AQUATIC SCIENCES and ENGINEERING

İSTANBUL UNIVERSITY PRESS

2021

VOLUME: 36 ISSUE: 2

E-ISSN 2602-473X

İSTANBUL UNIVERSITY PRESS

AQUATIC

SCIENCES and ENGINEERING

VOLUME: 36 ISSUE: 2 2021 E-ISSN 2602-473X

AQUATIC
SCIENCES and ENGINEERING

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Indexing and Abstracting

Web of Science - Emerging Sources Citation Index (ESCI)
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https://iupress.istanbul.edu.tr/tr/journal/ase/home

Publisher

Istanbul University Press
İstanbul University Central Campus, 34452 Beyazıt,
Fatih / İstanbul, Turkey
Phone: +90 (212) 440 00 00

Cover Photo

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Authors bear responsibility for the content of their published articles.

The publication language of the journal is English.

This is a scholarly, international, peer-reviewed and open-access journal published quarterly times a year in January, April, July, and October.

Publication Type: Periodical

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Editor in Chief: Prof. Devrim MEMİŞ
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AQUATIC
SCIENCES and ENGINEERING

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Short Communications

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 46-50 • DOI: https://doi.org/10.26650/ASE2020731575

Original Article

Spatio-Temporal Patterns of Abundance and Biomass of *Parapenaeus longirostris* (Lucas, 1846) in the Sea of Marmara, Turkey

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Cite this article as: Inceoglu, H., Ismen, A., Arslan Ihsanoglu, M., Kocabas, E., Daban, I.B., Kara, A., Cardak, M., Sirin, M., & Yigin, C.C. (2021). Spatio-Temporal patterns of abundance and biomass of *Parapenaeus longirostris* (Lucas, 1846) in the Sea of Marmara, Turkey. *Aquatic Sciences and Engineering, 36*(2), 46-50.

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Submitted:
09.05.2020

Revision Requested:
09.07.2020

Last Revision Received:
13.07.2020

Accepted:
13.07.2020

Online Published:
25.01.2021

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ABSTRACT

The present research study investigated the catch-per-unit-effort (CPUE, kg/h) and biomass of *Parapenaeus longirostris* in consideration of three parameters, i.e. seasons, regions, and depth levels. Beam trawls were used to collect the specimens at a total of 229 sampling stations in the Sea of Marmara between September 2011 and July 2014. In the Sea of Marmara, the mean CPUE of *P. longirostris* was calculated to be 8.4±0.5 kg h^{-1} , and the mean biomass to be 354 kg/km^{-2}. The mean CPUE value was at its highest in summer and autumn, and the lowest was observed in winter and spring. The by-region mean CPUE value of *P. longirostris* was the highest in the northern Sea of Marmara (14.3±1.9 kg h^{-1}), and the lowest was detected in the south (3.6±1.0 kg h^{-1}). The highest biomass value was found at a depth of 50-100 m, in the northern Sea of Marmara, while the lowest was calculated in the southeastern Sea of Marmara.

Keywords: *Parapenaeus longirostris*, CPUE, Abundance, Biomass, Sea of Marmara

INTRODUCTION

The crustacean *Parapenaeus longirostris* is widely distributed from the eastern Atlantic to the Mediterranean Sea. In the Mediterranean Sea, *P. longirostris* is found between 20 and 900 meters but abundant between 100 and 400 meters (Politou, Tserpes, & Dokos, 2008).

P. longirostris is the most important commercially valuable crustacean along the coasts of the Mediterranean Sea (Sbrana, Viva, & Belcari, 2006). Besides, it is the primary crustacean species that is caught in the Sea of Marmara by beam trawl (Zengin et al., 2004). Since trawl fishing is forbidden, fishermen commonly use beam trawls for shrimp fishing. The southwestern part, especially the Kapıdağ Peninsula, is known as the most efficient fishing area for this species in the Sea of Marmara. Shrimp fishing with beam trawl can be legally performed in the Sea of Marmara between September 1 and December 1, and between February 1 and April 14

The amount of captured deep-water rose shrimp in the Turkish seas decreased between 2007 to 2018. The amount of shrimp in 2007, amounting to 2761 tonnes, decreased to 1413 tonnes in 2010. A capture of 2500 tonnes in 2014 sharply fell in the following years to rise to 3213 tonnes in 2018 (Figure 1), when 1854 tonnes of rose shrimp were captured in the Sea of Marmara, 1234 tonnes in the Aegean Sea, and 124 tonnes in the Mediterranean Sea. The per-kilogram price for *P. longirostris* increased from 10 Turkish Liras in 2014 to 20 Turkish Liras in 2018 (TUIK, 2019). Gradual year-to-year decrease in the captured shrimps translated into raised prices.

Despite its commercial importance, research on deep-water rose shrimp is exiguous. The related

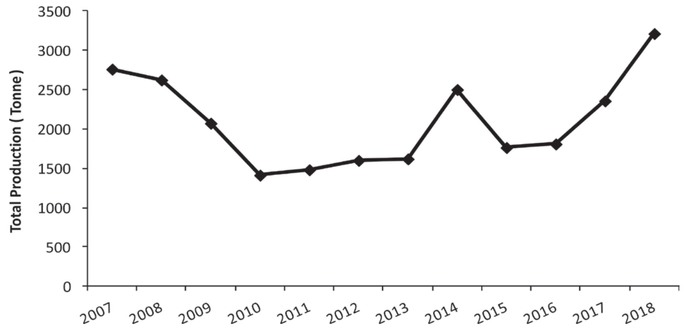

Figure 1. Total production of *P. longirostris* by years in the Turkish Seas.

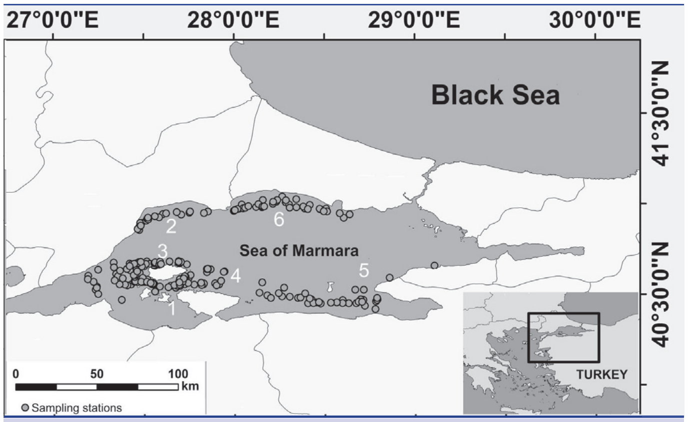

Figure 2. Study area (1. Erdek, 2. Tekirdağ, 3. Marmara Island, 4. Kapıdağ Peninsula, 5. Yalova, and 6. Silivri).

literature incorporates some studies on its distribution, biology, bycatch, selectivity, and population in the Turkish waters (Deval, Bök, Ateş, & Özbilgin, 2006; Demirci & Hoşsucu, 2007; Manaşırlı, Avşar, & Yeldan, 2008; Tosunoğlu, Akyol, Dereli, & Yapıcı, 2009; Öztürk, 2009; Bök, Göktürk, & Kahraman, 2011). Moreover, a few studies were observed to investigate catch composition and CPUE in the Sea of Marmara (Zengin et al., 2004; Bayhan, Çiçek, Ünlüer, Akkaya, 2006; Erten, 2009; Yazıcı, Ismen, Altınağaç, & Ayaz, 2006). These studies do not cover the entire area and are limited to the northern and southern Sea of Marmara.

This study is the most detailed monitoring study including the highest number of data collection stations and sampling durations. The aim is to determine the existing stock status of the species and to obtain the much-needed data for the fishing management authority, which is important for the regional and seasonal restrictions. Furthermore, establishing the productive areas is another likely beneficial result considered important for fishermen due to the commercial value of this species.

MATERIALS AND METHODS

The monthly data were collected during the beam trawl surveys aboard the fishery vessel in the Sea of Marmara between September 2011 and July 2014. For the purpose of the study, 229 beam trawl hauls were carried out. The trawls feature a cod-end mesh size of 32 mm. The average towing speed was 2.5 knots for 30 min at depths ranging from 50 to 160 m within two depth contours, i.e 50-100 m and 100-200 m. Considering the fishing areas of shrimp fishermen, the Sea of Marmara was divided into six regions, namely 1: Erdek, 2: Tekirdağ, 3: Marmara Island, 4: the Kapıdağ Peninsula, 5: Yalova, and 6: Silivri (Figure 2).

The targeted, incidental, and discarded catches were separately weighed (Alverson, Freeberg, Murawski, & Pope, 1994). The length and weight measurements of all the species were performed in a laboratory.

The catch-per-unit-effort (CPUE) values (kg h^{-1}) were determined and the mean values were computed based on seasons, locations, and depths. Biomass (kg/km^2) estimations were calculated by the swept area method (Sparre & Venema, 1998). The swept area (a) for each hauling was estimated by the following formula; $a = v \times t \times h \times X$ (v=velocity of the trawl over the ground when trawling, t=time spent for trawling, h=length of the head-rope, X: fraction of the head-rope length which is equal to the width of the path swept by the beam trawl).

RESULTS AND DISCUSSION

A total catch of 4.2 tonnes were sampled by using beam trawls in the Sea of Marmara between September 2011 and July 2014. The most weight-wise abundant catch was observed for invertebrate species, accounting for 60% of the total capture except for *P. longirostris*. The target species *P. longirostris* comprised 1.05 tonnes (25%) of the total catch. The teleost and cartilaginous fish were a small part (13% and 2%, respectively) of the catch.

The mean CPUEs were calculated to be 36.6±4.8 kg h^{-1}, 4.7±0.3 kg h^{-1}, 0.8±0.1 kg h^{-1}, and 22.6±4.6 kg h^{-1} for the total catch, teleost fish, cartilaginous fish, and invertebrate species, respectively. The mean CPUE of *P. longirostris* was found to be 8.4±0.5 kg h^{-1} in the Sea of Marmara. The CPUE value was the highest in summer and autumn and the lowest in winter and spring. Considering the depths and seasons, the highest seasonal CPUE of *P. longirostris* was determined to be 14.7±2.0 kg h^{-1} in spring 2013 at a depth of 100-200 m. The difference between the CPUE values of summer 2013 and spring 2014 was found to be statistically significant ($p<0.05$, ANOVA) (Table 1). In terms of the depth contours, these values were calculated to 8.5 kg h^{-1} at 50-100 m and 7 kg h^{-1} at 100-200 m. However, no significant difference was observed for the two depth contours ($p>0.05$, ANOVA). The CPUE results in the present research was found to be similar to the other studies conducted in the Aegean Sea (Tosunoğlu et al., 2009) and the Mediterranean Sea (Manaşırlı et al., 2008), which report the highest CPUE value in the summer months.

The mean region-based CPUE value of *P. longirostris* was the highest (14.3±1.9 kg h^{-1}) in Silivri in the northern Sea of Marmara and the lowest (3.6±1.0 kg h^{-1}) in the southeast (Yalova). Furthermore, the analysis of depth-wise CPUE change by the regions revealed that the deep-water pink shrimp preferred the depths more than 100 m in Erdek and Yalova. In the Tekirdağ region, the CPUE was found to be remarkably low at depths of over 100 m. High human population density and polluting factors severely affect the northern Sea of Marmara. These regions have been reported in previous studies to be poor in oxygen, especially in the summer and spring (Satılmış et al., 2017). The among-region differences in the CPUE values were statistically significant ($p<0.05$, ANOVA). According to the Tukey's test, regions 1, 3, and 4 (Erdek, Marmara Island, and Kapıdağ Peninsula) are similar in comparison to region 2 (Tekirdağ) and 6 (Silivri) (Table 2). It is obvious that the Sea of Marmara was divided into two parts, namely the northern and southern Sea of Marmara, for the purpose of the study.

The annual CPUE was determined to be 7.7±0.6 kg h^{-1} in 2012, and the value rose up to 11.0±1.1 kg h^{-1} in 2013 and then decreased to the lowest value (6.5±0.9 kg h^{-1}) in 2014. Statistically significant values were observed in 2013 but not in the other years. ($p<0.05$, ANOVA). When we compared the results obtained in our study with those in the studies available in Table 3, we realized that our CPUE results were higher than theirs except for Yazıcı et al. (2006).

The mean biomass of *P. longirostris* was found to be 354 kg/km^2 in the Sea of Marmara. Biomass values were observed to vary by season, year, depth, and region. The highest biomass was represented in 2013 (480 kg/km^{-2}), followed by the one in 2012 (297 kg/km^{-2}), and the lowest in 2014 (283 kg km^{-2}) (Table 4).

With respect to depth, relatively higher values were recorded to be 355.9 kg km^{-2} at depths of less than 50-100 m (189.1 kg/km^{-2}; ≥100 m). The highest biomass value was obtained in the northern Sea of Marmara, whereas the lowest was calculated in the southeast. There is only one study to have revealed the biomass of *P. longirostris* in the Sea of Marmara. Zengin et al. (2004) have found the highest biomass values at 50-100 m in winter.

In previous research studies, it has been stated that different factors exert effects on the distribution of the species. Ungaro & Gramolini (2004) have found that water circulation, temperature, and geomorphological differences are effective in species distribution. Guijarro, Massutí, Moranta, & Cartes (2009) state that the spatial-temporal differences in the density of the species are related to seabed topography, sediment composition, hydrographic characteristics, and amount of nutrients in the Balearic Islands in the Mediterranean Sea. Tosunoğlu et al. (2009) report that water temperature is important for the distribution of *P.longirostris* in the Aegean Sea.

Table 1. CPUE values of P. longirostris by depths and seasons.

Seasons	Depth			ANOVA-Tukey Test
	50-100 m	>100 m	Mean	
	kg h^{-1}	kg h^{-1}	kg h^{-1}	
Aug. 11	9.9±1.6	-	9.9±1.6	AB
Win. 12	5.1±0.9	-	5.1±0.9	AB
Spr. 12	6.2±0.9	7.4±2.6	6.3±0.9	AB
Sum. 12	9.1±1.6	4.6	8.9±1.5	AB
Aug. 12	10.8±2.2	-	10.8±2.2	AB
Win. 13	9.1±1.7	13.6	9.3±1.7	AB
Spr. 13	10.9±2.6	14.7±2.0	11.3±2.4	AB
Sum. 13	13.7±2.7	6.1±0.1	12.9±2.5	A
Aug. 13	7.2±2.2	-	7.2±2.2	AB
Win. 14	4.7±0.7	5.1±1.7	4.7±0.7	AB
Spr. 14	4.7±1.7	3.3±1.3	4.6±1.5	B
Sum.14	12.0±3.1	5.4±0.6	11.2±2.7	AB
Mean	8.5±0.6	7.0±1.1	8.4±0.5	

A, B, AB: Data sets with at least one of the same letters are significantly similar.

Table 2. CPUE values of P. longirostris by depth and region.

Depth	Regions*						Mean
	1	2	3	4	5	6	
	kg h^{-1}	kg h^{-1}	kg h^{-1}	kg h^{-1}	kg h^{-1}	kg h^{-1}	kg h^{-1}
50-100 m	5.7±0.6	11.0±1.5	8.5±1.1	6.7±0.8	3.3±1.0	14.3±1.9	8.5±0.6
>100 m	7.8±1.7	4.8	6.6±1.6	-	10.0	-	7.0±1.1
Total	5.9±0.6	10.8±1.4	8.2±1.0	6.7±0.8	3.6±1.0	14.3±1.9	8.4±0.5
ANOVA-Tukey's Test	BC	AB	BC	BC	C	A	

*1. Erdek, 2. Tekirdag, 3. Marmara Island, 4. Kapıdağ Peninsula, 5. Yalova, 6. Silivri; A, C, AB, BC: Data sets with at least one of the same letters are significantly similar.

Table 3. Previous research studies on CPUE and biomass values of *P. longirostris.*

Author	Area	CPUE	Biomass	Gear type
Zengin et al (2004)	Marmara Sea	5.9 kg h^{-1}	-	b*
Bayhan et al (2006)	Marmara Sea	3.73 kg h^{-1}	-	b*
Yazıcı et al (2006)	Marmara Sea	10 kg h^{-1}	-	b*
Demirci & Hoşsucu (2007)	Eastern Mediterranean Sea	5.9 kg h^{-1}	141 kg km^{-2}	a*
Manaşırlı et al (2008)	Babadillimanı Bight	5.48 kg h^{-1}	203.0 kg km^{-2}	a*
Tosunoğlu et al (2009)	Sığacık Bay	6.40 kg h^{-1}	130.56 kg km^{-2}	a*
İşmen et al (2010)	Saros Bay	4.84 kg h^{-1}	85.4 kg km^{-2}	a*
Kapiris et al (2013)	South Ionian Sea	-	6.46 kg km^{-2}	a*
This study	Marmara Sea	8.4 kg h^{-1}	354 kg km^{-2}	b*

*a: bottom trawl, b: beam trawl

Table 4. Biomass values of *P. longirostris* by the season, region and year (kg/km^{-2}).

Seasons	Regions*						
	1	2	3	4	5	6	Mean
Aug. 11	483	430	588	257	67	-	383±61
Win. 12	232	243	-	180	77	297	197±33
Spr. 12	194	283	338	220	142	-	243±34
Sum. 12	242	548	218	305	46	627	351±58
2012	**258**	**362**	**407**	**239**	**88**	**533**	**297±25**
Aug. 12	294	700	436	523	415	335	470±97
Win. 13	287	235	704	331	739	511	406±72
Spr. 13	167	-	449	-	200	1529	633±188
Sum. 13	438	907	419	199	-	774	559±107
2013	**288**	**662**	**452**	**394**	**394**	**675**	**480±47**
Aug. 13	165	177	475	343	-	-	314±94
Win. 14	224	400	218	107	159	235	205±29
Spr. 14	94	220	124	113	75	439	199±66
Sum.14	174	835	210	-	55	873	488±119
2014	**178**	**386**	**222**	**187**	**87**	**572**	**283±40**
Mean	**246±24**	**445±63**	**343±42**	**279±36**	**151±43**	**611±83**	**354±23**

*1. Erdek, 2. Tekirdag, 3. Marmara Island, 4. Kapıdağ Peninsula, 5. Yalova, 6. Silivri

CONCLUSION

It was concluded that the knowledge of the spatio-temporal pattern of *P. longirostris* is crucial for understanding the differences and for sustainable exploitation of the stock in the Sea of Marmara. The amount of captured species decreased from year to year, which may have resulted from the increased fishing pressure on the species. The analyses of all the data showed that the Sea of Marmara had two different structures in terms of CPUE and biomass, namely Northern Marmara and Southern Marmara. Population density and polluting factors may have caused this partition. Considering the scarcity of data or estimates about beam trawl in Turkish fisheries, this study is thought to help guide future research in the studied area.

Conflict of interests: The authors have no conflicts of interest to declare.

Ethics committee approval: Ethics committee approval is not required.

Funding: This study was financially supported by TAGEM project no: 2011/09/02/04.

Acknowledgments: This study was derived from the Ph.D. thesis with the entry number of 10150541. The authors would like to thank all the researchers for their valuable contributions to collection and evaluation of the data.

Disclosure: -

REFERENCES

Alverson, D. L., Freeberg, M. H., Murawski, S. A. & Pope, J. G. (1994). *A global assesment of fisheries bycatch and discard.* Food and Agriculture Organization of the United Nations, Rome. ISBN 92-5-103555-5

Bayhan, Y. K., Çiçek, E., Ünlüer, T. & Akkaya, M. (2006). Güney Doğu Marmara'da Algarna ile Karides Avcılığında Av Kompozisyonu ve Hedef Dışı Av. *E. Ü. Su Ürünleri Dergisi, 23*, 277-283.

Bök, T. D., Goktürk, D. & Kahraman, A. E. (2011). Bycatch in 36 and 40 mm PA Turkish twin rigged beam trawl cod ends. *African Journal of Biotechnology,* https://doi.org/ 10.5897/AJB11.356

Demirci, A. & Hoçsucu, H. (2007). Kuzeydoğu Akdeniz'de Derin Deniz Pembe Karidesinin (*Parapenaeus longirostris*) Populasyon Yapısı ve Yoğunluğu. *Türk Sucul Yaşam Dergisi, 3-5* (5-8), 50-55.

Deval, M. C., Bök, T., Ateş, C. & Özbilgin, H. (2006). Selectivity of PE and PA Material Codends for Rose Shrimp (*Parapenaeus longirostris*) in Turkish Twing Rigged Beam Trawl Fishery. *Fisheries Research.* [CrossRef]

Erten, M. (2009). Marmara Denizi'nde Manyat Avcılığı İle Karides (*Parapenaeus longirostris* Lucas, 1846) Avcılığının Araştırılması. Yüksek Lisans Tezi, İstanbul Üniversitesi

Guijarro, B., Massutí, E., Moranta, J. & Cartes, J. (2009). Short spatio-temporal variations in the population dynamics and biology of the deep-water rose shrimp *Parapenaeus longirostris* (Decapoda: Crustacea) in the western Mediterranean. *Scientia Marina, 73*, 183-197. [CrossRef]

İşmen, A., Özekinci, U., Özen, Ö., Ayaz, A., Altinağaç, U., Yiğin, Ç., Ayyildiz, H., Cengiz, Ö., Arslan, M., Ormanci, H. B., Çakir, F. & Öz, M. İ. (2010). Saroz Körfezi (Kuzey Ege Denizi) Demersal Balıklarının Biyo-Ekolojisi ve Populasyon Dinamiğinin Belirlenmesi. Tubitak Proje Raporu.

Kapiris, K., Markovic, O., Klaoudatos, D. & Djurovic, M. (2013). Contribution to the Biology of *Parapenaeus longirostris* (Lucas, 1846) in the South Ionian and South Adriatic Sea. *Turkish Journal of Fisheries and Aquatic Sciences.* [CrossRef]

Manaşırlı, M., Avşar, D. & Yeldan, H. (2008). Abundance and Depth Distribution of Deep Water Rose Shrimp (*Parapenaeus longirostris* Lucas, 1846) in Babadillimanı Bight(Turkey). *Journal of Fisheries Sciences, 2*, 524-535. [CrossRef]

Öztürk, B. (2009). Investigations of the rose shrimp *Parapenaeus longirostris* (Lucas, 1846) in the Northern Marmara Sea. *J. Black Sea/ Mediterranean Environment, 15*, 123- 134.

Politou, C. Y., Tserpes, G. & Dokos, J. (2008). Identification of deep-water pink shrimp abundance distribution patterns and nursery grounds in the eastern Mediterranean by means of generalized additive modeling. *Hydrobiologia.* [CrossRef]

Satılmış, M.M., Tanas, A.R., Olgun, S., Kantarlı, S., Olgun Eker, E., Bektaş, Ş., Selamoğlu Çağlayan, H., Polat Beken, Ç., Atabay, H., Tüfekçi, H., Karan, H., Tolun, L., Tan, İ., Mantıkcı, M., Aydöner, C., Ediger, D., Yüksek, A., Altıok, H., Taş, S., Gürkan, Y., Sezgin, M., Kurt Şahin, G., Ünlüer, F., Taşkın, E., Minareci, O., Çakır, M., Kıdeyş, A.E., Tuğrul, S. (2017). Denizlerde Bütünleşik Kirlilik İzleme İşi 2014-2016 Marmara Denizi Özet Raporu. Çevre ve Şehircilik Bakanlığı - Çevresel Etki Değerlendirmesi, İzin ve Denetim Genel Müdürlüğü, Ankara.

Sbrana, M. Viva, C. & Belcari, P. (2006). Fishery of the Deep-water Rose Shrimp Parapenaeus longirostris (Lucas, 1846) (Crustacea: Decapoda) in the Northern Tyrrhenian Sea (Western Mediterranean), *Hydrobiologia*. [CrossRef]

Sparre, P. & S.C. Venema. 1998. Introduction to tropical fish stock assessment. Part 1 – Manual. FAO, Roma. FAO Fisheries Technical Paper 306/1, Rev. 2, 337 pp.

TUIK. (2019). Fishery Production Statistics of Turkey. (TUİK), Ankara.

Tosunoğlu, Z., Akyol, O., Dereli, H. & Yapici, S. (2009). Sığacık Körfezi'nde Dip Trol Ağları ile Yakalanan Derin Su Pembe Karidesi (*Parapenaeus longirostris* Lucas, 1846)'nin Bazı Biyolojik ve Populasyon Özelliklerinin Araştırılması. TUBİTAK Proje No: 108Y102.

Ungaro, N., & Gramolini, R. (2004). Relationship between enviromental parameters and stok distribution: can the bottom temperature affect the adriatic population of the deep-water rose shrimp? *Aquatic Living Resources.* [CrossRef]

Yazıcı, M. F., İşmen., A, Altinağaç, U. & Ayaz, A. (2006). A study on the catch composition and bycatch of shrimp beam trawl in the Sea of Marmara. *E. U. Journal of Fisheries and Aquatic Sciences,* https://doi.org/10.12714/egejfas.2006.23.3.5000156728

Zengin, M., Polat, H., Kutlu, S., Dinçer, C., Güngör, H., Aksoy, M., Özgündüz, C., Karaarslan, E. & Firidin, S. (2004). Marmara Denizi'ndeki Derin Su Pembe Karidesi (*Parapenaeus longirostris*, LUCAS, 1846) Balıkçılığının Geliştirilmesi Üzerine Bir Araştırma. (TAGEM/HAYSUD/2001/09/02/004 No'lu Proje Sonuç Raporu). Tarım ve Köy İşleri Bakanlığı, Su Ürünleri Merkez Araştırma Müdürlüğü, Trabzon, 211s.

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 51-65 • DOI: https://doi.org/10.26650/ASE2020740218

Original Article

Phytoplankton Diversity of a Subtropical Reservoir of Meghalaya State of Northeast India

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Cite this article as: Sharma, B.K., & Sharma, S. (2021). Phytoplankton diversity of a subtropical reservoir of Meghalaya state of northeast India. *Aquatic Sciences and Engineering, 36*(2), 51-65.

ABSTRACT

The littoral and limnetic phytoplankton of 'soft and de-mineralized water' in the Nongmahir reservoir of Meghalaya state of northeast India (NEI) reveal a fairly diverse assemblage of a total of 52 species, depict a higher richness of Chlorophyta and desmids, and record a speciose constellation of 51 species per sample. Phytoplankton form a dominant quantitative component of net plankton and indicate the differential spatial dominance of important groups. Bacillariophyta > Chlorophyta indicate dominance in the littoral region and Chlorophyta records dominance in the limnetic region. *Staurastrum* spp. > *Cosmarium* spp. are important in the two regions. Seventeen 'specialist' species collectively contribute to phytoplankton abundance in the littoral (87.9±6.9%) and limnetic (91.6±3.3%) regions and the rest depict a 'generalist' nature. Phytoplankton records moderate species diversity and variations of dominance and evenness. The spatial monthly variations of composition, richness, similarities, abundance, diversity indices and influence of individual abiotic factors are hypothesised to differences in habitat heterogeneity amongst the two regions. The CCA registers 78.36 and 78.95% cumulative influence of 10 abiotic factors on the littoral and limnetic phytoplankton assemblages, respectively. Our results highlight distinct temporal variations of diversity parameters in comparison with the preliminary survey of June 1995–May 1996. This study is an important contribution to phytoplankton diversity of the reservoirs of India and the subtropical reservoirs in particular.

Keywords: Calcium poor, de-mineralized, soft water, Nongmahir, spatio-temporal variations

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Submitted: 20.05.2020

Revision Requested: 14.09.2020

Last Revision Received: 21.09.2020

Accepted: 22.10.2020

Online Published: 25.01.2021

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INTRODUCTION

Phytoplankton, an integral link of aquatic food-webs, has been studied from diverse freshwater environs since the inception of the Indian limnology during the early part of the 20th century. A sizeable fraction of the published works with incomplete species inventories and inadequate data-analysis comprise 'routine' ecology reports (Sharma, 2015). The noteworthy phytoplankton diversity Indian studies relate to the lakes of Kashmir (Zutshi et al., 1980; Zutshi and Wanganeo, 1984; Wanganeo and Wanganeo, 1991; Baba and Pandit, 2014; Ganai and Parveen, 2014), Himachal Pradesh (Thakur et al., 2013; Gupta et al., 2018; Jindal et al., 2013, 2014a, 2014b) and Uttarakhand (Sharma and Singh, 2018; Sharma and Tiwari, 2018; Singh and Sharma, 2018). Certain notable works from NEI are from the floodplain lakes (*beels*) of the Brahmaputra river basin of Assam (Sharma, 2004, 2012, 2015; Sharma and Hatimuria, 2017) and *pats* of the floodplains of Manipur (Sharma, 2009, 2010). Nevertheless, there is paucity of works on diversity of phytoplankton assemblages from the sub-tropical reservoirs of India in general and NEI in particular. The related work from NEI belong to the Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016), while Sharma (1995), Sharma and Lyngdoh (2003) and Sharma and Lyngskor (2003) dealt with the preliminary reports of three reservoirs of Meghalaya.

The present study, a follow-up of our limited survey of June 1995–May 1996 (Sharma and Lyngskor, 2003), attempts to provide detailed information on the phytoplankton diversity of the subtropical Nongmahir reservoir of Meghalaya; it assumes limnological importance in light of the stated lacunae. Our observations are based on analyses of monthly littoral and limnetic net plankton with reference to species composition, richness, community similarities, abundance, species diversity, dominance, evenness and trophic status as well as individual and cumulative influence of abiotic factors on phytoplankton assemblages. The results are compared and discussed with reference to studies from the Himalayan and sub-Himalayan sub-tropical lakes of India, and the floodplain lakes and the sub-tropical reservoirs of NEI. We comment on spatial variations of the observed parameters based on the sampled littoral and limnetic regions, and on temporal variations in comparison with an earlier survey of June 1995–May 1996.

MATERIALS AND METHODS

Our observations are based on a limnological survey (January–December, 2015) of the Nongmahir reservoir (25^0 08′ N; 91^0 50′ E; area: 70 ha; maximum depth: 25 m) commissioned in 1979 to serve as a pick up reservoir (Stage III) of the Umiam-Umtru hydroelectric project. It is located in the Ri-Bhoi district (Figure 1, A-B) and at a distance of about 45 km from Shillong city, the capital of Meghalaya state of NEI. This reservoir lacks any aquatic vegetation, and its fish fauna includes *Catla catla, Cirrhinus mrigala, Cyprinus carpio, Clarias batrachus, Danio acquipinnatus, D. dangila, Heteropneustes fossilis, Labeo rohita, Neolissocheilus hexagonolepis, Puntius sophore* and *Tor putitora.*

Water samples as well as qualitative and quantitative net plankton samples were collected at monthly intervals from the littoral and the limnetic regions (Sharma and Sharma, 2020). Water temperature was recorded using a centigrade thermometer, transparency was measured with a Secchi disc, pH and specific conductivity were recorded with field probes, dissolved oxygen was estimated using the modified Winkler's method, while other abiotic factors (total alkalinity, total hardness, calcium, magnesium, chloride, dissolved organic matter, phosphate, nitrate and sulphate) were analyzed following APHA (1992). Rainfall data was obtained from the local meteorological station.

The monthly qualitative net plankton samples, collected by towing a nylobolt plankton net (#40 µm) and preserved in 5% formalin, were screened with a Wild Stereoscopic binocular microscope. Phytoplankton was observed with a Leica stereoscopic microscope (DM 1000) and were identified following the works of Biswas (1949), Islam and Haroon (1980), Prescott (1982), Fitter and Manuel (1986), Anand (1998) and John et al. (2002). The community similarities were calculated vide Sørensen's index and the hierarchical cluster analysis was done using SPSS (version 20). The monthly quantitative net plankton samples were obtained by filtering 25 L of water for each sample through a nylobolt plankton net and were preserved in 5% formalin. Quantitative enumeration of phytoplankton, constituent groups, important taxa and species was done by using Sedgewick-Rafter counting cell and abundance was expressed as n/l. Species diversity (Shannon-Weiner's index), dominance (Berger-Parker's index) and evenness (E_1 index) were calculated vide Ludwig and Reynolds (1988) and Magurran (1988). Two-way analysis of variance (ANOVA) was used to ascertain the significance of variations of the different abiotic and biotic parameters. Pearson correlation coefficients, for the littoral and limnetic regions (r_1 and r_2, respectively), were calculated between abiotic factors and phytoplankton; p values were calculated *vide* http://vassarstats.net/tabs.html and their significance were ascertained after Bonferroni corrections. The canonical correspondence analysis (XLSTAT 2015) was done to observe the cumulative influence of 10 abiotic parameters (logistic limitations of the study period): water temperature, rainfall, transparency, specific conductivity, dissolved oxygen, total alkalinity, total hardness, phosphate, sulphate and nitrate on phytoplankton assemblages.

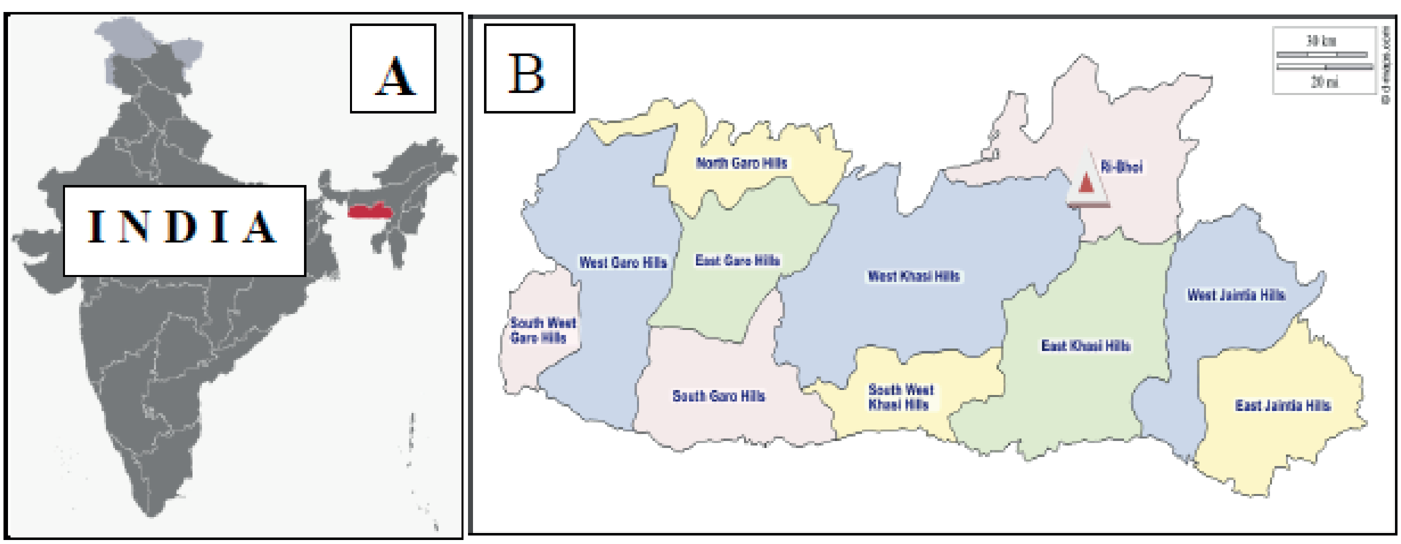

Figure 1. A-B. A, map of India showing Meghalaya state (red color); B, District map of Meghalaya showing location of the Nongmahir reservoir (red triangle) in the Ri-Bhoi district.

RESULTS AND DISCUSSION

Abiotic attributes

The Nongmahir reservoir is characterized by soft, slightly acidic-circum neutral, calcium poor and oxygenated waters with low specific conductivity, free carbon dioxide, chloride and nutrients (Tables 1-2). ANOVA depicts (Table 3) significant variations of transparency, total alkalinity, total hardness and dissolved organic matter between stations and months. Free carbon dioxide registers significant variation between stations. Water temperature, specific conductivity, calcium, magnesium, chloride, phosphate, nitrate and sulphate record significant monthly variations. Low specific conductivity is attributed to the leached and weathered nature of rocks and soils because of high rainfall (Sharma, 1995; Sharma and Bhattarai, 2005; Sharma and Sharma, 2020). This notable feature warrants inclusion of the sampled reservoir under 'Class I' category of trophic classification vides Talling and Talling (1965) and Payne (1986). The present study records temporal variations vis-à-vis the relative increase in specific conductivity, free carbon dioxide, total alkalinity, total hardness, calcium, phosphate and chloride, and decrease in transparency, magnesium, sulphate and nitrate in comparison with our preliminary June 1995–May 1996 survey (Sharma and Lyngskor, 2003).

Species richness

Our report of 52 phytoplankton species (Tables 3-4), belonging to seven groups, marks a distinct three-fold increase as compared with species reported vide the earlier survey (Sharma and Lyngskor, 2003). The richness concurs with 52 species each known from two floodplain lakes of Assam (Sharma, 2004, 2015) and broadly compares with 55 species observed from the Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016). Phytoplankton is distinctly speciose in contrast to the reports from the sub-tropical reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003), the floodplain lakes of Assam (Laskar and Gupta, 2009; Gupta and Devi, 2014; Devi et al. 2016; Deb et al., 2019) and Tripura (Bharati et al., 2020) states of NEI, and lakes of Kashmir (Shafi et al., 2013; Jeelani and Kaur, 2012; Chandrakiran et al., 2014; Nissa and Bhat, 2016), Uttarakhand (Rawat and Sharma, 2005; Negi and Rajput, 2015; Sharma and Singh, 2018; Singh and Sharma, 2018, Goswami et al., 2018), Himachal Pradesh (Gupta et al., 2018; Jindal and Thakur, 2014; Jindal et al, 2014b) from India, and adjacent south Asian countries of Bhutan (Sharma and Bhattarai, 2005) and Nepal (Hickel, 1973; Nakanishi et al., 1988). The richness is, however, marginally lower than the reports from Manipur (Sharma, 2009, 2012), Assam (Sharma, 2015), Kashmir (Baba and Pandit, 2014) and Himachal Pradesh (Thakur et al., 2013). The stated comparisons highlight the overall biodiverse nature of phytoplankton of the soft and de-mineralized waters of the Nongmahir reservoir in particular. Further, the 52 and 47 species observed from the littoral and limnetic regions (Table 4) indicate overall homogeneity with ~95% community similarity.

