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Aims and Scope

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Editor in Chief: Prof. Dr. Nuray ERKAN

Address: Istanbul University, Faculty of Aquatic Sciences, Department of Food Safety, Ordu Cad. No: 8, 34134 Fatih/Istanbul, Türkiye

E-mail: nurerkan@istanbul.edu.tr

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SHORT COMMUNICATION

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The first data on the population parameters and morphometry of *Mesogobius batrachocephalus* (Pallas 1814) (Family: Gobiidae) in the southern Black Sea

Mehmet AYDIN

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Ordu University, Fatsa Faculty of Marine Science, Ordu, Turkey

ORCID IDs of the author(s):
M.A. 0000-0003-1163-6461

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Correspondence:
Mehmet AYDIN
E-mail: maydin69@hotmail.com

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ABSTRACT

Knout goby, *Mesogobius batrachocephalus* Pallas, 1814, which belongs to Gobiidae, inhabits in the Black Sea, Sea of Azov, the Caspian Sea and the rivers that flow in these three seas. The major population parameters and morphometry of *Mesogobius batrachocephalus* from the coasts of the southern Black Sea were investigated in this study. A total of 641 individuals were sampled between January 2019 and December 2019 between the depths of 2 to 120 m depth by using a trammel net with a mesh size of 17-24 mm. The average length and weight values were calculated as 23.1 cm (5.3-34.0) and 130.1 g (1.34-377.54) respectively. The male to female ratio of the population was found as 1:0.91 ($P>0.05$). Age of sampled 641 individuals varies between zero and seven. For all the sampled individuals, the von Bertalanffy growth parameters were calculated as; $L_\infty = 38.2$ cm, $k = 0.245$ year^{-1} and $t_0 = -1.873$ year and the length-weight relationship was found as $W = 0.0058\ TL^{3.148}$. Total mortality (0.481), natural mortality (0.466), fishing mortality (0.015), growth performance index (2.55) and condition factor (0.913) were calculated. The maximum value of gonadosomatic index was reached in March. Average relative fecundity was found to be 118.3 eggs per g (78.9-234.5), while the average diameter of the eggs was found as 2733.0 µm ±221.18 (2287.1-3097.8). This study provides the first data on the population parameters and the morphometry of *Mesogobius batrachocephalus.* These data could contribute to the establishment of a sustainable management plan for fisheries resources in the Black Sea.

Keywords: Knout goby, Age, Growth, Reproductive, Fecundity, Morphometry**,** Black Sea

Introduction

The knout goby (Gobiidae) family, *Mesogobius batrachocephalus* (Pallas 1814), inhabits in the Black Sea, Caspian Sea and temporarily inhabits marine waters (Freyhof, 2011; Pinchuk et al., 2004). Among this ecologically diverse species group, knout goby (Froese and Pauly, 2019), is a Black Sea endemic fish found on sandy or rocky bottoms of inshore habitats, estuaries and brackish/fresh water lagoons (Freyhof, 2011). There are 34 (17.99%) endemic fish species in the Black Sea. Seventeen of 34 endemic fish species in the Black Sea belong to the Gobiidae (Yankova et al., 2014). The knout goby has a certain commercial value (Freyhof, 2011) as well as in Turkish coast of Black Sea (Pers. Obs. Dr. Mehmet AYDIN). There were some studies focusing on the length-weight relationship of knout goby for the Turkish coasts of the Black Sea (Demirhan and Can, 2007; Ak et al., 2009; Çalık and Erdoğan-Sağlam, 2017; Bengil and Aydın, 2020) and some studies related to the feeding ecology of the knout goby of the Black Sea (Porumb, 1961; Bănărescu, 1964; Mihălcescu, 2005; Crețeanu and Papadopol, 2006; Roşca and Surugiu, 2010; Roşca and Mânzu, 2011; Bengil and Aydın , 2020).

This study aims to contribute to the limited knowledge on the knout goby morphometry and its population parameters inhabiting the southern Black Sea. The main population parameters (age, length and weight relationships, sexual composition, growth, condition factor, and gonadosomatic index and morphometry properties) of *M. batrachocephalus* from coasts of the southern Black Sea are determined in this study. This is the first attempt to study on *M. batrachocephalus* in the Ponto-Caspian region and certainly will provide a significant contribution to the current literature and very important in terms of observation of the population.

Material and Methods

Samples of knout goby were collected monthly (January 2019 - December 2019) between the depths of 2 to 120 m depth by using a trammel net with a mesh size of 17-24 mm, which is commonly used by the fishermen of the southern coasts of the Black Sea (41°08'41.93"N - 37°17'41.29"E and 40°57'55.68"N - 38°07'24.97"E) (Figure 1). Samples were brought straight to the laboratory and morphological measurements were conducted while they are fresh. Total length measurements were performed by using a measuring board with a accuracy of 1 mm, while the weight and gonad weight (GW) measurements were made on an electronic scale with a accuracy of 0.01 g. Sex determinations were made through macroscopic observation of the gonad.

Length and Weight Relationships (LWRs)

LWRs of the species was estimated by applying the exponential regression model, $W = aTL^b$, where *a* and *b* are regression constants (Ricker, 1975). LWR was analyzed separately for males and females. The regression co-efficient for isometric growth is "3", while values greater or lesser than this value indicates an allometric growth. Regression analysis was used to estimate the confidence interval of "b" value and statistical relationships of morphometric measurements.

Age Determination

Sagittal otoliths of each specimen collected in this study were used for age determination. Otoliths were prepared for age determination and placed into a black pit plate. Stereomicroscope (up to X10 magnification) was used with illumination from top and side.

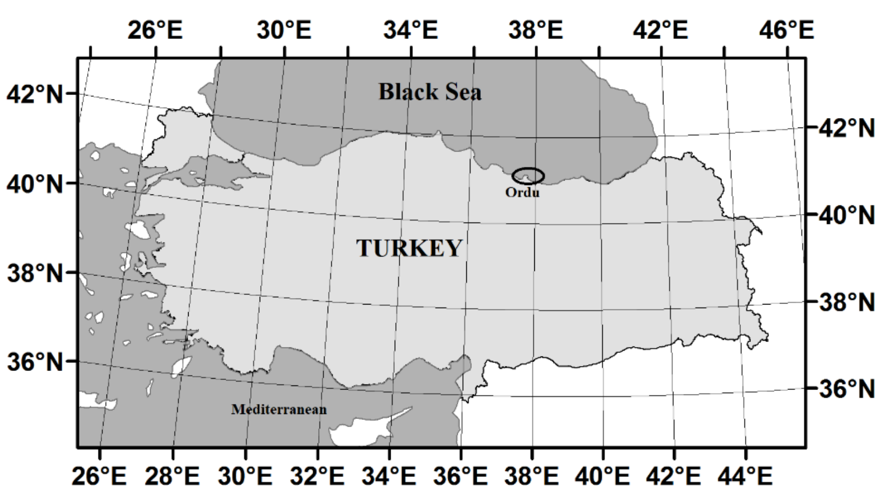

Figure 1. Study area

Growth Parameters

The von Bertalanffy growth equation (VBGE) was used to describe the growth of *M. batrachocephalus* for the total number of individuals sampled (King, 1995; Sparre and Venema, 1992). $L_{(t)} = L_\infty(1-e^{-k\ (t-t0)})$, where L_t is the total length at age t, L_∞ is the asymptotic length, k is the growth coefficient, and t_0 is the theoretical age when the fish was at zero total length. The same function was also used for describing the growth in weight; $W_{(t)} = W_\infty(1-e^{-k\ (t-to)})^b$, where W_t is the total weight, W_∞ is the asymptotic weight, and "b" is the power constant of the length-weight relationship. Values of L_∞, t_0 and K, which are parameters of the VBGE, were estimated by using the method of Ford-Walford (Gulland, 1969; Pauly, 1984). Growth parameters were estimated by using following formulas (King, 1995; Sparre and Venema, 1992): $L_\infty = a/(1-b)$, $k = -\text{Ln } b$, $t_0 = t + (1/k)*\text{Ln } [1-(L_t / L_\infty)]$.

Munro's phi-prime growth performance (Ø') was calculated by using the formula of Pauly and Munro (1984): $Ø'=\text{Log}(k)+2*\text{Log}(L_\infty)$.

Condition Factor

Fulton's coefficient of condition factor (CF) of *M. batrachocephalus* was calculated monthly by the equation $CF = (W/TL^3) \times 100$ (Ricker, 1975).

Gonadosomatic Index. Monthly values of the gonadosomatic index (GSI) were calculated for each sex.

$GSI = (GW / W) \times 100$ (De Vlaming et al., 1982).

Fecundity

Eggs of female individuals were collected and counted in March, when GSI reached the maximum in spawning season. A total of 33 individuals were examined for this purpose. When the relevant individuals were caught, gonads were collected, and eggs in ovaries were counted, immediately. Subsamples were counted using the gravimetric method, and the total number of eggs were calculated according to the following formula (Holden and Raitt, 1974): $F = \frac{G}{g} \times n$, where; F is the total number of eggs in the ovary, G is ovary weight (g), g is the weight of the subsample taken from the ovary (g), and "n" is the total number of eggs (including previtellogenic oocytes) in the ovary. It should be noted that only the mature oocytes (Lowerre-Barbieri et al., 2011) were taken into account while measuring the egg diameters.

Mortality Rates

Natural mortality (M) was computed by the equation (Pauly, 1980):

$$\text{Log } M = -0.0066 - 0.2790 \text{ Log } L_\infty + 0.6543 \text{ Log } k + 0.4634 \text{ LogT}$$

Where T is the average water temperature (15ºC) of the southern Black Sea. Fishing mortality (F) was estimated as $F = Z - M$ by Beverton and Holt (1957), where Survival rate (S) can be computed from the equation: $S_{(t)} = e^{-Z(t)}$ (Ricker, 1975) and the total mortality rate (Z) was calculated using the survival rate (S), as follows: $Z = -ln(S)$ (Ricker, 1975; Gulland, 1969).

Morphometry

Ninety-four individuals were sub-sampled to determine the morphometric characteristics. Fourteen morphometric measurements of *M. batrachocephalus* were performed. These are: 1. Total length (TL), 2. Standard length (SL), 3. Head length (HL), 4. Post-orbital distance (POD), 5. Eye diameter (ED), 6. Pre-dorsal distance (PDD), 7. Length of D1 fin basis (D1L), 8. Length of D2 fin basis (D2L), 9. Pre-anal distance (PAD), 10. Length of anal fin basis (AL), 11. Max. body depth (MBD), 12. Caudal peduncle minimal depth (CPMD), 13. Pectoral length (PecL), 14. Pelvic length (PelL) (Figure 2). Digital caliper with 0.01 cm accuracy was used for morphometric measurements. Fourteen morphometric characters were evaluated as TL %. Regression analysis of differences body parts against TL of the fish were drawn by least square method.

Statistical Analysis

The Pauly's t-test was used to compare the "b" values (Pauly, 1984) to determine whether there is any significant difference or not and chi-square test were used to compare sex in this study. Statistical applications were performed by using software of Microsoft Office Excel® and SPSS 18® package programme.

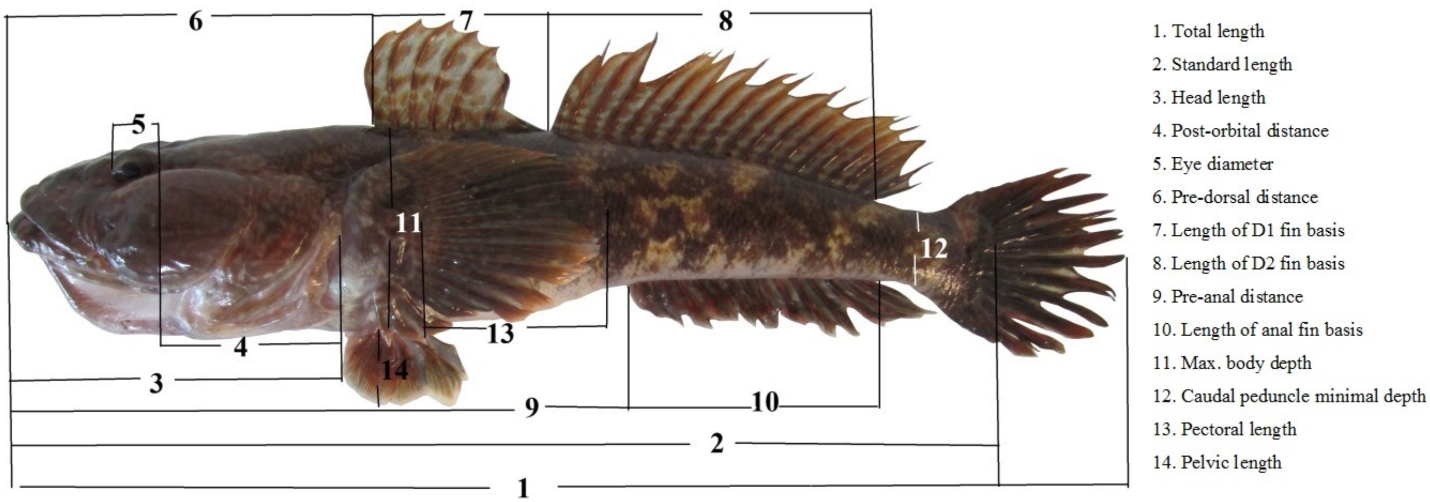

Figure 2. Overview of the morphometric measurements used in this study

Results and Discussion

Length-Frequency Distribution

A total of 641 individuals of knout goby species were obtained from the depths between 2 to 120 m during this study. The highest frequency belongs to 19-20 cm length group with 98 individuals (15.3 %). Minimum length was measured as 5.3 cm, while the maximum individual was 34.0 cm. Frequency distribution for each length group and the monthly variation of the length-frequency distribution are presented in Figure 3 and Figure 4, respectively.

Sex Composition

The percentage of total female and male individuals obtained during this study was calculated as 47.74 % (306) and 52.26 % (335) respectively, which concludes a male to female ratio of 1:0.91. The difference between the sex was found to be statistically insignificant (χ^2= 1.312, df= 1, P>0.05).

Length and Weight Relationship

The length-weight relationship for all individuals and for separate sexes is shown in Figure 5. Statistical descriptions of length and weight were presented in Table 1. Results showed positive allometry (b>3) for both clusters of the male, female and the total individuals (P>0.05) (Figure 5).

Age Composition

Sampled individuals have an age range of zero to seven. One year age group has presented with the highest frequency with a percentage of 39.0 %, while the percentage of the two oldest age group of 6 and 7 were found to be only 4 and 1 respectively (Table 2). Total number of the individuals in 0 age group was found to be 19 with a percentage of 2.96 %.

Von Bertalanffy Growth Parameters

Growth parameters of von Bertalanffy and equations were calculated and presented in Table 3. Growth performance value (Ø') was estimated as 2.55. Estimated and observed values of length age relationships were presented in Figure 6.

Spawning Period

The value of GSI in females started to increase by January and reached its peak value in March indicating that the spawning occurs in March. The average value of GSI for the female cluster is 20.96 in March, while the minimum value of GSI was found as 0.32 for September. Overall average value of GSI for female individuals was found as 4.70 ±6.32. Overall pattern of the GSI variation displays a similar behavior for male and female clusters, while the GSI value for the male cluster is systematically lower than the female one (Figure 7).

Fecundity

A total of 33 female individuals were examined in March for fecundity. Size of the individuals varies between 18.0 cm and 32.7 cm in length, and 56.0 g and 372.9 g in weight. A mini-mum and maximum value of total number of the eggs was estimated as 1707.7 and 9209.5, respectively. Average fecun-dity was calculated as 4253.6 ±1563.53. Relative fecundity was found to be 118.3 number/1g (48.9-234.5). Average di-ameter of eggs was measured as 2733.0 µm ±221.18 (2287.1-3097.8).

Condition Factor

The average condition factor of *M. batrachocephalus* was calculated as 0.913 ±0.06 (0.827-1.017) for all, 0.897 ±0.07 (0.778-0.994) for male and 0.928 ±0.07 (0.850-1.061) for female (Figure 8).

Mortality

Mortality parameters are the most important indicators for the assessment of the decrease in stocks. Total mortality rate (Z) was found as 0.481, while the survival rate (S) was calculated as 0.618. Natural mortality rate (M) was calculated by using growth parameters of the species and average temperature at depth that species live. Assuming an average habitat depth of 30 ±15 m with an average sea temperature of 13ºC for this species and utilizing the Pauly's approach M and F were estimated as 0.466 and 0.015, respectively.

Morphometric Characteristics

Ninety-four individuals were sub-sampled to determine the morphometric characteristics of the species. The average length and weight of the sub-sampled group were calculated as 23.5 cm (9.1-33.4) and 127.78 g (5.91-337.76) respectively. The means, standard errors, minimum and maximum values of the morphometric characteristics of the sub-sampled group were given in Table 4. Also, the morphometric properties of the *M. batrachocephalus* were proportional to the total length and the smallest ratio was eye size (3.7%) and the highest ratio was the standard size (85.4%).

The relationships between the morphometric characteristics and the total length were analyzed with linear regression equations. Correlation coefficients for morphometric lengths-total length relationships were given in Table 5.

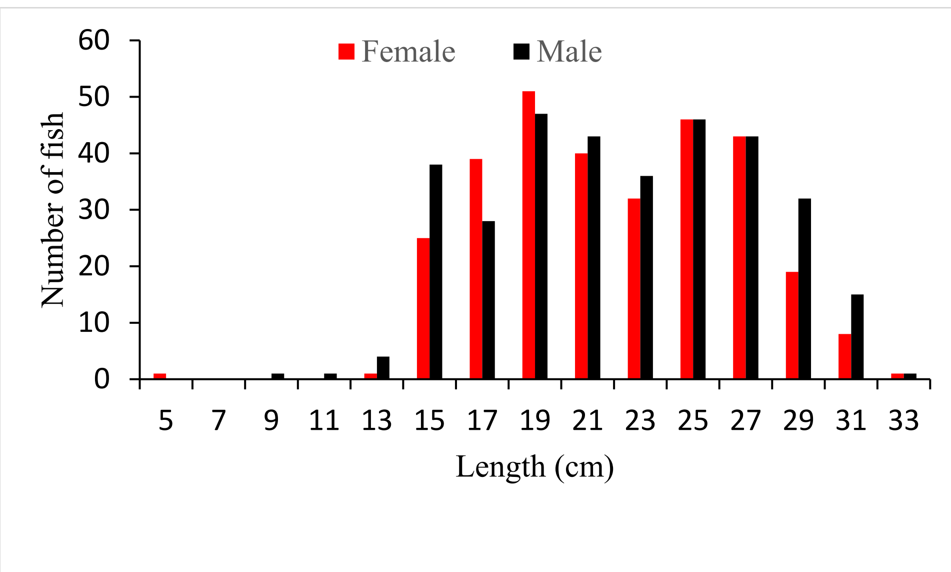

Figure 3. Frequency distribution of total length of *Mesogobius batrachocephalus* in the Black Sea

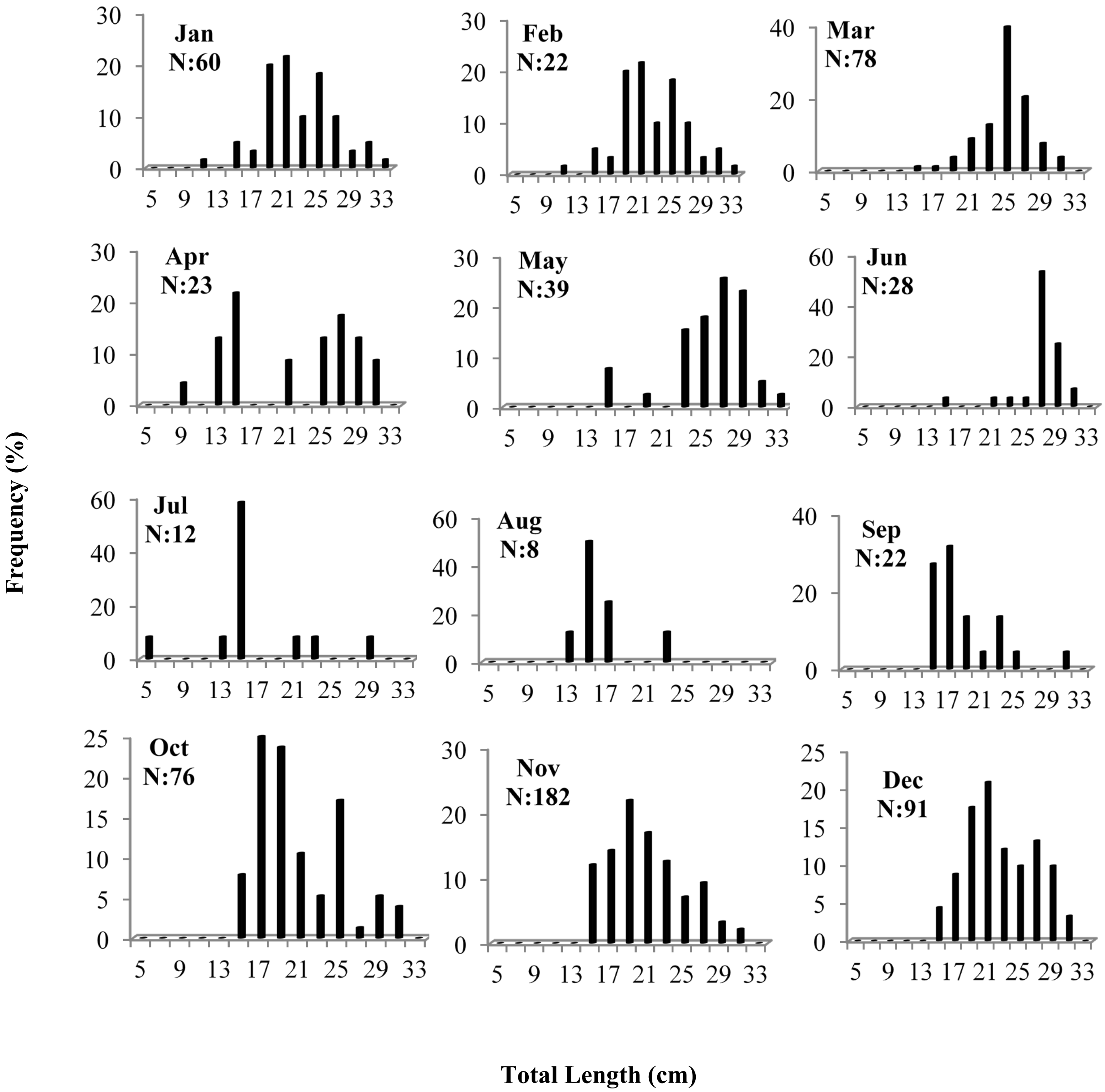

Figure 4. Monthly total length- frequency distributions of *Mesogobius batrachocephalus* in the Black Sea

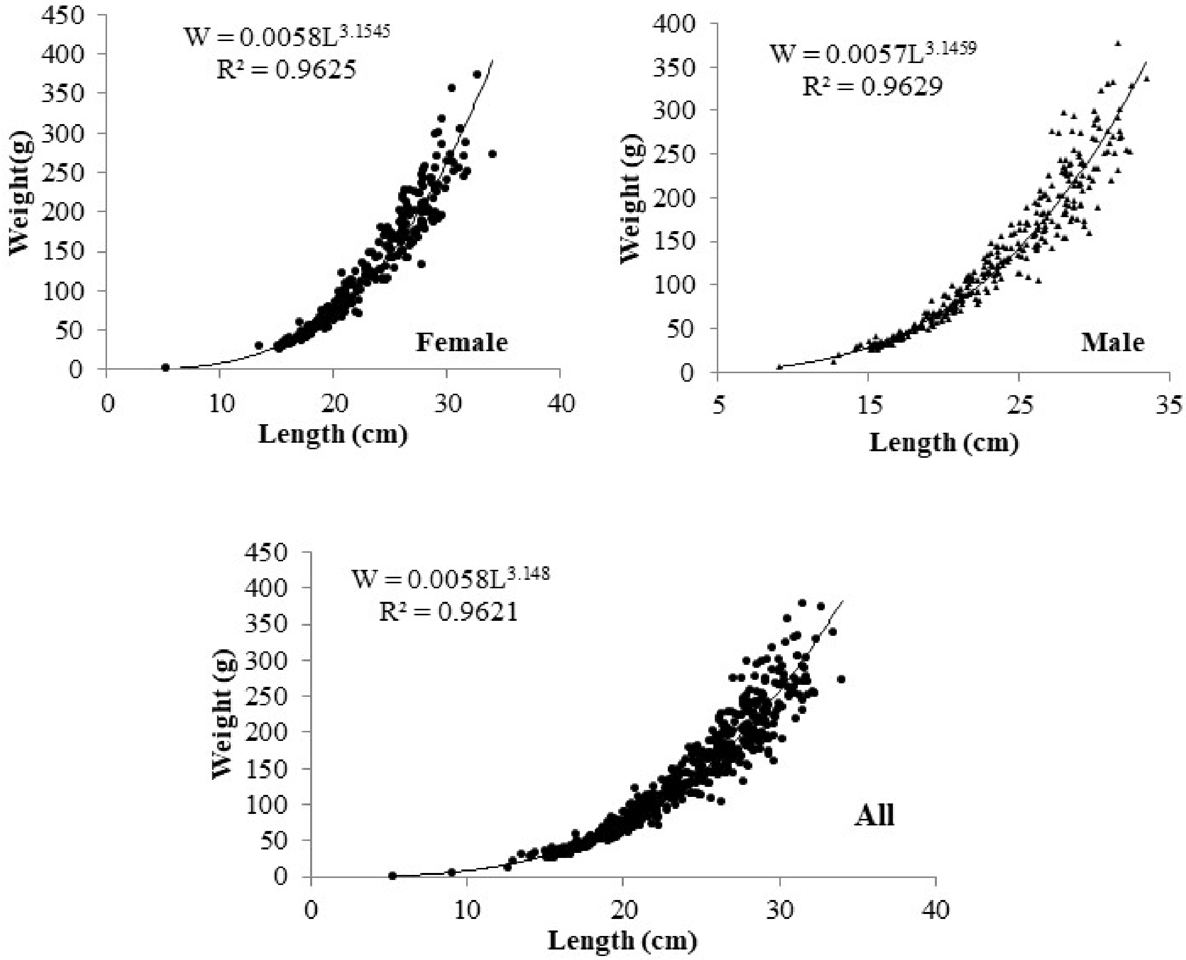

Figure 5. Total length-weight relationship of *Mesogobius batrachocephalus* in the Black Sea

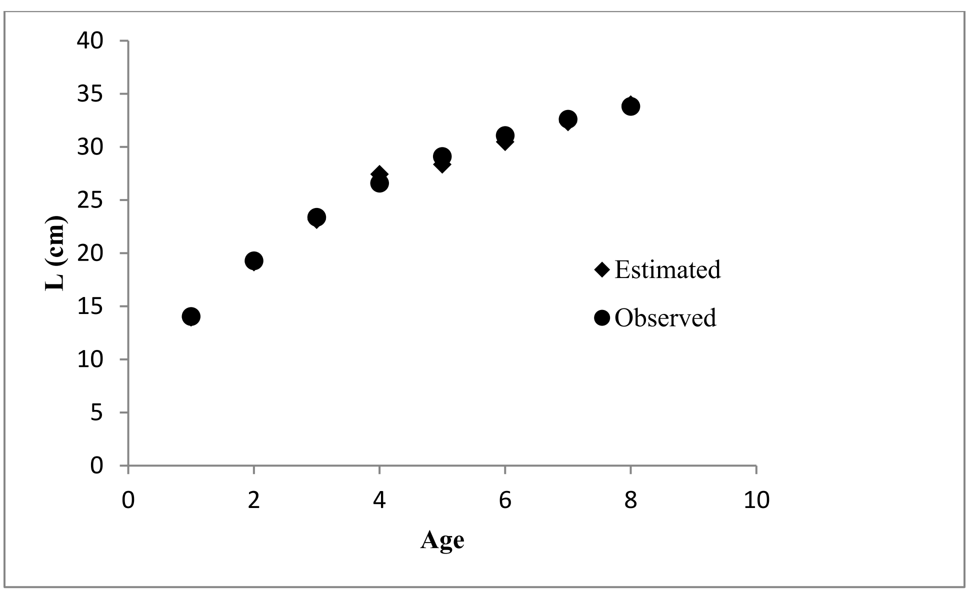

Figure 6. Age-total length relationship of *Mesogobius batrachocephalus* in the Black Sea

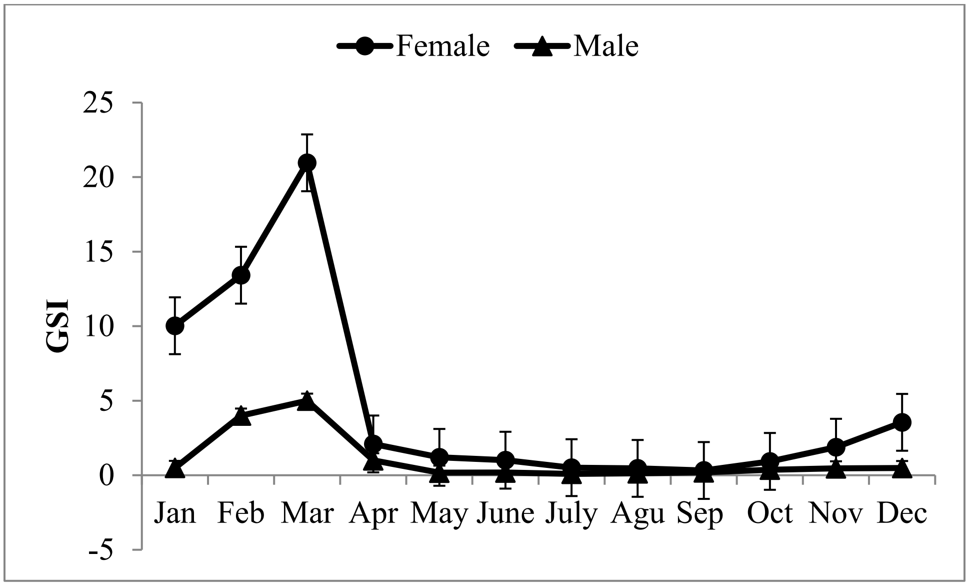

Figure 7. Monthly distribution of gonadosomatic index (GSI) values

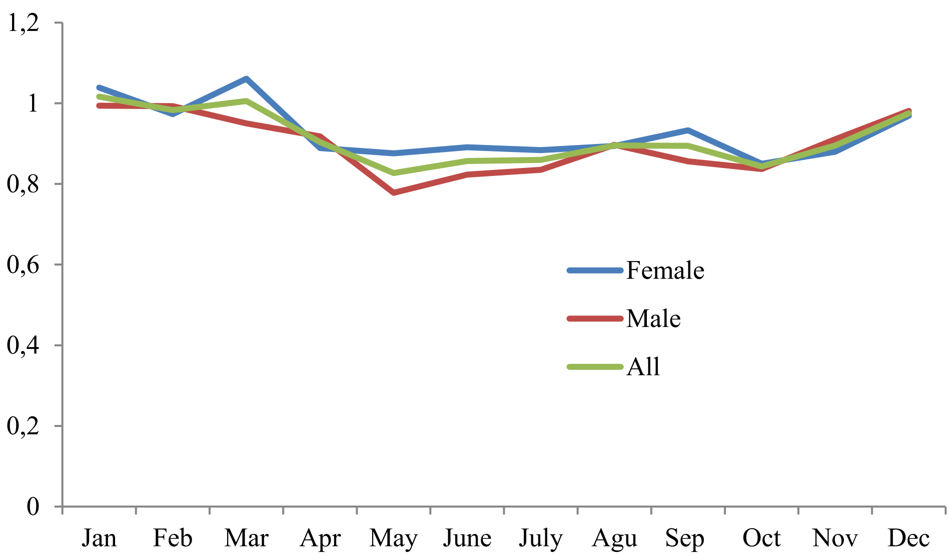

Figure 8. Monthly distribution of the Condition factor (CF) for *Mesogobius batrachocephalus*

Table 1. Total length and weight data of *Mesogobius batrachocephalus* for the total individuals and for separate sexes

	Length (cm)					Weight (g)				
	Mean	±	SD	Min.	Max.	Mean	±	SD	Min.	Max.
All	23.1	±	4.75	5.3	34	130.1	±	77.63	1.34	377.54
Female	22.9	±	4.56	5.3	34	128.9	±	75.00	1.34	372.90
Male	23.2	±	4.93	9.1	33.4	131.2	±	80.05	5.91	377.54

Table 2. Total length and weight data of the *Mesogobius batrachocephalus* for different age groups

Age	(N)	L (cm) (Mean ± SD)	W (g) (Mean ± SD)
0	19	13.96 ± 2.63	26.29 ± 9.51
1	250	19.16 ± 2.32	66.18 ± 28.94
2	142	23.15 ± 2.41	122.40 ± 38.23
3	146	27.44 ± 1.96	201.49 ± 50.80
4	56	28.36 ± 1.19	216.81 ± 40.99
5	22	30.49 ± 0.95	257.08 ± 47.24
6	5	32.36 ± 0.69	297.44 ± 54.78
7	1	34.00 ± 0 .00	272.78 ± 0.00
Total	**641**		

Table 3 Von Bertalanffy growth parameters and growth equations in *Mesogobius batrachocephalus*

Growth parameters					Length-growth functions	Weight-growth functions
L_∞	W_∞	K	t_0	b	$L(t)= L_\infty (1-e^{-k (t-to)})$	$W(t)= W_\infty (1-e^{-k (t-to)})^{b}$
38.2	432.34	0.2450	-1.873	3.148	$L(t)= 38.2 (1-e^{-0.2450(t+1.8735)})$	$W(t)=432.34(1-e^{-0.2450 (t+1.8735)})^{3.148}$

Table 4 The morphometric characteristics of *Mesogobius batrachocephalus*

Characters	Mean	SE	Min.	Max.	TL%
Total length (cm)	23.5	5.47	9.1	33.4	100
Standard length (cm)	20.07	4.66	8.2	28.4	85.4
Head length (cm)	5.77	1.35	2.6	8.4	24.6
Post-orbital distance (cm)	3.04	0.74	1.3	4.4	12.9
Eye diameter (cm)	0.87	0.19	0.5	1.3	3.7
Pre-dorsal distance (cm)	6.87	1.60	3.0	10.6	29.2
Length of D1 fin basis (cm)	2.96	0.81	1.1	4.4	12.6
Length of D2 fin basis (cm)	6.66	1.59	2.7	9.6	28.3
Pre-anal distance (cm)	11.94	3.02	4.8	17.4	50.8
Length of anal fin basis (cm)	5.05	1.10	2.1	7.4	21.5
Max. body depth (cm)	3.02	0.78	1.0	5.3	12.9
Caudal peduncle minimal depth (cm)	1.31	0.33	0.5	1.9	5.6
Pectoral length (cm)	3.66	0.88	1.6	5.8	15.6
Pelvic length (cm)	2.49	0.52	1.4	3.6	10.6
Total weight (g)	127.78	81.50	5.9	337.8	---

TL: Total length, SE: Standard Error, Min: Minimum, Max: Maximum

Table 5. Regression relationships and formulas in morphometric characters

Regression formula	r^2
SL =0.8485TL + 0.1307	0.994
HL = 0.2459TL – 0.0143	0.988
POD = 0.1324TL – 0.0759	0.973
ED = 0.0324TL + 0.1087	0.880
PDD = 0.2901TL + 0.056	0.984
D1L= 0.1448TL – 0.440	0.968
D2L = 0.2873TL – 0.0889	0.983
PAD = 0.5473TL – 0.9196	0.985
AL = 0.1982TL + 0.3902	0.979
MBD = 0.1384TL – 0.2305	0.941
CPMD = 0.0583TL – 0.0636	0.941
PecL = 0.1578TL – 0.0514	0.961
PelL= 0.0919TL + 0.3338	0.936

Total length: TL, Standard length: SL, Head length: HL, Post-orbital distance: POD, Eye diameter: ED, Pre-dorsal distance: PDD, Length of D1 fin basis: D1L, Length of D2 fin basis: D2L, Pre-anal distance: PAD, Length of anal fin basis: AL, Max. body depth: MBD, Caudal peduncle minimal depth: CPMD, Pectoral length: PecL, Pelvic length: PelL

The closest relationship was found between the total length (TL) and standard length (SL) with a linear regression value of r^2=0.99 and the weakest relationship was found to be with TL and the eye diameter (r^2=0.88).

