norvegicus* (Linnaeus, 1758)**

Synonyms: *Astacus rugosus* Rafinesque, 1814; *Cancer norvegicus* Linnaeus, 1758; *Nephrops norvegicus var. meridionalis* Zariquey Cenarro, 1935; *Nephrops norwegicus* (Linnaeus, 1758); *Nephropsis cornubiensis* Spence Bate and Brooking Rowe, 1880

N. norvegicus was reported by Özcan and Katağan (2009, 2011), Aydın and Aydın (2011), and Dereli et al. (2021) from Sığacık Bay.

Depth Range: 200-600 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

POLYCHELIDA

SUPERFAMILY: ERYONOIDEA DE HAAN, 1841

FAMILY: POLYCHELIDAE WOOD-MASON, 1874

GENUS: *POLYCHELES* HELLER, 1862

***Polycheles typhlops* Heller, 1862**

Synonyms: *Eryoneicus Kempi* Selbie, 1914*; Pentacheles Agassizii* A. Milne-Edwards, 1880; *Pentacheles Hextii* Alcock, 1894; *Polycheles doderleini* Riggio, 1895; *Polycheles hextii* (Alcock, 1894); *Polycheles typhlops typhlops* Heller, 1862; *Stereomastis artuzi* Artüz, Kubanç and Kubanç, 2014

The species was recorded by Özcan and Katağan (2009) from Sığacık Bay under the name *Polycheles typhlops typhlops*.

Depth Range: 300-400 m

Worldwide Distribution: Atlantic, Mediterranean (Falciai and Minervini, 1996).

DISCUSSION

In the present study, 16 deep-sea decapod crustaceans were determined from the Sığacık Bay, 5 of which belong to the Caridea, 3 to the Brachyura, 3 to the Dendrobranchiata, 1 to the Polychelida, 1 to the Astacidea, and 3 to the Anomura. Among these, 4 species (*Bathynectes maravigna*, *Munida intermedia*, *Processa canaliculata*, and *Pontophilus spinosus*) were new records for Sığacık Bay. *B. maravigna* was reported by Kocataş and Katağan (2003) from Aegean Sea coasts of Türkiye; and by Özcan et al. (2009b), Deval and Froglia (2016) and Deval et al. (2017) from the Mediterranean coasts of Türkiye. Previous records of *M. intermedia* from Turkish seas were only from Aegean Sea coasts of Türkiye (Katağan et al., 1988; Koçak et al., 2001; Kocataş and Katağan, 2003; Gönülal et al., 2014). *P. canaliculata* was previously reported by Müller (1986) from Sea of Marmara; by Santucci (1928) from the Aegean Sea coasts of Türkiye; by Kocataş and Katağan (2003), and Gönülal and Dalyan (2017) from the Mediterranean coasts of Türkiye. *P. spinosus* was reported by Adensamer (1898) and Kocataş and Katağan (2003) only from the Turkish Aegean Sea coasts.

In Özcan and Katağan (2009) 21 species are reported from Sığacık Bay, of which 5 are Caridea (*Aegaeon lacazei*, *Chlorotocus crassicornis*, *Plesionika narval* (as *Parapandalus narval*), *P. heterocarpus*, *Pasiphaea sivado*), 2 Dendrobranchiata (*Parapenaeus longirostris*, *Solenocera membranacea*), 10 Brachyura (*Calappa granulata, Goneplax rhomboides, Macropipus tuberculatus, Macropodia tenuirostris* (as *M. longipes*)*, M. rostrata, Medorippe lanata, Spinolambrus macrochelos* (as *Parthenope macrochelos*)*, Parthenopoides massena* (as *Parthenope massena*)*, Pilumnus hirtellus, Xantho pilipes*), 1 Astacidea (*Nephrops norvegicus*), 1 Polychelida (*Polycheles typhlops (as Polycheles typhlops typhlops*)), 2 Anomura (*Iridonida speciosa* (as *Munida rutllanti*), *Pagurus prideaux*). Among these, 9 were also recorded in the present study (*A. lacazei*, *P. longirostris*, *S. membranacea*, *P. heterocarpus*, *M. tuberculatus*, *N. norvegicus*, *P. typhlops*, *I. speciosa*, *P. prideaux*). Since then 3 more deep-sea decapod crustacean species have been reported from Sığacık Bay (*Inachus parvirostris* (Kocak, 2010), *Plesionika martia* (Koçak et al., 2012) and *Aristaeomorpha foliacea* (Dereli et al., 2021). The contributions increased the total number of deep-sea decapod crustacean species found in Sığacık Bay to 24.

CONCLUSION

In the present study, *Bathynectes maravigna*, *Munida intermedia*, *Pontophilus spinosus* and *Processa canaliculata* are the first record from Sığacık Bay. With these species, the total number of deep-sea decapod crustacean species in Sığacık Bay is raised from 24 to 28.

ACKNOWLEDGEMENTS AND FUNDING

I want to express my gratitude to Dr Zafer Tosunoğlu (Ege University, İzmir) who collected the specimens.

AUTHORSHIP CONTRIBUTIONS

Single author.

CONFLICT OF INTEREST STATEMENT

The author declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

All relevant data is in the article.

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Ege Journal of Fisheries and Aquatic Sciences, 41(1), 46-53 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.07

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Distribution of the critically endangered fan mussel *Pinna nobilis* population in the Çanakkale Strait and Marmara Sea

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Received date: 05.01.2024 *Accepted date: 17.02.2024*

How to cite this paper:
Acarlı, S., Acarlı, D., & Kale, S. (2024). Distribution of the critically endangered fan mussel *Pinna nobilis* population in the Çanakkale Strait and Marmara Sea. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 46-53. https://doi.org/10.12714/egejfas.41.1.07

Abstract: This study was conducted with the primary objective of determining the presence of both healthy and impacted *Pinna nobilis* populations along the European coasts of the Sea of Marmara, followed by the identification of *P. nobilis* abundance and survival rates in the region encompassing the Çanakkale Strait and the southern coasts of the Sea of Marmara. Underwater surveys were randomly conducted at 19 distinct stations, including 8 stations along the European coasts of the Sea of Marmara, 7 stations along the southern coasts of the Sea of Marmara, and 6 stations within the Çanakkale Strait. SCUBA diving equipment was utilized to record information on habitat structure, water temperature, depth, and visibility at each station. The transect length during underwater surveys and the number of transects at each station were determined based on the condition of the seabed and the size of the area, respectively. Throughout the study period (September 2021 and October 2023), water temperature fluctuated between 17.5°C and 26.6°C. At the end of the study, a total of 395 individuals (147 live, 248 dead) were observed, with live individuals exhibiting total lengths ranging from 16.4 cm to 50.9 cm. This study represents the first investigation into the spatial distribution of *P. nobilis* along the European coast of the Marmara Sea. The study contributes significantly to enhancing our understanding of the ecology of *P. nobilis* populations in both the Sea of Marmara and the Çanakkale Strait. Additionally, recommendations for the rehabilitation of impacted populations and the conservation of healthy populations have been provided for decision-makers and fisheries managers.

Keywords: *Pinna nobilis*, survival, density, conservation, mortality, attachment

INTRODUCTION

Pinna nobilis Linnaeus 1758 is endemic to the Mediterranean and exhibits a fan-shaped morphology, reaching lengths of up to 120 cm (Zavodnik et al., 1991). Found in seagrass meadows (*Posidonia oceanica* and *Cymodocea nodosa*) within sandy, sandy-muddy, and gravelly areas, these organisms partially embed themselves into the substrate from the umbo region, securing their attachment to the substrate through byssus threads (Tebble, 1966; Zavodnik et al., 1991; Acarli et al., 2011; Hendriks et al., 2011; Prado et al., 2014; Kurtay et al., 2018). Owing to its carbonate-hardened surface, *P. nobilis* provides a habitat for numerous substrate-dependent species (Acarlı et al., 2010).

P. nobilis possesses the ability to filter water, contributing to the quality of the surrounding water by reducing organic and inorganic material through its filtration process (Vicente et al., 2002; Basso et al., 2015; Natalotto et al., 2015). Furthermore, it is hypothesized to have the capacity to regulate regional water characteristics (Trigos et al., 2014). In laboratory conditions, individuals with a length of 30 cm have been reported to filter more than 2500 liters of water per day, a process dependent on their physiological energy requirements (Caballero, 2021).

In 2016, cases of *P. nobilis* mortality reaching 100% were first reported in Spain, followed by subsequent occurrences along other Mediterranean coasts, including France, Tunisia, Morocco, Cyprus, the Adriatic Sea, and the Aegean Sea (Vázquez-Luis et al., 2017; Catanese et al., 2018; Carella et al., 2019; Katsanevakis et al., 2019; Acarlı et al., 2020). Subsequently, the IUCN elevated the conservation status of *P. nobilis* to “Critically Endangered” due to these mass mortalities. *Haplosporidium pinnae* parasite was initially identified as the causative agent for these mass mortalities (Catanese et al., 2018). Later studies reported the involvement of different pathogens in conjunction with *H. pinnae* in these mass mortalities (Carella et al., 2019, 2020; Lattos et al., 2021a, b; Pensa et al., 2022).

Nevertheless, live populations of *P. nobilis* still exist in shallow bays, coastal lagoons (Katsanevakis et al., 2007; Ruitton and Lefebvre, 2021; García-March et al., 2020; Çınar et al., 2021a; Katsanevakis et al., 2022; Nebot-Colomer et al., 2022; Peyran et al., 2022; Papadakis et al., 2022), the Çanakkale Strait (Acarlı et al., 2021), and the Sea of Marmara (Çınar et al., 2021a; Acarli et al., 2021; Acarlı et al., 2022a; Karadurmuş and Sarı, 2022) in the Mediterranean region.

The Sea of Marmara, situated between the Black Sea and the Aegean Sea, functions as an inland sea influenced by the Black Sea, Aegean, and Mediterranean. The saline waters of the Mediterranean (up to 40‰) mix with the less saline waters of the Black Sea (approximately 20‰) through subsurface currents and form the surface currents in the waters of the Sea of Marmara. The Marmara ecosystem, encompassing biological components from both seas, is recognized as an ecological corridor and is considered unique (İşinibilir-Okyar et al., 2015; Demirel et al., 2023). Despite encountering environmental disasters such as mucilage in the Sea of Marmara (Balkis-Ozdelice et al., 2021), it has been reported to continue harboring healthy populations of the endangered *P. nobilis* species (Acarli et al., 2021).

Identifying healthy populations, revitalizing damaged populations, and rehabilitating them are crucial aspects. Although studies have been conducted on the presence of the species in some parts of the southern coast of the Çanakkale Strait and the Sea of Marmara, there is no information available regarding the situation on the European coast of the Sea of Marmara. Therefore, this study was conducted initially to determine the presence of healthy and damaged *P. nobilis* populations on the European coast of the Sea of Marmara. Subsequently, it aimed to assess the abundance and survival rate of *P. nobilis* on the southern coast of the Sea of Marmara Çanakkale Strait.

MATERIAL AND METHODS

This study was conducted at 19 different stations located in the Çanakkale Strait, the European coast of the Sea of Marmara, and the Anatolian coast (Figure 1). Additionally, observational dives were carried out at three different stations in the Çanakkale Strait, where healthy *P. nobilis* populations were reported by Acarlı et al. (2021, 2022a) and Acarli et al. (2021) (checkpoint stations: 10, 21, 22). A two-year monitoring program was conducted between September 2021 and October 2023. Water temperature, salinity, and depth were recorded using YSI probe and Oceanic GEO2. SCUBA equipment was employed for underwater observations in the study area. The substrate structure at the stations was determined as gravel, gravel with macroalgae, sandy, *Cymodocea nodosa*, *Posidonia oceanica*, and rocky.

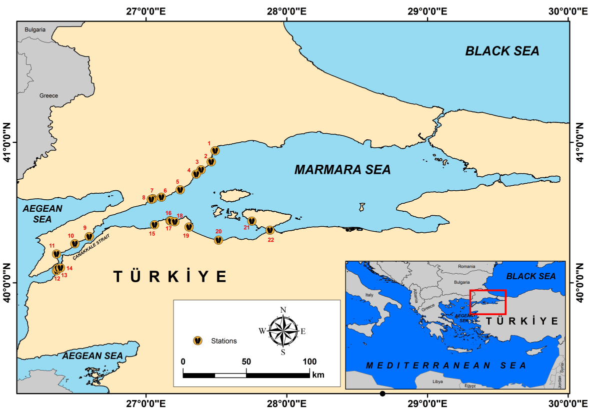

Figure 1. Map of the study area

The study area was systematically surveyed by a trained scientific diver, initiating the survey at a depth of 0.5 m perpendicular to the shoreline for each designated station. The transect underwater visual census method was employed for data collection, with transect lines initially planned at a standard distance of 50 m and a width of two meters on each side. However, variations in transect line distances occurred due to specific conditions at each station, including habitat structure, depth zone, and underwater visibility. At each station, a minimum of one transect was executed to assess the presence or absence of the *P. nobilis* population. Within each transect, a meticulously examined area of 200 m² was considered, and the number of transects ranged from 1 to 6. In instances where no *P. nobilis* individuals were initially observed, additional transects were undertaken. The decision to conduct supplementary transects was contingent upon factors such as habitat structure, depth zone, and underwater visibility, as delineated in Table 1. However, in cases where no individuals were detected in these supplemental transects, no further transect activities were pursued.

All shells of both living and deceased *P. nobilis* individuals were measured for their widths, and subsequently, their total volumes were calculated using the formula established by Acarli et al. (2018) as follows:

$$TL = 2.74W + 2.018 \qquad (1)$$

In this equation, *TL* denotes the total length, and *W* represents the width of the specimen. A one-way analysis of variance (ANOVA) was executed to compare the variations in lengths of *P. nobilis* among different stations. The population density for each station was determined by computing the number of individuals per 100 m². To assess potential differences in the population density (ind./100 m²) of *P. nobilis* among stations, permutational analysis of variance (PERMANOVA) was employed. The PERMANOVA analysis was carried out using Past (v4.08) (Hammer et al., 2001). The Euclidean distance matrix was applied, and groups were delineated based on the presence or absence of specimens at the stations. The stations, where *P. nobilis* was identified (8 levels), were designated as a fixed factor in conducting the PERMANOVA.

RESULTS

Table 1 provides information about the surveyed area, maximum depth, underwater visibility, temperature, salinity, and habitat structure of the investigated stations in the study. Among these, stations numbered 1, 2, 3, 5, 6, 13, 16, 17, 19, and 20 did not exhibit any presence of *P. nobilis* individuals. These stations were characterized by a predominant sandy substrate in terms of habitat structure. In contrast, stations numbered 4, 7, 8, 9, 11, 12, 13, 15, and 18 revealed the presence of *P. nobilis* individuals in habitats characterized by sandy substrate, *C. nodosa*, and to a lesser extent, *P. oceanica*.

Observations (monitoring dives) conducted at stations 10, 21, and 22 did not reveal any signs of intense mass mortality, indicating a healthy population. Furthermore, the presence of young individuals (>15 cm) recruiting to the population was noted at these stations. During underwater surveys, a total of 147 living individuals and 282 deceased individuals were identified (Table 2). Observations throughout the study revealed that the highest number of living individuals was recorded at station 9, while the highest number of deceased individuals was documented at station 12. The lengths of living individuals ranged from 16.4 to 50.9 cm at stations 8 and 4, respectively, whereas the lengths of deceased individuals varied between 30.1 and 68.2 cm at stations 15 and 9, respectively. Furthermore, stations 4 (100%) and 9 (94.9%) were identified as having the highest survival rates.

Table 1. Stations, surveyed area (m^2), maximum depth (m), horizontal underwater visibility (m), temperature (°C), salinity (‰), and observed habitat structure during underwater surveys conducted between September 2021 and October 2023 in the study area

Sta. No	Date	Surveyed Area (m^2)	Max. Depth (m)	Underwater Visibility (m)	Temperature (°C)	Salinity (‰)	Habitat Structure
1	August 2022	1000	8	2.0	25.8	20.2	Gravel (10%), Sandy (80%), Rocky (10%)
2	August 2022	2000	9	4.0	26.6	20.6	Gravel (5%), Sandy (95%)
3	August 2022	1000	11	6.5	25.6	20.6	Gravel with macroalgae (10%), Sandy (90%)
4	August 2022	750	9	7.5	25.8	20.2	Gravel with macroalgae (90%), Sandy (10%)
5	August 2022	1000	7	4.0	25.5	19.9	Gravel (70%), Sandy (10%), *C. nodosa* (20%)
6	September2021	1500	7	5.0	24.4	20.02	Gravel (10%), Sandy (20%), *C. nodosa* (70%)
7	September 2021	500	8	7.0	24.8	20.09	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
8	September 2021	750	5	3.5	24.7	20.09	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
9	October2023	1250	11	6.0	22.6	24.7	Sandy (10%), *C. nodosa* (90%)
10*	July 2023	750	9	3.0	27.9	18.3	*Posidonia* sp. (30%), *Zostera* sp. (70%)
11	October2023	500	7	4.0	18.0	22.4	Sandy (10%), *C. nodosa* (80%), *P. ocenica* (10%)
12	October2023	1000	4	2.0	22.2	24.6	Sandy (10%), *C. nodosa* (90%)
13	October2023	250	7	7.0	20.0	30.0	Shell fragments (85%), Sandy (5%), *C. nodosa* (10%)
14	October2023	750	4	2.5	20.0	26.9	Gravel (80%), Sandy (10%), *C. nodosa* (8%), *P. ocenica* (2%)
15	September 2021	1000	12	10.0	17.5	20.0	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
16	September 2021	1500	7	3.0	23.3	20.0	Gravel (30%), Sandy (30%), *C. nodosa* (40%)
17	September 2021	1000	6	4.0	24.7	20.5	Gravel (20%), Sandy (40%), *C. nodosa* (20%)
18	September 2021	1000	8	3.0	24.6	20.7	Gravel (10%), Sandy (10%), *C. nodosa* (80%)
19	September 2021	1200	3.5	2.0	25.2	19.9	Sandy (100%)
20	September 2021	1000	10	2-7	21.6	20.0	Sandy (70%), *C. nodosa* (30%)
21*	July 2023	1250	13	6.0	27.0	19.4	Gravel (10%), *C. nodosa* (90%)
22*	July 2023	500	10	2.0	26.6	18.6	Gravel (10%), Sandy (20%), *C. nodosa* (70%)

*Checkpoint stations previously studied by Acarlı et al. (2021, 2022a) and Acarli et al. (2021)

Table 2. Number of alive and dead individuals, minimum shell length (L_{Min}), and maximum shell length (L_{Max}) of *Pinna nobilis* individuals

Stations	N	Alive N	L_{Min}(cm)	L_{Max}(cm)	Mean±SD	Dead N	L_{Min}	L_{Max}	Mean±SD
4	21	21	27.8	50.9	42.7±7.0	0	-	-	-
7	41	21	22.9	35.0	27.3±6.7	20	33.0	45.1	38.2±3.8
8	32	26	16.4	45.1	34.6±6.7	6	32.7	56.4	39.9±8.5
9	59	56	18.5	47.3	37.9±5.4	3	39.6	68.2	50.7±15.3
11	21	4	29.2	40.7	34.6±5.8	17	42.6	53.3	47.5±5.4
12	92	0	-	-	-	92	33.0	53.6	42.3±4.7
14	26	11	31.9	39.6	34.9±2.3	15	31.8	40.5	35.4±4.5
15	72	8	21.5	44.8	30.2±8.4	64	30.1	54.5	35.5±4.7
18	31	0	-	-	-	31	31.0	42.0	37.35±4.7

The population density across stations, encompassing both living and deceased individuals, was determined to range between 2.8 ind./100 m² (gravelly habitat) and 8.2 ind./100 m² (seagrass habitat). The lowest population density was observed at station 4, while the highest population density was identified at station 7. It has been observed that *P. nobilis* is densely distributed in seagrass habitats while scarce or no populations are found in gravelly or sandy habitats. However, stations 12 and 18 exhibited a mortality rate of 100% (Figure 2).

Furthermore, the population demonstrated a concentrated distribution at depths between 2 and 4 m, with a decrease in the number of individuals as depth increased (Figure 3).

The results of the PERMANOVA, aimed at assessing variations in population density across stations, indicated a statistically significant difference in the population density of *P. nobilis* among the surveyed stations ($p<0.01$). The total sum of squares was 1196, with a within-group sum of squares of 229.1. The resulting pseudo-F value was 4.641, and the associated p-value was determined to be 0.0001.