The speciose Chlorophyta (Tables 3-4) of the Nongmahir reservoir broadly compares with the reports from the Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016) and Prashar Lake of Himachal Pradesh (Jindal and Thakur, 2014). Our results, however, depict species-rich Chlorophyta as compared with the reports from the various environs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003) and Assam (Laskar and Gupta, 2009; Gupta and Devi, 2014; Devi et al., 2016; Bharati et al., 2020) of NEI; and the lakes of Kashmir (Shafi et al., 2013; Baba and Pandit, 2014; Ganai and Parveen, 2014) and Uttarakhand (Negi and Rajput, 2015; Goswami et al., 2018; Sharma and Singh, 2018; Sharma and Tiwari, 2018). Nevertheless, the qualitative importance of the green-algae differs from that of Chlorophyta > Bacillariophyta (Sharma and Lyngskor, 2003; Rawat and Sharma, 2005; Sharma, 2012, 2015; Shafi et al., 2013), Chlorophyta > Cyanophyta (Sharma and Lyngdoh, 2003; Laskar and Gupta, 2009) and Bacillariophyta > Chlorophyta (Sharma, 2004; Baba and Pandit, 2014; Ga-

Table 1. Variations of abiotic factors.

Regions →	Littoral region		Limnetic region	
Factors ↓	**Range**	**Mean ± S.D**	**Range**	**Mean ± S.D**
Water temperature ^{0}C	16.0-24.0	20.7±2.7	16.5-24.5	20.8±2.6
Rainfall mm	1.4-803.2	230.2±227.8	1.4-803.2	230.2±227.8
Transparency cm	75-110	92.5±10.1	80-120	100.8±12.4
pH	6.7-7.2	6.95±0.16	6.8-7.2	6.95±0.13
Specific conductivity µS/cm	40.2-57.8	50.3±5.3	38.8-58.0	50.0±6.3
Dissolved oxygen mg/l	7.0-9.6	8.2±0.7	7.4-9.0	8.3±0.6
Free Carbon dioxide mg/l	9.0-14.0	11.3±1.5	6.0-8.0	7.1±0.9
Total Alkalinity mg/l	24.0-48.0	33.0±6.8	28.0-46.8	36.3±5.7
Total Hardness mg/l	16.8-32.0	23.0±4.8	18.6-38.8	25.6±5.8
Calcium mg/l	9.8-19.2	13.9±3.4	10.0-18.7	13.7±2.6
Magnesium mg/l	1.2-4.2	2.2±0.8	1.0-5.0	2.2±1.1
Chloride mg/l	12.0-18.0	14.5±2.1	1.8-2.8	2.3±0.4
Phosphate mg/l	0.090-0.208	0.151±0.041	0.102-0.234	0.160±0.046
Sulphate mg/l	0.159-2.020	1.022±0.664	0.259-2.004	0.939±0.558
Nitrate mg/l	0.062-0.108	0.090±0.016	0.052-0.110	0.086±0.016
Dissolved organic matter mg/l	2.2-4.8	3.1±0.7	1.6-3.4	2.1±0.6

Table 2. Monthly variations of abiotic factors at littoral and limnetic regions.

Parameters ↓	**Months →**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Water temperature (^{0}C)	Littoral	16.0	17.0	19.0	21.0	23.0	23.5	24.0	24.0	22.5	21.0	20.0
	Limnetic	16.5	17.0	19.5	21.0	23.0	23.0	24.5	24.0	22.0	21.0	20.0
Rainfall mm	Littoral	32.0	2.0	39.8	390.8	272.0	803.2	502.1	220.8	169.8	150.0	178.6
	Limnetic	32.0	2.0	39.8	390.8	272.0	803.2	502.1	220.8	169.8	150.0	178.6
Transparency cm	Littoral	90	95	100	95	105	90	80	75	80	90	100
	Limnetic	100	110	120	105	100	90	80	85	90	100	110
pH	Littoral	6.9	7.1	7.2	6.9	6.8	6.7	6.9	7.1	6.8	6.9	**7.2**
	Limnetic	6.9	6.8	7.1	7.1	6.9	6.9	6.8	6.9	6.8	7.2	7.1
Specific conductivity (µS /cm)	Littoral	51.6	47.7	51.4	54.0	56.0	57.8	45.0	40.2	44.2	46.8	52.2
	Limnetic	42.8	48.6	52.2	56.4	57.2	58	49	40.2	38.8	48.6	52
Dissolved oxygen mg/l	Littoral	8.2	9.6	9.0	8.6	7.0	9.0	8.2	8.0	7.0	7.8	7.9
	Limnetic	7.2	7.8	8.6	9.0	8.2	8.8	7.4	8.4	9.0	8.8	7.8
Free Carbon dioxide mg/l	Littoral	10.0	14.0	12.0	10.8	10.0	9.0	10.0	12.0	14.0	11.8	12.0
	Limnetic	6.0	8.0	8.0	6.0	6.0	7.8	8.0	6.8	8.0	6.0	6.0
Total alkalinity mg/l	Littoral	36.0	48.0	40.0	38.0	29.0	27.8	26.0	24.0	26.0	30.0	34.0
	Limnetic	40.2	46.8	44.0	40.2	36.0	34.6	30.0	28.6	28.0	32.8	36.4
Total hardness mg/l	Littoral	28.0	32.0	29.0	28.0	22.0	20.6	20.2	18.0	16.8	19.0	20.0
	Limnetic	30.0	38.8	32.2	29.8	26.4	24.0	20.8	19.8	18.6	20.2	22.6
Chloride mg/l	Littoral	12.0	14.0	16.0	12.0	18.0	16.0	15.9	17.8	14.0	13.2	13.0
	Limnetic	10.2	12.0	14.6	14.0	16.0	17.8	15.0	14.8	12.0	13.2	12.0
Calcium mg/l	Littoral	18.0	19.2	18.6	17.0	15.2	13.2	10.2	9.8	10.0	11.2	11.8
	Limnetic	16.2	18.7	17.0	16.4	14.0	12.2	10.8	10.0	11.2	12.4	12.8
Magnesium mg/l	Littoral	2.8	4.2	2.2	2.8	1.8	1.4	1.2	1.2	1.7	2.0	**2.6**
	Limnetic	3.2	5.0	2.0	3.2	2.0	1.1	1.0	1.1	1.5	1.8	2.0
Phosphate mg/l	Littoral	0.090	0.099	0.104	0.128	0.182	0.190	0.160	0.208	0.190	0.182	0.168
	Limnetic	0.110	0.102	0.094	0.159	0.214	0.234	0.142	0.148	0.190	0.205	0.198
Sulphate mg/l	Littoral	0.159	0.270	0.304	0.478	0.602	1.642	1.820	2.020	2.004	1.023	0.998
	Limnetic	0.259	0.370	0.404	0.478	0.502	1.042	1.320	1.920	2.004	1.023	0.998
Nitrate mg/l	Littoral	0.090	0.098	0.084	0.090	0.078	0.062	0.072	0.080	0.098	0.108	0.120
	Limnetic	0.092	0.082	0.082	0.078	0.069	0.052	0.079	0.089	0.098	0.108	0.110
Dissolved organic matter mg/l	Littoral	3.8	4.2	4.8	2.6	2.2	2.8	3.0	2.2	3.0	3.2	2.8
	Limnetic	3.2	3.4	2.0	1.8	1.6	2.0	2.2	1.8	2.0	2.2	1.8

nai and Parveen, 2014; Negi and Rajput, 2015; Goswami et al., 2018; Sharma and Singh, 2018; Singh and Sharma, 2018; Deb et al., 2019) reported elsewhere from India. Woelkerling and Gough (1976), Payne (1986) and Sharma (1995) hypothesized high desmid diversity to be a notable feature of the soft, calcium-poor and de-mineralized waters. We extend this hypothesis to the rich desmid flora of the Nongmahir reservoir (Table 3) indicating *Staurastrum* (7 species) = *Cosmarium* (7 species) > *Pediastrum* (3 species) > *Micrasterias* (2 species) = *Closterium* (2 species) and one species each of *Anthrodesmus*, *Coelastrum*, *Euastrum*, *Netrium*, *Pleurotaenium*, *Scenedesmus*, *Sirogonium*, *Staurodesmus* and *Xanthidium*. This salient feature concurs with the reports from Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003), Mizoram (Sharma and Pachuau, 2016), Assam (Sharma, 2015; Sharma and Hatimuria, 2017) and Himachal Pradesh (Thakur et al, 2013) but differs from the desmid paucity noted vide the earlier survey (Sharma and Lyngskor, 2003).

Our report of high phytoplankton monthly richness (Table 5) in the littoral region > the limnetic region (Figure 2) is hypothesized to greater habitat heterogeneity of the littoral region. Further, the notable speciose constellation / sample of 51 species observed in the littoral region of the Nongmahir reservoir during the winter (January) collection (Figure 2) is attributed to the possibility of co-existence of a number of phytoplankton species due to a high amount of niche overlap as hypothesized by MacArthur (1965). The differential and oscillating monthly phytoplankton richness variations (Figure 2) noted in the present study is affirmed by significant richness differences (vide ANOVA) between stations and months (Table 3). The peak richness noticed during January and December (winter) in the two regions, respectively concurs with the reports from the floodplains of Manipur (Sharma, 2010) and Assam (Devi et al., 2016). The monthly phytoplankton richness registers 50.7-79.6 and 39.4-87.4% community similarities in the littoral and limnetic regions (Table 4), respectively and depicts more heterogeneity in the latter region.

Table 3. ANOVA indicating significance of abiotic factors.

Parameters	Regions	Months
Abiotic factors		
Water temperature	-	$F_{11,23}$=233.294, P=2.19E-11
Transparency	$F_{1,23}$=17.742, P=0.001	$F_{11,23}$=10.871, P=0.0002
pH	-	-
Specific conductivity	-	$F_{11,23}$=11.1508, P=0.0002
Dissolved oxygen	-	-
Free Carbon dioxide	$F_{1,23}$=73.565, P=3.35E-06	-
Total Alkalinity	$F_{1,23}$=23.683, P=0.0005	$F_{11,23}$=30.097, P=1.31E-06
Total Hardness	$F_{1,23}$=30.644, P=0.0002	$F_{11,23}$=43.616, P=1.87E-07
Calcium	-	$F_{11,23}$=31.712, P=9.99E-07
Magnesium	-	$F_{11,23}$=26.706, P=2.44E-06
Chloride	-	$F_{11,23}$=6.0970, P=0.0028
Phosphate	-	$F_{11,23}$=8.972, P=0.0005
Sulphate	-	$F_{11,23}$=30.302, P=1.27E-06
Nitrate	-	$F_{11,23}$=15.625, P=3.68E-05
Dissolved organic matter	$F_{1,23}$=31.132, P=0.0002	$F_{11,23}$=3.893, P=0.016

(-) indicates insignificant variations

Table 4. Species composition of phytoplankton.

Phytoplankton ↓ Regions →	Littoral	Limnetic
CHLOROPHYTA		
1. *Anthrodesmus convergens*	+	+
2. *Cosmarium botrytis*	+	+
3. *Cosmarium contractum*	+	+
4. *Cosmarium decoratum*	+	+
5. *Cosmarium granatum*	+	+
6. *Cosmarium punctulatum*	+	-
7. *Cosmarium scabrum*	+	-
8. *Cosmarium undulatum*	+	+
9. *Closterium pseudolunula*	+	+
10. *Closterium kuetzingii*	+	+
11. *Coleastrum sphaericum*	+	+
12. *Dictyosphaerium* sp.	+	+
13. *Euastrum sinousum*	+	+
14. *Micrasterias foliacea*	+	+
15. *Micrasterias radians*	+	+
16. *Netrium digitus*	+	+
17. *Pediastrum boryanum*	+	+
18. *Pediastrum duplex*	+	+
19. *Pediastrum simplex*	+	-
20. *Pleurotaenium* sp.	+	+
21. *Scenedesmus acuminatus*	+	+
22. *Sirogonium sticticum*	+	+
23. *Staurastrum artiscon*	+	+
24. *Staurastrum sexangulare*	+	+
25. *Staurastrum sonthalianum*	+	+
26. *Staurastrum formosum*	+	+
27. *Staurastrum paradoxum*	+	+
28. *Staurastrum leptocladum*	+	+
29. *Staurastrum rotula*	+	+
30. *Staurodesmus dejectus*	+	+
31. *Spirogyra orientalis*	+	+
32. *Xanthidium* sp.	+	+
BACILLARIOPHYTA		
33. *Caloneis* sp.	+	+
34. *Diatoma vulgaris.*	+	+
35. *Frustulia rhomboides*	+	+
36. *Navicula radiosa*	+	+
37. *Pinnularia interrupta*	+	+
38. *Rhopalodia* sp.	+	+
39. *Stauronies* sp.	+	+
40. *Tabellaria flocculosa*	+	+
DINOPHYTA		
41. *Ceratium hirudinella*	+	+
42. *Peridinium cinctum*	+	+
CRYPTOPHYTA		
43. *Cryptomonas* sp.	+	+
CYANOPHYTA		
44. *Microcystis aeruginosa*	+	+
45. *Anabaena sp.*	+	+
46. *Oscillatoria limosa*	+	+
47. *Nostoc* sp.	+	-
48. *Spirulina agilis*	+	+
CHRYSOPHYTA		
49. *Dinobryon sociale*	+	+
EUGLENOPHYTA		
50. *Euglena acus*	+	+
51. *Euglena viridis*	+	-
52. *Phacus longicauda*	+	+
Total phytoplankton species	**52**	**47**

+ present; - absent

Table 5. Qualitative and quantitative variations of phytoplankton.

Taxa ↓ Regions →	Littoral region		Limnetic region	
Richness				
Phytoplankton	52 species: 37-51, 41±5 species		47 species: 23-38, 31±6 species	
Community similarity	50.7-79.6%		39.4-87.4%	
Chlorophyta	32 species: 19-31, 23±2 species		29 species: 15-22	19±2
Quantitative				
Net Plankton n/l	436-1736	1053±421	363-1346	747±325
Phytoplankton n/l	295-1555	854±154	234-983	529±256
Percentage of net plankton	58.4-89.6	76.7±9.9	41.8-63.0	57.7±5.3
Species Diversity	1.425-3.143	2.570±0.528	1.875-2.741	2.503±0.218
Dominance	0.136-0.514	0.264±0.131	0.145-0.567	0.241±0.106
Evenness	0.379-0.836	0.696±0.146	0.532-0.739	0.738±0.067
Different Groups				
Chlorophyta n/l	89-699	313±204	63-763	312±320
Percentage of phytoplankton	6.3-67.1	39.8±17.7	15.7-78.5	52.1±19.9
Bacillariophyta n/l	74-1352	356±417	17-307	75±85
Percentage of phytoplankton	8.2-86.9	35.6±23.2	2.2-74.7	19.0±19.9
Chrysophyta n/l	18-502	97±129	10-192	68±65
Percentage of phytoplankton	1.3-46.1	11.6±12.1	2.4-26.1	11.0±8.2
Dinophyta n/l	9-80	38±23	15-111	47±25
Percentage of phytoplankton	0.6-22.7	6.4±5.9	3.6-17.8	9.6±5.0
Cyanophyta n/l	20-69	36±17	7-96	47±25
Percentage of phytoplankton	1.4-7.5	5.0±2.0	1.6-16.7	4.8±4.0
Important taxa (n/l)				
Staurastrum spp.	42-457	191±149	38-555	217±77
Cosmarium spp.	15-200	63±55	5-144	44±46
Important species (n/l)				
Navicula radiosa	40-800	208±248	4-229	39±64
Diatoma vulgaris	2-530	103±177	1-40	11±11
Dinobryon sociale	19-502	97±127	10-192	68±65
Staurastrum artiscon	7-167	55±49	7-196	54±48
Staurastrum paradoxum	10-160	51±43	3-120	45±38
Cosmarium contractum	10-148	46±41	1-120	34±38
Tabellaria flocculosa	6-101	31±31	2-60	19±20
Ceratium hirudinella	6-68	29±22	9-105	40±26
Sirogonium sticticum	2-170	28±48	0-95	21±30
Staurastrum sonthalianum	2-98	28±29	1-130	41±45
Staurastrum formosum	5-97	23±27	2-108	30±31
Staurastrum rotula	1-72	15±22	1-89	30±29
Staurastrum sexangulare	1-31	13±10	1-52	14±14
Spirulina agilis	5-42	17±11	1-80	16±22
Staurodesmus dejectus	1-39	11±9	0-40	15±14
Cosmarium granatum	1-42	11±13	1-22	8±8
Microcystis aeruginosa	5-32	14±8	3-15	7±3

This generalization is affirmed by similarity values ranging between 61-80% in ~72% instances in the limnetic region as against ~ 83% instances in the former region. The heterogeneity is endorsed by different hierarchical cluster groupings (Figures 3-4) with peak affinity between January-July followed by September-December while February community records maximum species divergence in the littoral region. The limnetic phytoplankton indicates peak affinity between June-July and records maximum divergence during March. Chlorophyta indicate a richness (Table 5) varying between 19-31 > 15-22 species (Figure 2); it registers significant variations (vide ANOVA) between stations and months (Table 6) and significantly influences phytoplankton richness (r_1= 0.692, p = 0.027; r_2= 0.787, p = 0.007) in the two regions.

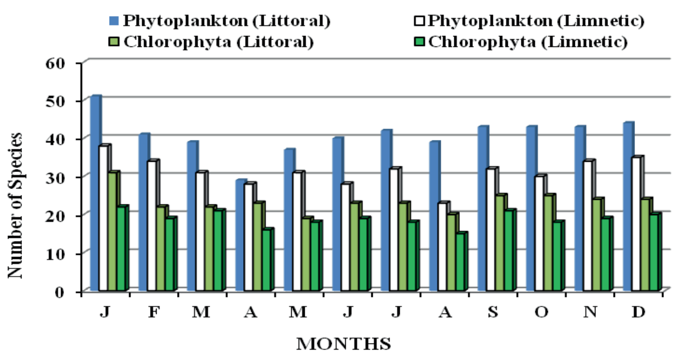

Figure 2. Monthly species richness variations of phytoplankton and Chlorophyta.

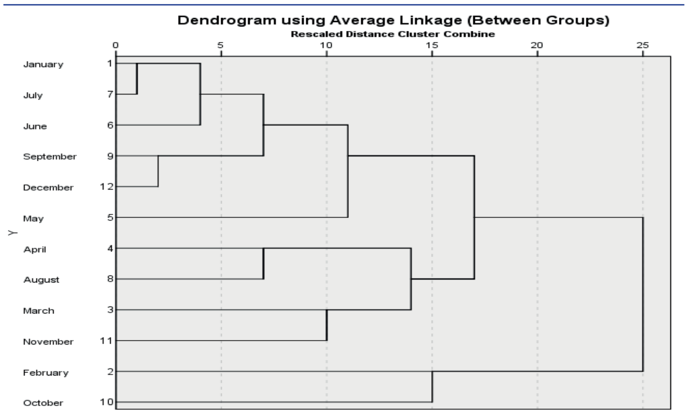

Figure 3. Hierarchical cluster analysis of Phytoplankton assemblages (Littoral region).

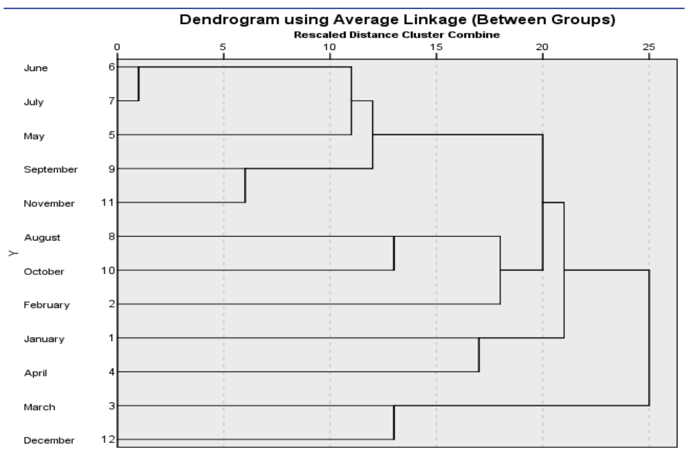

Figure 4. Hierarchical cluster analysis of Phytoplankton assemblages (Limnetic region).

Abundance

The Nongmahir reservoir indicates the highest phytoplankton abundance in comparison with other subtropical lacustrine environs of NEI (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Pachuau, 2016), while the density is notably higher than our earlier survey (Sharma and Lyngskor, 2003). Phytoplankton com-

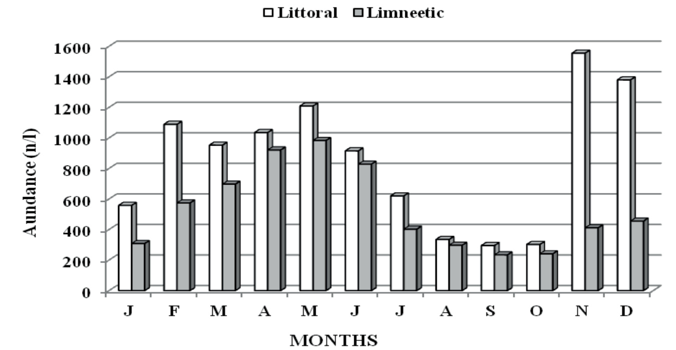

Figure 5. Monthly variations in Phytoplankton abundance.

prises the dominant component (76.7±9.9, 57.7±5.3%) and contributes significantly to net plankton (r_1 = 0.995, $p < 0.0001$; r_2 = 0.963, $p < 0.0001$) in both the regions, respectively. Wider phytoplankton density variations in the littoral > limnetic regions (Table 5) are affirmed by significant variations between stations and months registered vide ANOVA (Table 6); high abundance in the former region is hypothesized to its habitat heterogeneity. The quantitative dominance of phytoplankton of the sampled reservoir concurs with the results from Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003) and Mizoram (Sharma and Pachuau, 2016), Himachal Pradesh (Jindal and Prajapat, 2005; Jindal and Thakur, 2014), Assam (Sharma and Hatimuria, 2017) and Kerala (Krishnan et al., 1999). This study records oscillating monthly phytoplankton density variations (Figure 5) with wider oscillations in the littoral region. Pre-monsoon maxima observed in both regions and autumn peak in the limnetic region (Figure 5) concur with the results of Sharma and Pachuau (2016) and the former corresponds with the report of Sharma (2015). The autumn peak recorded in the limnetic region concurs with the report from Kashmir (Baba and Pandit, 2014) and Uttarakhand (Sharma and Singh, 2018), and the winter maxima in the two regions agree with the reports of Wanganeo and Wanganeo (1991), Sharma (1995, 2004, 2009, 2010), Sharma and Lyngdoh (2003), Sharma and Hatimuria (2017) and Goswami et al. (2018). Bacillariophyta influence autumn phytoplankton peak, Chrysophyta>Chlorophyta contribute to the winter maxima and Chlorophyta > Bacillariophyta result in pre-monsoon maxima in the littoral region. Chlorophyta mainly contribute to pre-monsoon phytoplankton peak and Bacillariophyta > Chlorophyta contribute to winter maxima in the limnetic region. Our results thus highlight differential spatio-temporal quantitative influence of important phytoplankton groups of the Nongmahir reservoir.

Our study highlights the quantitative importance of *Navicula radiosa* > *Diatoma vulgaris* > *Dinobryon sociale* > *Staurastrum artiscon*> *S. paradoxum* > *Cosmarium contractum* > *Tabellaria flocculosa* > *Ceratium hirudinella* ≥ *Sirogonium sticticum* > *Staurastrum sonthalianum* > *S. formosum* > *S. rotula* > *Spirulina agilis* > *Microcystis aeruginosa* > *Staurastrum sexangulare* > *Cosmarium granatum* > *Staurodesmus dejectus* in the littoral region (Table 5). Besides, *Dinobryon sociale* > *Staurastrum artiscon* > *S. paradoxum* > *S. sonthalianum* > *Ceratium hirudinella* ≥ *Navicula radiosa* > *Staurastrum formosum* > *S. rotula* >

Table 6. ANOVA indicating significance of Phytoplankton assemblages.

Parameters	Regions	Months
	Richness	
Phytoplankton	$F_{1,23}$=71.768, P=3.77E-06	$F_{11,23}$=5.545, P=0.0042
Chlorophyta	$F_{1,23}$=146.520, P=3.17E-06	$F_{11,23}$=3.479, P=0.0191
	Abundance	
Phytoplankton	$F_{1,23}$=9.777, P=0.009	$F_{11,23}$=2.956, P=0.042
Chlorophyta	-	$F_{11,23}$=42.833, P=2.06E-07
Bacillariophyta	$F_{1,23}$=7.538, P=0.019	-
Chrysophyta	-	$F_{11,23}$=3.089, P=0.037
Dinophyta	-	-
Cyanophyta	$F_{1,23}$=7.919, P=0.017	$F_{11,23}$=10.783, P=0.0002
	Diversity indices	
Species diversity	-	-
Dominance	-	$F_{11,23}$=5.171, P=0.005
Evenness	-	$F_{11,23}$=3.646, P=0.021
	Abundance of important taxa	
Staurastrum spp.	-	$F_{11,23}$=44.087, P=1.36-06
Cosmarium spp.	$F_{1,23}$=12.819, P=0.004	$F_{11,23}$=29.909, P=2.43E-06
	Abundance of important species	
Navicula radiosa	$F_{1,23}$=8.366, P=0.014	-
Diatoma vulgaris	-	-
Dinobryon sociale	-	$F_{11,23}$=3.089, P=0.037
Staurastrum artiscon	-	$F_{11,23}$=16.984, P=3.33E-06
Staurastrum paradoxum	-	$F_{11,23}$=8.341, P=0.0007
Cosmarium contractum	$F_{1,23}$=6.748, P=0.024	$F_{11,23}$=25.141, P=3.33E-06
Tabellaria flocculosa	-	-
Ceratium hirudinella	-	-
Sirogomium sticticum	-	$F_{11,23}$=13.077, P=8.79E-05
Staurastrum sonthalianum	-	$F_{11,23}$=5.886, P=0.003
Staurastrum formosum	-	$F_{11,23}$=14.208, P=5.87E-05
Staurastrum rotula	$F_{1,23}$=6.627, P=0.026	$F_{11,23}$=9.019, P=0.0004
Staurastrum sexangulare	-	$F_{11,23}$=6.531, P=0.002
Spirulina agilis	-	$F_{11,23}$=6.158, P=0.003
Staurodesmus dejectus	-	$F_{11,23}$=4.708, P=0.008
Cosmarium granatum	-	$F_{11,23}$=10.364, P=0.0002
Microcystis aeruginosa	$F_{1,23}$=12.736, P=0.004	-

(-) indicates insignificant variations

Cosmarium contractum > *Sirogonium sticticum* > *Staurastrum sexangulare* > *Spirulina agilis* > *Staurodesmus dejectus* > *Diatoma vulgaris* register importance in the limnetic region (Table 5) while *Cosmarium granatum* > *Microcystis aeruginosa* also deserve attention. We categorize these 17 species as 'specialists' which collectively contribute notably (776±411, 490±277 n/l; 87.9±6.9%, 91.6±3.3%) to phytoplankton abundance in the two regions, respectively. The Nongmahir reservoir records a notably rich assemblage of 'specialist' species as compared with the reports from the Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016) and the floodplains of Assam (Sharma, 2015; Sharma and Hatimuria 2017). Of the stated species, *Cosmarium contractum, Staurastrum rotula, Navicula radiosa* and *Microcystis aeruginosa* register significant density variations (vide ANOVA) between the two regions (Table 6), while *Cosmarium contractum, C. granatum, Dinobryon sociale, Sirogonium sticticum, Spirulina agilis, Staurastrum artiscon, S. formosum, S. paradoxum, S. rotula, S. sexangulare, S. sonthalianum* and *Staurodesmus dejectus* affirm significant monthly density variations (Table 6). *Navicula radiosa* (r_1 = 0.776, p = 0.008) individually influences phytoplankton abundance in the littoral region, and *Cosmarium contractum* (r_2= 0.866, p = 0.0012), *Staurastrum artiscon* (r_2 = 0.757, p = 0.011), *S. formosum* (r_2 = 0.772, p= 0.009), *S. paradoxum* (r_2 = 0.678, p = 0.031), *S. sexangulare* (r_2 = 0.878, p = 0.0008), *S. sonthalianum* (r_2 = 0.920, p = 0.0002), *Staurodesmus dejectus* (r_2 = 0.845, p = 0.0021) influence abundance in the limnetic region.

The Nongmahir reservoir depicts quantitative dominance of Chlorophyta (52.1±19.9.0%) and its significant contribution to phytoplankton abundance in the limnetic region (r_2=0.919, p = 0.0002), while this group indicates importance (39.8±17.7%) at the littoral region (Table 5). The significant density variations (Table 6) noted between regions (vide ANOVA) endorse differential spatial importance of Chlorophyta. This study depicts a higher abundance of the green-algae than the reports from the reservoirs of Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003) and Mizoram (Sharma and Pachuau, 2016) and the floodplain lakes (Sharma, 2004, 2009, 2010, 2012, 2015; Sharma and Hatimuria, 2017) of NEI; abundance is notably higher than in the earlier survey (Sharma and Lyngskor, 2003). Chlorophyta follows nearly identical patterns of monthly density variations in both the regions (Figure 6) with peak abundance in May; the latter concurs with the reports of the floodplains lakes of Assam (Sharma, 2012, 2015; Sharma and Hatimuria, 2017) and Nigeen Lake of Kashmir (Shafi et al., 2013).

Cosmarium contractum (r_1= 0.941, p < 0.0001), *C. granatum* (r_1= 0.883, p =0.001), *Staurastrum artiscon* (r_1= 0.884, p = 0.001), *S. formosum* (r_1= 0.800, p = 0.006), *S. paradoxum* (r_1= 0.749, p= 0.013), *S. sonthalianum* (r_1= 0.735, p= 0.015) and *S. rotula* (r_1= 0.782, p = 0.008) influence Chlorophyta abundance in the littoral region and *Cosmarium contractum* (r_2=0.954, p < 0.0001), *Staurastrum artiscon* (r_2= 0.857, p = 0.0002), *S. formosum* (r_2= 0.703, p<0.023), *S. paradoxum* (r_2=0.855, p=0.0016), *S. sonthalianum* (r_2= 0.926, p=0.0001), *S. sexangulare* (r_2= 0.804, p = 0.0051), and *Staurodesmus dejectus* (r_2= 0.914, p = 0.0002) influence abundance in the limnetic region. The stated species collectively (278±204 and 290±225 n/l; 83.1±9.9 and 90.0±5.6%) contribute to Chlorophyta abundance (r_1= 0.998, p < 0.0001; r_2= 0.999, p < 0.0001) in the two regions, respectively. Further, *Staurastrum artiscon* (167 n/l) > *Cosmarium contractum* (148 n/l) > *S. paradoxum* (101 n/l) > *S. rotula* (72 n/l) > *S. sonthalianum* (50 n/l) > *C. granatum* (42 n/l) > *S. formosum* (40 n/l) contribute to pre-monsoon Chlorophyta maxima in the littoral region; *Staurastrum artiscon* (196 n/l) > *Cosmarium contractum* (120 n/l) > *S. sonthalianum* (111 n/l) > *S. paradoxum* (92 n/l) > *S. rotula* (89 n/l) influence pre-monsoon maxima in the limnetic region. In general, the quantitative importance of desmids concurs with the reports of Sharma (2009, 2010) and Sharma and Lyngdoh (2003), Hulyal and Kaliwal (2009) and Thakur et al. (2013).

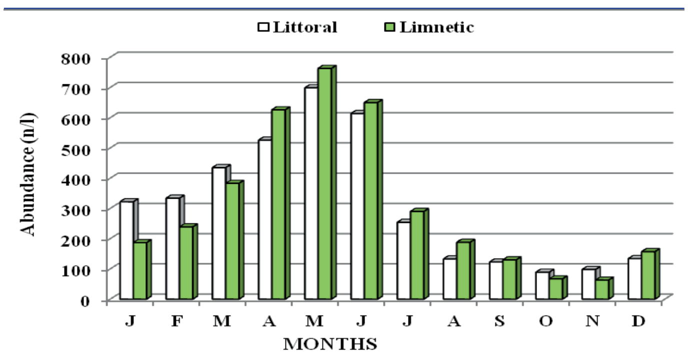

Figure 6. Monthly variations in Chlorophyta abundance.

Staurastrum spp. (191±149 and 217±77 n/l) > *Cosmarium* spp. (63±55 and 44 ± 46 n/l) together comprise notable fractions of phytoplankton (31.1±17.1 and 47.3±20.8%) and Chlorophyta (76.8±17.4 and 78.9±17.2%) abundance in the littoral and limnetic regions, respectively. ANOVA (Table 6) registers a significant monthly density variation of the two desmids, while *Cosmarium* spp. registers a significant density variation between the two regions of the Nongmahir reservoir. Further, *Staurastrum* spp. (r_1= 0.955, p < 0.0001) and *Cosmarium* spp. (r_1= 0.945, p < 0.0001) influence Chlorophyta abundance as well as pre-monsoon peak and winter maxima in the littoral region (Figures 7-8). Besides, *Staurastrum* spp. (r_2=0.889, p=0.0006; r_2=0.983, p< 0.0001) and *Cosmarium* spp. (r_2= 0.873, p= 0.0002; r_2= 0.961, p < 0.0001) influence abundance and influence pre-monsoon peaks and winter maxima of phytoplankton and Chlorophyta in the limnetic region, respectively (Figures 7-8). The importance of *Staurastrum* spp. > *Cosmarium* spp. observed vide the present study differs from the reports of *Staurastrum* spp. > *Xanthidium* spp. > *Cosmarium* spp. from the Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016); *Closterium* spp.> *Staurastrum* spp. > *Gonatozygon* spp. > *Micrasterias* spp. > *Cosmarium* spp. from Loktak Lake of Assam (Sharma, 2009); and *Closterium* spp.> *Gonatozygon* spp. > *Micrasterias* spp. > *Staurastrum* spp. from Utra Pat and *Closterium spp.* > *Cosmarium spp.* > *Staurastrum spp.* > *Xanthidium* spp. from Waithou Pat of Manipur (Sharma, 2010).

Phytoplankton depicts higher Bacillariophyta (Table 5) abundance in the littoral region (Figure 9), comprise an important quantitative component (35.6±23.2%) of phytoplankton (r_1=0.766, p=0.010), and record bloom during November-December (peak

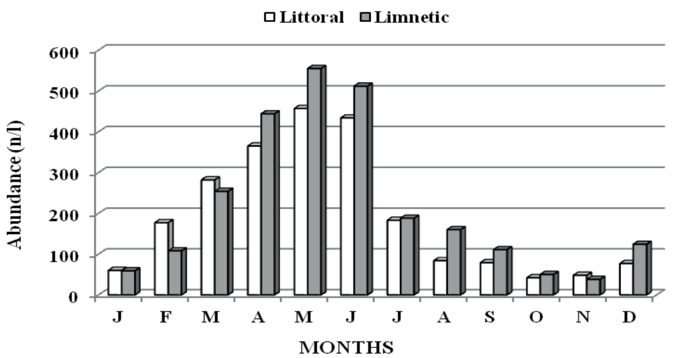

Figure 7. Monthly variations in *Staurastrum* spp. abundance.

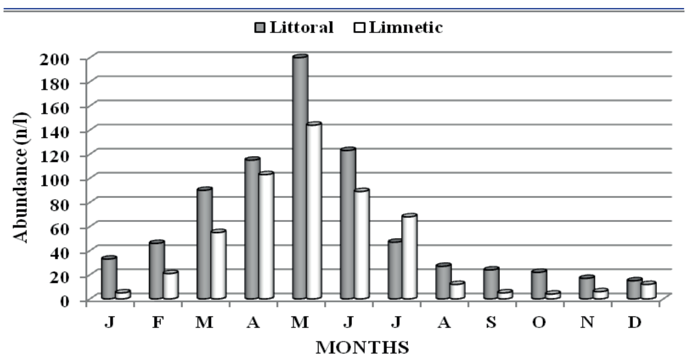

Figure 8. Monthly variations in *Cosmarium* spp. abundance.

during autumn) and maxima during pre-monsoon (May). In contrast, this group indicates sub-dominance (19.0±19.9%) in the limnetic region (Figure 9) with peak in autumn (November). The differential spatial importance of Bacillariophyta is affirmed by significant density variations (vide ANOVA) between the two regions (Table 6). The diatom dominance and sub-dominance at the two regions, respectively concurs with the results from Samuajan beel (Sharma, 2004) and the dominance in the former region corresponds with the reports from Deepor beel (Sharma, 2015) and Bhereki Beel (Sharma and Hatimuria, 2017) of Assam, and lakes of Himachal Pradesh (Jindal and Prajapat, 2005; Jindal et al., 2014b), Kashmir (Baba and Pandit, 2014; Nissa and Bhat, 2016) and Uttarakhand (Goswami et al., 2018). Bacillariophyta sub-dominance corresponds with the reports from Loktak Lake of Manipur (Sharma, 2009) and Holmari and Ghotonga beels (Sharma and Hatimuria, 2017) of Assam, and lakes of Kashmir (Shafi et al, 2013) and Uttarakhand (Sharma and Singh, 2018). Autumn Bacillariophyta peak in the littoral region concurs with the report from Nigeen Lake of Kashmir (Nissa and Bhat, 2016) and winter bloom in this region corresponds with the reports from Kashmir (Wanganeo and Wanganeo, 1991; Baba and Pandit, 2014), Meghalaya (Sharma and Lyngdoh, 2003) and Manipur (Sharma, 2009).