M. batrachocephalus is an endemic species of the Black Sea, the Sea of Azov and Caspian Sea. It lives in estuaries, brackish lagoons and occasionally in fresh waters (Freyhof, 2011; Froese and Pauly, 2019) and it has a certain commercial value (Patzner et al., 2011). In this study, all individuals were sampled between the depths of 2- 120 m in the Southern Black Sea coast. *M. batrachocephalus* was sampled 120 m depth. Although Miller (1986) reported that *M. batrachocephalus* is rarely found at a depth of 100 m, some of the samples of this study was obtained from as deep as 120 m. Keskin (2012) stated that the species exemplifies intensely at depths of 22-52 m in the south-western Black Sea shelf. Even though the species is endemic to the Black Sea, there are no studies focusing on the growth, population parameters, reproduction and its morphometric characters. The majority of studies are about the feeding habits limited to the region of the Romanian coastal of the Black Sea (Porumb, 1961; Bănărescu, 1964; Mihălcescu, 2005; Crețeanu and Papadopol, 2006; Roşca and Surugiu, 2010; Roşca and Mânzu, 2011). Only few works exist in the literature studying the length and weight relationship in Turkey coast with less number of individuals when compared with this study (Demirhan and Can, 2007; Ak et al., 2009; Çalık and Erdoğan-Sağlam, 2017).

A total of 641 individuals, 335 males and 306 females, of knout goby were sampled during this study. Length of the sampled individuals ranged from 5.3-34.0 cm and with a variation in weight from 1.34 g to 377.54 g (Table 1). A previous study conducted in the Black Sea is given Table 6. It has been reported that this species can grow up to 20 cm length and 200 g weight in the Azov Sea (URL, 1). Patzner et al., (2011) indicated that the species may reach maximum of length of 35 cm. In this study, a 34 cm length individual is sampled. *M. batrachocephalus* is larger than the all other goby species liv-ing in the Black Sea and the Azov Sea (Engin, 2008, URL, 1).

Bengil and Aydın (2020) stated positive allometry growth for *M. batrachocephalus* but Demirhan and Can (2007), Ak et al., (2009), Çalık and Erdoğan-Sağlam (2017) reported that this species shows a negative allometry. However, in this study, growth was found to have positive allometry (b>3) (P>0.05). In these three studies relatively smaller individuals (max: 23.5) were sampled, however 50.2 % of the obtained individuals are larger than 23 cm in this study, thus resulting in a higher "b" value as there are more mature individuals sampled.

The allometric coefficient (b) may differ between sexes and between juvenile and adult samples (Hartnoll, 1974).

The average egg diameter was calculated as 2733.0 µm in this study. Egg diameter and fecundity data of Mesogobius genus could not be found in the literature.

Table 6. Growth parameters of previous studies from the Black Sea

References	N	Lmin-Lmax	a	b	r^2	Region
Demirhan and Can (2007)	37	7.2-13.3	0.0203	2.750	0.930	Black Sea
Ak et al. (2009)	184	5.5-18.0	0.0240	2.736	0.913	Black Sea
Çalık and Erdoğan-Sağlam (2017)	35	12.2-23.5	0.0149	2.776	0.920	Black Sea
Roşca and Mânzu (2011)	227	16.1-22.6	---	---	---	Black Sea
Bengil and Aydın (2020)	470	12.6-31.8	0.0062	3.130	0.960	Black Sea
This study	641	5.3-34.0	0.0058	3.148	0.962	Black Sea

There had been published reports about egg diameters for another goby fish, *Neogobius melanostomus,* habiting in the Black Sea and has a smaller egg diameter than the knout goby (Engin, 2008; Lavrincikova and Kovac, 2007; Hôrková and Kovácˇ, 2014). In this study, average fecundity of *Mesogobius batrachocephalus* was calculated as 4253.6 (Min: 1707.7, Max: 9209.5). Engin (2008) reported average fecundity as 1325 eggs, Lavrincikova and Kovac (2007) 557 eggs, Hôrková and Kovácˇ (2014) 3512 eggs for *N. melanostomus.*

The reproductive time of the knout goby is during the spring season (Bănărescu, 1964; Berg, 1965; Roşca and Mânzu, 2011). In this study, it was shown that the reproduction took place in March. Similarly, Engin (2008) reported a spawning period in March for *Neogobius platyrostris, Gobius paganellus* and *Gobius cobitis* in the Black Sea. Kottelat and Freyhof (2007) mentioned that the species can reach a maximum of age of 8. However, in the present study, the maximum age was similarly found as 7.

In this study; total mortality, natural mortality and fishing mortality rates were found as 0.481, 0.466 and 0.015, respectively. These are first time results for *M. batrachocephalus* in the literature. The fact that the fishing mortality rate (0.015) being close to zero indicates that there is no fishing pressure on this species (Simpfendorfer et al., 2005). Morphometric characteristics of this species were also first added to the literature by this study.

Conclusion

The species is one of the discard species catch of the coastal fisheries of the Black Sea and has become more abundant in the discard composition. Due to its large size, it has a certain commercial value in some regions and is popular for sport fishers (Patzner et al., 2011). It has also sold at fish markets. Thus, this species has become a potential commercially valuable fish for coastal fisheries on the Black Sea coast of Turkey. Aim of this study is to contribute to the limited knowledge of knout goby population parameters and its morphometry inhabiting Southern Black Sea. This is the first major population parameter information of *M. batrachocephalus.* Knowledge of this information has a great importance for fisheries managers, decision makers (General Directorate of fisheries) and marine scientists.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

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

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Species composition, substrate specificity, and seasonal abundance of periphytic algae in a tropical riverine system- Periyar, India

Blessy JOHN, R. Sunil KUMAR

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Mahatma Gandhi University, Catholicate College, Department of Zoology Pathanamthitta- 689645, Kerala, India

ORCID IDs of the author(s):
B.J. 0000-0002-0037-8391
R.S.K. 0000-0003-2485-8936

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Correspondence:
Blessy JOHN
E-mail: bessyjohn87@gmail.com

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ABSTRACT

The study was conducted to assess the species composition, substrate specificity, and seasonal abundance of periphytic algae from the river Periyar. Monthly samples were collected for one year (June 2016 – May 2017) from different substrates of five selected stations. Eight physicochemical variables such as temperature, dissolved oxygen, pH, conductivity, chloride, sulfate, nitrate, and phosphate were also monitored during the study. Taxonomic studies recorded 156 species of periphytic algae belonging to 56 genera, 36 families, and 5 classes. Naviculaceae was the most abundant family followed by Fragilariaceae and Pinnulariaceae. The principal component analysis revealed the dominance of periphytic algae in the pre-monsoon period. Canonical correspondence analysis indicates pH, conductivity, and sulfate plays a crucial role in periphytic algal assemblages. Correspondence analysis and percentage abundance among different substrates showed the preference of leaf substrate for primary colonization and subsequent succession. The study signifies the importance of substratum and environmental variables in the dynamics of periphytic algal community composition and abundance.

Keywords: Substratum, Periphytic algae, Principal component analysis, Periyar river

Introduction

Periphyton forms an important component in the functioning of all aquatic ecosystems; it is cosmopolitan in distribution and thrives well in adverse conditions of rivers and streams. It is a micro-ecosystem found on the free surfaces of submerged substrata in aquatic bodies consists of algae, protozoa, bacteria, fungi, and small metazoans (Satkauskiene & Glasaite, 2013). Algae possess a pivotal position among the periphytic organisms due to their abundance and richness (Rusanov & Stanislavskaya, 2012). Periphytic biofilm appears mostly as a green mat due to the dominant algal assemblages. Perihytic algae act as a power source for all aquatic biota and as a major regulator of nutrient fluxes since it forms the basis of all food web interactions.

Periphyton significantly contributes to bio-manipulation monitoring; since it quickly responds to slight variations in the environmental conditions, its short life cycle, and abundance in the littoral zones of aquatic ecosystems (Wu, 2017; Kanavillil & Kurisseryl, 2013). Periphytic algal community composition varies greatly in spatial and temporal scale by several biotic and abiotic factors such as temperature, light availability, nutrient influx, substrate type, water currents, submersion time, and grazing (Albay & Akcaalan, 2008; De Souza *et al*., 2015). Periphytic biofilm can be found attached to dead or living substrates such as sediments, rocks, pebbles, macrophytes, and animal bodies (Wu, 2017).

Periphyton gains more attention in the riverine ecosystem due to its stable nature. Streams and rivers are continuously moving and any suspended particle in it can reach the sea within a few days (Srivastava *et al*., 2019; Gurumayum & Goswami, 2013). Sessile life forms are spatially compacted in define limits hence periphytic algal assemblages dominate more than planktonic forms in rivers compared to lakes and reservoirs (Franca *et al*., 2011). Even though periphytons play a crucial role in aquatic health; research works on periphyton in freshwater rivers of Kerala are too limited. Most of the hydrological studies concentrate on the planktonic forms and information on periphytic forms is scarce which is more important as they are found mostly attached to the more productive littoral zones of aquatic ecosystems.

Periyar the longest river of Kerala, on its course of flow passes through lush green forests, agricultural areas, human settlement regions, townships, and industrial areas. Thus the hydrology, flora, and fauna of the river Periyar are greatly influenced by the geographical areas next to the watercourse. The study sites were chosen from the middle and lower reaches of the river Periyar; the lower reaches of the river is a hub of major industrial and commercial activities while upper reaches are comparatively less influenced by anthropogenic activities. The study aims to understand the species composition, substrate specificity, and seasonal abundance of periphytic algae in relation to the environmental parameters from the selected stations of river Periyar.

Material and Methods

Study Area

Periyar a perennial river of Kerala originates from Sivagiri peaks of Western Ghats and has a total length of 244 km. Periyar river is also known as 'Lifeline of Kerala' forms the backbone to the economy of Kerala by providing water for drinking, agricultural purposes, and electrical power generation.

Five sampling stations were selected along different stretches of river Periyar to assess the periphytic algal composition (Figure 1). Station 1 (S1): Pooyamkutty; Station 2 (S2): Kuttampuzha; Station 3 (S3): Thattekadu; Station 4 (S4): Aluva and Station 5 (S5): Varappuzha (Table 1). Station 1, 2, and 3 were located in the middle stretches of the Periyar river. These stations mainly receive agricultural runoff, domestic wastes, and laundry wastes from the nearby area. Stations 4 and 5 are located in the lower stretches and receive an enormous amount of sewage, garbage dumps, and industrial effluents from nearby towns and industries. Station 5 is also influenced by seawater intrusion during tidal cycles.

Sampling Procedure

Biological analysis

Samples were collected for a one-year duration (June 2016 – May 2017) from five selected stations. Five different substrata such as leaf, root, rock, wall, and log were chosen from each station and 5 cm^2 areas were scrapped from the selected substrate using a scalpel, brush, or blade. The scrapped contents were rinsed into a tray using distilled water and then transferred to a sampling bottle via a funnel. The samples were preserved with 4% of formalin and made upto10 mL using distilled water (Biggs & Kilroy, 2000). One mL of the preserved sample was placed on a Sedgwick rafter counting chamber for enumeration. The counting chamber was then examined under an inverted microscope (Carl Zeiss Primovert, Germany) equipped with phase contrast. Sedgwick rafter consists of 1000 cells and each cell contains a considerable number of algal cells. For convenience 5 rows consisting of 250 cells were counted and the results were expressed in the number of individuals/cm^2. Measurements and photographs of algal cells were taken and identified using standard books, key, and literature (Adhikary & Das, 2012; Edmondson, 1959; John & Francis, 2012; Karthick *et al.,* 2013).

Physicochemical analysis

Physicochemical parameters such as pH, conductivity, temperature, and dissolved oxygen (DO) were determined on-site using a Cyberscan PCD 650 multiparameter probe (Eutec instruments, Singapore). Water samples were brought to the lab under 4^0C and dark for the determination of remaining water quality parameters. The concentration of sulfate, phosphate, chloride, and nitrate was determined using standard methods (APHA, 2005).

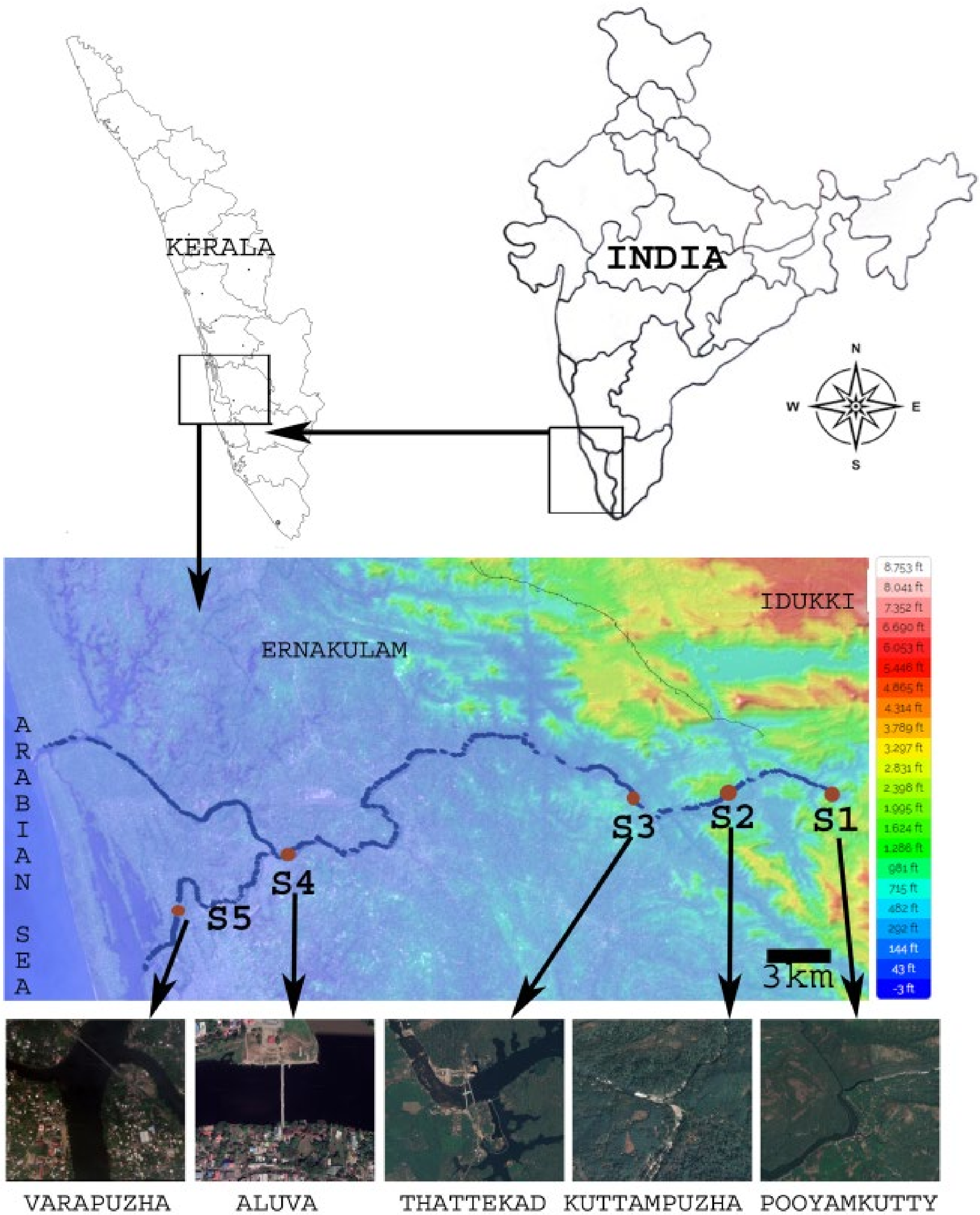

Figure 1. Map showing the selected study sites along the river Periyar

Statistical Analysis

Statistical analyses were performed using the software PAST version 318. Environmental data and periphytic algal data were subjected to normality tests using Monte-Carlo 999 permutation test. Principal Component Analysis (PCA) was conducted to know how the periphytic algal composition varies among monsoon, pre-monsoon, and post-monsoon seasons. To down weigh the contribution of abundant species, periphytic algal data were square-root transformed before analysis. Canonical Correspondence Analysis (CCA) was performed to demonstrate the relationship between periphytic algal assemblages and environmental variables. Environmental variables were subjected to Pearson's (Linear r) correlation to identify the significant variables ($p<0.05$) and were standardized using the formula (X-mean)/SD. Correspondence Analysis (CA) is also an ordination method like PCA and is used to determine the preferred distribution range of algal families to a particular substrate and station. Cluster analysis was performed using the algorithm UPGMA (Bray-Curtis similarity index) to know the percentage of similarity within the substrata and stations regarding periphytic algal abundance and distribution.

Table 1. Geographical coordinates of selected stations

Stations	Latitude	Longitude
S1 (Pooyamkutty)	10.1605° N	76.7769° E
S2 (Kuttampuha)	10.1525° N	76.7396° E
S3 (Thattekadu)	10.1040° N	76.7005° E
S4 (Aluva)	10.0758° N	76.2714° E
S5 (Varappuzha)	10.1004° N	76.3570° E

Results and Discussion

Periphyton itself is a micro-ecosystem with multiple interactions among the organisms present in it. Algae form the major proportion of periphytic biota contributing significantly towards carbon sequestration and nutrient cycling (Albay & Akcaalan, 2008). Periphytic algae can be found in all types of aquatic ecosystems due to its wide range of tolerance to adverse environmental conditions and varied habitats (Wu, 2017). The present study evaluated the seasonal distribution, substrate specificity, and habitat preference of periphytic algae with the environmental parameters.

Abiotic Parameters

Eight physicochemical parameters such as temperature, pH, dissolved oxygen, conductivity, chloride, sulfate, phosphate, and nitrate were monitored during the study period (Table 2). Correlations between the selected environmental parameters were provided in table 3. The temperature did not show much variation among selected stations even though lower reaches recorded high values of temperature, especially in the pre-monsoon period. Temperature showed a positive correlation with phosphate ($r=+0.946$) and nitrate ($r=+0.918$) at 0.05 level of significance. Dissolved oxygen values showed a gradual reduction from stations 1 to 5 in all seasons and the values were high in the middle reaches especially in the monsoon period. A negative correlation of DO with temperature ($r=-0.983$) and phosphate ($r=-0.982$) was observed at 0.01 level of significance. pH values recorded at station 5 were slightly alkaline compared to other stations. pH showed a positive correlation with conductivity ($r=+0.952$), sulphate ($r=+0.951$) and chloride ($r=+0.949$) at 0.05 level of significance. Station 5 exhibited a marked difference in conductivity from the rest of the stations and the pre-monsoon period recorded maximum conductivity values. Conductivity showed a positive correlation with pH ($r=+0.952$) at 0.05 level of significance. A high correlation of conductivity with sulfate ($r=+0.999$) and chloride ($r=+0.999$) was recorded at 0.01 level of significance. Chloride values exhibited a gradual increase from monsoon to pre-monsoon periods. A positive correlation of chloride with pH ($r=+0.949$) was reported at a 0.05 level of significance. Sulfate ($r=+0.999$) and conductivity ($r=+0.999$) values exhibited a positive correlation at 0.01 level of significance.

Nitrate has its highest value at station 4 and the pre-monsoon period marked the highest nitrate concentrations in all stations. Nitrate exhibits a positive correlation with temperature ($r=+0.918$) at 0.05 level of significance. Phosphate values showed a gradual increase from monsoon to pre-monsoon periods. Phosphate showed a positive correlation with temperature ($r=+0.946$) at 0.05 level of significance and a negative correlation with DO ($r=-0.982$) at 0.01 level of significance. Station 5 showed a significant difference in sulfate values from the rest of the stations and the pre-monsoon period recorded high values. Sulfate showed a positive correlation with pH (r=+0.951) at 0.05 level of significance. A high positive correlation of sulfate with conductivity (r=+0.999) and chloride (r=+0.999) was recorded at 0.01 level of significance.

Periphytic Algal Assemblages of River Periyar

Taxonomic studies on the periphytic algal composition of river Periyar revealed 156 species belonging to 56 genera, 36 families, and 5 classes (Table 4). Of the 36 families reported, Naviculaceae was found to be the most abundant one with 19.71% of periphytic algal species followed by Fragilariaceae (17.71%) and Pinnulariaceae (9.60%). All of these abundant families belong to the class Bacillariophyceae (Figure 2). Bacillariophyceae have specialized modifications and fixative structures for attaching to a varied substrate and they are considered as the pioneering colonizers in lotic ecosystems (Biggs, 1996). Many species of Bacillariophyceae were reported as fast and efficient colonizers of the aquatic system (Franca *et al*., 2011). The abundance of Bacillariophyceae due to its competitive ability towards adverse conditions in tropical ecosystems was reported by Cetto *et al*. (2004). Studies regarding the composition of periphytic algae from the Ganga river (Srivastava *et al*., 2019) and the Nemunas River (Satkauskiene & Glasaite, 2013) reported the dominance of Bacillariophyceae. Oterler (2016) and Kanavillil and Kurisseryl (2013) also reported the dominance of diatoms from their studies on different aquatic ecosystems.

Seasonal Distribution Based on Principal Component Analysis (PCA)

PCA showed the difference in the distribution of the periphytic algal assemblages among three seasons. Algal families were represented by vectors; the orientation and spacing of these vectors on the ordination space indicate the magnitude of dispersion of algal families among different seasons (Figure 3). Here vector for the Naviculaceae family showed maximum dispersion from the origin and showed maximum periphytic algal abundance for the pre-monsoon period. The least represented families form a cluster near the origin. Months were denoted by the dots on the ordination space which forms convex-hulls for corresponding seasons. The area enclosed by the convex hull denotes the variance of that particular group and here convex-hull for pre-monsoon shows maximum variance which signifies the dominance of the pre-monsoon period over other seasons. Principal Component (PC) 1 and 2 itself contributes to 75.22% of the variation in the data. The covariance obtained by eigenvalue showed 67.47% of the variance for the horizontal axis and 7.75% of the variance for the vertical axis. PC1 has its highest loading in the pre-monsoon season (March, April, and February). Naviculaceae and Fragilariaceae families contribute to higher scores for PC1 and thus signify the role of these families in the total algal abundance during the pre-monsoon period.

During the pre-monsoon period, generally in all lotic ecosystems water becomes more stable, organic, and nutrient load increases. The increased temperature enhances the rate of decomposition and helps in subsequent phytoplankton production (Hajong & Ramanujam, 2018; Kaparapu & Geddada, 2013). Increased water temperature and light availability in the pre-monsoon period result in the abundance of periphytic algae (Sohani, 2015). Low temperature, increased water currents, cloudy weather, and low nutrient availability may be the main causes of decreased periphytic algal abundance reported during monsoon season (Kaparapu & Geddada, 2013). As the water current increases the chances of washing off the periphytic mat increase, thereby affecting the succession pattern of the periphytic colonizers. These factors mainly contribute to the increased periphytic algal abundance in pre-monsoon and decreased abundance in monsoon. From their work on the Nemunas river and Kaunas lagoon, Satkauskiene and Glasaite (2013) reported the abundance of periphytic algae during the pre-monsoon period. Many authors agree with the dominance of the pre-monsoon period in association with periphytic algal abundance (Oterler, 2016; Franca *et al*., 2011; Srivastava *et al*., 2019).

Table 2. Physicochemical parameters monitored from five selected stations of river Periyar

	Seasons	Temperature (⁰C)	pH	DO (mg/l)	Conductiviy (mS)	Phosphate (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Chloride (mg/L)
S1	Monsoon	25.7	6.6	8.0	0.013	0.180	0.123	0.279	62.48
	Post-monsoon	25.0	6.4	8.3	0.019	0.520	0.252	0.434	74.98
	Pre-monsoon	26.2	6.1	7.8	0.03	1.060	0.172	3.600	99.97
S2	Monsoon	25.9	6.7	7.8	0.039	0.157	0.143	0.327	62.48
	Post-monsoon	26.0	6.4	8.1	0.019	0.554	0.300	0.446	74.98
	Pre-monsoon	27.1	6.0	7.5	0.029	1.072	0.266	5.000	87.47
S3	Monsoon	26.4	6.9	7.6	0.015	0.204	0.200	0.375	74.98
	Post-monsoon	27.7	6.6	7.5	0.024	0.686	0.331	0.506	74.98
	Pre-monsoon	28.0	6.3	7.1	0.033	1.160	0.200	5.900	99.97
S4	Monsoon	27.6	7.0	7.2	0.024	0.464	0.242	1.233	87.47
	Post-monsoon	29.5	6.0	6.8	0.038	0.997	0.458	2.652	99.97
	Pre-monsoon	29.7	5.8	6.5	0.043	1.511	0.369	9.805	112.46
S5	Monsoon	27.9	7.4	6.8	24.00	0.663	10.30	0.812	349.89
	Post-monsoon	30.1	7.3	6.3	46.70	1.323	40.90	2.960	1487.04
	Pre-monsoon	30.0	7.5	5.6	49.10	1.600	60.90	6.953	1928.78

Table 3. Correlation between different physicochemical parameters along the study sites of Periyar river.

	Temperature	pH	D.O	Conductiv-ity	Phosphate	Sulphate	Nitrate
Temperature							
pH	0.525						
D.O	-0.983**	-0.660					
Conductivity	0.628	0.952*	-0.760				
Phosphate	0.946*	0.661	-0.982**	0.795			
Sulphate	0.631	0.951*	-0.760	0.999**	0.797		
Nitrate	0.918*	0.182	-0.860	0.360	0.848	0.364	
Chloride	0.641	0.949*	-0.770	0.999**	0.805	0.999**	0.376
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

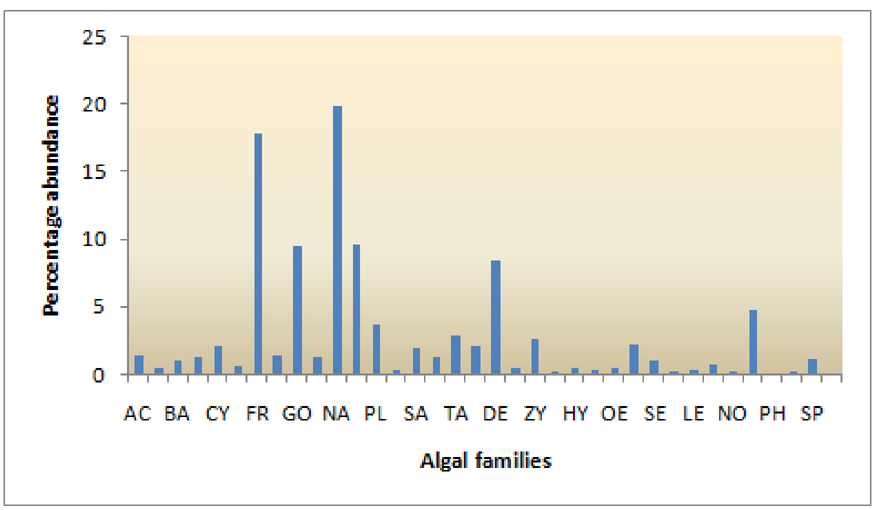

Figure 2. Percentage abundance of periphytic algal families from the river Periyar

Table 4. Taxonomic distribution of periphytic algal families identified from river Periyar

FAMILY	SPECIES	FAMILY	SPECIES
ACHNANTHACEAE (AC)	*Achnanthes brevipes* C. Agardh		*C. spinuliferum* West & G.S.West
	A .inflata (Kütz.) Grunow		*C. turgidum* Brébisson ex Ralfs
AMPHIPLEURACEAE (AM)	*Frustulia franguelli* Manguin		*Desmidium quadratum* Nordstedt
BACILLARIACEAE (BA)	*Bacillaria paxillifer* (O.F.Müller) T.Marsson		*Desmidium* sp.
	Nitzschia sigmoidea (Nitzsch) W.Smith		*Euastrum anastum* Ehrenberg ex Ralfs
	Nitzschia sp.		*E. coralloides* Joshua
	Tryblionella constricta W.Gregory		*E. didelta* Ralfs
CALENULACEAE (CA)	*Amphora ovalis* (Kützing) Kützing		*E. dubium* Nägeli
	Amphora sp.		*Hyalotheca dissiliens* Brébisson ex Ralfs
CYMBELLACEAE (CY)	*Cymbella affinis* Kützing		*Hyalotheca* sp.
	C. bengalensis Grunow		*Micrasteriasis foliacea* Bailey ex Ralfs
DIPLOEIDACEAE (DI)	*Diploneis elliptica* (Kützing) Cleve		*M. mahabuleswarensis* J.Hobson
FRAGILARIACEAE (FR)	*Asterionella* sp.		*M. pinnatifida* Ralfs
	Fragilaria capucina Desmazières		*M. radians* W.B.Turner
	F.virescens Ralfs		*Pleurotaenium* sp.
	Synedra acus Kützing		*Spondylosium planum* (Wolle) West & G.S.West
	S. ulna (Nitzsch) Ehrenberg		*Staurastrum bicorne* Hauptfleisch
EUNOTIACEAE (EU)	*Eunotia* sp.		*S. crenulatum* (Nägeli) Delponte
GOMPHONEMATACEAE (GO)	*Gomphonema angustatum* (Kützing) Rabenhorst		*S. cyrtocerum* Brébisson
	G. gracile Ehrenberg		*S. gracile* Ralfs ex Ralfs
	G. grunowii R.M.Patrick & Reimer		*S. nodulosum* Prescott
	G. intricatum Kützing		*S. perundulatum* Grönblad
	G. parvulum (Kützing) Kützing		*S. pinnatum* W.B.Turner
	G. telegraphicum Kützing		*S. spiniceps* Willi Krieger
MELOSIRACEAE (ME)	*Melosira granulate* (Ehrenberg) Ralfs		*S. tohopekaligense* Wolle
	M. monoliformis C. Agardh		*S. zonatum* Børgesen
	Melosira Sp.		*Staurodesmus conatus* (P.Lundell) Thomasson
NAVICULACEAE (NA)	*Navicula protracta* Grunow		*S. dickiei* (Ralfs) Lillieroth
	N. microspora Kant and Gupta	MESOTAENIACEAE (MS)	*Netrium digitis* Brébisson ex Ralfs
	N. radiosa Kützing	ZYGNEMATOPHYCEAE (ZY)	*Mougeotia operculata* Transeau
	N. striolata (Grunow) Lange-Bertalot		*Mougeotia* sp.
PINNULARIACEAE (PI)	*Pinnularia biceps* W.Gregory		*Spirogyra baileyi* Schmidle
	P. braunii Cleve		*S. chungkingensis* Jao
	P. divergens W. Smith		*S. elongate* (Vaucher) Dumortier
	P. gibba (Ehrenberg) Ehrenberg		*S. hyaline* Cleve
	P. major (Kützing) Rabenhorst		*S. lutetiana* Petit
	P. microstauron (Ehrenberg) Cleve		*S. maravillosa* Transeau
	P. nodosa (Ehrenberg) W.Smith		*S. nawashini* Kasanowsky
	P. viridis (Nitzsch) Ehrenberg		*S. parvula* (Transeau) Czurda

PLEUROSIGMATACEAE (PL)	*Gyrosigma acuminatum* (Kützing) Rabenhorst		*Zygnema gangeticum* Bhashyakarla Rao
	G. distortum (W.Smith) J.W.Griffith & Henfrey	GONIACEAE (GN)	*Gonium compactum* M.O.P.Iyengar
	G. eximum (Thwaites) Boyer	HYDRODICTYACEAE (HY)	*Pediastrum boryanum* (Turpin) Meneghini
	G. obtusatum (Sullivant & Wormley) C.S.Boyer		*P. duplex* Meyen
	G. scalproides (Rabenhorst) Cleve		*P. simplex* Meyen
	Pleurosigma lange -bertalotii Karthick & Kociolek	MICROSPORACEAE (MI)	*Microspora pachyderama* (Wille) Lagerheim
	Pleurosigma sp.		*Microspora* sp.
SIRURELLACEAE (SI)	*Sirurella robusta* Ehrenberg	OEDOGONIACEAE (OE)	*Oedogonium echinospermum* A.Braun ex Hirn
	Sirurella sp.		*Oedogonium* sp.
STAURONEIDACEAE (SA)	*Stauroneis acuta* W. Smith	SCENEDESMACEAE (SC)	*Scenedesmus denticulats* Lagerheim
	S. anceps Ehrenberg		*S. perforates* Lemmermann
	S. phoenicenteron (Nitzsch) Ehrenberg		*S. prismaticus* Brühl & Biswas
STEPHANODISCACEAE (ST)	*Cyclotella* sp.		*S. granulates* West & G.S.West
TABELLARIACEAE (TA)	*Tabellaria flocullosa* (Roth) Kützing		*S. quadricauda* (Turpin) Brébisson
CLOSTERIACEAE (CL)	*Closterium acerosum* Ehrenberg ex Ralfs		*S. quadrispina* Chodat
	C. dianae Ehrenberg ex Ralfs	SELENASTRACEAE (SE)	*Ankistrodesmus benardii* Komárek
	C. leibleinii Kützing ex Ralfs		*Ankistrodesmus spiralis* (W.B.Turner) Lemmermann
	C. monoliferum Ehrenberg ex Ralfs		*Ankistrodesmus* sp.
	C. parvulum Nägeli		*Selenastrum gracile* Reinsch
	C. tumidulum F.Gay	CHROCOCCACEAE (CH)	*Chroococcus* sp.
	C. venus Kützing ex Ralfs		*Aphanocapsa* sp.
DESMIDACEAE (DE)	*Cosmrium auriculatum* Reinsch	LEPTOLYNGBYCEAE (LE)	*Leptolyngbya lurida* (Gomont) Anagnostidis & Komárek
	C. botrytis Meneghini ex Ralfs	MERISMOPEDIACEAE (MR)	*Merismopedia tenuissima* Lemmermann
	C. circularae Reinsch	NOSTOCACEAE (NO)	*Anabaena* sp.
	C. contractum O.Kirchner	OSCILLATORIACEAE (OS)	*Lyngbya dendrobia* Brühl & Biswas
	C. decoratum West & G.S.West		*L. sordida* Gomont
	C. formulosum Hoff		*Oscillitoria constricta* Szafer
	C. javanicum Nordstedt		*O. princeps* Vaucher ex Gomont
	C. margaritatum (Lund.) Roy & Bissett		*O.rubescens* De Candolle ex Gomont
	C. obsoletum (Hantzsch) Reinsch		*O.salina* Biswas
	C. pardalis Cohn		*Oscillitoria* sp.
	C. perforatum P.Lundell		*O.subbrevis* Schmidle
	C. pluriradians Scott, A.M. & Grönblad		*O.tenius* C.Agardh ex Gomont
	C. porteanum W.Archer		*Phormidium crassior* (Behre) Anagnostidis
	C. pseudopyrimidatum P.Lundell		*Phormidium* sp.
	C. psuedobroomei Wolle	PHORMIDIACEAE (PH)	*Planktothrix rubrscens* De Candolle ex Gomont
	C. psuedoconnatum Nordstedt		*Symploca hydnoides* Kützing ex Gomont
	C. quadriverrucosum West & G.S.West	SCYTONEMATACEAE (SY)	*Scytonema rivulare* Borzì ex Bornet & Flahault
	C. quadrum P.Lundell	SPIRULINACEAE (SP)	*Spirulina major* Kützing ex Gomont
	C. speciosum P.Lundell	EUGLENACEAE (EU)	*Phacus* sp.