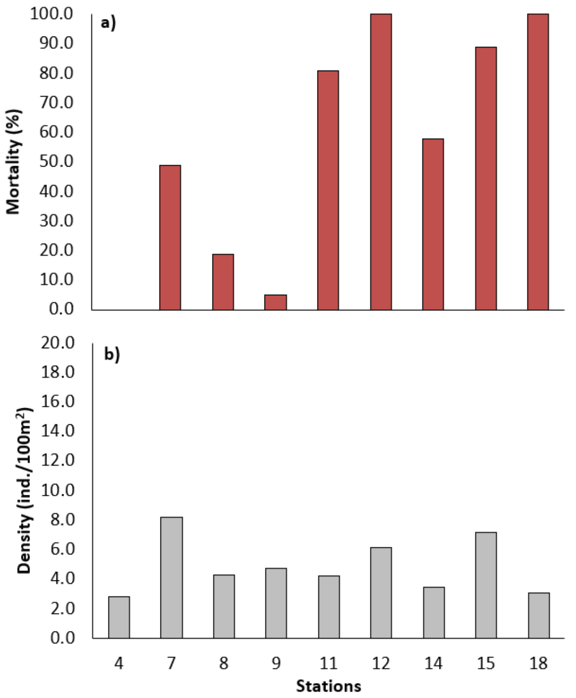

Figure 2. Population density (a) and mortality rates (b) of *Pinna nobilis* at stations

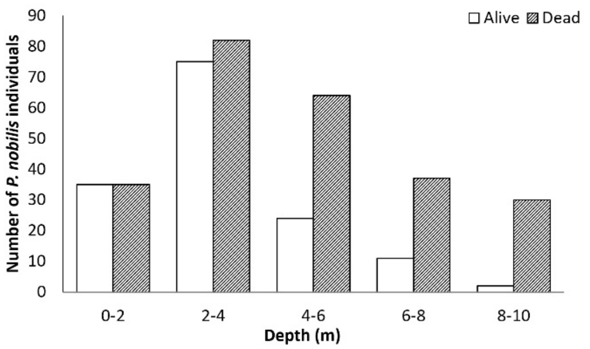

Figure 3. Frequency distribution of alive and dead *Pinna nobilis* individuals by depth (m)

DISCUSSION

P. nobilis is distributed in various seas surrounding Türkiye, excluding the Black Sea coast, including the Mediterranean, Aegean, and Marmara Seas, as well as the shallow waters of the Çanakkale Strait, encompassing sandy areas, seagrass beds, and calcium carbonate formations (locally called as 'tragana'). The northernmost reported point of its distribution in Turkish waters is the vicinity of the Marmara Sea near the Istanbul Strait (between Kızkulesi and Tophane) (Çınar et al., 2021a). Despite reports of intensive mortality cases in *P. nobilis* stocks at different points along the Aegean Sea coast of Türkiye, healthy *P. nobilis* beds have been identified in various locations in the Marmara Sea (Öndes et al., 2020a; Acarlı et al., 2021, 2022a; Çınar et al., 2021a). Acarlı et al. (2021) reported 100% mortality at the entrance of the Çanakkale Strait, connecting the Aegean and Marmara Seas, while a 90.38% survival rate was observed at station 10 in the Çanakkale Strait (checkpoint station). Similarly, Öndes et al. (2020a) identified a 90.48% survival rate at station 21 (checkpoint station). The lowest survival rate in the Çanakkale Strait was reported as 0.32% by Özalp and Kersting (2020). Additionally, mass mortalities have been reported in some stations in the Marmara Sea (Çınar et al., 2021b) and the Çanakkale Strait (Özalp and Kersting, 2020; Künili et al., 2021).

This study fills a gap in the literature by providing survival rates at stations along the European coast of the Marmara Sea, where no information was previously available. Survival rates were determined as 100%, 81.25%, and 51.22% at stations 4, 7, and 8, respectively. No dead or living individuals were encountered at five stations along the European coast of the Marmara Sea (stations 1, 2, 3, 5, and 6). In contrast, variable survival rates were observed at stations along the Çanakkale Strait and the Asian coasts of the Marmara Sea. Despite similar findings reported by different researchers in relatively close areas (Çınar et al., 2021a, b; Acarlı et al., 2021, 2022a, b), examinations of these studies reveal differences in the numbers of living and dead individuals, population density (ind./100 m^2), and survival rates.

Furthermore, three different locations previously studied by Acarlı et al. (2021, 2022a) and Acarli et al. (2021) (Çanakkale Strait: station 10; Marmara Sea: stations 21 and 22) were designated as checkpoint stations in the current study, and no mass mortality was encountered during observation dives conducted in 2023. This highlights the crucial role of factors such as the spread or transport of the disease (Vázquez-Luis et al., 2017), environmental factors like wind direction, and current regimes that enhance the spread (Acarlı et al., 2022a) in the occurrence of mass mortalities in *P. nobilis* populations distributed in different areas. On the other hand, Çınar et al. (2021b) reported an 88% mortality rate during the period of mucilage occurrence, whereas Acarli et al. (2021) determined a mortality rate of 35.9% before the mucilage period (for the year 2020) and 16.1% during the mucilage period (for the year 2021). Acarlı et al. (2022b) proposed that this phenomenon is attributed to the influx of Aegean Sea water, carried by bottom currents through the Çanakkale Strait, reaching the island region in the southern part of the Marmara Sea. Moreover, despite high mortality rates observed in the same region, the presence of healthy populations in certain areas is believed to be due to different current regimes and prevailing northward winds (Acarlı et al., 2022b). The current study's observations near stations with intensive mortalities (stations 10, 21, and 22) still show a significantly high number of healthy individuals, supporting this assumption.

The youngest individuals identified in the study were determined to have lengths of 16 cm and 18.5 cm at stations 7 and 24, respectively. These individuals exhibited thin and transparent shells. It has been observed that in the cultivation of this species, they reach a length of 150 mm at the end of the first year (Kožul et al., 2011; Acarlı et al., 2011; Demirci and Acarli, 2019). Hence, on the basis of the morphological characteristics of these individuals, it can be concluded that they are part of the previous year's cohort and are one year old. Acarlı et al. (2021) and Acarli et al. (2021) reported the detection of newly recruited individuals into the stock, emphasizing the dynamic nature of the population. Additionally, newly settled individuals were commonly observed at stations designated as checkpoint stations. The observation of this phenomenon in the Marmara Sea is of great significance. This is because, during the mucilage period observed from the fall of 2020 through 2021, researchers noted that *P. nobilis* spat could not attach to collectors left to gather juveniles (Personal observation). In other words, the identification of newly recruited healthy individuals after the mucilage formation period is promising, indicating that there is still hope for the sustainability and continuity of *P. nobilis* populations in the Marmara Sea. This finding suggests that efforts can be made to ensure the healthy maintenance and continuity of stocks in the face of environmental challenges, such as mucilage events.

The population density varied between 2.8 ind./100 m² and 8.2 ind./100 m² (by excluding practically zero densities). Rabaoui et al. (2010) indicated that the population density was zero in very shallow waters (<0.3 m depth) and increased in the 0-6 m depth. Rabaoui et al. (2010) noted the average and maximum measured densities were 1.5 and 56 ind./100 m², respectively. In addition, several studies reported different densities in the Mediterranean Sea. Mean densities were reported as 11.5 ind./100 m² in Mljet National Park, Croatia (Šiletić and Peharda, 2003), 0.57 ind./100 m² in Souda Bay, Greece (Katsanevakis and Thessalou-Legaki, 2009), 11.6 ind./100 m² in Gulf of Oristano, Sardinia, Italy (Addis et al., 2009), 2.5 ind./100 m² in Tunisia coast (Rabaoui et al., 2008), 0.02 ind./100 m² in Lake Faro (Sicily, Italy) (Donato et al., 2021), 2.21 ind./100 m² in the shallow sites of Isla del Barón and 4.95 ind./100 m² Pueblo Cálido in the Mar Menor lagoon, located in the southeast of the Iberian Peninsula, (Nebot-Colomer et al., 2022). On the other hand, in the Marmara Sea, Acarlı et al. (2022a) noted that the highest mean population density was 27 ind./100 m² which is very close to Öndes et al. (2020a) with 25.2 ind./100 m². However, Öndes et al. (2020b) stated that there was an exceptional population density of 100 ind./100 m² in the Aegean Sea. Acarli et al. (2021) recorded that the maximum population density reached 112 ind./100 m² in the Ocaklar Bay, southern part of the Marmara Sea. Çınar et al. (2021b) mentioned that population density varied from 0.3 ind./100 m² to 12 ind./100 m² along the coastlines of islands in the southern part of the Marmara Sea. Çınar et al. (2021a) affirmed that the average density ranged from 6 ind./100 m² to 240 ind./100 m² in the Marmara Sea (along the coastlines of islands in the southern part of the Marmara Sea). Densities depend largely on sampling design and field size; both vary significantly across studies.

In this study, it has been determined that *P. nobilis* individuals exhibit a dense distribution up to a depth of 6 meters. Generally, the depths at which this species is distributed show regional variations. Vázquez-Luis et al. (2014) reported that the highest densities are mostly limited to shallow coastal regions, with the expected maximum density being below 20 meters, and densities decreasing with increasing depth. Similarly, Basso et al. (2015) documented that there was a decreasing trend in the number of individuals with increasing depth, with higher densities in the first 10-12 m. It has also been observed that *P. nobilis* densely distributed in seagrass habitats while scarce or no population has been observed in gravelly or sandy habitats. Many researchers have reported the dense distribution of *P. nobilis* populations within seagrass meadows (Coppa et al., 2010; Basso et al., 2015; Tatton et al., 2019; Acarli, 2021; Acarlı et al., 2021). Basso et al. (2015) compared 24 scientific papers based on 77 observations and noted that *P. nobilis* were most frequently observed in *P. oceanica* beds with an average of 8.06±2.35 ind./100 m², while in *Cymodocea* meadows with averages of 11.06±1.82 ind./100 m². The widespread occurrence of *P. nobilis* individuals, especially in environments with seagrasses such as *P. oceanica* and *C. nodosa*, suggests that this species has a high oxygen demand. In other words, it is evident that *P. nobilis* thrives in areas where water quality is relatively good. Likewise, Rabaoui et al. (2010) indicated that the density increased with the distance from the city and it was attributed to pollution. Similarly, in the present study, the highest number of live individuals was observed among *C. nodosa* and *P. oceanica* seagrasses. The lowest number was found in sandy habitats, possibly due to the vulnerability of young individuals with thin and fragile shells to water movements and potential predators in sandy habitats.

However, individuals among seagrasses may exhibit a higher survival rate due to both increased protection against predators and less impact from water movements. Similarly, researchers have reported higher densities of *P. nobilis* populations in sheltered biotopes with weak hydrodynamics (low wave motion and low current velocity) and substrates composed of rocky, gravel, and biodegraded material along with *P. oceanica* and *C. nodosa* (Rabaoui et al., 2008, 2009; Hendriks et al., 2011; Acarlı et al., 2022a). On the other hand, Çinar and Bilecenoglu (2023) observed two cases related to predation pressure by the spiny sea star *Marthasterias glacialis* on *P. nobilis* juvenile individuals. Acarlı et al. (2022b) reported that no *P. nobilis* individuals were observed in all stations dominated by the north wind on the coast of the Kapıdağ Peninsula (southern Marmara Sea). Therefore, this ecosystem type is considered highly favorable for the settlement and survival of Pinnidae spat.

In the current study, the majority of *P. nobilis* individuals at all stations were observed to be oriented perpendicular to the shore. This positioning can be explained as a reduction in the potential effects by minimizing the exposed surface area subjected to hydrodynamic forces, aiming to alleviate the stress created by wave motion.

Following mass mortalities observed at different locations in the Mediterranean, the focus has shifted towards identifying healthy *P. nobilis* populations. Despite reports of mass mortalities at various points in the Marmara Sea and the Çanakkale Strait, the documentation of the presence of healthy and dynamic populations is crucial for the continuity of the species. This study identified healthy populations at 9 researched stations (4, 7, 8, 9, 11, 13, and 15) and 3 checkpoint stations (10, 21, and 22). To ensure species sustainability, it is essential to continuously monitor populations identified as healthy in the Marmara Sea. Additionally, it is recommended to establish special environmental protection areas, such as marine parks, to conserve these habitats. Furthermore, the collection of young individuals using collectors in these areas and their transplantation to suitable locations with protected systems on the seafloor should be undertaken to ensure the conservation of the species.

CONCLUSION

This research represents the first exploration of the spatial distribution of *P. nobilis* along the European coast of the Marmara Sea. Healthy populations at 12 researched stations during the two-year monitoring study and no mass mortality was encountered during observation dives conducted in 2023 at checkpoint stations. It has also been observed that individuals of *P. nobilis* are densely distributed extending to a depth of 6 meters. In spite of reports indicating widespread mortalities at different locations in the Marmara Sea and the Çanakkale Strait, documenting the existence of thriving and dynamic populations is essential for the species' continuity. While the lowest numbers were found in sandy habitats, individuals among seagrasses exhibited a higher survival rate possibly due to both increased protection against predators and less impact from water movements. The identification of recently recruited, healthy individuals following the mucilage formation period is promising, suggesting that there is still optimism for the sustainability and persistence of *P. nobilis* populations in the Marmara Sea. This study significantly contributes to advancing our comprehension of the ecology of *P. nobilis* populations in both the Sea of Marmara and the Çanakkale Strait. Therefore, recommendations for the restoration of affected populations and the preservation of healthy populations should be applied by decision-makers and fisheries managers.

ACKNOWLEDGEMENTS AND FUNDING

This research has not received a specific grant, fund or other support from any funding agency in the public, commercial, or not-for-profit sectors.

AUTHORSHIP CONTRIBUTIONS

Sefa Acarlı: Conceptualization, Writing-Original draft, Writing-Review and Editing, Supervision, Deniz Acarlı: Methodology, Writing-Original draft, Semih Kale: Writing-Original draft, Writing-Review and Editing, Formal analysis.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

All relevant data is in the article.

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 54-62 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.08

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Estimation of spawning stock biomass and spawning areas of sardine, (*Sardina pilchardus*) with winter time ichthyoplankton sampling in the Sea of Marmara, Türkiye

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Received date: 10.10.2023 *Accepted date: 21.02.2024*

How to cite this paper:
Daban, İ.B., Şen, Y., Öztekin, A., Ayaz, A., Altınağaç, U., İşmen, A., Yüksek, A., Özekinci, U., Çakır, F., Demirkıran, T., Uğur, G.E., Ayaz, O., & Selçuk, B.B. (2024). Estimation of spawning stock biomass and spawning areas of sardine, (*Sardina pilchardus*) with winter time ichthyoplankton sampling in the Sea of Marmara, Türkiye. *Ege Journal of Fisheries and Aquatic Sciences,* 41(1), 54-62. https://doi.org/10.12714/egejfas.41.1.08

Abstract: The spawning areas and spawning stock biomass of sardine were studied with ichthyoplankton sampling in the winter period from the 32 stations, in the Marmara Sea. The mean fish egg and larvae biomass in a unit area were calculated as 18.4 ± 5.3 eggs/10 m^2 and 2.5 larvae/10 m^2, respectively. Three main spawning areas were detected as Karacabey Floodplain area, Gönen, and Büyükçekmece estuarine area. The larvae are mostly located in the western part. The batch fecundity of sardine was detected between 2415.9 and 16738.3, with a mean of 6899.8 ± 255.7 eggs. The sex ratio (*R*), spawning fraction (*S*), mortality rate, and daily egg production (*Po*) were calculated as 0.53, 0.098, 0.62, and 9.25 eggs/m^2 in the Marmara Sea. The spawning stock biomass (*B*) is estimated at 2998 tonnes in the Marmara Sea. Both ichthyoplankton biomass and spawning stock biomass were found relatively lower. It is recommended to apply stricter management sanctions for the sustainability of sardine stocks.

Keywords: Fish eggs, fish larvae, small pelagic fish, stock estimation, daily egg production

INTRODUCTION

Sardine, *Sardina pilchardus* (Walbaum, 1792) has a wide geographical distribution from Northeastern Atlantic to Senegal, and the Mediterranean including Adriatic, Marmara Sea, and the Black Sea (Whitehead, 1988). It is mostly found in marine waters, but it can be distributed in brackish and freshwaters (Riede, 2004). The preferred depth range of the sardine occurs between 25 m and 100 m depths (FAO-FIGIS, 2005). It forms a school and shows more coastal distribution between 10 m and 35 m at night. The diet of juvenile and adult sardines differ (Nikolioudakis et al., 2011) and juvenile sardines fed heavily on copepods, whereas diatoms and autotrophic dinoflagellates (Nikolioudakis et al., 2012). The maximum reported length was 27.5 cm SL (Macer, 1974), and the maximum age was 15 (Muus and Nielsen, 1999).

Sardine is a member of Clupeidae, and is one of the most important fish species in both the global fishing industry and Türkiye, due to high supply demand for fresh fish and canned products. The Clupeidae family is represented by 12 species, and between them, *S.pilchardus* and *Sprattus sprattus* are two abundant Clupeidae species in Türkiye waters. *S.sprattus* has a minor commercial interest, it is usually utilized as a fishmeal component. Whereas *S. pilchardus* is evaluated as human consumption in Türkiye, mostly caught in the Marmara Sea and Aegean Sea. In terms of landing data presented by TUIK (2023) sardine ranked third after Anchovy and Bonito, with 825.5 tonnes of catch. When considered small pelagic fish species, its landing was higher than *Pomatomus saltatrix* (618.7 tonnes), *Trachurus trachurus* (751.4 tonnes), *Trachurus mediterraneus* (508.6 tonnes), *Scomber japonicus* (480.9 tonnes), *Sardinella aurita* (26.7 tonnes), and *Scomber scombrus* (3.9 tonnes), but relatively lower than *Engraulis encrasicolus* (13,444.6 tonnes) and *Sarda sarda* (3,113.4 tonnes) catch landings.

Although of great importance for small-scale gillnet fisheries, 85-90% of the total global catch stemmed from seine net fisheries in recent years. According to FAO 2019 fishing reports, a global catch of sardine was reported as 1,499,361 tonnes, whereas 1.4% of the total catch (19,119 tonnes) was caught in Türkiye waters (FAO, 2021). With the increasing industrialization of fishing vessels, the seine net fishery asserted its dominance over commercial catch, and small-scale gillnet fisheries have become able to catch fish only in the summer months when the seine net fishery is under seasonal restriction. This pattern caused a great decline in catchable stocks of sardine in Turkish waters, which was 34,709 tonnes in 2011 and decreased to 16,729 tonnes in the

2022 (TUIK, 2023). The sardine landing constitutes only 5.5% of the total catch (301,747 tonnes) in 2022 fishing season.

Previous studies were realized according to the reproductive biology of adult sardines. The first maturity length (TL, total length) was found as 12 cm in the Aegean Sea (Cihangir, 1995), 12.5 cm in Spain and 13.5 cm in Adriatic (Beverton, 1963), 13.5 cm in the Gulf of Lion (Campillo, 1992), 15 cm in the Gulf of Biscay (Dorel, 1986), and 16 cm in the Madeira (Silva et al., 2006). Also, spawning season occurred between October and April in Portugal (Figueiredo and Santos, 1989), between October and January in Northwest Africa (Delgado and Fernandez, 1985), between January and September in Southwest England (Wirtz et al., 2008), between December and February in the Sığacık Bay (Uygun and Hoşsucu, 2020), and between October and May in the Çanakkale Strait (Daban, 2013). According to Turkish notification on the regulation of commercial fishing, the minimum landing size of sardine is 11 cm in TL. The seasonal restriction application on a species-basis is not available, but the closed season of purse-seining is being implemented between April and September, which is not related to the spawning season of this species.

This declining pattern of sardine stocks may pose a clear threat in the near future in terms of sustainability. A sustainable use of natural resources is known as one of the most important heritage that a nation can leave to future generations. Due to the fisheries stocks being under excessive fishing pressure, lots of stocks become near threatened. Thus, some protective measures should be conducted to prevent sudden collapses of fish stocks. Whereas fisheries managers need accurate information to deal with stock size capacity for stock assessment. Fish stock assessment methods should reveal more robust results by using sufficient observational data obtained from field surveys (Chrysafi and Kuparinen, 2016). Ichthtyoplankton-based data allows estimation independently of occupational fishing (Govoni, 2005) with lower survey costs and in less time (Yüksek, 1993). Besides, ichthyoplanktonic data presents concrete results for estimating stock size and determining stock size-recruitment relationships (Lockwood, 1988). In addition, the most accurate method of the determination of spawning areas and spawning season of fish species was stated as ichthyoplankton studies (Fuiman and Werner, 2002). Although varied stock assessment models have been applied to lots of species such as analysis of length frequency data of catches (Length Cohort Analysis – LCA) and analysis of catch-at-age data (Virtual Population Analysis – VPA), the most appropriate model for small pelagic fish species stated as direct assessment methods based on ichthyoplanktonic data (Oliver, 2002). Among all direct stock assessment methods, the daily egg production method is defined as one of the most important tools, especially for the determination of the stock size of small pelagic fish species. The biomass of fish eggs and prelarvae, sampled with an ichthyoplankton survey constitutes an important part of this method along with fecundity information obtained from adult fish (Alheit, 1993). Among all other species, sprats, anchovies, sardines, and mackerels were the species whose stock size was most frequently calculated with the daily egg production method. Whereas, the previous findings for stock size estimation with daily egg production method were limited only to Taylan and Hoşcucu (2016)'s study in Turkish waters.

After noticing the decrease in catch records, we aimed to reveal the stock size of sardine by applying the daily egg production method. In addition, we tried to ascertain the spawning areas of sardine in the Marmara Sea with a broad-scale geographical sampling strategy.

MATERIALS AND METHODS

To determine stock size with daily egg production method and spawning areas, three ichthyoplankton surveys were conducted in December 2021, February 2022, and March 2022 from 32 stations located at equal distance from each other (10 miles) in the Marmara Sea, Türkiye (Figure 1). The sardine eggs and prelarvae obtained from the vertical hauls of each station were sorted from plankton samples, recorded, and standardized with a unit of individual number/10 m^2.

For the purpose of the stock estimation of sardine based on the daily egg production method, both ichthyoplankton (sardine eggs and prelarvae) and adult sardine individuals were examined. The sexes of the adult individuals were determined and recorded, and all sexed individuals were weighted. Then, the sex ratio for spawning stock biomass (R) was determined from the division of mean female weight to mean total weight of all individuals. For determining batch fecundity (F), the hydrated oocytes of adult females were examined (Hunter et al., 1985). Oocytes were counted and their diameters were measured under a binocular microscope. Oocytes greater than 395 µm diameter were accepted as "large-hydrated" oocytes. The spawning fraction (S) is the fraction of mature females spawning per day (spawning frequency) which is determined by the development stages of oocytes. The total survey area (A) was calculated from the results of ichthyoplankton sampling. In accordance with the method requirement, the stations containing fish eggs and prelarvae were marked as positive, and the positive-coded areas were calculated differently from the total area. The total area of the Marmara Sea was accepted as 11500 km^2. The total survey area (A) in the spawning stock biomass equation is estimated from the fraction of positive stations to all stations, due to all stations being located at equal distances. To calculate the daily egg production (P_0), initially, the ages of eggs need to be determined. The aging of fish eggs was determined according to the temperature-dependent model of sardine developmental rate (Miranda et al., 1990),

$$Y = 17.52 * e^{-0.136T-0.173i} * i^{2.222} \qquad (1)$$

where T is the sea surface temperature of the station (5 m), Y is the sampling hour of the fish egg, i is the development stage of the fish egg (stage 1-10), and peak spawning time is 20.00 (Ganias et al., 2003).