Navicula radiosa, *Diatoma vulgaris* and *Tabellaria flocculosa* collectively comprise a significant fraction of Bacillariophyta of the Nongmahir reservoir in the littoral (342±416 n/l; 89.2±7.0%) and limnetic (69±83 n/l; 87.6±13.9 %) regions, and contribute to phytoplankton (r_1= 0.765, p =0.009) and Bacillariophyta (r_1= 0.999, p < 0.0001), and Bacillariophyta (r_2= 0.998, p < 0.0001) abundance in the two regions, respectively. In addition, *N. radiosa* (800 n/l) > *D. vulgaris* (530 n/l) influence autumn phytoplankton and Bacillariophyta peaks in the littoral region, while *N. radiosa* (229 n/l) > *T. flocculosa* (60 n/l) influence autumn peak in the limnetic region. These remarks are further affirmed by significant influence of *N. radiosa* (r_1= 0.999, p < 0.0001) and *D. vulgaris* (r_1= 0.976, p < 0.0001), and *N. radiosa* (r_2 = 0.984, p < 0.0001) and *T. flocculosa* (r_2 = 0.895, p < 0.0005) on Bacillariophyta abundance in the two regions, respectively.

Chrysophyta (represented by *Dinobryon sociale*) forms a subdominant phytoplankton component in the two regions with relatively wider quantitative variations (Table 5) in the littoral region; ANOVA

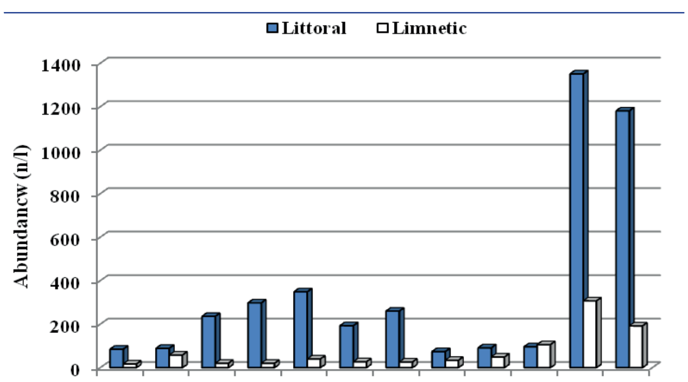

Figure 9. Monthly variations in Bacillariophyta abundance.

registers its significant density variations between months (Table 6). Chrysophyta depicts importance at both the regions from February-May; it records bloom (peak) during winter (February) in the littoral region and during April in the limnetic region (Figure 10). Our results are in contrast to poor Chrysophyta abundance reported from various floodplain lakes and reservoirs of NEI (Sharma, 1995, 2009, 2010, 2012, 2015; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003). Dinophyta, another sub-dominant group, records relatively lower abundance (Table 5) in the limnetic region > the littoral region and depicts insignificant density variations (vide ANOVA) between the two regions. This group indicates oscillating patterns of monthly density variations with peak during winter (February) and maxima during monsoon (August) in the littoral region (Figure 11), and peak during monsoon (June) in the limnetic region (Figure 12). Dinophyta abundance is influenced by *Ceratium hirudinella* at the two regions (r_1= 0.978, p < 0.0001; (r_2= 0.989, p < 0.0001). The winter peaks of Dinophyta and *C. hirudinella* agree with the report Loktak Lake of Manipur (Sharma, 2009) but differ from the summer maxima recorded from Garhwal (Sharma and Singh, 2018). Our results differ from poor Dinophyta abundance reported vides Sharma and Lyngdoh (2003), Sharma and Lyngskor (2003) and Sharma (2010).

Cyanophyta, yet another sub-dominant group (Table 5) of phytoplankton, is largely influenced by *Spirulina agilis* (r_1 = 0.978, p <0.0001; r_2 = 0.995, p < 0.0001) > *Microcystis aeruginosa* (r_1 =

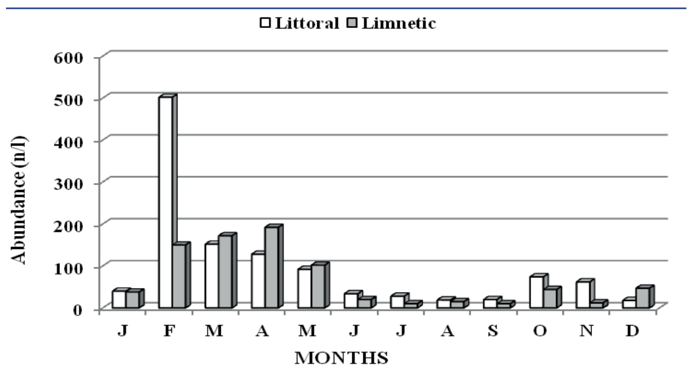

Figure 10. Monthly variations in Chrysophyta abundance.

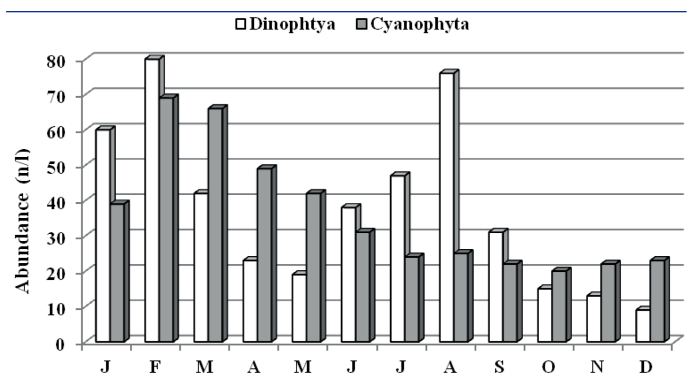

Figure 11. Monthly variations in Dinophyta and Cyanophyta abundance (Littoral region).

0.910, p = 0.0003) in the littoral and limnetic stations, respectively. ANOVA indicates significant density variations of this group between months (Table 6). The blue green algae depict oscillating monthly density variations with peak during winter (February) in the two regions (Figures 11-12). The sub-dominance of Cyanophyta concurs with the reports from Himachal Pradesh (Jindal and Prajapat, 2005), Assam (Sharma, 2015), Mizoram (Sharma and Pachuau, 2016) and Kashmir (Baba and Pandit, 2014). Euglenophyta and Cryptophyta record poor abundance in the Nongmahir reservoir corresponding with the reports of Sharma and Lyngdoh (2003), Sharma (2009) and Sharma and Pachuau (2016).

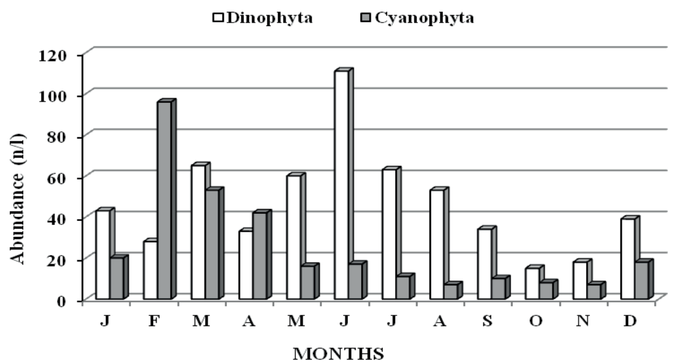

Figure 12. Monthly variations in Dinophyta and Cyanophyta abundance (Limnetic region).

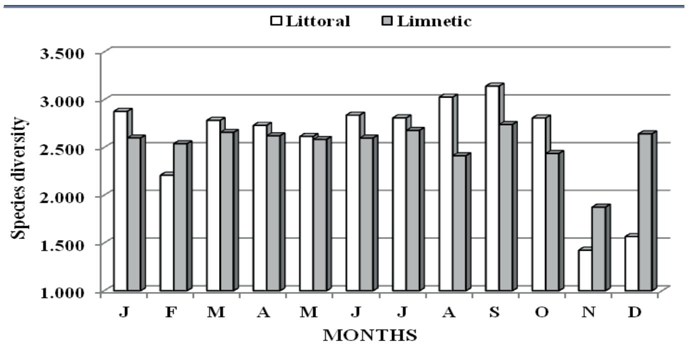

Figure 13. Monthly variations in phytoplankton species diversity.

Diversity indices

Our study highlights the moderate species diversity (Table 4) of Phytoplankton of the Nongmahir reservoir. It depicts differential spatial monthly variations with higher values in the littoral > limnetic regions during January and March-October, and the limnetic > littoral pattern during February and November-December (Figure 13). The diversity compares with the report from Khawiva reservoir from Mizoram (Sharma and Pachuau, 2016) vis-à-vis moderate diversity, overall variations and few instances of higher values, while this study records higher diversity than the reports from Meghalaya (Sharma, 1995, Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003). Further, the species diversity is inversely influenced by abundance of phytoplankton (r_1= -0.808, p = 0.005), Chlorophyta (r_1= -0.834, p= 0.003) and Chrysophyta (r_1= -0.909, p= 0.0003), *Navicula radiosa* (r_1= -0.911, p= 0.0002) and *Diatoma vulgaris* (r_1= -0.891, p = 0.0005) in the littoral region, and by Bacillariophyta (r_2= -0.772, p= 0.008) and *N. radiosa* (r_2= -0.832, p= 0.003) in the limnetic region. It is inversely influenced by dominance (r_1= -0.879, p = 0.0008; r_2= -0.847, p = 0.002) as also affirmed by concurrence of the lowest diversity during autumn with peak dominance in both regions. The diversity is positively influenced by phytoplankton evenness (r_1= 0.984, p < 0.0001; r_2= 0.916, p = 0.0002) in the two regions, respectively. We consider the Shannon Weiner diversity index for assessing the health of aquatic biotopes (Wilhm and Dorris 1968; Masson 1998). In general, phytoplankton diversity variations noted vide the present study depict the 'meso-trophic' status of the Nongmahir reservoir, while H$^{/}$ value > 3.0 during monsoon (August and September) in the littoral region reflects the shift to a 'meso-eutrophic' nature. The stated remarks concur with trophic status assessment of this reservoir based on our zooplankton species diversity results (Sharma and Sharma, 2020).

Our observations depict monthly differences of phytoplankton dominance in the two regions (Table 4); this generalization is also affirmed by significant monthly dominance variations noted vide ANOVA (Table 6). Peak dominance and maxima are noted during autumn (November) and winter (February), and winter (December) and winter (January) in the littoral and limnetic regions, respectively. The 'specialist species' influence higher dominance while low values during certain months concur with equitable abundance of the 'generalist species' as suggested by McNaughton (1967). These remarks are affirmed by the positive influence of Bacillariophyta (r_1= 0.686, p = 0.029; r_2= 0.754, p = 0.012), *Navicula radiosa* (r_1= 0.684, p = 0.0292; r_2= 0.812, p = 0.003) on dominance in the two regions and that of *Diatoma vulgaris* (r_1= 0.731, p = 0.0163) in the limnetic region in particular. The extant of dominance variations broadly correspond with the reports of Sharma and Pachuau (2016) and Sharma and Hatimuria (2017).

Phytoplankton depicts differential variations of evenness (Table 5) in the littoral and the limnetic regions; ANOVA registers significant evenness variations between months. High evenness during several months is attributed to equitable abundance of the majority of taxa (Washington, 1984) while dominance of certain species results in moderate evenness. This generalization is affirmed by an inverse correlation of evenness vs. dominance (r_1 = -0.910, p= 0.0003; r_2 = - 0.925, p = 0.0001) in the two regions as well as by inverse influence of abundance of *Navicula radiosa* (r_1 = -0.886, p = 0.0006) and *Diatoma vulgaris* (r_1= -0.896, p= 0.0005) in the littoral region, and of *Navicula radiosa* (r_2 = -0.882, p = 0.0007) at the limnetic region. Further, evenness is inversely influenced by abundance of phytoplankton (r_1= -0.728, p = 0.017), Chlorophyta (r_1= -0.763, p = 0.010) and Chrysophyta (r_1= -0.887, p = 0.0006) in the littoral region and by Bacillariophyta abundance (r_2= -0.842, p = 0.002) in the limnetic regions.

Influence of abiotic factors

Inverse influence of water temperature on phytoplankton richness (r_2=-0.728, p=0.017) in the limnetic region of the Nongmahir reservoir is attributed to lower richness during warmer months (April - June and August), while more richness variations in the littoral region result in insignificant inverse correlation with temperature. High phytoplankton abundance concurrent with the periods of high ionic concentration results in positive influence by specific conductivity (r_1= 0.836, p = 0.0026; r_2= 0.803, p = 0.0052) at the two regions, while high abundance during February-March, November-December coincides with the relatively higher transparency (r_1= 0.718, p= 0.019) in the littoral region. The importance of specific conductivity concurs with the report of Sharma and Lyngdoh (2003) and Sharma and Bhattarai (2005).

The positive influence of dissolved oxygen on Chlorophyta (r_1= 0.731, p = 0.016) and *Staurastrum artiscon* (r_1= 0.751, p = 0.035) in the littoral region is attributed to concurrence of a higher abundance of these taxa with the relatively high dissolved oxygen during February-April and June. The positive influence of chloride on Chlorophyta (r_2= 0.719, p = 0.0191), *Cosmarium contractum* (r_2= 0.715, p = 0.020) and *Staurodesmus dejectus* (r_2= 0.750, p = 0.012) in the limnetic region results from a concurrence of high abundance of three taxa and a marked influx of chloride with rainwater during early monsoon. Further, the higher abundance of *Staurastrum formosum* during the early-monsoon months in the littoral region affirms positive influence by rainfall (r_1= 0.815, p = 0.004) and higher densities of this desmid in the limnetic region coincides with periods of the relatively high specific conductivity (r_2= 0.758, p = 0.011). *Cosmarium granatum* is inversely influenced by nitrate (r_1= -0.706, p = 0.026) in the littoral region, and *Staurastrum sexangulare* is positively influenced by nitrate (r_2= 0.770, p = 0.009) in the limnetic region. Peak abundance of *Sirogomium sticticum* during winter results in inverse influence by water temperature (r_1= -0.744, p = 0.014; r_2= -0.764, p = 0.0101) in the littoral and limnetic regions; this species is positively influenced by total alkalinity (r_2= 0.700, p = 0.024), total hardness (r_2= 0.776, p = 0.008) and dissolved organic matter (r_2= 0.875, p = 0.006) in the limnetic region. The positive influence of water temperature (r_2= 0.711, p = 0.002), rainfall (r_2= 0.830, p = 0.003) and chloride (r_2= 0.880, p = 0.0008) on *Staurastrum paradoxum* in the limnetic region is attributed to higher abundance during warmer early and mid-monsoon periods which also coincides with the influx of chloride. Our results thus highlight the differential spatial influence of abiotic factors on Chlorophyta and its notable species in the two regions.

The notable feature of lack of significant influence of abiotic factor on Bacillariophyta abundance concurs with the reports of Sharma (2009) and Sharma and Pachuau (2016). Chrysophyta is positively influenced by dissolved oxygen (r_1= 0.678, p = 0.031), total alkalinity (r_1= 0.783, p = 0.007) and total hardness (r_1= 0.725, p = 0.028) in the littoral region and by total alkalinity (r_2= 0.770, p = 0.009) and total hardness (r_2= 0.789, p = 0.006) in the limnetic region. Cyanophyta is positively influenced by dissolved oxygen (r_1= 0.803, p = 0.005), total alkalinity (r_1= 0.773, p = 0.009) and total hardness (r_1= 0.905, p = 0.0003) in the littoral region. These remarks are endorsed by important species of blue-green algae i.e. *Spirulina agilis* with positive correlations with dissolved oxygen (r_1= 0.842, p = 0.002), total alkalinity (r_1= 0.817, p = 0.004), total hardness (r_1= 0.921, p = 0.0002), while *Microcystis aeruginosa* indicates the positive influence of dissolved oxygen (r_1= 0.735, p = 0.015), total hardness (r_1= 0.733, p = 0.016) in the littoral region. Cyanophyta is positively influenced by total alkalinity (r_2= 0.829, p = 0.003), total hardness (r_2= 0.913, p = 0.0002) and sulphate (r_2= 0.847, p = 0.002), while *S. agilis* is positively influenced by total alkalinity (r_2= 0.796, p = 0.006) and total hardness (r_2= 0.895, p = 0.0005) in the limnetic region. Our results thus indicate overall conducive influence of total alkalinity and total hardness in promoting higher abundance Chrysophyta and Cyanophyta. Dinophyta is positively influenced by rainfall (r_2= 0.695, p=0.025) and chloride (r_2= 0.786, p=0.0067), while *Ceratium hirudinella* is positively influenced by chloride (r_2= 0.734, p = 0.016) in the limnetic region. These relationships are affirmed by a high abundance of these taxa during monsoon which also marks the influx of chloride. In general, the present study registers the differential importance of water temperature, rainfall, transparency, specific conductivity, dissolved oxygen, total alkalinity and total hardness on phytoplankton assemblages. Referring to notable individual phytoplankton species, our results indicate a distinct departure from the reports of Sharma (1995, 2009. 2010, 2012, 2015), Sharma and Lyngdoh (2003), Sharma and Lyngskor (2003) and Sharma and Pachuau (2016) and Sharma and Hatimuria (2017) yielding little insight on the influence of abiotic factors vis-a-vis important species.

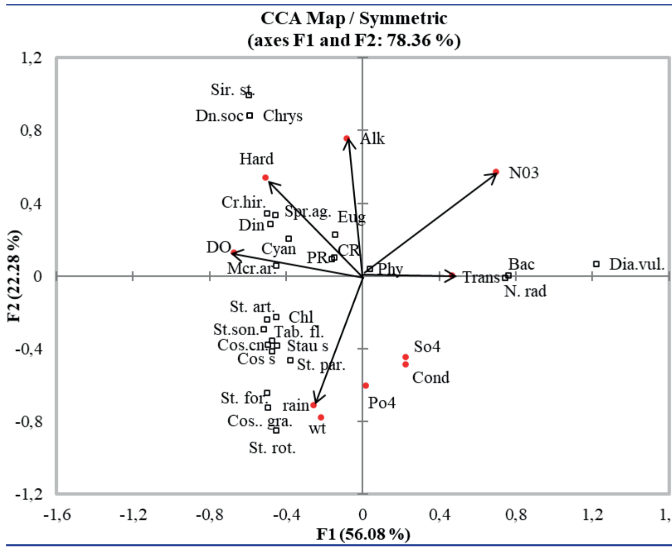

Figure 14. CCA coordination biplot of phytoplankton and abiotic factors (Littoral region).

Abbreviations: Abiotic factors: Alk (alkalinity), Cond (conductivity), DO (dissolved oxygen), hard (hardness), rain (rainfall), Trans (transparaency), No3 (nitrate), Po4 (phosphate), So4 (sulphate), wt (water temperature. **Biotic factors:** Bac (Bacillariophyta), Chl (Chlorophyta), Chry (Chrysophyta), Cos. cn. (*Cosmarium contractum*), Cos.gra. (*Cosmarium granatum*), Cos s (*Cosmarium* spp.), CR (Chlorophyta richness), Cr. hir. (*Ceratium hirudinella*), Crypt (Cryptophyta), Cyan (Cyanophyta), Dia. vul. (*Diatoma vulgaris*), Din (Dinophyta), Dn. soc. (*Dinobryon sociale*), Eug (Euglenophyta), Mcr. ar (*Microcystis aeruginosa*), N rad. (*Navicula radiosa*),PR (phytoplankton richness), Phy (Phytoplankton), Sir. st. (*Sirogonium sticticum.)*, Spr. ag. (*Spirulina agilis*), Staur s (*Staurastrum* spp.), St. art. (*Staurastrum artiscon),* St. for. (*Staurastrum formo-*

sum), St. par. (*Staurastrum paradoxum*). St. rot. (*Staurastrum rotula*), St. son. (*Staurastrum sonthalianum),* St. sex. (*Staurastrum sexangulare*), Tab. fl. (*Tabellaria flocculosa*)

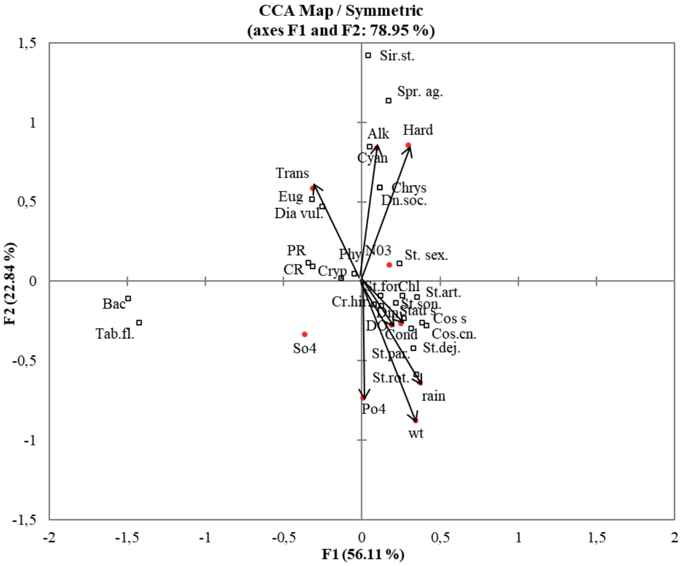

Figure 15. CCA coordination biplot of phytoplankton and abiotic factors (Limnetic region).

Abbreviations: Abiotic factors: Alk (alkalinity), Cond (conductivity), DO (dissolved oxygen), hard (hardness), rain (rainfall), Trans (transparaency), No3 (nitrate), Po4 (phosphate), So4 (sulphate), wt (water temperature. **Biotic factors:** Bac (Bacillariophyta), Chl (Chlorophyta), Chry (Chrysophyta), Cos. cn. (*Cosmarium* contractum); Cos s (*Cosmarium* spp.), CR (Chlorophyta richness), Cr.hir. (*Ceratium hirudinella*), Crypt (Cryptophyta), Cyan (Cyanophyta), Dia. vul. (*Diatoma vulgaris*), Din (Dinophyta), Dn. soc. (*Dinobryon sociale*), Eug (Euglenophyta), PR (phytoplankton richness), Phy (Phytoplankton), Sir. st. (*Sirogomium sticticum),* Spr. ag. (*Spirulina agilis*), Staur s (*Staurastrum* spp.*),* St. art. (*Staurastrum artiscon),* St. for. (*Staurastrum formosum),* St. par. (*Staurastrum paradoxum*). St. rot. (*Staurastrum rotula*), St. son. (*Staurastrum sonthalianum),* St. sex. (*Staurastrum sexangulare*), St. dej. (*Staurodesmus dejectus*), Tab. fl. (*Tabellaria flocculosa*)

The Canonical correspondence analysis (CCA) registers the high cumulative influence (78.36 and 78.95%) of 10 abiotic factors, along first two axes, on phytoplankton assemblages in the littoral and limnetic stations, respectively. The CCA co-ordination biplot indicates the influence of transparency and nitrate on phytoplankton abundance; hardness on phytoplankton and Chlorophyta richness, and on abundance of Cyanophyta, Dinophyta, *Dinobryon sociale* and *Spirulina agilis*; dissolved oxygen on *Microcystis aeruginosa*; alkalinity and hardness on Euglenophyta in the littoral region. The CCA biplot depicts the influence of alkalinity and hardness on Chrysophyta and *Dinobryon sociale*; transparency on richness of phytoplankton and Chlorophyta, and phytoplankton and Euglenophyta abundance; specific conductivity on Chlorophyta, *Staurastrum* spp., *S. artiscon*, *S. formosum*, *S. sonthalianum*; specific conductivity, dissolved oxygen and rainfall influenced Dinophyta, *Ceratium hirudinella*; rainfall influenced *Staurastrum paradoxum* and *Staurodesmus dejectus*; rainfall and water temperature influenced *Staurastrum rotula* in the limnetic region. Phytoplankton assemblages of the Nongmahir reservoir depict higher cumulative influence of abiotic factors than the reports from the Khawiva reservoir (Sharma and Pachuau, 2016) of Mizoram; Bhereki and Holmari beels (Sharma and Hatimuria, 2017), and in the littoral station of Deepor beel (Sharma, 2015) of Assam, while it broadly compares with the report from Ghotonga (Sharma and Hatimuria, 2017) beel of Assam. The comparisons with the reports of Sharma (1995, 2004), Sharma and Lyngskor (2003) and Sharma and Lyngdoh (2003), however, deserve caution because of lack of CCA analyses.

CONCLUSIONS

The soft, slightly acidic-circum neutral, calcium poor and de-mineralized waters of the Nongmahir reservoir in particular depict fairly biodiverse phytoplankton, speciose Chlorophyta with diverse desmids, and interesting constellation of 51 species per sample. Our study highlights the quantitative dominance of phytoplankton vis-a-vis net plankton. The differential spatial dominance of Bacillariophyta and Chlorophyta, importance of 17 'specialist' species and *Staurastrum* spp. > *Cosmarium* spp. in the littoral and the limnetic regions, resources utilization both by 'specialist' and 'generalist' species, high cumulative influence of 10 abiotic factors on phytoplankton assemblages and meso-trophic status of the Nongmahir reservoir are noteworthy features. The differential spatial variations of species richness, abundance, diversity indices and influence of individual abiotic factors are hypothesised to habitat heterogeneity amongst the littoral and limnetic regions of the sampled reservoir. Overall, this study is an important contribution to phytoplankton diversity of the reservoirs of India in general and the subtropical reservoirs in particular.

Ethics committee approval: Ethics committee approval is not required for this study.

Conflict of Interest: The authors have no conflicts of interest to declare.

Acknowledgements: The senior author (BKS) thanks the Head, Department of Zoology, North-Eastern Hill University, Shillong for laboratory facilities and various research students for the field work help on several occasions. We thank our reviewers: Prof. Dr. Yelda Aktan Turan and Dr. E. Kasaka for useful comments and suggestions. We thank Prof Dr. Özkan Özden, Editor-in-Chief, ASE for support and encouragement during the review process, and to Alan Newson for the proofreading of our manuscript.

Disclosure: -

REFERENCES

Anand, N. (1998). *Indian Freshwater Microalgae*. Bishen Singh Mahendra Pal Singh, Dehradun, 94 p.

APHA (1992). *Standard methods for the examination of water and wastewater* (18th Ed.). American Public Health Association, Washington D.C. 1198 p.

Baba, A.I. & Pandit, A.K. (2014). Composition, diversity and population dynamics of phytoplankton at Saderkot in Wular Lake, Kashmir. *Journal of Ecosystem & Ecography,* 4(1), 142. [CrossRef]

Bharati, H., Deshmukhe, G., Das, S.K., Kandpal, B.K., Sahoo, L., Bhusan, S. & Singh, Y.J. (2020). Phytoplankton communities in Rudrasagar Lake, Tripura (North-East India) – A Ramsar Site. *International Journal of Bio-resource and Stress Management*, 11(1), 001-007. [CrossRef]

Biswas, K. (1949). Common fresh and brackish algal flora of India and Burma. *Records Botanical Survey of India,* 15(2), 1–169.

Chandrakiran, Sharma, K.K. & Sharma, R. (2014). Phytoplankton community response to changing physico-chemical environment of a subtropical Lake Mansar, India. *International Journal of Biosciences,* 4(11), 95–103. [CrossRef]

Deb, S., Saikia, J. & Kalamdhad, A.S. (2019). Ecology of Deepor beel wetland, a Ramsar site of Guwahati, Assam with special reference to algal community. *European Journal of Biomedical and Pharmaceutical Sciences*, 6(2), 232–243.

Devi, M.B., Gupta, S. & Das, T. (2016). Phytoplankton community of Lake Baskandi anua, Cachar District, Assam, North East India – An ecological study. *Knowledge and Management of Aquatic Ecosystems,* 417, 2. [CrossRef]

Fritter, R. & Manuel R. (1986). *Field guide to the Freshwater life of Britain and North-West Europe*. William Collins Sons & Co. Ltd, London, 382 p.

Ganai, A.H. & Parveen, S. (2014). Effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir. International *Journal of Biodiversity and Conservation*, 6(1), 71–84. [CrossRef]

Goswami, M., Das, T., Kumar, S. & Mishra, A. **(**2018). Impact of physico-chemical parameters on primary productivity of Lake Nainital. *Journal of Entomology and Zoology Studies*, 6(4), 647-652.

Gupta, S. & Devi S.S. (2014). Ecology of Baskandi anua, an oxbow lake of south Assam, North East India. *Journal of Environmental Biology,* 35, 1101–1105.

Gupta, S., Singh, D., Rawat, M.S. & Ahmed, R (2018). Phytoplankton community in relation to physicochemical characteristics of Renuka Lake and Parshuram Tal (H.P.), India. *International Journal of Scientific Research and Reviews*, 7(3), 769-780.

Hickel, B. (1973). Limnological investigation in lakes of the Pokhra valley. *Internationale Revue der gesamten Hydrobiologie,* 58(5), 659–672. [CrossRef]

Hulyal, S.K. & Kaliwal, B.B. (2009). Dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir of Bijapur district, Karnatak state. *Environmental Monitoring & Assessment,* 153 (1-4), 45–59. [CrossRef]

Islam, A.K.M.N. & Haroon, A.K.Y. (1980). Desmids of Bangladesh. *Internationale Revue gesamten Hydrobiologie,* 65(4), 551–604. [CrossRef]

Jindal, R. & Prajapat, P. (2005). Productivity and trophic status of Renuka wetland (Distt. Sirmour, Himachal Pradesh. *Indian Journal of Ecology,* 32(2), 180–183.

Jindal, R. & Thakur, R.K. (2014). Hydrobiology and productivity of Kuntbhyog Lake, (District Mandi, Himachal Pradesh), India. *International Journal of Environmental Engineering*, 6 (4), 449–459. [CrossRef]

Jindal, R., Thakur, R.K., Singh, U.B. & Ahluwalia, A.S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environmental Monitoring & Assessment*, 185 (10), 8355–8373. [CrossRef]

Jindal, R., Thakur, R.K., Singh, U.B. & Ahluwalia, A.S. (2014a). Phytoplankton dynamics and species diversity in a shallow eutrophic, natural mid-altitude lake in Himachal Pradesh (India): role of physicochemical factors. *Chemistry and Ecology*, 30(4), 328–338. [CrossRef]

Jindal, R., Thakur, R.K., Singh, U.B. & Ahluwalia, A.S. (2014b). Phytoplankton dynamics and water quality of Prashar Lake, Himachal Pradesh, India. *Sustainability of Water Quality and Ecology*, 3–4, 101–113. [CrossRef]

Jeelani, M. & Kaur, H. (2012). Ecological Understanding of Anchar Lake, Kashmir. *Bionano Frontier*, 5(2), 57–61.

John, D.M., Whitton, B.A. & Brook, A.J. (2002). *The Freshwater Algal Flora of the British Isles: An Identification Guide to Freshwater and Terrestrial Algae*. Cambridge University Press: Cambridge, UK.

Krishnan, K.H., Thomas, S., George, S., Murugan, R.P., Mundayoor, S. & Das, M.R. (1999). A study on the distribution and ecology of phytoplankton in the Kuttanad wetland ecosystem, Kerala. *Pollution Research*, 18, 261–269.

Laskar, H.S. & Gupta, S. (2009). Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak valley, Assam, North East India-A seasonal study. *Journal of Environmental Biology,* 30(9), 1007–1012.

Ludwig, J.A. & Reynolds J.F. (1988). *Statistical ecology: a primer on methods and computing*. John Wiley & Sons, New York, 337 p.

MacArthur, R.H. (1965). Patterns of spices diversity. *Biological Reviews*, 40, 510–533. [CrossRef]

Magurran, A.E. (1988). *Ecological diversity and its measurement*. Croom Helm Limited, London, 179 p. [CrossRef]

Masson, C.F. (1998). *Biology Freshwater Pollution* (3rd Edn). Harlow (Essex), Longman.

McNaughton, J. (1967). Relationship among functional properties of California grassland. *Nature*, 216, 168–169. [CrossRef]

Nakanishi, M., Watanabe, M.M., Terashima, A., Soko, Y., Konda, T., Shrestha, K., Bhandary, H.R. & Ishida, Y. (1988). Studies on some limnological variables in subtropical lakes of the Pokhara valley, Nepal. *Japanese Journal of Limnology,* 49, 1–86. [CrossRef]

Negi R.K. & Rajput, V. (2015). Assessment of phytoplankton diversity in relation to abiotic factors of Nainital Lake of Kumaon Himalayas of Uttarakhand State, India. *Asian Journal of Scientific Research*, 8(2), 157–164. [CrossRef]

Nissa, N & Bhat, S.U. (2016). An assessment of phytoplankton in Nigeen Lake of Kashmir Himalaya. *Asian Journal of Biological Sciences*, 9, 27–30. [CrossRef]

Payne, A.R. (1986). *The ecology of Tropical Lakes and Rivers*. John Wiley & Sons, New York.

Prescott, G.W. (1982). *Algae of the Western Great Lakes area*, Otto koeltz Science Publishers, W. Germany, 977 p.

Rawat. M.S. & Sharma, R.C. (2005). Phytoplankton population of Garhwal Himalayan lake Deoria Tal, *Uttranchal Journal of Ecophysiology & Occupational health*, 5, 73–76.

Shafi, N., Ahmad, A. & Pandit, A.K. (2013). Phytoplankton Dynamics of Nigeen Lake in Kashmir Himalaya. *International Journal of Environment and Bioenergy*, 6(1): 13–27.

Sharma B.K.. (1995). Limnological studies in a small reservoir in Meghalaya (N.E. India). In K.H. Timotius & F. Goltenboth (Eds.). *Tropical Limnology,* II, 1–11. Satya Wacana University Press, Salatiga, Indonesia.

Sharma B.K. (2004). Phytoplankton communities of a floodplain lake of the Brahmaputra river basin, Upper Assam. *Journal of Inland Fisheries Association,* 31, 27–35.

Sharma B.K. (2009). Phytoplankton communities of Loktak lake (a Ramsar site), Manipur (N. E. India): composition, abundance and ecology. *Journal of Threatened Taxa*, 1(8), 401–410. [CrossRef]

Sharma, B.K. (2010). Phytoplankton diversity of two floodplain lakes (pats) of Manipur (N. E. India). *Journal of Threatened Taxa*, 2(11), 1273–1281. [CrossRef]

Sharma, B.K. (2012). Phytoplankton diversity of a floodplain lake of the Brahmaputra River basin, Assam, north-east India. *Indian Journal of Fisheries*, 59(4), 131–139.

Sharma, B.K. (2015). Phytoplankton diversity of Deepor Beel- a Ramsar site in the floodplain of the Brahmaputra River Basin, Assam, north-east India. *Indian Journal of Fisheries,* 62(1), 33–40.

Sharma, B.K. & Bhattarai, S. (2005). Hydro-biological analysis of a peat bog with emphasis on its planktonic diversity and population dynamics in Bumdeling Wildlife Sanctuary: eastern Bhutan. *Limnology,* 6, 183–187. [CrossRef]

Sharma, B.K., & Hatimuria, M.K. (2017). Phytoplankton diversity of floodplain lakes of Majuli River Island, Brahmaputra river basin of Assam, northeast India. *International Journal of Aquatic Biology,* 5(5), 295–309. [CrossRef]

Sharma, B.K. & Lyngdoh, R.M. (2003). Abundance and ecology of net and phytoplankton of a subtropical reservoir of Meghalaya (N. E. India). *Ecology, Environment & Conservation,* 9 (4), 497–503.

Sharma, B.K. & Lyngskor, C. (2003). Plankton communities of a subtropical reservoir of Meghalaya (N. E. India). *Indian Journal of Animal Sciences,* 73 (2), 88–95.

Sharma, B.K. & Pachuau, L. (2016). Diversity of Phytoplankton of a subtropical reservoir of Mizoram, northeast India. *International Journal of Aquatic Biology,* 4(6), 360–369.

Sharma, B.K. & Sharma, S. (2020). Zooplankton diversity of a subtropical reservoir of Meghalaya, northeast India with remarks on spatial and temporal variations. *Opuscula Zoologica Budapest,* 50(1), 67–86. [CrossRef]

Sharma, R.C. & Singh, S. (2018). Water quality and phytoplankton diversity of high altitude wetland, Dodi Tal of Garhwal Himalaya, India. *Biodiversity International Journal*, 2(6), 484–493. [CrossRef]

Sharma, R.C. & Tiwari, V. (2018). Phytoplankton diversity in relation to physico-chemical environmental variables of Nachiketa Tal, Garhwal Himalaya. *Biodiversity International Journal,* 2(2), 128–136. [CrossRef]

Singh, S. & Sharma, R.C. (2018). Monitoring of algal taxa as bioindicator for assessing the health of the high altitude wetland, Dodi Tal, Garhwal Himalaya, India. *International Journal of Fisheries and Aquatic Studies,* 6(3), 128–133. [CrossRef]

Talling J.F. & Talling I.B. (1965). The chemical composition of African lake waters. *Internationale Revue der gesamten Hydrobiologie*, 50, 421–463. [CrossRef]

Thakur, R.K., Jindal, R., Singh, U.B. & Ahluwalia, A.S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environment Monitoring & Assessment*, 185 (10), 8355–8373. [CrossRef]

Washington, H.G. (1984). Diversity, biotic and similarity indices. A review with special relevance to aquatic ecosystems. *Water Research*, 18, 653–694. [CrossRef]

Wanganeo, A. & Wanganeo, R. (1991). Algal population in valley lakes of Kashmir Himalayas. *Archiv fur Hydrobiologie,* 121, 219–223.

Wilhm, J.L. & Dorris, T.C. (1968). Biological parameters for water quality criteria: *Bioscience*, 18, 477–481. [CrossRef]

Woelkerling, W. & Gough, S.B. (1976). Wisconsin Desmids. III. Desmid community composition and distribution in relation to lake type and water chemistry. *Hydrobiologia*, 51, 3–32. [CrossRef]

Zutshi, D.P., Subla, B.A., Khan, M.A. & Wanganeo, A. (1980). Comparative limnology of nine lakes of Jammu and Kashmir Himalayas. *Hydrobiologia*, 72, 101–112. [CrossRef]

Zutshi, D.P. & Wanganeo A (1984). The phytoplankton and primary productivity of a high altitude subtropical lake. *Internationale Vereinigung für Theoretische und Angewandte Limnologie Verhandlungen*, 222, 1168–1172. [CrossRef]

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 66-71 • DOI: https://doi.org/10.26650/ASE2020768078

Original Article

Assessment of Spatial – Temporal Variations in Freshwater Pollution by Means of Water Quality Index: A Case Study of Hasanağa Stream Basin (Edirne, Turkey)

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Cite this article as: Tokatli, C. (2021). Assessment of spatial – temporal variations in freshwater pollution by means of water quality index: A case study of Hasanağa stream basin (Edirne, Turkey). *Aquatic Sciences and Engineering, 36*(2), 66-71.