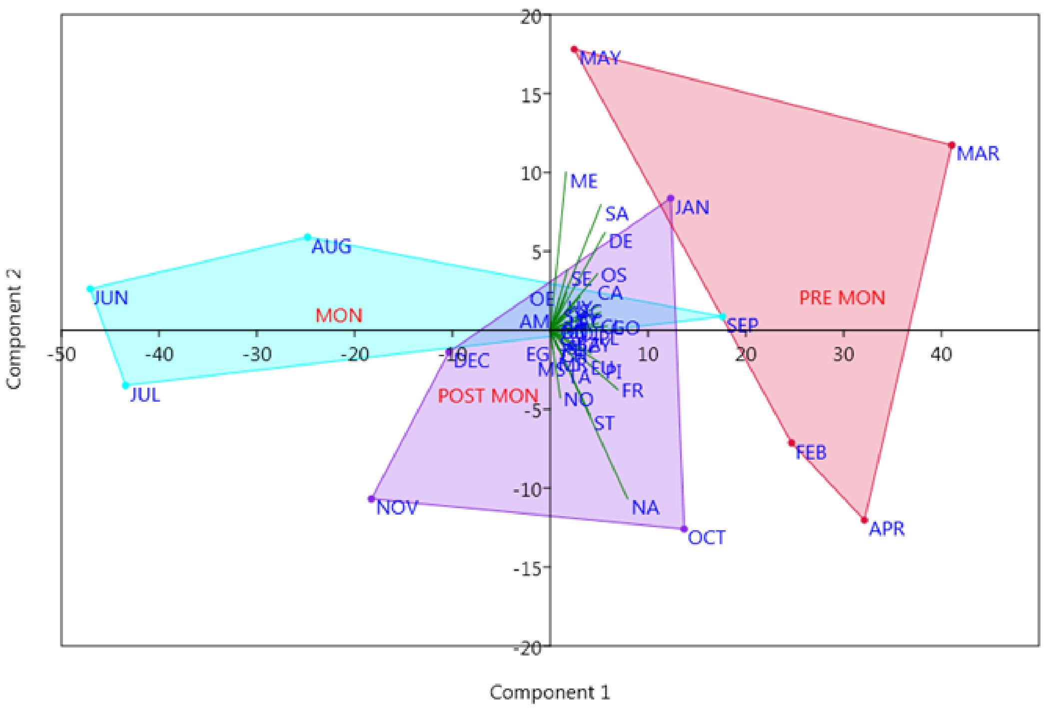

Figure 3. PCA depicting periphytic algal community composition and seasonal abundance. Algal families were represented by the vectors radiating from the origin. Dots on the plot represents months(JUN-June, JUL-July, AUG-August, SEP-September, OCT-October, NOV- November, DEC- December, JAN- January, FEB- February, MAR-March, APR-April) and convex-hull denotes 95% confidence level for corresponding seasons(MON-monsoon, POST MON-post-monsoon, PRE MON- re-monsoon). Abbreviations for algal families were provided in table 2.

Canonical Correspondence Analysis (CCA)

Canonical Correspondence Analysis (CCA) was conducted to know the relation existing between the eight environmental parameters studied and 36 periphytic algal families reported. Eigenvalues of axis1 (lambda = 0.14) and axis 2 (lambda = 0.07) itself explain 73.44% of the relationship between the data. In the ordination plot, environmental parameters were represented by vectors radiating from the origin, and algal families were represented by dots on the space (Figure 4). The vector for dissolved oxygen (DO) is an obtuse angle with all other vectors; illustrates that DO is negatively correlated with all other environmental variables. Vectors for nitrate and phosphate form an acute angle denote the positive correlation with each other; likely conductivity, chloride, temperature, and sulfate were positively correlated.

Axis 1 forms positive association with pH (r = 0.778), conductivity (r = 0.626), sulphate (r = 0.626), temperature (r = 0.618), phosphate (r = 0.576) and with station 5. Periphytic algal families like Pinnulariaceae, Cymbellaceae, Oscillatoriaceae, Euglenaceae, Acanthaceae, Calenulaceae, Stephanodiscaceae, Spirulinaceae, and Bacillariaceae also have positive loadings for axis 1 and thus illustrate the role of pH, temperature, conductivity, sulfate, and phosphate in the distribution of these algal families around station 5. Acute angles formed by these environmental vectors illustrate a positive correlation with each other. Station 5, Varappuzha is located in the lower stretches of river Periyar and is continuously receiving an enormous amount of sewage, garbage dumps, and industrial effluents from nearby industries and towns resulted in the increased values for phosphate, sulfate, and conductivity at this station. This station also receives a considerable amount of seawater during tidal cycles account for the increased chloride, conductivity, and pH. Satkauskiene and Glasaite (2013) from their studies on the Nemunas river, Lithuania reported that higher temperatures and alkaline pH favor the growth of periphyton. A significant positive association of phytoplankton with water temperature, pH, and chlorides were reported by Kaparapu and Geddada (2013) from their studies conducted on a tropical freshwater system. Axis 1forms a negative association with dissolved oxygen (r=-0.653) and with stations 1and 2. Periphytic algal families Closteriaceae, Chrococcaceae, Selenastraceae, Desmidaceae, Goniaceae, and Nostocaceae also have negative loadings for axis 1, and clearly define the role of DO in the distribution and abundance of these families around Stations 1 and 2. These stations were located in the middle stretches of river Periyar and DO values recorded from these regions were comparatively higher than other stations. Oterler (2016) reported a negative correlation of phytoplankton with DO from his studies on the Tundzha river, Turkey. Kaparapu and Geddada (2013) also agree with the negative correlation of DO with periphytic algal assemblages as per their studies on the Riwada reservoir, Andra Pradesh.

Station Wise Distribution of Periphytic Algae

Percentage abundance of station wise distribution of periphytic algae follows the order; station 4 (S4) > station 1 (S1) > station 5 (S5) > station 2 (S2) > station 3 (S3) (Figure 5). The maximum number of species was reported from station 4 (29.52%) and minimum from station 3 (12.54%). *Navicula micropspora, N. protracta, Fragilaria virescens, F. capucina, Synedra ulna, S. acusa, Gomphonema grunowii, Pinnularia viridis* and *Tabellaria floculosa* were the dominant species reported from station 4.

Correspondence analysis (CA) ordination plot indicates that all the periphytic algal families fall within the 95% ellipse region and most of the families were distributed around stations 4 and 5 (Figure 6).

Cluster analysis based on the Bray Curtis similarity index resulted in a dendrogram which shows a total of 68% similarity between selected stations (Figure 7). Stations 4 and 5 located in the lower reaches showed 81% similarity in the periphytic algal composition. Stations 1 and 2 showed 73% of similarity while S3, the center lying station forms an outlier and shows the least similarity (68%) with other stations.

The nature of the habitat and the hydrological conditions existing in an area clearly defines the composition of organisms present in that locality. Estimation of periphytic algal abundance among selected stations showed that station 4 harbors more species and station 3 harbors the least number of species. The ordination plot resulted from CA analysis also showed that most of the families were distributed around stations 4 and 5. Station 4, Aluva is a major industrial center and an important commercial town. Periyar river flowing through the Aluva region receives a considerable amount of organic and inorganic pollution load from nearby industries and towns which accounts for the increased nitrate and phosphate content in this station (Joseph, 2004, KSPCB, 1981). Domestic sewage discharge and increased anthropogenic activities result in nutrient enrichment and the corresponding increase in periphytic algal production (Dhanasekaran et al., 2016; Joseph, 2017). Dendrogram resulted from cluster analysis of the algal assemblages from selected stations showed 70% of similarity in species composition of periphytic algae among selected stations although their number may vary between stations.

Substrate Wise Distribution of Periphytic Algae

Percentage abundance of substrate wise distribution of periphytic algae follows the order leaf > root > log > wall > rock (Figure 8). Leaf harbor maximum number of periphytic algae with 34.46% of abundance followed by root (22.70%). Rock was the least preferred substrate with only 9% of abundance. *Fragilaria capucina, F. virescens, Synedra ulna, Gomponema grunowii, Navicula protracta, N. microspora, Pinnularia viridis* and *Tabellaria flocullosa* were the most dominant species found on leaf substratum.

The ordination plot resulted from correspondence analysis illustrates the distribution of periphytic algal families along the selected substrate. All families except Chrococcaceae, Phormidaceae, and Amphipleuraceae fall in the 95% ellipse region and most of the families prefer leaf as their preferred substrate for colonization (Figure 9).

Dendrogram drawn based on the cluster analysis between different substrata resulted in two groups with a total of 72% of similarity. Log and wall (86%) showed a higher percentage of similarity in periphytic algal composition followed by leaf and root (85%) whereas rock forms an outlier showing the least similarity with the rest of the substrate (Figure 10).

Substrate plays a crucial role in the colonization and composition of periphytic algae compared to planktonic forms. All substrata are highly dynamic in their physical characteristics and functional interactions with the attached biota. Most of the periphytic algal forms are seen in the littoral zones of lotic systems and are easily encountered by all types of contaminants that originate from the nearby land area (Kanavillil & Kurisseryl, 2013). These littoral areas possess different substrata like rock, leaf, wall, and log where periphytic algae can easily attach and grow. Estimation of percentage abundance of periphytic algae among different substrata showed the abundance of periphyton in leaf followed by root. The correspondence analysis plot also shows the importance of leaf as a suitable substratum for colonization. Periphytic algal mat is developed from the propagules of planktonic forms; leaves are continuously facing the water currents and due to its large surface area these planktonic propagules can easily attach and colonize (Kanavillil & Kurisseryl, 2013). Most of the periphytic algal assemblages choose leaf as their preferred substratum because of the large surface area, easy colonization, and attachment using specific modifications.

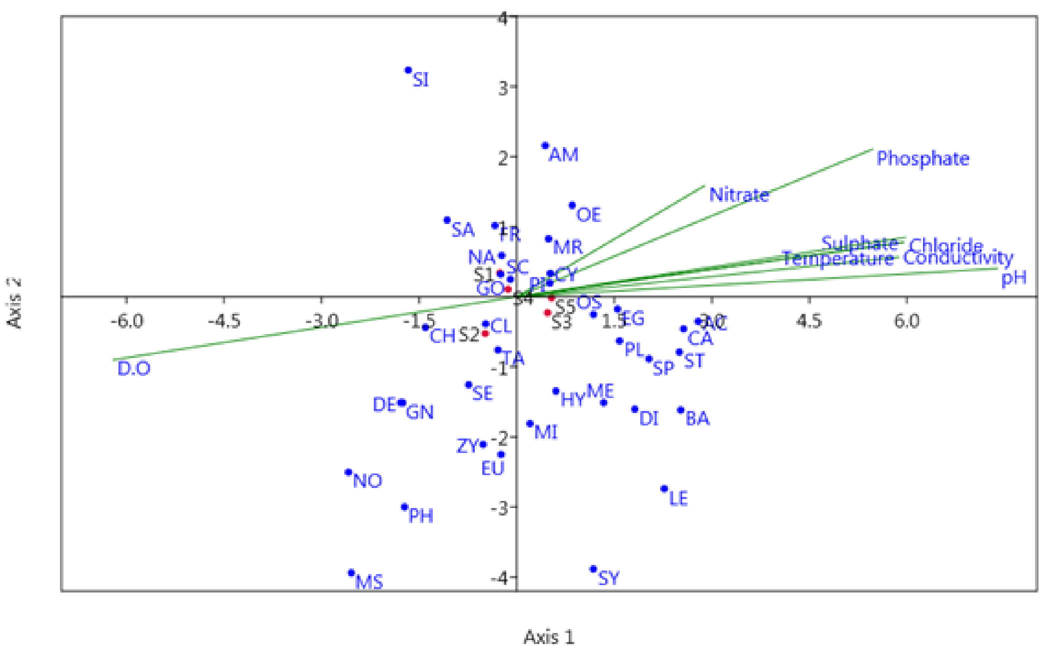

Figure 4. CCA ordination plot depicting the relationship between environmental parameters and algal assemblages. Environment variables were represented by vectors radiating from the origin. Algal families were represented by dots on the plot (abbreviations given in table2). Red dots denote selected stations (S1-station 1, S2-station 2, S3-station 3, S4-station 4, S5- station 5).

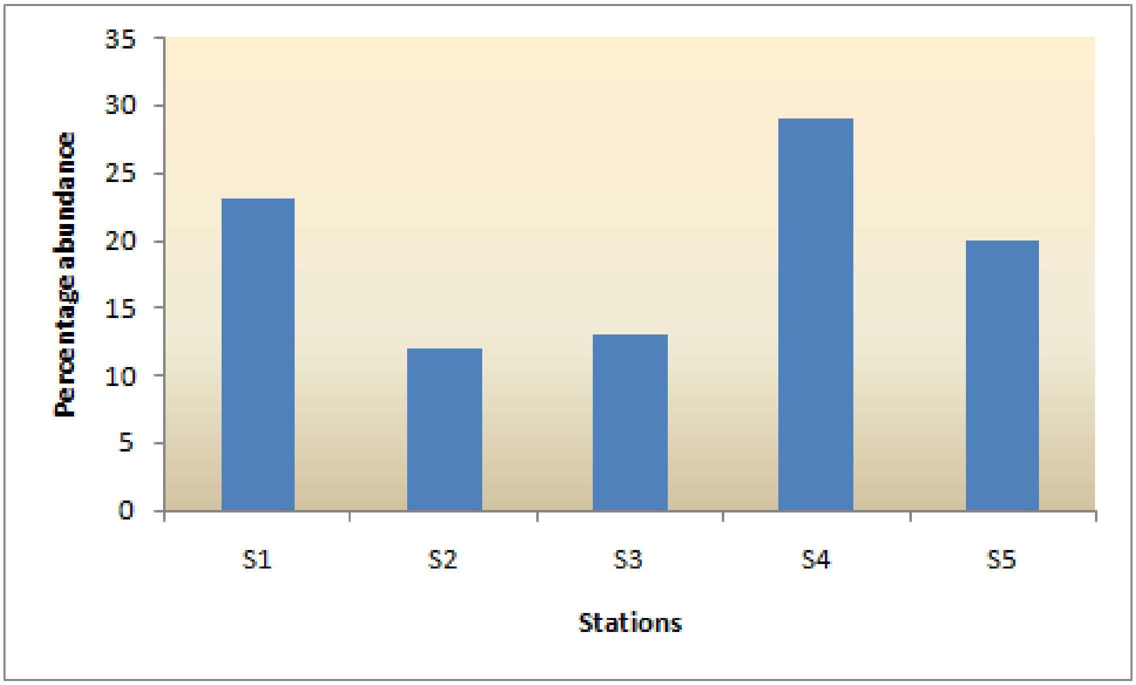

Figure 5. Percentage abundance of periphytic algae from selected stations of river Periyar

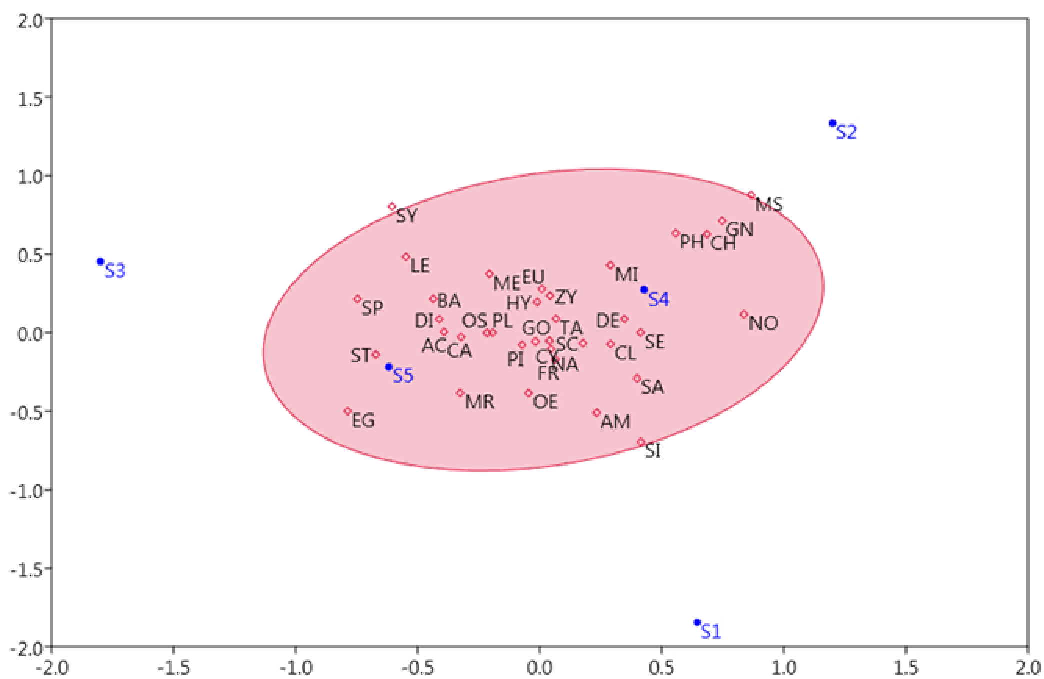

Figure 6. CA ordination plot depicting the distribution of periphytic algal families on selected stations. The ellipse encloses 95% confidence level. Diamond denotes periphytic algal families (abbreviations for were provided in table 2). Stations were represented by dots on the plot (S1-station 1, S2-station 2, S3-station 3, S4- station4, S5-station 5)

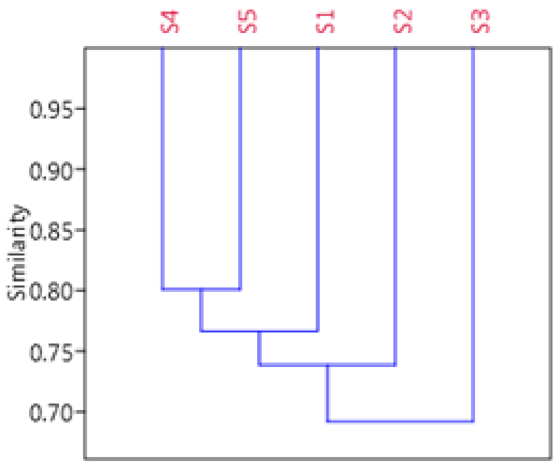

Figure 7. Dendrogram(UPGMA) based on Bray Curtis similarity index depicting the taxonomic composition of periphytic algal families along with different stations

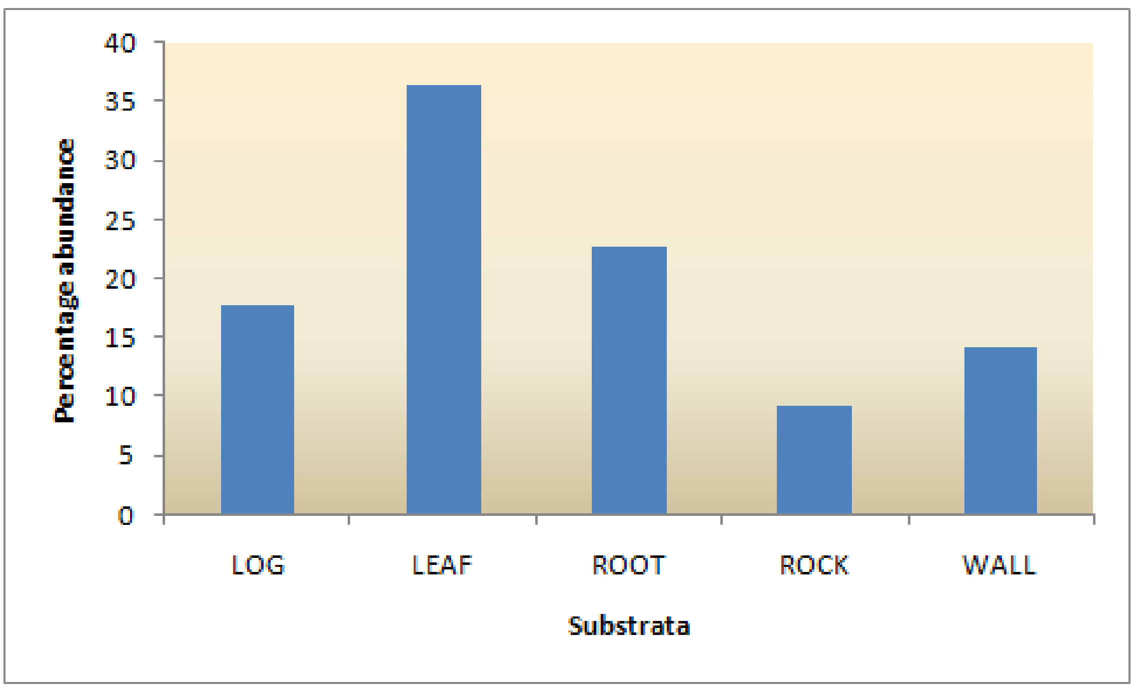

Figure 8. Percentage abundance of periphytic algae from different substrata of river Periyar

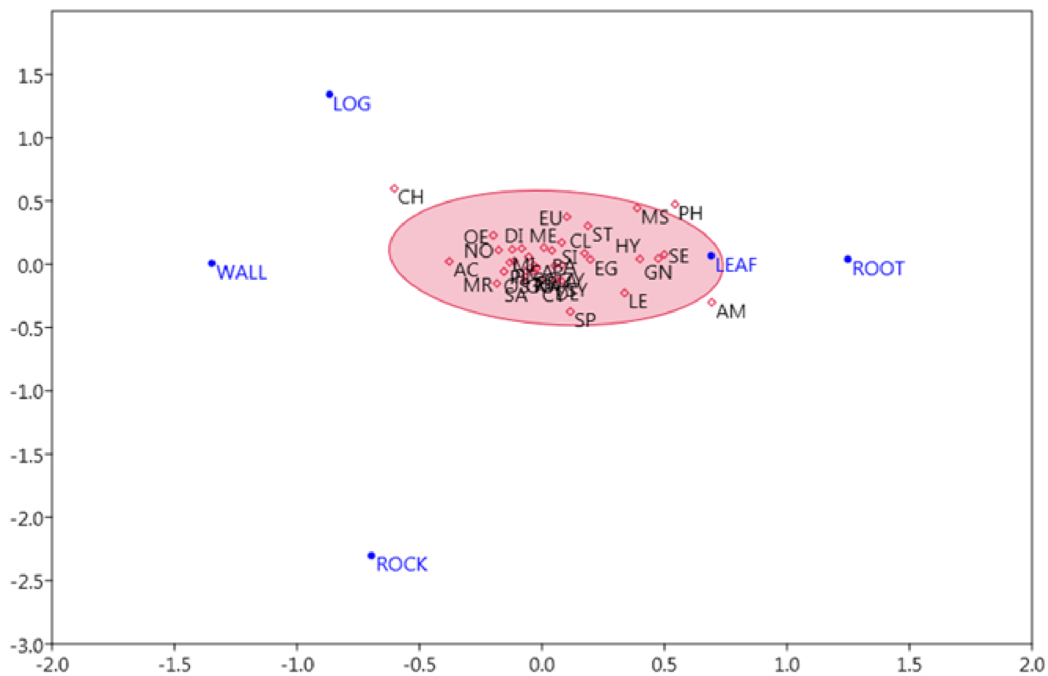

Figure 9. CA plot depicting the distribution of periphytic algal families along the selected substrate. The ellipse encloses 95% confidence level. Periphytic algal families were represented by the diamond symbol (abbreviations for were provided in table 2). Dots on the plot denote different substrata.

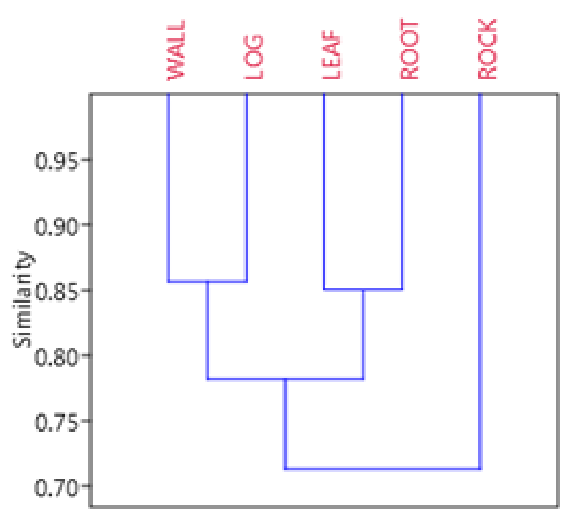

Figure 10. Dendrogram (UPGMA) based on Bray Curtis similarity index depicting the taxonomic composition of periphytic algae on varying substrate.

Conclusion

Algae possess a pivotal space among periphytic organisms. Due to its photoautotrophic nature algae acts as a power source for the whole periphytic biota and a regulator for nutrient fluxes. Its short life cycle and the ability to respond to slight environmental variations make periphytic algae as a good bioindicator. The present study deals with species composition, substrate specificity, and environmental preference of periphytic algae of river Periyar. The maximum abundance of periphytic algae was reported from station 4, which also experienced the maximum nutrient load. Most of the periphytic algal species choose leaf as their preferred substratum followed by root and log. PCA revealed the dominance of Naviculaceae and Fragilariaceae families in the pre-monsoon period. CCA illustrates that the combined actions of several environmental variables like pH, conductivity, sulfate, temperature, phosphate, and DO determine the periphytic algal composition, diversity, and richness along river Periyar. Since adequate and accurate information regarding periphytic algae of river Periyar is too scarce, the data obtained will serve as a base-line for future studies.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: All authors declare that this study does not include any experiments with human or animal subjects.

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New distributional record of oblique-banded grouper, *Epinephelus radiatus* (Day, 1868) from the St. Martin Island, Bangladesh

Md. Abu HANIF[1], **Md. Rajib SHARKER**[1, 2], **Shaharior HOSSEN**[2], **Moniruzzaman BIPU**[3]

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[1] Patuakhali Science and Technology University, Department of Fisheries Biology and Genetics, Patuakhali-8602, Bangladesh

[2] Chonnam National University, College of Fisheries and Ocean Sciences, Department of Fisheries Science, 50 Daehakro, Yeosu, Jeonnam, 59626, Republic of Korea

[3] Riverine Station, Bangladesh Fisheries Research Institute (BFRI), Chandpur-3600, Bangladesh

ORCID IDs of the author(s):
M.A.H 0000-0002-9198-3879
M.R.S. 0000-0002-2423-5459
S.H. 0000-0003-3581-2271
M.B. 0000-0002-6154-8278

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Correspondence:

Md. Abu HANIF
E-mail: mahanif.pstu@gmail.com

ABSTRACT

Groupers are mostly found in the reef-associated marine habitat, of which some are pelagic and others are demersal. Recently, a grouper species called Oblique-banded grouper, *Epinephelus radiatus* (Day, 1868) was newly reported while conducting research work on the availability of reef-associated fishes in St. Martin Island. This species had never been reported to occur not only from this coral reef area but also from the water area of Bangladesh. *E. radiatus* was easily identified following morphological traits, especially color pattern. The findings of the present study added new distributional range for this grouper species from Bangladeshi water.

Keywords: First record, Grouper, Coral reef, St. Martin Island, *Epinephelus radiatus*

Introduction

A coral reef is one of the most important biodiversity hotspots on earth, which contain some species-rich communities of marine fishes (Stuart-Smith et al. 2013, Rabosky et al. 2018, Atta et al. 2019). St. Martin's is the only coral belonging Island of Bangladesh endowed with vast marine and land resources having a global biodiversity significance. Molony et al. (2006) recorded a total of 225 fish species from this island of which most abundant fishes are Parrot, Snappers, Damsel, Surgeon, Butterfly, Emperors and Grouper. Thompson and Islam (2010) documented a list of 98 coral-associated fish species from this Island, including five species of grouper.

Groupers of the family Epinephelidae, earlier placed as a subfamily in Serranidae are of considerable economic value in tropical and subtropical countries (Rimmer and Glamuzina, 2017). The family comprises more than 160 species in 16 genera in the world (Tucker et al. 2016, Zhuang et al. 2013). Initially, Hossain (1969) listed eight species of epinephelids from the marine water of Bangladesh; however, nine more species had been added in the recent decade (Rahman et al. 2009; Thompson and Islam, 2010, Habib et al. 2017). By now, 17 species in 4 genera are available in this reef. *Epinephelus radiatus* of this family is distributed widely in the Indo-Pacific from East Africa to Tonga, including Zanzibar, Chagos, Lacadives, St. Brandon's Shoals, Maldives, Sri Lanka, India, Nazareth Bank, Sumatra, Fiji (Randall et al. 2003). It is a coral reef-associated species and inhabits relatively deep waters of rocky and coral reefs associated area in tropical region. It may also occur in marine protected areas in some parts of its range. However, juvenile *E. radiatus* mainly occur shallow rocky area while adults comparatively deeper water. This species is explicitly rare but abundantly found when it forms large schools. Although, the species is considered as a protogynous hermaphrodite; however, further research is needed to confirm this. The present paper reports a new record of *E. radiatus* for the first time from Bangladeshi water.

Material and Methods

In March 2018, three individuals of a species of grouper fish were sampled from a fisherman catch captured from the Saint Martin's Island (coordinate 20.611° N and 92.327° E) of Bangladesh (Figure 1) at a depth approximately 22m during coral-associated fish diversity survey. Collected specimens were preserved in ice box and transported to the laboratory for identification. In the laboratory, fourteen morphometric measurements and seven meristic counts were taken from the collected species (Table 1) by using measuring board nearest to 0.1cm. A digital electric balance were used to measure the weight of sampled specimens up to 0.1g. The specimens were identified as *E. radiatus* according to traditional morphology-based taxonomic keys (Randall and Heemstra, 1991; Heemstra and Randall, 1993; Baldwin et al. 1994) and color pattern. The examined specimens (F1807SM-48) were deposited in the Fisheries Lab., Department of Fisheries Biology and Genetics, Patuakhali Science and Technology University, Patuakhali, Bangladesh.