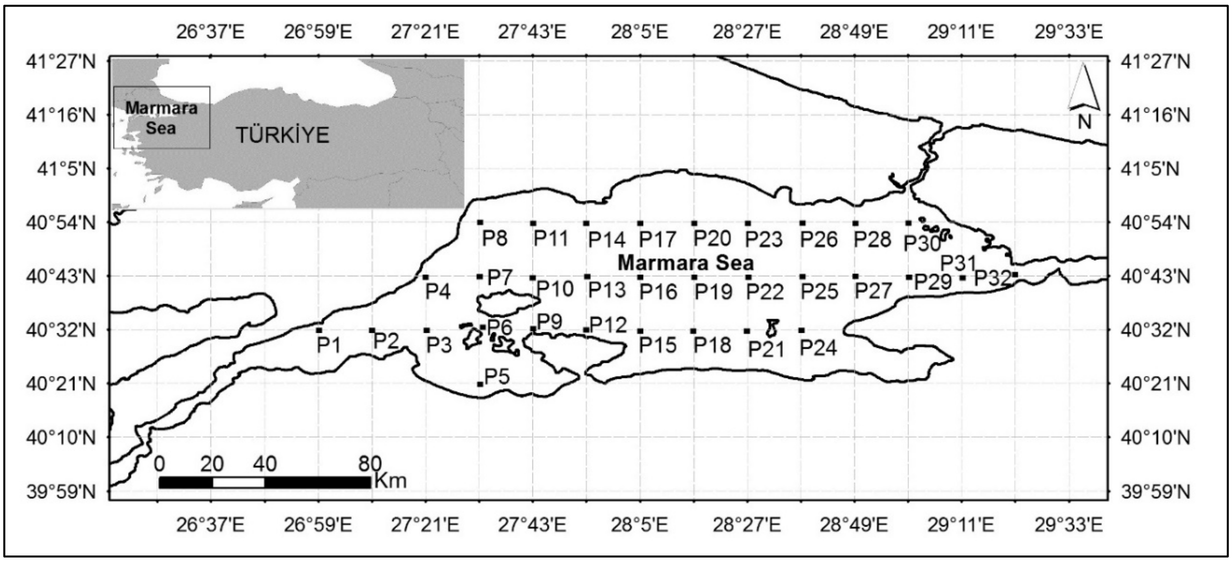

Figure 1. Study area and equally-spaced ichthyoplankton sampling stations in the Marmara Sea, Türkiye

The age of the egg was accepted as “zero” when the development stage was between 1st and 6th, whereas accepted as “one” when the development phase was ranged from the 7th to 12th stage. Due to zero-age development being completed in less than 24 hours, the zero-age stage revealed an estimated spawning time. When the estimated spawning time was subtracted from the sampling time, if the duration was higher than 48 hours, the age of the egg was determined as 2. Somarakis (2005) stated that the mortality rate calculation did not show differences from 0 when the mortality curve was constituted only from fish eggs and advised that the mortality curve should be plotted using both fish eggs and prelarvae count. The aging of prelarvae is determined according to eye pigmentation, where age accepted 1 when pigmentation has not started yet, and 2 when brown pigmentation occurred (Somarakis, 2005). After all age classes were determined, a single mortality curve was constructed for both eggs and prelarvae. The slope of the curve reveals the daily instantaneous mortality rate (Z). Thus, daily egg production (P_0) is estimated according to the given equation:

$$P_t = P_o e^{-zt} \qquad (2)$$

where e is the number of eggs or yolk-sac larvae produced per day per unit area at age t days; Po is daily egg production at age zero; and Z is the daily instantaneous mortality rate (Lo, 1986).

The spawning stock biomass (B) was estimated according to the given equation of Stauffer and Picquelle (1980);

$$B = (k * P * A * W)/(R * F * S) \qquad (3)$$

where k defines the conversion factor from grams to metric tons, P_0 is the daily egg production (the number of eggs and prelarvae per sampling unit (m²)), A the total survey area, W is the mean weight of mature females (g), R the sex ratio, F the batch fecundity and S the fraction of mature females spawning per day.

Non-parametric Kruskal–Wallis test was used to compare the spatial variation of physico-chemical parameters rather than parametric tests because the data was limited due to 3-month sampling and did not show a normal distribution.

Besides, Kruskal–Wallis test is preferred due to this distribution-free test proved to be more robust than its parametric counterpart in the case of non-normal distribution of sample data, and it is a viable alternative to parametric statistics (Potvin and Roff 1993). The variations in abundance and physico-chemical parameters based on sampling months and stations were tested with the non-parametric Kruskal-Wallis test. Then, the Mann-Whitney U post-hoc test was applied to understand where differences occurred within these variables. Significant differences were established at 0.05 significance level.

RESULTS

Spawning area estimation

Mean sea surface temperature, salinity, and dissolved oxygen values of 32 ichthyoplankton stations were measured. The temperature values ranged from 11.2ºC (P7) to 12.1ºC (P15) (mean: 11.5 ± 0.03ºC) in December 2022, ranged between 6.8ºC (P8) and 7.8ºC (P5) (mean: 7.2 ± 0.05ºC) in February 2023 and distributed from 6.4ºC (P19) to 9.1ºC (P6) (mean: 7.4 ± 0.1ºC) in March 2023. The temporal variation of sea surface temperature (SST) showed statistically important variations. The SST in December was statistically different from the SST of February and March (K-W test; H=63.39; $P \leq 0.05$). The salinity values ranged from 25.6 ppt (P13) to 26.9 ppt (P6) (mean: 26.7 ± 0.6 ppt) in December, ranged between 24.4 ppt (P27) and 30.7 ppt (P3) (mean: 28.8 ± 0.3 ppt) in February and distributed from 22.3 ppt (P28) to 28.3 ppt (P1) (mean: 25.9 ± 0.3 ppt) in March. The dissolved oxygen values were ranged from 7.6 mg/l (P3) to 9.3 mg/l (P25) (mean: 8.4 ± 0.07 mg/l) in December, ranged between 8.4 mg/l and 9.4 mg/l (mean: 8.9 ± 0.04 mg/l) in February, and distributed from 6.9 mg/l to 9.5 mg/l (mean: 7.8 ± 0.14 mg/l) in March. The salinity values were statistically differ between December and February (K-W test; H=35.56; P≤0.05) and between February and March (K-W test; H=35.56; P≤0.05). The dissolved oxygen values were statistically different between December and February (K-W test; H=35.56; P≤0.05), between December and March (K-W test; H=35.56; P≤0.05), and between February and March (K-W test; H=35.56; P≤0.05). Whereas SST did not differ statistically between the stations (K-W test; H=9.71; P≥0.05). Similarly, the sea surface salinity (K-W test; H=35.98; P≥0.05) and dissolved oxygen (K-W test; H=36.26; P≥0.05) values did not differ statistically between stations.

The mean sardine egg biomass in a unit area was calculated as 18.4 ± 5.3 eggs/10 m² in the Marmara Sea. 15 of 32 stations contained sardine eggs. The dead fish egg ratio was detected as 5.5%. Using spatial variation of sardine eggs, the highest biomass was observed in station 18 where under the influence of Karacabey Floodplain area with a 130.7 eggs/10 m² mean biomass (22.2% of the total biomass). The area between Karabiga and Gönen Stream was found the second most abundant area with a mean of 58.8 eggs/10 m². The other abundant area was detected as between Büyükçekmece and İstanbul Strait, with a 43.6 eggs/10 m² mean biomass. A common feature of all 3 areas is their proximity to freshwater input.

Between all sites, the prelarvae of sardine were only detected in station 18 (Karacabey Floodplain area). Postlarvae of sardine were observed in 6 of 32 stations, with a relatively low mean biomass (2.5 postlarvae/10 m²). Postlarave distribution was also supported by the fish egg distribution data, which was closer to the shores of the freshwater input. When all 3 life phases were considered together, the main spawning area was seen as Karacabey Floodplain area, and Gönen Estuarine and Büyükçekmece estuarine areas were the other spawning sites of sardine in the Marmara Sea (Figure 2)

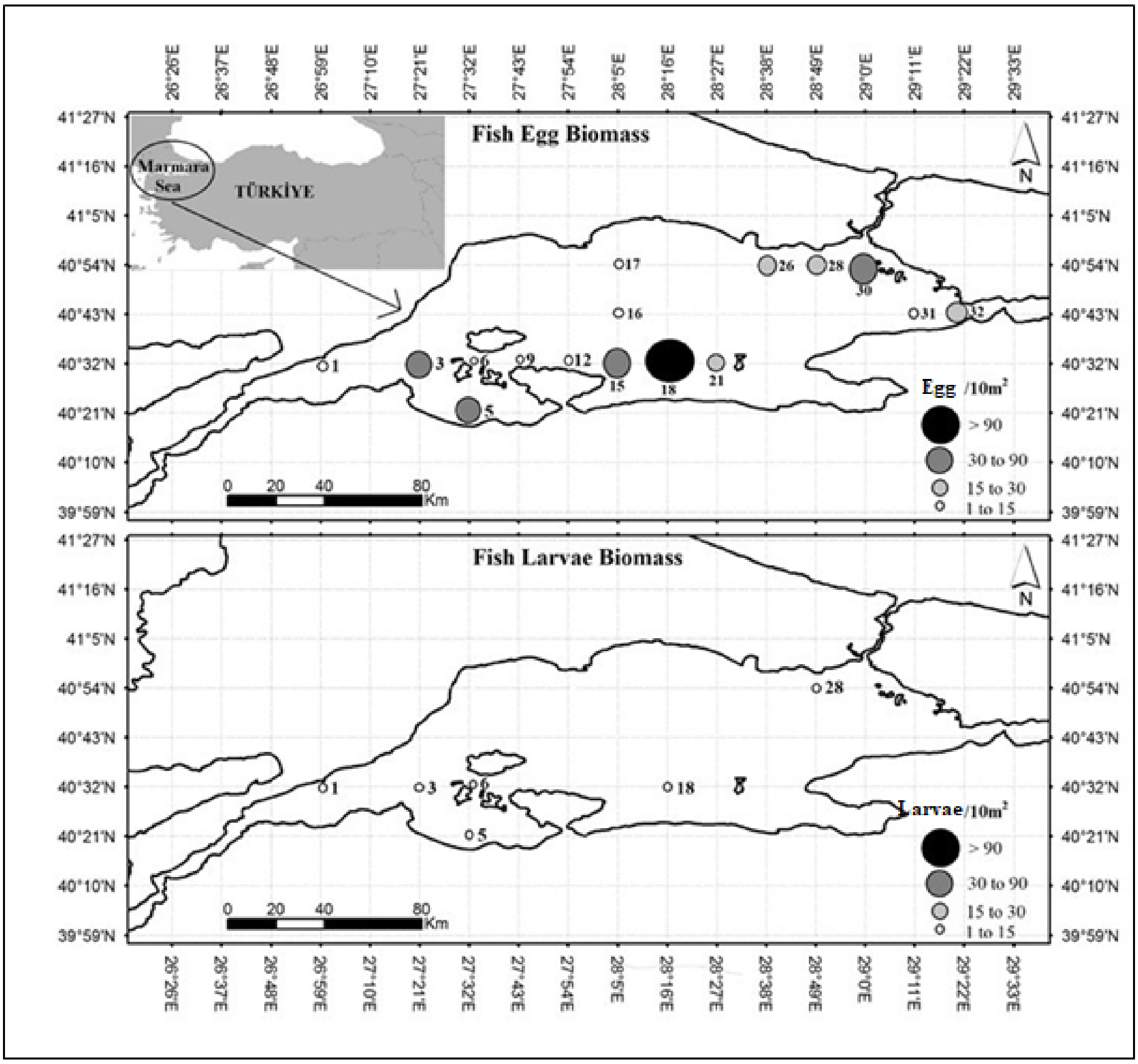

Figure 2. The spatial variation of sardine, *Sardina pilchardus* eggs, and larvae in the Marmara Sea, Türkiye

Stock size estimation

The parameters used for estimating spawning stock biomass such as mean female weight (W), batch fecundity (F), and sex ratio (R) were determined from the examination of adult sardine individuals. For this purpose, a total of 257 individuals were examined, and 114 of 257 individuals was detected as female. The remaining 128 individuals were male and 15 were not sexed due to damaged reproduction organs. The mean gonad-free body weight of mature females was calculated as 21.49 g. The sex ratio (R) in this study was calculated as 0.53. Yolk compact mass diameters in hydrated oocytes ranged between 395 µm and 935 µm with a mean of 695 ± 11 µm. The batch fecundity ranged between 2415.9 and 16738.3, with a mean of 6899.8 ± 255.7 eggs. The fish length-batch fecundity relationship was shown in Figure 3, and a linear relationship was detected.

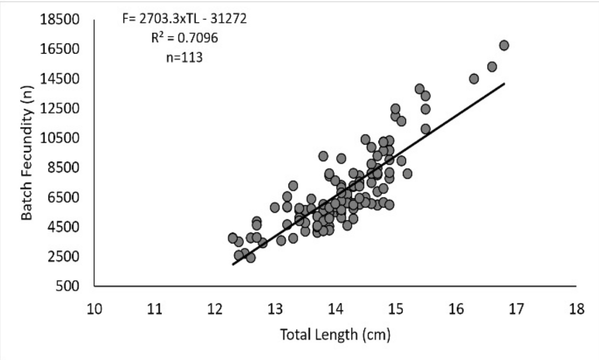

Figure 3. The fish length (TL) – batch fecundity (F) relationship of sardine, *Sardina pilchardus* in the Marmara Sea, Türkiye

15 of the 32 stations contained fish eggs and/or prelarvae, and were codded as positive areas. Thus, the total survey area (A) which is also referred to as the spawning area was detected as 5405 km^2. The spawning fraction (S) was calculated as 0.098.

The mortality rate is estimated from the slope of the mortality curve as 0.62 (Figure 4). Thus, the daily egg production (P_0) was estimated as 9.25 eggs/m^2 in the Marmara Sea. When the calculated R, A, W, F, S, and P_0 variables were substituted into the equation, the spawning stock biomass (B) was estimated as 2998 tonnes in the Marmara Sea.

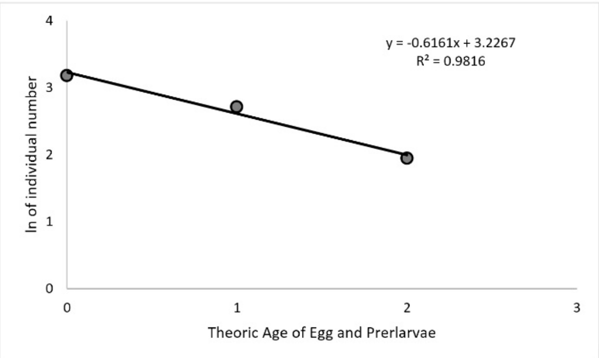

Figure 4. The mortality curve of sardine, *Sardina pilchardus*

DISCUSSION

The mean fish egg (18.4 ± 5.3 eggs/10 m^2) and larvae (2.5 larvae/10 m^2) biomass of sardine were detected relatively lower than the results of the previous studies. Kara (2015) found that the mean egg biomass in Erdek Bay was 166 eggs/10 m^2, and the highest mean egg biomass was calculated in October as 600 eggs/10 m^2. Daban (2013) stated that the mean sardine egg biomass was 118 eggs/10 m^2, with the highest mean egg biomass at 326 eggs/10 m^2 in February in the Çanakakle Strait, Marmara Sea. Yüksek (1993) found only a single fish egg individual in the northeastern Marmara Sea (Büyükçekmece) and stated that this egg drifted with currents from the southwestern part to this area and was sampled accidentally. In the present study, it can be seen in Figure 2, except from Büyükçekmece and nearby areas, fish eggs and larvae of sardine were not found in the Northern part of the Marmara Sea. We detected both early life phases (egg, prelarvae, and postlarvae) of sardine in Büyükçekmece region. In addition, Daban et al. (2023) detected juvenile individuals of sardine around Büyükçekmece coasts with beach seine samplings. Thus, we thought that, Büyükçekmece region is one of the local spawning areas for sardine in the Sea of Marmara. According to our results, this situation was not related to sea water physico-chemical properties. As explained in the results section, the temperature, salinity, and dissolved oxygen values did not show statistical variations between the North and South parts of the Marmara Sea. Thus, the absence of Sardine in the northern part (except Büyükçekmece) could not be explained by physico-chemical properties. It may be associated with the spawning area selection of adults such as vicinity of estuarine areas.

In the same area, Alimoğlu (2002) detected the highest mean egg biomass of sardines in October as 180 eggs/10 m^2. In our study, although Büyükçekmece was the 3rd abundant area for sardine egg biomass, the mean value was determined as 43.6 eggs/10 m^2. As well, Karacabey Floodplain area, the most abundant area for sardine eggs in this study, had a lower mean value (130.7 eggs/10 m^2) than in previous studies. Also, relatively higher mean fish egg and larvae biomass values were reported from the Aegean Sea and Mediterranean Sea. The mean fish egg biomass in a unit area was found as 607 eggs/10 m^2 in Edremit Bay (Türker Çakır, 2004; Türker Çakır et al., 2008), as a 49 eggs/10 m^2 in the Sığacık Bay (Uygun and Hoşsucu, 2020), and as 40 eggs/10 m^2 in the Mersin Bay (Ak, 2004). It can be seen that the mean biomass was found lowest in the present study. Several parameters may have caused to occur these differences. In addition, a dense fishing effort by purse seiners on small pelagic fish species in the semi-enclosed basin, Marmara Sea can play a major role. As a result of the high fishing pressure, species become mature earlier than they should be. Thus, younger females generate smaller eggs and embryos, and the survival rate of these larvae faces trouble due to inadequate development in unfavorable conditions. Besides, the increasing pollution and resulting decreases in dissolved oxygen, and the changes in water temperatures due to global warming may cause changes in spawning areas.

The results of this study and previous ichthyoplankton studies from the Marmara Sea showed that the *S.pilchardus* spawning peaked in specific temperature intervals between 11°C and 16°C, and mostly centered upon 12-13°C. According to monthly sampling intervals, Daban (2013) detected that the spawning peaked at 11.8°C in February in the Dardanelles, whereas Kara (2015) found that it peaked at 12.3°C in October in the Erdek Bay. In the present study, the fish egg and larvae biomass decreased with the decrease of the sea surface temperature (SST) from 11.5°C in December to 7–8°C in February and March. Also, similar temperature intervals and spawning seasons were stated in the Aegean Sea. Sardine spawning peaked between 13-15°C in İzmir Bay (Hoşsucu, 1992), and 12.5-15.3°C in February in the Sığacık Bay (Uygun and Hoşsucu, 2020). Similar SST ranges were revealed also for the Bay of Biscay as between 12.5 and 15°C according to Sola et al. (1990) and 10-16°C according to Arbault and Lacroix (1977). The main factor that controls the spawning density was explained as SST for small pelagic fish species (Maynou et al., 2020; Peck et al., 2012). The results of sardine spawning pattern confirm this hypothesis. Whereas, more frequent sampling intervals should be applied for understanding temporal changes (Daban and İşmen, 2020).

The present study revealed the first results related to spatial variation of sardine eggs and larvae on a scale covering the entire Marmara Sea. Three main spawning areas were detected explicitly such as Karacabey Floodplain area, Büyükçekmece area, and the Gönen estuarine area, where all these are close to brackish waters. Whereas larvae of Sardine increased in Gönen estuarine area, Karabiga and Mürefte, where located western part of the Marmara Sea. In addition, both Daban et al. (2023) identified early juveniles of sardine as a school with beach seine in the Büyükçekmece and high fish egg and larvae biomass in the present study in this area supported the hypothesis that this area is a spawning location. Palomera et al. (2007) stated that estuarine areas are favorable for the growth of planktivorous small pelagic fish species due to carrying high nutrients through streams. Some authors stated that sardine avoid cloudy waters and lower saline waters and distributed off-shore areas rather than coastal areas (Olivar et al., 2003; Coombs et al., 2004; Santos et al., 2004). Conversely, Ramos et al. (2009) found relatively high sardine eggs and larvae around the Lima estuary during 2-year ichthyoplankton sampling and stated that the total ichthyoplankton biomass was dominated by sardine. When the results were compared, the outputs coincided with the findings of Palomera et al. (2007) and Ramos et al. (2009). As can be seen in Figure 2, the fish egg and larvae biomass is mostly concentrated around shallower areas rather than deeper waters. This may be a result of the instinct to be close to river input, accordingly nutrient and food. Somarakis et al. (2006) stated that sardines mostly prefer depths between 40 m and 90 m for spawn, and biomass is concentrated especially in zooplankton-rich areas in open water conditions in the Aegean Sea. Also, Zwolinski et al. (2006) determined the dense fish egg biomass around 40-60 meter depths between the Gulf of Cadiz and Algarve, Portugal, and stated the eggs distributed between 25 and 75 meters in the Sığacık Bay (Uygun and Hoşsucu, 2020). In the present study, the stations in which sardine fish egg and larvae biomass was higher (3, 5, 15, 18, and 30) were mostly located between 35 and 53 m depths. The depths deeper than 60 meters had relatively lower biomass values and the deepest center channel had not any sardine eggs and larvae. The results show similarities with the findings of Somarakis et al. (2006), Zwolinski et al. (2006), and Uygun and Hoşsucu (2020).