ABSTRACT

In this research, spatial – temporal variations of water quality in the fluvial components of the Hasanağa Stream Basin were evaluated by using the Water Quality Index. Surface water samples were taken from seven stations selected on the basin in the winter seasons of 2019 and 2020. Eleven variables including dissolved oxygen, oxygen saturation, pH, electrical conductivity, total dissolved solids, salinity, turbidity, nitrate, nitrite, phosphate and sulphate were measured in freshwater samples. The Water Quality Index (WQI) and Cluster Analysis (CA) were applied to the detected data in order to determine the differences among the spatial – temporal contamination levels and classify the investigated locations according to their similar water quality characteristics. According to the detected data, the water of the Hasanağa Stream Basin has 1. – 2. Class quality in 2019 and 2. – 3. in 2020, in general. According to the results of WQI, although it was determined that the water quality decreased significantly in 2020, the basin was found to be of "A Grade – Excellent" water quality (<50) in both 2019 and 2020. According to the results of the CA, 3 statistical clusters were formed and they were named as “less polluted zone”, “moderate polluted zone” and “more polluted zone”.

Keywords: Hasanağa stream basin, water quality index, cluster analysis

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Submitted: 11.07.2020

Revision Requested: 30.10.2020

Last Revision Received: 03.11.2020

Accepted: 04.11.2020

Online Published: 27.01.2021

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INTRODUCTION

Contamination of freshwater resources is a significant environmental problem, because of the increasing world population, the developments of industry and no environmental awareness in society. It is known that one of the main points in the effective management of freshwater resources is the monitoring of the quality of aquatic environments (Arslan et al., 2011; Tokatlı et al., 2014; 2016; Köse et al., 2014; 2016).

Water quality assessment indices are known to be an effective tool in evaluating the quality of water ecosystems. The Water Quality Index (WQI) has achieved increasing significance in the management of freshwater resources and it is one of the most commonly used freshwater quality indices and it is calculated from the perspective of the suitability of water for human consumption (Tyagi et al., 2013; Akter et al., 2016; Sutadian et al., 2016; Mukatea et al., 2019; Ustaoğlu and Tepe, 2019; Varol, 2020; Tokatlı and Ustauğlu, 2020). Describing the suitability of freshwater resources for domestic use especially in terms of the WQI is one of the most convenient ways to describe the current qualities of water ecosystems. The WQI also enables the modifications of policies by various environmental agencies (Akoteyon et al., 2011; Tokatlı and Ustauoğu, 2020; Ustaoğlu and Aydın, 2020; Tokatlı, 2020a).

Multi-statistical methods have been used to evaluate and characterise freshwater resources and they help in the interpretation of complex data matrices and for them to be better understood. Cluster Analysis (CA) is known as one of the most convenient multivariate statistical methods. It assembles the objects based on the similar characteristics they possess (Akın et al., 2011; Varol et al., 2012; Belkhiri and Narany, 2015; Köse et al., 2018; Atıcı et al., 2018; Çiçek et al., 2019; Tokatlı, 2020b).

The Meriç–Ergene River Basin is the main watershed of the Thrace Region of Turkey. The Hasanağa Stream Basin is located in the Edirne Province of Turkey and it is one of the sub–basins of the Tunca River that is one of the main parts of the Meriç–Ergene River Basin. As in many aquatic ecosystems, the Hasanağa Stream Basin is adversely affected by agricultural and domestic discharges. The aim of this study was to determine the spatial and temporal variations of the water quality in this significant watershed by using the WQI.

MATERIALS AND METHODS

Sample collection

In this study, surface water samples were collected from seven stations located on the Hasanağa Stream Basin (3 of them were on the Sinanköy Stream, 3 of them were on the Korucuköy Stream and 1 of them was on the Hasanağa Stream) in the winter seasons of 2019 and 2020. The coordinate information of the locations is given in Table 1 and a map of the study area and the seven selected stations of the basin are given in Figure 1.

Physical – Chemical and Statistical Analysis

Dissolved oxygen (DO), oxygen saturation (OS), pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity variables were determined by using a multi – parameter device (Hach Lange – HQ40D) in the field studies; the turbidity variable was determined by using a turbidimeter device (Hach Lange – 2100Q) in the field studies; nitrate (NO_3), nitrite (NO_2), phosphate (PO_4) and sulphate (SO_4) variables were determined by using a colorimeter device (Hach Lange – DR890) and by using a spectrophotometer device (Hach Lange – DR3900) in the laboratory studies.

Cluster Analysis (CA) and Similarity – Distance Index (SDI) (in terms of Bray Curtis) were applied to the detected data in order to the define the spatial differences of contamination by using the "PAST" package statistical program.

Table 1. Coordinate information of stations.

Station Code	Name of Stream	Coordinate	
		North	East
S1		41.838	26.749
S2	Sinanköy Stream	41.777	26.683
S3		41.719	26.636
K1		41.862	26.700
K2	Korucuköy Stream	41.791	26.657
K3		41.725	26.631
H	Hasanağa Stream	41.732	26.569

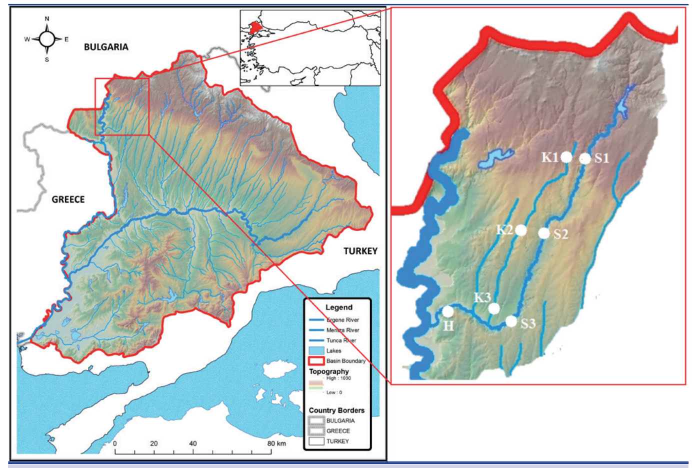

Figure 1. Meriç – Ergene River Basin, study area and selected stations.

Water Quality Index (WQI)

The WQI is an effective method in evaluating the drinking water quality and has commonly been used, especially in recent years (Wang et al., 2017; Tokatlı, 2019c; Ustaoğlu et al., 2020). The following formula was used to calculate the WQI;

$$WQI = \sum\left[W_i \times \left(\frac{C_i}{S_i}\right) \times 100\right] \quad (1)$$

$$Wi = \frac{w_i}{\Sigma w_i} \quad (2)$$

Where, W_i is relative weight and W_i values are assigned as a maximum of 5 and a minimum of 1, taking into account the relatively significant effects of the toxicants on human health and their significance in terms of potability (Meng et al., 2016). C_i is the trace-toxic element concentration measured in water and the S_i values refer to the standard values determined by TS266 (2005), EC (2007) and WHO (2011) for drinking water. The Standard values (Si) of the investigated parameters with the assigned Wi coefficients in the present application are given in Table 2 (Meng et al., 2016). The scale of WQI is given in Table 3 (Xiao et al., 2019).

Table 2. Standard values, assigned weights and relative weights of parameters.

Variable	Unit	Standart Value (S_i)	Assigned Weight (W_i)	Relative Weight (W_i)
pH		7.5	3	0.111111
EC	µS/cm	1500	4	0.148148
TDS	mg/L	600	4	0.148148
Turbidity	NTU	5	3	0.111111
Nitrate	mg/L	50	5	0.185185
Nitrite	mg/L	3	5	0.185185
Sulphate	mg/L	250	3	0.111111

Table 3. Water quality rating for WQI.

Value	Rating of Water Quality	Usage Possibilities	Grading
< 50	Excellent water quality	Drinking, irrigation, industrial	A
50 – 100	Good water quality	Drinking, irrigation, industrial	B
100 – 200	Poor water quality	Irrigation, industrial	C
200 – 300	Very Poor water quality	Irrigation	D

RESULTS AND DISCUSSION

The results of the detected limnological parameters in the main fluvial components of the Hasanağa Stream Basin in 2019 and 2020 are given in Table 3.

According to the Turkish Regulations (2004; 2015), In the winter season of 2019, the Hasanağa Stream Basin had a 1. Class quality in terms of dissolved oxygen, oxygen saturation, pH, TDS and sulphate parameters and has a 2. Class quality in terms of the EC, nitrate, nitrite and phosphate parameters in general (Uslu and Türkman, 1987). In the winter season of 2020, the basin has a 1. Class quality in terms of dissolved oxygen, oxygen saturation, TDS and sulphate parameters, and has a 2. Class quality in terms of the EC and nitrite parameters and has a 3. Class quality in terms of the pH, nitrate and phosphate parameters in general (Uslu and Türkman, 1987). It was also determined that any investigated locations (except K3 station for turbidity parameter) did not exceed the drinking water standards in terms of the investigated parameters (TS266, 2005; EC, 2007; WHO, 2011).

Nitrate is caused by the oxidation of ammonia, which occurs as a result of the decomposition of proteins contained in animal and vegetable wastes, and especially nitrate fertilisers used in agricultural areas. A small amount of nitrate in clean waters is the most common form of nitrogen in streams (Wetzel, 2001; Manahan, 2011). Nitrite is an intermediate in biological oxidation from ammonium to nitrate, and it may have oxidised to nitrate or reduced to ammonia. It is mostly low in natural waters. Nitrite can reach high densities in low oxygenated waters with organic pollution and suggests sewage contamination if it is found in high amounts. The most important sources of nitrite in soils and waters are organic substances, nitrogenous fertilisers and some minerals (Wetzel, 2001; Manahan, 2011). Phosphorus is a significant essential element for plant growth. It is necessary for crop production and is commonly used in fertilisers. It is known as one of the main elements that increase the nutrient enrichment of surface waters and cause the ageing of lakes or streams (Wetzel, 2001; Manahan, 2011). The reason for the quite high nitrate, nitrite and phosphate values detected in the water of some basin components may have been the applied intensive agricultural fertilisers in the region.

CA was applied to the data in order to obtain the similarity groups among the investigated localities on the Hasanağa Stream Basin according to their similar water quality characteristics. The diagram of CA calculated by using the WQI scores of locations is given in Figure 2 and the calculated similarity coefficient of locations are given in Table 4.

According to the results of CA, 3 statistically significant clusters were formed. Cluster 1 (C1) was named as a "less contaminated zone" and corresponded to the stations S1 and K1; Cluster 2 (C2) was named as a "moderate contaminated zone" and corresponded to the station H, S2, S3 and K2; Cluster 3 (C3) was named as a "more contaminated zone" and corresponded to the station of K3.

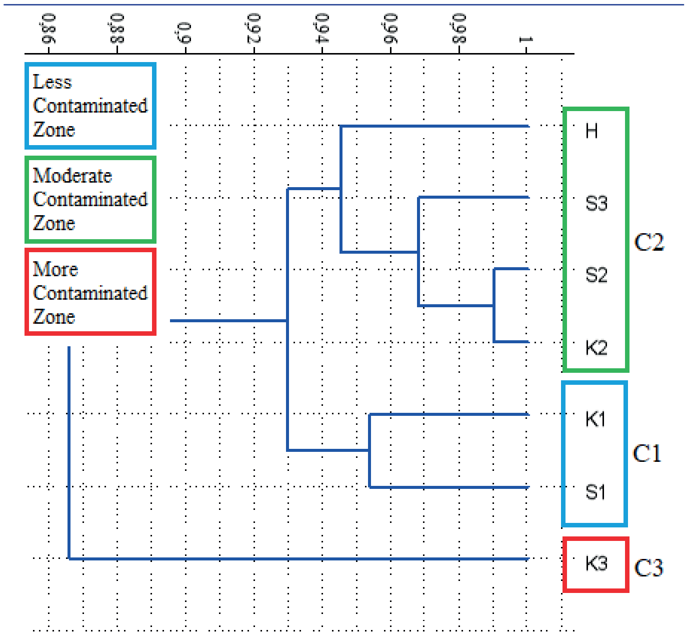

Figure 2. CA diagram.

Table 4. Similarity coefficients of locations.

	S1	S2	S3	K1	K2	K3	H
S1	1.000						
S2	0.942	1.000					
S3	0.910	0.968	1.000				
K1	0.954	0.951	0.936	1.000			
K2	0.942	0.990	0.968	0.941	1.000		
K3	0.806	0.862	0.894	0.851	0.862	1.000	
H	0.884	0.941	0.954	0.930	0.941	0.920	1.000

The Monomial and multinomial risks of pH, EC, TDS, turbidity, nitrate, nitrite and sulphate parameters in the water of the Hasanağa Stream Basin were determined for all the investigated habitats and seasons by using the WQI and the detected data are given in Table 4 and Figure 3.

According to the results of WQI, the values of the overall WQI were within the permissible limits (<100), and all the investigated stations on the Hasanğa Stream Basin in all the seasons were found as "A grade – Excellent" in water quality characteristics. It was also determined that the risk sequence of the investigated parameters in the surface water of the basin is as follows; pH > TDS

Table 3. Physical and chemical data detected in 2019 and 2020.

Winter Season of 2019											
Parameters *											
St.	**DO ppm**	**O2Sat %**	**pH**	**EC ms/cm**	**TDS ppm**	**Sal. $‰$**	**Tur. NTU**	**NO_3 ppm**	**NO_2 ppm**	**PO_4 ppm**	**SO_4 ppm**
S1	12.26 1. Class	108.3 1. Class	7.89 1. Class	303 1. Class	208 1. Class	0.21	4.53	1.73 1. Class	0.007 1. Class	0.041 2. Class	39 1. Class
S2	12.53 1. Class	109.9 1. Class	7.74 1. Class	482 1. Class	340 1. Class	0.34	2.44	7.29 2. Class	0.047 2. Class	**0.176 3. Class**	51 1. Class
S3	12.20 1. Class	107.0 1. Class	7.70 1. Class	541 2. Class	382 1. Class	0.38	2.27	7.60 2. Class	0.025 2. Class	0.087 2. Class	54 1. Class
K1	12.71 1. Class	111.8 1. Class	7.73 1. Class	513 2. Class	360 1. Class	0.36	2.90	8.48 2. Class	0.015 2. Class	0.084 2. Class	71 1. Class
K2	10.91 1. Class	96.7 1. Class	7.77 1. Class	448 2. Class	311 1. Class	0.31	2.02	**12.80 3. Class**	0.037 2. Class	0.052 2. Class	32 1. Class
K3	12.20 1. Class	103.0 1. Class	7.65 1. Class	559 2. Class	409 1. Class	0.41	7.90	**10.60 3. Class**	0.041 2. Class	0.151 2. Class	40 1. Class
H	11.74 1. Class	96.2 1. Class	7.19 1. Class	541 2. Class	409 1. Class	0.41	4.46	7.97 2. Class	**0.077 3. Class**	**0.163 3. Class**	80 1. Class
Min	10.91	96.20	7.19	303	208	0.21	2.02	1.73	0.01	0.04	32.00
Max	12.71	111.80	7.89	559	409	0.41	7.90	12.80	0.08	0.18	80.30
Mean	12.08	104.70	7.67	483	345	0.35	3.79	8.07	0.04	0.11	52.51
SD	0.60	6.26	0.22	88	70	0.07	2.08	3.42	0.02	0.05	17.72
Winter Season of 2020											
Parameters *											
St.	**DO ppm**	**O2Sat %**	**pH**	**EC ms/cm**	**TDS ppm**	**Sal. $‰$**	**Tur. NTU**	**NO_3 ppm**	**NO_2 ppm**	**PO_4 ppm**	**SO_4 ppm**
S1	11.51 1. Class	113.3 1. Class	**9.35 4. Class**	643 2. Class	387 1. Class	0.39	1.75	9.10 2. Class	0.005 1. Class	**0.640 3. Class**	50 1. Class
S2	10.01 1. Class	99.6 1. Class	**9.48 4. Class**	630 2. Class	390 1. Class	0.39	2.05	**22.40 4. Class**	0.009 1. Class	**0.760 4. Class**	51 1. Class
S3	9.79 1. Class	95.3 1. Class	**9.39 4. Class**	6472. Class	406 1. Class	0.41	3.01	**24.30 4. Class**	0.036 2. Class	**1.210 4. Class**	64 1. Class
K1	9.23 1. Class	89.3 2. Class	**9.10 4. Class**	601 2. Class	416 1. Class	0.32	1.88	**15.10 3. Class**	0.011 2. Class	0.070 2. Class	17 1. Class
K2	8.64 1. Class	83.4 2. Class	**8.73 3. Class**	676 2. Class	431 1. Class	0.43	2.48	**23.70 4. Class**	0.021 2. Class	0.150 2. Class	27 1. Class
K3	7.57 2. Class	73.1 2. Class	**8.60 3. Class**	827 2. Class	528 2. Class	0.53	4.65	**24.30 4. Class**	**0.065 3. Class**	**0.370 3. Class**	43 1. Class
H	9.98 1. Class	97.2 1. Class	**8.76 3. Class**	694 2. Class	437 1. Class	0.44	2.59	**20.20 4. Class**	0.054 2. Class	0.130 2. Class	73 1. Class
Min	7.57	73.10	8.60	601	387	0.32	1.75	9.10	0.01	0.07	17.00
Max	11.51	113.30	9.48	827	528	0.53	4.65	24.30	0.07	1.21	73.00
Mean	9.53	93.03	9.06	674	427	0.42	2.63	19.87	0.03	0.48	46.43
SD	1.23	12.78	0.36	73	48	0.06	0.99	5.76	0.02	0.42	19.59

St.: Stations; Sal.: Salinity; Tur.: Turbidity; Min: Minimum; Max: Maximum; SD: Standard Deviation; *3. – 4. Class water qualities are given in bold

> turbidity > EC > nitrate > sulphate > nitrite for 2019 and pH > TDS > nitrate > EC > turbidity > sulphate > nitrite in general.

In a study performed in the catchments of the Emet and Orhaneli Streams, the water quality of the basin was evaluated by using the WQI. According to the results of this investigation, being significantly different from the present investigation, the general trend of the WQI for Emet and Orhaneli Streams was found to be of a heavily polluted water quality (WQI > 300) (Omwene et al., 2019).

Table 4. Monomial and multinomial results of applied WQI.

Parametre	Sinanköy Stream			Korucuköy Stream			Hasanağa Stream
	S1	S2	S3	K1	K2	K3	H
Winter Season of 2019							
pH	11.689	11.467	11.407	11.452	11.511	11.333	10.652
EC	2.993	4.760	5.343	5.067	4.425	5.521	5.343
TDS	5.136	8.395	9.432	8.889	7.679	10.099	10.099
Turbidity	10.067	5.422	5.044	6.444	4.489	17.556	9.911
Nitrate	0.641	2.700	2.815	3.141	4.741	3.926	2.952
Nitrite	0.043	0.290	0.154	0.093	0.228	0.253	0.475
Sulphate	1.742	2.244	2.400	3.173	1.422	1.787	3.569
WQI	**32.310**	**35.279**	**36.596**	**38.259**	**34.495**	**50.474**	**43.001**
Winter Season of 2020							
pH	13.852	14.044	13.911	13.481	12.933	12.741	12.978
EC	6.351	6.222	6.390	5.936	6.677	8.168	6.854
TDS	9.556	9.630	10.025	10.272	10.642	13.037	10.790
Turbidity	3.889	4.556	6.689	4.178	5.511	10.333	5.756
Nitrate	3.370	8.296	9.000	5.593	8.778	9.000	7.481
Nitrite	0.031	0.056	0.222	0.068	0.130	0.401	0.333
Sulphate	2.222	2.267	2.844	0.756	1.200	1.911	3.244
WQI	**39.270**	**45.070**	**49.081**	**40.283**	**45.870**	**55.591**	**47.437**

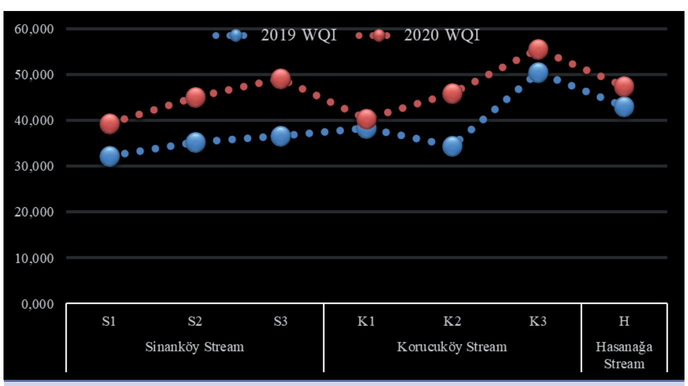

Figure 3. Spatial – temporal comparison of WQI scores.

In another study performed in the same watershed, the groundwater quality of the Ergene River Basin was evaluated by using the WQI. According to the results of this research, as similar to the present research, the investigated element accumulations in the groundwater of the basin were recorded within the range of human consumption standards (Tokatlı, 2019).

In a study performed in the Black See Region of Turkey, the WQI was used to assess the surface water qualities. As similar to the data of the current study, it was reported that the investigated Turnasuyu Stream has an excellent water quality in terms of the WQI (Ustaoğlu et al., 2020).

In a study conducted abroad in the city of Nagpur (India), The WQI was applied to determine the quality of different surface water resources. According to the results of this study, as different of the results of the present study, the calculated WQI for the various lakes studied showed poor water quality (Puri et al., 2011).

CONCLUSION

In the present research, the temporal and spatial change of the water quality of the Hasanağa Stream Basin including the Sinanköy, Korucuköy and Hasanağa Streams were evaluated by using the Water Quality Index (WQI) and Cluster Analysis (CA). As a result of this research, the water quality of the basin was found to have significantly decreased over time and it has a 1. – 2. Class water quality in 2019 and has a 2. – 3. Class water quality in 2020 in general. As a result of the WQI, the basin was found as having "A Grade – Excellent" water quality (<50) in both 2019 and 2020. As a result of CA, 3 statistically significant clusters were formed and the locations investigated were classified as "less polluted zones", "moderate polluted zones" and "more polluted zones". For the protection and sustainability of this important aquatic system, it is necessary to constantly monitor and raise the awareness of local people in agricultural activities.

Financial Disclosure: The present study was funded by Trakya University, Commission of Scientific Research Projects (Project No. 2019/127).

Ethics committee approval: Ethics committee approval is not required.

Conflict of Interest: The authors have no conflicts of interest to declare.

Acknowledgments: -

Disclosure: -

REFERENCES

Akin, B. S., Atıcı, T., Katircioglu, H., Keskin, F. (2011). Investigation of water quality on Gökçeekaya dam lake using multivariate statistical analysis, in Eskişehir, Turkey. *Environmental Earth Sciences*, *63*: 1251–1261. [CrossRef]

Akoteyon, I. S., Omotayo, A. O., Soladoye, O., Olaoye, H. O. (2011). Determination of water quality index and suitability of urban river for municipal water supply in lagos-Nigeria. *European Journal of Scientific Research, 54*: 263–271.

Akter, T., Jhohura, F. T., Akter, F., Chowdhury, T. R., Mistry, S. K., Dey, D., Barua, M. K., Islam, M. A. & Rahman, M. (2016). Water quality index for measuring drinking water quality in rural Bangladesh: A cross-sectional study. *Journal of Health, Population and Nutrition*, *35*:4. [CrossRef]

Arslan, N., Tokatlı, C., Çiçek, A., Köse, E. (2011). Determination of some metal concentrations in water and sediment samples in Yedigöller region (Kütahya). *Review of Hydrobiology 4*,1: 17-28.

Atıcı, T., Tokatlı, C., Çiçek, A. (2018). Diatoms of Seydisuyu stream basin (Turkey) and assessment of water quality by statistical and biological approaches. *Sigma Journal of Engineering and Natural Sciences*, *36* (1): 271-288.

Belkhiri, L., Narany, T. S. (2015). Using multivariate statistical analysis, geostatistical techniques and structural equation modeling to identify spatial variability of groundwater quality. *Water Resources Management*, *29*: 2073–2089. [CrossRef]

Çiçek, A., Köse, E., Tokatlı, C. (2019). Use of factor analysis to evaluate the sediment quality of a significant mining area: Seydisuyu stream basin (Turkey). *Polish Journal of Environmental Studies,* 28 (3): 2021-2025. [CrossRef]

EC (European Communities) (2007). *European Communities (drinking water) (no. 2)*, Regulations 2007, S.I. No. 278 of 2007.

Köse, E., Çiçek, A., Uysal, K., Tokatlı, C., Emiroğlu, Ö. & Arslan, N. (2016). Evaluation of surface water quality in Porsuk stream. *Unıversıty Journal of Scıence and Technology – C Life Sciences and Biotechnology*, *4* (2): 81-93. [CrossRef]

Köse, E., Emiroğlu, Ö., Çiçek, A., Tokatlı, C., Başkurt, S., Aksu, S. (2018). Sediment quality assessment in porsuk stream basin (Turkey) from a multi-statistical perspective. *Polish Journal of Environmental Studies, 27* (2): 747-752. [CrossRef]

Köse, E., Tokatlı, C. & Çiçek, A. (2014). Monitoring stream water quality: A statistical evaluation. *Polish Journal of Environmental Studies, 23* (5): 1637-1647.

Manahan, S. E. (2011). *Water Chemistry: Green Science and Technology of Nature's Most Renewable Resource.* Taylor and Francis Group. CRC Press, 398p. [CrossRef]

Meng, Q., Zhang, J., Zhang, Z., Wu, T. (2016). Geochemistry of dissolved trace elements and heavy metals in the dan river drainage (China): Distribution, sources, and water quality assessment. *Environmental Science and Pollution Research, 23*, 8091–8103. [CrossRef]

Mukatea, S., Wagha, V., Panaskara, D., Jacobs, J. A. & Sawantc, A. (2019). Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water. *Ecological Indicators, 101*, 348-354. [CrossRef]

Puri, P. J., Yenkie, M. K. N., Sangal, S. P., Gandhare, N. V., Sarote, G. B. & Dhanorkar, D. B. (2011). Surface water (lakes) quality assessment in nagpur city (India) based on water quality index (WQI). *Rasayan Journal of Chemistry, 4*(1): 43-48.

Sutadian, A. D., Muttil, N., Yilmaz, A. G., Perera, B. J. C. (2016). Development of river water quality indices—A review. *Environmental Monitoring and Assessment,* 188: 58. [CrossRef]

Tokatlı, C. (2019). Drinking Water Quality Assessment of Ergene River Basin (Turkey) by water quality index: Essential and toxic elements. *Sains Malaysiana, 48* (10): 2071-2081. [CrossRef]

Tokatlı, C., 2020a. Use of water quality index to evaluate the groundwater characteristics of villages located in edirne province. *International Journal of Agriculture, Environment and Food Sciences, 4*(3): 362-367. [CrossRef]

Tokatlı, C., 2020b. Water quality assessment of Ergene river basin using multivariate statistical analysis. *Journal of Limnology and Freshwater Fisheries Research, 6* (1): 38-46. [CrossRef]

Tokatlı, C., Köse, E., Arslan, N., Emiroğlu, Ö., Çiçek, A. & Dayıoğlu, H. (2016). Water quality of emet stream basin. *Uludağ University Journal of the Faculty of Engineering, 21*(2): 9-24. [CrossRef]

Tokatlı, C., Köse, E. & Çiçek, A. (2014). Assessment of the effects of large borate deposits on surface water quality by multi statistical approaches: A case study of the Seydisuyu stream (Turkey). *Polish Journal of Environmental Studies, 23*(5): 1741-1751.

Tokatlı, C., Ustaoğlu, F. (2020). Health risk assessment of toxicants in Meriç river delta wetland, thrace region, Turkey. *Environmental Earth Science, 79*, 426. [CrossRef]

TS 266 (2005). *Sular-İnsani tüketim amaçlı sular.* Türk Standartları Enstitüsü, ICS 13.060.20.

Turkish Regulations (2004). *Yüzeysel Su Kalitesi Yönetimi Yönetmeliği*, 31 Aralık 2004, Resmi Gazete No: 25687, http://suyonetimiormansu.gov.tr.

Turkish Regulations (2015). *Yüzeysel su kalitesi yönetimi yönetmeliğinde değişiklik yapılmasına dair yönetmelik,* 15 Nisan 2015, Resmi Gazete No: 29327, http://suyonetimiormansu.gov.tr.

Tyagi, S., Sharma, B., Singh, P. & Dobhal, R. (2013). Water quality assessment in terms of water quality index. *American Journal of Water Resources, 1*(3):34–8. [CrossRef]

Uslu, O. & Türkman, A. (1987). *Su kirliliği ve kontrolü.* T.C. Başbakanlık Çevre Genel Müdürlüğü Yayınları, Eğitim Dizisi 1, Ankara.

Ustaoğlu, F., Aydın, H. (2020). Health risk assessment of dissolved heavy metals in surface water in a subtropical rivers basin system of Giresun (north-eastern Turkey). *Desalination and Water Treatment, 194*, 222-234. [CrossRef]

Ustaoğlu, F. & Tepe, Y. (2019). Water quality and sediment contamination assessment of Pazarsuyu stream, Turkey using multivariate statistical methods and pollution indicators. *International Soil and Water Conservation Research, 7*, 47-56. [CrossRef]

Ustaoğlu, F., Tepe, Y. & Taş, B. (2020). Assessment of Stream quality and health risk in a subtropical Turkey river system: A combined approach using statistical analysis and water quality index. *Ecological Indicators*, [CrossRef]

Varol, M. (2020). Use of water quality index and multivariate statistical methods for the evaluation of water quality of a stream affected by multiple stressors: a case study. *Environmental Pollution,* 266: 115417. [CrossRef]

Varol , M., Gökot B., Bekleyen, A., Şen, B. (2012). Water quality assessment and apportionment of pollution sources of Tigris river (Turkey) Using multivariate statistical techniques—a case study. *River Research and Applications, 28*, 1428–1438. [CrossRef]

Wang, J., Liu, G., Liu, H. & Lamc, P. (2017). Multivariate statistical evaluation of dissolved trace elements and a water quality assessment in the middle reaches of Huaihe river, Anhui, China. *Science of the Total Environment*, 583: 421–431. [CrossRef]

Wetzel, R. G. (2001). *Limnology: Lake and River Ecosystems.* Elsevier Academic Press. 1006p. [20] Manahan, S.E. (2011) Water Chemistry: Green Science and Technology of Nature's Most Re-newable Resource. Taylor and Francis Group. CRC Press, 398p.

WHO (World Health Organization) (2011). *Guidelines for Drinking-water Quality.* World Health Organization Library Cataloguing-in-Publication Data, NLM classification: WA 675.

Xiao, J., Wang, L., Deng, L. & Jin, Z. (2019). Characteristics, sources, water quality and health risk assessment of trace elements in river water and well water in the Chinese loess plateau. *Science of the Total Environment,* 650: 2004-2012. [CrossRef]

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 72-77 • DOI: https://doi.org/10.26650/ASE2020793465

Original Article

Investigation of the Effects of Hook Size and Bait Type on the Catch of Whiting, *Merlangius merlangus* (Linnaeus, 1758) (Gadidae) in Bottom Longline Fisheries of the Black Sea

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Cite this article as: Ari, B., & Balik, İ. (2021). Investigation of the effects of hook size and bait type on the catch of whiting, *Merlangius merlangus* (Linnaeus, 1758) (Gadidae) in bottom longline fisheries of the Black Sea. *Aquatic Sciences and Engineering, 36*(2), 72-77.

ABSTRACT

This study was carried out along the Ünye coasts of the South-eastern Black Sea (Turkey), in order to investigate the effects of hook size and bait type on the catch of whiting, *Merlangius merlangus* (Linnaeus, 1758) (Gadidae) in the bottom longline fisheries. For this, a set of bottom longline with a total of a hundred hooks, including 20 from each hook number 2, 4, 6, 8 and 10, was tested in a total of 24 trials twice a month between March 2017 and February 2018. Each hook type was baited with squid, horse mackerel, chicken breast and whiting. During the study, a total of 373 whiting were caught. Most of the whiting catch was obtained with the hook no 2. With the reduction in hook size, both the amount of catch and the size of the fish caught decreased. Most whiting were-caught by the hooks baited with squid. This was followed by the hooks baited with horse mackerel, chicken breast and whiting, respectively. This result shows that hook size no 2 or larger should be used for catching whiting when using bottom longline in the Ünye coasts of the South-eastern Black Sea. Howev-er, considering the bait types used in this study, it is recommended to use squid as bait. If squid is thought to increase the cost of fishing, alternatively horse mackerel or chicken breast can also be used as bait.

Keywords: Bait type, catch, hook size, longline, whiting

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Submitted:
10.09.2020

Revision Requested:
20.10.2020

Last Revision Received:
21.10.2020

Accepted:
30.10.2020

Online Published:
27.01.2021

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INTRODUCTION

Longline fishing is one of the most traditional and widespread fishing methods throughout the world from small-scale artisanal fishing to modern mechanised longline operations (Björdal & Løkkeborg, 1996). It is an environmentally friendly fishing method and gives excellent quality and high profitability while requiring only a low fuel consumption (Endal, 1980; Løkkeborg & Björdal, 1992). Since longline fishing has high selectivity, its use is encouraged for protection in fisheries management. However, it is not possible to expect the same success in a habitat from a longline team used in the fishing of only one species.

Since 2006, fishing with bottom trawls has been forbidden in the South-eastern coasts of the Black Sea (Tarım ve Orman Bakanlığı, 2006). Therefore, the benthic fish species have typically been caught only with gillnets and trammel nets in the south-eastern parts of the Black Sea. However, the use of gillnets in fishing is generally considered to be more efficient when more than one species of fish is caught with the same gillnet. Longline are considered as a type of fishing gear that can easily be arranged according to the target species and size (Løkkeborg & Björdal, 1992), and, in particular, it can contribute to the renewal of distressed stocks such as whiting and red mullet, *Mullus barbatus* Linnaeus, 1758 in this part of the Black Sea. In addition, it offers the opportunity to catch fish in stony and rocky areas which are not suitable for fishing with other fishing gear but where the fish are densely concentrated.

In longline fisheries, the fish is attracted to the hook by visual motivation, either by natural bait or more commonly in the form of artificial imitations of prey organisms such as lures, jigs and rubber worms. Hook type (size and shape) varies greatly depending on the target species. There is also a great variation in baits used in different longline fisheries, but the major types of bait are either different pelagic fish (e.g. herring, mackerel, sardine, saury) or different species of squid (Björdal, 2009). The bait used in fishing is divided into two groups, namely, natural and artificial. Artificial baits are the those that imitate the creature's favourite prey. Natural bait is the most preferred bait group in longline fisheries and can be a whole fish, live or inanimate fish, cuttlefish and squid, pheasant, mammal, pipe worm, goat, crab, mussel and sea cucumber. In the selection of bait, easy availability, cost, fast deterioration, easy attachment to the hook, easy exit from the hook, and the best way to attract the target fishing features are sought (İlkyaz, Aydın, Soykan & Kınacıgil, 2012). Different baits have been used in studies on whiting fishing with longline. For example, squid has been used as bait in many previous studies in the bottom longline fisheries and its catching efficiency was found higher than some other bait varieties (Ekanayake, 1999; Özdemir, Ayaz, Gurbet & Erdem, 2006; İlkyaz et al., 2012). Fishing with longlines along the Turkish coasts of the Black Sea is not common. For this reason, most of the fishermen do not have enough information about longline fisheries.The goal of the present study was to investigate the effect of hook size and bait type used in bottom longline on the whiting catch.

MATERIALS AND METHODS

Study area and experimental fishing trials

This study was conducted along the Ünye coasts of the South-eastern Black Sea in the area 41°06´ – 41°08´ N, 37°22´ – 37°260´ E (Figure 1).

In the study, a set of bottom longline with 100 hooks was used. Longline have 20 hooks from each of 2, 4, 6, 8 and 10 hook sizes.

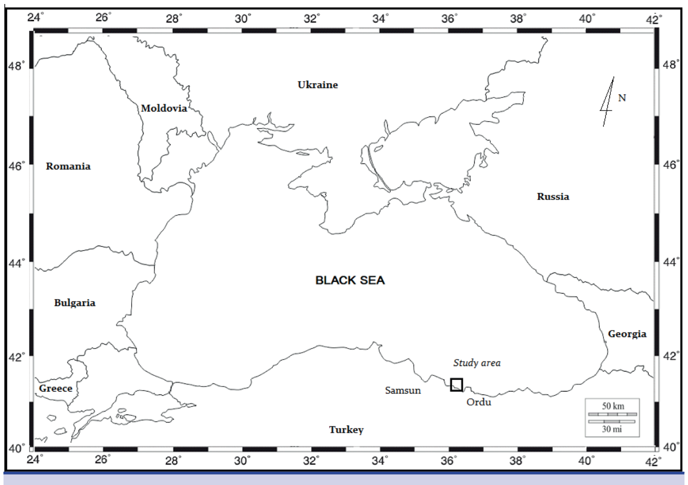

Figure 1. The study area in the Ünye coasts of the South-eastern Black Sea.

Hooks were attached to the main line in order "2,2,2,2; 4,4,4,4; 6,6,6,6; 8,8,8,8; 10,10,10,10". This procedure was repeated 5 times. The hooks were standard "J" large-shank hooks (Youvella). The structural size measurements of the hooks are shown in Figure 2.

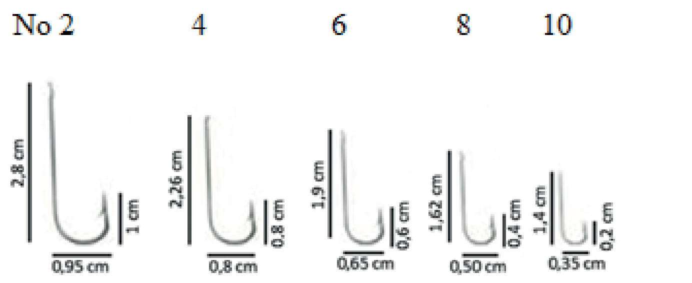

Figure 2. Hooks used in making longline and their structural dimensions.