Results and Discussion

Morphometric and meristic traits of *E. radiatus* are given in Table 1. *E. radiatus* is a fusiform fish. Both body and head are compressed; maxilla reaching to hind margin orbit; midlateral part of the lower jaw with two rows of palatine teeth (Figure 2); posterior margin of preopercle serrated and five enlarged serrae at the coner; three spines on opercle and one spine hided membrane; dorsal spines easily distinguished from rays; third dorsal spine longest; second and third anal spines subequal; pelvic fins not reaching anus; caudal fin convex to moderately rounded.

Colour Pattern

Immediately after capture, *E. radiatus* had greyish brown with five irregular oblique dark-edged brown bands (Figure 2); the first band curvilinearly extending from upper half of orbit to nape; second band branching from the first band just behind the eye, crossing anterior dorsal margin of the operculum, broadening on back and extending fourth dorsal spine; the third band began basally to the second band at opercular flap, expanding into posterior spinous of dorsal fin; fourth band runs from a rear end of dorsal fin, branching at medial side, with one branch going towards the origin of the anal fin, the other to a rear end of the base of the anal fin, the fifth band on the caudal peduncle, also branching ventrally. But after preservation, greyish brown with five irregular oblique dark-edged brown bands paler than alive; expressly, a margin of body paled.

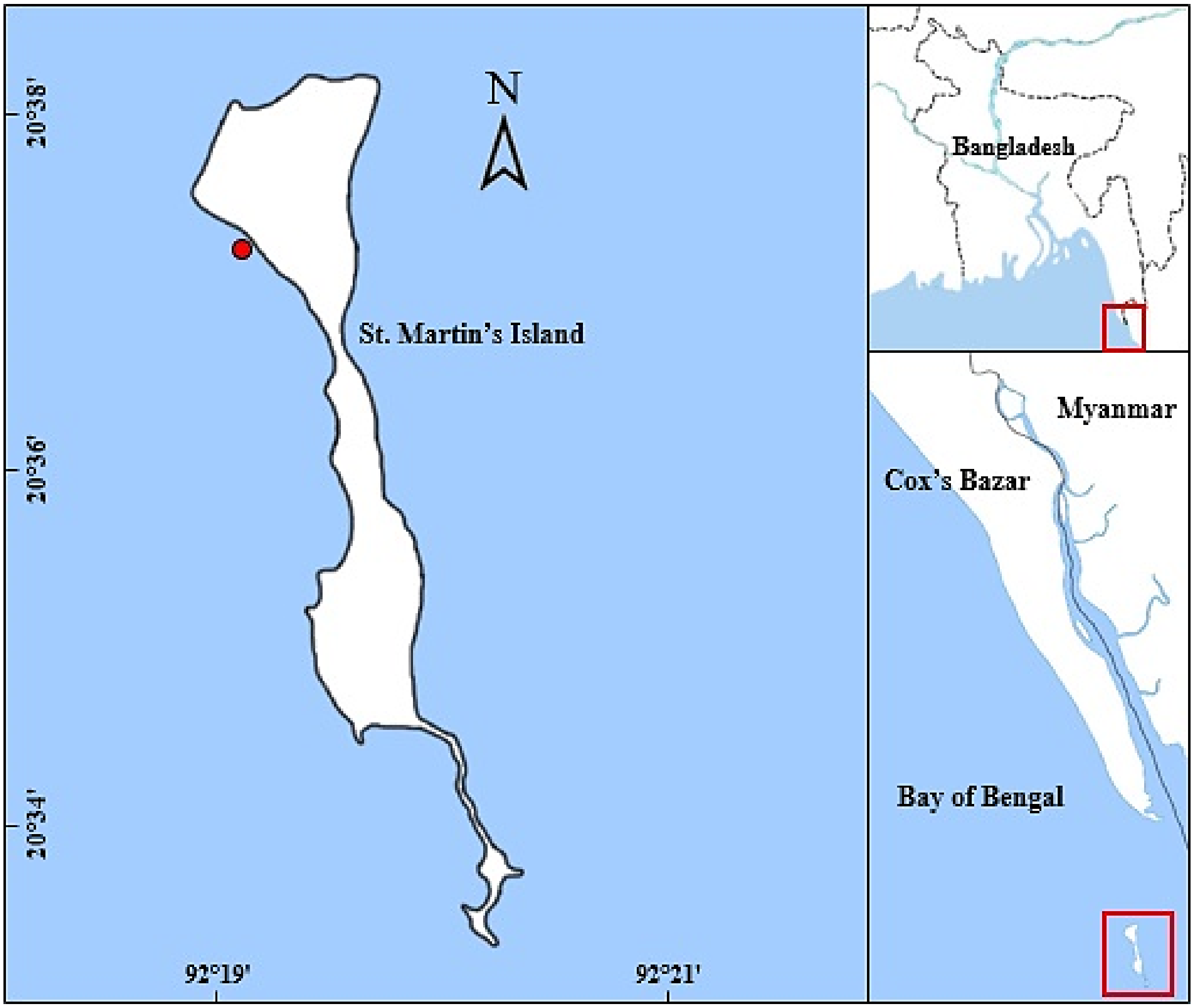

Figure 1. Sampled area of *E. radiatus,* St. Martin Island, Bangladesh

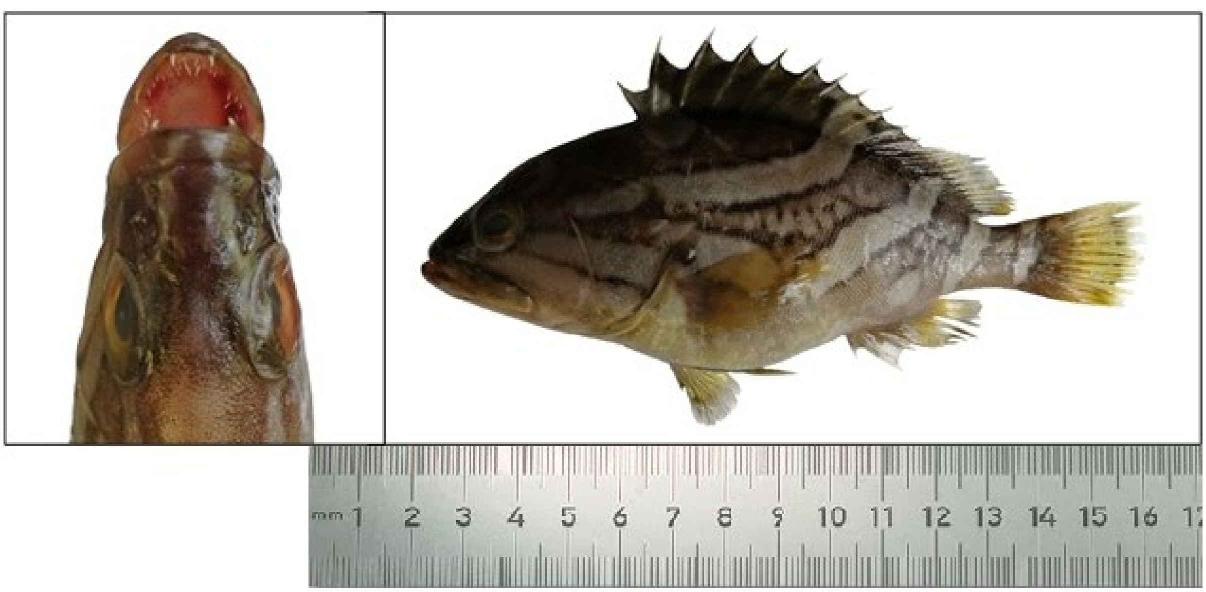

Figure 2. Lateral view with palatine teeth of *E. radiatus* collected from Saint Martin's Island

Table 1. Comparison of morphometric measurements and meristic counts with the present study and published previous studies

Parameter	**Present study, n=3**			**Han et al. (2014), n=1**
Morphometric characters	**1st specimen**	**2nd specimen**	**3rd specimen**	
Total length (TL)	13.7	14.2	14.1	-
Standard length (SL)	11.5	11.7	11.7	371
Body depth (BD)	5.1	5.2	5.0	35.1
Body width (BW)	1.9	2	2.1	18.7
Head length (HL)	4.3	4.4	4.4	40.7
Inter-orbital length (IOL)	0.9	0.9	0.9	7.9
Eye diameter (ED)	0.7	0.8	0.8	-
Snout length (SL)	1.0	1.1	1.1	10.7
Pre-dorsal length	4.1	4.3	4.2	33.1
Pre-pectoral length	4.4	4.5	4.5	38.7
Pre-anal length	7.6	7.8	7.9	71.7
Upper jaw length	1.7	1.8	1.8	19.0
Caudal peduncle depth (CPD)	1.0	1.1	1.0	-
Meristic counts				
Dorsal fin spines	11	11	11	11
Dorsal fin soft rays	14	14	14	14
Pectoral fin soft rays	16	17	17	17
Pelvic fin spine	1	1	1	-
Pelvic fin soft rays	5	5	5	-
Anal fin spines	3	3	3	3
Anal fin soft rays	8	8	8	-

Generic identification of these Epinephelid was made following the diagnostic morphological characteristics described by Heemstra and Randall (1993). The members under the family Epinephelidae are typically identified by their color pattern, morphological characters and size of the fins, the shape and relative size of the head and various parts of the head and body (Elamin et al. 2011). Sometimes they exhibit different colours and morphological counts in the juvenile stage. However, a morphological feature, especially meristic counts, were in line with previous studies by Heemstra and Randall (1993), and Han et al., (2014). Previously, 15 species of Epinephelids under four genera, namely *Cephalopholis* (3 spp.), *Cromileptes* (1 sp.), *Epinephelus* (10 spp.), *Plectropomus* (1 spp.) which compare to very low found in Indian waters. Ranjan et al. (2017) estimated that, a total of 54 numbers of Epinephelids had been recorded from Indian waters.

Pisces are primarily mobile, and they may shift their location more quickly than species on land because they face fewer physical barriers (Pinsky et al. 2013). Also, many marine species, for instance; fish, do not have fixed nesting places or dwellings that might otherwise compel them to stay in one place. Species distribution is affected by a simple 'suitability' measure, established by the combination of unimodal responses to environmental variables (Meynard and Quinn, 2007; De-Marco et al. 2008). Climate changes are predicted to potentially affect population size, survival and distribution of organisms (Walther et al. 2002; Preuss et al. 2014; Su et al. 2015; Lu et al. 2015; Hanif et al. 2017; Siddik and Hanif, 2020). The highly discrete geographical distribution of species points towards a strong preference for a particular type of habitat (Hanif et al. 2019). Reef fish diversity of St. Martin Island of Bangladesh including other marine species, remains, to date, relatively unexplored (Hanif 2019). Currently, 12% of groupers worldwide are considered under threat of extinction (i.e. Critically Endangered, Endangered, or Vulnerable), with another 13% considered as Near Threatened (Castellanos-Galindo et al. 2018). The discovery of grouper species presented in this paper demonstrates the need for Bangladesh's reef fish and other understudied marine fauna available in Bangladesh, to be surveyed and documented, to produce an updated inventory of local marine species. Therefore, this present article has confirmed the presence of *E. radiatus* in the Saint Martin's Island, Bay of Bengal and indicates the possibility of the existence of more species in the family *Epinephelus* in Bangladesh waters that have been overlooked in past surveys.

Conclusion

The present study confirms the occurrence of oblique-banded grouper, *E. radiatus* in the water area of Bangladesh. The findings of the study contribute to better understanding on biology, taxonomy, morphology, genetic and phylogenetic diversity as well as distribution of this species which would be helpful for sustainable management of this grouper species in Bangladesh.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: All authors declare that this study does not include any experiments with human or animal subjects.

Funding disclosure: -

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Disclosure: -

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Bacteriological quality of cage-cultured abalone *Haliotis asinina*

Jhonamie A. MABUHAY-OMAR, Genese Divine B. CAYABO, Lota A. CREENCIA

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[1] College of Fisheries and Aquatic Sciences, Western Philippines University-Puerto Princesa Campus, Sta. Monica, Puerto Princesa City, Palawan, Philippines

ORCID IDs of the author(s):
J.A.M.O. 0000-0002-8384-4449
G.D.B.C. 0000-0001-8038-0485
L.A.C. 0000-0002-8586-8604

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Correspondence:
Jhonamie A. MABUHAY-OMAR
E-mail: jhonamie.omar@wpu.edu.ph

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ABSTRACT

Abalone is one of the most highly priced seafood delicacies and prepared in various dishes like breaded, soup, steamed and sashimi. They are susceptible to microbial contamination since it is eaten raw sometimes and pathogenic microorganisms can be hazardous to consumers. The present study was carried out to determine the coliform load and the presence of presumptive pathogenic bacteria in cage-cultured abalone in Taytay, Palawan, Philippines. The study was limited to the detection of coliform and some presumptive pathogenic bacteria in different parts of abalone such as gut, gills and mantle. The result of the study revealed that the count of coliforms present in the mantle and gills of abalone falls within the normal standard limit (7 – 21 MPN $100g^{-1}$ sample). On the other hand, the gut of abalone was beyond the standard limit (460 MPN $100g^{-1}$ sample). Moreover, the gut of abalone harbors *Vibrio* spp., *Salmonella* spp. and *Shigella* spp. and general enteric bacteria. Foodborne infections caused by *Vibrio*, *Salmonella* and *Shigella* are common in Asia.

Keywords: Abalone, Cage culture, Coliform, Microbial load, Most probable number, *Salmonella, Vibrio*

Introduction

Seafood is one of the most important food components for many people particularly those in coastal communities worldwide (Edun et al., 2016; Bakr et al., 2011). Marine products such as fish and other organisms are not only the cheapest sources of protein but also a significant foreign exchange earner in global trade for a number of countries in the world (Yagoub & Ahmed, 2003). One of the most important fishery products is abalone, a marine vetigastropod that contributes a comparatively low fraction in aquaculture production but considered as one of the most highly priced seafoods worldwide (Cook, 2016). They are marketed as live (US$15-US$200 kg^{-1}), dried (US$156 kg^{-1}), frozen (US$5.5-US$180 kg^{-1}), canned (US$12-US$75 can^{-1}) and steak (US$180 kg^{-1}) (Encena & Bayona, 2010). Countries like China, Hong Kong, Japan, Singapore, Taiwan, Malaysia and USA are the leading importers of abalone products (FAO, 2016).

Abalone is of great importance as food because of its high nutritive value containing Vitamin E (Alpha Tocopherol), Vitamin B12, Iron, Magnesium and Phosphorus as well as bioactive compounds that are antioxidant, anti-thrombotic, anti-inflammatory, antimicrobial and anti-cancer activities (Suleria et al., 2017). However, abalone can be contaminated by various pathogens if the environment is polluted and contaminated during harvesting and handling. The contaminants may include *Vibrio* species, a known foodborne pathogen which are naturally occurring in marine environment and *Escherichia coli* and *Salmonella* spp. which are found in water polluted by sewage (Gnanambal & Patterson, 2005; Chinnadurai et al., 2020).

Consumption of the shellfish which are contaminated by pathogens may cause disease or intoxication to the consumers. *Vibrio cholerae* causes the third-highest number of shellfish-related illnesses, after noncholera *Vibrio* spp. On the other hand, the occurrence of *Salmonella* infections due to seafood consumption is still low compared with salmonellosis associated with other foods (Sanjee & Karim, 2016). Despite this fact, detection of *Salmonella* spp. in seafood should be included as it is responsible for most of the foodborne diseases or gastroenteritis characterized by diarrhea, abdominal cramp, vomiting, nausea, and fever. The Centers for Disease Control and Prevention (CDCP) declared that *Salmonella* is the foremost causative agent of bacterial foodborne diseases resulting in approximately 1.4 million nontyphoidal illnesses, 15,000 hospitalizations, and 400 deaths in the USA annually (Sanjee & Karim, 2016). In addition, fecal coliforms such as *E. coli* are used as monitoring tool of the quality of shellfish-growing waters and bivalve molluscs. There is a need for additional methods to lower coliform aerobic mesophilic count in culture areas and in harvested shellfish (Martinez et al., 2009).

Abalone is prepared in various highly priced dishes like breaded, soup, steamed and sashimi. Abalone is susceptible to microbial contamination and since it is sometimes eaten raw (Surtida, 2000), pathogenic microorganisms can be hazardous to consumers. Thus, this study was conducted to determine the coliform load and the presence of presumptive pathogenic bacteria such as *Vibrio*, *Salmonella*, *Shigella,* and general enteric bacteria in different body parts of cage-cultured abalone. This study showed which part of the abalone is safe to consume raw and which part must be removed or cooked before consumption.

Material and Methods

Collection of Samples

Thirty samples of adult cage-cultured abalone *H. asinina* (30-35mm) were collected from Pamantolon, Taytay, Palawan, Philippines (Figure 1) in September 2018. Collection was only done once. The abalone was cultured in floating bamboo cages along the lines of farmed seaweed. The site is near a populated area where majority of the houses are made up of indigenous materials. The average water temperature, salinity and pH of the area were 28°C, 30ppt and 6.5, respectively. Abalone samples were carefully handpicked from the cages while riding a motorless boat. The collected samples were placed in sterile cooler box and were transported live to the Microbiology Laboratory of the Western Philippines University-Puerto Princesa Campus for microbial examination. Upon arrival, the abalone samples were cleaned by immersing it in sterile seawater for 5 minutes followed by another 10 minutes in cold sterile distilled water at 4-6°C to relax the organisms.

Sample Preparation for Microbial Analysis

The abalone samples were soaked in 55°C sterile distilled water. The shell and meat were separated before dissection. Different body parts of abalone; gills (G), foot mantle (M) and the gut (D) were aseptically separated and extracted using sterile dissection tools inside a laminar flow. Ten grams of each of the abalone body parts was blended with 90 mL of sterile distilled water to dilute and to homogenize. The samples of the body parts were processed fresh to maximize inventory of viable organisms.

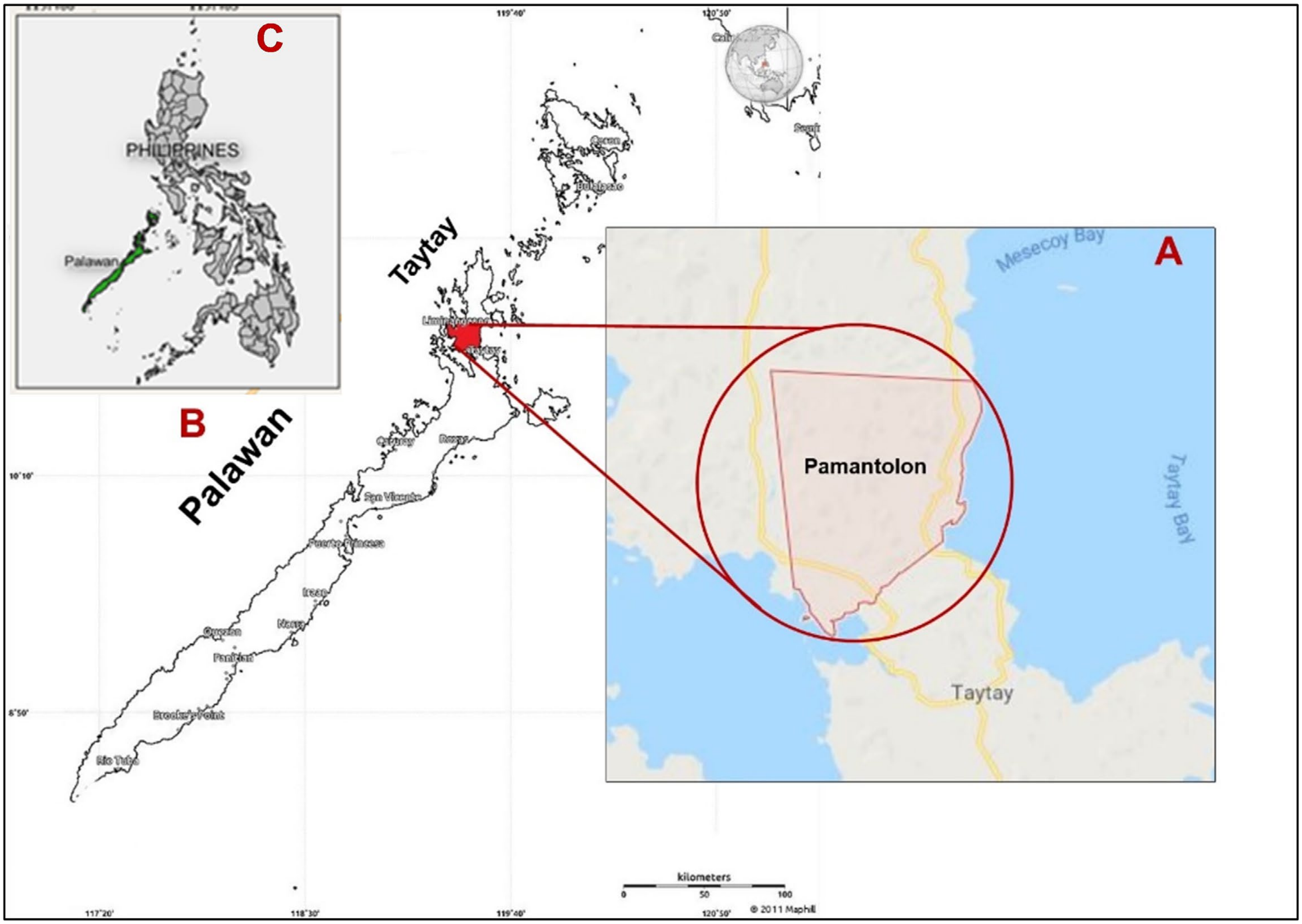

Figure 1. Map showing the site of abalone culture in Pamantolon, Taytay (A), Palawan (B). Philippines (C)

Coliform Detection (MPN Method)

The number of coliform in the samples was determined using the conventional three-tube MPN (most probable number) method (Brown, 2005). Ten mL of the homogenized sample was added in test tube containing 10 mL volume of double strength lactose broth (DSLB). One mL and 0.1 mL of the sample were added separately in test tube containing 10 mL volume of single strength lactose broth (SSLB). The total sets of tubes were incubated at 35°C for 24 h and examined for the presence of growth accompanied by gas production. Those cultures positive for gas formation were inoculated into Eosin Methylene Blue (EMB) agar and were incubated at 35°C for 24 h. After incubation, EMB Agar plates were examined. *Escherichia coli* colonies grow with a metallic sheen with a nucleated center, *Aerobacter aerogenes* colonies have a brown center, and nonlactose-fermenting Gram-negative bacteria appear pink. A loopful of sample from positive EMB agar were inoculated in DSLB tubes and incubated for 24 h. at 35°C. Gram staining followed for verification. Quantification was done using the standard MPN table and coliform was reported as MPN 100 g^{-1} sample.

Enumeration of Presumptive Pathogenic Bacteria

The pour-plate method was used in this study as adopted from the study of Sanders (2012). Different selective culture media were used to enumerate presumptive pathogenic bacteria from cage-cultured abalone *H. asinina.* The Thiosulfate Citrate Bile Salts Sucrose (TCBS) was used for total *Vibrio* species, *Salmonella-Shigella* (SS) agar for total *Salmonella* and *Shigella* species and McConkey agar for total enteric bacteria. Each medium was prepared according to the suggested ratio and proportion of the manufacturer found in the labels. One mL of each previously homogenized sample was added to the prepared medium, mixed gently, and poured into the petri dish and allowed to solidify. There were three replicates prepared for each body part and each selective culture medium. All plates with different culture media were incubated at 35 °C for 24 hours. After incubation, all plates were examined. Colonies growing on each plate were examined for individual characteristics, counted as colony forming units (CFU) and recorded. Rapid lactose fermenting colonies such as *E. coli* appear pink in color on MacConkey agar. Colonies of *Salmonella* species appear red with black centers while *Shigella* species are red to pink colonies without black center on SS agar. *Vibrio* colonies appear yellow and green on TCBS agar.

Statistical Analyses

The data on the number of presumptive pathogenic bacteria at different parts of abalone were analyzed using one-way analysis of variance (ANOVA) to test the significant differences. The data were subjected to Post hoc test (Tukey's Test) to compare the means ($p < 0.05$).

Results and Discussion

Samples from different body parts of abalone showed gas formations after 24 h of incubation in multiple tube test indicating the presence of gas-forming lactose fermenters which implied the presence of coliform bacteria. When confirmation test was done, it was confirmed that the coliform present in this study was *E. coli*. Results of this study showed that the gut of abalone exceeded the acceptable limit of *E. coli* for shellfish with a count of 460 MPN $100g^{-1}$ (Table 1). The acceptable limit of *E. coli* for shellfish is 230 MPN $100g^{-1}$ based on several references enumerated in Table 1. *Escherichia coli* is frequently used as an indicator of fecal contamination because it lives naturally in human feces and can survive in water (Duncan et al., 2009). The high level of *E. coli* in the gut could be due to the probable high count of fecal coliforms in their growing water areas. It was observed that the culture areas in Pamantolon, Taytay were surrounded by houses built with low-cost materials with comfort rooms that don't have septic tank and very near the shore so runoff from terrestrial area could have contributed to the presence of coliforms. Chinnadurai et al. (2020) proved that bacterial concentrations in shellfish correlate strongly with those in the waters. Their sampling sites (growing sites of shellfish) receive high levels of contaminants from drainage channels, open toilet drain, non-functional septic tank and livestock production areas, and they found similar high contamination in the shellfish from the areas. Another study examined the concentration of coliforms in oysters in the River Blackwater Estuary in the UK where they found that the main source of *E. coli* and *Streptococci* to the oyster beds are sewage and agricultural sources, respectively (Florini et al., 2020).

Microorganisms that can be found in marine environment and most commonly encountered by marine species are free-living forms found in water and sediment and rarely include any species of mammalian pathogens (ICMSF, 1986). Hence, fish and shellfish that are handled properly during harvest from waters not polluted by human or animal wastes are often free from intrinsic microbiological hazard. Fish and other marine animals do not usually carry *Escherichia coli,* the 'fecal coliforms', and enterococci as these microorganisms are generally considered to be typical mammalian microflora. The presence of human enteric organisms on marine food products is clear evidence of contamination from a terrestrial source (ICMSF, 1986). It is important to understand the origin of fecal contamination in shellfish farms to assess the associated health risks as well as the actions needed to address the problem (Florini et al., 2020). In addition, since the abalone samples of this study were also cultured along the lines of farmed seaweeds, the water current and mixing may be obstructed resulting in possible accumulation of microorganisms around the area. On the other hand, the gills and mantle of the abalone had *E. coli* number lower than the microbial limit for shellfish. This is reassuring to note as the part of abalone mostly consumed is the mantle.

Table 1. Most probable number (MPN) of coliform bacteria present in different parts of adult abalone *Haliotis asinina* and the microbial limit (*Escherichia coli*) for shellfish based on European Communities (EC) (2007) and Philippine National Standards - Bureau of Agriculture and Fisheries Product standards (PNS-BAFPS) (2011).

Sample	*E. coli* MPN/100g	Microbial Limit
Gut	460	230 MPN/100g according to PNS-BAFPS (2011) and EC (2007)
Gills	21	
Mantle	7	

The presence of *E. coli* in food or water implies that there could be other pathogens present like *Klebsiella* and *Vibrio* and other clinically important bacterial pathogen (WHO, 2001). In this study, presumptive pathogenic bacteria were detected in different body parts of abalone. The analysis of variance (ANOVA) proved that there were significant differences in the number of presumptive pathogenic bacteria ($p < 0.05$) at different parts of abalone. Tukey's test showed that the total enteric bacteria had the highest number in the gills of abalone with a count of 29 CFU g^{-1} sample followed by *Salmonella-Shigella* and then *Vibrio* (Figure 2). In the gut, ANOVA proved significant differences among the different groups of presumptive pathogenic bacteria and Tukey's test showed that *Vibrio* and enteric bacteria were higher in terms of total number of colonies with a count of 101 CFU g^{-1} sample and 93 CFU g^{-1} sample respectively, than the number of *Salmonella* and *Shigella* (Figure 2). On the other hand, *Vibrio* was found to be significantly highest in the mantle with 22 CFU g^{-1} (Figure 2). Among the three body parts of abalone that were tested, the gut harbors the highest number of presumptive pathogenic bacteria. In addition, the *Vibrio* group had the highest number found in abalone. According to PNS-BAFPS (2011), *Salmonella* species should be absent in 25 g sample and *Vibrio* should not exceed 100 MPN/100g sample.

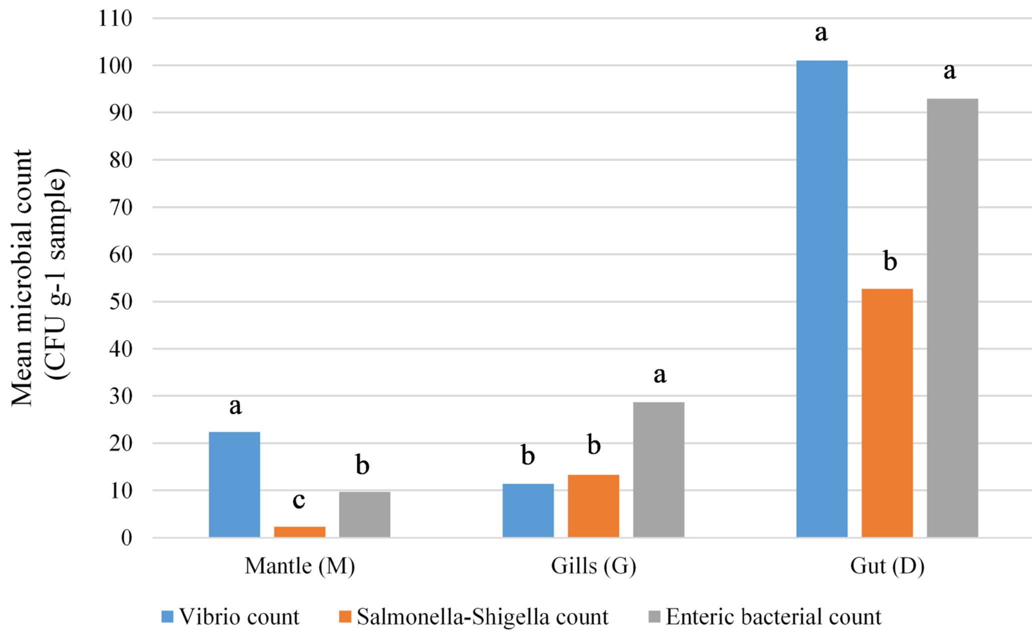

Figure 2. Mean microbial count of presumptive pathogenic bacteria from the gills, gut and mantle of adult cage-cultured abalone *Haliotis asinina* Linn. Different letters signify significant differences at $p< 0.05$.

The outbreak of seafood infections from contaminated waters are caused by variety of bacteria, viruses and parasites have been reported worldwide (Florini et al., 2020). Centers for Disease Prevention and Control (CDC) reported to the Food-borne Disease Outbreak Surveillance System (FDOSS) 188 outbreaks of seafood-associated infections, causing 4,020 illnesses, 161 hospitalizations, and 11 deaths from 1973 to 2006. A total of 76.1% of these seafood-associated outbreaks were due to a bacterial agent (CDC, 2010). It was recorded that *Vibrio* and *Salmonella* were the most commonly reported bacteria that cause seafood contamination outbreaks (Iwamoto et al., 2010).

Salmonella species is one of the most important food-borne pathogens and have been detected in seafoods (Edun et al., 2016). In this study, *Salmonella* was present in the mantle, gills and gut of abalone. This species can cause wide range of illness. Example is the common typhoid fever caused by *Salmonella typhi* with common symptoms of fever, headache, malaise, anorexia and red spots on the trunk (WHO, 1996). In Brazil, the absence of *Salmonella* spp. in 25 g of oyster flesh is required (Brazilian Regulations, 2019). Similar microbial limit in *Salmonella* spp. is also imposed in the Philippines by PNS-BAFPS (2011). In the study conducted by Lameira Silva et al. (2020), *Salmonella* spp. was present in the flesh of oyster in all sampling sites in Amazon estuaries in Pará, Brazil irrespective of the seasonal period. In contrast, the study conducted by Sorio and Peralta, (2018) revealed that *Salmonella* spp. was not detected in any samples of oysters growing in selected production areas in Dumangas, Iloilo, Philippines. Similar result was presented by Martinez et al. (2009) wherein all molluscan shellfish samples (mussel, clams and cockles) in their study were negative for the presence of genes encoding virulence factors in *Salmonella*. Another study was conducted in South Korea to analyze the microbiota of abalone to improve awareness on outbreaks and causes of food poisoning and to help the management of seafood products (Lee et al., 2016). In this study, there were over 2700 species of microorganisms detected in the samples but only five species were potentially pathogenic and did not include either *Salmonella* or *Vibrio* species.

Vibrio species are problems in molluscan shellfish hatcheries including abalone (Lee et al., 2001; Handlinger et al., 2005; Kua et al., 2011). According to Romalde et al. (2014), *Vibrio parahaemolyticus, V. harveyi, V. splendidus, V. aglinolyticus, V. anguillarum* and *V. vulnificus* (Lee et al., 2001; Handlinger et al., 2005; Cai et al., 2006; Pitchon et al., 2013) are major species infecting abalone species. Aside from outbreaks of diseases caused by *Vibrio* species that leads to mass mortalities and economic losses in cultured species, they are also associated with live seafood as they form part of the indigenous microflora of the marine environment. Foodborne infections caused by *Vibrio* spp. are common throughout the world so proper precautionary measures are also important (FAO & WHO, 2020). In the USA, consumption of raw oysters with contamination of *V. vulnificus* and *V. parahaemolyticus* causes septicemia and other infection (FAO & WHO, 2005). In Japan, *V. parahaemolyticus* infections results from consumption of raw seafoods (FAO & WHO, 2011). On the other hand, bacterial infection is low in Thailand and other Southeast Asian countries including Philippines because shellfish are generally consumed after cooking (FAO & WHO, 2011). Although in one particular event in Cebu City, Philippines, *V. parahaemolyticus* has been linked to fish and shellfish contamination causing foodborne disease wherein 97 people were hospitalized (Borromeo, 2007). This bacterium is a common cause of bloody diarrhea, abdominal cramps, nausea, vomiting, and fever worldwide that occur about 4–96 h from the time of ingestion (FSIS, 2014). Undercooking could explain the presence of *Vibrio* in fish and shellfish commodities that leads to infection and disease (FAO & WHO, 2020). On the other hand, some countries like Japan, France, Australia, New Zealand, China and Taiwan isolated several species of *Vibrio* such as *V. campbellii, V. harveyi, V. parahaemolyticus, V. alginolyticus and V. splendidus* from different species of *Haliotis* where these *Vibrio* species caused mass mortality in cultured abalone (Bower, 2017).