Roy et al. (1989) stated that sardine adapted their reproductive strategy to the coastal upwelling ecosystem of the Portuguese West coast to minimize Ekman offshore transport effects. Due to the two-layered stratification of the Marmara Sea, the Black Sea water flow discharges via the upper thermocline. It was thought that immobile and semi-mobile fish eggs and larvae could be transported from one place to another by this strong current. However the results of the spatial variation of sardine egg and larvae biomass did not reflect this situation and it was seen to be concentrated in 3 main regions, especially close to freshwater inlets. The absence of biomass in the middle deep water channel strengthened this finding. The coastal distribution of the sardine has aroused curiosity as to whether it is a strategy developed to be less affected by the Marmara Sea surface current. This issue generates another study issue, which should be considered together with physical oceanographers.

By means of the reproductive biology of sardine, several valuable works were realized in the Marmara Sea and the Aegean Sea. Taylan et al. (2019) were detected that the fecundity of sardine ranged between 4.600 and 9.800 eggs, with a mean of 6.110 ± 1.755, which closely similar to the findings of the presented study which fecundity estimated between 2.416 and 16.738, with a mean of 6.899 ± 255.7 eggs. A slightly higher fecundity in the present study may be a result of the higher length distribution of the adult females in the present study. Similarly, linear length-fecundity relationships were found in both two studies. Also, Cihangir (1995) stated that the lengths at first maturity of sardine were to be 12.0 cm for females and 12.7 cm for males in the Aegean Sea. As can be seen in Figure 3, all mature females examined for fecundity ranged between 12.4 and 16.8 cm in TL in the present study. This coincides with the findings of the authors. Also, the gonadosomatic index, which shows the spawning period of fish, peaked between December and February in İzmir Bay, when the STT values were lowest (Cihangir, 1996). Thus, it was understood that the adult reproductive characteristics coincide with the results of ichthyoplankton studies.

The estimation of spawning stock biomass by daily egg production method has been applied to lots of small pelagic fish stocks up to date, but it has not been applied sufficiently in Turkish waters. In a single study, the spawning stock biomass of anchovy, *Engraulis encrasicolus* estimated as 403.9 metric tonnes (mt) in the Edremit Bay, Aegean Sea by Taylan and Hoşsucu (2016).

The estimated value is relatively higher than our findings which calculated for sardine as 2998 tonnes (~3 mt). In terms of previous findings related sardine spawning stock biomass from adjacent seas or other seas, it was estimated as 134195 tonnes in Galicia, 33503 tonnes in western Cantabrian, and 12467 tonnes in the eastern Cantabrian (Garcia et al., 1992), 14196 tonnes in the Adriatic (Casavola et al., 1996), 5149 tonnes in the Ionian Sea (Somarakis et al., 2006), 16174 tonnes in the Aegean Sea (Somarakis et al., 2006). In both studies, the highest egg production took place between 20:00 and 24:00, during the day. When all previous findings were compared, the estimation of spawning stock size was close to the estimation of the Ionian Sea, and lower stock size was detected against all other areas. These differences may have arisen due to the long passage of time since previous studies were conducted. Besides, the increased fishing pressure in all these areas from the past to date may reveal variations in the spawning stock size of sardine in these areas.

The comparison with current studies may provide an opportunity to make more accurate comparisons. Nevertheless, it was stated that the spawning stock biomass showed variations among each survey area and over the years in the same areas. The fishing pressure on demersal fish stocks of the Marmara Sea has increased within the last 20 years (Daban et al., 2021). For these reasons, fisheries efforts verge upon the fisheries of small pelagic fish species in the Marmara Sea. In terms of fisheries of sardine in the Türkiye Seas, the highest pressure stemmed from purse seine net boats, which are fishing intensively in the winter period, when the sardine spawning occurs.

Sardine spawning occurs from October to May, and peaks in December and January. In Greece, sardine fishing in the North Aegean Sea with purse seining is banned between mid-December and the end of February (Stergiou et al., 1997). A similar short intermediate fishing ban should also be conducted by the Fisheries Management Authority of Türkiye.

CONCLUSION

The sustainability of these species becomes even more important for eutrophic seas such as the Marmara Sea due to they act as a bridge between the lower and upper food web. Hence, the studies related estimation of spawning stock size should be supported permanently and more efforts should be realised in varied local seas and varied small pelagic fish species such as *E. encrasicolus, S. pilchardus,* and *S. sprattus.* Additionally, the spawning season of these species should be monitored more closely, and seasonal fishing restrictions related to these should be revised more frequently by the fisheries management authority. Once continuous stock size information is obtained, quota application can be initiated on these species when necessary.

ACKNOWLEDGEMENT AND FUNDING

This work is supported by TUBITAK (The Scientific and Technological Research Council of Turkey) (Project No: 121G097). The authors thank Captain Osman Odabaşı and Able Seaman Umut Tunçer for their help in the field works.

AUTHOR CONTRIBUTIONS

İsmail Burak Daban: Writing-Original draft, data analyses, sampling. Yusuf Şen: Sampling, laboratory works, visualization, investigation. Ali İşmen, Ahsen Yüksek: Supervision, data-analyses. Uğur Özekinci, Fikret Çakır: Laboratuary works, visualization, investigation. Alkan Öztekin, Adnan Ayaz, Uğur Altınağaç, Tekin Demirkıran, Gençtan Erman Uğur, Oğuzhan Ayaz, Buminhan Burkay Selçuk: Sampling, laboratuary Works.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

For questions regarding datasets, the corresponding author should be contacted.

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 63-68 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.09

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Prebosphoric occurrence of Korean rockfish, *Sebastes schlegelii* Hilgendorf, 1880 in southwestern Black Sea with notes on its morphometry and dispersal potential

Güneybatı Karadeniz'in boğaz önü sularında görülen Kore iskorpiti, *Sebastes schlegelii* Hilgendorf, 1880'in morfometrisi ve yayılma potansiyeli

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Received date: 21.01.2024 *Accepted date: 07.03.2024*

How to cite this paper:
Uzer, U., Karakulak, F.S., & Kabasakal, H. (2024). Prebosphoric occurrence of Korean rockfish, *Sebastes schlegelii* Hilgendorf, 1880 in southwestern Black Sea with notes on its morphometry and dispersal potential. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 63-68. https://doi.org/10.12714/egejfas.41.1.09

Abstract: On 21 December 2023 one specimen of *Sebastes schlegelii* Hilgendorf, 1880 have been captured by means of a commercial bottom trawler towed at a depth of 30 m off Şile coast. Following its first occurrence in Turkish Black Sea waters off Giresun coast on 6 March 2023, it has recently reported from the Sea of Marmara (Gulf of İzmit) on 7 January 2024, exhibiting a noteworthy dispersal speed which required less than one year to migrate across nearly a 1,000 km. Therefore, the dispersal and potential interactions with indigenous species of this invasive teleostean along theTurkish coast should be monitored carefully. In the present article, authors provide full morphometric and meristic characters of *S. schlegelii*, as well.

Keywords: Sebastidae, invasive alien species, prebosphoric, dispersal

Öz: 21 Aralık 2023 tarihinde Şile açıklarında 30 m derinlikte çekilen ticari dip trolü ile avcılık sırasında *Sebastes schlegelii* Hilgendorf, 1880 türünün bir bireyi elde edilmiştir. *S. schlegelii* Türkiye sularında ilk kez görüldüğü (Giresun, güneydoğu Karadeniz) 6 Mart 2023 tarihi ile Marmara Denizi'nde (İzmit Körfezi) ilk kez kaydedildiği 7 Ocak 2024 arasında dikkate değer bir yayılım başarısı sergilemiştir ki bir yıldan az bir sürede 1,000 km'ye yakın bir mesafeyi aştığı görülmektedir. Bu nedenle, bu istilacı türün gerekTürkiye kıyısı boyunca güney yönünde yayılımı gerekse yerel türlerle olası etkileşimleri dikkatle izlenmelidir. Bu makalede incelenen *S. schlegelii* bireyinin eksiksiz morfometrisi de verilmektedir.

Anahtar kelimeler: Sebastidae, istilacı yabancı tür, boğaz önü, yayılma

INTRODUCTION

The Korean rockfish, *Sebastes schlegelii* Hilgendorf, 1880 (Perciformes: Scorpaenoidei), is a member of the teleostean family Sebastidae, which is represented by 7 genera and 133 species worldwide (Froese and Pauly, 2023). *S. schlegelii* is a livebearing (ovoviviparous), demersal fish occurring near shore and over rocky bottoms at the depths between 3 and 100 m in temperate waters of northwest Pacific off the coasts off Japan, Korean peninsula and China (Froese and Pauly, 2023).

In a recently published checklist of Mediterranean marine fishes, which is based on evidence approach criteria for the definition of "confirmed occurrence", Kovačić et al. (2021) emphasized that no representatives of genera *Sebastes* have been reported to occur in any parts of the region. So, the dispersal of *Sebastes* into the Black Sea can be assumed as a very remote possibility in the light of its absence in the Mediterranean Sea. However, after it was realized that a record of a teleostean captured off the Crimean coast misidentified as dogtooth grouper (*Epinephelus caninus*) (Boltachev and Karpova, 2013), was actually a Korean rockfish, of which further specimens from the region were caught thereafter, confirmed the first record and the presence of an established population in the Black Sea (Karpova et al., 2021). *S. schlegelii* is a boreal species, of which the natural distribution range extends in very limited area in northwest Pacific (Froese and Pauly, 2023); therefore, its introduction in the region assumed may because of random introduction with ship ballast waters or during acclimatization of the giant oyster (*Crassostrea gigas*) (Karpova et al., 2021).

S. schlegelii reported from Turkish Black Sea coast for first time by Bilecenoğlu et al. (2023) based on specimens previously sighted (and photographed) or captured from several localities in the region, which followed by another recent capture of the species off the coast of Akçakoca (southwestern Black Sea; Yağlıoğlu et al., 2023) and the first record of the Korean rockfish in the Sea of Marmara (Karadurmuş et al., 2024). In the present article authors report on a prebosphoric capture of *S. schlegelii*, provide detailed morphometric and meristic characteristics of the examined specimen, as well as make a projection of its dispersal potential along Turkish coasts.

MATERIAL AND METHODS

Study area

The area of investigation of the present study is located in the southwestern Black Sea and in accordance with GFCM's definition of geographical subareas (GSAs) of the Mediterranean Sea, Black Sea is defined as GSA29 (Carpentieri et al., 2021).

Examined specimens have been captured, almost 8,3 kilometers away to the west from northern entrance of the Bosphorus Strait, which measured as a point-to-point distance by means of Google Maps measure distance function (Figure 1).

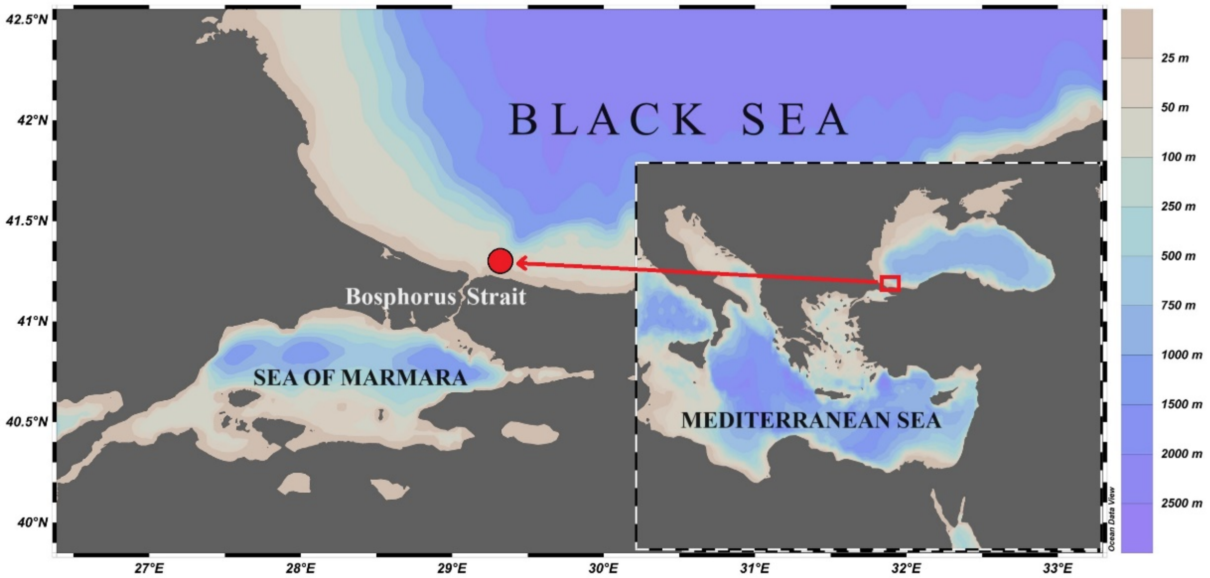

Figure 1. Map shows the approximate locality (red dot) of capture of the examined specimen of *Sebastes schlegelii* in prebosphoric Black Sea

Examined specimen

On 21 December 2023, one specimen of *S. schlegelii* (Figure 2) has been captured by means of a commercial bottom trawler towed at a depth of 50 m off Şile coast (41º16.69'N - 29º13.53'E). Following the capture, the present specimen was stored in a deep freezer at minus 18ºC on board of the fishing trawler, then transferred to İstanbul University, Faculty of Aquatic Sciences, Department of Fisheries Technologies, and Management laboratories. Since the *Sebastes* species occurring in the Atlantic Ocean have 14-16 spiny rays in the dorsal fin, and one or two lachrymal (also called as preorbital) spines (Hureau and Litvinenko, 1986), identification of *S. schlegelii* was based on the following descriptive characters (Karpova et al., 2021): 13 spiny rays in the dorsal fin and three lachrymal spines on the head. Taxonomic nomenclature follows Froese and Pauly (2023). Morphometric measurements and meristic counts were performed in accordance with the procedure adopted from Kai and Nakabo (2002) and Bilecenoğlu et al. (2023). Morphometric distances were measured either with a measurement tape to the nearest 0.5 mm (for distances >10 cm) or with a digital vernier caliper to the nearest 0.05 mm (for distances ≤10 cm) on fresh specimen to avoid affecting shape variations or changing of the distances because of fixation (Martinez et al., 2013). Definitions of body depths 1 and 2 are the distances between the anterior origin of the 13th dorsal spine and that of the 1st anal spine, and body depth 2 is the distance between the anterior origin of the 1st dorsal spine and that of the pelvic spine, respectively (Kai and Nakabo, 2002). Body proportions were expressed as percentages of standard length (SL) and head length (HL). Terminology of head spines follows Orr et al. (2000). Total weight (TW) of the examined specimen was weighed on a precision balance to the nearest 0.05 g. The best practice approach for the first record notes that proposed by (Bello et al., 2014), which requires depositing of evidence specimens preserved in curated collection, photographs of the examined specimen, and morphometric measurements and meristic counts, was strictly followed. The examined specimen was fixed in 10% formalin and 90% distilled water buffered with borax and deposited in the Istanbul University Faculty of Aquatic Sciences laboratory with the barcode number PSC20230114-120.

RESULTS

The examined specimen has a slightly laterally compressed and robust body, and a large head with prominent spines (Figures. 2 and 3). Three lachrymal spines are present, one of which is quite separated from the other two (Figure 3). Strong nasal, preopercular and postocular spines are present (Figure 3), with weakly developed superior cranial spines and suborbital ridge. On the preopercle five spines, of which the second one is the longest, are developed (Figure 3). On the upper corner of the opercle, two flattened and posteriorly directed spines, of which the upper one is the larger, are visible. A single dorsal fin with 13 spines and 13 soft rays (XIII-13), of which the 13th spine, providing anterior support to soft part of the dorsal fin, is longer than the 12th one. Formulae of pelvic and anal fins I-5 and III-8, respectively. Caudal fin rounded. Ctenoid scales covering the body and 46 pored scales were counted along the lateral line. 25 gill rakers were counted on the first gill arch on the left side of the head. A large and oblique mouth with a maxilla extending the posterior rim of eye. The main color of the body is brown with darker fades on dorsal surfaces and become paler ventrally, blotched with dark spots scattered with an irregular pattern; ventral surface is light grayish with brownish spots; a dark brown stripe on the maxilla; two dark bands, of which the front one is more prominent, are extending radially from the eye. Morphometric measurements of the present specimen is presented in Table 1.

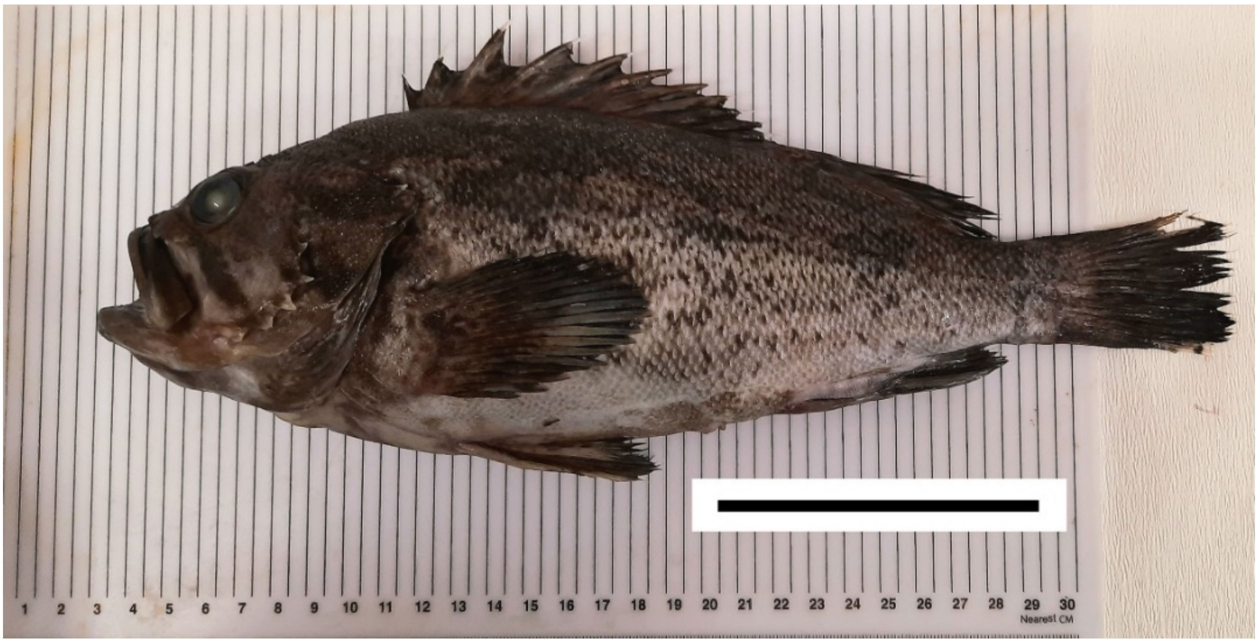

Figure 2. Examined specimen of *S. schlegelii*. Scale bar = 90 mm

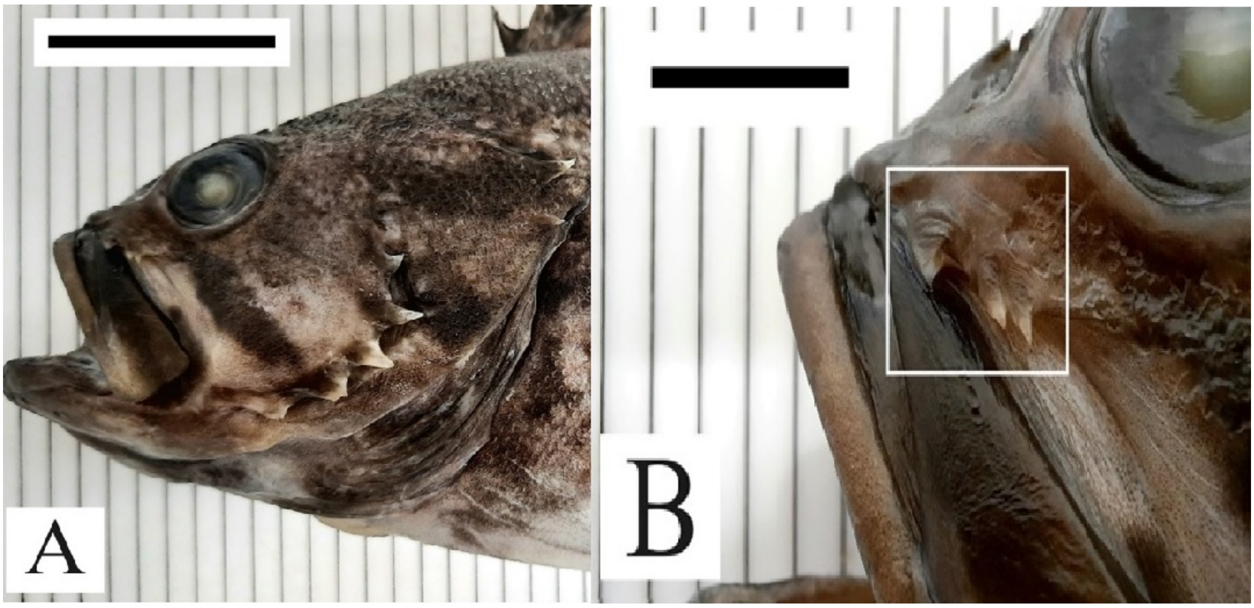

Figure 3. (A) Side view of the head of *S. schlegelii*. Scale bar = 40 mm. (B) Close-up view of three lachrymal spines denoted by the white rectangle. Scale bar = 20 mm

Table 1. Morphometric measurements of the examined and published specimens of *S. schlegelii* recorded from the Marmara (*) and Black Seas