In addition, technical characteristics of the bottom longline used in the trials are given in Table 1. A plastic basin of 50 cm diameter was used as the longline basket. Floats are attached to a big cement weight (about 5 kg) by means of a rope at the beginning and end of the main line. As seen in Figure 3, during the fishing operation floats and sinkers were attached with a rope at beginning and end of the main line. During the study which was carried out between March 2017 and February 2018, a total of 24 trials were conducted twice a month. The depth of the fishing trials conducted was about 30 m in the summer when the water temperature increased, while it reached a depth of 80 m in the winter months. When fishing in shallow areas (30-35 m) during the summer months, the depth went down to 80 m due to the decrease in water temperature. It is known that this fish species migrates to the waters below the thermocline layer in summer and lives in water temperatures of 7.5-8.5 ° C (Knudsen, Zengin & Koçak, 2010).

In this study, squid, horse mackerel, whiting and chicken breast were used as bait to investigate the effect of hook size and bait type on catch amount. As mentioned above, many previous studies reported that more fish were caught in the hooks baited with squid. For this reason, squid was also used as bait in the trials. Chicken breast was preferred because it was cheap and eas-

Table 1. Technical characteristics of the bottom longline used in trials

Gear	Specification
Length deployed (m)	~300 m
Mean soak time (hour)	About one hour
Hook type	J-hook
Hook size	2, 4, 6, 8 and 10
Number of hooks	20 hooks for each sizes
Diameter of main line (mm)	PA multifilament Ø 4.2 mm
Material of branchline (snood)	PA monofilament Ø30
Branchline length	50 cm
Float line	PP Ø 3 mm

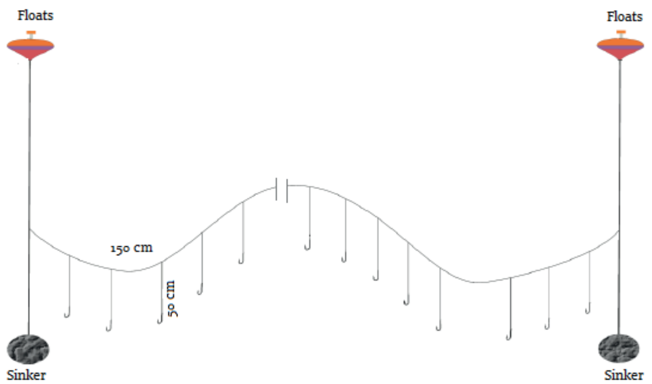

Figure 3. Diagram of longline used in this study.

ily available. In the study, the bait types were cut into cubes wherever possible and in equal sizes proportional to the hook size. In each trial, a total of 20 hooks from each size group were baited with squid, horse mackerel, chicken breast and whiting. A wooden fishing boat of 7.30 m length with 32 HP motor was rented for the fishing trials. Longline remained about one hour at sea and then it was hauled from the sea. After the fish were separated from the hooks, they were classified according to the size of the hooks and the bait types. The total length and weight of the whiting samples were measured to the nearest 1 mm and weighed to the nearest 0.01 g.

Data analysis

$CPUE_n$ (Catch Per Unit Effort by number of fish) and $CPUE_b$ (Catch Per Unit Effort by biomass of fish) were calculated for each hook size and bait type. In the calculation of $CPUE_n$ and $CPUE_b$ equations by Godøy, Furevik & Løkkeborg (2003) were used:

Catch Per Unit Effort for No. of fish, $CPUE_n = \frac{N}{\sum h * \sum t}$

Catch Per Unit Effort for biomass, $CPUE_b = \frac{W}{\sum h * \sum t}$

N: No. of fish

W: biomass of fish

h: number of hooks per setting

t: number of setting

Statistical analysis

First, a normality test (Shapiro-Wilk test) and a homogeneity test (Levene test) were applied to the data. The differences in catch rate and in size among hook sizes and bait types were assessed for each hook size and bait type using one-way analysis of variance (ANOVA, α=0.05) or Kruskal-Wallis test (α=0.05) for parametric or non-parametric data, respectively. When statistical differences in catch and in fish size were observed, LSD test in parametric data and Mann-Whitney U-test in non-parametric data were applied for pairwise compare of mean significant differences. Statistical analysis was conducted using SPSS package program.

RESULTS AND DUSCUSSION

Effect of hook size on catch

During the study, 373 whiting with a total mass of 8439 g were caught. Most whiting were obtained with hook no 2 (Table 2). The $CPUE_b$ of the whiting caught with hook no 2 was higher by 1.16, 1.44, 1.35 and 1.46 times than the those caught with hooks no 4, 6, 8 and 10, respectively. 1.24, 1.17 and 1.26 times more whiting were caught with hook no 4 than with hooks no 6, 8 and 10, respectively. On the other hand, hooks no 6, 8 and 10 had similar $CPUE_b$ values of whiting. Catch rates were significantly affected by hook size for whiting fishing (Kruskal-Wallis test; $P<0.05$). The amount ofwhiting caught with hook no 2 was significantly higher than that caught with hooks no 6 (Z=-2.269; P=0.023), 8 (Z=-2.070; P=0.038) and 10 (Z=-3.707; P=0.000). Similarly, the catch amounts of whiting caught with hooks no 4 and 6 were statistically different (Mann-Whitney U test; Z=-2.634; P=0.008).

Hook size significantly influences the catch amount of a species as well as its size (Patterson, Porch, Tarnecki & Strelcheck, 2012). Therefore, increasing the hook size can affect catch efficiency and reduce the chances of catching small fish (Alós, Cerdá, Deudero & Grau, 2008; Campbell, Pollack, Driggers & Hoffmayer, 2014). Our results indicated that most whiting were caught by hook no 2, while it decreased gradually with decreasing hook size (from 2 to 10). Özdemir et al. (2006) reported that hook size in the bottom longline fisheries in the Gulf of Izmir affects catch amount. On the other hand, Ekanayake (1999) found that in the waters of Sri Lanka the catches were similar for hooks no 7 and 12. It is understood that the effect of hook size on catch amount and fish size may vary from species to species and even from habitat to habitat for the same species.

The weights of the whiting samples varied between 19.3 g and 26.8 g and their length ranged from 13.6 cm to 15.4 cm. Length and weight distributions of whiting samples are shown in Figure 4 and 5. These figures showed that the weight and length of the whiting samples increased with increasing hook size (hook size from no 10 to 2). This paper concludes that the size of the fish caught increases with an increase in hook size. In many studies, it has been concluded that hook size is directly related to the

Table 2. Number (N), Biomass (g), $CPUE_n$ (No. of fish hook^{-1} h^{-1}) and $CPUE_b$ (g hook^{-1} h^{-1}) of the whiting by hook size

Hook no	No. of Fish (N)	Biomass (g)	$CPUE_n$ (N)	$CPUE_n$ (weight)
2	79	2119	0.165	4.415
4	80	1830	0.167	3.813
6	68	1470	0.142	3.063
8	71	1570	0.148	3.271
10	75	1450	0.156	3.021

length of the fish caught. For example, McCracken (1963) and Saetersdal (1963) conclude that the lengths of *Gadus morhua* and *Merlanogrammus aeglefinus* in the longline fishery increased with increasing hook size. In the study carried out by Çekiç & Başusta (2004) in the Mediterranean, it was found that the fish-caught by hooks no. 8 and 10 were larger than those caught by hook no. 14. Erzini, Gonçalves, Bentes & Lino (1995) also reported similar results.

The results of the pairwise comparisons with the Mann-Whitney U test showed that the difference of average weights were statistically significant between hooks no 2 and 6 (Z=-2.269; P=0.023), 2 and 8 (Z =-2.070; P=0.038), 2 and 10 (Z =-3.707; P=0.000), 4 and 10 (Z=-2.634; P=0.008). In terms of average length, differences were found to be significant between hooks no 2 and 6 (Z=-2.861; P=0.004), 2 and 8 (Z=-2.101; P=0.036), 2 and 10 (Z=-4.321; P=0.000), 4 and 10 (Z=-3.160; P=0.002), 8 and 10 (Z=-2.160; P=0.031).

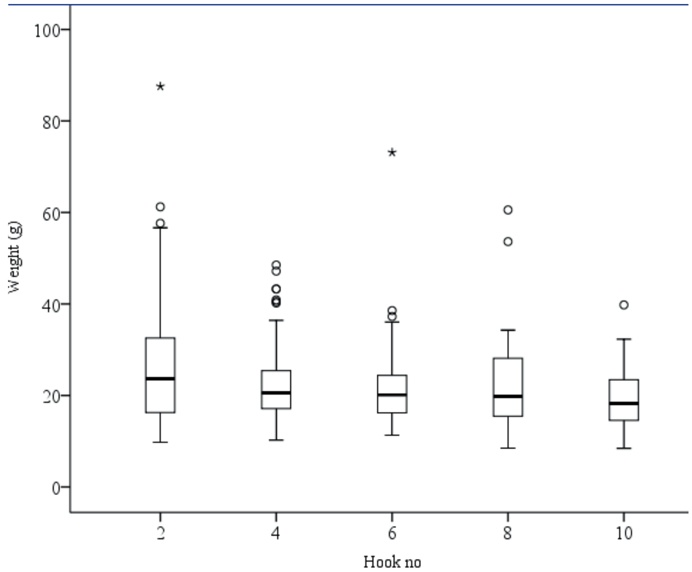

Figure 4. Weight distribution of whiting samples caught by hook size.

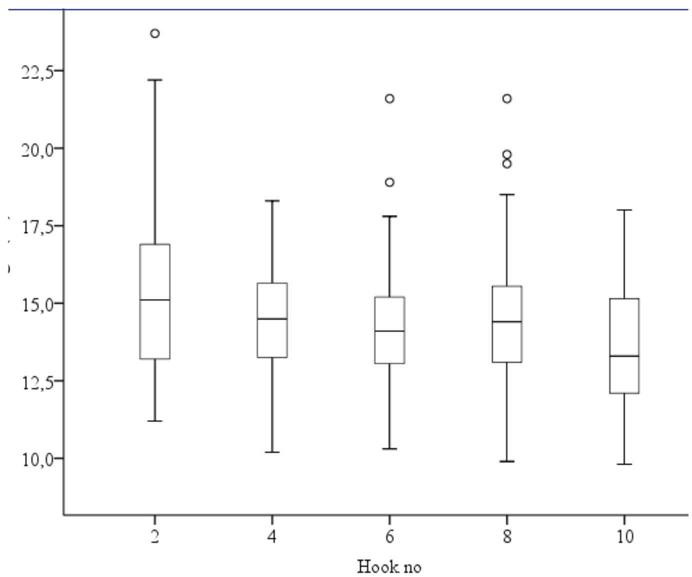

Figure 5. Length distribution of whiting samples caught by hook size.

Effect of bait type on catch

Most of the whiting were caught by hooks baited with squid (114 individuals, 2517 g). This bait type was followed by horse mackerel in biomass (Table 3). In terms of the effect of the bait type on catching yield, squid (Z=-2.823; P=0.005), horse mackerel (Z=-2.624; P=0.009) and chicken breast (Z=-2.673; P=0.008) were different from whiting.

Table 3. Number (N), Biomass (g), $CPUE_n$ (No. of fish $hook^{-1} h^{-1}$) and $CPUE_b$ (g $hook^{-1} h^{-1}$) of the whiting by bait types

Bait	Fish number	Biomass (g)	$CPUE_n$	$CPUE_b$
Squid	114	2.517	0.190	4.195
Horse mackerel	98	2.353	0.163	3.922
Chicken breast	100	2.259	0.167	3.765
Whiting	61	1.310	0.102	2.183

$CPUE_b$ of whiting for squid was 1.07, 1.11 and 1.92 times higher than that of the horse mackerel, chicken breast and whiting, respectively. Statistical analyses showed that there was no difference among the average weights (χ^2 = 2.501, df = 3, P=0.475) and the average lengths (χ^2 = 3.155, df = 3, P=0.368) of the whiting caught with bait variety. In other words, bait types used in this study did not affect the size of the whiting caught for the longline fisheries in the south-eastern Black Sea. The behaviour of the fish that is directed to longline is affected by the bait at all stages of the process of catching the hook, searching for the location of the bait, attacking the food, inserting the bait in the mouth, or inserting it into the hook (Løkkeborg, 1989). The effect of nutrient availability is the first necessary step during feeding. Almost all fish use their sniffing senses to locate a distant bait. On the other hand, baits leave chemical stimulants that will affect living things in the environment. The chemical structure of the bait also affects the feeding preference of the species. In addition, the species' vision, sniffing senses and mouth structure, depending on both hook shape and bait size, has an effect on the amount and composition of catch (Løkkeborg & Johannesen, 1992).

This is clearly seen in Figures 6 and 7 showing the weight and length distributions of the whiting samples caught by the bait varieties. The average weight of the whiting caught with bait varieties ranged from 21.9 to 24.0 g and the average length ranged from 14.2 to 14.7 cm.

The main factors affecting longline fishing are migration movements and behaviours of target species or species in longline

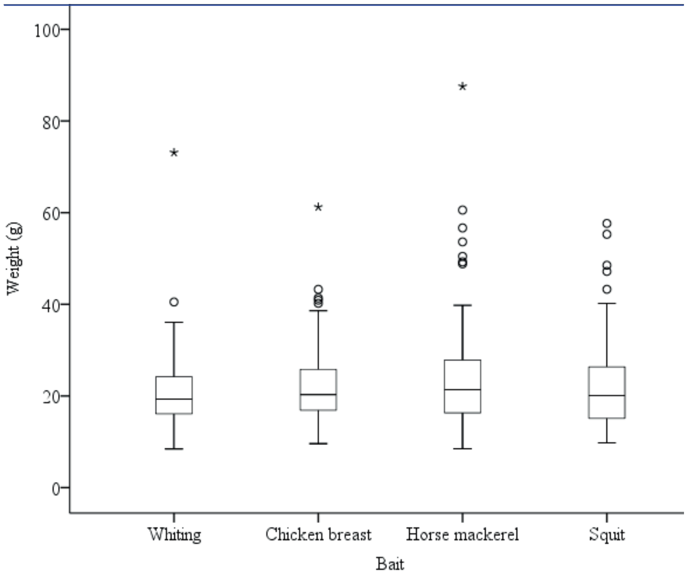

Figure 6. Weight distribution of whiting samples caught by bait type.

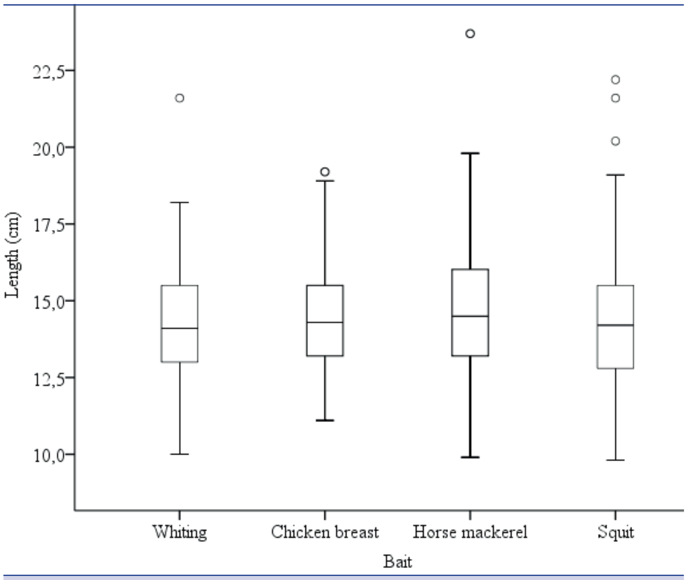

Figure 7. Length distribution of whiting samples caught by bait type.

fishing, their depth, water movements, feed type, the physical properties of the hooks used, catching time and duration, physical properties of the main body and shackle materials (Björdal, 1981). Our study determined that most whiting was caught by hook baited with squid. This bait was followed by chicken breast and horse mackerel, respectively. Hooks baited with whiting yielded the least catch of whiting. It is noteworthy that some longline studies show catching efficiency to be high where squid, or other cephalopod, and horse mackerel are used as bait. For example, in a study conducted on the coast of Sinop, 64% and 36% of the total catch in weight was caught by hooks baited with horse mackerel and anchovy, respectively (Özdemir, Erdem & Çetin, 2007). In a similar study conducted by Çekiç & Başusta (2004) in the Gulf of İskenderun it was reported that 473 of a total of 1059 fish were caught by hooks baited with squid, and 586 of them were caught by hooks baited with sardine. In another longline fisheries study in İzmir Bay, the catch ratio of hooks baited with sardine and squid-fed hooks was found to be 1: 3.5 (Özdemir et al., 2006). In a study conducted in Sri Lankan waters, it was reported that 36.5% of the total catch was caught by hoosk baited with squid, 27.7% by hooks baited with herring and 35.9% by hooks baited with sand snakes (Ekanayake, 1999). According to He (1996) the squid as bait remains longer on the hook than the fish as bait. This affects catching efficiency. Both the results of our study and the results of the above mentioned studies show that whiting generally prefer squid and horse mackerel as bait in longline fisheries. Almost all the whiting caught with hooks used in the study were determined to be larger than the minimum landing size (Tarım ve Köyişleri Bakanlığı, 2016). This shows that when compared to bottom trawl fishing, longline fishing does not harm the whiting population.

CONCLUSION

The results of our research show that while the number of whiting caught did not differ significantly with the increase in hook size, the size of whiting caught increased with hook size. Therefore, the hook number to be used in longlines for fishing of whiting in the south-eastern Black Sea should be size 2 or larger. In this way, a greater catch of whiting will be obtained while at the same time preventing the fishing of small whiting. When the bait types used in our study are taken into consideration, squid should be used as a bait for the fishing of whiting with longline. Alternatively, Mediterranean horse mackerel meat and chicken breast can also be a choice of bait in bottom longline fishing.

Conflict of interest: The authors declare no financial, commercial and legal conflict of interest.

Ethics committee approval: The authors declare that this studydoes not need ethics committee approval.

Financial disclosure: This study was supported by TF-1641 project by Ordu University Scientific Research Projects Coordination Unit and produced from the master thesis prepared by the first author under the supervision of the second author.

REFERENCES

Alós, J., Cerdá, M., Deudero, S. & Grau, A.M. (2008). Influence of hook size and type on short-term mortality, hooking location and size selectivity in a Spanish recreational fishery. *Journal of Applied* Ichthyology, 24, 658–663. [CrossRef]

Björdal, A. & Lokkebor, S. (1996). *Longlining.* Oxford: Fishing News Books, 56 p.

Björdal, A. (1981). *Engineering and fish reaction aspects of longlining - a review.* ICES CM.1981/B35, 22 p.

Björdal, A. (2009). Regulation of Fishing Gears and Methods. In K.L. Cochrane & S.M. Garcia (Eds.), *A Fishery Manager's Guidebook* (pp. 167-195). Roma, Italy: Second Edition, Published by The Food and Agriculture Organization of the United Nations and Wiley-Blackwell.

Campbell, M.D., Pollack, A.G., Driggers, W.B. & Hoffmayer, E.R. (2014). Estimation of hook selectivity of Red Snapper and Vermilion Snapper from fishery-independent surveys of natural reefs in the northern Gulf of Mexico. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* [online serial] 6, 260-273. [CrossRef]

Çekiç, M. & Başusta, N. (2004). İskenderun Körfezi'nde Kullanılan Paraketa Takımlarında Yem Çeşidi ve İğne Büyüklüğünün Tür Seçimine Etkisi. *Ege Üniversitesi Su Ürünleri Dergisi*, 21(1-2), 73-77.

Ekanayake, E.M.A.B. (1999). The effect of hook size and bait type on the fishing selectivity of longline gear (Report No. UNU - Fisheries Training Programme, Final Projects). National Institute of Fisheries Training, Sri Lanka, 23 p.

Endal, A. (1980). Fuel saving potential in Norwegian Fisheries (C.M. 1980/B:14). Trondheim, Norway, 16 p.

Erzini, K., Gonçalves, J. M. S., Bentes, L. & Lino, P.S. (1995). Small Hook Longline Selectivity Study (Report No. BIOECO/93/04). Portugal, 3-17 p.

Godøy, H., Furevik, D. & Løkkeborg, S. (2003). Reduced by catch of red king crab (*Paralithodes camtschaticus*) in the gillnet fishery for cod (*Gadus morhua*) in northern Norway. *Fisheries Research*, 62, 337-384. [CrossRef]

He, P. (1996). Bait Loss Bottom-Set Longlines As Determined by Underwater Observations and Comparative Fishing Trials. *Fisheries Research*, 27 (1-3), 29-36. [CrossRef]

İlkyaz, A., Aydın, C., Soykan, O. & Kınacıgil, T. (2012). Dip Paragatında Yem Etkinliği ve İğne Seçiciliği. Ege Üniversitesi Bilimsel Araştırma Proje Kesin Raporu, PROJE NO. 2007/SÜF/012, İzmir, 46 p.

Knudsen, S., Zengin, M. & Koçak, M.H. (2010). Identifying drivers for fishing pressure. A multidisciplinary study of trawl and sea snail fisheries in Samsun, Black Sea coast of Turkey. *Ocean and Coastal Management*, 53, 252-269. [CrossRef]

Løkkeborg, S. & Björdal, A. (1992). Species and Size Selectivity in Longline Fishing. *Fisheries Research*, 13, 311-322. [CrossRef]

Løkkeborg, S. & Johannessen, T. (1992). The Importance of Chemical Stimuli in Bait Fishing-Fishing Trials with Pre-soaked Bait. *Fisheries Research*, 14, 21-29. [CrossRef]

Løkkeborg, S. (1989). *Longline bait: Fish behaviour and the influence of attractant release rate and bait appearance* (PhD Thesis). Department of Biology, University of Bergen, Bergen, Norway.

McCracken, F. D. (1963). Selection by codend meshes and hooks on cod, haddock, flatfish and redfish. In N. S. Dartmouth (Ed.), *The selectivity of fishing gear* (647-665). Canada: International Commission for the Northwest Atlantic Fisheries (ICNAF) Special Publication 5.

Özdemir, S., Ayaz, A., Gurbet, R. & Erdem, Y. (2006). Farklı büyüklükte kanca ve farklı tipteki yem ile sabah tanı ve Gündüz zamanlarında kullanılan dip paraketasının av verimi. *Anadolu Üniversitesi Bilim ve Teknoloji Dergisi*, 7(2), 405-411.

Özdemir, S., Erdem, Y. & Çetin, S. (2007). Dip paraketasında kullanılan iki farklı yemin balık davranışları ve av verimi yönünden karşılaştırılması. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi*, 3, 177-187.

Patterson, W.F., Porch, C.E., Tarnecki, J.H. & Strelcheck, A.J. (2012). Effect of circle hook size on reef fish catch rates, species composition, and selectivity in the northern Gulf of Mexico recreational fishery. *Bulletin of Marine Science*, 88, 647-665. [CrossRef]

Saetersdal, G. (1963). Selectivity of longlines. *ICNAF Spec. Publ.* 5, 189-192. [CrossRef]

Tarım ve Orman Bakanlığı (2006). Denizlerde ve İçsularda Ticari Amaçlı Su Ürünleri Avcılığını Düzenleyen 2006-2008 Av Dönemine Ait 37/1 Numaralı Sirküler. 24.08.2006 Tarih ve 26269 Sayılı Resmi Gazete.

İSTANBUL UNIVERSITY PRESS

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 78-84 • DOI: https://doi.org/10.26650/ASE2020790717

Original Article

Determination of Snowmelt Water Quality in Outdoor Green Areas: A Case Study at Van Province (Turkey)

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Cite this article as: Yeler, O. Tas Divrik, M., & Camur Elipek, B. (2021). Determination of Snowmelt Water Quality in Outdoor Green Areas: A Case Study at Van Province (Turkey). *Aquatic Sciences and Engineering, 36*(2), 78-84.

ABSTRACT

Freshwater resources are used for many purposes such as drinking, tap water, industrial usage and agricultural irrigation. Although unpolluted surface waters and groundwater are preferred for the irrigation of landscape plants in parks and gardens, snowmelt water is generally ignored. Like other precipitation types, snow can absorb solid and liquid substances in the atmosphere and it can rain on the earth with its natural chemical structure changed. Also, this water from snowmelt which includes different chemicals can enter surface waters and groundwater resources. In this study, the snowmelt water quality in outdoor green areas of the Van Province was examined. Some physico-chemical features (pH, conductivity, salinity, Ca, Mg, total hardness, Cl, NO_3-N, NO_2-N, SO_4, and PO_4) of the snow samples were taken at monthly intervals from six sampling stations between the dates of December 2019 - February 2020. Also, metal ion concentrations (Cd, Pb, As, Cu, Cr, Co, Ni, Zn, Fe, Mn, B, Se, Ba, Al, Na, Be, V, Mo, Si, K, Sr, Ag, Sb, Tl) and the values of SAR (Sodium Adsorption Ratio) and Na% in some sampling stations, which have intense industrial and settlements located in the area, were determined to evaluate the water quality level of the snowmelt water. While, it was observed that some parameters values exceeded the first quality level when compared with the quality levels of the surface water resources control regulation of Turkey and the rates in irrigation water quality values, a general evaluation of the results showed that snowmelt can be alternative irrigation water for plants. Also, the species of the landscape plants in the studied area were identified and the possible effects of the parameters on the development of the plants were discussed.

Keywords: Freshwater, snowmelt, landscape plants, metal ions, irrigation water

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Submitted: 04.09.2020

Revision Requested: 12.10.2020

Last Revision Received: 17.10.2020

Accepted: 18.10.2020

Online Published: 28.01.2021

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INTRODUCTION

In urban outdoor green areas, the visual landscape is provided by annual or seasonal plants. The surface waters and groundwater are generally used as irrigation resources for the plants in outdoor green areas. Furthermore, snow meltwater released by snowfall is also a potential irrigation water source for plants in these areas at spring season especially (Cooper, Dullinger, & Semenchuk, 2011). But, snow properties which are ignored generally can cause significant changes in soil and vegetation processes (Rixen et al., 2008). The atmosphere, one of the main receptive environments such as water and soil, may also be exposed to increasing pollutants, especially due to the intensive use of fossil fuels in winter. As the water vapour in the atmosphere condenses and descends to the soil in the form of rain, snow or hail, it is likely that these pollutants involved in precipitation have some effect on the soil and therefore on the plants (Rixen et al., 2008; Seven, Can, Darende, & Ocak, 2018). However, depending on the use of fossil fuels and industrial activities, pollutants enter the atmosphere and can be included in the precipitation. Thus it can lead to negative physico-chemical contents that affect plant growth (Yücedağ & Kaya, 2016). In some studies, it has been reported that snowmelt water contains some elements in higher proportions than rainwater, and surface water is affected by the melting of snow (Hagen & Langeland, 1973; Johannessen & Henriksen, 1978; Jeffries, 1990; Pehlivan, 2016; Galeczka, Sigurdsson, Eiriksdottir, Oelkers, & Gislason, 2016).

Up to now, there has not been a study on the snowmelt water quality in the landscape areas of the Van Province. In this study, physico-chemical properties of water from snowmelt in the outdoor green areas of Van province were examined. Thus, it was aimed to determine snowmelt water quality which can enter the surface and groundwater resources. Also, the possible effects of snow meltwater as an alternative irrigation water on the growth of the landscape plants were discussed in this study.

MATERIALS AND METHODS

The Van province which is located on east side of Turkey and has 20921 km^2, is a major city with a population of over 1 million. Fossil fuels for heating and transportation are used throughout the city, and organisations from different industries are also located in the region. There are many parks and gardens created for recreation in the outdoor green areas of the city and they have many different landscape plants which are completely under snow in the winter season.

In this study, a total of 6 sampling stations were selected from recreational outdoor green areas which contain plants planted by the municipality: Van-Kocaeli Dostluk Park (st1), Kurtuluş Park (st2), 15 Temmuz Şehitler Park (st3), Atatürk Kültür Park (st4), Yüzüncü Yil University Alle Park (st5), Iskele Yasar Kemal Park (st6) (Fig.1). The snow samples were taken from the surface to 5 cm of snow package at monthly intervals (December 2019, January 2020 and February 2020) under sterile conditions, they put into 1 L polyethylene cups and allowed to melt at room temperature (+24 °C). The values of pH and conductivity (EC as μS cm^{-1}) were measured during the field studies and the water samples from snowmelt were filtered by filtered paper and were transported to the laboratory to analyse Ca, Mg, total hardness (TH), Cl, salinity, NO_3-N, NO_2-N, SO_4, PO_4 (Egemen & Sunlu, 1999).

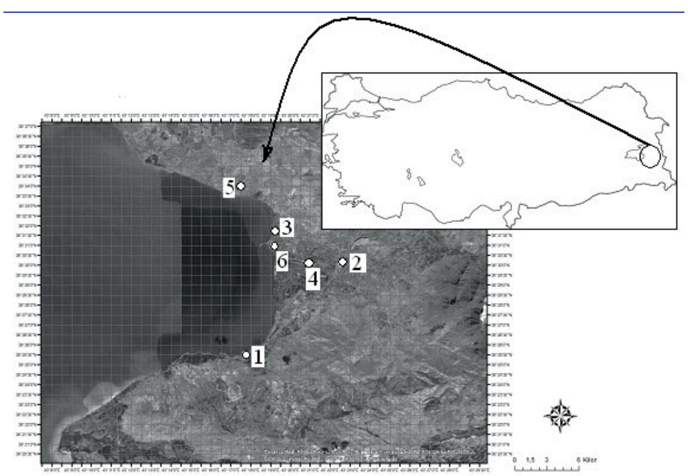

Figure 1. Location of Van province and the sampling stations.

Also, the melting snow samples taken from the sampling stations st1, st2 and st5, which are located at areas that have intense industrial and settlements, were put into sterile polyethylene bottles (100 cc) with the addition of 0.1 N.HNO_3 to reduce pH levels below 2 and transported to the laboratory to measure some metal ion concentrations (Van Loon, 1980; Welz & Sperling, 1999). The average values were taken after three replicated at flame atomic absorption spectrophotometer (Perkin-Elmer A-Analyst 800 device). Also, the values of Na^+, Ca^{+2}, Mg^{+2}, K^+ ions were converted to me L^{-1} from the obtained chemical analysis results and the SAR value (sodium adsorption ratio) and the Na% (sodium percentage ratio) were calculated (Ayers & Wescott, 1985; FAO, 2007).

Alp (1999), Yeler & Yeler (2019) and Van Lake Basin Virtual Herbarium (Demirkuş, 2019) were used to identify the landscaping plants. The species were separated into four groups as evergreen trees (ET), deciduous trees (DT), evergreen shrubs (ES), and deciduous shrubs (DS). The Bray-Curtis Cluster Analysis in the program "BioDiversity Pro 2.0" was used to determine the similarities of the sampling stations for their floral diversity (McAleece, Gage, Lambshead, & Paterson, 1997).

RESULTS AND DISCUSSION

Snow thicknesses at the sampling stations were measured as 7 cm (Dec.), 15 cm (Jan.), and 7 cm (Feb.) The physico-chemical results and their average values of the snowmelt water samples are presented in Table 1 and Figure 2.

Physico-chemical properties: The pH can affect the availability of macro and micro nutrients by plants when it has an undesirable level (Toor & Lusk, 2011). pH values were observed between the levels of 6.5 and 8.4 in this study (Toor & Lusk, 2011). When the results were evaluated according to the limits in Surface Water Resources Control Regulation (SWRCR) of Turkey and irrigation water quality (Ayers & Westcot, 1985; Toor, 2009; Anonymous, 2004, 2010; Toor & Lusk, 2011; Erdoğan & Dağdelen, 2012): the EC were found at compatible levels for the freshwater character (45.7-131.5 μS cm^{-1}). These values showed parallelism with the salinity (0.02-0.05 ‰), the chloride (1.99-14.99 mg L^{-1}) and the TH values (2.4-5.4 FS^0). The EC values should range between 0-3 dS m^{-1} for irrigation water and they should have a value of < 700 μS cm^{-1} as there is human contact in landscape areas such as parks and gardens (Ayers & Westcot, 1985; Anonymous, 2010). In this study, the EC values were determined at T1 class in terms of irrigation water, and high quality in terms of classification by the Schofield method (Erdoğan & Dağdelen, 2012). In a study carried out at Van Çaldıran Plain, which is located close to our area of study, it was reported that the EC in the surface waters of the region was 1203 μS cm^{-1} higher than our results (Aydın, 2017). Woodless plants rather than annual plants are sensitive to chloride concentrations (Ayers & Westcot, 1985). The Cl values were observed at first class water quality in this study, and < 4 me Cl L^{-1} signals that this water resource could be used even in the irrigation of sensitive plants according to the Schofield method (Anonymous, 2004; Erdoğan & Dağdelen, 2012). It is reported that irrigation of the soil with this water has high a sodium concentration and disturbs the physical structure of the soil and this prevents plant growth, indirectly (Erdoğan & Dağdelen, 2012). Although

Table 1. The results of physico-chemical features of the sampling stations.

	Parameters/Stations	St1	St2	St3	St4	St5	St6
December 2019	pH	7.39	7.50	7.68	7.38	8.36	8.70
	Conductivity (µS cm^{-1})	54.2	75.7	98.2	62.5	48.4	131.5
	Magnezyum (mg L^{-1})	0.19	0.26	0.38	0.46	0.29	0.48
	Calcium (mg L^{-1})	4.80	7.21	5.61	6.41	7.21	4.80
	Total Hardness (FS°)	2.8	4	4.6	5.4	4.2	5.2
	Salinity (‰)	0.03	0.02	0.03	0.05	0.05	0.03
	Chloride (mg L^{-1})	5.99	8.99	10.99	8.99	5.99	14.99
	NO_2-N (mg L^{-1})	0.037	0.034	0.026	0.030	0.053	0.022
	NO_3-N (mg L^{-1})	4.540	4.208	6.866	4.651	6.091	5.759
	Phosphate (mg L^{-1})	0.007	0.004	0.079	0.055	0.072	0.143
	Sulphate (mg L^{-1})	0.37	0.41	0.303	0.394	0.359	0.253
January 2020	pH	7.64	7.63	7.56	7.65	7.55	7.75
	Conductivity (µS cm^{-1})	58.5	78.2	98.4	66.7	45.7	119.7
	Magnezyum (mg L^{-1})	0.34	0.26	0.29	0.34	0.29	0.41
	Calcium (mg L^{-1})	4	7.21	5.61	3.20	2.40	4
	Total Hardness (FS°)	3.8	4	3.8	3.6	3	4.4
	Salinity (‰)	0.05	0.03	0.04	0.04	0.02	0.02
	Chloride (mg L^{-1})	12.99	4.99	7.99	3.99	4.99	4.99
	NO_2-N (mg L^{-1})	0.026	0.018	0.011	0.020	0.040	0.009
	NO_3-N (mg L^{-1})	5.53	4.96	7.70	6.06	7.17	6.86
	Phosphate (mg L^{-1})	0.003	0.010	0.139	0.091	0.088	0.190
	Sulphate (mg L^{-1})	0.371	0.394	0.280	0.337	0.299	0.204
February 2020	pH	7.59	7.65	7.60	7.58	7.70	7.68
	Conductivity (µS cm^{-1})	60.2	80.3	96.2	68.3	48.6	122.3
	Magnezyum (mg L^{-1})	0.04	0.24	0.24	0.36	0.60	0.17
	Calcium (mg L^{-1})	8.01	2.40	8.01	4.80	8.01	6.41
	Total Hardness (FS°)	2.4	2.6	2.8	4.2	7	3
	Salinity (‰)	0.03	0.02	0.03	0.02	0.04	0.02
	Chloride (mg L^{-1})	1.99	2.99	1.99	3.99	2.99	4.99
	NO_2-N (mg L^{-1})	0.008	0.007	0.006	0.0002	0.018	0.001
	NO_3-N (mg L^{-1})	7.199	4.433	6.645	7.199	7.973	7.530
	Phosphate (mg L^{-1})	0.0008	0.005	0.149	0.094	0.094	0.216
	Sulphate (mg L^{-1})	0.329	0.363	0.223	0.268	0.223	0.147
THE AVERAGE VALUES		**St1**	**St2**	**St3**	**St4**	**St5**	**St6**
	pH	7.54	7.59	7.61	7.53	7.87	**8.03**
	Conductivity (µS cm^{-1})	57.6	78.0	97.6	65.8	47.5	**124.5**
	Magnezyum (mg L^{-1})	0.19	0.25	0.30	0.38	**0.39**	0.35
	Calcium (mg L^{-1})	5.6	5.6	**6.4**	4.8	5.8	5.0
	Total Hardness (FS°)	3.0	3.5	3.7	4.4	**4.7**	4.2
	Salinity (‰)	0.03	0.02	0.03	0.03	0.03	0.02
	Chloride (mg L^{-1})	6.99	5.65	6.99	5.65	4.65	**8.32**
	NO_2-N (mg L^{-1})	0.023	0.019	0.014	0.016	**0.037**	0.010
	NO_3-N (mg L^{-1})	5.75	4.53	**7.07**	5.97	**7.07**	6.71
	Phosphate (mg L^{-1})	0.003	0.006	0.122	0.080	0.084	**0.183**
	Sulphate (mg L^{-1})	0.356	**0.389**	0.268	0.333	0.293	0.201

most annual plants are not very sensitive to sodium, the excess sodium rate still has a toxic effect on plants. In addition, it is recommended to determine the SAR (Sodium Adsorption Ratio) value for the effect of sodium in irrigation waters (Ayers & Wescott, 1985). In this study, the SAR and Na% did not exceed the limits for irrigation water quality (SAR values and Na% were calculated as 0.11 and 12.5% for st1, 0.12 and 11.9% for st2, 0.40 and 8.4% for st5, 0.07 and 7% for December, 0.14 and 16% for

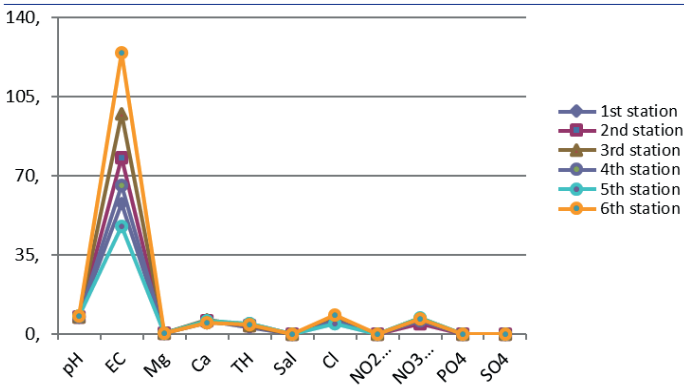

Figure 2. The distribution of average values of the physico-chemical parameters in the sampling stations.