In this study, results showed that most of the pathogenic bacteria were found in the gut of abalone. This result supports the previous studies (Mabuhay-Omar et al., 2019; Santiago & Mabuhay-Omar, 2019) wherein the gut of abalone harbored the highest number of microorganisms compared to gills and mantle. Mantle is the part of abalone usually consumed by human and so it is good to note that the number of microorganisms is very small compared to the maximum limit but since fecal coliform and some presumptive pathogenic bacteria are present, it is important to depurate and properly prepare the abalone before eating. The presence of fecal coliform and presumptive pathogenic bacteria in the mantle of abalone can be due to contamination during handling and lack of proper cleaning protocol. In addition, removal of gut and gills of abalone before cooking or preparing uncooked menu is needed since presumptive pathogenic microorganisms are found in these parts of abalone.

Conclusion

This study proved the presence of coliform such as *E. coli* and some presumptive pathogenic microorganisms in abalone such as *Salmonella*, *Shigella*, *Vibrio* and total enteric bacteria. With this information, it is recommended for the abalone farmers to optimize the culture management practices such as monitoring of the physico-chemical parameters of water since the presumptive pathogenic bacterial species detected are also opportunistic pathogens and could cause massive losses in abalone production under favorable conditions. Also, these species are considered to be human pathogens and could cause various infections among human population. It is also important to properly cook the abalone before eating. In addition, removal of gut and gills of abalone before preparing uncooked menu is needed since microorganisms are found in these parts of abalone. Prior to selling cultured abalone to consumers, depuration methods may be applied to minimize possible contamination.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: This work does not require ethic permissions.

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Disclosure: -

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Does commercial probiotics improve the growth performance and hematological parameters of Nile tilapia, *Oreochromis niloticus*?

Rashedul HASAN, **Mohammad Amzad HOSSAIN**, **Md. Rashedul ISLAM**, **Mohammed Mahbub IQBAL**

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[1] Sylhet Agricultural University, Faculty of Fisheries, Department of Fish Biology and Genetics, Sylhet-3100, Bangladesh.

ORCID IDs of the author(s):
R.H. 0000-0001-6781-965X
M.A.H. 0000-0001-9219-3628
Md.R.I. 0000-0002-7864-8021
M.M.I. 0000-0001-5720-4029

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Correspondence:
Mohammad Amzad HOSSAIN
E-mail: mamzad.fbg@sau.ac.bd

ABSTRACT

Oreochromis niloticus becoming a promising aquaculture species globally, but recent disease outbreaks and poor growth with commercial feed making it challenging. A 60 days long aquarium trial and series of laboratory assays have been conducted to assess the growth performance of *O. niloticus* fed with a locally available commercial probiotic. *O. niloticus* fry's were fed with a mixture of basal diet and probiotics supplementation at a level of 0% (control), 0.2%, 0.4% and 0.8%. After the trial phase weight gain, length gain, specific growth rate (SGR), percentage of weight gain (PWG), percentage of length gain (PLG) were noted. Among all, highest values of above parameters were observed at T_1 (0.2%) treatment group. Weight gain, length gain, PLG and PWG were significantly improved in T_1 treatment group ($p<0.05$). Additionally, hematological parameters including hemoglobin (Hb), white blood cell (WBC) and red blood cell (RBC) were also observed for all groups and T_1 was found to have highest values for all these parameters, although there were no statistically significant differences between the values of T_1 and T_2. The results of this study showed that 0.2% dietary probiotics supplements in basal diet would optimize the growth performance and hematological parameters of aquarium reared *O. niloticus*.

Keywords: Probiotics, Growth performance, Hematological parameters, *Oreochromis niloticus*

Introduction

A native fish group of Africa continent, tilapias are among the most practiced species in aquaculture industry worldwide as well as in Bangladesh (Alam et al., 2014; Akter et al., 2019) due to their high productivity rate, disease tolerance and flesh quality (Yuan et al., 2017; Gabriel, 2019;). The commercial hatcheries in Bangladesh produced all male mono-sex fry to adopt rapidly growth rate as well as to reduce undesirable reproduction in culture pond (Lind et al., 2015; Das et al., 2019). Use of chemicals, hormones, drugs and probiotics are getting very popular among aquaculture practices in Bangladesh (Uddin et al., 2017). The need for high-quality fish feeds with a premium protein content, associated nutrients and minerals; which is tasty, keeps animals healthy and providing a high growth rate is increasing (Soltan et al., 2016; Hua et al., 2019; Yue et al., 2020). Probiotics are combination of live microorganisms that are efficient to adapt, colonize and grow within the gut of the host and develop a beneficial stability of microorganisms to improve animals health (Martínez Cruz et al., 2012; Carbone & Faggio, 2016). Numerous benefits of probiotics for growth, defense and intestinal health of the host were revealed and broad use of probiotics in aquaculture could prevent diseases, promote growth and reduce the extensive use of antibiotic (Austin & Austin, 2016). Probiotics retard or completely inhibit the growth of pathogenic bacteria following a competitive exclusion (Akayli et al., 2016), also boost up the immune response and secretion of mucosal enzymes to promote host growth and they do not cause secondary pollution problems (Xia et al., 2020). Variations in fish blood parameters would be a good pointer of water quality, nutrition and health (Satheeshkumar et al., 2012; Ahmed et al., 2020). Alterations in hematological parameters are due to the result of stress condition such as hypoxia, contact to pollutants, transportation, handling and liberation of energy associated with the use of chemicals and anesthetics (Roche & Bogé, 1996; Fazio et al., 2015; Simide et al., 2016). Therefore, the present research was directed towards the evaluating the growth of *O. niloticus* fed with dietary probiotics as well as determining the optimum supplementation level to produce an effective diet, which would provide a favorable physiological condition to culture this species commercially in Bangladesh.

Material and Methods

Experiment Designing and Diet Preparation

A 60 days long trial have been conducted in 140 litre glass aquaria. The experiment was designed with four treatments designated with three replications as well. A commercial floating fish feed (moisture 11%, protein 40 %, lipids 6%, carbohydrate 25 %, 450 fiber 5%, ash 10%, calcium 2% and phosphorous 1 %) was used. A commercial probiotics mixture (AquaStar growout powder; Renata animal health Ltd. Bangladesh) that contains *Bacillus, Enterococcus, Pedicoccus* and *Lactobacillus sp.* bacteria was added in diets of experiments groups with a rate of 0% (Tc), 0.2% (T1), 0.4% (T2) and 0.8% (T3). Tilapia (*O. niloticus*) fry's were acclimated to laboratory conditions for 14 days and fed only with commercial feed. *Then* twenty fish with a mean weight of 1.72 ± 0.42g were randomly allotted into each aquarium. They were fed three times a day at 6% of their body weight at the first month of experiment and gradually reduced to 5% in the second month. Underground freshwater which was stored in a reservoir and supplied to the aquaria. Each aquarium was equipped with automated aeration and internal carbon filtration facilities. Uneaten feed and the waste materials of aquarium were siphoned out twice per day and approximately 20 percent water was exchanged every two days to keep the water environment suitable for fish survival.

Monitoring Water Quality Parameters and Fish Sampling

Various water quality parameters such as temperature (with a simple thermometer), dissolved oxygen (YSI digital DO meter, model 58) and pH (pH meter - Hanna Instruments, Japan) in each aquarium was monitored once in a week during the experiment period. Every 15 days, three fishes from each aquarium were sampled randomly in all treatments groups for length and weight gain after a 24 hours starvation period.

Analysis of Growth Parameters

At the end of the feeding trial various growth parameters were analyzed by using the mathematical formula according to Olvera-Novoa et al., (1990), Panase & Mengumphan, (2015) and Pechsiri & Yakupitiyage, (2005).

Weight gain= Mean value of final weight- Mean value of initial weight

Percentage of weight gain

$$= \frac{\text{Mean value of final fish weight} - \text{Mean value of initial fish weight}}{\text{Mean value of initial fish weight}} \times 100$$

Specific growth rate SGR (%) $= \frac{ln W2 - ln W1}{T2 - T1} \times 100$, Where W_1= the initial body weight (gm) at a time, W_2= the final body weight (gm) at a time, T_2-T_1= Duration in days

Length gain=Mean value of final length- Mean value of initial length

Percentages of length gain

$$=\frac{\text{Mean value of final fish length} - \text{Mean value of initial fish length}}{\text{Mean avlue of initial fish length}} \times 100$$

Average daily weight gain

$$=\frac{\text{Mean value of final weight} - \text{Mean value of initial weight}}{\text{Duration of experiment in days}}$$

Average daily length gain

$$=\frac{\text{Mean value of final length} - \text{Mean value of initial length}}{\text{Duration of experiment in days}}$$

The values of Fulton's condition factor (K) was estimated by plotting length weight data on the following equation adopted from Htun-Han, (1978); $K=(W/L^3)*100$

Blood Sample Collection and Hematological Analysis

Blood samples were collected (3 fishes from each group) after a 24 hours starvation period from the caudal vena and stored in EDTA (Ethylene diamine tetra-acetic acid). Hemoglobin, WBC, and RBC analysis was carried out by using Automated Hematology Analyzer BC-3000 Plus.

Data Analysis

The one-way analysis of variance (ANOVA) and Duncan's multiple Range Test (DMRT) were conducted to figure out the differences among the groups means at significance level of P<0.05. All statistics were carried out using Statistical Package for Social Science (IBM SPSS) version 22.

Results and Discussion

In this study tilapia fry were feed with a standard commercial feed and with the addition of various amounts of a probiotic mixture and the differences in growth and blood parameters in fish were revealed.

Water quality parameters are vital as they influence the growth and physiological activities of fish (Maucieri et al., 2019). Temperature is a key factor for the production management and feed consumption in fish. The optimal thermal range for the proper growth of *O. niloticus* was proposed as 25-27 °C (Makori et al., 2017) and 27-32 °C (Mengistu et al., 2020). Dissolved oxygen, which is a crucial factor for fish growth, health, and physiology should be over 5 mg/L for sustainable growth of *O. niloticus* (Riche & Garling, 2003; Makori et al., 2017). pH is an imperative factor which specifies the health and production output of a water body and optimum range was proposed as 5.5-9.0 (Rebouças et al., 2016) and 6.1-8.3 (Makori et al., 2017) for *O. niloticus*. Water quality parameters i.e., temperature, dissolved oxygen (DO) and pH observed during the study were shown in Table 1. These results showed that the water quality parameters were appropriate for *O. niloticus* culture.

Among four experimental groups fed with basal commercial feed and probiotic mixture - 0% (Tc), 0.2% (T1), 0.4% (T2) and), 0.8% (T3) - maximum mean weight gain was detected in T_1 (16.1975 ±3.16g) followed by T_2 (12.79 ±3.16g) and T_3 (10.326 ±2.47g) respectively (Table 2). The lowest mean weight was observed in T_C (8.23 ±1.83g) and the means of the weight gains among all the treatments groups were significantly varied between each other (P<0.05). Among the groups, T_1 (0.2%) showed the highest weight gain and T_C (0%, Probiotic) showed the lowest growth performance. The mean percentages of weight gain (PWG) in *O. niloticus* was recorded in T_C (478.86 ±204.86[a]), T_1 (981.52 ±382.27), T_2 (863.31 ±339.98) and T_3 (702.09 ±298.95) (Table 2). Highest mean PWG was found in T_1 followed by T_2, T_3 and T_C, respectively. However, difference between T_2 and T_3 (P>0.05) were statistically uniform and the lowest mean PWG was observed in control treatment. Specific Growth Rate (SGR%) of *O. niloticus* was recorded as 2.83 ±0.55, 3.87 ±0.57, 3.68 ±0.56 and 3.36 ±0.62 in T_C, T_1, T_2 and T_3 groups respectively (Table 2). Highest SGR value (3.87 ±0.57) was observed in T_1 while the lower SGR value was recorded in T_C (2.83 ±0.55) group. The differences between T_1, T_2, T_2 and T_3 diet groups (P>0.05) remained still statistically non-significant.

The mean length gain of *O. niloticus* was recorded as 4.38 ±0.84 cm, 8.02 ±1.09cm, 5.93 ±0.94 cm and 5.18 ±1.03 cm in T_C, T_1, T_2 and T_3 groups respectively (Table 2). The length gain was increased in T_1 groups followed by T_2, T_3 and T_C groups, respectively. The highest mean length was observed in T_1 diet group whereas the control group (T_C) showed the lowest mean length gain during 60 days of experiment. The difference among all groups were significant at P<0.05. The highest percentages of length (PLG) were observed as 184.44±48.27 in T_1 groups followed by T_2, T_3 and T_C groups, respectively. PLG (%) values 141.33 ± 36.84 and 120.04±33.94 were recorded in T_2 and T_3 groups respectively (Table 2). T_C (102.37±25.38) group showed the lowest percentage of length gain. T_1 group showed a significant difference than the other treatment but there is no significant difference between T_2 and T_3 groups (P>0.05) in terms of percentage length gain.

Table 1. Mean value of water quality parameters (Mean Value ±SD)

Water quality parameter	Experiment groups			
	T_C (commercial feed only)	T_1 (0.2% probiotics)	T_2 (0.4% probiotics)	T_3 (0.8% probiotics)
Temperature (˚C)	26.33±1.03[a]	26.67±1.03[a]	26.67±0.81[a]	26.5±1.04[a]
Dissolved oxygen (mg/L)	5.33±0.21[a]	5.55±0.08[a]	5.35±0.16[a]	5.41±0.12[a]
pH	7.43±0.08[a]	7.6±0.30[a]	7.5±0.28[a]	7.4±0.08[a]

Table 2. Growth parameters of *O. niloticus* after 60 days treatment (means ± standard deviation) (P>0.05)

Parameters	Experiment groups			
	T_C (commercial feed only)	T_1 (0.2% probiotics)	T_2 (0.4% probiotics)	T_3 (0.8% probiotics)
Mean Initial Weight (g)	1.90±0.56[a]	1.79±0.45[a]	1.59±0.42[a]	1.59±0.36[a]
Mean Initial Length (cm)	4.36±0.49[a]	4.46±0.50[a]	4.30±0.49[a]	4.42±0.44[a]
Mean Final Weight (g)	10.13±1.92[a]	17.99±3.01 [d]	14.38±3.11[c]	11.92±2.31[b]
Mean Final Length (cm)	8.75±0.81[a]	12.48±0.83[d]	10.23±0.73[c]	9.60±0.76[b]
Weight Gain (g)	8.23±1.83[a]	16.19±3.16[d]	12.79±3.16[c]	10.32±2.47[b]
Length Gain (cm)	4.38±0.84[a]	8.02±1.09[d]	5.93±0.94[c]	5.18±1.03[b]
% Weight Gain	478.86±204.86[a]	981.52±382.27[c]	863.31±339.98[b]	702.09±298.95[b]
% Length Gain	102.34±25.38[a]	184.44±48.27[c]	141.33±36.84[b]	120.04±33.94[a, b]
SGR %	2.83±0.55[a]	3.87±0.57[c]	3.68±0.56[b, c]	3.36±0.62[b]
ADWG	0.13±0.03[a]	0.26±0.05[b]	0.21±0.05[c]	0.17±0.04[d]
ADLG	0.07±0.014[a]	0.13±0.018[b]	0.09±0.015[c]	0.086±0.017[d]
Condition factor, K	1.78±0.23[a]	1.19±0.22[b]	1.39±0.19[b, c]	1.55±0.31[d]

SGR= Specific growth rate, **ADWG**= Average daily weight gain, **ADLG**= Average daily length gain.

Supplementation of probiotics in the diet of aquatic animal increased enzymatic activity, developed digestive activity, synthesis of vitamins and weight gain which enhance the growth of fish (Reyes-Becerril et al., 2008; Nayak, 2010) and modulate immune response (Giri et al., 2013; Galagarza et al., 2018). The dietary supplementation of probiotic and bacterial cocktails were found to improve the gut immune response, morphology and microbial assemblage of intestine in juvenile *Oreochromis niloticus* (Ayyat et al., 2014; Yamashita et al., 2017; Xia et al., 2020). In this study, supplementation of probiotics in all experiment groups resulted higher growth than the control group (Table 2). It might be occurred due to proper digestion and better nutrient absorption in the fish body. The optimum probiotic level that resulted high in terms of weight gain (g), length gain (cm), SGR (%), Percentage of weight gain, percentage of length gain growth of *O. niloticus* was found in T_1 (0.2% probiotic) diet group. This indicated that the overall better growth performance was found in T_1 group. Similar observations have been reported on *Labeo rohita* (Munirasu & Ramasubramanian, 2017), *Clarias gariepinus* (Al-Dohail et al., 2009) and *Catla catla* (Bandyopadhyay & Das Mohapatra, 2009). All the above study had proven that growth performance of these fishes was meaningly improved in the diet containing probiotic containing than those in control.

Lower SGR (%) was observed in T_C group (2.83 ±0.12g) but among the probiotics treatments T_3 (3.36 ±0.13) showed the lowest SGR (%) rate (Table 2). However, there was no significant improvement among the treatment groups in case of SGR (%). However, there is possibility of arising different toxic elements along with the secretion of enzyme which may hinder the growth or other parameters of fish (Rahman et al., 2019; Chen et al., 2020) and while using very high dosage of probiotics and better growth performance might not be always associated with higher concentration of the probiotic (Ghosh et al., 2008; Mahmoud et al., 2021). A previous study on same species reported highest weight gain at 0.2% probiotics dietary supplement group in compared with the control groups (Chowdhury et al., 2020).

The condition factor (K) represent the nature of physical factors and biological regulating the growth of fish and it is found to be influenced by a set of factors including feeding types and stress associated with parasitic and physiological agents (Hartman & Margraf, 2006; Datta et al., 2013; Shoko et al., 2015; Jisr et al., 2018). The k>1 indicate a healthy environment of animals surroundings (Golam Mortuza & Al-Misned, 2013; Asmamaw et al., 2019;). The value of k has been reported above 1 and significantly varied between different treatment groups (Table 2), which indicate the quality of water, feed, and animal welfare on current research.

Hematological parameters represent a better illustration about fish health and environmental monitoring (Eissa & AbouElGheit, 2014; Dowidar et al., 2018) and they are influenced by various factors including animal's size, growth phase, physiological position, diet and overall environmental circumstances (Cho et al., 2015; Parrino et al., 2018). Highest mean hemoglobin (Hb) value was recorded in T_1 (5.70 ±0.17 g/dL) compared to T_2 (5.30 ±0.30 g/dL), T_3 (4.56 ±0.20 g/dL) and T_C (3.76 ±0.25g/dL) respectively (Table 3). Insignificant differences of Hb was observed between T_1 and T_2 groups (P>0.05). Control group showed a lower level of Hemoglobin. In case of mean white blood cell (WBC) counts, there were also no significant different between T_1 and T_2 (P>0.05). The highest WBC was observed in T_1 (10.89 ± 0.55 × 10^4/cumm) followed by T_2 (10.15 ± 0.64 ×10^4/cumm) (Table 3). The mean amount of red blood cell (RBC) was higher in T_1 (1.19 ±0.06 m/µL) compared to the other groups (P>0.05) (Table 3). The T_C groups showed significantly lower level of RBC.

The present research has been revealed that dietary probiotics supplementation increases hemoglobin (Hb), white blood cell (WBC) and red blood cell (RBC) contents in all the groups compared with the control group (Table 3). The fish fed with probiotic mixed food became more nutritious due to declined cortisol levels in the plasma haemolymph (Carnevali et al., 2006; Rollo et al., 2006; Al-Dohail et al., 2009) and high cortisol level increase glucose in blood which seems an indicator of physiological stress in fish (Silva et al., 2015). The high level of hemoglobin in fish fed with probiotic might be occurred due to the increasing of iron absorption in blood mediated through releasing acids in gut (Mohapatra et al., 2014; Silva et al., 2015). Firouzbakhsh et al., (2011) stated that a rise in the number of RBC increases the overall hemoglobin concentration in fish blood. In WBC Count T_1 (0.2%, probiotic) and T_2 (0.4%, Probiotic) were insignificantly higher than the other treatments and this blood contents are engaged in modulation of innate immunity via phagocytosis and toxic cell formation (Chico et al., 2018; Puente-Marin et al., 2019). These indicate that the strong immune system might positively affect the health and growth of fish.

Table 3. Blood parameters of *O. niloticus* in different groups (means ± standard deviation) (P>0.05)

Parameters	T_C (commercial feed only)	T_1 (0.2% probiotics)	T_2 (0.4% probiotics)	T_3 (0.8% probiotics)
Hb (g/dL)	3.76 ± 0.25^{a}	5.70 ± 0.17^{c}	5.30 ± 0.30^{c}	4.56 ± 0.20^{b}
WBC (x10^4/cumm)	5.58 ± 1.16^{a}	10.89 ± 0.55^{c}	10.15 ± 0.64^{c}	7.64 ± 2.42^{b}
RBC (m/µL)	0.70 ± 0.133^{a}	1.19 ± 0.064^{c}	$0.99 \pm 0.056^{b,c}$	0.76 ± 0.18^{b}

***WBC**= White blood Cell, **RBC**= Red Blood Cell, **g/dL**= gram/deciliter, **cumm**= cubemeter, **m/µL**= million/microliter.

Conclusion

The present research was conducted for the determination of the optimum probiotics level in feed to obtain to obtain a better growth of *O. niloticus.* The results of this study showed that probiotic had a higher impact on the growth performance and some blood parameters of *O. niloticus.* After considering the overall performance, it can be concluded that 0.2% dietary probiotics can be the optimum to provide a better growth performance of *O. niloticus*. The addition of this dietary level of this probiotic mixture may be used in commercial culture of this species. In addition, further study should be designed to observe the result of probiotics in addition to other additives on the cultured growth of tilapia as well as other species.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: Approved by institutional, regional and national animal ethical statements.

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Marmara denizi körfezlerinin baskı–etki durumu ve ötrofikasyon açısından değerlendirilmesi

İbrahim TAN

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TÜBİTAK Marmara Araştırma Merkezi Çevre ve Temiz Üretim Enstitüsü, Gebze, Kocaeli, Türkiye

ORCID IDs of the author(s):
İ.T. 0000-0002-4948-7687

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Correspondence: İbrahim TAN
E-mail: ibrahim.tan@tubitak.gov.tr

ÖZ

Marmara Denizi'ndeki kapalı ya da kapalı körfezlerde su kalış süresi uzun olduğundan kara kökenli kirleticiler organik madde zenginleşmesine ve sonrasında ötrofikasyona neden olabilmektedir. Bu bağlamda İzmit, Gemlik, Bandırma ve Erdek Körfez'lerinde insan aktivitelerinden kaynaklı baskıların ortaya koyulabilmesi için Baskı İndeksi yöntemi kullanılmış ve bu yöntemin uygunluğu ilk kez test edilmiştir. Baskıların değerlendirmesi sonucunda İzmit, Gemlik iç ve Bandırma Körfezi üzerindeki baskıların yüksek, buna karşın Erdek ve Gemlik dış Körfez'lerindeki baskıların orta düzeyde olduğu belirlenmiştir. Bu körfezlerde gerçekleştirilen izleme çalışmalarına ait besin elementleri, klorofil-*a* ve seki disk verileri ötrofikasyon açısından "Kentsel Atık Suların Arıtımı Yönetmeliği Hassas ve Az Hassas Alanlar Tebliği" ve "Yerüstü Su Kalitesi Yönetmeliği" eşik değerleriyle karşılaştırılmıştır. Yönetmeliklere göre baskı indeks değerlerinin değerlendirmelerde farklılıklar olsa da İzmit, Gemlik iç ve Bandırma Körfez'lerinde ötrofik - hipertrofik, Erdek ve Gemlik dış Körfez'lerinde ise mezotrofik koşulların hakim olduğu saptanmıştır. Kıyı sularının yönetmeliklerce değerlendirilmesinde farklı değişkenler ve sınır değerler kullanılmasından ötürü sonuçlarda farklılıklar ortaya çıkmaktadır. Yönetmeliklerin tek başlık altında toplanması yanında ötrofikasyon değerlendirmesine biyolojik kalite elemanlarının da dahil edilmesi önerilmektedir.

Anahtar Kelimeler: Marmara denizi, Ötrofikasyon, Baskı-etki, Kıyı suları, Kirlilik

ABSTRACT

Evaluation of Marmara Sea bays in terms of pressure-impact status and eutrophication

Closed or semi-enclosed bays in the Marmara Sea, which have long residence time, can be exposed to eutrophication as a result of organic matter enrichment from land-based pollutants. The Pressure Index method was tested for the first time in this study in order to reveal the pressure exerted by land-based sources on Izmit, Gemlik, Bandırma and Erdek Bays. As a result of the evaluation of the pressures, it was determined that the pressures on Izmit, Gemlik inner and Bandırma Bay were high, whereas Erdek and Gemlik Outer Bays were under moderate pressure. In terms of eutrophication, the nutrient, chlorophyll-a and secchi disk data of the monitoring studies carried out in the bays were compared with the limit values of the "Urban Wastewater Treatment Regulation Sensitive" and "Less Sensitive Areas Declaration and the Surface Water Quality Regulation". Although there are differences according to the regulations, it has been determined that Izmit, Gemlik (Inner) and Bandırma Bays have eutrophic-hypertrophic conditions, Erdek and Gemlik (Outer) Bays have mesotrophic conditions. There are differences in the results due to the use of different variables and limit values in the evaluation of coastal waters by regulations. In addition to collecting regulations under a single heading, it is recommended to include biological quality elements in the eutrophication assessment.

Keywords: Marmara sea, Eutrophication, Pressure – impact, Coastal waters, Pollution

Giriş

Ülkelerin ekonomik gelişimini, doğal kaynakların sürdürülebilirliği ve etkin kullanımı belirlemektedir. Kaynakların sürdürülebilirliği, ulusal güvenlik stratejisinin, ekonomik kalkınmanın ve toplumsal gelişim sürecinin en önemli bir birleşenlerinden biridir. Doğal kaynakların bir bileşeni olan kıyı alanları barındırdığı canlı ve cansız kaynak potansiyeline bağlı olarak özellikle son yüzyılda ekonomik ve toplumsal faaliyetler için çekici hale gelmiştir (Sönmez, 1993). İnsan kaynaklı bu faaliyetlerden en önemlileri nüfus artışı, evsel ve endüstriyel atık sular, katı atıklar, arazi kullanımının değişimi, habitat kaybı, aşırı ve tahrip edici şekilde avlanma, yabancı türler, iklim değişikliği ve gıdaya olan ihtiyacın artması sayılabilir. Bu faaliyetler özellikle açık sularla etkileşimi zayıf körfez ekosistemleri üzerinde geri dönüşümü zor olan ekolojik sorunlara neden olmaktadır (UNEP, 2006; Holon ve ark., 2015, Tan ve ark., 2017).

Antopojenik etkilerin en aza indirilmesi ve ekosistemin sürdürebilirliğinin sağlanması amacıyla ulusal- uluslararası birçok yönetmelik ve düzenlemeler yayınlanmış olup, hala yayınlanmaya devam etmektedir (EC, 2003; MSFD, 2017). Avrupa Birliği'ne uyum sürecinde olan ülkemiz bu kapsamda, yürürlükte olan yönetmelikleri güncellenmekte ve yeni yönetmelik çalışmalarına devam etmektedir. Kıyıların ötrofikasyon hassasiyetine göre kentsel atıksuların toplanması, arıtılması ve deşarjı ile belirli endüstriyel sektörlerden kaynaklanan atıksu deşarjının olumsuz etkilerine karşı çevreyi korumayı amaçlayan "Kentsel Atıksuların Arıtılması Yönetmeliği (KAAY, RG: 26047)" 2006 yılında yürürlüğe girmiştir. Yönetmeliğin belirli maddelerine düzenleme getiren "KAAY Hassas ve Az Hassas Tebliğ" ise 2009 yılında yayımlanmış olup, ötrofikasyon açısından kıyıları sınıflandırmakta ve denizlere göre ötrofikasyon sınır değerlerini ortaya koymaktadır. Kıyıların ötrofikasyon açısından değerlendirildiği ve sınır koşulların belirlendiği diğer bir düzenleme 2016 yılında yayımlanan "Yerüstü Su Kalitesi Yönetmeliği"dir (YSKY, RG: 29797). Bununla birlikte, havzalardan gelen yüklerin azaltılması ve kıyı ekosistemini korumak amacıyla "Su Kirliliği Kontrol Yönetmeliği" (SKKY, RG: 25687) 2004 yılında güncellenmiştir. Avrupa Birliği kıyı sularının kalitesinin korunması ve sürdürebilirliği kapsamında yürürlükteki yönetmelikleri ve düzenlemeleri tekrar ele alarak ortak bir çatı altında toplayan "Su Çerçeve Direktifi" (SÇD, 2000/60/EC) ve "Deniz Strateji Çerçeve Direktifi" (DSÇD, 2008/56/EC) birer şemsiye yönetmelik olduğu söylenebilir. SÇD, kıyı sularının "iyi kimyasal ve ekolojik duruma" ulaşmasını (EC, 2003); DSÇD ise kıyı ve deniz sularının ''iyi bir çevresel duruma ulaşmasını'' hedeflemektedirler (MSFD, 2017).

Kıyısal alanların, SÇD'nin tanımıyla iyi ekolojik ve kimyasal duruma, DSÇD'nin tanımıyla iyi çevresel duruma ulaşıp/ulaşamadığını belirlenmesinin yanı sıra ötrofikasyon açısından değerlendirilebilmesinde en önemli basamak baskı ve etkilerin tanımlanmasıdır (Borja ve ark., 2006). Baskı - Etki değerlendirmesinde farklı yöntemlerde mevcut olsa da en çok uygulanan metodoloji DPSIR (Sürücü [Driver- D], Baskı [Pressure –P], Durum [State –S], Etki [Impact – I], Önlem [Response – R]) sürecidir (EC, 2003; Borja ve ark., 2006). Baskı–Etki analizi, model aracılığıyla veya baskı-etki indeksleri geliştirilmesi gibi çeşitli yöntemlerle yapılabilmektedir. Söz konusu indeksler içerisinde yer alan baskı grupları ve bunların etki dereceleri uzman görüşlerine göre belirlenmektedir. Geliştirilen indekslerin baskı– etkileri doğru tanımlanması, uyumluluğu ve sonuçların karşılaştırılabilir olması önemlidir. Bunun yanı sıra indeks yöntemlerinin seçilmesinin diğer nedeni ise hızlı, kolay ve maliyetlerinin düşük olmasıdır. Söz konusu indekslere örnek olarak Bİ (Baskı İndeksi) (Aubry ve Elliott, 2006; Borja ve Rodiguez 2010, Borja ve ark. 2011; Pavlidou ve ark., 2015; Simboura ve ark., 2016), LUSI (Land Uses Simplified Index) (Gardi ve ark., 2010; Flo ve ark., 2011; Romero ve ark.,2013), LAWA (Almanya Etki Değerlendirme Metodu) ve İtalya kıyılarına uygulanan baskı-etki analiz uygulaması verilebilir (Lopez ve ark., 2009).

Bu çalışmada, Marmara Denizi'nde yer alan İzmit, Gemlik, Erdek ve Bandırma Körfez'lerindeki insan aktivitelerin ortaya koyulması, ulusal ve uluslararası yönetmeliklere göre bütüncül bir yaklaşımla indeks yöntemi kullanılarak baskı durumlarının belirlenmesi ve **"KAAY Hassas ve Az Hassas Tebliğ"** ile **"Yerüstü Su Kalitesi Yönetmeliği"** ötrofikasyon sınır değerleriyle karşılaştırılması hedeflenmiştir. Ayrıca, KAAY ve YSKY'nin sınır değerlerinin, ötrofikasyon durumunun değerlendirilmesinde kullanılabilirliği test edilmiştir.

Materyal ve Metot

Çalışma Alanı

Bir iç deniz olan Marmara Denizi Çanakkale Boğazı ile Akdeniz'e ve İstanbul Boğazı ile Karadeniz'e bağlanmaktadır. Marmara Denizi'nin genişliği 70 km uzunluğu ise 250 km olup, yüzey alanı yaklaşık 11.500 km^2'dir (Tutak ve ark., 2011; Tan ve ark, 2017). Güneyde geniş kıta sahanlığa sahip olan deniz, kuzeyde ise üç derin çukura sahiptir. Bu çukurlar batıdan doğuya 1100 m, 1390 m ve 1240 m derinliklere sahiptirler. Marmara Denizi iki tabakalı bir hidrografik yapıya sahip olup, bu iki tabaka birbirinden 25 m derinlikte yoğunluk farklılığı ile ayrılmaktadır. Karadeniz kökenli az tuzlu sular üst tabakada (~18 psu) ve Akdeniz kökenli çok tuzlu sular(~38 psu) alt tabakada yer almaktadır (Ünlüata ve ark.,1990; Beşiktepe ve ark., 1994).