Measurements (mm)	Present Specimen		Karpova et al. (2021)	Bilecenoğlu et al. (2023)	Yağlıoğlu et al. (2023)	Karadurmuş et al. (2024)*
TL	311		325-391	245	350	275
SL	263.5		277-331	206	299.3	240
	(mm)	(% of SL)	(% of SL)	(% of SL)	(% of SL)	
Body depth 1	89.98	34.15	-	36.5	34.0	38.3
Body depth 2	73.95	28.06	-	30.1	-	-
Caudal peduncle depth	25.87	9.82	10.2-10.5	9.7	10.2	9.2
Predorsal length	77.47	29.40	33.0-35.8	27.1	31.1	33.3
Postdorsal length	10.01	3.80	12.5-13.1	13.3	-	
Prepelvic length	103.45	39.26	37.4-38.9	39	34.0	41.3
Preanal length	178.57	67.77	67.8-69.2	66.7	-	68.8
Prepectoral length	88.22	33.48	33.6-35.5	29.8	-	37.1
Distance between pelvic and pectoral fins	15.15	5.75	4.7-5.2	4.7	-	
Distance between pelvic and anal fins	60.62	23.01	18.8-30.2	22.4	-	-
Dorsal fin base length	154.92	58.79	62.5-62.7	60.8	15.8	63.8
Anal fin base length	43.72	16.59	15.5-16.4	15.9	17.8	
Pectoral fin length	59.25	22.49	21.2-22.9	25.2	20.1	24.2
Pelvic fin length	49.21	18.68	20.3-20.6	22.7	34.0	-
Pelvic spine length	26.98	10.24	-	-	-	-
Caudal fin length	52.9	20.08	21.1-21.2	13.4	17.0	-
1st dorsal fin spine	12.99	4.93	-	-	-	-
2nd dorsal fin spine	22.06	8.37	-	-	-	-
3rd dorsal fin spine	29.26	11.10	-	-	-	-
4th dorsal fin spine	34.62	13.14	-	-	-	-
5th dorsal fin spine	36.36	13.80	-	-	-	-
12th dorsal fin spine	18.72	7.10	-	-	-	-
13th dorsal fin spine	24.36	9.24	-	-	-	-
1st anal fin spine	13.04	4.95	-	-	-	-
2nd anal fin spine	27.08	10.28	-	-	-	-
3rd anal fin spine	26.53	10.07	-	-	-	-
Pelvic fin spine	26.97	10.24	-	-	-	-
Head length	90.36	34.29	35.5-40.1	34	30.5	36.7
		% of HL	**% of HL**	**% of HL**	**% of HL**	**% of HL**
Snout length	20.9	23.13	29.7-32.0	19.8	30.6	-
Orbit length	15.49	17.14	18.3-21.1	18.7	18.9	20.4
Postorbital length	56.55	62.58	52.5-52.5	61.5	-	-
Interorbital width	38.04	42.10	-	-	30.9	-
Upper jaw length	32.29	35.73	47.2-49.4	45.5	-	-

DISCUSSION

The above description of the examined specimen is coincided with those given in Karpova et al. (2021), Froese and Pauly (2023), Bilecenoğlu et al. (2023), Yağlıoğlu et al. (2023 and Karadurmuş et al. (2024). The morphometric distances of the examined specimen of *S. schlegelii* are also coincided with those reported in the literature (Karpova et al., 2021; Bilecenoğlu et al., 2023; Yağlıoğlu et al., 2023; Karadurmuş et al., 2024), and the slight differences between the examined and published ratios (as % SL), all of which are in the safe limits for the Korean rockfish, may be arised because of intraspecific allopatry (Moyle and Cech Jr., 1988). The number of observed lachrymal spines (3) in the examined specimen, one of the main descriptive characteristic of *S. schlegelii*, as well as the number preopercular (5) and opercular (2) spines are also coincided with the numbers reported by Karpova et al. (2021), Bilecenoğlu et al. (2023) and Yağlıoğlu et al. (2023), also confirm the identification of the examined specimen.

According to Froese and Pauly (2023), maximum total length (TL) of *S. schlegelii* is 650 mm and the published maximum total weight (TW) is 3100 g. With a reported maximum age of 20 years, Korean rockfish attain sexual maturity between a TL range of 260 to 280 mm (Froese and Pauly, 2023). Although the present specimen is larger (TL 311 mm) than the reported size range of maturity, its dissection revealed that it is female and bearing ovaries (total weight of both ovaries were 1.25 g) at 2c stage that described in the MEDITS maturity scale for bony fish (Follesa and Carbonara, 2019). To date, reproductive biology of *S. schlegelii* from the Black Sea has not been investigated and available information was not allowed to evaluate the reason of the occurrence of such nonmatured ovaries due to recent spawning or the Korean rockfish attains maturity at a larger size in the Black Sea. Further research is required to clarify this uncertainty.

In the past 10 years between the first record date of *S. schlegelii* in the Black Sea (26 May 2013; Boltachev and Karpova, 2013) and date of capture of present specimen (21 December 2023), Korean rockfish distributed from the Crimean coast (northern Black Sea) to prebosphoric waters. During this time, chronological order of records of *S. schlegelii* has begun off southwestern coast of Crimean peninsula (Boltachev and Karpova, 2013), then further specimens reported from the Russian waters along the eastern coast of the Black Sea (Karpova et al., 2021), of which followed by the sighting records of Korean rockfish off Giresun (6 March 2023), Ordu (27 April 2023) and Kastamonu (13 June 2023) coasts along the Turkish coast of eastern and central Black Sea (Bilecenoğlu et al., 2023). With the capture of a specimen off Fatsa coast on 16 June 2023, first physical evidence of *S. schlegelii* from Turkish Black Sea waters has been obtained (Bilecenoğlu et al., 2023), which was followed by the capture of a single specimen off Akçakoca coast (southwestern Black Sea; Yağlıoğlu et al., 2023). According to (Bilecenoğlu et al., 2023) Korean rockfish is captured regularly but with few numbers off the coast of Ordu (southeastern Black Sea).

Based on Google Maps measure distance function result, the distance between Giresun (southeastern Black Sea), where *S. schlegelii* sighted in Turkish waters for first time on 6 March 2023, and Şile (prebosphoric Black Sea), where the present specimen captured on 21 December 2023, is about 833 km and just a few weeks later, on 7 March 2024 the Korean rockfish finally occurred in the Gulf of İzmit, where it has been reported for the first time in the Sea of Marmara (Karadurmuş et al., 2024). Regarding the above mentioned dates, dispersal of *S. schlegelii* along this distance just took 10 months, suggesting a remarkable dispersal speed (83.3 km per month) from east to west, from southeastern Black Sea to the Sea of Marmara. Marine environment is a dynamic realm, and the distribution of species in the marine environment can be deeply affected and changed under the influence of changing conditions (Chen et al., 2021). The Black Sea is one of the marine areas where the species composition of marine life has changed, either due to natural processes (e.g. Mediterrannization; Azzurro et al., 2011), or due to anthropogenic factors (e.g. transportation with ballast waters; Öztürk, 2021). As emphasized in a recent FAO publication, the number of non-native species in the fauna of the Black Sea is gradually increasing (Öztürk, 2021), and among these species there are fish that are not native to the region (Yankova et al., 2013). Although the number of alien fish species in the Black Sea was reported to be 2 a decade ago (Yankova et al., 2013), new species are being added to this number with changing conditions, and one of them is *S. schlegelii* (Karpova et al., 2021; Bilecenoğlu et al., 2023; Yağlıoğlu et al., 2023).

The chronology of the distribution direction of *S. schlegelii*, which has been occurring in the Black Sea since the early 2010s (Karpova et al., 2021; Bilecenoğlu et al., 2023; Yağlıoğlu et al., 2023), reminds the dispersal history of the invasive gastropod *Rapana venosa* (Öztürk, 2021). The rapa whelk has been first recorded in the Black Sea in 1947 near Novorossiysk (northeastern Black Sea) and followed by the records of *R. venosa* off the coast of Sinop (central south Black Sea) in 1955, in the Sea of Marmara in 1966 and in the Aegean Sea in 1969 (Öztürk, 2021). *R. venosa*, which was initially tried to be eradicated due to the damage it caused to mussel (*Mytilus* sp.) and oyster (*Ostrea* sp.) beds, is now considered an important economic resource in the Black Sea (Öztürk, 2021). Based on our previous ecological experience with *R. venosa* in the Black Sea, Sea of Marmara and Aegean Sea, the occurrence and dispersal of *S. schlegelii* far from its natural distribution range (nortwestern Pacific), arise several questions, such as whether the Korean rockfish brings with ecological problems or economic opportunities as it moves towards the Sea of Marmara, where it has been recently reported (Karadurmuş et al., 2024). Although *Sebastes* species were previously classified in the same family with closely related species of scorpion fish (Scorpaenidae) in the past (Hureau and Litvinenko, 1986), are today divided into the Sebastidae family (Froese and Pauly, 2023). Therefore, *S. schlegelii* can be assumed to compete with *Scorpaena notata*, *S. porcus* and *S. scrofa*, which are indigenous species of the fish fauna of Sea of Marmara (Bilecenoğlu et al., 2014), can not be ruled out. Since Korean rockfish is an economically valuable aquaculture species in its natural distribution area, just like in the case of the rapa whelk, *S. schlegelii* can induce its own economy in the future.

CONCLUSION

According to Chen et al. (2021), who emphasize that changing climatic conditions will negatively affect the distribution patterns of *S. schlegelii* in the northwest Pacific, if the conditions do not change, it is predicted that the species will experience a 45% habitat loss in its natural distribution area by the end of this century. The most important environmental parameter affecting the distribution of *S. schlegelii* is bottom water temperature, and the species can be expected to be occur in regions with bottom water temperatures between 3ºC and 13ºC (Chen et al., 2021). Considering the fact that the annual average sea water temperature in the Sea of Marmara is increasing year-by-year (Turkish State Meteorological Service, 2022), the southward dispersal of this relatively cold-water inhabitant species may not extend further than Sea of Marmara. Documenting the species' southerly dispersal and possible colonizations is necessary to achieve an in-depth understanding of the persistence and potential impacts of *S. schlegelii* in its new habitat.

ACKNOWLEDGMENTS

Authors thank to the crews of commercial fishing trawler (Ömer Halis Demir) and the fisherman Sefer GÜZEY for generously sharing the specimen of *S. schlegelii* examined in the present study. Authors also thank to anonymous reviewers for their valuable comments, which improved the content and quality of the article.

FUNDING

No additional grants to carry out or direct this particular research were obtained.

AUTHORSHIP CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Hakan Kabasakal and Uğur Uzer. The first draft of the manuscript was written by Hakan Kabasakal and all authors commented on previous versions of the manuscript. All authors approved the final manuscript.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

ETHICS APPROVAL

Specimen of *Sebastes schlegelii* examined in the present study was consisted of a bycatch fish captured in commercial fisheries. Live fishes were never euthanized and their wellfare were never violated. Since the present sample was only consisted of already death animal, no approval of ethical committe required.

DATA AVAILABILITY

Raw data, including excel tables, figures, etc. are available on request from corresponding author for further inspection.

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http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 41(1), 69-81 (2024)

Su Ürünleri Dergisi (2024)
DOI: 10.12714/egejfas.41.1.10

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) endüstrisinde yeni bir yaklaşım: "Türk Somonu" üretim ve pazarlama eğilimleri

A new approach in rainbow trout (Oncorhynchus mykiss Walbaum, 1792) industry: "Turkish Salmon" production and marketing trends

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Received date: 17.10.2023 *Accepted date: 26.02.2024*

How to cite this paper:
Çakmak, E., Özel, O.T., Batır, E., & Evin, D. (2024). Gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) endüstrisinde yeni bir yaklaşım: "Türk somonu" üretim ve pazarlama eğilimleri. *Ege Journal of Fisheries and Aquatic Sciences, 41*(1), 69-81. https://doi.org/10.12714/egejfas.41.1.10

Öz: Türkiye'de 2022 yılı itibarıyla farklı üretim kapasitelerine sahip 1703 adet işletme alabalık üretimi yapmaktadır. Bu işletmelerin porsiyonluk (200-250 g) , filetoluk adayı (400-600 g) ve filetoluk (Türk Somonu) (>3000 g) alabalık üretimi toplam 167.286 ton/yıl'dır. Türk Somonu üretiminde kuluçkahane, baraj gölü ağ kafes sistemleri ve açık deniz ağ kafes sistemleri üretim zinciri şeklinde kullanılmaktadır. Alabalık yumurta ve yavru üretimi için 680 adet kuluçkahane kullanılmakta olup toplam yumurta üretimi 1.360.029.485 adet/yıl'dır. Genel olarak Türk Somonu adayı alabalıkların (400-600 g) üretimi için 622 adet gölet/baraj gölü ağ kafes sistemleri kullanılmakta olup bu işletmelerin üretim kapasitesi 163.525 ton/yıl'dır. Karadeniz'de toplam 6 ilin denizel alanında açık deniz ağ kafes sistemlerinde Türk Somonu üretimi yapılmakta, 2 il için de üretim planlaması devam etmektedir. Bu illerin toplam planlanan üretim sahası 15.650.000 m², proje kapasiteleri ise 221.188 ton/yıl olarak hesaplanmıştır. Dünya su ürünleri sektöründe yaşanan gelişmelere kayıtsız kalmayan Türkiye, farklı türlerin yetiştiriciliğine uygun çevresel koşulları ve yeni teknoloji kullanımı ile günümüzde sektörde söz sahibi ülkeler tarafından dikkatle takip edilmektedir. Dünya alabalık üretiminde söz sahibi ülkelerin üretim kapasiteleri düşünüldüğünde, Türkiye'nin yumurta/yavru üretim kapasitesi oldukça iyi durumdadır. Fakat Türkiye doğal sucul alanları için biyolojik ve genetik risk teşkil eden biyoteknoloji uygulanmış gözlenmiş yumurta ithalatına halen devam etmektedir. Türkiye'nin alabalık üretimi son 20 yılda 3,75 kat büyüyerek 167.286 ton/yıl'a ulaşmış ve önemli bir gıda üretim endüstrisi haline gelmiştir. Bu başarıda; elverişli çevresel şartlar, sürekli yükselme eğilimi gösteren tüketici talebi ve üretimde yeni teknolojilerin kullanılması ile birlikte istikrarlı yatırımın etkili olduğu görülmektedir. Ancak, alabalık yetiştiriciliği sektöründe yaklaşık 5 yıldır yaşanan hızlı büyüme beraberinde kontrol edilemeyen düşük yaşama oranını da getirmiştir. Azalan yaşama oranı; hastalıkların yaygınlaşması, yanlış tedavi yöntemleri, yanlış damızlık yönetimi uygulamaları, yanlış işletme yönetimi, kontrolsüz balık nakilleri, sıhhi ve çevresel koşullara bağlanabilir.

Anahtar kelimer: Fileto, büyük boy alabalık, yetiştiricilik, kuluçkahane, ağ kafes

Abstract: With favorable environmental conditions and the adoption of new technologies, Türkiye has 1703 enterprises producing trout as of 2022. These enterprises collectively produce 167,286 tons of trout per year, including portioned fish (200-250 g), fillet candidates (400-600 g), and fillets (known as Turkish Salmon) (>3000 g). The production chain for Turkish Salmon involves hatcheries, dam lake net cage systems, and offshore net cage systems. There are 680 hatcheries producing trout eggs and fry, with a total annual production of 1,360,029,485 eggs. Additionally, 622 pond/dam lake net cage systems are used for producing Turkish Salmon candidates weighing 400-600 g, with a total production capacity of 163,525,079 kg per year. Offshore net cage systems in the Black Sea region, spread across six provinces, are utilized for Turkish Salmon production. Production planning is underway for two provinces, with a total planned production area of 15,650,000 m² and a projected capacity of 221,188,000 kg per year. Türkiye is actively involved in the global aquaculture sector, paying close attention to its advancements. Türkiye has a strong egg/juvenile production capacity compared to other countries involved in trout production globally. However, the importation of biotechnology-applied and observed eggs continues, posing biological and genetic risks to Türkiye's natural aquatic areas. Over the past 20 years, Türkiye's trout production has grown significantly, reaching 167,286 tons per year, marking it as a significant food production industry. This success can be attributed to favorable environmental conditions, increasing consumer demand, the adoption of new technologies, and consistent investments. However, the rapid growth in the trout farming sector over the past five years has led to an uncontrollable decline in survival rates. This decline can be attributed to the spread of diseases, incorrect treatment methods, improper breeding management practices, flawed business management, unregulated fish transport, and compromised sanitary and environmental conditions.

Keywords: Fillet, large size trout, aquaculture, hatchery, net cage

GİRİŞ

Birleşmiş Milletler Gıda ve Tarım Örgütünün (FAO) tahminlerine göre, sürekli artış eğilimi gösteren dünya nüfusunun 2050 yılına kadar 9,3 milyara ulaşması beklenmektedir. Bu nüfusun gıda talebini karşılamak için toplam gıda üretiminin %60 oranında büyümesi gerekmektedir. Bu arada, doğal kaynakların da tükenmeye devam ettiği unutulmamalıdır. FAO, gıda arz ve talebi arasındaki boşluğu doldurmada su ürünleri yetiştiriciliğinin kilit bir role sahip olduğunu, bunun gerçekleşmesi için sürdürülebilir bir üretime ihtiyaç olduğunu belirlemiştir (FAO, 2022). Dünya toplam su ürünleri üretiminde yıllar itibarıyla avcılıktan gelen üretim miktarı küçük dalgalanmalarla sabit kalırken yetiştiricilik üretiminin payı sürekli olarak artış göstermektedir. Yetiştiricilik üretiminin yıllar içinde artması, gıda gereksinimi için su ürünleri temininde avcılığın yerini yetiştiriciliğe bırakması olarak değerlendirilebilir. Dünya su ürünleri üretimi 2021 yılında 218.378.013,33 milyon ton olarak gerçekleşmiş, bu üretimin 126.035.296,8 tonu (%57,71) yetiştiricilik, 92.342.716,53 milyon tonu (%42,29) avcılık yolu ile elde edilmiştir (FAO, 2023). Dünya yetiştiricilik sektöründe

2021 yılında en yüksek üretim 72.805.297 ton ile Çin ilk sırada yer alırken, bu ülkeyi 1.665.112 ton ile Norveç ve 1.460.868 ton ile Şili takip etmektedir. Türkiye ise 471.686 ton ile sektörde söz sahibi Ülkeler arasında yer almaktadır (FAO, 2023).

Dünyada, yetiştiriciliği yapılan türler arasında Gökkuşağı alabalığı (*Oncorhyncus mykiss*) 15. sırada olup yetiştiriciliği yapılan alabalık türleri arasında ise en ön sıradadır (FAO, 2022). Dünya gökkuşağı alabalığı yetiştiricilik sıralamasında ise 326.054 ton ile Şili ilk sırada yer alırken, İran 193.852 ton ile ikinci ve Türkiye 165.683 ton ile üçüncü sırada yer almaktadır (FAO, 2023) (Tablo 1).

Türkiye su ürünleri sektöründeki gelişmeler, dünya su ürünleri sektöründe yaşananlar ile benzerlik göstermektedir. Türkiye'nin 2022 yılı toplam su ürünleri üretimi 849.808 ton olarak gerçekleşmiş ve bu üretimin %60,58'ı yetiştiricilik yoluyla, %39,42'ı ise avcılık yolu ile elde edilmiştir (TUİK, 2023). Ülkemizde, son 10 yılda yetiştiricilikten sağlanan üretim miktarı yıllık 212.410 tondan 471.686 tona ulaşmıştır. Yetiştiriciliği yapılan türler arasında ilk sırayı alabalık (%35,5) almakta, bunu sırası ile levrek (%32,9), çipura (%28,3), granyöz, orkinos, midye ve diğerleri izlemektedir (TUİK, 2022). Son yıllarda oldukça hızlı gelişme gösteren Karadeniz'de ağ kafes sistemlerindeki balık yetiştiriciliği ilk sırayı gökkuşağı alabalığı (*Oncorhynchus mykiss*) üretimi almaktadır. Bunun yanı sıra Karadeniz alabalığı (*Salmo labrax*), levrek (*Dicentrarchus labrax*) ve diğer bazı türlerin üretimi de yapılmaktadır. Av stoklarındaki azalmanın önüne geçilebilmesi ve artan nüfusun ihtiyaç duyacağı su ürünleri kaynaklı proteinin elde edilmesi için yetiştiricilik faaliyetlerinin ülkesel çapta artırılması büyük önem taşımaktadır.

Tablo 1. Dünyada söz sahibi ülkelerin yetiştiricilik üretimi, ton (FAO, 2023)

Table 1. Aquaculture production of the countries that have a say in the world, tons (FAO, 2023)

Ülkeler	Toplam Yetiştiricilik Üretimi (ton)	G. alabalığı Üretimi (ton)	Toplam Üretimdeki Payı (yüzde)	İthalat (ton)	İhracat (ton)
Çin	72.805.297	37.258,81	0,05	37.258,81	11.878,98
Norveç	1.665.112	94.659,75	5,68	224,24	63.359,06
Şili	1.460.868	326.053,52	22,32	394,61	326.053,52
İran	478.737	193.852	40,49	22,89	2.673,00
Türkiye	471.686	165.683	35,13	291,47	50.563,53
ABD	451.878	18.035,57	3,99	221.216,56	18.035,57
Kanada	194.517	5.512,33	2,83	58.217,37	5.512,33
Kolombiya	192.521	30.185	15,68	4,87	1.529,72
Finlandiya	14.399	13.550	94,10	4.856,81	2.811,22

Türkiye su ürünleri sektöründeki gelişmeler, dünya su ürünleri sektöründe yaşananlar ile benzerlik göstermektedir. Türkiye'nin 2022 yılı toplam su ürünleri üretimi 849.808 ton olarak gerçekleşmiş ve bu üretimin %60,58'ı yetiştiricilik yoluyla, %39,42'ı ise avcılık yolu ile elde edilmiştir (TUİK, 2023). Ülkemizde, son 10 yılda yetiştiricilikten sağlanan üretim miktarı yıllık 212.410 tondan 471.686 tona ulaşmıştır. Yetiştiriciliği yapılan türler arasında ilk sırayı alabalık (%35,5) almakta, bunu sırası ile levrek (%32,9), çipura (%28,3), granyöz, orkinos, midye ve diğerleri izlemektedir (TUİK, 2022). Son yıllarda oldukça hızlı gelişme gösteren Karadeniz'de ağ kafes sistemlerindeki balık yetiştiriciliği ilk sırayı gökkuşağı alabalığı (*Oncorhynchus mykiss*) üretimi almaktadır. Bunun yanı sıra Karadeniz alabalığı (*Salmo labrax*), levrek (*Dicentrarchus labrax*) ve diğer bazı türlerin üretimi de yapılmaktadır. Av stoklarındaki azalmanın önüne geçilebilmesi ve artan nüfusun ihtiyaç duyacağı su ürünleri kaynaklı proteinin elde edilmesi için yetiştiricilik faaliyetlerinin ülkesel çapta artırılması büyük önem taşımaktadır.