January, 0.07 and 8% for February. So, the SAR values were found <1 value and were determined in the A1 category (Erdoğan & Dağdelen, 2012). The Na% values were found far below the 50-60% value that would damage the trees and decorative woody plants that are more sensitive to soil and especially sodium (Ayers & Westcot, 1985; Erdoğan & Dağdelen, 2012). All the sampling stations were found to be of first class quality and had desirable values in terms of SO_4, while the NO_3-N values exceed this level (Ayers & Westcot, 1985; Anonymous, 2004). Also, the NO_2-N ratios were found to be of second and third class quality while the PO_4 contents were found at first class in all of the sampling stations except st5 which has the most landscape plant diversity. However, it may be more appropriate to determine the amount of nitrogen to evaluate the toxic effects of the nitrogen content contained in these compounds on plants. According to the calculations made based on the NO_3-N values per L (the maximum value was measured as 7.9 mg NO_3-N L^{-1} in this study), it was observed that the nitrogen amount in the snow meltwaters was even below 5 mg L^{-1} which is a harmful ratio for sensitive plants in irrigation waters (Ayers & Westcot, 1985; Erdoğan & Dağdelen, 2012). In one study, it was reported that the SO_4 concentrations increased from 2 to 14 mg L^{-1} in the stream waters in the area during and immediately after the snow melts (Siegel, 1981). In another study, it was determined that the NO_3-N and SO_4 in rainwater were higher than those in snow melt (Pehlivan, 2016). The SO_4, which is less toxic than chlorine in irrigation waters, causes calcium to precipitate in high concentrations, causing plants not to get calcium (Arslan, Güler, Cemek, & Demir, 2007). For this reason, it is recommended that the SO_4 value in irrigation waters should not exceed 20 me L^{-1} (Ayers & Westcot, 1985).

Metal ions: Data on the metal ions from the st1, st2, and st5 are presented in Table 2. In this study, the snowmelt water was determined as being of a first class water quality level in terms of the Cd, As, Cu, Cr, Co, Fe, Mn, B, Se, Ba, Al, Na, Pb, Zn concentrations according to the SWRCR and the values of Be, Cd, Ni, V, K, Si did not exceed the limit values given for irrigation water (Anonymous, 2004; Erdoğan & Dağdelen, 2012; Smith, Oster, & Sposito, 2014; Horuz, 2016). The chloride and boron are most commonly ions to lead toxic hazard to the plants at higher than the critical levels which is 70 ppm for Cl and 0.7 ppm for Boron (Toor & Lusk, 2011). In this study, the boron values determined between 0.001 mg L^{-1} and 0.4 mg L^{-1} were found to be of a quality that can be used even for sensitive plants, and they were found in first class level irrigation water quality according to the Christiansen system (Erdoğan & Dağdelen, 2012). Although the values of Pb in st5 at January and Zn in st2 in December exceeded the first quality class levels at the SWRCR, these values were found at far below the toxic limits (5 mg Pb L^{-1} and 2 mg Zn L^{-1}) for the irrigation of plants (Anonymous, 2010; Erdoğan & Dağdelen, 2012). But, it was observed that the Mo value exceeded the limit value 0.01 mg L^{-1} (10 ppb) in January at the all sampling stations (Erdoğan & Dağdelen, 2012). It is reported that the high rates of molybdenum, which are effective on nitrogen fixation in soil, will decrease the nitrogen fixation of the plant (Vuralın & Müftüoğlu, 2012). When determining the quality of irrigation water for plants, the total salt concentration, the percentage of sodium and its relation to other cations, the amount of calcium and magnesium, as well as the Boron concentration, which has a significant impact on plants, are taken into consideration (Özer & Köklü, 2019). Also, the chloride values were found at <10 ppm. In one study it was reported that snow water is richer in terms of certain elements (Al, Ba, Cu, Pb, Mn, Ni, Si, U and Zn) than rainwater (Pehlivan, 2016). The reason for this can be considered as the release of major ions, trace metals and organic pollutants contained in snow masses into surface waters with melting of snow (Jeffries, 1990). This provides a reduction in pH, acid neutralisation capacity and base cations in surface waters, especially in spring (Jeffries, 1990).

While the ground of all the sampling stations was covered with mixed turfgrass, a total of 45 landscape plant species were determined in the study area and the species were separated to four groups: evergreen trees (ET) with 13 species, deciduous trees (DT) with 17 species, evergreen shrubs (ES) with 7 species, deciduous shrubs (DS) with 8 species (Table 3). The diversity of the landscape plant species in the sampling stations was determined as st5 > st1 > st4 > st3 and st6 > st2 (Figure 3). When the sampling stations were compared using the Bray-Curtis Cluster Analysis method in terms of the flora diversity they contain, it was found that the stations st5 and st1 were the most similar (58% similarity), and the stations st3 and st2 were completely different from each other (Figure 4).

CONCLUSION

When the results of the snowmelt water obtained in this study was compared with the quality levels in SWRCR of Turkey (Anonymous, 2004), it was found that it has a first class water quality level for a lot of parameters. Although the concentrations of some parameters (NO_2-N, NO_3-N, PO_4, Pb and Zn) in some sampling stations exceeded the first quality level, these concentrations were not found above the limit values for irrigation (Ayers & Westcot, 1985; Anonymous, 2004; Erdoğan & Dağdelen, 2012). It was observed that only the Mo values exceed the maximum limit for irrigation water in all of the sampling stations in January. It is known that this metal is used in the steel industry and it is an essential element for higher plants and its toxicity danger in plants is small (Anke & Seifert, 2007). The values of pH, conductivity, Na, K, Ca, Mg, total alkalinity, Cl,

Table 2. The metal ion concentrations of the sampling stations.

	December 2019			January 2020			February 2020		
ppb	**St1**	**St2**	**St5**	**St1**	**St2**	**St5**	**St1**	**St2**	**St5**
Cd	0.130	0.055	0.061	0.071	0.186	0.055	0.029	0.041	0.034
Pb	11.896	10.332	7.252	1.802	0.989	60.212	2.457	6.063	0.976
As	7.216	8.098	6.454	7.128	6.481	6.212	7.169	6.779	6.346
Cu	10.417	13.790	4.637	9.409	5.755	6.442	5.821	8.028	6.185
Cr	1.491	1.291	0.988	1.373	1.223	11.802	1.197	1.979	1.667
Co	0.697	0.366	0.112	0.133	0.083	0.249	0.093	0.155	0.093
Ni	3.212	4.346	0.928	4.728	6.947	9.987	1.917	4.730	1.082
Zn	106.133	479.764	34.642	32.730	27.409	95.441	15.394	115.643	36.786
Fe	129.516	70.380	47.394	137.653	43.797	98.284	46.238	93.089	108.955
Mn	11.250	4.784	3.314	4.180	3.036	6.900	3.486	5.547	2.929
B	5.335	2.613	40.884	5.941	9.572	11.934	3.253	4.301	1.121
Se	1.425	1.317	1.384	1.443	1.380	1.456	1.427	1.333	1.335
Ba	61.383	35.417	49.982	18.939	22.378	92.938	11.657	67.992	18.194
Al	113.568	68.127	59.135	104.826	68.458	115.820	31.908	64.013	71.233
Na	945.686	879.675	796.549	1309.536	1633.743	917.333	1006.926	974.995	568.483
Be	0.010	0.006	0.004	0.009	0.004	0.009	0.003	0.007	0.005
V	8.705	9.604	9.497	9.612	8.460	8.882	8.604	9.156	9.429
Mo	10.512	9.851	8.265	**45.291**	**135.339**	**23.146**	9.434	8.793	8.432
Si	187.114	193.613	149.674	132.112	99.013	184.270	117.322	151.785	211.288
K	374.463	214.730	234.453	555.872	256.899	239.428	347.163	361.952	242.486
Sr	7.451	5.288	3.829	6.680	8.933	14.336	5.157	7.880	4.079
Ag	1.959	2.355	1.427	1.594	1.498	2.507	28.641	46.106	17.009
Sb	0.228	0.149	0.121	0.139	0.148	0.177	0.156	0.134	0.118
Tl	0.007	0.005	0.004	0.005	0.003	0.005	0.002	0.004	0.003

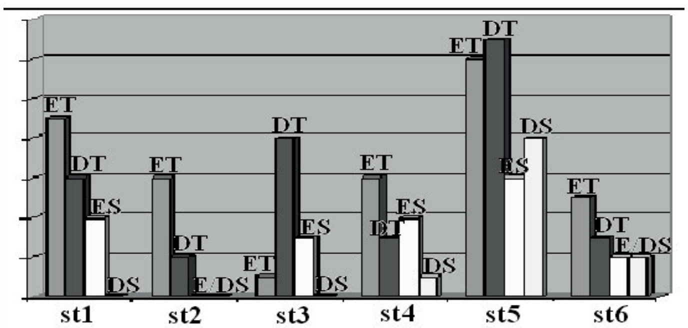

Figure 3. The distribution of landscape plants in the sampling stations.

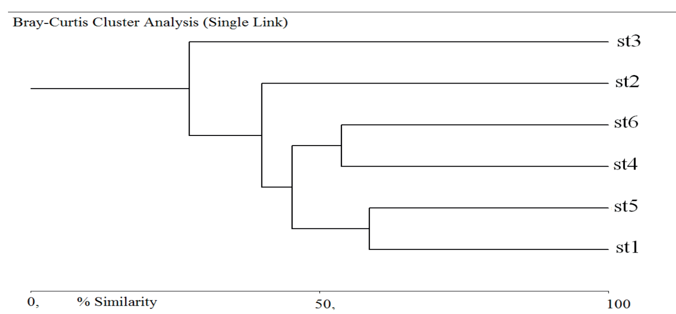

Figure 4. The similarities of the sampling stations according to the floral contents.

SO_4, total hardness, B and SAR are taken into consideration in determining the irrigation water quality (Ayers & Westcot, 1985; Anonymous, 2004; FAO, 2007; Hussain, Alquwaizany, & Al-Zarah, 2010; Erdoğan & Dağdelen, 2012). When the data obtained in this study were evaluated considering the mentioned parameters, it was determined to have a very good water quality in terms of Schofield classification system (Erdoğan & Dağdelen, 2012). Furthermore, according to the sodium diagram by Wilcox, the quality of the studied samples was found to be of S1 category (Hussain et al., 2010).

It has been observed that perennial woody plants are generally used as landscape plants in the study area. There is also mixed grass material in the study area and seasonal/sensitive cultivars are planted in these areas after the winter period. In this study, it was observed that some parameters exceeded the first class water quality level in the SWRCR (Anonymous, 2004). It is possible that these substances enter underground and surface water sources with the melting of snow and are to be used in the irrigation of sensitive plants to be planted in landscape areas after the winter period.

Table 3. The list of landscape plant species determining in the sampling stations.

Group	Species ↓ Stations→	st1	st2	st3	st4	st5	st6
Evergreen Trees (ET)	*Abies nordmanniana*		●		●	●	
	Aesculus hippocastanum	●				●	
	Cedrus libani	●			●	●	
	Cupressus arizonica	●	●			●	
	Platanus orientalis				●	●	●
	Populus alba	●	●			●	●
	Picea pungens	●				●	
	Picea orientalis	●	●		●		●
	Pinus nigra	●	●		●	●	●
	Pinus sylvestris				●	●	
	Quercus robur	●	●			●	
	Thuja occidentalis					●	●
	Thuja orientalis	●		●		●	
Deciduous Trees (DT)	*Acer negundo*		●			●	●
	Acer platanoides	●				●	
	Acer pseudoplatanus	●				●	
	Betula pendula					●	●
	Catalpa speciosa	●				●	
	Elaeagnus angustifolia				●	●	
	Fraxinus excelsior			●	●	●	
	Malus domestica					●	
	Malus floribunda			●		●	
	Morus alba	●		●		●	
	Morus platanifolia	●				●	
	Prunus cerasifera			●		●	
	Salix alba		●			●	
	Salix babylonica			●	●		●
	Syringa vulgaris			●			
	Tamarix tetrandra	●		●			
	Tilia tomentosa			●			
Evergreen Shrubs (ES)	*Ilex crenata*			●			
	Juniperus horizontalis	●			●	●	●
	Juniperus sabina			●	●	●	
	Photinia Serrulata	●		●		●	
	Prunus laurocerasus	●				●	
	Pyracantha coccinea	●			●	●	●
	Viburnum tinus				●	●	
Deciduous Shrubs (DS)	*Berberis thunbergii*					●	
	Cotoneaster horizontalis					●	
	Cydonia japonica					●	
	Ribes aureum					●	
	Rosa polyantha				●	●	●
	Spiraea vanhouttei					●	
	Viburnum opulus					●	●
	Vitex agnus-castus					●	

Consequently, the quality of snow meltwater was examined in the outdoor green areas of the Van province in this study. The obtained results showed that the snow meltwater were not at the concentrations that would cause negative effects on the landscape plants in the study area. It was thought that the high values encountered at some stations from time to time may be due to the atmosphere. It is recommended that snow water is also considered as an alternative irrigation source for outdoor green areas and should be monitored periodically.

Ethics committee approval: Ethics committee approval is not required.

Conflict of interests: The authors declare that they have no conflict of interest.

REFERENCES

Alp, Ş. (1999). Van kenti yeşil dokusuna yönelik bazı ağaç ve çalıların saptanması üzerine bir araştırma. *Van Yüzüncü Yıl University PhD Thesis.*

Anke, M. & Seifert, M. (2007). The biological and toxicological importance of molybdenum in the environment and in the nutrition of plants, animals and man. *Acta Biologica Hungarica*, *58*(3), 311-324. [CrossRef]

Anonymous (2004). Su Kirliliği Kontrol Yönetmeliği, Official Gazette No: 25687 of 31 December, Ankara. Retrieved from http://www.mevzuat.gov.tr (accessed 10.03.2020).

Anonymous (2010). Atıksu Arıtma Tesisleri Teknik Usuller Tebliği. TC. Çevre ve Orman Bakanlığı. Retrieved from http://www.resmigazete.gov.tr/eskiler/2010/03/20100320-7.Htm. (accessed 10.03.2020).

Arslan, H., Güler, M., Cemek, B. & Demir, Y. (2007). Bafra Ovası yeraltı suyu kalitesinin sulama açısından değerlendirilmesi. *Tekirdağ Ziraat Fakültesi Dergisi*, *4*(2), 219-226.

Aydın, F. (2017). Van Çaldıran ovası yüzey sularının içme ve sulama suyu açısından incelenmesi. *Journal of the Institute of Science and Technology*, *7*(3), 171-179. [CrossRef]

Ayers, R. S. & Westcot, D. W. (1985). *Water quality for agriculture*. FAO Irrigation and Drainage Paper, Rome. ISBN 92-5-102263-1

Cooper, E. J., Dullinger, S., & Semenchuk, P. (2011). Late snowmelt delays plant development and results in lower reproductive success in the High Arctic. *Plant Science*, *180*, 157-167. [CrossRef]

Demirkuş, N. (2019). The virtual herbarium of Lake Van Basin. Retrieved from http://Vanherbaryum.Yyu.Edu.Tr/İngindex.Htm (accessed 10.01.2020).

Erdoğan, N. & Dağdelen, E. (2012). Sulama Suyu Kalitesi. Retrieved from File:///C:/Documents%20and%20Settings/XP/Belgelerim/Downloads/Sulamasuyukalitesi-Son%20(1).pdf. (accessed 10.03.2020).

FAO (2007). *Handbook On Pressurized İrrigation Techniques*, Chapter 7: Water Quality For Irrigation, FAO, Rome, ISBN 978-92-5-105817-6

Galeczka, I., Sigurdsson, G., Eiriksdottir, E. S., Oelkers, E. H. & Gislason, S. R. (2016). The chemical composition of rivers and snow affected by the 2014/2015 Bárðarbunga Eruption, Iceland. *Journal of Volcanology and Geothermal Research*, *316*, 101-119. [CrossRef]

Hagen, A. & Langeland, A. (1973). Polluted snow in Southern Norway and the effect of the meltwater on freshwater and aquatic organisms. *Environmental Pollution*, *5*, 45-57. [CrossRef]

Horuz, A. (2016). Silisyumun bitki gelişimine olan etkileri. *Toprak Bilimi ve Bitki Besleme Dergisi*, *6*(2), 151-163.

Hussain, G., Alquwaizany, A. & Al-Zarah, A. (2010). Guidlines for irrigation water quality and water management in the Kingdom of Saudi Arabia: An Overview. *Journal of Applied Sciences*, *10*(2), 79-96. [CrossRef]

Jeffries, D. S. (1990). Snowpack storage of pollutants, release during melting, and impact on receiving waters. *Acidic Precipitation, 4*, 107-132. [CrossRef]

Johannessen, M. & Henriksen, A. (1978). Chemistry of snow meltwater: changes in concentration during melting. *Water Resources Research, 14*(4), 615-619. [CrossRef]

McAleece, N., Gage, J. D. G., Lambshead, P. J. D. & Paterson, G. L. J. (1997). Biodiversity Professional Statistic Analysis Software. Jointly Developed By The Scottish Association For Marine Science And The Natural History Museum London. Retrieved from https://www.sams.ac.uk/science/outputs/ (accessed 10.03.2020).

Özer, Ç. & Köklü, R. (2019). Aşağı Sakarya Nehri su kalitesinin sulama suyu açısından değerlendirilmesi. *Çoruh Üniversitesi Doğal Afetler Uygulama ve Araştırma Dergisi, 5*(2), 237-246. [CrossRef]

Pehlivan, R. (2016). Sarma Deresi Havzasındaki yağışın ayrışma ve su kalitesine etkisi, Düzce, Türkiye. *Jeoloji Mühendisliği Dergisi, 40*(1), 103-121. [CrossRef]

Rixen, C., Freppaz, M., Stoeckli, V., Huovinen, C., Huovinen, K. & Wipf, S. (2008). Altered snow density and chemistry change soil nitrogen mineralization and plant growth. *Arctic, Antarctic and Alpine Research, 40*(3), 568-575. [CrossRef]

Seven, T., Can, B., Darende, B. N. & Ocak, S. (2018). Hava ve toprakta ağır metal kirliliği. *Ulusal Çevre Bilimleri Araştırma Dergisi, 1*(2), 91-103.

Siegel, D. I. (1981). The effect of snowmelt on the water quality of Filson Creek and Omaday Lake, Northeastern Minnesota. *Water Resources Research*, Retrieved from https://doi.org/10.1029/WR017i001p00238. (accessed 10.03.2020). [CrossRef]

Smith, C. J., Oster, J. D. & Sposito, G. (2014). Potassium and Magnesium in irrigation water quality assessment. *Agricultural Water Management*, Retrieved from http://dx.doi.org/10.1016/J.Agwat.2014.09.003. (accessed 10.03.2020). [CrossRef]

Toor, G. S. (2009). Book review: Turfgrass and landscape irrigation water quality - assessment and management. *Journal of Environmental Quality, 38*(6), 2478-2478. [CrossRef]

Toor, G. S. & Lusk, M. (2011). Reclaimed water use in the landscape: understanding landscape irrigation water quality tests. *University of Florida, IFAS Extension, SL341*, 1-9. Retrieved from https://discover.pbcgov.org/coextension/horticulture/pdf/commercial/Understanding_reclaimed_tests.pdf (accessed 10.03.2020).

Van Loon, C. J. (1980). *Analytical Atomic Absorption Spectroscopy: Selected Methods*. Academic Press, ISBN:978-0-12-714050-6.

Vuralın, A. & Müftüoğlu, N. M. (2012). Farklı dozlarda uygulanan molibdenin bakla (*Vicia faba* L.) bitkisinin azot içeriğine etkisi. *Ege Üniversitesi Ziraat Fakültesi Dergisi, 49*(1), 53-62.

Welz, B. & Sperling, M. (1999). *Atomic Absorption Spectrometry*. Third Edition. WILEY-VCH Verlag GmbH, ISBN:9783527285716 [CrossRef]

Yeler, O. & Yeler, T. S. (2019). Van ili ekolojik koşullarında kullanılması uygun bazı dış mekân süs bitkilerinin bitki gruplarına göre genel özellikleri, *II. Int Sci and Acad Cong, Konya, Türkiye, 1*(14), 133-145.

Yücedağ, C. & Kaya, L. G. (2016). Hava kirleticilerin bitkilere etkileri. *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Dergisi, 7*(1), 67-74. [CrossRef]

İSTANBUL UNIVERSITY PRESS

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 85-88 • DOI: https://doi.org/10.26650/ASE2020742885

Short Comminication

The Northernmost Record of *Champsodon nudivittis* (Ogilby, 1895) in the Mediterranean Sea

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Cite this article as: Dalyan, C., Gonulal, O., Kesici, N.B., & Yapici, S. (2021). The northernmost record of *Champsodon nudivittis* (Ogilby, 1895) in the Mediterranean Sea. *Aquatic Sciences and Engineering, 36*(2), 85-88.

ABSTRACT

Champsodon nudivittis (Ogilby, 1895), also known as the nakedband gaper, is distributed in the Aegean and Levantine parts of the Mediterranean Sea. It has been reported in the Mediterranean Sea as a Red Sea immigrant. The first record of the species in the Mediterranean Sea was reported in 2009 from the Levantine coasts. In this study, two individuals of nakedband gaper were captured about two months apart from the north of Gokceada Island, in the North Aegean Sea. The specimens were obtained using a trawl at depths of 100-120 m. Their total lengths were measured as 117 and 122 mm. This report extends the distribution of *C. nudivittis* to the North Aegean Sea, marking its northernmost record in the Mediterranean Sea to date. Moreover, the species is the second Red Sea originated fish recorded in the area between Gokceada Island, Samothraki Island and Saros Bay. *C. nudivittis* is known as a predator, hence, its population density should be monitored and its impact on the ecosystem should be assessed in the North Aegean Sea.

Keywords: Champsodontidae, new record, Nakedband Gaper, North Aegean Sea, Turkey

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Submitted:
27.05.2020

Revision Requested:
09.07.2020

Last Revision Received:
29.07.2020

Accepted:
09.08.2020

Online Published:
05.02.2021

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INTRODUCTION

According to Nemeth (1994), the family Champsodontidae has one genus and thirteen species around the world. These fishes are known by their large mouths, laterally compressed bodies and small denticulate scales. They are originated from the Indo-Pacific oceans and their populations are concentrated around the tropical zone. Among them, *Champsodon nudivittis* (Ogilby 1895), *C. vorax* Günther, 1867 and *C. capensis* Regan, 1908 were reported in the Mediterranean Sea as Red Sea immigrants (Bariche, 2010; Çiçek & Bilecenoğlu, 2009; Dalyan et al., 2012). Finally, Stern et al. (2020) asserted that all of the recorded individuals belonged to *C. nudivittis* in the light of morphological and genetic data in the Mediterranean Sea. The Aegean and Levantine Seas represent the expanded range of the species in the Mediterranean Sea (Figure 1). All Mediterranean records of the nakedband gaper are listed in (Table 1).

Champsodon nudivittis is native to the Indo-West Pacific, and found in Madagascar, Indonesia, the Philippines, Australia and the Red Sea (Froese & Pauly, 2020; Goren et al., 2012). It is a bathypelagic species and found at depths between 0 – 716 m (Dalyan et al., 2012; Froese & Pauly, 2020). It is known as the deepest invasive fish that was recorded at a depth of 716 m, in the Mediterranean Sea (Dalyan et al., 2012).

Previously, the species has reached up to the Central Aegean Sea (Kebapçıoğlu & Dereli, 2016). And, the present report is related to the first record of *C. nudivittis* in the North Aegean Sea. Besides *Lagocephalus sceleratus* (Gmelin, 1789), which has also been recorded in this area (Katsanevakis et al., 2014), this report provides the second record of Red Sea immigrant fish species in the area between Gokceada Island, Samothraki Island and Saros Bay, which is a special zone due to its high biodiversity.

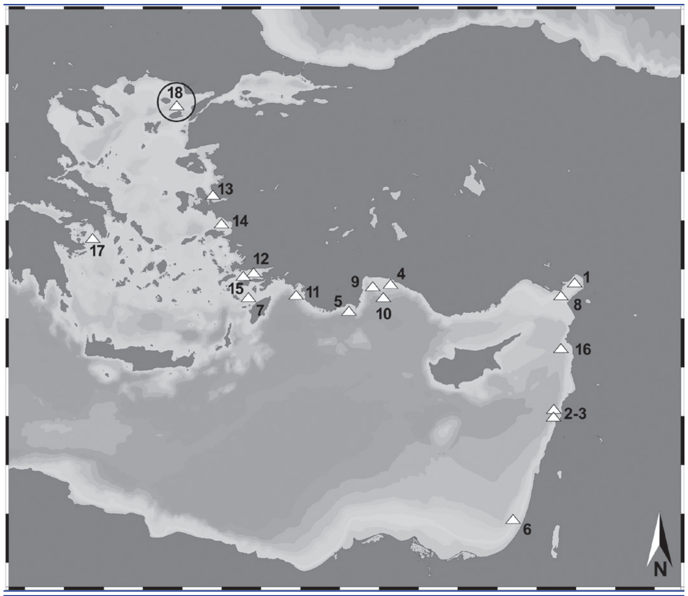

Figure 1. Distribution map of *C. nudivittis* in the Mediterranean Sea.

MATERIALS AND METHODS

On 12 November, 2019 and 5 January, 2020, two specimens of *C. nudivittis* were captured by trawl in the north of Gokceada Island, Turkey, in the North Aegean Sea at depths of 100-120 m (on a sandy-muddy bottom). The first individual was found at coordinates between 40°14′10″N;25°49′54″N and 40°13′58″N;25°48′06″E. The coordinate of the second specimen could not be recorded. The specimens were caught by the commercial vessel UĞUR REİS-3 (17 m, 500 HP). Morphological features were measured on the individuals using a digital caliper (nearest 0.01 mm).

The specimens were identified as *C. nudivittis* following Nemeth (1994) and Stern et al. (2020). The individuals were preserved in 50% ethanol solution and stored in the Istanbul University Science Faculty, Hydrobiology Museum (IUSHM 2019-1414, IUSHM 2020-1419).

RESULTS AND DISCUSSION

The captured specimens of the nakedband gaper, *C. nudivittis*, were 122 and 117 mm total length and they weighed 10 and 9 g respectively (Table 2). The specimens had the following features: Head length 3.6-3.7 times and body width 6.5-6.8 times the standard length, SL. Snout length 3.6-4.0 times and eye diameter 4.8-4.6 times the head length, HL. The body was well compressed. The maxilla extended beyond the eye, the chin was without scales and covered with melanophore spots. The breast was scaled.

All metric and meristic data, forming of the specialized scales, and color of the features individuals were consistent with Nemeth (1994) and Stern et al. (2020) and indicated the identification to be *C. nudivittis* (Figure 2). It is distinguished from its congenerics by having no scales on its chin while it has a restricted or wide scaled area on the pectoral. In the last decade, *C. nudivittis* have appeared to be the main subject of many articles with their high invasive characteristic in the Eastern Mediterranean Sea, and the common view is that the species entered the Mediterranean through the Suez Canal (Bariche, 2010; Çiçek & Bilecenoğlu, 2009; Dalyan et al., 2012). Moreover, *C. nudivittis* were reported in the Red Sea (Goren et al., 2014).

It is not surprising that the species that reach the maximum age early and have an r-selected life history, have opportunistic characters and will be invasive in their newly arrived areas. The maximum age of *C. nudivittis* is determined as two (Yağlıoğlu et al., 2014) and four (Demirci et al., 2016) in the Mediterranean. This can be considered as an advantage that strengthens the invasive character of the fish.

Table 1. Records of *C. nudivittis* in the Mediterranean Sea.

	Year	Locality	References
1	2009	Iskenderun Bay (Turkey) / Levantine Sea	Çiçek & Bilecenoğlu, 2009
2	2010	Coast of Baotrun (Lübnan) / Levantine Sea	Bariche, 2010
3	2011	Coast of Baotrun (Lübnan) / Levantine Sea	Bariche, 2011
4	2011	Gulf of Antalya (Turkey) / Levantine Sea	Gökoğlu et al., 2011
5	2011	Finike Bay (Turkey) / Levantine Sea	Erguden & Turan, 2011
6	2011	off Ashdod (Israel) / Levantine Sea	Goren et al., 2011
7	2012	North of Rodos (Greece) / Aegean Sea	Kalogirou and Corsini-Foka, 2012
8	2012	Iskenderun Bay (Turkey) / Levantine Sea	Dalyan et al., 2012
9	2013	Gulf of Antalya (Turkey) / Levantine Sea	Gökoğlu & Özvarol, 2013
10	2013	Gulf of Antalya (Turkey) / Levantine Sea	Gökoğlu & Özvarol, 2013
11	2014	Ekincik and Fethiye Bay (Turkey) / Aegean Sea	Filiz et al., 2014
12	2015	Gokova Bay (Turkey) / Aegean Sea	Akyol & Ünal, 2015
13	2015	Izmir Bay (Turkey) / Aegean Sea	Aydın & Akyol, 2015
14	2016	Kusadasi Bay (Turkey) / Aegean Sea	Kebapcioglu & Dereli, 2016
15	2016	Gokova Bay (Turkey) / Aegean Sea	Yapıcı et al., 2016
16	2017	off Jableh (Syria) / Levantine Sea	Ali et al., 2017
17	2019	Saronikos Gulf (Greece) / Aegean Sea	Kousteni & Christidis, 2019
18	2020	North of Gokceada Island (Turkey) / Aegean Sea	Present study

Table 2. Morphometric and meristic features of *C. nudivittis* in the north of Gokceada Island.

Measurement	Spc. 1	Spc. 2
Total length (mm)	122	117
Standard length (mm)	104	101
Body depth (mm)	16	14.9
Body width (mm)	11	10.5
Head length (mm)	29	27.4
Snout length (mm)	8	6.9
Eye diameter (mm)	6	5.9
Standard length/Head length	3.6	3.7
Standard length/Body depth	6.5	6.8
Head length/Snout length	3.6	4.0
Head length/Eye diameter	4.8	4.6
D1	V	V
D2	19(1)	19
A	17(1)	18
P	13	13

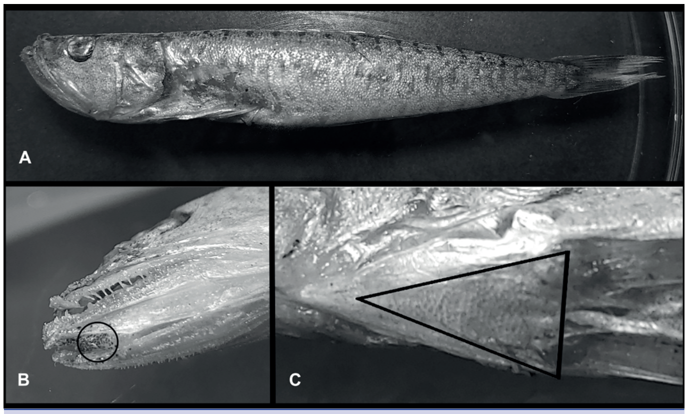

Figure 2. The whole body (A), chin (B) and breast (C) of the sampled specimen of *C. nudivittis* from the northwest of Gökçeada Island, Turkey.

CONCLUSION

This study provides the northernmost record of *C. nudivittis* in the Mediterranean Sea it is also the second documented Red Sea immigrant fish species to has been found in the area between Gokceada Island, Samothraki Island and Saros Bay. The population density of the fish should be monitored in the North Aegean Sea due to its high trophic level; besides its impact on the ecosystem should be assessed.

Conflict of interests: The authors have no conflicts of interest to declare.

Ethics committee approval: This study was conducted in accordance with ethics committee procedures of animal experiments.

Funding: This study was supported by the Research Fund of Istanbul University (Project No. FBA-2017-23597).

Acknowledgments: Authors wish to thank the crew of the UĞUR REİS-3 for their help with the samplings.

Disclosure: -

REFERENCES

Akyol, O. & Ünal, V. (2015). Occurrence of the Indo-Pacific *Champsodon nudivittis* (Perciformes, Champsodontidae) in the Bay of Gökova (Southern Aegean Sea, Turkey). *Turkish Journal of Fisheries and Aquatic Sciences, 15*(1), 187–190. [CrossRef]

Ali, M., Saad, A., Jabour, R., Rafrafi-Nouira, S. & Capapé, C. (2017). First record of nakedband gaper *Champsodon nudivittis* (Osteichthyes: Champsodontidae) off the Syrian Coast (Eastern Mediterranean). *Journal of Ichthyology, 57*, 161–163. [CrossRef]

Aydın, İ. & Akyol, O. (2015). First Record of an Indo-Pacific Gaper, *Champsodon vorax* (Actinopterygii: Perciformes: Champsodontidae), from the Aegean Sea, Turkey. *Acta Ichthyologica Et Piscatoria, 45*(2), 207–209. [CrossRef]

Bariche, M. (2010). *Champsodon vorax* (Teleostei: Champsodontidae), a new alien fish in the Mediterranean. *Aqua International Journal of Ichthyology, 16*(4), 197-200.

Bariche, M. (2011). First record of the cube boxfish *Ostracion cubicus* (Ostraciidae) and additional records of *Champsodon vorax* (Champsodontidae), from the Mediterranean. *Aqua, International Journal of Ichthyology, 17*(4), 181–184.

Çiçek, E. & Bilecenoğlu, M. (2009). A new alien fish in the Mediterranean Sea: *Champsodon nudivittis* (Actinopterygii: Perciformes: Champsodontidae). *Acta Ichthyologica et Piscatoria, 39*(1), 67-69. [CrossRef]

Dalyan, C., Yemişken, E. & Eryılmaz, L. (2012). A new record of gaper (*Champsodon capensis* Regan, 1908) in the Mediterranean Sea. *Journal of Applied Ichthyology, 28*(5), 834-835. [CrossRef]

Ergüden, D. & Turan, C. (2011). Occurrence of the nakedband gaper, *Champsodon nudivittis* (Ogilby, 1895) (Osteichthyes: Champsodontidae), in Finike Bay, eastern Mediterranean, Turkey. *Journal of Applied Ichthyology, 27*(6), 1397–1398. [CrossRef]

Filiz, H., Akçimar, S.C. & Irmak, E. (2014). Occurrence, length-weight and length-length relationships of *Champsodon nudivittis* (Ogilby, 1895) in the Aegean Sea. *Journal of Applied Ichthyology, 30*(2), 415–417. [CrossRef]

Froese, R, & Pauly, D. (2020). *FishBase, World Wide Web electronic publication*, Available from: http://www.fishbase.org, (03/2020).

Gökoğlu, M., Ünlüsayın, M., Balcı, B. A., Özvarol, Y. & Çolak, H. (2011). Two alien fish in the Gulf of Antalya: *Apogon queketti* Gilchrist, 1903 (Apogonidae) and *Champsodon nudivittis* (Ogilby, 1895) (Champsodontidae). *Zoology in the Middle East, 54*(1), 138–140. [CrossRef]

Gökoğlu, M. & Özvarol, Y. (2013). Additional Records of *Champsodon vorax* and *Champsodon capensis* (Actinopterygii: Perciformes: Champsodontidae) From The Eastern Mediterranean Sea. *Acta Ichthyologica Et Piscatoria, 43*(1), 79-82. [CrossRef]

Gören, M., Stern, N., Galil, B. S. & Diamant, A. (2011). On the occurrence of the Indo-Pacific *Champsodon nudivittis* (Ogilby, 1985) (Perciformes, Champsodontidae) from the Mediterranean coast of Israel, and the presence of the species in the Red Sea. *Aquatic Invasions 6*, 115–117. [CrossRef]

Gören, M., Ganga, U. & Jinesh, T. P. (2014). *Champsodon vorax* and *Champsodon nudivittis*, two new records from the north-eastern Arabian Sea (Perciformes, Champsodontidae). *Marine Biodiversity Records, 7*, 1-4. [CrossRef]

Kalogirou, S. & Corsini-Foka, M. (2012). First record of the Indo-Pacific *Champsodon nudivittis* (Ogilby, 1895) (Perciformes, Champsodontidae) in the Aegean waters (eastern Mediterranean Sea). *BioInvasions Records, 1*, 229–233. [CrossRef]

Katsanevakis, S., Ammar, I., Acar, U., Bekas, P., Balci, B. A., Belmonte, M., Chintiroglou, C. C., Consoli, P., Dimiza, M., Fryganiotis, K., Gerovasileiou, V., Gnisci, V., Gulsahin, N., Hoffman, R., Issaris, Y., Izquierdo-Gomez, D., Izquierdo-Munoz, A., Kavadas, S., Koehler, L., Konstantinidis, E., Mazza, G., Nowell, G., Onal, U., Ozen, M.R., Pafilis, P., Pastore, M., Perdikaris, C., Poursanidis, D., Prato, E., Russo, F., Sicuro, B., Tarkan, A.N., Thessalou-Legaki, M., Tiralongo, F., Triantaphyllou, M., Tsiamis, K., Tuncer, S., Turan, C., Turker, A., & Yapici, S. (2014). "New Mediterranean Biodiversity Records (October, 2014)". *Mediterranean Marine Science*, *15*, 675-695. [CrossRef]

Kebapçıoğlu, T. & Dereli, H. (2016). First record of gaper (*Champsodon capensis* Regan, 1908) in the Aegean Sea. *Mediterranean Marine Science*, *17*(3), 794-821.