Marmara Denizi çevresinde, yer alan İstanbul, Kocaeli ve Bursa İlleri ülkemiz nüfusunun %25'ini oluşturmakta olup, bu iller, yoğun kentleşme ve sanayinin olduğu bölgelerdir. Ayrıca, Marmara Denizi jeostratejik konumu sebebiyle yoğun deniz taşımacılığının olduğu bir denizdir. Marmara Denizi'nin kuzey şelfi nüfus ve sanayi tesisleri baskısı altında iken, güney kıyılarında yayılı kaynak baskısı daha yüksektir. Örneğin, Marmara Denizi kuzey şelfinde bulunan İstanbul ili, atıksularının büyük kısmı birincil arıtmadan sonra derin deniz deşarjı ile bırakılmaktadır. Güney şelfinde yer alan Susurluk, Biga ve Gönen nehirleri ise besin elementleri ve kirleticileri taşımaktadırlar (Tan ve ark, 2017; ÇŞB, TÜBİTAK MAM,2017).

İzmit Körfezi, yarı kapalı bir su havzası özelliğinde olup, Marmara Denizi'nin kuzeydoğusunda yer almaktadır (Şekil 1). Körfez, dar açıklıklarla birbirine bağlanan iç, orta ve dış olmak üzere üç basenden oluşmaktur (Morkoç ve ark.,2001). İzmit Körfezi'nin genişliği 1.5 km ile 10 km arasında değişmektedir. Dış basen, Hersek Deltasıyla orta basenden ayrılmıştır. Basenin derinliği batıda 200 m'den fazla iken, doğu kısımda 50 m'nin altına düşmektedir. Orta basen, Körfez'in en geniş kısmı olup, genişliği 10 km'ye kadar ulaşmaktadır. Basenin en derin noktası 200 m'dir. Körfez'in en iç kısmı ise en dar ve sığ kısmıdır. Söz konusu basenin uzunluğu 15 km olup, derinlikler 40 m'yi geçmez (Oğuz ve Sur, 1986; Beşiktepe ve ark., 1994; Ünlüata ve ark., 1990). Körfez'in üzerinde kentsel ve endüstriyel baskıların yanı sıra deniz taşımacılığı ve yayılı kaynaklardan da gelen yoğun baskılar mevcuttur (Tan ve ark, 2017).

Marmara Denizi'nin güney kıyısında yer Gemlik Körfezi, Marmara çukurlarından 50 m derinliği olan bir eşikle ayrılmaktadır. Körfez'in uzunluğu batı-doğu doğrultusunda 31 km olup, genişliği 14 km'dir. Gemlik Körfezi, çevresindeki yoğun endüstriyel baskı nedeniyle kalıcı organiklere ve ağır metal kirliliğine maruz kalmaktadır. Ayrıca, deniz trafiği, kentsel atık sular ve yağışla beraber akışa geçen sular diğer kirletici unsurlardır (Ünlü ve ark., 2008).

Bandırma Körfezi, Marmara Denizi güneyinde konumlanmış olup, en derin bölgesi 55 m'ye ulaşmaktadır (Şekil 1). Körfez'in güneyinde bulunan ve deniz trafiği açısından Türkiye'nin en yoğun limanlarından biri olan Bandırma Limanı, İstanbul'a olan yakınlığı sebebiyle oldukça önemlidir (Koç, 2002). Bandırma'da bulunan BAGFAŞ ve sülfürik asit tesisleri, körfez üzerindeki en ciddi baskı unsurlarıdır. Yüksek fosfat kirliliğinin körfezdeki gübre fabrikasından kaynaklı olduğu söylenebilir. Ayrıca, kentsel atıksuların ön arıtım sonrası derin deniz deşarjıyla körfez içine aktarılması ve tavukhanelerin yoğun olması körfeze baskı yaratan diğer unsurlardır. Tüm bu baskıların birlikte değerlendirildiğinde körfez olumsuz yönde etkilenmektedir.

Erdek Körfezi, Kapıdağı ve Biga Yarımada'larının arasında olup, Marmara Denizi'nin güneybatısında konumlanmaktadır (Şekil 1). Körfezin uzunluğu 130 km ve derinliği ise 55 m'dir. Körfez'in kuzeybatısında Paşalimanı Adası ve Türkeli Adaları yer almaktadır. Körfez içerisine Biga ve Gönen nehirleri dökülmektedir. Balıkçılık açısından Erdek Körfezi önemli bir alandır ve ticari balık türleri tarafından üreme veya yuvalama alanı olarak kullanılmaktadır (Okuş ve ark. 1997; Keskin, 2007; Keskin ve Gaygusuz, 2010). Özellikle kuzeyli rüzgarlarla nehirlerin taşıdığı kirlilik yüklerinin etkisi Türkeli Adaları bölgesinde bile etkisini göstermektedir. Erdek Körfezi, noktasal ve yayılı kaynakların yanı sıra turizm kaynaklı kirlilik baskısı altındadır. Özellikle kış ve yaz nüfusu arasındaki dalgalanmalar atıksu arıtma tesislerinin çalışmasını zorlaştırmaktadır. Körfezin kuzeyindeki Paşalimanı Adası, Marmara Denizi'nde deniz çayırı *Posidonia oceanica*'nın görüldüğü tek alandır (Meinesz ve ark., 2009). Yayılım alanları baskılardan dolayı gün geçtikçe azalmaktadır.

Baskı ve Etki Değerlendirme Yöntemi

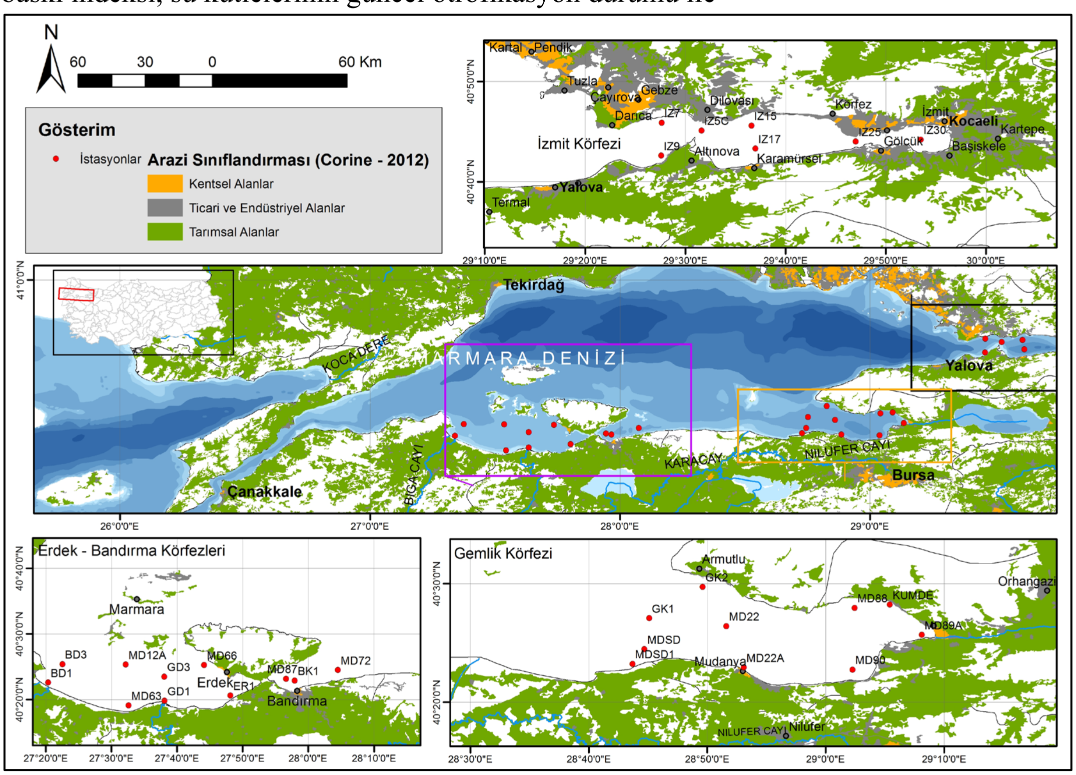
Körfezler, kentsel nüfus, tarım, endüstri, kentsel atık su arıtımı (KAAT) durumu, katı atık tesisi durumu, nehir girişi, hayvancılık, balık çiftliği, taşımacılık, liman, tersane ve diğer (HES, su çekimi vb.) aktiviteler olmak üzere tüm baskılar göz önünde bulundurularak Baskı İndeksi (Bİ) yöntemiyle değerlendirilmiştir (Aubry ve Elliott, 2006; Borja ve Rodriguez 2010, Borja ve ark. 2011; Pavlidou ve ark., 2015; Simboura ve ark., 2016). Baskı İndeksi (Bİ), baskı göstergelerinin toplamının (B) göstergelerin sayısına (n) bölümünden hesaplanmaktadır.

$$\text{Bİ} = \frac{\sum_{i=1}^{n} \text{B}}{n} \quad (1)$$

Baskı göstergeleri dört puanlık (0-3) bir sistemle uzman görüşüne göre değerlendirilmiştir (Tablo 1a). Sistemde, en düşük puan sıfırken, en yüksek puan üç olarak belirlenmiştir. Bİ sınıflandırma yöntemi Borja ve ark. (2011)'a göre belirlenmiş olup, beş kategoride değerlendirilmiştir. Bİ sınır değerleri dikkate alındığında, < 0,56: baskı olmadığını; 0,56-0,83: az baskının olduğunu; 0,83-1: orta baskının olduğu, 1-1,27: yüksek baskının ve 1,27 - 2 çok yüksek baskının olduğunu göstermektedir (Tablo 1b). Baskıların ve Baskı İndeksinin değerlendirmesinde renk kodları kullanılmış olup, bunlara ait bilgiler Tablo 1'de sunulmuştur.

Körfez üzerindeki aktivitelerin bütüncül olarak ele alındığı baskı indeksi, su kütlelerinin güncel ötrofikasyon durumu ile karşılaştırılmış ve etki değerlendirmesi yapılmıştır. Körfezlerin, ötrofikasyon durumunun belirlenmesi amacıyla TÜBİTAK Marmara Araştırma Merkezi Çevre ve Temiz Üretim Enstitüsüne ait R/V TÜBİTAK MARMARA gemisiyle Denizlerde Bütünleşik İzleme Programı'nın 2014-2016 yılları arasında körfezlerde üretilen besin elementleri (NO_2+NO_3-N (NO_x), PO_4-P, TP), klorofil-*a* ve seki disk (SD) verileri kullanılmıştır (ÇŞB-ÇEDİDGM ve TÜBİTAK-MAM, 2017). İzleme çalışmaları kapsamında, İzmit Körfez'inde 7, Gemlik Körfez'inde 10, Bandırma ve Erdek Körfezlerinde sırasıyla 3 ve 8 istasyonda olmak üzere toplamda 28 istasyonda, 3 sene boyunca kış ve yaz mevsimi verileri değerlendirilmiştir.

Körfezlerin, yüzey suyu (0-10 m) ortalamaları **"Kentsel Atıksu Arıtımı Hassas ve Az Hassas Alanlar Yönetmeliği EK-6 Hassas, Az Hassas ve Gri Alanlarda İzleme Tablosu"** ve **"Yüzeysel Su Kalitesi Yönetimi Yönetmeliği Ek 7 Tablo 8b Marmara Denizi Kıyı Suları Ötrofikasyon Kriterleri"** tablosu ile karşılaştırılarak ötrofikasyon durumu mevsimsel olarak belirlenmiştir. Baskı İndeksi ve ötrofikasyon durumu beraber irdelenerek körfezlerin nihai durumu ortaya konmuştur.



Şekil 1. Çalışma alanı, örnekleme istasyonları ve arazi sınıflandırma dağılımının gösterimi

Figure 1. Demonstration of the study area, stations and land classification distribution

Tablo 1. Baskı grupları (a) ve Baskı indeksi sınıflandırması (b) ile renk kodları.

Table 1. Pressure groups (a) and colour codes of the Pressure indices classification (b)

Baskı Grupları	Renk Kodları
0	Baskı Yok
1	Az Baskı
2	Orta Baskı
3	Yüksek Baskı

(a)

Baskı İndeksi Aralığı	Renk Kodları
0.56	Baskı Yok
0.56-0.83	Az Baskı
0.83-1	Orta Baskı
1-1.27	Yüksek Baskı
>1.27	Çok Yüksek Baskı

(b)

Bulgular ve Tartışma

Çalışmanın yürütüldüğü körfezlerin havza nüfusu, Marmara Denizi havzalarının toplam nüfusunun %10'unu oluşturmaktadır (TUIK, 2020). Kentsel nüfus, Bandırma ve Erdek Körfezlerinde orta yoğunlukta iken İzmit ve Gemlik Körfez'lerinde yoğundur (Tablo 2). Ancak, Erdek Körfezi'nde özellikle yaz nüfusu kış nüfusunun yaklaşık 5 katı kadardır (Balıkesir İÇDR, 2019).

Tarım ve hayvancılık faaliyetleri Bandırma ve Erdek Körfezlerinde diğer körfezlere göre daha yoğun yapılmaktadır. Söz konusu körfezler, tarım ve hayvancılık açısından yüksek ve orta riskli olduğu tespit edilmiştir. Buna karşın, diğer körfezler (İzmit ve Gemlik) orta – düşük riskli kategorisinde yer almıştır (Tablo 2).

Bandırma ve Erdek Körfez'lerinin atıksuları ön arıtım sonrasında derin deniz deşarjı (DDD) ile uzaklaştırılmaktadır (Balıkesir İÇDR, 2019). İzmit Körfezi atıksu arıtma tesisleri açısından diğer körfezlere göre daha iyi durumda olup, Kullar, Dilovası, Gebze ile Plaj yolunda ileri atıksu arıtma tesisleri bulunmaktadır (Kocaeli İÇDR, 2019). Gemlik Körfezi'nde, Bursa Merkez ilçesinde doğu ve batı atıksu arıtma tesisi olmak üzere iki adet ileri arıtım mevcuttur. Gemlik ilçesinde ise ön arıtım sonrası derin deniz deşarj yer almaktadır. Ayrıca, proje aşamasında 9 adet atıksu arıtma tesisi mevcuttur (Bursa İÇDR, 2019). Atık arıtma tesislerinin hizmet ettiği nüfus göz önüne alındığında, Gemlik dış Körfezi az riskli kategoride olup, diğer körfezler orta riskli olarak değerlendirilmiştir (Tablo 2).

Kocaeli ve Bursa illerinde sanayi tesisleri oldukça yoğundur (Burak ve ark., 2004; Atmış ve ark., 2007). Kocaeli Sanayi Odasına kayıtlı 1690 adet firma bulunmaktadır. Bu firmaların 62 adedi gıda, 66 adedi tekstil, 38 adedi tarım ilaçları üretimi, 65 adedi ana metal ürünleri, 121 adedi otomotiv, 63 adedi ise kimya ve ilaç üretimi sektörlerinde faaliyet göstermektedir. Yalova Ticaret ve Sanayi Odası kayıtlarına göre, ilde 2008 yılı itibarı ile büyük ölçekli sanayi kuruluşları ile konfeksiyon dikim atölyelerinin sayısı; 17'si gerçek, 117'si tüzel olmak üzere toplam 134'tür. Yalova'da kurulması planlanan 2 adet organize sanayi bölgesi (OSB), henüz faaliyette değildir (TÜBİTAK MAM, 2010). Bursa Ticaret ve Sanayi Odası'na kayıtlı 45.865 adet firma bulunmaktadır. Sektörel sınıflandırmaya göre %17,6'sı inşaat , %16,4'sı hizmet, %14,7'si tekstil ve % 9,35'i ile otomotiv sektörüdür (BTSO, 2020). Bandırma ili'nde gelişmiş önemli sektörler gıda, tarım, süt ürünleri, yem ve yem makineleri, mermercilik ve elektrik panoları sayılabilir. Bandırma Limanı'nın işletmeye girmesiyle sanayi tesisleri artmıştır. Büyük ölçekli tesisler olarak, Eti Bor A.Ş' ait Bandırma Bor ve Asit, Mauri Maya, Savola A.Ş., BAGFAŞ Gübre Fabrikaları A.Ş. ve Banvit A.Ş. bulunmaktadır. Türkiye'de üretilen gübrenin % 15'i ve beyaz etin % 22'si Bandırma ilçesinde üretilmektedir (BANTB, 2020). Erdek Körfezi'nin kıyılarında ise sanayi tesisleri az sayıdadır. Sanayi baskıları İzmit iç ve dış baseni, Gemlik iç baseni ve Bandırma Körfez'lerinde yüksek, Erdek Körfez'inde ise düşük olarak gözlenmiştir (Tablo 2). Ancak, Erdek Körfezi'ne nehirler üzerinde bulunan gıda, süt, tabakhane ve mezbahalar kaynaklı atıksular ulaşmakta ve körfez üzerinde baskı oluşturmaktadır.

Sanayi tesisleri yoğun olan İzmit, Gemlik ve Bandırma Körfezlerinde üretilen malların ulusal ve uluslararası pazarlara açılmasında en önemli unsur limanlardır. Söz konusu, körfezlerin ortak noktası güçlü ve büyük limanlarının bulunmasıdır. Örneğin, Kocaeli İlinde irili ufaklı 35 liman bulunmaktadır. Bandırma Körfezinde ise Bandırma Limanı Marmara Denizi'nin İstanbul'dan sonra ikinci büyük limanı konumundadır. Bununla birlikte Gemlik Körfezi içerisinde 7 adet liman bulunmaktadır. Söz konusu limanlarda ülkemizin toplam konteyner elleçlenmesinin %10'u, dökme yük açısından %5'i gerçekleşmektedir (Oral ve Esmer, 2011). Liman faaliyetleri beraberinde deniz trafiğinin de artışına neden olmaktadır. Bu kapsamda, liman ve taşımacılık aktiviteleri İzmit, Gemlik ve Bandırma Körfezlerinde yüksek, Erdek Körfez'inde düşük olarak sınıflanmıştır (Tablo 2).

Körfezlere irili ufaklı birçok dere dökülmektedir. Bunların bir kısmı yazın kuruyan derelerdir. Körfezlere dökülen dereler havza içlerinden noktasal ve yayılı kirleticilerin yüklerini taşımaktadırlar. Erdek Körfez'ine debisi yüksek olan Biga ve Gönen nehirleri akarken, Bandırma Körfez'ine ise düşük debili dereler dökülmektedir. İzmit Körfezi'ne irili ufaklı birçok dere dökülmekte olup, bunlardan bazıları evsel ve sanayi tesislerinin atıksuları ile katı atıkların yüksek oranda girdilerine maruz kalmaktadır. Nehirler taşıdığı kirlilik yükü durumuna göre değerlendirmiş olup, bu bağlamda Erdek ve İzmit Körfez'lerine dökülen dereler yüksek, Gemlik Körfezi orta baseni ve Bandırma Körfez'lerine dökülenler ise düşük riskli olarak sınıflandırılmıştır (Tablo 2) Körfezlere kıyısı bulunan ilçelerde oluşan katı atıklar düzenli katı atık bertaraf tesislerine gitmektedir ve düşük risk grubundadırlar (Tablo 2). Ayrıca, körfezlerde balık çiftlikleri bulunmadığından risk teşkil etmemektedir. Buna karşın Erdek Körfezi üzerindeki balıkçılık faaliyetlerden kaynaklı baskılar dikkat çekicidir (Bandırma Manşet, 2020).

Körfez ekosistemleri noktasal/yayılı kaynaklar ve diğer baskıların etkisi altında olan besin elementi artışlarından kolay etkilenen bölgelerdir. Bu ekosistemlerin su değişim kapasitelerinin düşük olmasından dolayı kirleticilerin birikmesine uygundur. Kirleticilerin birbirleriyle olan etkileşimleri, belirsizlikler ve kısıtlamalar nedeniyle baskı-etkilerin karakterizasyonu zorlaştırmaktadır (Islam ve Tanaka, 2004).

Marmara Denizi körfezleri'nde baskı-etkilerin belirlenmesinde baskı indeksi metodu kullanılmıştır. Bu metodun seçilme nedeni, Bİ'nin hızlı, kolay ve maliyeti yüksek olmayan bir analiz yöntemi olmasıdır. Ayrıca indeksin farklı denizlerde denenmiş olması (Aubry ve Elliott, 2006; Borja ve ark. 2010, 2011; Pavlidou ve ark., 2015; Simboura ve ark., 2016) indeksin sonuçların diğer ülkeler ile kıyaslaması açısından da oldukça önemlidir. Çalışmada Baskı İndeksi 0,91 – 1,82 aralığında değişim göstermiştir. En düşük değer Erdek Körfezi ve Gemlik dış Körfezi'nde, en yüksek değerler ise Bandırma, Gemlik iç ve İzmit Körfez'lerinde gözlenmiştir. Bu alanların, 2014-2016 yılı kış ve yaz mevsimi yüzey suyu (0-10 m) ortalamaları KAAY ve YSKY'e göre değerlendirildiğinde, baskıların yüksek olduğu körfezlerde kış mevsimi KAAY'a göre ötrofik, YSKY'e göre hiperotrofik durumlar oluşmuştur (Tablo 2). Buna karşın yaz mevsiminde oligotrofik şartların baskın olduğu belirlenmiştir (Tablo 2).

Tablo 2. Baskı İndeksi değerlendirmelerinin güncel yönetmeliklerin ötrofikasyon değerlendirmeleriyle karşılaştırılması

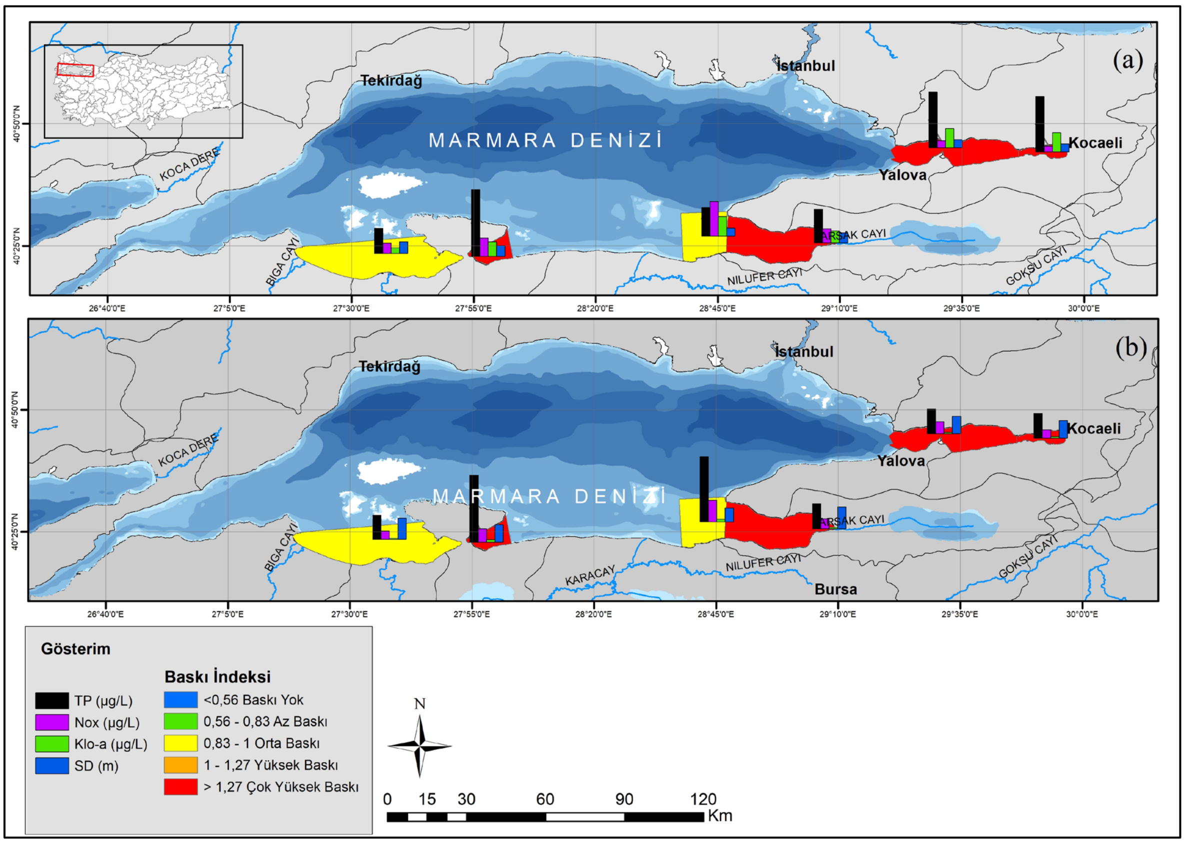
Table 1. Comparison of current regulation of pressure index assessment with eutrophication assessments

	Bölge	Bandırma Körfezi	Erdek Körfezi	İzmit Körfezi		Gemlik Körfezi	
				İç	Dış	İç	Dış
Etkilerin Değerlendirmesi	YSKY- Yaz						
	KAAY- Yaz						
	YSKY- Kış						
	KAAY- Kış						
Baskıların Değerlendirmesi	Kentsel Nüfus						
	Tarım						
	Endüstriyel						
	KAAT Durumu						
	Katı Atık						
	Nehir Girişi						
	Hayvancılık						
	Balıkçiftliği						
	Taşımacılık						
	Liman,Tersane						
	Diğer						
	Baskı İndeksi (BI)						

Tablo 3. KAAY - Hassas ve Az Hassas Tebliğ ve YSKY'nin ötrofikasyon değişkenleri sınır değerleri

Table 3. UWWT - Sensitive and Less Sensitive Notification and Eutrophication variables limit values of SWQR

Sınıflandırma	KAAY - Hassas ve Az Hassas Tebliğ				YSKY				
	TN (µM)	TP (µM)	Kl-*a* (µg/l)	SD (m)	NO_x (µM)	TP (µM)	Kl-*a* (µg/l) (ilkbahar)	Kl-*a* (µg/l) (sonbahar)	SD (m)
Oligotrofik	<18,5	<0,32	<1	>6	<1	<0,45	<3	<1	>6
Mesotrofik	18,5-25	0,32-0,96	1-3	3-6	1-14,2	0,45-0,67	3-4,3	1-2	6-4,5
Ötrofik	28,5	0,96-1,29	3-5	1,5-3	1,42-2,42	0,67-0,96	6	2-4	4,5-3
Hiperötrofik	>28,5	>1,29	>5	<1,5	>2,42	>0,96	>6	>4	<3



Şekil 2. Körfezlerde baskı sınıflandırmasına göre kış (a) ve yaz (b) besin elementleri, klorofil-a ve toplam fosfordaki değişimler

Figure 2. Changes in winter (a) and summer (b) nutrients, chlorophyll-a, and total phosphorus by pressure classification in the gulfs

Bandırma Körfezi'nde yoğun tarım faaliyetleri ve endüstri tesisleri bulunmaktadır. Sanayi tesislerinin yoğunluğuna paralel olarak liman ve taşımacılık faaliyetleri de yüksektir. Bu bağlamda, Bİ skoru 1,64 olup, yüksek risk sınıfına girmektedir (Şekil 2). Özellikle gübre fabrikası kaynaklı olduğu düşünülen yüksek toplam fosfor (TP) konsantrasyonları beraberinde birincil üretimin miktarında artışa neden olup, bunu klorofil-*a* (kl-*a*) değerlerinde artıştan gözlemlemek mümkündür. TP ve kl-*a* konsantrasyonları (Şekil 2) kış mevsiminde KAAY ve YSKY sınır değerlerinden yüksek olup, ötrofik–hipertrofik koşulların hakim olduğunu göstermektedir (Tablo 2). Yaz mevsiminde de çoğunlukla yüksek TP değerleri ölçülmüş olup, körfez suları mezotrofik olarak sınıflandırılmıştır (Tablo 2).

Marmara Denizi'nin kuzey ve güney doğusunda bulunan İzmit ve Gemlik iç Körfez'leri endüstriyel tesislerin yoğunluğu, yoğun liman ve taşımacılık faaliyetleri, nehir girdilerinin fazla miktarda oluşu ile hayvancılık ve tarımsal faaliyetlerin düşük olması bakımından birbirlerine çok benzemektedirler. İzmit ve Gemlik iç Körfez'leri de yüksek baskı altında olup, Bİ skorları sırasıyla 1,82 ve 1,73'tür. Baskı gruplarının benzer olmasının yanısıra besin elementlerinin seviyelerinin de benzer olduğu tespit edilmiştir. Kış mevsiminde her iki körfezde de yüksek konsantrasyonda kl-*a* ve orta seviyede TP değerler gözlenmiş olup (Şekil 2a), ötrofik koşulların hakim olduğu belirlenmiştir (Tablo 2). Yaz mevsiminde ise oligotrofik koşullar sıcaklıkların yükselmesi ve yağışların azalması sonucunda düşük kl-*a* konsantrasyonları ve seki disk derinlikleriyle (Şekil 2b) karakterize edilmiştir (Tablo 2).

Gemlik dış Körfezi'nde baskılar iç körfeze göre daha az (Şekil 2) ve açık denizle etkileşimin daha yüksek olmasından dolayı su kalitesi daha iyi durumdadır. Ancak, bölgedeki Susurluk Nehri'nin varlığı göz önünde bulundurulması gerekmektedir. Susurluk Nehri, dökülmeden önce kentsel ve endüstriyel baskıların yüksek olduğu Nilüfer Çayı ile birleşmektedir (Küçükali, 2013). Bu bağlamda, Susurluk Nehri'nin üzerindeki yoğun kirlilik taşıyan sular belli dönemlerde Gemlik Körfezi'nin su kalitesini olumsuz etkileyebilmektedir. Nehrin akıntı profillerinin çıkarılması ve nehir sularını takip edilerek körfezin etkilediği bölgelerin belirlenmesi oldukça önem taşımaktadır.

Erdek Körfezi'nde sanayi tesisleri düşük yoğunluktadır. Buna karşın, körfez içerisine dökülen Biga ve Gönen Nehir'leri havza içerisinden yüksek kirletici yüklerini taşımaktadırlar. Özellikle yaz nüfusu yüksek olan ilçede atık suların ön arıtma sonrasında derin deniz deşarjıyla uzaklaştırılması körfez için ciddi baskı unsurudur. Baskılar bütüncül olarak değerlendirildiğinde Bİ skoru 1.00 olup, orta riskli bir durumu işaret etmektedir (Şekil 2). Üzerindeki baskılara rağmen Akdeniz kökenli oksijence zengin alt sular körfezin özümseme kapasitesini arttırmaktadır (Beken, 2017). Körfez, KAAY ve YSKY'e göre kışın sırasıyla mesotrofik ve ötrofik, yazın ise iki yönetmelikte de oligotrofik sınıftadır (Tablo 2).

KAAY- Hassas ve Az Hassas Tebliğ ve YSKY'nin Marmara Denizi ötrofikasyon sınır değerlerine göre körfezler sınıflandırıldığında farklılıklar oluşmaktadır (Tablo 2). Örneğin, Erdek Körfezi kış mevsimi KAAY Hassas ve Az Hassas Tebliğine göre mezotrofik statüde iken YSKY'ye göre ötrofik sınıfta değerlendirilmektedir (Tablo 2). Diğer körfezler kış mevsiminde KAAY'a göre ötrofik YSKY'ye göre hipertrofiktir. Yaz mevsiminde ise İzmit ve Gemlik dış körfezleri YSKY'ye göre oligotrofik olup, KAAY'a göre mezotrofiktir (Tablo 2). KAAY - Hassas ve Az Hassas Tebliği'ne göre toplam azot (TN), TP, kl-*a* ve SD göre ötrofikasyon değerlendirmesi yapmaktadır. YSKY, KAAY'dan farklı olarak nitrit+ nitrat azotu (NO_x) ile kl-*a* miktarının değerlendirmesini ilkbahar ve sonbahar mevsimlerinde ayrı ele alarak ötrofikasyon sınıflandırması yapmaktadır (YSKY, 2012). YSKY sınır değerleri KAAY değerlerine göre daha katıdır (Tablo 3). Hem değişkenlerin farklılığı hem de sınır değerlerin farklı oluşu ötrofikasyon sınıfının belirlenmesinde farklılıklar yaratmaktadır.

Bu çalışma ile, Marmara Denizi'nin baskı-etki değerlendirmeleri farklı indeksler aracılığıyla ortaya koyulmuştur. Nitel gözlemlere dayalı objektif yöntem olan LUSI (land uses simplified index) Tan ve ark. (2017) tarafından Marmara Denizi kıyısal alanlarının değerlendirilmesinde kullanılmıştır. Uzman görüşü ve nitel gözlemlere dayalı olan MA-LUSI (Makro Algea land uses simplified index) (MEDGIG; EC, 2011) ve LUSIVal (land uses simplified index Valencia) (Romero ve ark.,2013) indeksleri LUSI indeksinin modifiye edilmiş halleridir. Taşkın ve ark. (2020) MA-LUSI indeksi, Tan ve ark. (2017) tarafından LUSIVal indeksi kullanılarak Marmara Denizi kıyısal alanları değerlendirmişlerdir. Bu çalışmada, ilk kez öznel gözlemlere dayalı bir metot olan Baskı İndeksi (Bİ) kullanılarak Marmara Denizi körfezleri'nin baskı-etki durumu değerlendirilmiştir. Marmara Denizi'nde yapılan diğer çalışmalarla Bİ sonuçları benzerlik göstermektedir (Tan ve ark, 2017; Taşın ve ark., 2020). Bu çalışmada elde edilen sonuçlar, Denizlerde Bütünleşik Kirlilik İzleme Programı (2014 – 2016)'ında ekolojik kalite durumu çalışmasıyla benzerlik göstermektedir (ÇŞB, TÜBİTAK MAM, 2017).

Sonuç

Bu çalışmada, baskı indeksi yönteminin Marmara Denizi Körfezleri'nde kullanımının uygun olduğu ve diğer indekslerle uyumlu sonuçlar verdiği tespit edilmiştir. Ülkemiz kıyı sularının ötrofikasyon açısından değerlendirmesinde kullanılan yönetmelikler (KAAY ve YSKY) farklı değişkenler ve sınır değerler kullanmasından ötürü aynı kıyı su kütleleri için farklı sonuçlar ortaya koymaktadır. Söz konusu yönetmelikler aynı çatıda birleştirilerek ve güncel verilerle sınır değerler tekrar belirlenerek değerlendirmelerin yapılması önerilmektedir. Ayrıca, Denizlerde Bütünleşik Kirlilik İzleme Programı ekolojik kalite durumları açıkça göstermiştir ki kıyı sularının ötrofikasyon durumlarının değerlendirilmesinde sadece besin elementleri, klorofil-*a* ve seki disk değişkenlerinin kullanılması yetersiz kalmaktadır. Değerlendirmelerin etki kısmına fitoplankton veya makroalg gibi biyolojik bir kalite elemanlarının da eklenmesi değerlendirmelerin daha sağlıklı ve güvenilir yapılabilmesine olanak sağlayacaktır.