Türkiye Tarım ve Orman Bakanlığı Balıkçılık ve Su Ürünleri Genel Müdürlüğü, 2018 yılında Karadeniz tuzluluğunda yetiştiriciliği yapılan büyük boy gökkuşağı alabalığının "Türk Somonu" markası altında dünya balık pazarına giriş yapmasına vesile olmuştur (Turan ve Çenesiz, 2023). Bununla birlikte Chris Loew (2023) alabalıkların, Japonya'da bir tür somon olarak kabul edildiğini ve Türk ihracatçıların, kültür koşullarında yetiştirilen gökkuşağı alabalığını Japonya'da "Türk Somonu" olarak pazarladığını bildirmiştir. Türkiye'de özellikle büyük boy alabalığa (Türk Somonu-*Oncorhynchus mykiss*) yurtdışından gelen yüksek talep, kültür balıkçılığı üretimindeki artışa hız kazandırmıştır. Tatlısu kaynakları, baraj gölleri ve denizi ile büyük boy alabalık üretimi için oldukça uygun çevresel koşullara sahip olan Karadeniz Bölgesi üretimde cazibe merkezi olmuştur. Kuluçkahane, havuz, baraj gölü ağ kafes ve deniz ağ kafes sistemlerinin yumurtadan hasat boyuna kadar üretim zinciri halinde kullanılabilmesi Karadeniz Bölgesinin önemini gün geçtikçe artırmaktadır.

Türkiye'de 2022 yılı itibarıyla farklı üretim kapasitelerine sahip 1.703 adet işletme alabalık yetiştiriciliği yapmaktadır. Bu işletmelerin porsiyonluk (200-250 g), filetoluk adayı (400-600 g) ve filetoluk (Türk Somonu) (>3000 g) alabalık üretimi toplam 167.286 ton/yıl'dır (BSGM, 2022). Türkiye'nin sahip olduğu coğrafyada alabalık üretimi için uygun çevresel koşullara sahip tatlısu kaynakları bulunmaktadır. Bu nedenle kuluçkahane ve tatlısu havuz yetiştiriciliği oldukça yaygındır. Çoğunluğunda geleneksel üretim yönteminin kullanıldığı 670 adet kuluçkahanede 1.350.629.485 adet/yıl yumurta üretimi yapılmaktadır (TUİK, 2022).

Bu çalışma, Türkiye'de son yıllarda yüksek oranda talep gören Türk somonu yetiştiriciliğinin mevcut durumunu belirleyerek sürdürülebilir üretimin sağlanmasına yönelik tartışmalara katkı sağlamak amacıyla hazırlanmıştır.

MATERYAL VE METOT

Çalışmada, mevcut durumun belirlenmesinde Balıkçılık ve Su Ürünleri Genel Müdürlüğü (BSGM) ve Türkiye İstatistik Kurumu (TÜİK) verileri ile Su Ürünleri Merkez Araştırma Enstitüsü (SUMAE) tarafından yürütülen projelerin verileri kullanılmıştır. Çalışmada, büyük boy alabalık üretiminde sacayağı olan tatlısu kara, baraj ağ kafes ve deniz ağ kafes işletmeleri bölgesel olarak değerlendirmeye tabi tutulmuş ve geleceğe dönük üretim potansiyelleri ülkemiz sucul alanları dikkate alınarak irdelenmiştir.

Su ürünleri yetiştiricilik işletmeleri değerlendirilirken üretilen tür Alabalık-Gökkuşağı olanlar dikkate alınmıştır. Su ürünleri yetiştiricilik işletmeleri ile ilgili bilgiler BSGM tarafından yayınlanan verilerden derlenmiştir (BSGM, 2022). Kuluçkahanesi olan işletmelerde türün adet olarak verilen üretim kapasite miktarları yumurta üretim miktarı olarak alınmıştır. Kuluçkahaneler yumurta üretim kapasitesine göre 4 sınıfa (≤199 bin, 200-599 bin, 600-999 bin ve ≥1 milyon) ayrılmıştır. BSGM verilerinde yer alan ve tesis tipi büyütme olan Alabalık-Gökkuşağı işletmeleri üretim metoduna göre havuz, baraj ağ kafes ve deniz ağ kafes olarak ayrılmıştır. Üretim metodu beton/toprak havuz olanlar Kaynak/akarsu havuz işletmeleri olarak belirlenmiştir. Havuz işletmeleri üretim kapasitesine göre 4 sınıfa (≤ 29 ton, 30-99 ton, 100-499 ton ve ≥500 ton) ayrılmıştır. Baraj gölü ağ kafes işletmeleri belirlenirken "Üretim Metodu" ağ kafes olanlar seçilmiş, ilin denize sınırı yoksa baraj ağ kafes işletmesi olarak alınmıştır. Eğer hem baraj hem deniz ağ kafes işletmesi varsa "Proje Kapasitesi" <1000 ton/yıl olanlar baraj ağ kafes olarak alınarak hesaplanmıştır. Baraj gölü ağ kafes işletmeleri üretim kapasitesine göre 4 sınıfa (≤ 29 ton, 30-99 ton, 100-499 ton ve ≥500 ton) ayrılmıştır. Deniz ağ kafes işletmeleri de baraj işletmelerindeki kriterler dikkate alınarak belirlenmiştir. Denize kıyısı olan illerde "Üretim Metodu" ağ kafes olan işletmeler ve baraj gölü olup denize sınırı olan illerde "Proje Kapasitesi" >950 ton/yıl olanlar deniz ağ kafes işletmesi olarak belirlenmiştir. Deniz ağ kafes işletmeleri üretim kapasitesine göre 3 sınıfa (≤ 499 ton, 500-999 ton, ≥1000 ton) ayrılmıştır.

İhracat miktarlarının değerlendirilmesinde Tarım ve Orman Bakanlığı, Hayvan ve Hayvansal Ürünler Sınır Kontrol Daire Başkanlığı Gıda ve Kontrol Genel Müdürlüğü verileri kullanılmıştır (TUİK, 2022). Canlı olarak ihraç edilen balıkların kuluçkahane ve tatlısu havuz işletmelerinden hasat edildiği kabul edilmiştir. İhracatta kullanılan ürünler; taze veya soğutulmuş alabalık, dondurulmuş alabalık, taze veya soğutulmuş alabalık fileto, dondurulmuş alabalık fileto ve tütsülenmiş alabalık olarak isimlendirilmiştir. Üretim sistemleri ve ürün isimleri işleme tesisleri ile görüşülerek belirlenmiştir.

Çalışmada elde edilen sonuçlar Microsoft Excel 2016 programı kullanılarak analiz edilmiştir.

BULGULAR

Kuluçkahaneler ve yumurta/yavru üretimi

Türkiye'nin sahip olduğu yedi coğrafik bölgede alabalık üretimi için uygun çevresel koşullara sahip tatlı su kaynakları bulunmaktadır. Bundan dolayı kuluçkahane ve tatlısu havuz yetiştiriciliği ülke geneline yayılmış durumdadır. Çoğunluğu aile işletmesi (0-29 ton/yıl) niteliği taşıyan ve geleneksel üretim yönteminin kullanıldığı 670 adet kuluçkahanede 1.350.629.485 adet/yıl yumurta üretimi yapılmaktadır. Karadeniz Bölgesi 192 adet kuluçkahane ile ilk sırayı almasına rağmen üretim kapasitesi sıralamasında dördüncü sırada yer almaktadır. 374.107.490 adet/yıl üretim kapasitesi ile ilk sırada yer alan Ege Bölgesi, kuluçkahane sayısı sıralamasında 144 adet kuluçkahane ile ikinci sırada yer almaktadır (Tablo 2).

Kuluçkahanelerin tamamına yakını yumurta inkübasyonu ve yavru alabalık üretiminde kaynak suyu kullanmaktadır. Kaynak sularının miktar bakımından fazla olduğu bölgelerde (Ege, Doğu Anadolu, Akdeniz) üretim kapasitesi yüksek işletmeler yoğunlaşırken, kaynak sularının sayısal olarak fazla, fakat debi olarak az olduğu Karadeniz Bölgesinde ise kuluçkahane sayısı fazla üretim kapasitesi düşük olan işletmeler bulunmaktadır. Marmara Bölgesinde kaynak suları diğer bölgelere nazaran sayısal ve miktar olarak oldukça azdır. Bu nedenle bölgede 42 kuluçkahanede 27.062.271 adet/yıl yumurta üretilmektedir. Güneydoğu Anadolu Bölgesi kaynak suları bakımından oldukça zengin olmasına rağmen bölgede yalnızca 6 kuluçkahane bulunmaktadır ve üretim kapasitesi 27.905.000 adet yumurta/yıldır (Tablo 2). Bunun başlıca nedenlerinin; iklim koşullarının ve coğrafik koşulların zorluğu olduğu düşünülmektedir.

Kuluçkahaneler yumurta üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazarı gözetilerek 4 grupta irdelenmiştir (Tablo 3). Toplam kuluçkahane sayısının çoğunluğunu oluşturan (%70) 1. ve 2. grup kuluçkahaneler kendi tesisinin ihtiyacını karşılayacak miktarda üretim yaptığından Türk Somonu üretimine katkı sağlamamaktadır. %3 oranı ile temsil edilen 3. grup kuluçkahaneler Türk Somonu üretimine az miktarda katkı sağlarken, asıl üretimin %28 pay ile temsil edilen 4. grup kuluçkahanelerden sağlandığı görülmektedir. Kuluçkahanelerin üretim kapasiteleri dağılımında %95 kapasiteye sahip olan 4.grup kuluçkahaneler Türk Somonu üretiminde ilk sırada yer almaktadır.

Tablo 2. Bölgeler bazında kuluçkahane ve yumurta kapasitesi
Table 2. Hatchery and egg capacity by regions

Bölge Adı	Kapasite Sınıfı (Bin adet)	Kuluçkahane Sayısı (Adet)	Üretim Miktarı (Bin Adet)	Bölge Adı	Kapasite Sınıfı (Bin adet)	Kuluçkahane Sayısı (Adet)	Üretim Miktarı (Bin Adet)
Akdeniz	≤ 199	58	3.534	İç Anadolu	≤ 199	37	2.341
	200-599	20	6.788		200-599	13	4.730
	600-999	3	2.750		600-999	1	750
	1.000 ≥	50	278.960		1.000 ≥	19	145.300
Karadeniz	≤ 199	116	6.020	Doğu Anadolu	≤ 199	44	3.501
	200-599	37	13.160		200-599	10	3.500
	600-999	3	1.900		600-999	1	600
	1.000 ≥	36	158.299		1.000 ≥	30	289.418
Marmara	≤ 199	25	1.162	Güneydoğu Anadolu	≤ 199	1	105
	200-599	9	2.750		200-599	0	0
	600-999	2	1.700		600-999	1	800
	1.000 ≥	6	21.450		1.000 ≥	4	27.000
Ege	≤ 199	82	4.844	Toplam	≤ 199	363	21.510
	200-599	15	5.470		200-599	104	36.398
	600-999	2	1.448		600-999	13	9.948
	1.000 ≥	45	362.344		1.000 ≥	190	1.282.772

Tablo 3. Yumurta üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazarına göre kuluçkahane grupları
Table 3. Hatchery groups according to egg production capacities, production purposes, production method and target market

Grup Sıra No	Üretim Kapasitesi (adet/yıl)	Üretim Kapasitesi (ton/yıl)	İşletme Sayısı (adet)	Üretim Kapasiteleri (adet/yıl)	Kuluçkahanenin Özellikleri
1	≤199.000	0-29	363	21.510.191	Porsiyonluk balık üreten, geleneksel üretim yapan, kendi ihtiyacı kadar yumurta üreten ve restoranı olan aile işletmeler
2	200.000–599.000	30-99	104	36.398.000	Porsiyonluk balık üreten, teknik personel çalıştıran, yeni teknoloji kullanan, diğer kuluçkahanesi olmayan işletmelere de yumurta üreten ve çoğunlukla restoranı olan işletmeler
3	600.000–999.000	100-999	13	9.948.500	Kendi işletmesine ve diğer kuluçkahanesi olmayan işletmelerle beraber az miktarda baraj gölü ağ kafes işletmelerine yavru balık temini için üretim yapan işletmeler
4	≥1.000.000	≥150	190	1.282.772.794	Kendi işletmesine ve daha çok baraj gölü ağ kafes işletmelerine Türk Somonu adayı yavru balık temini için üretim yapan işletmeler

Kuluçkahanelerde, 2021 yılında toplam 1.350.629.485 adet gökkuşağı alabalığı yumurtası üretilmiştir. Aynı yıl (16.655.000 g/ 0,090 g/adet) 185.055.556 adet yumurta ithalatımız olmuştur (BSGM, 2022). Türkiye'nin 2021 yılı toplam 167.286.000 kg alabalık üretimi için 1.535.685.041 adet yumurta kullanılmıştır. 167.286.000 kg alabalık hasadında kullanılan yumurta sayısı hesabı aşağıda verilmiştir.

2021 yılı deniz ağ kafes sistemlerinden hasat edilen alabalıkların tamamı (31.554.000 kg) Türk Somonu olarak ihracatta kullanılmış olarak kabul edilmiştir. Zayiatsız hasat miktarı kriter alınarak yumurta ihtiyacı (31.554.000 kg ÷ ortalama hasat ağırlığı 3 kg) 10.518.000 adet olmuştur. Aynı yıl akarsu havuz işletmelerinin toplam balık üretimi 40.690.708 kg olmuştur. Bu üretimin %10 (4.069.070 kg)'u somon adayı (ortalama ağırlık 500 g) olarak deniz ağ kafes işletmelerine satılırken geriye kalan %90 (39.621.637 kg)'ı restoranı olan işletmelerde veya işletmeden taze porsiyonluk (ortalama ağırlık 250 g) olarak satıldığı varsayılmıştır. Buna göre akarsu havuz işletmelerinin zayiatsız hasat kriter olarak kabul edildiğinde ihtiyaç duyulacak yumurta miktarı (36.621.637.000 g ÷ ortalama hasat ağırlığı 250 g) 146.486.548 adet olmuştur. Türkiye'nin 2021 yılı içsu alabalık üretimi 135.732.000 kg olmuştur (TÜİK, 2022). Bu üretimin 40.690.708 kg akarsu havuz işletmelerinde, geriye kalan 95.041.292 kg baraj gölü ağ kafes işletmelerinde gerçekleşmiştir.

2021 yılı toplam alabalık ihracatımız 50.569.436 kg olmuştur. Bu miktarın (50.569.436 kg – deniz ağ kafes hasatı 31.554.000 kg) 19.015.436 kg'ı baraj gölü ağ kafes işletmelerinden özellikle yaz aylarında taze balık (ortalama ağırlık >2 kg) ihracatında kullanıldığı anlaşılmaktadır. İhracat üretimi için zayiatsız hasat kriter olarak kabul edildiğinde ihtiyaç duyulacak yumurta miktarı (19.015.436 kg ÷ 2 kg) 9.507.718 adettir. Baraj gölü üretiminden Türk somonu üretimi için deniz ağ kafes işletmelerine somon adayı (ortalama ağırlığı 500 g) satılmaktadır. Bu üretimin toplam miktarı (10.518.000 adet yumurta x 500 g) 5.290.000 kg'dır. Bu durumda baraj gölü ağ kafes işletmelerinden iç piyasaya satılan balık miktarı ise (95.041.292 kg – (19.015.436 kg + 5.290.000 kg) 70.735.856 kg olarak hesaplanmıştır. Baraj gölü üretiminden iç piyasaya genelde porsiyonluk balık (ortalama ağırlığı 250 g) satılmaktadır. Buna göre baraj gölü ağ kafes işletmelerinin zayiatsız hasat kriter olarak kabul edildiğinde ihtiyaç duyulacak yumurta miktarı (70.735.856.000 g ÷ 250 g) 282.943.424 adettir. Deniz ağ kafes işletmeleri için 10.518.000 adet, akarsu havuz işletmeleri için 146.486.548 adet, baraj gölü ağ kafes işletmelerinden ihracatta kullanılan üretim için 9.507.718 adet ve baraj gölü ağ kafes işletmelerinden iç piyasaya satışı yapılan üretim için 282.943.424 adet olmak üzere toplam 449.455.690 adet/yumurtadır.

Buna göre alabalık üretiminde zayiatsız hasat kriter olarak kabul edildiğinde yumurtadan hasata üretim başarası %30,10 olarak hesaplanmıştır. Kuluçkahanelerde hasat, büyütme işletmelerinin tercihine uygun yapılmaktadır. Bazı tatlısu havuz işletmeleri/baraj gölü ağ kafes işletmeleri üretimde 3-5 g ağırlığındaki yavru balıkları tercih ederken bazıları da 20-30 g ağırlığa sahip hastalık direnci gelişmiş yavruları tercih etmektedir.

İçsu/Akarsu havuz işletmelerinde üretim

Daha çok taze balık tüketiminin tercih edildiği Türkiye'de kaynak/akarsu havuz alabalık işletmeleri tüm bölgelere dağılmış durumdadır. Bu işletmelerin toplam sayısı 948 adet, üretim kapasitesi ise 40.691 ton/yıl'dır. Karadeniz Bölgesi işletme sayısı (266 adet) bakımından en zengin bölge olmasına rağmen en büyük kapasiteye (19.065 ton/yıl) sahip bölge Ege Bölgesidir.

İçsu/akarsu havuz işletmeleri üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazarı gözetilerek 4 sınıfta irdelenmiştir (Tablo 4).

Tablo 4. Üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazara göre içsu/havuz işletmeleri grupları

Table 4. Groups of inland water/pool businesses according to production capacities, production purposes, production method and target market

Grup Sıra No	Üretim Kapasitesi (ton/yıl)	Üretim Kapasitesi (ton/yıl)	İşletme Sayısı (adet)	Havuz İşletmelerinin Özellikleri
1	≤29	9.605	767	Çoğunluğu kuluçkahaneli, porsiyonluk balık üreten, restoranı olan ve geleneksel üretim yapan aile işletmeleridir. Bu işletmelerin Türk Somonu üretimine katkısı yok denecek kadar azdır
2	30-99	4.729	98	Kendi ihtiyacını karşılayacak kapasitede porsiyonluk balık üreten, çoğunlukla restoranı olan, diğer restoranlı işletmelere satış yapan, teknik personel istihdam eden, ekstansif üretim yapan ve Türk Somonu üretimine katkısı az olan işletmelerdir.
3	100-499	14.102	68	Diğer restoranlı işletmelere satış yapan, teknik personel istihdam eden, ekstansif üretim yapan, baraj gölü işletmelerine yavru temini, deniz ağ kafes işletmelerine az sayıda Türk somonu adayı temini yapan ve Türk Somonu üretimine katkısı az olan işletmelerdir.
4	≥500	12.254	15	Teknik personel istihdam eden, konvansiyonel üretim tekniği kullanan, baraj gölü ağ kafes işletmelerine ve deniz ağ kafes işletmelerine Türk Somonu adayı satışı yapan ve Türk Somonu üretimine katkısı diğer gruplara nazaran oldukça yüksek işletmelerdir.

Ülkemizdeki kaynak/akarsu havuz işletmelerinin tamamına yakını üretimde akarsu kullanmaktadır. Kaynak/akarsuların miktar bakımından fazla olduğu bölgelerde (Ege, Doğu Anadolu, Akdeniz) üretim kapasitesi yüksek işletmeler yoğunlaşırken, kaynak/akarsuların sayısal olarak fazla fakat miktar (debi) olarak az olduğu Karadeniz Bölgesinde ise havuz işletmeleri sayısı fazla üretim kapasitesi düşük olan işletmeler bulunmaktadır. Marmara Bölgesinde alabalık üretimine uygun kalitede kaynak/akarsular diğer bölgelere nazaran sayısal ve miktar olarak oldukça azdır. Bu nedenle bölgede 65 adet kaynak/akarsu havuz işletmesinde 3.165 ton/yıl üretim mevcuttur. Güneydoğu Anadolu Bölgesi kaynak/akarsu bakımından zengin olmasına rağmen bölgede yalnızca 13 adet kaynak/akarsu havuz işletmesi bulunmakta ve üretim kapasitesi de (473 ton/yıl) diğer bölgelere nazaran oldukça azdır (Tablo 5). Bölgede, güçlü ve verimli Fırat ve Dicle'nin kolları olan Nizip, Göksu, Garzan, Batman ve Botan akarsuları bulunmaktadır. Güneydoğu Anadolu Bölgesinde, yetiştiricilik sektörünün geliştirilmesi ve istihdam oluşturulması için bu akarsular küçük kollarıyla beraber değerlendirilmelidir.