Kousteni, V. & Christidis, G. (2019). Westward range expansion of the Indo-Pacific nakedband gaper *Champsodon nudivittis* (Ogilby, 1895) in Saronikos Gulf, Greece. *BioInvasions Records, 8*(1), 167-174. [CrossRef]

Nemeth, D. (1994). Systematics and distribution of fishes of the family Champsodontidae (Teleostei: Perciformes), with descriptions of three new species. *Copeia, 2*, 347–371. [CrossRef]

Yapici, S., Fricke, R. & Filiz, H. (2016). Champsodontids at the gates: first record of *Champsodon vorax* Günther, 1867 from the Aegean Sea (Teleostei: Champsodontidae). *Journal of Applied Ichthyology, 32*(1), 120-122. [CrossRef]

Yemişken, E., Dalyan, C. & Eryılmaz, L. (2014). Catch and discardfish species of trawl fisheries in the Iskenderun Bay (Northeastern Mediterranean) with emphasis on lessepsian and chondricthyan species. *Mediterranean Marine Science, 15*(2), 380-389. [CrossRef]

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 89-94 • DOI: https://doi.org/10.26650/ASE2020771666

Short Comminication

A Review on the Occurrence of the Blunthead Puffer, *Sphoeroides pachygaster* (Müller & Troschel, 1848) in the Mediterranean with a New Occurrence from Oran Bay (Western Algeria)

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Cite this article as: Hussein, K.B., Bensahla-Talet, L. & Chakouri, A. (2021). A review on the occurrence of the Blunthead puffer, *Sphoeroides pachygaster* (Müller & Troschel, 1848) in the Mediterranean with a new occurrence from oran bay (Western Algeria). *Aquatic Sciences and Engineering*, *36*(2), 89-94.

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Submitted:
20.07.2020

Revision Requested:
20.09.2020

Last Revision Received:
26.05.2020

Accepted:
23.09.2020

Online published:
05.02.2021

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ABSTRACT

The blunthead puffer, *Sphoeroides pachygaster* was first recorded in Algerian waters in 2009 from Annaba Gulf (Western Mediterranean) caught by a trawler at 150 m depth. Since then the records show there been no further observations in Algerian waters. In this paper, we report a new record of *S. pachygaster* from western Algerian coasts, eleven years after it was first recorded in Eastern Algeria. Two specimens were caught, the first by an angler in Bousfer beach on 25th January, 2020, measuring 360.6 mm TL and weighting 2250g and the second by trammel net in "Les Andalouses" bay measuring 409.5 mm TL and weighting 2420g. Accordingly, we describe biometrical and meristic characteristics, literature, databases and fish collections reviews of this Tetraodontidae, a species new to the Western Algerian fish fauna.

Keywords: Puffer, Blunthead, Tetraodontidae, Oran Bay, Algeria, Western Mediterranean

INTRODUCTION

Non-native fauna or flora are organisms found outside their known area of distribution in which the Mediterranean Sea is not part of their original distribution area (UNEP-MAP-RAC/SPA.2011). Marine environment is continuously assaulted by anthropic activities pressures namely habitat destruction, resources over-exploitation and climate change (Crain et al., 2008; Halpern et al., 2015). Occhipinti-Ambrogi & Galil (2010), stated that climate change on its own facilitates overcoming historic geographic barriers.

Blunthead *Sphoeroides pachygaster* is a marine benthopelagic species living in a depth between 50 and 480 m (Matsuura and Tyler, 1997) but usually lives between 50 and 250 m (Ragonese et al., 1992). Found in all oceans of central and temperate latitudes (Shipp, 1974 in Carpenter et al., 2016) it is also the most wide-ranging species in the genus Sphoeroides (Shipp, 2002). This family shares with its near relatives, the diodontidae, the ability to inflate, probably for protection from predation (Martin and Drewry,1978). It inhabits sandy, muddy and rocky bottoms (Schneider, 1990) and young specimens are pelagic (Robins and Ray, 1986). *S. pachygaster* feeds mainly on squid (Smith and Heemstra, 1986), cuttlefish, octopus, but also feeds on small bony fish (Psomadakis et al., 2008). Juveniles of *S. pachygaster* are known to be pelagic whereas adults prefer benthic habitats such as sandy, muddy, and rocky bottoms (Robins and Ray 1986; Tortonese, 1986). In general, Tetraodontidae are capable of inflating their abdomens with water when frightened or disturbed and are capable of producing and accumulating toxins such as tetrodotoxin and saxitoxin in the skin, gonads, and liver. The degree of toxicity varies by species, and also according to geographic area and season (Allen and Erdmann, 2012). Noguchi and Arakawa (2008) consider blunthead puffer as weakly toxic while in the Mediterranean, it is considered non-toxic (Ragonese and Morara 2012). Little is known about reproduction and other life history aspects of this species.

Sphoeroides pachygaster is not directly targeted by fishing gears but can be a by-catch of semi-industrial fishing, purse seines, trawls, gillnets, bottom longlines, drifting longlines. Shao et al., (2014) stated that it is a least concern species on the IUCN Red List (ver 3.1) and that although it may be subject to high discard mortality when taken as bycatch in some fisheries, there do not appear to be any major threats and there are no recorded population declines.

A review of available literature showed that a reduced number of articles dealt with this Tetraodontidae: Ishizaki et al., (2006); Vella et al., (2017) on molecular identification, Carlucci et al., (2019) on isolation of glycoconjugates, Nagashima et al., (2018) on toxicity, Ragonese and Morara (2012); Peatman et al., (2017) on bycatch; Cammilleri et al., (2019) on parasites. The remaining available documentation focused on occurrence all around the world: Wirtz et al., (2017) in Ascension Island (South Atlantic Ocean); Sampaio et al., (2001) in Brazilian waters; Gilhen et al., (1985) in Canadian waters; Hanel and John, (2014) in Cape Verde islands; Quero et al., (1991; 1998); Bearez et al., (2017) in Atlantic French waters; Wheeler and Van Oijen, (1985); Quigley and Flannery, (1992; 2004) in Irish waters; Shinohara et al., (2009, 2011, 2014) in Japanese waters; Duffy and Ahyung, (2015) in New Zealander waters; Okan and Aydın, (2017) in Turkish waters; Edwards and Glass, (1987) in Saint Helena Island (South Atlantic Ocean).

In the Mediterranean basin, the first occurrence of this Tetraodontidae was observed for the first time in 1979 (Oliver, 1981) near the Balearic Islands, since then the blunthead puffer has spread through the western Mediterranean as a new environment; in the western basin it was recorded first in the early '90s in Tunisian waters Bradai et al., (1993) then in Algerian waters Hemida et al., (2009). in central Mediterranean, it was recorded first in Italian waters Tursi (1992); then in Croatian waters Dulcic (2002); Slovenian waters Lipej et al., (2013) and Libyan waters Shakman et al., (2017). The occurrence of *S. pachygaster* in eastern Mediterranean was noticed lately, first in Turkish waters Erilmaz et al., (2003); then in Greek waters Peristeraki et al., (2006); in Syrian waters Rahman et al., (2014); Egyptian Farrag et al., (2016) bottom trawl; and Lebanese waters Crocetta and Bariche in Gerovasileiou et al., (2017). Except observation of Hemida et al., (2009), in eastern Algeria (Annaba) up to date, no works or new occurrences were reported on this Tetraodontidae for Algerian water this last decade.

Here, we report the first confirmed record of the blunthead, *Sphoeroides pacygaster* from the Oran shoreline and the second for Algerian waters. This record is also an additional data for the entire Mediterranean basin to help with monitoring and managing invasive species newly established.

MATERIALS AND METHODS

On January 25th, 2020 a blunthead puffer (Fig.1) was caught by an angler in Bousfer Beach (35°43'33.1"N 0°50'56.5"W) at 300 m from the shoreline at a depth of 10 m using squid as bait. The second specimen was caught on May 5th, 2020 in "les Andalouses" Bay (35°45'36.1"N 0°53'58.7"W) by trammel net at 120 m depth but the specimen was in a deteriorated (dried out) condition. The two fishermen reported the specimens and donated them to our team composed of researchers from university Oran1 Ahmed BENBELLA and marine ecology association members (BARBAROUS). Morphometric and meristic characteristics were taken.

Figure 1. Caught specimen of *Sphoeroides pachygaster* reported in this study (36.06 cm TL) caught in Oran Bay, Algeria (Photographed by L. Bensahla-Talet).

Measures were carried out using a caliper to the nearest 0.01 mm. Three meristic characters and thirteen morphometric characteristics (Fig.2) were measured: total length TL; standard length SL; preocular POD1; eye diameter ED; post ocular POD2 distance; post ocular POD3 distance; dorsal fin length DFL; pectoral fin length PFL; Inter orbital distance (IOD); Body thickness (BT); maximum body height Hmax; minimum body height Hmin; Caudal width (CFW).

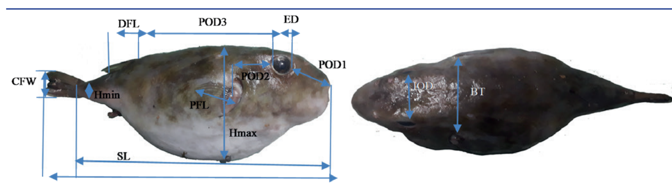

Figure 2. Morphometric measurements of the blunthead puffer *Sphoeroides pachygaster* caught in Bousfer Beach.

RESULTS AND DISCUSSION

Specimen morphological characteristics were in accordance with those described by Shipp (1974) for blunthead *Sphoeroides pachygaster*, the body was entirely smooth; pigmentation mostly uniformed, except for a few dark spots on the flanks. Also, this species differs from other species of Sphoeroides genus by having no spinules or spines on the body. Morphometric measurements are presented in Table 1.

Table 1. Morphometric (in cm) and meristic characters of analyzed specimen of blunt head *Sphoeroides pachygaster* from the western Algerian costs (Oran Bay).

Measurements	Length (mm)	% of TL	Length (mm)	% of TL
Total length (TL)	384.00	100.00	409.50	100.00
Standard length (SL)	342.40	89.17	356.40	8.70
Preorbital distance (POD1)	55.78	14.53	54.92	1.34
Eye diameter (ED)	23.60	6.15	24.40	0.60
Post orbital distance (POD2)	43.42	11.31	39.41	0.96
Post orbital distance (POD3)	178.28	46.43	187.84	45.87
Inter orbital distance (IOD)	66.40	17.29	55.65	13.59
Body thickness (BT)	115.34	30.04	104.06	25.41
Pectoral fin length (PFL)	51.29	13.36	62.70	15.31
Dorsal fin length (DFL)	36.98	9.63	24.04	5.87
Hmax	126.03	32.82	113.6	27.74
Hmin	15.94	4.15	17.56	4.29
Caudal fin width (CW)	57.26	14.91	55.21	13.48
Meristic characters				
Dorsal fin rays		8		
Anal fin rays		8		
Pectoral fin rays		14		

Streftaris and Zenetos (2006) included *Sphoeroides pachygaster* in the list of the 100 "Worst Invasives" in the Mediterranean coming from the Atlantic Ocean; characterized by a fast spread (Ragonese et al., 1997; Psomadakis et al., 2008; Lipej et al., 2013). In the Mediterranean basin, the first occurrence of this Tetraodontidae was observed for the first time in 1979 (Oliver, 1981) near the Balearic Islands, since then the blunthead puffer has spread through the western Mediterranean as a new environment; in the western basin it was recorded first in the early '90s in Tunisian waters Bradai et al., (1993) then Cherif et al., (2010); Enajjar et al., (2015) then in Algerian waters Hemida et al., (2009).

The majority of records concerning this invasive species (Figure 3) were made in central Mediterranean, first in Italian waters Tursi (1992); Arculeo and Riggio (1994); Ragonese et al., (1997); Bedini (1998); Ligas et al., (2007); Psomadakis et al., (2008); Giordano et al., (2012); Carbonara et al., (2017) then in Croatian waters Dulcic (2002); Slovenian waters Lipej et al., (2013) and Libyan waters Shakman et al., (2017) but established population seems to be concentrated between Italian waters and Malta (Ragonese et al., 1997; Sciberras and Schembri 2007; Ragonese and Morara 2012; Evans et al., 2015).

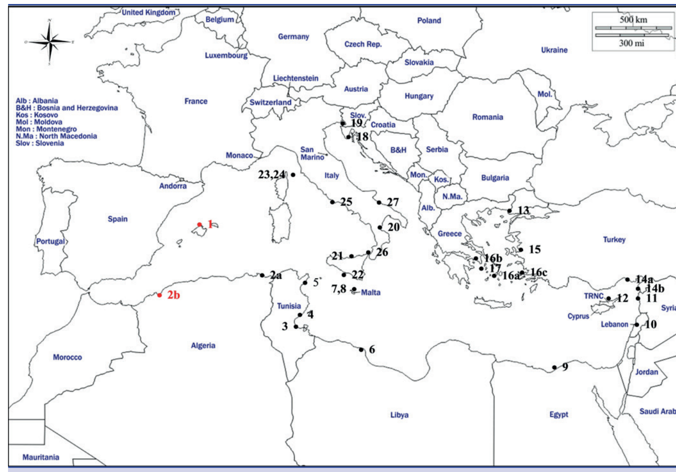

Figure 3. Map showing countries in the Mediterranean Sea where Blunthead *Sphoeroides pachygaster* has been recorded (1-first record in the Mediterranean, 2b-new record in Oran Bay in red). (d-maps.com©2020 adapted). 1) Oliver,1981, 2a) Hemida et al.,2009, 2b) Present study, 3) Bradai et al., 1993, 4) Cherif et al., 2010, 5) Enajjar et al., 2015, 6) Shakman et al., 2017, 7) Sciberras and Schembri, 2007, 8) Evans et al., 2015, 9) Farrag et al 2016, 10) Crocetta et al 2017, 11) Rahman et al., 2014, 12) Ioannou et al 2009 in Katsanevakis et al., 2009, 13) Erilmaz et al., 2003, 14a) Erguden et al in Elefteriou et al., 2011, 14b) Erguden et al in Elefteriou et al., 2011, 15) Akyol and Aydin 2017, 16a) Peristeraki et al 2006, 16b) Peristeraki et al 2006, 16c) Peristeraki et al 2006, 17) Dailanis et al., 2016, 18) Dulcic,2002, 19) Lipej et al.,2013, 20) Tursi,1992, 21) Arculeo and Riggio,1994, 22) Ragonese et al., 1997, 3) Bedini, 1998, 24) Ligas et al 2007, 25) Psomadakis et al., 2008 , 26) Giordano et al 2012, 27) Carbonara et al., 2017.

The occurrence of *S. pachygaster* in eastern Mediterranean was noticed lately, first in Turkish waters Erilmaz et al., (2003); Erguden et al in Elefteriou et al., (2011); Akyol and Aydin (2017), then in Syrian waters Rahman et al., (2014); Greek waters Peristeraki et al., (2006); Dailanis et al., (2016); Egyptian Farrag et al., (2016); and Lebanese waters Crocetta and Bariche in Gerovasileiou et al., (2017). Except observation of Hemida et al., (2009), up to date, no works or new occurrence were reported on this Tetraodontidae for Algerian waters.

In a recent study, Kleitou et al., (2020) noticed that a large number of pufferfish species (Diodontidae and Tetraodontidae) have invaded or expanded their ranges in the Mediterranean Sea. Golani et al., (2002) supported the hypothesis that the blunthead puffer entered the Mediterranean from the Atlantic Ocean via Gibraltar Strait given that most of the records were recorded from the western and central Mediterranean regions. Coll et al., (2010) characterized the semi-enclosed Mediterranean Sea as a basin "under siege" at the forefront of ecosystem alterations, facing human pressures. The spread of non-indigenous species these last year's causes an increasing impact over time, resulting in changes in trophic flows, interactions between native and non-indigenous species and biodiversity loss and/or changes (Galil, 2007; Corrales, 2019).

Global warming was already mentioned in several regions of the world (Walther et al., 2002; Parmesan, 2006; González-Lorenzo et al., 2013). Santos et al., (2012) observed a change in species distribution around the Canary Islands related to an increase in sea surface temperature (SST) this thirty years with records of temperatures over 24 °C. in the Mediterranean basin. Moullec et al., (2016) concluded the same phenomenon and deducted that temperature has a major direct effect on the physiology, growth, reproduction, recruitment and behavior of poikilothermic organisms such as fish. It is clear that the warming of the Mediterranean Sea nowadays affects the fitness of marine biota as already shown by records of changes in abundance, survival, fertility, phenology and the most important species migration (Quero et al., 1998, Dulčić 2002, Marbà et al., 2015). Data available from online biogeographic information databases contain between 2,435 (GBIF,2020) and (OBIS,2020) 2900 georeferenced records with a majority around the Australian continent and Eastern Atlantic which let us suppose that migration of this invasive species initiated from the West African coastline to reach the Mediterranean basin.

CONCLUSION

We concluded that citizens have contributed and still contribute to the detection of non-indigenous species in Algerian waters via social media as it is the case of our study which is an efficient tool already tried in other regions of the Mediterranean (Giovos et al., 2019; Kleitou et al., 2019; Kousteni et al., 2019). We believe that eco-citizen concept coupled with NGO efforts can surely contribute to enrich future databases of alien marine species and cover all Algerian coastline to detect, manage and monitor this biological invasion harmful to aquatic biodiversity.

Conflict of interests: There are no conflicts of interest to declare.

Ethics committee approval: Ethics committee approval is not required.

Funding: -

Acknowledgments: The authors are grateful to the anonymous angler in "Bousfer" and fisherman in "les Andalouses" beaches who made the specimens available for us.

Disclosure: -

REFERENCES

Akyol, O. & Aydın, I. (2017). Occurrence of blunthead After *Sphoeroides pachygasyer* (Müller and Troschel, 1848) Tetraodontidae in north eastern Aegean Sea, Izmir Bay, Turkey. *Journal of Applied Ichthyology, 33*, 524-526 pp. [CrossRef]

Allen, G. R. & Erdmann, M. V. (2012). *Reef fishes of the east indies*. Tropical Reef Research, Perth, Australia.

Arculeo, M., Riggio, S., & D'anna, G. (1994). First record of *Sphoeroides pachygaster* (Tetraodontidae) in the south Tyrrhenian (N/W Sicily). Cybium (Paris), *18*(2), 209-210.

Bazairi, H., Sghaier, Yr, Benamer, I., Langar, H., Pergent, G., Bouras, E., Verlaque, M., & Zenetos, A. (2013). Alien marine species of Libya: first inventory and new records in El-Kouf national park (Cyrenaica) and the neighbouring areas. *Mediterranean Journal of Marine Science, 14*(2): 224-237. [CrossRef]

Bearez, P., Pruvost, P., Feunteun, E., Iglesias, S., Francour, P., Causse, R., & Bailly, N. (2017). Checklist of the marine fishes from metropolitan France. *Cybium, 4*, 351-371.

Bedini, R. (1998). First record of *Sphoeroides pachygaster* (Tetraodontidae) from the northern Tyrrhenian Sea. *Cybium* (Paris), *22*(1), 94-96.

Bradai, M. N., Ghorbel, M., Bouain, A. (1993). Premières observations dans le golfe de Gabès (Tunisie) de Sphoeroides cutaneus (Tétraodontidae). *Cybium, 17*(1), 86.

Cammilleri, G., Graci, S., Buscemi, M. D., Collura, R., Costa, A., Dico, G. M. L., & Cumbo, V. (2019). New report of Anikasis larvae from Blunthead Puffer, *Sphoeroides pachygaster* caught off Strait of Sicily. *Biodiversity Journal, 10*(4): 475–478. [CrossRef]

Carbonara, P., Kolitari, J., Đurović, M., Gaudio, P., Ikica, Z., Kroqi, G., & Spedicato, M. T. (2017). The presence of Tetraodontidae species in the Central Mediterranean: an update from the southern Adriatic Sea. Acta Adriatica: *International Journal of Marine Sciences, 58*(2), 325-336. [CrossRef]

Carlucci, R., Mentino, D., Semeraro, D., Ricci, P., Sion, L., & Scillitani, G. (2019). Comparative histochemical analysis of intestinal glycoconjugates in the blunthead pufferfish *Sphoeroides pachygaster* and grey triggerfish Balistes capriscus (Teleostei: Tetraodontiformes). *Journal of Fish Biology, 94*(1), 122-131. [CrossRef]

Cherif, M., Amor, M. M. B, Bdioui, M., Salem, S. B., & Missaou, H. (2010). Additional records of the Blunthead Puffer, *Sphoeroides pachygaster* (Osteichthyes: Tetraodontidae) off the Tunisian coast (central Mediterranean). *Annales, Series Historia Naturalis, 20*(1): 33-36.

Crain, C. M., Kroeker, K., & Halpern, B. S. (2008). Interactive and cumulative effects of multiple human stressors in marine systems. *Ecology Letters, 11*(12), 1304-1315. [CrossRef]

Dailianis, T., Akyol, O., Babali, N., Bariche, M., Crocetta, F., Gerovasileiou, V., & Julian, D. (2016). New mediterranean biodiversity records (July 2016). *Mediterranean Marine Science, 17*(2), 608-626. [CrossRef]

Duffy, C. A., & Ahyong, S. T. (2015). Annotated checklist of the marine flora and fauna of the Kermadec Islands Marine Reserve and northern Kermadec Ridge, New Zealand. *Bulletin of the Auckland Museum, 20*, 19-124

Dulčić, J. (2002). Northernmost occurrence of *Sphoeroides pachygaster* (Tetraodontidae) in the Adriatic Sea. *Bulletin of Marine Science, 70*(1): 133-139.

Edwards, A. J., & Glass, C. W. (1987). The fishes of Saint Helena Island, South Atlantic Ocean: I. The shore fishes. *Journal of Natural History, 21*(3), 617-686. [CrossRef]

Enajjar, S., Hamida, N. B. H., Saadaoui, A., & Bradaï, M. N. (2015). New data on puffer fish species (Osteichthyes: Tetraodontidae) occurring in Tunisian waters (central Mediterranean Sea). *Marine Life, 18*, 33-41.

Erguden, D., Eleftheriou, A., Anagnostopoulou–Visilia, E., Anastasopoulou, E., Ates, A. S., Bachari, N. E. I., Cavas, L., & Derici, O. B. (2011). New mediterranean biodiversity records (December 2011). *Mediterranean Marine Science, 12*(2), 491-508. [CrossRef]

Eryılmaz, L., Özuluğ, M., & Meriç, N. (2003). The Smooth Pufferfish, *Sphoeroides pachygaster* (Müller & Troschel, 1848) (Teleostei: Tetraodontidae), new to the Northern Aegean Sea. *Zoology in the Middle East, 28*(1), 125-126. [CrossRef]

Evans, J., Barbara, J., & Schembri, P. J. (2015). Updated review of marine alien species and other 'newcomers' recorded from the Maltese Islands (Central Mediterranean). *Mediterranean Marine Science, 16*(1), 225-244. [CrossRef]

Farrag, M., El-Haweet, A. A., & Moustafa, M. A. (2016). Occurrence of puffer fishes (Tetraodontidae) in the eastern Mediterranean, Egyptian coast-filling in the gap. *BioInvasions Record, 5*(1). [CrossRef]

Figueiredo, J. L., Santos, A. P. D., Yamaguti, N., Bernardes, R. Á., & Wongtschowski, C. L. D. B. R. (2002). Peixes da Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil: levantamento com rede de meia água. São-Paulo: Editora da Universidade de São Paulo; Imprensa Oficial do Estado, 242 p.

GBIF. (2020) Secretariat. *Sphoeroides pachygaster* (Müller & Troschel, 1848) in GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-04-23.

Gerovasileiou, V., Akel, E. K., Akyol, O. K. A. N., Alongi, G., Azevedo, F., Babali, N., & Chintiroglou, C. C. (2017). New Mediterranean Biodiversity Records (July, 2017). *Mediterranean Marine Science, 18*(2), 355-384. [CrossRef]

Gilhen, J., Gruchy, C. G., & McAllister, D. E. (1985). The blunthead puffer, *Sphoeroides pachygaster* (Muller and Troschel, 1848) (Pisces: Tetraodontidae) new to Nova Scotia and Canada.

Giordano, D., Profeta, A., Pirrera, L., Soraci, F., Perdichizzi, F., Greco, S., & Rinelli, P. (2012). On the occurrence of the blunthead puffer, *Sphoeroides pachygaster* (Osteichthyes: Tetraodontidae), in the Strait of Messina (Central Mediterranean). Journal of Marine Biology, 2012. [CrossRef]

González-Lorenzo, G., González Jiménez, J. F., Brito, A. & González, J. A. (2013). The family Bramidae (Perciformes) from the Canary Islands (northeastern Atlantic Ocean), with three new records. *Cybium, 37*(4): 295-303.

Halpern, B. S., Frazier, M., Potapenko, J., Casey, K. S., Koenig, K., Longo, C., & Walbridge, S. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications, 6*(1), 1-7. [CrossRef]

Hanel, R., & John, H. C. (2014). A revised checklist of Cape Verde Islands sea fishes. Journal of Applied Ichthyology, *J Appl Ichthyol*, 1–35. [CrossRef]

Hemida, F., Ben Amor, M. M., & Capapé, C. (2009). First confirmed record of the blunthead puffer, *Sphoeroides pachygaster* (Osteichthyes: Tetraodontidae) off the Algerian coast (south-western Mediterranean). *Pan-American Journal of Aquatic Sciences, 4*(2), 188-192.

Ioannou et al., 2009 in Katsanevakis, S., Tsiamis, K., Ioannou, G., Michailidis, N., & Zenetos, A. (2009). Inventory of alien marine species of Cyprus (2009). *Mediterranean Marine Science, 10*(2), 109-134. [CrossRef]

Ishizaki, S., Yokoyama, Y., Oshiro, N., Teruya, N., Nagashima, Y., Shiomi, K., & Watabe, S. (2006). Molecular identification of pufferfish species using PCR amplification and restriction analysis of a segment of the 16S rRNA gene. Comparative Biochemistry and Physiology Part D: *Genomics and Proteomics, 1*(1), 139-144. [CrossRef]

Katsanevakis, S., Tsiamis, K., Ioannou, G., Michailidis, N., & Zenetos, A. (2009). Inventory of alien marine species of Cyprus. *Mediterranean Marine Science, 10*(2), 109-134. [CrossRef]

Kleitou, P., Giovos, I., Antoniou, C., Ioannou, G., & Bernardi, G. (2020). The third record of black-spotted porcupinefish *Diodon hystrix* Linnaeus, 1758 in the Mediterranean Sea. *Journal of Applied Ichthyology, 36*(2), 227-230. [CrossRef]

Ligas, A., Sartor, P., Sbrana, M., Sirna, R., & De Ranieri, S. (2007). New findings of Fistularia commersonii Rüppell, 1835 and *Sphoeroides pachygaster* (Müller & Troschel, 1848) in the northern Tyrrhenian Sea. *Atti della Società Toscana di Scienze Naturali Memorie, Serie B, 114*, 131-133.

Lipej, L., Mavric, B., & Paliska, D. (2013). New Northernmost Record of The Blunthead Pufferfish, *Sphoeroides Pachygaster* (Osteichthyes: Tetraodontidae) In The Mediterranean Sea/Nuova Segnalazione A Nord Del Pesce Palla Liscio, *Sphoeroides pachygaster* (Osteichthyes: Tetraodontidae), Nel Mare Mediterraneo. In Annales: Series Historia Naturalis (Vol. 23, No. 2, p. 103). Scientific and Research Center of the Republic of Slovenia.

Marbà, N., Jordà, G., Agustí, S., Girard, C. & Duarte, C. M. (2015). Footprints of climate change on Mediterranean Sea biota. *Front Mar Sci, 2*, 56. [CrossRef]

Martin, F. D., & Drewry, G. E. (1978). Development of Fishes of the Mid-Atlantic Bight. Volume VI. Stromateidae through Ogcocephalidae. US Department of the Interior, Fish and Wildlife Service, Biological Services Program. FWS/OBS-78/12.

Matsuura, K. & Tyler, J. C., (1997). Tetraodontiform fishes, mostly from deep waters, of New Caledonia. p.173-208. In Séret B. (ed.) Paris 1997. Résultats des Campagnes MUSORSTOM, vol. 17. no.9. Mem. Mus. Natl. Hist. Nat. MNHN (Mémoires du Muséum National d'Histoire Naturelle. Zoologie), 174, 215 p 174.

Moullec, F., Ben Rais Lasram, F., Coll, M., Guilhaumon, F., Halouani, G. & Hattab, T. (2016). Climate change impacts on marine resources: From individual to ecosystem responses in The Mediterranean Region under Climate Change: A Scientific Update IRD Éditions/AllEnvi (2016) *Marseille, 2*(1.3): 229-248. [CrossRef]

Müller, J. P., & Troschel, F. H. (1848). Pachygaster, Tetrodon (Cheilichthys) in Schomburgk, R. H. 1848. The history of Barbados; comprising a geographical description of the island and an account of its geology and natural productions. London. i-xx + 1-722, 7 pls. [Fishes are on pp. 664-678. Reprinted as Schomburgk, R. H., 1848. Ann. Mag. Nat. Hist., ser. 2, v. 2 (no. 7):11-20.]

Nagashima, Y., Ohta, A., Yin, X., Ishizaki, S., Matsumoto, T., & Ishibashi, T. (2018). Difference in uptake of tetrodotoxin and saxitoxins into liver tissue slices among pufferfish, boxfish and porcupinefish. *Marine Drugs, 16*(1), 17. [CrossRef]

Noguchi, T., & Arakawa, O. (2008). Tetrodotoxin–distribution and accumulation in aquatic organisms, and cases of human intoxication. *Marine Drugs, 6*(2), 220-242. [CrossRef]

OBIS. (2020). Distribution records of *Sphoeroides pachygaster* (Müller & Troschel, 1848). Ocean Biogeographic Information System. Intergovernmental Oceanographic Commission of UNESCO. accessed via www.iobis.org on 2020-04-23.

Occhipinti-Ambrogi, A. & Galil, B. (2010). Marine alien species as an aspect of global change. *Adv. Oceanogr. Limnol, 1*(1), 199-218. [CrossRef]

Parmesan, C. (2006). Ecological and evolutionary responses to recent climate change. *Annu Rev Ecol Evol Syst, 37*(2006), pp. 637–669. [CrossRef]

Peatman, T., Allain, V., Caillot, S., Williams, P., & Smith, N. (2017). Summary of purse seine fishery bycatch at a regional scale, 2003–2016. In 13th Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC13, Rarotonga, Cook Islands (pp. 9-17).

Peristeraki, P., Lazarakis, G., Skarvelis, C., Georgiadis, M., & Tserpes, G. (2006). Additional records on the occurrence of alien fish species in the eastern Mediterranean Sea. *Mediterranean Marine Science, 7*(2), 61-66. [CrossRef]

Psomadakis, P., Ceddia, P., & Vacchi, M. (2008). Additional record of *Sphoeroides pachygaster* (Pisces: Tetraodontidae) in the Tyrrhenian Sea and notes on the distribution of the species in the Mediterranean. Marine Biodiversity Records, 1, E18. [CrossRef]

Quero, J. C., Du Buit, M. H., Fonteneau, J., Kergoat, B., & Vayne, J. J. (1991). Premières observations dans les ports français de *Sphoeroides pachygaster* (pisces, tetraodontiformes, tetraodontidae), capturés au nord de leur aire de répartition connue. In Annales de la Société des Sciences Naturelles de la Charente-Maritime (Vol. 7, No. 9, pp. 1059-1063). Société des Sciences Naturelles de la Charente-Maritime. [CrossRef]

Quero, J. C., Du Buit, M. H., & Vayne, J. J. (1998). Les observations de poissons tropicaux et le réchauffement des eaux dans l'Atlantique européen. Oceanologica acta, 21(2), 345-351. [CrossRef]

Quigley, D. T. G., & Flannery, K. (1992). Further specimens of blunt head puffer fish *Sphoeroides pachygaster* Muller & Troschel 1848 (*S. cutaneus* Gunther 1870) from Irish waters. *The Irish Naturalists' Journal*, *24*(4), 155-157.

Quigley, D. T. G., & Flannery, K. (2004). Blunt Head Puffer Fish *Sphoeroides pachygaster* Muller & Troschel, 1848. *The Irish Naturalists' Journal, 27*(10), 408-409.

Ragonese, S., Rivas G. & Jereb, P. (1992). Spreading of puffer *Sphoeroides cutaneus* Günther, 1870 (Pisces, Tetraodontidae) in the Sicilian Channel. Is it an exploding population?. *Rapp Comm Int Mer Méditerr, 33*, 308.

Ragonese, S., Jereb, P., & Morara, U. (1997). Morphometric relationships of *Sphoeroides pachygaster* (Pisces-Tetraodontidae) of the strait of sicily (Mediterranean Sea). Cahiers de Biologie marine, 38(4), 283-290. Ragonese, S and Morara U. 2012. Evidence of short-term discard mortality of trawled *Sphoeroides pachygaster* (Osteichthyes, Tetraodontidae) off the southern coast of Sicily (Central Mediterranean Sea). *Pan-American Journal of Aquatic Sciences, 7*(2):73-76

Rahman, W. A., Galiya, M., & Ali, A. K. (2014). First record of the blunthead puffer *Sphoeroides pachygaster* (Osteichthyes: Tetraodontidae) in Syrian marine waters (eastern Mediterranean). Marine Biodiversity Records, 7. [CrossRef]

Robins, C. R. & G. C. Ray, (1986). A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A. 354 p.

Sampaio, C. L. S., Lopes, P. R. D., & Olavo, G. (2001). Registros de *Lagocephalus lagocephalus* (linnaeus, 1758) e *Sphoeroides pachygaster* (Müller & Troschel, 1848) (actinopterygii: tetraodontidae) para o litoral da bahia, nordeste do Brasil. *Interciencia*, *26*(4), 157-160.

Santos, F., Decastro, M., Gómez-Gesteira, M. & Álvarez, I. (2012). Differences in coastal and oceanic SST warming rates along the Canary upwelling ecosystem from 1982 to 2010. *Cont Shelf Res*, *47*, 1-6. [CrossRef]

Schneider, W., (1990). FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. Rome: FAO. 268 p.

Sciberras, M., & Schembri, P. J. (2007). A critical review of records of alien marine species from the Maltese Islands and surrounding waters (Central Mediterranean). *Mediterranean Marine Science, 8*(1), 41-66. [CrossRef]

Shakman, E. A., Abdalha, A. B., Thala, F., Al-Faturi, A., & Bariche, M. (2017). First records of seven marine organisms of different origins from Libya (Mediterranean Sea). *BioInvasions Records, 6*(4), 377-382. [CrossRef]

Shao, K., Liu, M., Jing, L., Matsuura, K., Hardy, G. & Leis, J. L. (2014). *Sphoeroides pachygaster.* The IUCN Red List of Threatened Species 2014: e.T190193A1943625. [CrossRef]

Shinohara, G., Narimatsu, Y., Hattori, T., Ito, M., Takata, Y., & Matsuura, K. (2009). Annotated checklist of deep-sea fishes from the Pacific coast off Tohoku District, Japan. *National Museum of Nature and Science Monographs, 39*, 683-735.

Shinohara, G., Shirai, S. M., Nazarkin, M. V., & Yabe, M. (2011). Preliminary list of the deep-sea fishes of the Sea of Japan. *Bulletin of the National Museum of Nature and Science, Series A (Zoology), 37*, 35-62.

Shinohara, G., Nakae, M., Ueda, Y., Kojima, S., & Matsuura, K. (2014). Annotated checklist of deep-sea fishes of the Sea of Japan. *National Museum of Nature and Science Monographs, 44*, 225-291.

Shipp, R. L. (1974). The pufferfishes (Tetraodontidae) of the Atlantic Ocean. Publications of the Gulf Coast Research Laboratory Museum, 41: 162 p in Carpenter, K. E. & De Angelis, N., eds. 2016. The living marine resources of the East ern Central Atlantic. Volume 4: Bony fishes part 2 (Perciformes to Tetradontiformes) and Sea turtles. FAO Species Identification Guide for Fishery Purposes, Rome, FAO. pp. 2343–3124.

Shipp, R. (2002). Tetraodontidae. In: Carpenter, K. (ed.), The Living Marine Resources of the western central Atlantic, pp. 1988-2006. FAO, Rome.

Smith, M. M. & Heemstra, P. C. (1986). Smith's Sea Fishes. Springer-verlag Berlin Heidelberg New York London Paris Tokyo. 1047p.

Streftaris, N., & Zenetos, A. (2006). Alien marine species in the Mediterranean-the 100 'Worst Invasives' and their impact. *Mediterranean Marine Science, 7*(1), 87-118. [CrossRef]

Tortonese, E. (1986). Tetraodontidae. p. 1341-1345. In: P.J.P. Whitehead, J.C. Hureau, J. Nielsen, E. Tortonese (Eds.), Fishes of the northeastern Atlantic and the Mediterranean, 1984-1986, Unesco 1, Paris. [CrossRef]

Tursi A., D'Onghia G. & Matarrese A. 1992. First finding of *Sphoeroides pachygaster* (Muller and Troschel, 1848) (Tetraodontidae) in the Ionian Sea (middle eastern Mediterranean). *Cybium*, *16*(2): 171-172.

UNEP-MAP-RAC/SPA.2011. Non-native species in the Mediterranean: What, when, how and why? Ed: RAC/SPA, Tunis. 28 pp.