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İstanbul Boğazı'nda deniz trafik düzenlemelerinin kaza oranına etkisinin değerlendirmesi

Gizem KODAK[1], **Tayfun ACARER**[2]

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[1] İstanbul Teknik Üniversitesi, Avrasya Yer Bilimleri Enstitüsü, İklim ve Deniz Bilimleri Anabilim Dalı, 34469 Sarıyer/ Maslak/ İstanbul, Türkiye

[2] İstanbul Bilgi Üniversitesi, Meslek Yüksek Okulu Bilgisayar Teknolojileri Bölümü İstanbul, Türkiye

ORCID IDs of the author(s):
G.K. 0000-0002-1845-7901
T.A. 0000-0003-2407-5552

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Correspondence: Gizem KODAK
E-mail: kodak@itu.edu.tr

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Öz

Dünya'nın en riskli doğal suyollarından biri olan İstanbul Boğazı'nda tarih boyunca pek çok deniz kazası meydana gelmiş, bu kazalardan bazıları ciddi boyutta can kaybı, maddi / çevresel zarar ve dünya çapında endişeye sebep olan çevre felaketleri ile sonuçlanmıştır. Günümüzde İstanbul Boğazı'ndan geçiş yapan gemilerin önemli bir bölümünün tehlikeli yük taşıyan tankerler olması, geçiş yapan gemi boyutlarının giderek büyümesi ve taşınan tehlikeli yük miktarının artması, meydana gelebilecek kazaların boyutlarını daha dramatik hale getirmektedir. Yakın tarihte meydana gelen kazalar sonrasında, bölgedeki seyir emniyetini arttırmak amacıyla deniz trafiğini düzenleyen birçok uygulama gerçekleştirilmiştir. Bu uygulamaların en kapsamlısı 2003 yılında kurulan ve Boğaz'daki trafiğin emniyetli ve etkin bir şekilde işleyebilmesi için gemilere bilgi, seyir yardımı ve trafik organizasyon hizmetlerini sunan Türk Boğazları Gemi Trafik Hizmetleri (TBGTH) olmuştur. Bu çalışmada, Türkiye kıyılarında en çok deniz kazasının meydana geldiği İstanbul Boğazı'nda 2001 – 2015 yılları arasında gerçekleşen deniz kazaları; geçiş yapan gemi sayısı ile kaza miktarı arasındaki ilişki temelinde ele alınmış ve deniz trafiğine yönelik gerçekleştirilen yasal düzenlemeler ile eş zamanlı olarak incelenmiştir. Böylelikle TBGTH sonrası yapılan düzenlemelerin kaza oranına etkisi ortaya konmuş ve kazalar üzerinde en etkili uygulamaların profili çıkarılmıştır. Elde edilen bulguların, bölgede seyir emniyetini arttıracak yeni tedbirler geliştirilmesi için alt yapı oluşturması hedeflenmiştir.

Anahtar Kelimeler: Deniz emniyeti, Deniz kazaları, Denizde haberleşme, İstanbul Boğazı

ABSTRACT

Evaluation of the effect of maritime traffic regulations on the accident rate in the strait of Istanbul

In the Strait of Istanbul, which is one of the most perilous natural waterways of the World, many marine accidents have occurred throughout the history. Some of these accidents resulted in deaths, financial losses, and environmental disasters. The fact that a significant proportion of the ships passing the Strait are tanker carrying hazardous cargo further increases this danger. Especially the increasing size of the ships, the increase in the cost of the for transported and the transportation of dangerous cargoes, especially oil and derivatives, to a great extent by sea, made the possible consequences of the accidents even more catastrophic. For this reason, many regulatory measures have been taken regarding the Sea Traffic in Istanbul, Çanakkale Straits and Marmara Sea, which have been named as the "Turkish Straits System" in recent years, and these measures have been collected under the Turkish Straits Vessel Traffic Service, which is briefly defined as TBGTH. Within the scope of this study, maritime accidents in the Strait of Istanbul have been examined chronologically in terms of the number of ships passing and maritime traffic regulations. The effects of the applications implemented after 2003, when Istanbul VTS started its operations, on the safety of navigation have been investigated. In this way, it is aimed to demonstrate the effect of the Vessel Traffic Services and related regulations on the improvement in the rate of marine accidents. The numerical determination of the relationship between the number of passing ships and the number of accidents in the Strait can be used as a statistically significant criterion for the realization of new regulations depending on the maritime traffic volume in the coming years.

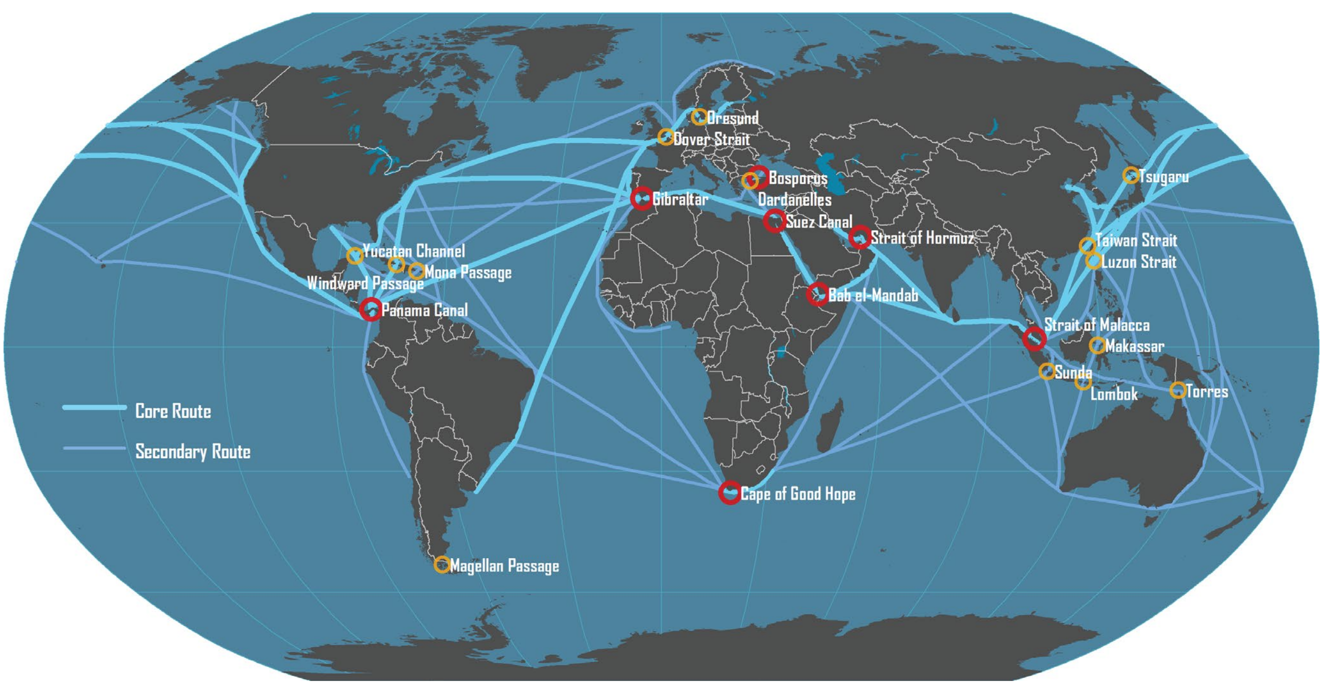
Keywords: Safety navigation, Maritime accidents, Maritime communication, Strait of Istanbul

Giriş

En ucuz taşıma, birim maliyeti en düşük olandır. Birim taşıma maliyeti düşük taşımalar ise çoğunlukla kitle taşımalarıdır. Kitle taşımacılığı 60'lı yıllardan bu yana yaygın gelişme göstermiştir. Denizyolu, demiryolu, iç suyolu ve boruyolu taşımacılığı bunun temelini oluşturmaktadır. Zaman kriteri ihmal edildiğinde, kitle taşımacılığı içinde birim taşıma maliyeti en düşük olanı, deniz yoludur. Bu nedenle de sanayileşmiş deniz ülkeleri taşımacılıkta denizyolunu yeğlemektedirler (Kodak, 2011). Uluslararası Deniz Ticaret Odası verilerine göre, Günümüzde dünya ticaretinin % 90'ı deniz yoluyla yapılmaktadır (ICS, 2020). Denizyolu taşımacılığının demiryoluna göre 3.5, karayoluna göre 7, havayoluna göre 22 kat ucuz olması, bu taşıma şeklinin öneminin ve hacminin her geçen gün artmasına yol açmaktadır. (Aygün, 2012).

Zaman içinde hem taşınan yüklerin hacminin, hem de değerinin giderek artması, denizyolu taşımacılığında kazalar nedeniyle ortaya çıkan zararı daha da büyütmektedir. Bu kazalar sırasında meydana gelen can kayıplarının bedelini ise, parasal olarak tanımlamak mümkün değildir.

Tarihsel veriler, deniz kazalarının genellikle dar ve işlek su yollarında meydana geldiğini göstermektedir (Butt vd., 2012). Dünya deniz ticaretinin atar damarı olan bu suyolları, her biri kendine özgü stratejik üstünlük ve kısıtlara sahiptir. Örneğin, yılda ortalama 22.000 geminin geçiş yaptığı Bab-el-Mandeb'de en büyük tehlike korsanlık ve terörist faaliyetler olarak tanımlanırken, Süveyş Kanalı'nda konvoyların oluşturduğu kısıtlar bulunmakta ve Kanal'daki en büyük tehdit, Mısır'daki politik çalkalanmalar ve terörist faaliyetler olarak öne çıkmaktadır. Yıllık gemi geçiş sayısı açısından dünyanın en işlek suyolu olan Batı Malezya ve Sumatra adası arasındaki 805 km uzunluğundaki Malakka Boğazı'nda, en büyük tehlike türü korsanlık iken; İstanbul Boğazı'nda en büyük tehlike, zorlu coğrafi faktörler ve seyir özellikleri dolayısıyla ortaya çıkan deniz kazası riski olarak tanımlanmıştır (Rodrigue, 2004). Rodrigue 2017, tarihli Major Maritime Shipping Routes and Strategic Passages isimli çalışmasında, dünya deniz ticaretinin ana güzergâhlarını büyük ekonomiler arasında köprü görevi gören birincil rotalar ve daha küçük pazarlar arasındaki bağlantıları oluşturan ikincil rotalar olarak ikiye ayırmıştır. Yapılan bu sınıflama doğrultusunda, dünya deniz ticaretinin ana rotaları üzerinde bulunan ve deniz ticaret ağının kesişim noktalarını oluşturan birincil suyolları ve ana ticaret rotalarını destekleyen ikincil su yolları aşağıda, Harita 1'de incelenmiştir.



Harita 1: Dünya Deniz Ticareti Ana Rotaları ve Bağlantı Noktaları (Rodrigue, 2017)

Map 1. World Maritime Trade Main Routes and Connection Points (Rodrigue, 2017)

Harita 1'den görüldüğü üzere İstanbul Boğazı, dünya deniz ticaretinin büyük ekonomileri arasında köprü görevi gören birincil rotalar üzerinde bulunmaktadır. Bu doğrultuda bölgeden, geçiş yapan gemi sayısı, dünyanın en yoğun gemi trafiğine sahip diğer suyollarıyla karşılaştırılmış ve 2018 yılı için elde edilen bulgular aşağıda Tablo 1'de sunulmuştur. Burada görüldüğü gibi İstanbul Boğazı, gemi geçiş sayısı açısından Malakka Boğazı'ndan sonra dünyanın en işlek suyoludur ve dünya deniz ticareti ağı üzerinde bulunan diğer emsalleri içerisinde deniz kazası tehlikesiyle öne çıkan tek suyoludur (Rodrigue, 2004). İstanbul Boğazı'nda yakın geçmişte gerçekleşen deniz kazaları içerisinde dünya çapında endişeye neden olan çevre felaketi ve can kayıpları meydana getiren kazalar mevcuttur. 1979 yılında meydana gelen Independenta kazasında 94.000 ton ham petrol deniz dökülmüş ve kaza şiddetli hava / deniz kirliliğine yol açmıştır (ITOPF, 2018). 30.000 ton ham petrolün yandığı, 64.000 ton ham petrolün ise denize karıştığı kazada, hafif bileşenlerin buharlaşmasının ardından 46 g/m^2 yoğunluktaki katran tabakası 5.5 km yarıçapında bir dip yüzeyine çökmüştür. Marmara Bölgesi ve İstanbul sahillerini derinden etkileyen kaza sonucunda bölgede sadece 9 deniz dibi canlı türü hayatta kalabilmiş ve ölüm oranı %96 olarak kayıtlara geçmiştir (Küçükyıldız, 2014: 21; Öztürk vd., 2006; Baykut vd., 1985). Independenta kazasından başka Nassia kazası bölgede yakın geçmişte yaşanan tarihe geçen diğer büyük kazalardan biridir. 1994 senesinde yaşanan Nassia kazasında 29.000 ton ham petrol denize dökülmüş, birçok sahil ve koy petrolle kaplanmış ve 1500'den fazla deniz kuşu petrolle büyük ölçüde temas sonucunda telef olmuştur (Küçükyıldız, 2014; Öztürk vd., 2006; Baykut vd., 1985).

Tablo 1. Dünya'nın En İşlek Su Yollarına İlişkin 2018 Yılı Gemi Geçiş Sayısı Verileri (Canal de Panamá, 2020; SCA, 2020; KEGM, 2020; Jariod, 2019; WSV, 2020)

Table 1. 2018 Data on the Number of Ships on the World's Busiest Waterways (Canal de Panamá, 2020; SCA, 2020; KEGM, 2020; Jariod, 2019; WSV, 2020)

Su Yolu	Geçiş yapan Gemi Sayısı
Malakka Boğazı	85.030
İstanbul Boğazı	41.112
Süveyş Kanalı	18.174
Kiel Kanalı	29.000
Panama Kanalı	13.785

Günümüzde, gelişen gemi inşa teknolojisi ile Boğaz'dan geçiş yapan gemilerin boyutları ve tehlikeli yük taşıma kapasitelerine paralel olarak, meydana gelen kazaların sayısı da yıllara göre artmıştır. Bu durum, UNESCO Dünya kültür mirası listesinde yer alan ve 15.52 milyon nüfusa sahip olan İstanbul şehrinin ortasından geçen Boğaz'da, bugün olası bir kazada meydana gelebilecek felaketin boyutlarını da dramatik hale getirmektedir. Bu nedenle, bölge için gerçekleştirilen kaza analizleri, bu konuda alınan önlemler ve varılan sonuçlar, yapılacak yasal düzenlemeler için büyük önem taşımaktadır. Kazaları değerlendiren analizler sonucunda geliştirilecek çözüm önerileri, mikro ölçekte İstanbul Boğazı'nda makro ölçekte ise benzeri suyollarında meydana gelebilecek kazalarda kayıpların/zararların azaltılmasını sağlayacak, emniyet seviyesinin arttırılmasına katkıda bulunacak ve ulusal/uluslararası regülasyonlar için altyapı oluşturacaktır.

Günümüzde küresel ticaretin %90'ı deniz yoluyla gerçekleştirilmektedir (ICS, 2020). Birleşmiş Milletler Ticaret ve Kalkınma Konferansı Raporu'na göre dünya deniz ticareti 2017 yılında hız kazanmış ve son beş yılın en hızlı büyümesini kaydetmiştir. Bu büyümenin 2018 ile 2023 yılları arasında yıllık yüzde 3,8'lik bir oranla sürmesi beklenmektedir. (UNCTAD / RMT / 2018). Artan deniz ticaretine paralel olarak, uluslararası deniz trafiği de artış gösterecektir. Çalışma kapsamında elde edilen bulgular; geçiş yapan gemi sayısının deniz kazaları üzerindeki etkisini sayısal ortaya koymuş ve 2023'e kadar öngörülen büyümenin İstanbul Boğazı için kaza riskini arttıracağını göstermiştir.

Bu çalışmanın amacı; İstanbul Boğazı'ndaki deniz kazalarını, geçiş yapan gemi sayısı ve deniz trafiği ile ilgili yapılan düzenlemeler doğrultusunda incelenmek ve İstanbul Gemi Trafik Hizmetleri'nin faaliyete geçtiği 2003 yılı sonrasında gerçekleştirilen uygulamaların seyir emniyeti üzerindeki etkisini incelemektir. Bu doğrultuda, 2001 ile 2015 yılları arasında İstanbul Boğazı'ndan geçiş yapan gemi sayısı ve bölgede gerçekleşen kaza sayısı karşılaştırılmış ve geçiş yapan gemi başına kaza oranı hesaplanmıştır. Her iki değişkenin önce zamana bağlı hareketi incelenmiş ardından geçiş yapan gemi sayısı ve kaza sayısı arasında lineer regresyon modeli kurularak trafik hacminin bölgedeki kaza sayısı üzerindeki sayısal etkisi açıklanmıştır. Çalışma kapsamında; İstanbul Boğazı'nın fiziksel özellikleri, bölgeden geçiş yapan gemilerin manevra kabiliyetini kısıtlayarak kaza oluşumunu tetikleyen faktörler doğrultusunda incelenmiş, bölgede deniz trafiğine etki eden akıntı sistemi, rüzgar yönü ve rüzgar hızı dinamiklerinin profili ortaya konmuş ve bölgede seyir emniyetine yönelik şimdiye değin gerçekleştirilen zamansal ve mekansal analizler araştırılmıştır. İncelenen çalışmalar literatür araştırması dahilinde Tablo 2'de sunulmuştur. Buna ek olarak çalışma, 2001- 2015 yılları arasında bölgede deniz trafiğine yönelik gerçekleştirilen yasal düzenlemeleri kronolojik olarak incelemesi ve geçiş yapan gemi başına kaza oranının ilgili düzenlemelerle eş zamanlı analizi dolayısıyla, alınan tedbirlerin etkinliğini ortaya koyarak literatüre katkıda bulunulmuştur.

İstanbul Boğazı'nın Sınırları ve Fiziksel Özellikleri

İstanbul Boğazı'nın sınırları, kuzeyde Anadolu ve Türkeli Fenerlerini birleştiren hat ile güneyde Ahırkapı Feneri'ni Kadıköy İnciburnu Mendirek Feneri'ne birleştiren hat arasında tanımlanmıştır (Türk Boğazları Deniz Trafik Düzeni Yönetmeliği, 2019).

Ortalama genişliğin 1600 metre olduğu İstanbul Boğazı'nın en geniş yeri 3600 metre ile Anadolu ve Türkeli Fenerleri arası, en dar yer ise 698 metre ile Anadolu Hisarı ve Rumeli Hisarı arasıdır. Ortalama derinliği 36,3 metre olan Boğaz'ın dibinde yer yer 70 ile 80 metreye varan çukurlar bulunmakta, en derin nokta ise 110 metre ile Kandilli önlerinde ölçülmektedir (Taşlıgil, 2004).

Artan Dünya ticaretiyle birlikte geçiş yapan gemi sayısının artması yanında, bölgedeki riski arttıran bir diğer faktör tehlikeli yük taşıyan gemi sayısındaki artıştır. İstanbul Boğazı'ndan geçiş yapan gemilerin % 18'ini tehlikeli yük taşıyan tankerler meydana getirmektedir. (Yaycı, 2013).

Malakka Boğazı'ndan sonra, dünyanın en yoğun deniz trafiğine sahip suyolu olan İstanbul Boğazı, gerek çift yönlü akıntı sistemi gerekse kıvrımlı jeomorfolojik yapısı dolayısıyla dünya deniz ticaret ağı üzerinde gemiler için en zorlu rotalardan birini oluşturmaktadır. Öyle ki Boğaz'dan geçiş yapan bir geminin sekiz ayrı noktada geniş açılı dönüş yapması gerekmektedir (DNV, 2013). Söz konusu dönüşler Harita 2' de, dönüş açıları ise Tablo 3'de incelenmiştir.

Tablo 3. İstanbul Boğazı'nda Geniş Açılı Manevra Gerektiren Dönüşler ve Dönüş Açıları (DNV, 2013)

Table 3. Significant Turns and Turn Angles in the Strait of Istanbul (DNV, 2013)

Dönüş Noktası	Dönüş Açısı
1 - Fil Burnu	13°
2 - Macar Burnu	73°
3 - Köybaşı Burnu	82°
4 - Kanlıca	46°
5 - Aşiyan Burnu	39°
6 - Kandilli Burnu	21°
7 - Defterdar Burnu	36°
8 - Kız Kulesi	51°

Harita 2. İstanbul Boğazı'nda Geniş Açılı Manevra Gerektiren Dönüşler (DNV, 2013)

Map 2. Significant Turns in the Strait of Istanbul (DNV, 2013)

İstanbul Boğazı sınırları içerisinde işleyen deniz trafiği, Denizde Çatışmayı Önleme Tüzüğü'ne (COLREG 72 - Convention on the International Regulations for Preventing Colisions at Sea) göre düzenlenmiş ve Uluslararası Denizcilik Örgütü-IMO (International Maritime Organization) tarafından kabul edilmiş olan trafik ayrım düzeni çerçevesinde ve bu düzen içerisinde ters yönlü gemi trafiğini birbirinden ayırmak için tesis edilen trafik şeritleri dahilinde işlemektedir (Denizde Çatışmayı Önleme Tüzüğü, 2017). Bu kapsamda Boğaz, kuzeyden güneye doğru Sektör Türkeli, Sektör Kandilli ve Sektör Kadıköy olmak üzere üç sektörel alana bölünmüş olup, ilgili sektör sınırları, Harita 3'de gösterilmiştir (Türk Boğazları Seyir Rehberi, 2015).

Harita 3. İstanbul Boğazı VTS Sektörleri (Türk Boğazları Seyir Rehberi, 2015)

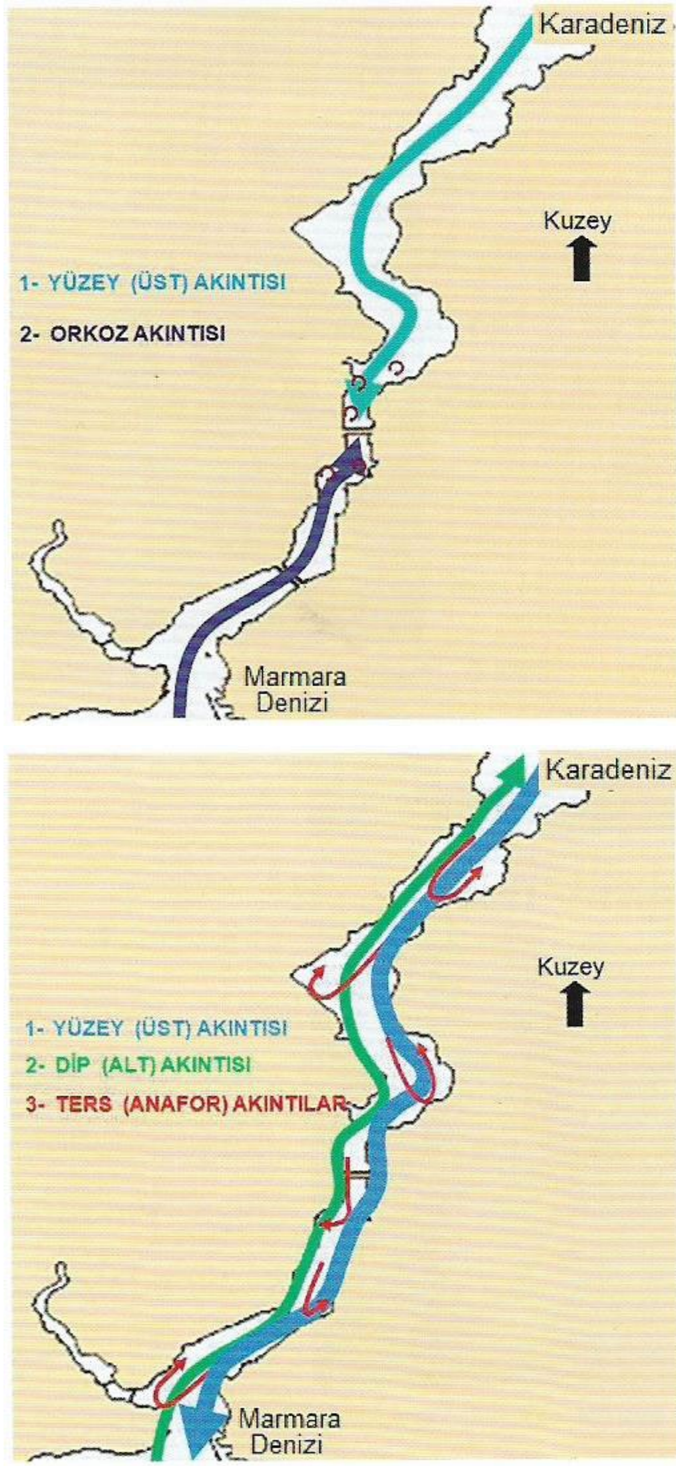
Map 3. VTS Sectors in the Strait of Istanbul (Türk Boğazları Seyir Rehberi, 2015)

Bu sistemde gemiler ile TBGTH çalışanları arasındaki haberleşme, "Çok Yüksek Frekans" - VHF (Very High Frequency) deniz sistemleri üzerinden sağlanmakta ve bu amaçla, ulusal düzenlemeler ile tahsis edilmiş olan VHF bandı deniz kanalları kullanılmaktadır (Acarer, 2016).

İstanbul Boğazı'nda Deniz Trafiğine Etki Eden Dinamik Faktörler

Akıntı Sistemi

Oldukça dar bir su yolu olan İstanbul Boğazı'nda yüzey akıntıları, dip akıntıları, ters akıntılar ve Orkoz olmak üzere 4 farklı akıntı bulunmaktadır. Bu durum, gemilerin manevra kabiliyetini güçleştirerek seyir emniyetini olumsuz yönde etkilemektedir. İstanbul Boğazı akıntı sistemini oluşturan söz konusu akıntılar Harita 4'de gösterilmiştir.



Harita 4. İstanbul Boğazında Farklı Akıntı Türleri (Aybay, 2001; Oğuzülgen vd., 2018)

Map 4. Current System in the Strait of Istanbul (Aybay, 2001; Oğuzülgen vd., 2018)

Tablo 2. İstanbul Boğazı'nda meydana gelen kazaların değerlendirildiği literatür araştırması listesi

Table 2. Literature research list evaluating the accidents that occurred in the Istanbul strait

Çalışma Adı	Yayın Türü	Yazar	Çalışma Kapsamı
Reducing the probability for the collision of ships by changing the passage schedule in Istanbul Strait	Makale	Korçak ve Balas, 2020	İstanbul Boğazı seyir emniyeti Deniz kazaları, çatışma türü kaza olasılığı Simülasyon
Strait of Istanbul, major accidents and abolishment of left-hand side navigation	Makale	İstikbal, 2020	İstanbul Boğazı seyir emniyeti, İstanbul Boğazı gemi trafik düzeni, Sol trafik düzeni
Web-Based GIS for Safe Shipping in Istanbul Bosphorus Strait	Makale	Gümüşay, 2018	Mekânsal Analiz Web tabanlı GIS İstanbul Boğazı deniz kazaları
Maritime Traffic Analysis of the Strait of Istanbul based on AIS data	Makale	Altan ve Otay, 2017	İstanbul Boğazı seyir emniyeti Risk Analizi Gemi trafik düzeni
The analysis of life safety and economic loss in marine accidents occurring in the Turkish Straits	Makale	Uğurlu vd., 2016	Deniz Kazaları
Designing and modelling coast management GIS for Bosphorus	Makale	Gümüşay vd., 2016	Mekânsal Analiz Web tabanlı GIS Kıyı yönetimi
Risk Assessment in the Istanbul Strait Using Black Sea MOU Port State Control Inspections	Makale	Kara, 2016	İstanbul Boğazı Seyir Emniyeti Risk Analizi PSC, Black Sea Mou
Formal Safety Assessment for Ship Traffic in the Istanbul Straits	Makale	Görçün ve Burak, 2015	İstanbul Boğazı seyir emniyeti, İstanbul Boğazı gemi trafiği Güvenlik değerlendirmesi
Comprehensive scenario analysis for mitigation of risks of the maritime traffic in the Strait of Istanbul	Makale	Özbaş vd., 2013	İstanbul Boğazı seyir emniyeti, Risk analizi Senaryo analizi
Risk assessment of potential catastrophic accidents for transportation of special nuclear materials through Turkish Straits	Makale	Bolat vd., 2013	Türk Boğazları Risk Analizi Deniz Kazaları Tehlikeli yük taşımacılığı
İstanbul Boğazı'nda Transit Gemilerin Kullandığı Seyir Rotalarının Coğrafi Bilgi Sistemi Yardımıyla İncelenmesi ve İyileştirilmesi	Makale	Başaraner, Yücel ve Özmen, 2011	Coğrafi Bilgi Sistemleri Mekânsal analiz Uğraksız geçiş yapan gemi trafiği

An analytic hierarchy process approach to the analysis of ship length factor in the Strait of Istanbul	Makale	Keçeci ve Yurtören, 2010	Analytic Hierarchy Process İstanbul Boğazı seyir emniyeti Gemi boyu faktörü
Risk Analysis of the Vessel Traffic in the Strait of Istanbul	Makale	Uluscu vd., 2009	İstanbul Boğazı gemi trafiği Risk analizi
Analytical investigation of marine casualties at the Strait of Istanbul with SWOT – AHP method	Makale	Arslan ve Turan, 2009	İstanbul Boğazı deniz kazaları Seyir emniyeti SWOT – AHP metodu
A Navigation Safety Support Model for the Strait of Istanbul	Makale	Yazıcı ve Otay, 2009	İstanbul Boğazı seyir emniyeti
Transit Vessel Scheduling in the Strait of Istanbul	Makale	Uluscu vd., 2009	İstanbul Boğazı Gemi Trafik Düzeni Gemi Trafik Hizmetleri
Simulation based risk analysis study of maritime traffic in the Strait of Istanbul	Makale	Özbaş vd., 2009	Risk analizi, İstanbul Boğazı deniz trafiği
Turkish Straits: Difficulties and the importance of pilotage. Turkish Straits-Maritime Safety, Legal and Environmental Aspects	Makale	İstaikbal, 2006	Türk Boğazları Seyir emniyeti Türk Boğazlarına ilişkin yasal düzenlemeler Çevresel etki değerlendirmesi
Finding risky areas for oil spillage after tanker accidents at Istanbul Strait	Makale	Başar vd., 2006	İstanbul Boğazı Deniz kirliliği Deniz Kazaları
Regulating Navigation through the Turkish Straits: A Challenge for Modern International Environmental Law	Makale	Mitchell and Joyner, 2002	Türk Boğazları Seyir Emniyeti Yasal Düzenlemeler
Det Nortske Veritas, Report Escort Tug Effectiveness in the Bosphorus Strait	Sektör Raporu	DNV, 2013	İstanbul Boğazı'nda seyir emniyeti, Boğaz trafiğinde römorkör etkinliği Römorkör operasyonları Risk analizi
Accidental risk analyses of the Istanbul and Canakkale straits	Bildiri	Eşsiz ve Dağkıran, 2017	İstanbul Boğazı seyir emniyeti Deniz kazaları Risk analizi Mekânsal analiz
Evolution of maritime traffic management strategies from vessel traffic service (VTS) to sea traffic management (STM)	Bildiri	Yıldız vd., 2016	Seyir Emniyeti Gemi Trafik Hizmetleri Deniz Trafik Yönetimi
A Study on Ship Accidents in the Anchorage Area of the Strait of Istanbul	Bildiri	Keçeci, 2011	İstanbul Boğazı seyir emniyeti, İstanbul Boğazı demir sahaları
Stochastic Prediction of Maritime Accidents in the strait of Istanbul	Bildiri	Otay vd., 2003	İstanbul Boğazı Mekânsal Analiz Deniz Kazası Tahmin Modeli

Kanal İstanbul Çok Disiplinli Bilimsel Değerlendirme	Kitap	İBB, 2020	İstanbul Boğazı'nın gemi geçişleri açısından değerlendirilmesi İstanbul Boğazı'nın gemi hareketleri yönünden değerlendirilmesi
The Sea of Marmara Marine Biodiversity, Fisheries, Conservation and Governance	Kitap	Özsoy vd., 2016	Marmara Denizi Gemilerden kaynaklanan deniz kirliliği Deniz Kazaları ve çevresel etkileri
Türk Boğazları Seyir ve Çevre Emniyeti ve Yönetimi	Kitap	Oğuzülgen vd., 2018	Türk Boğazları ile ilgili uluslararası / ulusal yasal düzenlemeler ve gemilere verilen hizmetler Türk Boğazları'nda seyir emniyeti Türk Boğazları bölgesinde meydana gelen deniz kazaları
İstanbul Boğazı Risk Analizi ve Gemi Trafiğinin Modellenmesi	Doktora Tezi	Özlem, 2018	Matematiksel Modelleme Kolmogorov-Sminov (K-S) tests
İstanbul Boğazı'nda Otomatik Gemi Takip Sistemi Temelli Deniz Trafiği ve Gemi Çatışması Analizi ve Modellenmesi	Doktora Tezi	Altan, 2017	Matematiksel Modelleme Çatışma tipi kaza olasılığı AIS DATA SQL
İstanbul Boğazı'nda Kimyasalların Deniz Yolu İle Taşınması Sırasında Meydana Gelen Kazaların Yönetimi İçin Bir Model Geliştirilmesi	Doktora Tezi	Korçak, 2015	İstanbul Boğazı gemi trafiği Risk analizi Yapısal emniyet değerlendirilmesi (FSA) yöntemi İstanbul Boğazı'nda dökülme ihtimali olan kimyasal türlerinin hareketinin değerlendirilmesi Havada dağılım modeli ALOHA 5,4,5 Suda dağılım modeli GNOME 1,3,9 Patlama modeli ALOHA 5,4,5
İstanbul Boğazı'nda Deniz Kazaları Tahmin Modeli	Doktora Tezi	Küçükosmanoğlu, 2012	İstanbul Boğazı'nda deniz kazaları tahmini Yapay sinir ağları
İstanbul Boğazı Gemi Geçiş Trafiğinin Risk Analizi	Doktora Tezi	Özbaş, 2010	İstanbul Boğazı gemi trafiği Uğraksız geçiş yapan gemi kaynaklı risk unsurları Trafik düzeni, geçiş yapan gemi profili, yerel trafik yoğunluğu, kılavuzluk ve römorkaj hizmetlerinin değerlendirilmesi Risk değerlendirme modeli
İstanbul Boğazı'nda Deniz Trafik Güvenliğinin Risk Tabanlı Bulanık - AHP ve FMEA Yöntemleri ile İncelenmesi	Doktora Tezi	Bayar, 2010	İstanbul Boğazı Risk Analizi Fuzzy AHP FMEA