Kaynak/akarsu havuz işletmelerinde hasat, tamamen müşteri tercihine uygun yapılmakta ve işletme yönetim planı da balık hasat boyu kriter alınarak oluşturulmaktadır. 1. ve 2. sınıf işletmeler genel olarak restoranı olan küçük işletmelerdir. Bu işletmeler porsiyonluk boya (200 g) kadar semirtme yapmakta ve hasat ettiği balıkları restoranında veya taze olarak yerinde pazarlamaktadır. 3. ve 4. sınıf işletmeler 20-30 g yavru balık, 200 g porsiyonluk balık ve 500 g Türk Somonu adayı üretimi yapmaktadır. Genel olarak 20-30 g yavru balıklar baraj gölü ağ kafes işletmelerine, 200 g porsiyonluk balıklar üretim tesisi olmayan restoranlara veya taze satışa ve 500 g balıklar Türk somonu adayı olarak deniz ağ kafes işletmelerine pazarlanmaktadır. Türk Somonu üretiminde kullanılan aday balıkların yaklaşık %10'u kaynak/akarsu işletmelerinden temin edilmektedir.

Tablo 5. Bölgeler bazında içsu/akarsu havuz işletmeleri sayısı ve kapasiteleri

Table 5. Number and capacities of inland water/river pond enterprises by region

Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)	Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)
Akdeniz	≤ 29	155	2.062.500	İç Anadolu	≤ 29	76	1.051.000
	30-99	27	1.190.500		30-99	12	643.000
	100-499	10	1.365.000		100-499	5	1.580.000
	500 ≥	0	0		500 ≥	1	750.000
Karadeniz	≤ 29	241	2.33.059	Doğu Anadolu	≤ 29	85	1.571.567
	30-99	17	727.000		30-99	13	765.822
	100-499	8	1.558.000		100-499	13	1.920.200
	500 ≥	0	0		500 ≥	1	500.000
Marmara	≤ 29	51	542.860	Güneydoğu Anadolu	≤ 29	8	160.000
	30-99	10	52.000		30-99	4	193.000
	100-499	1	120.000		100-499	1	120.000
	500 ≥	3	2.000.000		500 ≥	0	0
Ege	≤ 29	151	1.914.200	**Toplam**	≤ 29	767	9.605.186
	30-99	15	708.000		30-99	98	4.729.322
	100-499	30	7.439.000		100-499	68	14.102.200
	500 ≥	10	9.004.000		500 ≥	15	12.254.000

Baraj ağ kafes işletmelerinde üretim

Türkiye'de barajlar; içme suyu temininde, sulama/sanayi suyu temininde, hidroelektrik enerji üretiminde, taşkınların önlenmesinde, eğlen-dinlen alanlarının oluşturulmasında ve balık üretiminde kullanılmaktadır. Son yıllarda özellikle büyük boy alabalık yetiştiriciliğinde baraj gölleri, coğrafi ve çevresel özelliklerinden dolayı yetiştiricilik sektörünün gözdesi durumuna gelmiştir. Kuluçkahanelerde 2-5 veya 30 g ağırlığa kadar büyütülen yavru balıklar baraj gölü ağ kafes işletmelerine nakledilerek porsiyonluk (250 g), Türk Somonu adayı (500 g) veya filetoluk (>2000 g) boya kadar büyütülmektedir. Baraj gölü ağ kafes işletmeleri üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazarı gözetilerek 4 sınıfta irdelenmiştir (Tablo 6). Türkiye'nin sahip olduğu yedi coğrafik bölgede ağ kafeslerde alabalık üretimi için uygun çevresel koşullara sahip baraj gölleri bulunmaktadır. Farklı üretim kapasitelerine sahip toplam 622 adet baraj gölü ağ kafes işletmesi faaliyet göstermekte olup üretim kapasiteleri 164.810 ton/yıldır. Keban Baraj gölünü alabalık üretiminde avantaj olarak kullanan Doğu Anadolu Bölgesi 240 adet işletme ve 55.538 ton/yıl üretim kapasitesi ile ülkemizde ilk sırda yer almaktadır. Az sayıda ve alabalık yetiştiriciliği için uygun olmayan su kaliteli baraj göllerinin bulunduğu Marmara Bölgesi ise 11 adet işletme ve 2.854 ton/yıl kapasite ile son sırada yer almaktadır. Baraj gölü ağ kafes işletmelerinde hasat, tamamen müşteri tercihine uygun yapılmakta, işletme yönetim planının oluşturulmasında baraj gölünün su kalite kriterleri ve hasat boyu etkili olmaktadır. 1. ve 2. sınıf işletmeler genel olarak yurtiçi piyasaya porsiyonluk (200 g) balık üreten işletmelerdir.

Bu işletmelerin bir kısmı deniz ağ kafes işletmeleri ve büyük kapasiteli baraj gölü ağ kafes işletmelerinin de içinde olduğu çatı işletmelere aittir, üretim kapasiteleri küçük olmasına rağmen Türk somonu adayı (500 g) alabalık üretimi de yapmaktadırlar. 3. ve 4. sınıf işletmeler genel olarak Türk Somonu adayı üretim yapmakla beraber özellikle yaz aylarında yurtdışı filetoluk alabalık ihtiyacının tümünü karşılamaktadır. Türk Somonu üretiminde kullanılan aday balıkların yaklaşık %90'ı baraj gölü ağ kafes işletmelerinden temin edilmektedir (Tablo 7).

Tablo 6. Üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazara göre baraj gölü ağ kafes işletmeleri grupları

Table 6. Dam lake net cage enterprise groups according to production capacities, production purposes, production method and target market

Grup Sıra No	Üretim Kapasitesi (adet/yıl)	Üretim Kapasitesi (ton/yıl)	Toplam Sayı (adet)	Kafes İşletmelerinin Özellikleri
1	≤29	4.485	178	Çoğunluğu yurtiçi tüketime porsiyonluk alabalık üretimi, çatı şirketlerin küçük işletmesi şeklinde geleneksel üretim yapan ve Türk Somonu üretimine katkısı yok denecek kadar az olan işletmelerdir.
2	30-99	2.316	39	Genel olarak yurtiçi tüketime porsiyonluk alabalık, az miktarda Türk Somonu adayı alabalık üretimi yapan ve Türk Somonu üretimine katkısı az olan işletmelerdir.
3	100-499	69.230	289	Çoğunluğu Türk Somonu adayı ve filetoluk alabalık, az miktarda porsiyonluk alabalık üretimi yapan ve Türk Somonu adayı alabalık üretimine katkısı oldukça fazla olan işletmelerdir.
4	≥500	89.929	119	Genel olarak Türk Somonu adayı alabalık üretimi ve filetoluk alabalık üretimi yapan işletmelerdir. Türk Somonu adayı alabalık üretimine katkısı fazladır.

Tablo 7. Bölgeler bazında baraj gölü ağ kafes işletmeleri sayısı ve kapasiteleri
Table 7. Number and capacities of dam lake net cage enterprises on a regional basis

Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)	Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)
Akdeniz	≤ 29	32	753.200	İç Anadolu	≤ 29	8	204.000
	30-99	17	1.008.000		30-99	2	125.000
	100-499	39	7.595.000		100-499	22	5.895.000
	500 ≥	17	10.927.000		500 ≥	30	25.490000
Karadeniz	≤ 29	20	540.000	Doğu Anadolu	≤ 29	89	2.246.500
	30-99	6	449.000		30-99	12	674.000
	100-499	50	12.984.000		100-499	112	26.925.296
	500 ≥	12	6.000.000		500 ≥	30	25.692.000
Marmara	≤ 29	1	29.000	Güneydoğu Anadolu	≤ 29	22	638.000
	30-99	1	40.000		30-99	0	0
	100-499	7	1.215.000		100-499	20	4.938.000
	500 ≥	2	1.570.000		500 ≥	22	15.200.000
Ege	≤ 29	6	74.250	**Toplam**	≤ 29	178	4.484.950
	30-99	1	20.000		30-99	39	2.316.000
	100-499	38	9.858.000		100-499	288	69.080.316
	500 ≥	4	4.050.000		500 ≥	117	88.929.000

Deniz ağ kafes işletmeleri üretimi

Özellikle büyük boy alabalığa yurtdışından gelen talep, kültür balıkçılığı üretimindeki artışa hız kazandırmıştır. Karadeniz Bölgesi coğrafi ve çevresel özelliklerinden dolayı büyük boy alabalık üretimi için ideal bir bölgedir. Alabalık yetiştiriciliği için uygun çevresel koşullara sahip akarsu/kaynak suları, baraj gölleri ve deniz sistemlerinin Türk Somonu üretiminde sacayağı halinde kullanılabilmesi lokalitenin önemini gün geçtikçe artırmaktadır. Karadeniz'de alabalık yetiştiriciliğini ve işletme yönetimini etkileyen en önemli kriter su sıcaklığıdır.

Karadeniz'de, farklı üretim kapasitelerine sahip toplam 59 adet deniz ağ kafes işletmesi faaliyet göstermekte olup üretim kapasiteleri 57.369 ton/yıldır (BSGM, 2022). Deniz ağ kafes işletmelerinde hasat, tamamen müşteri tercihine uygun yapılmakta, işletme yönetim planının oluşturulmasında da pazar talebi dikkate alınmaktadır. Deniz suyu sıcaklığının 20°C'nin altına düştüğü 8 Ekim-7 Kasım döneminde baraj gölü ağ kafes işletmelerinden veya tatlısu havuz işletmelerinden ortalama ağırlıkları 500 g olan Türk Somonu adayı alabalıklar deniz ağ kafes işletmelerine nakledilmekte, deniz suyu sıcaklığının 18°C'ye yükseldiği 21 Mayıs-20 Haziran döneminde hasat yapılmaktadır.

Günümüzde, biyoteknolojik uygulamalar, yem teknolojisindeki gelişmeler ve balık refahına riayet sayesinde üretim dönemi içinde deniz ağ kafes sistemlerine nakledilen alabalıklarda 6-8 kat ağırlık artışı sağlanabilmektedir. Hasat ağırlığında pazar talebi dikkate alınarak üretim dönemi başında Türk Somonu adayı alabalıkların nakil ağırlığı belirlenmektedir. Ortalama 3000 g hasat ağırlığı için 500 gramlık Türk Somonu adayları tercih edilirken daha büyük hasat ağırlığı için 1000 g ve üzerindeki alabalıklar tercih edilmektedir (Tablo 8). Deniz ağ kafes işletmeleri üretim kapasitesine göre 3 sınıfa ayrılmıştır (Tablo 9).

Tablo 8. Bölgeler bazında baraj gölü ağ kafes işletmeleri sayısı ve kapasiteleri
Table 8. Number and capacities of dam lake net cage enterprises on a regional basis

Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)	Bölge Adı	Kapasite Sınıfı (Ton)	İşletme Sayısı (Adet)	Üretim Miktarı (Ton)
Akdeniz	≤ 499	0	0	İç Anadolu	≤ 499	0	0
	500-999	1	150.000		500-999	0	0
	1000 ≥	0	0		1000 ≥	0	0
Karadeniz	≤ 499	1	80.000	Doğu Anadolu	≤ 499	0	0
	500-999	56	54.022.000		500-999	0	0
	1000 ≥	0	0		1000 ≥	0	0
Marmara	≤ 499	0	0	Güneydoğu Anadolu	≤ 499	0	0
	500-999	0	0		500-999	0	0
	1000 ≥	0	0		1000 ≥	0	0
Ege	≤ 499	0	0	Toplam	≤ 499	1	80.000
	500-999	2	1.000.000		500-999	59	55.172.000
	1000 ≥	0	0		1000 ≥	0	0

Tablo 9. Üretim kapasiteleri, üretim amaçları, üretim metodu ve hedef pazara göre deniz ağ kafes işletmeleri grupları

Table 9. Groups of marine net cage enterprises according to production capacities, production purposes, production method and target market

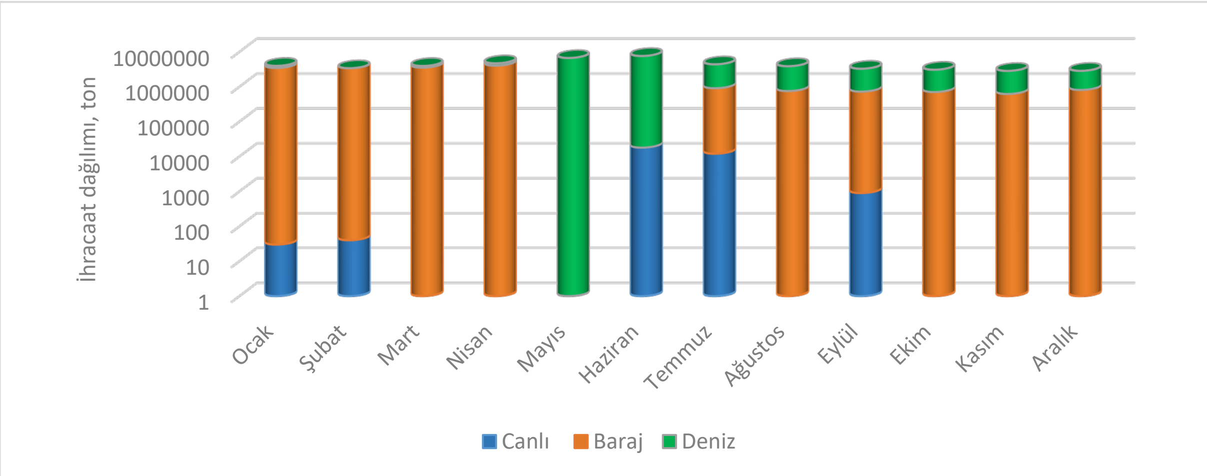
Grup Sıra No	Üretim Kapasitesi (adet/yıl)	Üretim Kapasitesi (ton/yıl)	Toplam Sayı (adet)	Kafes İşletmelerinin Özellikleri
1	≤ 500	3.347	13	Deniz ağ kafes sistemleri için yetiştiricilik alanlarının sınırlı ve müracaatçı sayısının fazla olduğu lokalitelerde düşük üretim kapasiteli işletmelerdir. Türk somonu üretimine katkısı en az olan işletmelerdir.
2	500-999	33.482	43	Türk Somonu üretimine en çok katkısı olan işletmelerdir.
3	≥1000	20.540	13	İşletme kurulumunda ve işletilmesinde yeni teknolojilerin ülkemizde kullanılmaya başlaması ile büyük kapasiteli işletmelere ilgi artmıştır. Gelecekte Türk Somonu üretimi için bu tür işletmelerin yaygın kullanılma olasılığı oldukça yüksektir. Türk Somonu üretimine katkısı gün geçtikçe artmaktadır.

Türk Somonu ihracatı

Su ürünleri, dünyada en çok ticareti yapılan gıda ürünlerinden biridir. Uluslararası su ürünleri ticaretinin büyümesinde küreselleşmeye bağlı olarak ekonomik büyüme ile kültürel ve teknolojik ilerleme etkili olmuştur. Su ürünleri ticaret değeri, ticaret miktarına oranla daha fazla artış göstermektedir. Bunun nedeni ekonomik değeri yüksek türlerin işlenmesi ile katma değer kazandırılarak ticaretinin yapılmasıdır (FAO, 2022).

Türkiye'nin 2021 yılı içsu ve deniz yetiştiricilik işletmelerinin toplam alabalık üretimi 167.286 ton olarak gerçekleşmiş ve bu üretimin 50.568 tonu ihracatta kullanılmıştır (TÜİK, 2022). Kuluçkahane ve tatlısu havuz işletmelerinde üretilen 31ton alabalık canlı, baraj gölü ağ kafes işletmelerinde üretilen 18.939 ton ve deniz ağ kafes işletmelerinde üretilen 31.598 ton alabalık işlenerek ihracatta kullanılmıştır.

Aylık ihracat verileri dikkate alındığında en fazla ihracatın deniz ağ kafes işletmelerinin hasat dönemi olan Haziran ve Mayıs aylarında olduğu, en düşük ihracatın ise baraj gölü ağ kafes işletmelerine yavru nakil dönemi olan Ekim, Kasım ve Aralık aylarında gerçekleştirildiği görülmektedir (Şekil 1).

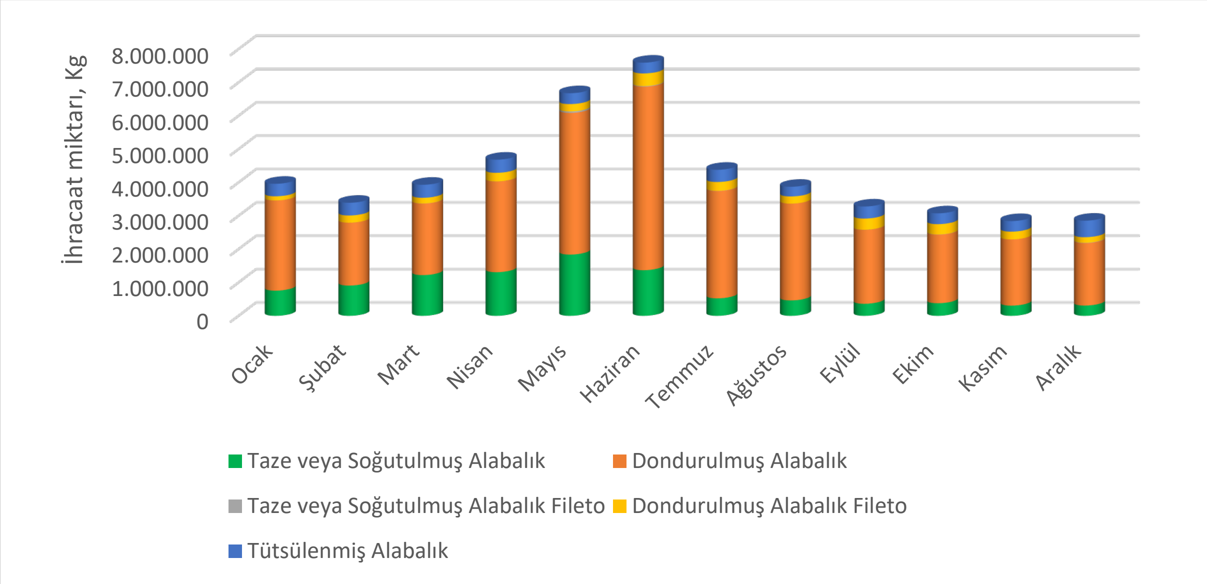


Şekil 1. Farklı üretim sistemlerinden hasat edilen alabalıkların aylık ihracat dağılımı (ton)

Figure 1. Monthly export distribution of trout harvested from different production systems (tons)

İhracatta genel olarak işleme tesislerinde işlem gören ve ürün vasfı kazanan büyük boy alabalıklar kullanılmaktadır. Bu balıklar taze veya soğutulmuş, dondurulmuş, taze veya soğutulmuş fileto, dondurulmuş fileto ve tütsülenmiş ürünler olarak ihraç edilmektedir. 2021 yılı aylık işlenmiş ürün ihracatında 33.468.438 kg ile dondurulmuş alabalık ilk sırayı alırken 90.335 kg ile taze veya soğutulmuş fileto en az ihracatta kullanılan ürün olmuştur. Farklı üretim sistemlerinden hasat edilen alabalıkların aylık ihracat dağılımına benzer şekilde işlenmiş ürün gruplarında da en fazla ihracat deniz ağ kafes hasat periyodu olan Haziran ve Mayıs aylarında gerçekleştirilmiştir. En düşük miktarda ihracat ise Kasım ve Aralık aylarında yapılmıştır (Şekil 2). Deniz ağ kafes ve baraj gölü ağ kafes işletmelerinden 2021 yılı içinde hasat edilen büyük boy alabalıklar 45 ülkeye ihraç edilmiştir.

Toplam ihracat içinde 29.913.869 kg ile Rusya Federasyonu %59,54 oranla ilk sırada yer almakta, bunu AB ülkeleri ve Asya ülkeleri izlemektedir (Tablo 10). Rusya Federasyonu ve AB ülkeleri daha çok taze veya soğutulmuş ve dondurulmuş ürünleri tercih ederken diğer ülkeler dondurulmuş, fileto ve tütsülenmiş ürünleri tercih etmektedir. Bu durumda nakil işlemlerinin etkili olduğu görülmektedir (BSGM, 2022; TUİK, 2022).