Vella, A., Vella, N., Karakulak, F. S., & Oray, I. (2017). DNA barcoding of Tetraodontidae species from the Mediterranean Sea: Filling knowledge gaps for improved taxonomic accuracy. *Genetics of Aquatic Organisms, 1*(2), 61-69. [CrossRef]

Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J. C., Fromentin, J. M., Hoegh-Guldberg, O. & Bairlein, F. 2002. Ecological responses to recent climate change. *Nature, 416* (2002), 389–395. [CrossRef]

Wirtz, P., Bingeman, J., Bingeman, J., Fricke, R., Hook, T. J., & Young, J. (2017). The fishes of Ascension Island, central Atlantic Ocean–new records and an annotated checklist. *Journal of the Marine Biological Association of the United Kingdom, 97*(4), 783-798. [CrossRef]

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2021; 36(2): 95-100 • DOI: https://doi.org/10.26650/ASE2020702855

Short Comminication

Wild *Salmo trutta labrax* from the Bıçkı Stream in the Marmara Region: Gamete Quality and First Reproduction Under Aquaculture Conditions

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Cite this article as: Memiş, D., Tuncelli, G. & Yamaner, G. (2021) Wild *Salmo trutta labrax* from the Bıçkı stream in the Marmara Region: Gamete quality and first reproduction under aquaculture conditions. *Aquatic Sciences and Engineering, 36*(2), 95-100.

ABSTRACT

In this study, the quality and reproductive success of wild Black Sea Trout (Salmo trutta labrax) were investigated. In total 32 wild trout (27.3±13.6 g and 13.9±2.3 cm) from the Bıçkı Stream in Kocaeli Province in the Marmara Region were kept in circular fiberglass outdoor flow-through tanks (1.5m ø) at the mean water temperature of 11.8±4.5 °C. In November 2016, when the water temperature was 8.4 °C, the first spawning of wild trout occurred. Sperm volume (ml), Motility (%) and VCL (μm/sec) values were determined to be 7.5±2.5, 70.42±0.83 and 70.35±3.98, respectively. The weight (g), total fecundity and egg diameter (mm) values of female fish were listed to be 513.75±78, 1.171±171, and 3.84±0.02, respectively. In the experiment, 5.859 wild Black sea trout eggs were fertilized. The eyed-egg stage occurred 24 days (288 day-degree) post fertilization and the survival rate from fertilization to the eyed-stage was 28%. Wild Black Sea trout larvae from P1 (Paternal Generation) hatched 48 days after fertilization with the hatching rate of 7%.

Keywords: Wild trout, sperm quality, egg quality, fertilization, first spawning

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Submitted: 12.03.2020

Revision Requested: 13.05.2020

Last Revision Received: 15.07.2020

Accepted: 15.07.2020

Online Published: 05.02.2021

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INTRODUCTION

Domesticating and cultivating wild fish are the first stages of aquaculture. In these stages, huge losses can occur in the fish stock due to stress. Aquaculture success of a species depends on the losses at this stage and the reproductive ability of individuals adapted to culture conditions (Bromage and Roberts, 1995; Teletchea et al., 2014; Özgür et. al., 2016).

The Salmonidae family has many species of commercial, cultural and environmental value. Thirteen species in the family have been listed as either "endangered, "critically endangered" or "vulnerable," according to The International Union of Conservation of Nature - Red List of Threatened Species (IUCN, 2020). For decades, the pollution of water, habitat destruction, hydro-electric power stations, sand-mines, weirs, dams and the lack of control overfishing have caused a decrease in the Salmonid species population of Turkey and the world. The rearing of endangered salmonid species for both commercial and ecological purposes has received considerable attention. From an ecological perspective, the rearing of wild fish in culture conditions may provide potential solutions for the rehabilitation of damaged populations. Aquaculture is one of the most widely used methods to increase the natural populations after adaptation to the culture conditions of endangered species (Cabrita et al., 2009).

According to the environment or geographical region where they are adapted, the genus Salmo is present in almost all cold streams and rivers of Anatolia with high diversity, such as *Salmo. abanticus, S. caspius, S. platycephalus, S. rizeensis, S. coruhensis, S. tigridis, S. labecula, S. opimus, S. chilo, S. kottelati, S. okumusi, S. euphrataeus and S. munzuricus*. Black Sea Trout (*Salmo trutta labrax*) are distributed along the eastern part of the Black Sea, and are endemic anadromous species of Salmonidae family. This species lives in the Black Sea until sexual maturity and migrates upstream in order to spawn (Turan et al., 2009).

Reproduction and bio-ecological characteristics, first feeding problems, and growth properties of Black Sea Trout have been studied systematically and the majority of studies have been conducted regarding the development of aquaculture practices in order to restock their natural habitat (Çakmak et al., 2004; Aksungur et al., 2005).

Collecting gametes from wild fish under captive conditions can only be achieved by creating conditions similar to natural conditions. A successful adaptation process is possible by the "no mortality " and "reproduction" of the existing species. After the adaptation periods are completed, aquaculture success depends on obtaining gametes and the quality and quantity of gametes obtained. The monitoring of gamete quality is a key issue for efficient artificial reproduction strategy. The quality of gametes allows us to make certain predictions to the gamete's capacity for successful fertilization or survival possibility (Migaud et al., 2013).

In Black Sea trout, there have been certain spawning techniques and protocols developed (Çakmak et al., 2004). In addition, the determination of gamete quality has become a main step to optimize breeding techniques. Quality and quantity of gametes can be influenced by factors including fish origin, fish health and age, time of stripping during the spawning season, nutrition and pre-spawning broodstock management (Bobe and Labbe 2010).

The aim of the present study is to describe for the first time, the reproduction specialty and gamete quality of both genders of wild Salmonid species (*Salmo trutta labrax*) from the Bıçkı Stream and provide information for the fertilization rate of newly adapted fish.

MATERIALS AND METHODS

Broodstock and rearing system

Fish were captured two years before the fertilization experiment by an electroshock device in the Bıçkı Stream (40°34'42.99"N; 29°55'57.60"E) in Kocaeli Province on 28 January 2014 and transported by aerated transfer tank to Istanbul University Faculty of Aquatic Science, Sapanca Inland Fish Culture Research and Application Unit.

In total 32 wild trout (27.34±13.66 g, and 13.91±2.33 cm) were placed in circular fiberglass outdoor flow-through tanks (1.5 m diameter) at a mean water temperature of 11.79±4.55°C and they were kept under culture conditions until ready for the reproduction. The first feeding of wild trout was maintained by conducting social interaction with domesticated rainbow trout, which already had experienced the feeding process. Wild trout and rainbow trout of the same length were fed commercial trout feed (2-3 mm depending on the fish size; 48% protein; 17% oil; 11% ash) until their first spawning (Başçınar et al., 2010b).

Reproductive performance

In order to investigate wild Black Sea trout spawning adaptability in culture conditions, gamete maturation was checked between September and January in 2015 and 2016. The gender and stage of the sexual maturity of each fish were determined via investigation of eggs or sperm. The first spawning activity occurred two years post-capture. In total five female (mean weight of 476.32±107 g) and two male (mean weight of 529±51 g) broodstocks spawned for the first time at 8.4°C in November 2016. Gentle hand pressure was applied to the abdomen to obtain eggs and sperm samples.Contamination of blood, feces, and urine during stripping were avoided.

Determination of gamete quality

1. Egg quality

The total number of eggs for each individual were estimated gravimetrically. The subsamples of about 1 g of eggs were counted for each fish and the total fecundity was calculated to be F=nG/g where *F* is fecundity, *n* is the number of eggs in the subsample, G is the total weight of the fish and g is the weight of subsample (Hunter et al., 1985). Fifty eggs from each female were taken at random, placed under the stereomicroscope and photographed, measured to the nearest 0.01 mm using a stereomicroscope. An average egg size for each female fish was then calculated.

2. Sperm quality

The sperm volume (ml) was calculated using labelled glass beakers. The sperm cell motility parameters (Motility, VCL) were determined with the Computer Assisted Sperm Analysis (CASA, CEROS, Hamilton Thorne, Beverly, MA, USA) system connected to a CX41 microscope (Olympus Japan). Recordings were made with a digital camera (U-TV1X-2 Tokyo, Japan) at 60 images per second using Salmonid variables pre-determined in the Hamilton configuration. Sperm were considered immotile at velocities <20 μm s^{-1}, and motile at velocities >20 μm s^{-1}. Hatchery water was used as a sperm activation solution.

3. Fertilization experiment

The fertilization was performed by the dry method. The eggs of each female were fertilized with two male's pooling sperm. The sperm and eggs were gently stirred for 15-20 seconds, then 250 ml water from broodstock holding tanks was added. The eggs were left for 30 minutes until completion of swelling. The eggs were placed on the vertical incubation system which has constant well water (12.0°C) (2 L/min) in the hatchery (Okumuş et al., 2007). The fertilization rates were measured at the eyed stage and calculated as the number of eyed eggs × initial egg $number^{-1}$ × 100 and hatching stages calculated as several hatching larvae × eyed $eggs^{-1}$ × 100 (Hunter et al., 1985).

Statistical analysis

The data obtained from the analysis are given as mean value and standard deviation (± *SD*). An independent T-test was performed using STATISTICA v.8.

RESULTS AND DISCUSSION

Physicochemical parameters of water

Water temperature was measured weekly and found to be 11.79±4.55°C in outdoor tanks, and 12 °C in the incubation unit. The dissolved oxygen level varied between a minimum of 8.2 and a maximum of 9.4 mg/lt. The water pH level ranged between a minimum of 7.4 and a maximum of 8.2 during the study.

Reproductive performance of female individuals

The first spawning activity took place two years later, while the wild *S. trutta labrax* were kept under aquaculture conditions. Spawning occurred in November 2016 when the water temperature was 8.4°C. Five female individuals spawned and a total number of 5,859 eggs were collected (Table 1). The eggs (*M*=3.84, *SD*=0.02) were yellow, spherical, non-adhesive and demersal.

Table 1. Weight, total fecundity and the mean egg diameters of wild *S. trutta labrax* females.

Individuals	Weight of female (g)	Total fecundity (egg / individual)	Egg diameter (mm) (n=50)
1	327	1247	3.82±0.08
2	470	1044	3.82±0.08
3	624	1300	3.85±0.06
4	514	1330	3.84±0.07
5	447	938	3.88±0.07
Mean±SD	476.32±107	1171±171	3.84±0.02

*Values with different superscript letters and numbers are significantly different (p<0.05, Independent T test).

Salmonid fish *reach* sexual maturity at the age of 2-5 years (Bromage and Roberts 1995). In this study, we observed the first ovulation two years from capture. This is consistent with the observations in this study where the individuals who were given gametes but did not mature. It has been well documented in the literature that spawning among Salmonids generally occurs during the autumn-winter period: the beginning of October to the end of January. It is indicated that additional genetic conditions, the origin of broodstock, feeding regime, size and age of individuals were the main factors controlling the spawning, and consequently, fertilization success. Geldiay and Balık (1996) reported that the spawning age of salmonid species is between 2-4 years in Turkey. The present study shows that after two years in captivity in trout farm conditions, wild Black Sea trout were able to naturally spawn in November.

The amount and size of the egg are the two main parameters for the determination of the quality of female broodstock individuals in aquaculture (Bromage and Roberts 1995). Several studies (Okumuş et al., 2007; Woynarovich et al., 2011) have stated that the fecundity of Salmonid species is about 300-2.000 eggs × broodstock^{-1}. The fecundity of *Salmo trutta macrostigma* was found as 1.322±233 eggs × individual^{-1} (Alp et al., 2010). Reported as a new Salmonid species of Alakır trout (*Salmo kottelati*), the fecundity was changed to between 1.035-1.632 eggs × individual^{-1} (Kanyılmaz, 2016). For some *Salmo trutta* species, fecundity was reported as a maximum of 1.250 eggs × individual^{-1} (Arslan and Aras 2007). Aksungur et al. (2011) found a total fecundity of 3.226±320 numbers of eggs per individual in the broodstock of marine ecotype Black Sea trout. Some researchers, however, have reported a higher number of eggs produced by brown trout, such as 2.000-5.000 eggs × kg^{-1} (Geldiay and Balik 1996); 3.099 eggs × kg^{-1} (Alp et al., 2010). In our study, the number of spawned eggs per female (n=5) was found as 1.172±171. Fecundity values achieved in our study showed similarities with other Salmonid fish reports.

Egg size is another key parameter for measuring the egg quality. The egg size per diameter may vary among fish species and within the same species (Bromage and Roberts 1995). In rainbow trout egg diameter ranges from 4.9 to 7.2 mm, while egg diameter in brown trout ranges from 5 to 5.33 mm (Gjedrem and Gunnes 1978). Egg diameter in Black Sea trout was found as 3.0-5.3 mm (Sonay 2008), 4.5-4.7 mm (Başçınar et al., 2010a), and 4.5-5.1 mm (Erbaş and Başçınar 2013). In our study, egg diameter was recorded as 3.8±0.02 mm and it was in agreement and comparable with earlier reports.

Reproductive performance of male individuals

Spermiation occurred in three males before the spawning of females and in two males at the same time the females spawned. Sperm volume and the kinematic parameters of sperm (motility (%), and VCL (µm/sec) values gained in the experiment) are given in Table 2. Sperm volume ranged from 5 ml to 10 ml per individual. Sperm cell motility was higher than 70% in each individual, and the mean motility percentage was 70.42±0.83% for five males.

Table 2. Sperm (volume, ml) and Spermatological parameters (motility (%), VCL (µm/sec) of the wild *S.trutta labrax* (mean±*SE*).

Sperm and Spermatological parameters	Values (Mean±SE) (n=5)
Sperm volume (ml)	7.5±2.5
Motility (%)	70.42±0.83
VCL (µm/sec)	93.79±6.51

Sperm volume in fish is directly related to water temperature, stripping frequency, age of the individual, presence of females in the pool and rearing conditions (Büyükhatipoğlu and Holtz 1984). In salmonids, the total sperm volume stripped from an individual varies between 5-30 ml during a complete breeding season. While a total sperm amount of 4.5-18 ml was reported in brown trout, 19.6 ml sperm volume was reported in rainbow trout (Rainis et al., 2005). Total sperm volume was reported as 8.4±0.4 ml in *Salmo trutta macrostigma* (Yavaş et al., 2011), 8.45±1.32 ml (Erbaş and Başçınar 2013), and 1.6±0.04 ml (Şahin et al., 2013) in Black Sea trout. In the present study, total sperm volume was detected as 7.5±2.5 ml in males. Our findings for sperm counts in the present study show parallel findings with earlier reports on trout.

High sperm cell motility is required for successful fertilization and it is the most important parameter for determining the fertilization ability of sperm cells. Sperm cell motility can change between 0% and 100% under aquaculture conditions, where any manipulation processes are applied. Ruling out the details and variables in sperm cell freezing or sperm cell activation studies, more than 70% of the cells in a fresh sperm sample is a reason for preference (Cabrita et al., 2009). In fresh sperm collected from salmonid fishes without any manipulation, the spermatozoa motility was determined between 20-100% in brown trout (Dziewulska, Rzemieniecki, & Domagała, 2008); 50-89% in rainbow trout (Dziewulska, Rzemieniecki, & Domagała, 2008; Ekici et al., 2012; Şahin et al., 2013), and 60-90% in Black Sea trout (Erbaş and Başçınar 2013). In our study, sperm motility was determined as 70.42±0.83% These motility values determined in Black Sea trout are similar to earlier reports on Black Sea trout as well as other trout species mentioned above.

The VCL value, the curvilinear velocity related to the sperm motility, also varies among species and within the same species in salmonids. The sperm cell with higher speed is more successful in fertilizing (Lahnsteiner et al., 2011). In salmonid fishes, various VCL values were determined as 38.1-149.5 µm/sec in Chinook salmon (*Oncorhynchus tshawytscha*) (Rosengrave et al., 2009); 96-127 µm/s in Atlantic salmon (*Salmo salar*) (Rosengrave et al., 2009); 191.8±56.9 µm/s (Dziewulska, Rzemieniecki, & Domagała, 2008); 102.50±18,39 µm/s (Tunçelli and Memiş 2020) 59.42±24.63 µm/s in *Salmo turtta labrax*, and 141.2-240 µm/s in *Oncorhynchus mykiss*. In our study, VCL values were determined as 93.79±6.51 µm/s. VCL values achieved in our study showed similarities with the previous reports.

Fertilization and survival rate of larvae

In the experiment, some of the 5,859 Black Sea trout eggs were fertilized. The eyed egg stage was determined at 24 days (288 day-degree) post-fertilization and the survival rate from fertilization to the eyed stage was 28%. Black Sea trout larvae hatched 48 days after fertilization with a hatching rate of 7% (Figure 1).

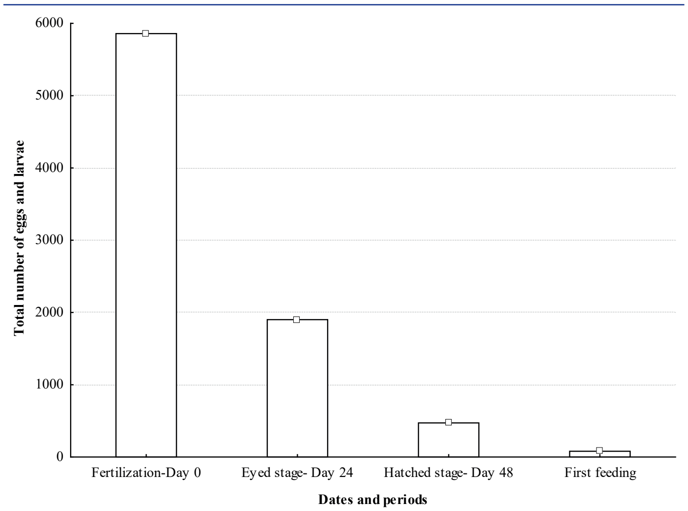

Figure 1. Total number of fertilized, eyed and hatched larvae of wild trout (*S.trutta labrax*).

The temperature of the incubation period greatly impacts the survival of fish embryos (Cabrita et al., 2009; Simcic et al., 2015). Reference for the optimum temperature for incubation and hatching is between 8-14°C for Salmonid (Pennell and Barton 1996), however, incubation time, development of embryonic and larval stages, hatching and swim-up larvae as day-degree reveal differences in Salmonids (Başçınar et al., 2010a). These studies showed that the reproduction period, gamete quality and fertilization rate in different conditions can be different between interspecies and between species. It was reported that in brown trout, the incubation temperature varied between 10.5-10.9°C and the rate of hatching was determined to be between 32 and 57% (Demir et al., 2010). In the other study, *S. trutta labrax* eggs hatched after 38 days under 10°C (Firidin, Çakmak, & Aksungur, 2012). According to Marten (1992), in order to gain a high survival rate in brook trout, the incubation temperature should be maintained between 3-8°C during the incubation period. Some species of salmonids, such as Brook trout embryos, grew much faster in the warm water treatment than their siblings in the cold-water treatment. This was consistent with previous studies of other species, showing individuals in warmer environments had earlier hatch dates (Cook et al., 2018). In the present study, the eggs of wild Black Sea trout incubated at 12.0°C during the incubation period, the water temperature changed between 8.4 and 12.3°C (11.3±1.2). Although the water temperature was considered suitable for Black Sea trout eggs in the incubation unit, the low hatching rate is thought to be related to the low quality of gametes. As is well known, the quality of eggs can be determined by healthy larvae in the hatchery after fertilization. While the number and size of the eggs are important criteria for determination of gamete quality of the female broodstock, the rate of fertilization and eyed egg ratio are also important for the quality. During the incubation, survival rates of Salmonid eggs may vary 0-100% (Bromage et al., 1992). The survival of eggs during the incubation period and hatching larvae recorded in the present study was lower than previously reported for some salmonids species (Pennell and Barton 1996). Neither the egg number nor egg size proved to be useful indicators of egg quality and egg viability of wild oradapted broodstock of *S. trutta labrax*. The hatching rate of larvae of wild broodstock individuals was calculated as >10% despite fertilization. The majority of eggs were lost due to mortality during embryogenesis which could indicate that there were several factors causing the egg loss (Cabrita et al., 2009). Lower survival rate during the incubation conditions could possibly be explained by the lower adaptation to culture conditions of broodstock individuals, even though these individuals were given the gametes. Gamete growth occurred in wild broodstock, but gamete maturation was not enough for the embryonic development for first spawning under culture conditions (Bobe and Labbe 2010). Also, the egg quality should be affected by broodstock nutrition, genetics, environmental conditions and any stress factors such as handling and spawning induction (Migaud et al., 2013).

Sperm quality has been described as "the ability of sperm to successfully fertilize an egg" (Rurangwa et al., 2004). This definition reflects the former consensus that sperm quality only affected fertilization rates, while paternal effects on offspring viability are limited to genetic information carried by the sperm quality of the father rather than his sperm. However, embryonic survival and development are affected by sperm quality (Labbe et al., 2017). Because of oxidative stress during spermatogenesis, if there is some damage to the chromatin or RNA in the spermatozoa, the sperm still have the ability to fertilize an egg. However, embryonic development will be disturbed due to damage to these molecules (Johnson et al., 2011). The present study determined acceptable sperm quality with regard to the motility and kinematic parameters of motility. All parameters were found to be similar to the salmonid sperm quality, which is described in previous studies (Dziewulska et al., 2008; Ekici et al., 2012; Şahin et al., 2013) but together with information on fertilization and embryonic survival rates of present study, these data showed that there should be a paternal effect on reproduction performance.

CONCLUSION

In conclusion, *Salmo trutta labrax* individuals, which were caught from their natural habitat (Bıçkı stream) could be adapted to culture conditions. As was observed, all individuals could have finished the oogenesis and spermatogenesis cycle under culture conditions in consideration of first spawning. However, the first gametes of these individuals showed bad quality for both genders, which led to low and unacceptable rates for the aquaculture conditions. The first spawning from the wild parental generation results can be considered as ordinary results and the success will increase in the next generations. With regard to the sustainable culture conditions of this species in farms, the ways of increasing the "breeding success" and "gamete quality" of this wild trout species should be investigated in future studies.

Conflict of interests: The author has no conflicts of interest to declare.

Ethics committee approval: Ethical approval was not required for this study.

Funding: The study was supported by COST Action FA1205: AQUAGAMETE.

Acknowledgments: The authors are grateful to Branch office of Kocaeli (Zone 1) of Directorate General for Nature Conservation and National Parks of Turkey, staff of Freshwater Resources and Management and Aquaculture Programmes of Faculty of Aquatic Sciences which gave help for fish sampling in the Bıçkı Stream.

Disclosure: -

REFERENCES

Aksungur, M., Yılmaz, C., Tabak, İ., Aksungur, N., & Mısır, D.S. (2005). Adaptation of Black Sea Trout (*Salmo trutta labrax*, Pallas, 1811) to Culture Condition. Fırat University, *Journal of Science and Engineering, 17(2)*: 349-359. [CrossRef]

Aksungur, M., Zengin, M., Tabak, İ., Aksungur, N., & Alkan, A. (2011). Migration Characteristics of the Black Sea Trout (*Salmo trutta labrax,* Pallas, 1814) in the Eastern Black Sea Coasts and Streams. *Turkish Journal of Fisheries and Aquatic Sciences, 11*, 643-650. [CrossRef]

Alp, A., Erer, M., & Kamalak, A. (2010). Eggs Incubation, Early Development and growth in Frys of Brown Trout (*Salmo trutta macrostigma*) and Black Sea Trout (*Salmo trutta labrax*). *Turkish Journal of Fisheries and Aquatic Sciences, 10*: 387-394. [CrossRef]

Arslan, M. & Aras, M. (2007). Structure and Reproductive Characteristics of Two Brown Trout (*Salmo trutta*) Populations in the Çoruh River Basin, North-eastern Anatolia, Turkey, *Turk J Zool, 31*, 185-192.

Başçınar, N., Kocabaş, M., Şahin, Ş. A., & Okumuş, İ. (2010a). Comparison of hatching performances and yolk sac absorptions of Black Sea trout (*Salmo trutta labrax* Pallas, 1811), brook trout (*Salvelinus fontinalis* Mitchill, 1814) and their hybrid. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 16*, 205-209. [CrossRef]

Başçınar, N., Şahin, A. Ş., & Kocabaş, M. (2010b). Effect of duo-culture on growth performance of brook trout (*Salvelinus fontinalis* Mitchill, 1814) and black sea trout (*Salmo trutta labrax* Pallas, 1811) in tank reared condition. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 16(3)*, 249-254. [CrossRef]

Bobe, J., & Labbé, C. (2010). Egg and sperm quality in fish. *General and Comparative Endocrinology, 165*: 535–548. [CrossRef]

Bromage, N.R. & Roberts, R.J. (1995). Broodstock Management and Egg and Larval Quality, Blackwell Science, Oxford.

Bromage, N., Jones, J., Randall, C., Thrush, M., Davies, B., Springate, J., & Barker, G. (1992). Broodstock management, fecundity, egg quality and the timing of egg production in the rainbow trout (*Oncorhynchus mykiss*). *Aquaculture, 100 (1-3)*, 141-166. [CrossRef]

Büyükhatipoglu, S., & Holtz, W. (1984). Sperm output in rainbow trout (*Salmo gairdneri*) Effect of age, timing and frequency of stripping and presence of females. *Aquaculture, 37*, 63-71. [CrossRef]

Cabrita, E. Robles, V. & Herráez, P. (2009). *Methods in reproductive aquaculture: marine and freshwater species*, CRC Press. United States of America. [CrossRef]

Çakmak, E. Kurtoğlu, İ. Z., Çavdar, Y., Firidin, Ş., & Aksungur N. (2004). Karadeniz alabalığı yetiştiriciliği ve Balıklandırma Amacı ile Kullanımı. Tarım ve Köyişleri Bakanlığı. Trabzon.

Caldeira, C., Hernández-Ibáñez, S., Valverde, A., Martin, P., Herranz-Jusdado, J. G., Gallego, V., & Soler, C. (2019). Standardization of sperm motility analysis by using CASA-Mot for Atlantic salmon (*Salmo salar*), European eel (*Anguilla anguilla*) and Siberian sturgeon (*Acipenser baerii*). *Aquaculture, 502*, 223-231. [CrossRef]

Cook, C. J., Burness, G., & Wilson, C. C. (2018). Metabolic rates of embryos and alevin from a cold-adapted salmonid differ with temperature, population and family of origin: implications for coping with climate change. *Conservation physiology, 6*, 1, cox076. [CrossRef]

Demir, O., Gülle, İ., Gümüş, E., Küçük, F., Günlü, A., & Kepenek, K. (2010). Some reproductive features of brown trout (*Salmo trutta macrostigma* Dumeril, 1858) and its larval development under culture conditions. *Pakistan Veterinary Journal, 30*, 4, 223-226.

Dziewulska, K., Rzemieniecki, A., & Domagała, J. (2008). Basic physico-chemical parameters of milt from sea trout (*Salmo trutta m. trutta*), brook trout (*Salvelinus fontinalis)* and rainbow trout *(Oncorhynchus mykiss*). *Journal of Applied Ichthyology, 24, 4*, 497-502. [CrossRef]

Ekici, A., Baran, A., Yamaner, G., Özdaş, Ö. B., Sandal, A. İ., Güven, E., & Baltacı, M. A. (2012). Effects of different doses of taurine in the glucose-based extender during cryopreservation of rainbow trout (*Oncorhynchus mykiss*) semen. *Biotechnology & Biotechnological Equipment, 26, 4*, 3113-3115. [CrossRef]

Erbaş, H. İ. & Başçınar, N. (2013). Yemleme sıklığının Karadeniz Alabalığı (*Salmo trutta labrax* Pallas, 1811)'nın sperm ve yumurta kalitesine etkisinin belirlenmesi, *Biyoloji Bilimleri Araştırma Dergisi, 6*, 11-16.

Firidin, Ş., Çakmak, E., & Aksungur, N. (2012). The Black Sea Trout (*Salmo trutta labrax* Pallas, 1811)'s Embryonic Development Stages. *Aquaculture Studies, 12, 2*, 007-016.

Geldiay, R. & Balık, S. (1996). *Türkiye Tatlısu Balıkları*, Ege Üniversitesi Su Ürünleri Fakültesi Yayınları. Bornova, İzmir.

Gjedrem, T., & Gunnes, K. (1978). Comparison of Growth Rate in Atlantic Salmon, Pink Salmon, Arctic Char, Sea Trout and Rainbow Trout Under Norwegian Farming Conditions, *Aquaculture, 13*, 135-141. [CrossRef]

Hunter, J. R., Lo, N. C., & Leong, R. J. (1985). Batch fecundity in multiple spawning fishes. *NOAA Technical Report, NMFS, 36*, 67-77.

IUCN (2020). Salmonidae family. The IUCN Red List of Threatened Species 2017: e.T10066A20191442 [online]. [CrossRef]

Johnson, G. D., Sendler, E., Lalancette, C., Hauser, R., Diamond, M. P., & Krawetz, S. A. (2011). Cleavage of rRNA ensures translational cessation in sperm at fertilization, *Molecular Human Reproduction, 17, 12*, 721–726. [CrossRef]

Kanyılmaz, M. (2016). Reproductive Performance of a Newly Described Salmonid Fish, Alakir Trout (*Salmo kottelati*), a Candidate Species for Aquaculture, *Pakistan J Zool, 48*, 1, 83-89.

Labbé, C., Robles, V., & Herraez, M. P. (2017). Epigenetics in fish gametes and early embryo. *Aquaculture, 472*, 93-106. [CrossRef]

Lahnsteiner, F., Mansour, N., & Kunz, F. A. (2011). The effect of antioxidants on the quality of cryopreserved semen in two salmonid fish, the brook trout (*Salvelinus fontinalis*) and the rainbow trout (*Oncorhynchus mykiss*). *Theriogenology, 76, 5*, 882-890. [CrossRef]

Marten, P. S. (1992). Effect of temperature variation on the incubation and development of brook trout eggs. *The Progressive Fish Culturist, 54, 1*, 1-6. [CrossRef]

Migaud, H., Bell, G., Cabrita, E., McAndrew, B., Davie, A., Bobe, J., & Carrillo, M. (2013). Gamete quality and broodstock management in temperate fish. *Reviews in Aquaculture, 5,* 194-223. [CrossRef]

Okumus, I., Kurtoglu, I. Z., & Atasaral, S. (2007). General Overview of Turkish Sea Trout 770 (*Salmo trutta* L.) Populations, In: Harris, G. and Milner, N. (Eds.), Sea Trout: Biology, Conservation and Management (pp:115-126). Blackwell Publishing. [CrossRef]

Özgür, M. E., Akbulut, A., & Demirsoy, A. (2016). Characterization of the Embryonic and Larval Development of Wild Pike-Barb (Luciobarbus esocinus) Biological Parameters, and the Possibility of Breeding. *The Israeli Journal of Aquaculture-Bamidgeh, 68*, 1-10.

Pennell, W. & Barton, B. A (1996). *Principles of Salmonid Culture*. Developments in Aquaculture and Fisheries Science, Vol:26, The Netherlands. ISBN: 0-444-82152-X.

Rainis, S., Gasco, L., & Ballestrazzi, R. (2005). Comparative study on milt quality features of different finfish species. *Italian Journal of Animal Science, 4*, 355-363. [CrossRef]

Rosengrave, P., Taylor, H., Montgomerie, R., Metcalf, V., McBride, K., & Gemmell, N. J. (2009). Chemical composition of seminal and ovarian fluids of chinook salmon (*Oncorhynchus tshawytscha*) and their effects on sperm motility traits. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 152, 1*, 123-129. [CrossRef]

Rurangwa, E., Kime, D. E., Ollevier, F., & Nash, J. P. (2004). The measurement of sperm motility and factors affecting sperm quality in cultured fish. *Aquaculture, 234, 1, 4*, 1-28. [CrossRef]

Şahin, T., Kurtoğlu, İ. Z., Delihasan Sonay, F., & Ak, K. (2013). Quantitative characteristics and short-term storage of *Salmo coruhensis* Sperm. *The Israeli Journal of Aquaculture-Bamidgeh, IJA, 65*, 828.

Simčič, T., Jesenšek, D., & Brancelj, A. (2015). Effects of increased temperature on metabolic activity and oxidative stress in the first life stages of marble trout (*Salmo marmoratus*). *Fish Physiology and Biochemistry 41,* 1005–1014. [CrossRef]

Sonay, F. D. (2008). Parental effects on fertilization rate, incubation efficiency, larvae and fry development in Black Sea trout (*Salmo trutta labrax*), Master thesis, Rize University Institue of Applied Science (in Turkish).

Teletchea, F., & Fontaine, P. (2014). Levels of domestication in fish: implications for the sustainable future of aquaculture. *Fish and fisheries, 15(2)*, 181-195. [CrossRef]

Tunçelli, G. & Memiş, D., (2020). Effects of constant and changing water temperature on sperm quality of the endangered Çoruh Trout, *Salmo coruhensis*, *Journal of Applied Aquaculture*. [CrossRef]

Turan, D., Kottelat, M., & Engin, S. (2009). Two new species of trouts, resident and migratory, sympatric in streams of northern Anatolia (Salmoniformes: Salmonidae). *Ichthyological Exploration of Freshwaters, 20(4)*, 333-364.

Woynarovich, A., Hoitsy, G., & Moth-Poulsen, T. (2011). Small-scale rainbow trout farming. *FAO fisheries and aquaculture technical paper*, (561), I.

Yavas, I., Bozkurt, Y., & Karaca, F. (2015). Short-term preservation of Brown Trout (*Salmo trutta macrostigma*) sperm: effect of extenders on motility, International Conference Aquaculture and Fishery, Belgrade (Serbia), 5.

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Tables should be included in the main document, presented after the reference list, and they should be numbered consecutively in the order they are referred to within the main text. A descriptive title must be placed above the tables. Abbreviations used in the tables should be defined below the tables by footnotes (even if they are defined within the main text). Tables should be created using the "insert table" command of the word processing software and they should be arranged clearly to provide easy reading. Data presented in the tables should not be a repetition of the data presented within the main text but should be supporting the main text.

Table 1. Limitations for each manuscript type

Type of manuscript	Page	Abstract word limit	Reference limit
Original Article	≤20	250	40
Review Article	≤25	250	60
Short Communication	≤5	250	20

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Figures, graphics, and photographs should be submitted as separate files (in TIFF or JPEG format) through the submission system. The files should not be embedded in a Word document or the main document. When there are figure subunits, the subunits should not be merged to form a single image. Each subunit should be submitted separately through the submission system. Images should not be labeled (a, b, c, etc.) to indicate figure subunits. Thick and thin arrows, arrowheads, stars, asterisks, and similar marks can be used on the images to support figure legends. Like the rest of the submission, the figures too should be blind. Any information within the images that may indicate an individual or institution should be blinded. The minimum resolution of each submitted figure should be 300 DPI. To prevent delays in the evaluation process, all submitted figures should be clear in resolution and large in size (minimum dimensions: 100 × 100 mm). Figure legends should be listed at the end of the main document.

All acronyms and abbreviations used in the manuscript should be defined at first use, both in the abstract and in the main text. The abbreviation should be provided in parentheses following the definition.

When a drug, product, hardware, or software program is mentioned within the main text, product information, including the name of the product, the producer of the product, and city and the country of the company (including the state if in USA), should be provided in parentheses in the following format: "Discovery St PET/CT scanner (General Electric, Milwaukee, WI, USA)"

All references, tables, and figures should be referred to within the main text, and they should be numbered consecutively in the order they are referred to within the main text.

Limitations, drawbacks, and the shortcomings of original articles should be mentioned in the Discussion section before the conclusion paragraph.

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While citing publications, preference should be given to the latest, most up-to-date publications. If an ahead-of-print publication is cited, the DOI number should be provided. Authors are responsible for the accuracy of references. List references in alphabetical order. Each listed reference should be cited in text, and each text citation should be listed in the References section. The reference styles for different types of publications are presented in the following examples.

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- American Psychological Association. (2010). Publication manual of the American Psychological Association (6th ed.). Washington, DC: APA.
- http://www.apastyle.org

Accuracy of citation is the author's responsibility. All references should be cited in text. Reference list must be in alphabetical order. Type references in the style shown below.

Citations in the Text

Citations must be indicated with the author surname and publication year within the parenthesis.

If more than one citation is made within the same paranthesis, separate them with (;).

Samples:

More than one citation;
(Esin et al., 2002; Karasar, 1995)
Citation with one author;
(Akyolcu, 2007)
Citation with two authors;
(Sayıner & Demirci, 2007)
Citation with three, four, five authors;
First citation in the text: (Ailen, Ciambrune, & Welch, 2000) Subsequent citations in the text: (Ailen et al., 2000)
Citations with more than six authors;
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- **A book chapter, print version:** Haybron, D. M. (2008). Philosophy and the science of subjective well-being. In M. Eid & R. J. Larsen (Eds.), *The science of subjective well-being* (pp. 17-43). New York, NY: Guilford Press. ISBN 4546469999
- **An eBook:** Millbower, L. (2003). *Show biz training: Fun and effective business training techniques from the worlds of stage, screen, and song.* Retrieved from http://www.amacombooks.org/ (accessed 10.10.15)
- **An article in a print journal:** Carter, S. & Dunbar-Odom, D. (2009). The converging literacies center: An integrated model for writing programs. *Kairos: A Journal of Rhetoric, Technology, and Pedagogy, 14*(1), 38-48.
- **An article with DOI:** Gaudio, J. L. & Snowdon, C. T. (2008). Spatial cues more salient than color cues in cotton-top tamarins (saguinus oedipus) reversal learning. *Journal of Comparative Psychology,* https://doi.org/10.1037/0735-7036.122.4.441
- **Websites - professional or personal sites:** The World Famous Hot Dog Site. (1999, July 7). Retrieved January 5, 2008, from http://www.xroads.com/~tcs/hotdog/hotdog.html (accessed 10.10.15)
- **Websites - online government publications:** U.S. Department of Justice. (2006, September 10). Trends in violent victimization by age, 1973-2005. Retrieved from http://www.ojp.usdoj.gov/bjs/glance/vage.htm (accessed 10.10.15)
- **Photograph (from book, magazine or webpage):** Close, C. (2002). *Ronald.* [photograph]. Museum of Modern Art, New York, NY. Retrieved from http://www.moma.org/collection/object.php?object_id=108890 (accessed 10.10.15)
- **Artwork - from library database:** Clark, L. (c.a. 1960's). *Man with Baby.* [photograph]. George Eastman House, Rochester, NY. Retrieved from ARTstor
- **Artwork - from website:** Close, C. (2002). *Ronald.* [photograph]. Museum of Modern Art, New York. Retrieved from http://www.moma.org/collection/browse_results.php?object_id=108890 (accessed 10.10.15)

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