Şekil 2. Farklı ürün gruplarının aylık ihracat dağılımı (ton)

Figure 2. Monthly export distribution of different product groups (tons)

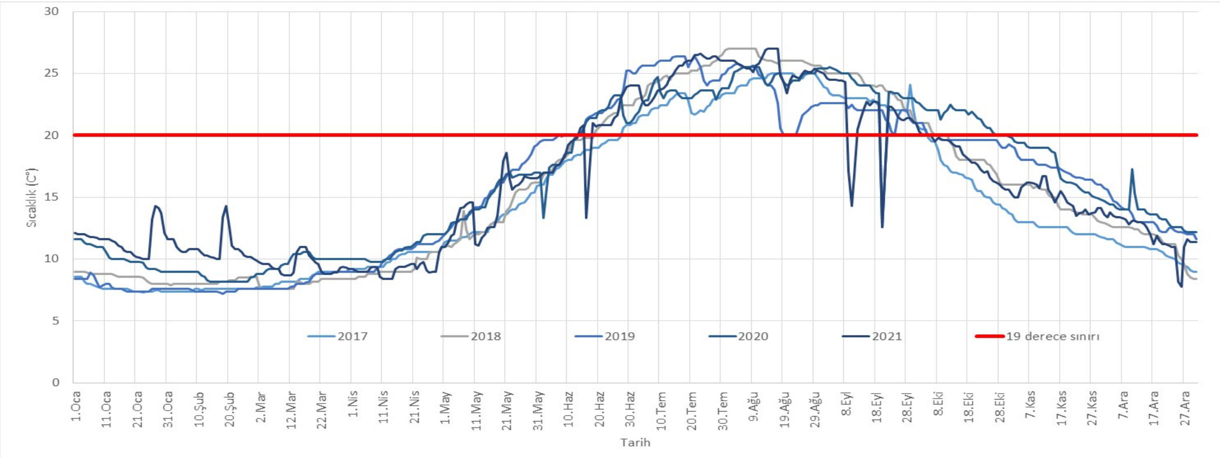
Tablo 10. 2021 yılına ait işlenmiş ürünlerin ihraç edildiği ülkeler ve ihracat miktarı (Kg)

Table 10. Countries to which processed products are exported in 2021 and export amount (Kg)

Ülke	Ürün (Alabalık) (kg)					Toplam
	Taze/ Soğutulmuş	Dondurulmuş	Fileto (Taze/Soğutulmuş)	Fileto (Soğutulmuş)	Tütsülenmiş	
Çekya	0	236.338	0	29.280	500	266.118
ABD	1.167	19.476	850	436.934	0	458.427
Almanya	270.820	3.586.244	12.440	378.029	3.614.537	7.862.070
Avusturya	2.469	81.816	132	36.560	0	120.977
Azerbaycan	14.000	100.295	600	0	0	114.895
BAE	11	2.000	0	0	7.505	9.516
Belarus	151.235	426.665	0	19.000	0	596.900
Belçika	0	66.785	0	3.120	13.115	83.020
Birleşik Krallık	216	5.670	652	59.458	9.110	75.106
Bosna Hersek	0	18.500	0	0	0	18.500
Bulgaristan	0	112.310	0	0	0	112.310
Cezayir	0	0	0	2.000	0	2.000
Çin	0	345.301	0	0	0	345.301
Danimarka	0	28.772	0	5.640	35.072	69.484
Fransa	53	768	0	128	0	949
Gürcistan	286.541	397.183	2.721	600	125	687.170
Hırvatistan	0	35.000	0	0	0	35.000
Hollanda	0	259.024	25.800	451.709	209.548	946.081
Irak	0	56.114	0	40.978	0	97.092
Ispanya	0	0	19.800	21.667	0	41.467
Israil	0	74.716	0	0	0	74.716
Isveç	0	1.248	0	0	0	1.248
Isviçre	88	4.500	0	18.962	0	23.550
Italya	0	6.360	0	301.118	0	307.478
Japonya	0	599.901	0	266.719	3	866.623
Kanada	0	0	18.747	73.283	0	92.030
Kazakistan	0	97.200	0	0	0	97.200
Kuzey Kıbrıs	61.156	3.203	293	576	265	65.493
Litvanya	0	0	1	99.370	0	99.371
Macaristan	0	124.120	600	3.800	1.200	129.720
Moldova	0	3.360	0	0	0	3.360
Polonya	0	579.665	0	69.120	60.694	709.479
Romanya	661.997	1.006.660	3.770	277.790	25.740	1.975.957
Rusya	7.857.871	21.801.520	0	254.476	0	29.913.867
Sırbistan	0	690.795	0	48.100	1.680	740.575
Singapur	0	11.600	0	0	0	11.600
Slovakya	0	19.200	0	0	0	19.200
Slovenya	0	95.435	0	40.530	0	135.965
Suriye	64.851	435	0	0	0	65.286
Tayland	0	27	0	9.695	0	9.722
Ukrayna	355.128	36.893	0	0	0	392.021
Umman	61	0	0	0	0	61
Urdün	280	2.014	0	2.024	0	4.318
Vietnam	0	2.543.744	0	0	0	2.543.744
Yunanistan	5.328	0	6.800	2.400	0	14.528

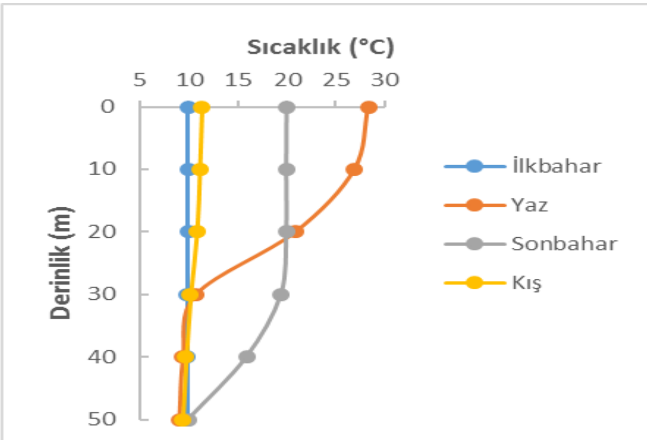
TARTIŞMA

Su sıcaklığı balıkların davranış, beslenme, büyüme ve üreme gibi biyolojik ve fizyolojik özelliklerini etkiler. Farklı türlerin farklı su sıcaklılarına gereksinimleri vardır. Sürdürülebilir alabalık üretimi etkileyen en önemli kriterlerden biri de su sıcaklığıdır. Karadeniz, yüzey suyu sıcaklığı dikkate alındığında ancak Ekim-Haziran ayları arasında alabalık üretimi uygundur. Su Ürünleri Merkez Araştırma Enstitüsü Müdürlüğü ve diğer AR-GE kurumları tarafından denizel alanda yapılan çalışmalar sonucunda elde edilen bulgular bu durumu doğrulamaktadır (Şekil 3, 4). Derinliğe bağlı sıcaklık değişiminde, özellikle alabalık yetiştiriciliği için olumsuz şartların oluştuğu yaz aylarında 10 m derinlikten sonra sıcaklığın azaldığı, 15 m'de ise uygun şartların oluştuğu görülmektedir (Şekil 4). Bu derinliklerin suyu, uygun kafes modelleri kullanılarak Türk Somonu üretiminin yapılabileceği ayrıca değerlendirilmelidir. Türkiye denizlerinden sadece Karadeniz, sahip olduğu çevresel koşullardan dolayı ağ kafeslerde alabalık üretimi için uygundur. Deniz yüzey suyu sıcaklığının alabalık üretimi için uygun olduğu aylarda, alabalıklar baraj gölü ağ kafes işletmelerinden deniz ağ kafes işletmelerine nakledilerek büyük boya (Türk Somonu, ≥3000 g) ulaşmaları sağlanmaktadır.



Şekil 3. Karadeniz yüzey suyu sıcaklık verileri (Parlak ve diğ., 2022)

Figure 3. Black Sea surface water temperature data (Parlak et al., 2022)



Şekil 4. Karadeniz'de derinliğe göre sıcaklık değişimi [TAGEM/HAYSUD/B/19/A6/P3/01 (2019-2021)] (Fidan ve diğ., 2022)

Figure 4. Temperature according to depth in the Black Sea [TAGEM/HAYSUD/B/19/A6/P3/01 (2019-2021)] (Fidan et al., 2022)

Klimatolojik, oşinografik ve su kalitesi gibi çevresel faktörler ülkelerin alabalık üretim zincirinde kullanılan halkaları belirler. Nitekim, Paisley ve ark., (2010) İskandinav ülkelerinde, üretim zinciri halkalarını sırasıyla kuluçkahaneler, kara tabanlı deniz suyu kullanılan büyütme tesisleri ve deniz ağ kafes sistemlerinden oluştuğunu bildirmektedir. Son yıllarda dünya alabalık üretiminde söz sahibi ülkelerden biri olan Şili'de ise Olsen ve Criddle, (2008) kuluçkahanede büyütülen filetoluk adayı alabalıkları deniz ağ kafes sistemlerine nakletmektedir. Ülkemizde ise yumurtadan hasada kadar üretim zinciri sırasıyla kuluçkahaneler, kara tabanlı tatlısu havuz işletmeleri, baraj gölü ve son halka olan deniz ağ kafes işletmeleri olarak sıralanmaktadır. Ülkemiz çevresel koşullarından farklı çevresel koşullara sahip olan ülkelerde alabalık üretim zinciri halkaları kısmen benzerlik göstermekte olup üretim maliyetini etkileyen farklılıklarda mevcuttur. Dünya alabalık üretiminde söz sahibi olan ülkelerden farklı olarak ülkemizde baraj gölü ağ kafes sistemlerinin kullanılıyor olması üretim maliyeti, büyüme bakımından ülkemize avantaj sağlamaktadır.

Şili'de deniz suyu sıcaklıklarından dolayı kış aylarında büyüme yavaş olmakla birlikte, deniz ağ kafes sistemlerinde alabalıkların filetoluk boya (2-5 kg) büyütülmesi 8-14 ay sürmektedir (Olsen ve Criddle, 2008). İskandinav ülkelerinde kuluçkahane veya deniz suyu kullanılan kara tabanlı işletmelerde 1 kg'a kadar büyütülen alabalıklar ilkbaharda deniz ağ kafes sistemlerinde 2-5 kg ağırlığa kadar büyütülerek hasat edilmektedir (Paisley ve ark., 2010). Ülkemizde baraj gölü ağ kafes sistemleri kullanılarak filetoluk adayı (400-600 g) boya ulaştırılan alabalıklar transfer edildikleri deniz ağ kafes sistemlerinde 6-7 aylık sürede ortalama 3 kg ağırlığa büyütülmektedir. Ülkemizde kuluçkahaneden sonra türe özgü çevresel şartlara uygun mera özellikli baraj gölü ağ kafes ve deniz ağ kafes sistemlerinin kullanılması filetoluk alabalık (Türk somonu) üretiminde büyüme süresini kısaltmakta ve üretim maliyetini azaltmaktadır.

Şili alabalık üretiminde 2000 yılına kadar Norveç'te üretilen yumurtalara bağımlı kalmış ve 2000 yılından sonra yumurta üretimini önemli ölçüde artırmıştır. 2005 yılında Şili kuluçkahanelerinde kullanılan yumurtaların %90,1'i yerel anaçlardan üretilmiştir (Verdugo, 2006). Ülkemiz 2021 yılında toplam yumurta üretimi 1.360.029.485 adet/yıl olarak gerçekleştirmiş olup, aynı yıl içerisinde 185.055.556 adet/yıl yumurta ithal edilmiştir. Bu rakam toplam yumurta üretimin %13,60'ına denk gelmektedir. Günümüzde Şili alabalık yumurtası ihraç eden sayılı ülkeler arasında yer almakla birlikte, yumurta ithalatı yaptığımız ülkeler arasında yer almaktadır. Ülkemiz çevresel koşulları özellikle alabalık üretimi için oldukça uygun olmasına rağmen günümüzde halen yumurta ithal eden ülkeler arasında yer almamız damızlık ve kuluçkahane yönetimindeki aksaklıkları ortaya koymaktadır.

Dünya gökkuşağı alabalığı yetiştiriciliğinde hayatta kalma oranı [Magerhans, (2009)'a göre %81,3-96,5 ve Butzge, (2021)'e göre %54,5-71,4] düşünüldüğünde Türkiye başarısı %30,10 ile oldukça düşüktür. Doğal çevresel koşulların avantajlarına rağmen hayatta kalma oranındaki düşüklük; hastalıkların görülmesi, yanlış tedavi yöntemlerinin uygulanmasına, damızlık yönetimi uygulamaları ve işletme yönetiminde yapılan yanlışlıklar, kontrolsüz balık nakilleri, sıhhi ve çevresel koşullar gibi pek çok faktöre bağlanabilir. Türk Somonu üretiminde hayatta kalma oranının iyileştirilmesi için;

(I) Balık sağlığı, sürdürülebilir üretimin temel anahtarıdır. Ülke hastalık haritası çıkarılmalı ve hastalık durumu dikkate alınarak havzalar numaralandırılmalıdır.

(II) Tatlısu, baraj gölü ve deniz işletmelerinde kronikleşen hastalıklar belirlenmeli, hastalıklara yönelik koruyucu önlemler alınmalı ve gerekli görülmesi halinde bölgesel özel akredite balık hastalıkları laboratuvarları kurulumu desteklenmeli, ilaç ve dezenfektan kullanımı kontrolleri artırılmalıdır.

(III) Yumurta ve yavru üretimi için uygun çevresel koşullara sahip tatlısu kaynakları belirlenmeli, bu kaynaklarda hastalıktan ari kuluçkahane işletmelerinin kurulması teşvik edilmeli ve ülke çevresel şartlarına uygun ve endemik hastalıklara dirençli damızlık stoklar üretilmelidir.

(IV) Türk Somonu üretim zincirinde kullanılan altyapı (tank, beton/toprak havuz, kafes, su temin sistemleri vb.) ve su alabalık üretimi için doğal yaşam alanı çevresel özelliklerine uygun özelliklere sahip olmalı, balık refahı ve biyogüvenlik uygulamaları ön planda tutulmalı ve sürekli izleme yapılmalıdır.

(V) Belirlenecek üretim havzaları arasında balık nakli, biyolojik ve genetik kirlilik gözetilerek yapılmalı hastalıkların taşınımı engellenmelidir.

(VI) İyi balık sağlığı, yeterli biyogüvenlik uygulamaları, sanitasyon, balık refahı, uygun yetiştirme koşulları ve ekipman kullanımı, iyi beslenme, bağışıklığı yüksek tutma ve genel hastalık önleme uygulamaları, kontrol ve izleme ile sağlanmalıdır.

Doğal ortamdan yakalanan balıklar, tavuk eti ve sığır eti gibi kara kaynaklı protein kaynaklarına göre daha düşük karbon ayak izine sahiptir. Su ürünleri yetiştiriciliğinden elde edilen ürünler, en verimli kara kökenli kaynaklardan biri olan tavuğa benzer bir karbon ayak izine sahiptir. Su ürünleri yetiştiriciliğiyle ilgili mevcut emisyonların, yem kullanımını azaltarak ve ormansızlaşma içermeyen girdilere geçiş yaparak yarı yarıya azaltılabilir (Desrochers, 2022). Ayrıca alabalıkgiller, tilapya, yayın balığı ve sazan gibi canlıları yetiştirmek tıpkı tavuk yetiştiriciliği gibi karada doğaya en az zarar veren hayvansal üretimlerden biridir. Mavi gıda yetiştiriciliği karada yapılan besiciliğe kıyasla daha az sera gazı yayar, daha az su kirliliği yaratır ve daha az toprak ve su kaynağı kullanır. Bunlara ek olarak alabalık, tavuğa kıyasla 19 kat omega-3 yağ asidi içerir (Hashempour, 2021). Son yıllarda yapılan bilimsel araştırmalar su ürünleri yetiştiriciliğinin yetersiz beslenme, karbon ayak izi ve ekonomik sorunları gidermek için önemli bir fırsat olacağını göstermektedir. Özellikle büyük boy alabalık üretimi için uygun çevresel koşullara sahip olan Karadeniz coğrafyası mavi gıda sektörünü çevresel, ekonomik ve sağlık faydalarını daha yukarıya taşımak amacıyla değerlendirilmelidir.

Halen çalışmaları devam eden "Denizlerde Potansiyel Su Ürünleri Yetiştiricilik Alanlarının Belirlenmesi (TAGEM/HAYSUD/ÜG/17/SU/P-01/05)" isimli proje kapsamında birçok ilin denizel alanı çalışılmıştır. Bu çalışmalarda halen üretim yapılan işletmelerle beraber toplam proje üretim kapasitesi 221.188 ton/yıl olan 160 adet işletme alanı belirlenmiştir (Parlak ve diğ., 2022). Belirlenen üretim alanlarının çoğu üretim kapasitesi artırımı için uygun özelliklere sahiptir. Son yıllarda artan pazar talebi Türk Somonu üretimine hız kazandırmıştır, talep artışının devam etmesi durumunda gelecekte sadece Karadeniz'den 361.341 ton/yıl üretimin karşılanabileceği öngörülebilir (Tablo 11).

Tablo 11. Karadeniz'de planlanan üretim alanları, kapasiteleri ve potansiyel üretim kapasitesi

Table 11. Planned production areas, capacities and potential production capacity in the Black Sea

İl	İşletme Sayısı[1]	Toplam Alan (m^2)[1]	Üretimde Kullanılan Alan (m^2)[2]	Proje Kapasitesi (Ton/Yıl)[3]	Proje Kapasitesi Artırma Olasılığı (%)[4]	Potansiyel Kapasite (Ton/Yıl)[4]
Artvin	10	600.000	300.000	9.500	80	17.100
Rize	24	1.440.000	720.000	22.800	80	41.040
Trabzon	22	1.830.000	915.000	28.975	70	52.155
Giresun	18	1.580.000	790.000	25.013	100	50.026
Ordu	24	1.440.000	720.000	22.800	70	38.760
Samsun	57	3.540.000	1.770.000	56.050	50	84.075
Sinop	28	1.680.000	840.000	26.600	50	39.900
Zonguldak	19	1.860.000	930.000	29.450	30	38.285
TOPLAM	**160**	**15.650.000**	**6.985.000**	**221.188**		**361.341**

[1]Denizlerde potansiyel ağ kafes alanlarının belirlenmesi projesi kapsamında belirlenen tesis sayısı.
[2]Denizlerde potansiyel ağ kafes alanlarının belirlenmesi çalışmalarında tesis kurulacağı alana rotasyon alanı da dâhil edilir. Üretimde kullanılacak alan tüm alanın yarısı olarak hesaplanmıştır.
[3]Denizlerde potansiyel proje kapasitenin hesaplanmasında ortalama 30.000 m^2 alan için 950 ton alınmıştır.
[4]Tesislerin açık deniz yönü durumu, denizin hali, hâkim rüzgâr ve derinlik kriterlerine göre hesaplanmıştır.

Türkiye'nin canlı hayvanlar ve hayvansal ürünlerde rekabet gücünün düşük olduğu belirlenmiştir. Ayrıca, HS 03 (Su ürünleri) ve HS 05 (Diğer hayvansal menşeli ürünler) ürünlerde endüstri-içi ticaret seviyesinin yüksek olduğu belirlenmiştir. Buna göre Türkiye'nin canlı hayvanlar ve hayvansal ürünlerde endüstri-içi ticaret seviyesinin yüksek olduğu ürünler arasında HS 03 (Su ürünleri) ve HS 05 (Diğer hayvansal menşeli ürünler) bulunmaktadır (Bashimov, 2018). Son yıllarda su ürünleri yetiştiriciliği ve işleme teknolojilerindeki gelişmeler Türkiye'nin su ürünleri dış ticaretinde ihracatçı konumunu sürdürmesinde etkili olmuştur. TÜİK verilerine göre, Türkiye su ürünleri ticareti 2021 yılında bir önceki yıla göre büyüme göstermiş olup, ihracatta %24 oranında artış kaydedilmiştir (FAO, 2022). Türk Somonu adayı üretim işletmeleri ile deniz ağ kafes işletmelerinin tam kapasite kullanımında ve potansiyel alanların da üretime dahil edilmesi durumunda ihracat kapasitesi yaklaşık beş kat artırılabilecektir.

SONUÇ

Dünyada tuzlu suda yetiştirilen alabalıklar "somon alabalığı" olarak isimlendirilmekle beraber ülkemizde Karadeniz'de yetiştiriciliği yaygınlaşan büyük boy alabalık da uluslararası pazarda "Türk somonu" olarak kabul görmektedir.Bu bağlamda, büyük boy alabalık yetiştiriciliği Türkiye su ürünleri ekonomisinde büyük bir itici güç olma yolundadır.

Çevreye duyarlı şekilde yetiştirilmesi gereken mavi gıdanın üretim alanları, üretim basamakları, üretilen canlıların ne ile beslendiği ve ürünlerin besin değeri tüketiciler tarafından sürekli merak konusu olmaktadır. Tüketici duyarlılığı dikkate alınarak pazar için üretilen su ürününün sudan çıkarılıp satış noktasına ulaşıncaya kadar tüm aşamaların şeffaf şekilde takibine tam erişim sağlanmalıdır. Dünya yetiştiricilik sektörü ile rekabet edebilir aşamaya ulaşan güvenli, sorumlu ve etik kurallara uygun büyük boy alabalık yetiştiriciliğinin daha yukarılara taşınması adına üretim zincirinin uçtan uca sertifikalandırılması sağlanmalıdır. Sektörün daha da büyüyebilmesi için daha da yüksek sürdürülebilirlik standartlarının sağlanması gerekmektedir. Bunun için yem girdisi, balık sağlığı, üretim alanlarındaki sektörel çatışmalar, doğal ekosisteme yönelik tehditler gibi zorlukları ele alarak çözüme kavuşturmak önemlidir. Türkiye daha iyi yöntemleri, daha iyi teknolojiyi, daha iyi yönetimi, daha iyi ürünleri ve daha iyi pazarlamayı başaracak bilgi ve donanıma sahiptir.

TEŞEKKÜR VE MADDİ DESTEK

İşleme ve muhafaza tesislerinde yılın hangi dönemlerinde hangi ürünün işlendiği dair vermiş oldukları bilgilerden dolayı Sayın Osman Parlak'a, Sayın İlker Yıldırım'a, Sayın Hasan Kuzuoğlu'na, ve Sayın Tayfun Denizer'e teşekkür ederiz.

ÇIKAR ÇATIŞMASI BEYANI

Yazarlar bu çalışmayı etkileyebilecek finansal çıkarlar veya kişisel ilişkiler olmadığını beyan etmektedir.

YAZAR KATKILARI

Çalışma kurgusu: Eyüp Çakmak, Literatür taraması: Esin Batır, Metodoloji: Eyüp Çakmak, Veri toplama: Derya Evin, Veri analizi: Eyüp Çakmak, Osman Tolga Özel, Esin Batır, Makale yazımı: Eyüp Çakmak, Denetleme: Tüm yazarlar nihai taslağı onaylamıştır.

ETİK ONAY BEYANI

Bu çalışmada deney hayvanları kullanılmaması nedeniyle Yerel Etik Kurul Onayı alınmamıştır.

VERİ KULLANILABİLİRLİK BEYANI

Bu çalışmada kullanılan veriler makul talep üzerine ilgili yazardan temin edilebilir.

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