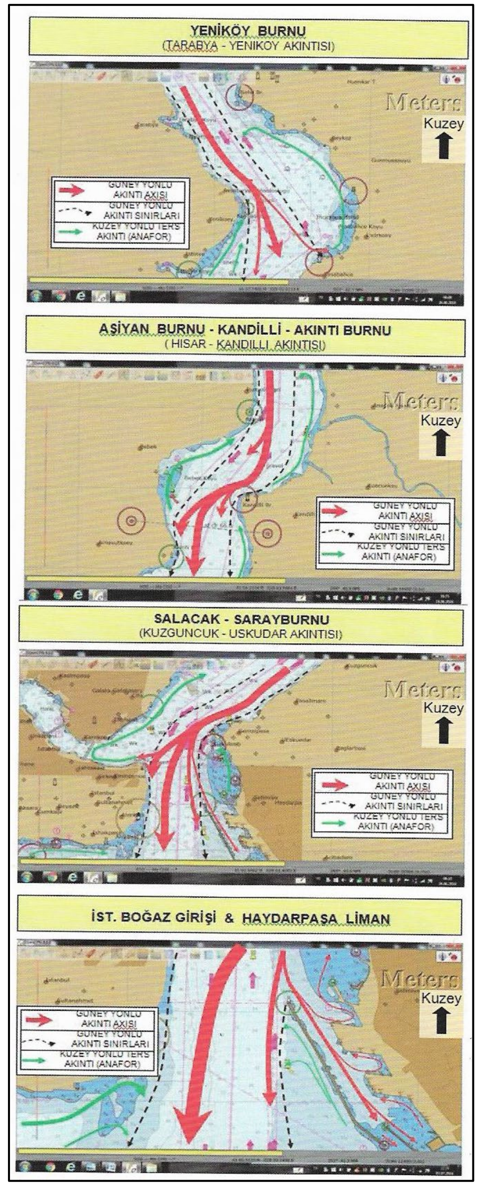
İstanbul Boğazı'nın Risk Değerlendirmesi ve Yönetimi	Doktora Tezi	Türker, 2008	Analytic Hierarchy Process Lojistik Regresyon
Türk Boğazları'nda meydana gelen gemi kazalarının konumsal analizi ve değerlendirilmesi	Yüksek Lisans Tezi	Özdemir, 2019	Mekânsal Analiz ArcGIS
Türk Boğazları'ndan Gemi Geçişleri ve Geçiş Sürelerinin Analizi	Yüksek Lisans Tezi	Taşan, 2019	Gemi geçiş süreleri açısından değerlendirme
Bulanık Analitik hiyerarşi Sürecini Kullanarak İstanbul Boğazı'nda Deniz Kazaları Risk Analizi	Yüksek Lisans Tezi	Kılıç, 2015	Analytic Hierarchy Process Fuzzy - Analytic Hierarchy Process (F-AHP)
İstanbul Boğazı'nda Q-MAX LNG Tanker Kazalarının Risk Analizi	Yüksek Lisans Tezi	Karabay, 2014	İstanbul Boğazı seyir emniyeti Tehlikeli yük taşımacılığı Risk analizi
İstanbul ve Çanakkale Boğazlarından Geçiş Yapan Gemi Sayısının Trend Analizi İle Değerlendirilmesi	Yüksek Lisans Tezi	Arslan, 2014	Çevre Gerilim (ES) Modeli
İstanbul Boğazı'nda Uğraksız Gemi Geçişi Çizelgelemesi	Yüksek Lisans Tezi	Candanoğlu, 2013	Senaryo Analizi
İstanbul Boğazı Gemi Trafiğinin Simülasyonu	Yüksek Lisans Tezi	Özlem, 2011	İstanbul Boğazı gemi trafik akışı Simülasyon modeli
İstanbul ve Çanakkale Boğaz Geçiş Sisteminin İncelenmesi	Yüksek Lisans Tezi	Türk, 2010	İstanbul Boğazı gemi trafiği Mekansal Analiz Germi Trafik Yönetim Bilgi Sistemi (GTYBS) Global Konum Belirleme Sistemleri
İstanbul Boğazı Deniz Olayları ve Kazalarının İstatistiksel İncelemesi	Yüksek Lisans Tezi	Baş, 2010	İstanbul Boğazı gemi trafiği Ki – Kare Analizi Lojistik Regresyon modeli
İstanbul Boğazı'nda Gemi Boyu Faktörünün Güvenli Seyre Etkisinin AHP Metodu Kullanılarak Analiz Edilmesi	Yüksek Lisans Tezi	Keçeci, 2010	Analytic Hierarchy Process İstanbul Boğazı deniz kazaları Gemi boyu faktörü Seyir emniyeti
İstanbul Boğazı'nda Yerel Trafiğin İncelenmesi	Yüksek Lisans Tezi	Atasoy, 2008	İstanbul Boğazı seyir emniyeti Risk analizi

İstanbul Boğazı'ndaki yüzey akıntıları, Karadeniz ile Marmara Denizi arasındaki 40 cm'lik su seviyesi farkından meydana gelmekte ve daha yüksek seviyede olan Karadeniz sularının Marmara Denizi'ne akmasıyla oluşmaktadır. Boğaz'ın orta kesimlerine kadar fazlaca görülen bu akıntılar özellikle Kandilli Burnu'ndan güneye doğru artmaktadır. Tuzluluk oranı farkından meydana gelen dip akıntıları ise kuzey – güney yönlü yüzey akıntılarının tersine güneyden kuzeye doğru hareket etmektedir. Bu durum, tatlı sularla beslenen ve Akdeniz'e göre buharlaşma oranı daha düşük olan Karadeniz sularının Marmara ve Ege denizlerinden daha az tuzlu olmasından kaynaklanmaktadır. İstanbul Boğazı'ndaki dip akıntıları, 15 m derinlikten itibaren başlayıp ve 45 m ye kadar etkili olmaktadır. Boğaz'da etkili olan bir başka akıntı türü, koy ve burunların kıvrımlarına giren suların sahil kıvrımlarını takip ederek ters yönde kıyıdan ilerlemesiyle ana akıntıya karşı oluşturduğu ters akıntılar olup, bu akıntıların hızları ana akıntının günlük şiddetine göre değişmektedir. İstanbul Boğazı'nda meydana gelen orkoz akıntısı ise bu kapsamda tanımlanabilecek son akıntı türü olup, güney rüzgârlarının Marmara sularını kuzeye yığarak, su seviyesini İstanbul Boğazı'nın güney girişinde yarım metre kadar yükseltmesi sonucunda oluşmaktadır. Orkoz akıntıları bölgedeki deniz trafiğini olumsuz etkilemekte ve çoğu zaman şehir hatları vapurlarının iptal edilmesine sebep olacak ölçekte seyir zorluğu yaratmaktadır (İstanbul Boğazı Yerel Trafik Rehberi, 2012). Kıvrımlı jeomorfolojisinin yanında, sahip olduğu zorlu akıntı sistemi, Boğaz'dan geçiş yapan gemiler için seyir emniyetini güçleştiren dinamik faktörlerin başında gelmektedir. Harita 2'de gösterilen keskin dönüşlere ek olarak, Boğaz'dan geçiş yapan bir geminin karşı karşıya olduğu akıntı yön ve şiddetleri aşağıda, Harita 5'de sunulmuştur.

Rüzgar Yönü

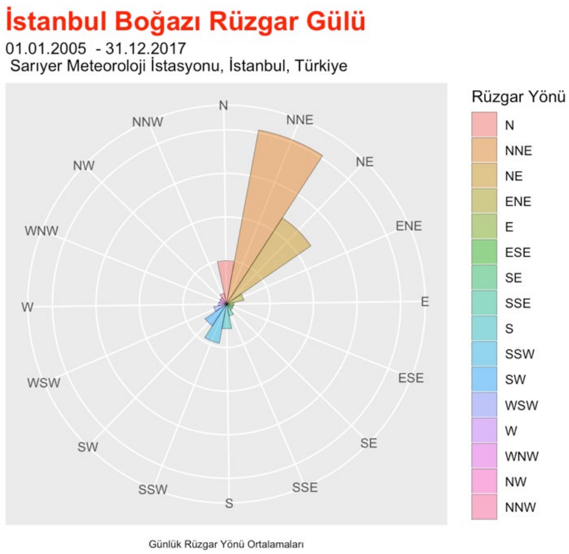
İstanbul Boğazı'nda deniz trafiğine etki eden dinamik faktörlerden bir diğeri rüzgar yönüdür. Bölgedeki rüzgar yönü profilini incelemek üzere, T.C. Meteoroloji Genel Müdürlüğü'nden temin edilen günlük rüzgar yönü verileri kullanılmıştır. İstanbul Boğazı VTS bölgelerini kapsayan ilgili veriler doğrultusunda aşağıdaki rüzgar gülü diyagramları oluşturulmuştur.

Şekil 1 ve 2, İstanbul Boğazı'nda 01.01.2005 – 31.12.2017 yılları arasında öçülen günlük rüzgar yönü ortalamalarını göstemektedir. Bu doğrultuda, her iki meteoroloji istasyonundan alınan günlük rüzgâr yönü ortalamaları, Boğaz'daki hâkim rüzgâr yönünün ezici bir çoğunlukla NNE (Kuzey Kuzey Doğu) olduğunu ortaya koymuştur. Sarıyer Meteoroloji İstasyonu verileri, ilgili alanda gözlenen diğer rüzgarların sırasıyla NE, N ve SSW olduğunu gösterirken, Atatürk Meteoroloji istasyonunda en sık görülen diğer rüzgâr yönleri sırasıyla NE, N, SW, NNW ve SSW olarak kaydedilmiştir. Oluşturulan her iki rüzgâr gülü de Boğaz'daki hâkim rüzgâr yönünün kuzeyli rüzgarlar olduğunu ortaya koymuştur. Bu durum, Harita 5'de görülen güney yönlü akıntıları güçlendirmekte ve gemilerin manevra kabiliyetini zorlaştırmaktadır.



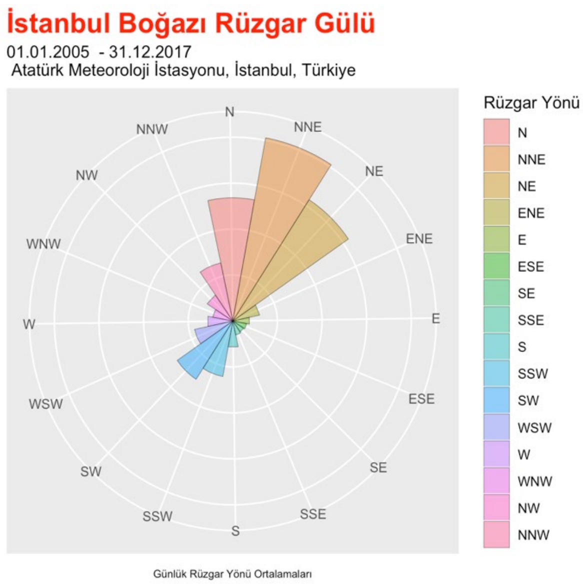
Harita 5. İstanbul Boğazı Kritik Bölgelerinde Akıntı Yönleri ve Şiddetleri (Oğuzülgen vd., 2018)

Map 5. Currents and Their Intensity in Critical Areas of the Istanbul strait (Oğuzülgen vd., 2018)



Şekil 1. İstanbul Boğazı Günlük Rüzgâr Yönü Ortalamaları- Sarıyer Meteoroloji İstasyonu

Figure 1. Istanbul Strait Daily Wind Direction Averages - Sarıyer Meteorology Station



Şekil 2. İstanbul Boğazı Günlük Rüzgâr Yönü Ortalamaları- Atatürk Meteoroloji İstasyonu

Figure 2. Istanbul Strait Daily Wind Direction Averages- Atatürk Meteorology Station

Rüzgar Hızı

İstanbul Boğazı'nda deniz trafiğini etkileyen dinamik faktörlerden rüzgar hızı, Sarıyer ve Atatürk meteoroloji istasyonlarından alınan günlük veriler dahilinde aşağıda incelenmiştir. 2005 – 2017 yılları arasındaki günlük ölçümer doğrultusunda elde edilen aylık, mevsimlik ve senelik rüzgar hızı ortalamaları aşağıda Şekil 3'de sunulmuştur.

Şekil 3, Sarıyer Meteoroloji İstasyonu kayıtlarına göre bölgedeki 12 yıllık günlük rüzgâr hızı ortalamasının genel olarak 15 m/s'nin altında kaydedildiğini göstermiştir. 01.01.2005 ile 31.12.2017 tarihleri arasında günlük rüzgâr hızı ortalaması, sadece iki defa 15 m/s'nin üzerine çıkmıştır.

Aylık ortalamalar açısından incelendiğinde rüzgâr hızı ortalamasının genel olarak 2 ile 5 m/s arasında olduğu ve 12 yıl boyunca sadece üç defa 5 m/s'yi aştığı gözlemlenmiştir. Bu aşımlar sırasıyla, 2009, 2013 ve 2016 yılı Eylül aylarında gerçekleşmiştir. 12 yıllık süreçte rüzgâr hızının mevsimsel profili incelendiğinde, aylık ortalama sonuçlarına paralel olarak, rüzgâr hızı ortalamasının tepe noktalarına sonbahar aylarında ulaştığı ve mevsimlik rüzgâr hızı ortalamalarının tepe ve dip noktaları açısından her yıl benzer eğilimlere sahip olduğu gözlenmiştir. Bölgedeki rüzgâr hızı ortalamaları yıllık bazda incelendiğinde ise, 2005 – 2010 yılları arasında rüzgâr hızı ortalamalarının 3 ile 3.2 m/s aralığında stabil seyrettiği, yıllık bazdaki en keskin yükselişin ise 2010 – 2011 yılları arasında meydana geldiği görülmüştür. 2011 yıl sonu itibariye tepe noktasına ulaşan ve 3.6 m/s'nin üzerinde kaydedilen rüzgar hızı ortalaması, 2014 yılına kadar istikrarlı bir düşüş eğilimi göstermiş ve 2014 yılı boyunca 3.0 m/s civarında yatay bir hareket sergilemiştir. 2015 yılı itibariyle yeniden artış eğilimi gösteren rüzgâr hızı ortalamasında, en sert düşüş ise 2017 yılının Ocak - Aralık ayları arasında kaydedilmiştir. Sektör Kadıköy bölgesindeki rüzgâr hızı profilini incelemek üzere referans alınan Atatürk Meteoroloji İstasyonu rüzgâr hızı verileri dahilinde günlük, aylık, mevsimlik ve senelik rüzgâr hızı ortalamaları grafikleri oluşturulmuş ve bölgedeki rüzgâr hızı profili aşağıda incelenmiştir.

Atatürk Meteoroloji İstasyonu verilerine göre, 01.01.2005 – 31.12.2017 yılları arasında ölçülen günlük rüzgâr hızı ortalamaları ezici bir çoğunlukla 12 m/s altında gerçekleşmiştir. Söz konusu dönemde günlük rüzgâr hızı ortalamasının 12 m/s üzerine sadece 4 defa çıktığı gözlemlenmiştir.

Aylık ortalamalar bazında incelendiğinde, İstanbul Boğazı'ndaki aylık rüzgâr hızı profilinin 3.0 ile 5.5 m/s arasında gerçekleştiği görülmüştür. Aylık rüzgâr hızı ortalaması 12 yıl boyunca, Ocak 2015, Ağustos 2016 ve Aralık 2016 olmak üzere üç defa 5.5 m/s üzerinde kaydedilmiştir. Mevsimlik ortalamalar, Atatürk Meteoroloji İstasyonu rüzgâr hızı ortalamalarının, Sarıyer Meteoroloji İstasyonu verilerine göre daha düzensiz bir dağılım gösterdiğini ve yıllık bazda gözle görülür mevsimsel bir oto korelasyon bulunmadığını ortaya koymuştur. Atatürk Meteoroloji İstasyonu'nda 2005 – 2017 yılları arasında mevsimsel rüzgâr hızı ortalaması genel olarak 3.5 ile 5 m/s arasında kaydedilmiştir. Yıllık rüzgâr hızı ortalamaları, Boğaz'ın Sektör Kadıköy kesitinde hâkim olan yıllık rüzgâr hızı ortalamasının genel itibariyle 3.5 ile 4.5 m/s arasında olduğunu göstermiştir. Yıllar içerisinde düzensiz bir dağılım gösteren rüzgâr hızı ortalaması, Aralık 2006'da 3.5 m/s altında gerçekleşerek en düşük seviyede kaydedilmiştir. 12 yıl içerisinde görülen en keskin artış ise 2007 yılında gerçekleşmiştir. Bu bağlamda, ocak ayında dip seviyede olan rüzgâr hızı ortalamasının, yıl boyunca istikrarlı bir artış göstererek aralık ayında 4.5 m/s sınırına dayandığı görülmüştür. 2008 Ocak ayından 2014 yılı sonuna kadar 4 ile 4.5 m/s arasında seyreden rüzgar hızı ortalaması, 2014 Aralık itibariyle yeniden artış trendi göstermiş ve 2016 yılı Aralık ayına kadar yükselmeye devam etmiştir. 12 yıl boyunca yıllık rüzgar hızı ortalaması tepe noktasına 2016 Aralık'ta ulaşmış ve 2017 yılı sonuna kadar istikrarlı bir düşüş eğilimi göstermiştir.

İstanbul Boğazı'nda Deniz Trafiğini Düzenleyen Aktörler

İstanbul Boğazı'nda trafik düzeninin planlanması, seyir emniyeti ve deniz güvenliğinin sağlanmasında yetkili otorite Türkiye Cumhuriyeti Ulaştırma ve Altyapı Bakanlığı olup; denizlerde seyir, can, mal ve çevre emniyetini sağlamaya yönelik kuralları belirlemeye ve gerekli tedbirleri almaya ilişkin görev, yetki ve sorumluluklara sahiptir. Bu amaçlar doğrultusunda, 30.12.2003 tarihinde Türk Boğazları'nda ulusal ve uluslararası düzenlemelere uygun olarak seyir, can, mal ve çevre emniyetinin artırılması için Türk Boğazları Gemi Trafik Hizmetleri (TBGTH) kurulmuştur. Bu sistemin işletilmesi, 30.09.1998 tarih ve 23479 Sayılı Resmî Gazete kararı ile kurulan Kıyı Emniyeti Genel Müdürlüğü tarafından yapılmaktadır. (Oğuzülgen vd., 2018).

30.12.2003 tarihinden bu yana hizmet veren TBGTH ile Türk Boğazlar Sistemi'nde gemilerin hareketleri anlık olarak izlenmekte ve gemi geçişleri buna göre düzenlenmektedir. Bu sistem içinde İstanbul Boğazı'nda 8 adet, Çanakkale Boğazı'nda 5 adet ve Marmara Denizi alanında 2 adet olmak üzere toplam 15 VTS Kulesi aracılığı ile hizmet verilmektedir. (Güler vd., 2018).

Bu sistemde her bir kulede "VHF, Radar, AIS ve Kamera" cihazları bulunmakta ve bu sistemler aracılığı ile toplanan veriler, İstanbul ve Çanakkale'de bulunan VTS Merkezlerine iletilmektedir. Otomatik Gemi Tanımlama Sistemi–AIS (Automatic Identification System) aracılığı ile gemilerin Elektronik Harita (Ecdis) üzerinden çevrimiçi olarak izlenmesi de mümkün olup, bu amaçla "VHF 87b ve 88b kanalları" kullanılmaktadır (Acarer vd., 2020). Denizcilik Genel Müdürlüğü koordinesinde Kıyı Emniyeti Genel Müdürlüğü tarafından işletilen TBGTH'ın Bakanlık organizasyon şemasındaki yeri Şekil 5'de gösterilmiştir.

İstanbul Gemi Trafik Hizmetleri

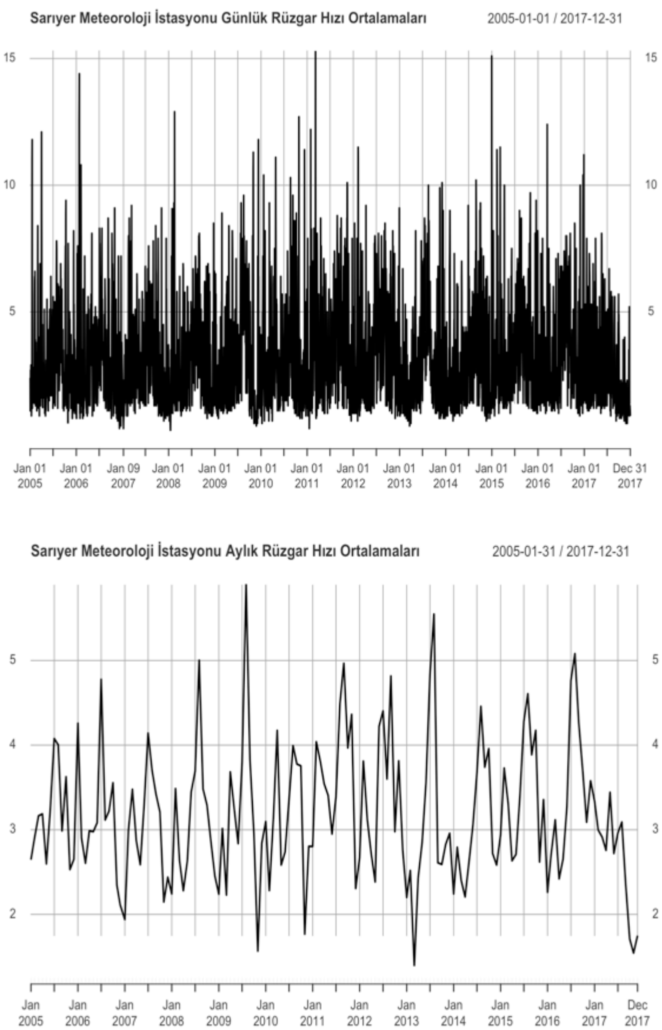
İstanbul Gemi Trafik Hizmetleri, kuzeyden güneye doğru Türkeli, Kandilli, Kadıköy ve Marmara sektörlerinden ibaret olup, bu sektörler içinde bulunan gemiler ile TBGTH operatörleri arasındaki irtibat VHF sistemi üzerinden kurulmaktadır. Bu amaçla tahsis edilen VHF çalışma kanalları Tablo 4'de gösterilmiştir. (Türk Boğazları Gemi Trafik Hizmetleri Kullanıcı Rehberi, 2018). Bölgedeki trafiğin anlık olarak izlenmesini ve yönlendirilmesini sağlayan TBGTH hizmetlerinin esasları ise Uluslararası Seyir Yardımcıları ve Fener Otoriteleri Birliği -IALA'nın (International Association Of Marine Aids To Navigation and Lighthouse Authorites) GTH ile ilgili karar ve tavsiyeleri dikkate alınarak belirlenmiş olup, IMO'nun A.857(20) ve A.827(19) no'lu kararlarına uygun olarak bilgi, seyir yardımı ve trafik organizasyon hizmetlerini kapsamaktadır (Türk Boğazları Gemi Trafik Hizmetleri Kullanıcı Rehberi, 2018). Bu sistem 30.12.2003 tarihinde hizmete başlamış olup, bu hizmetlerin detaylarına ilişkin bilgi Şekil 6'da verilmiştir.

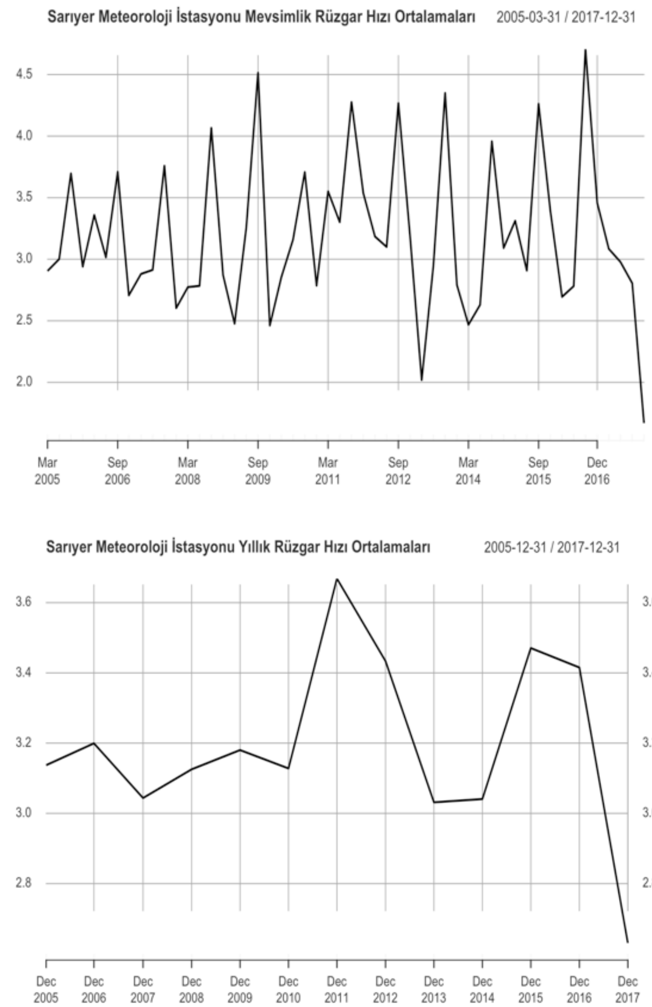
Trafik organizasyonu hizmetlerinin temel dayanağı gemiler tarafından verilen seyir planları SP 1 ve SP 2 olup, bu raporlara ilişkin detaylar Türk Boğazları Raporlama Sistemi bölümünde ele alınmıştır.

Bilgi Hizmeti: TBGTH tarafından verilen bilgi hizmeti; deniz trafiği bilgisi, mevkii bilgisi, rota ve yere göre hız bilgisi, diğer gemilerin olası hareketlerinin bilgisi, denizcilere uyarılar, meteoroloji koşulları, akıntı durumu ile seyir yardımcılarının durumu hakkında raporlanmış bilgileri içermektedir (Oğuzülgen vd., 2018).

Seyir Yardımı Hizmeti: TBGTH tarafından verilen seyir yatdımı hizmeti; trafik ayrım düzeni içinde seyir emniyetini sağlamak için gemi pozisyon bilgilerinin aktarımını, çevre gemilere ait bilgilerin aktarımını ve tehlike arzeden olası durumlar için yapılacak olan uyarıları kapsamaktadır (Oğuzülgen vd., 2018).

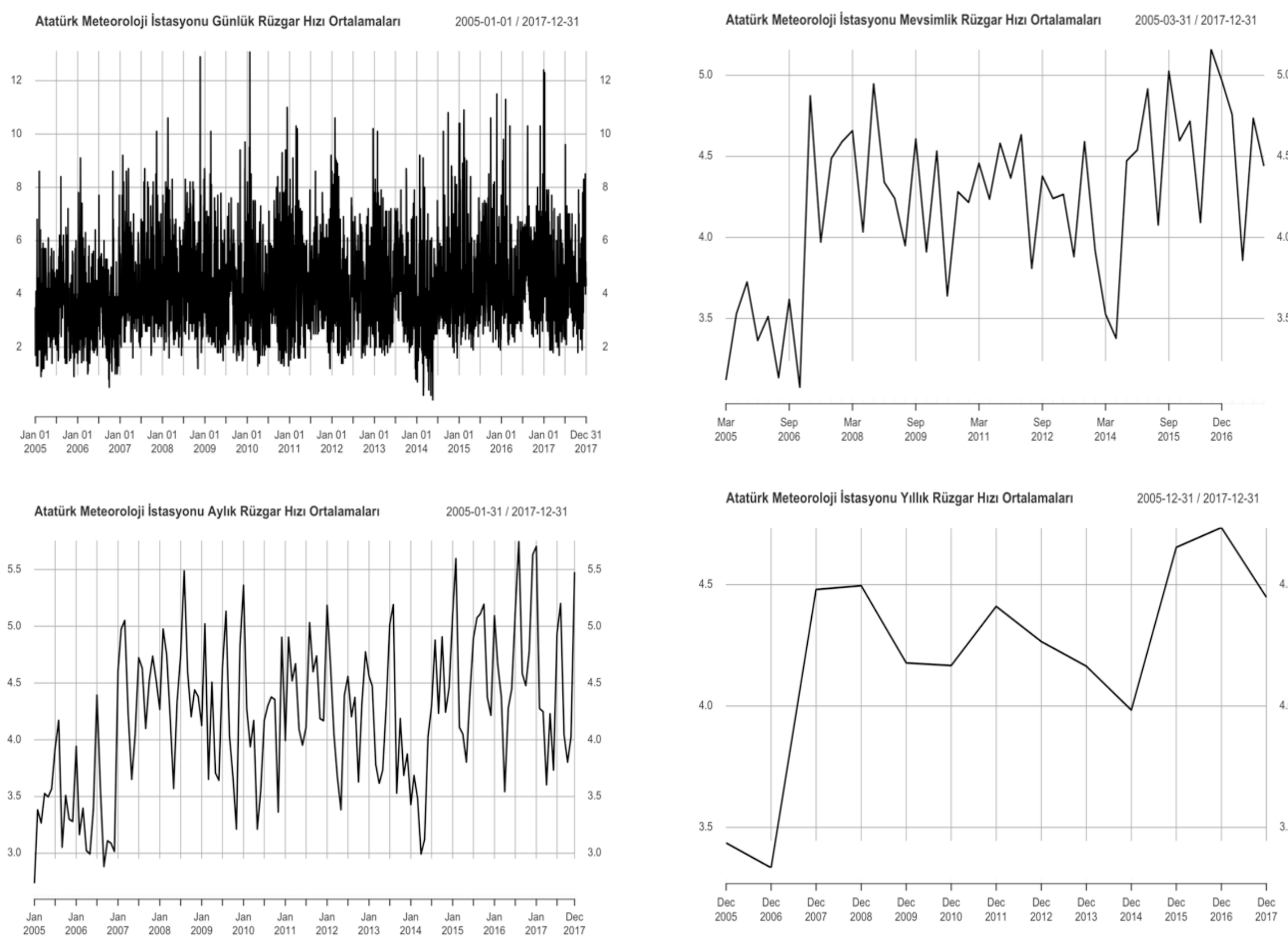
Trafik Organizasyonu Hizmeti: TBGTH tarafından verilen trafik organizasyonu hizmeti, gemilerin İstanbul ve Çanakkale Boğazlarına giriş izinleri, seyir planları ile bu planlardaki olası değişiklikleri ve Boğazlara giriş öncesinde trafik organizasyonu ile ilgili gerekli operasyonel bilgileri içermektedir (Oğuzülgen vd., 2018).





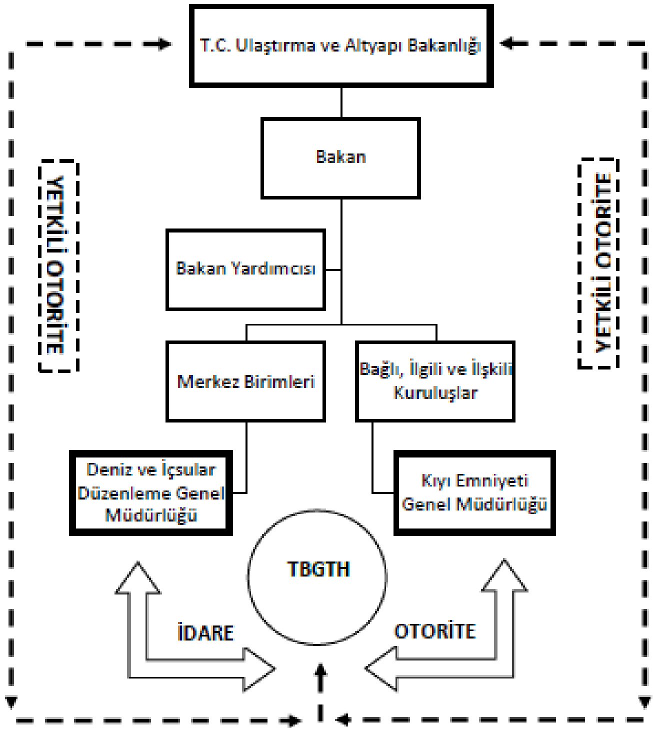
Şekil 3. İstanbul Boğazı Rüzgâr Hızı Profili (Sarıyer Meteoroloji İstasyonu)

Figure 3. Daily Wind Speed Profile in the Strait of Istanbul (Sarıyer Meteorology Station)



Şekil 4. İstanbul Boğazı Rüzgâr Hızı Profili (Atatürk Meteoroloji İstasyonu)

Figure 4. Daily Wind Speed Profile in the Strait of Istanbul (Atatürk Meteorology Station)



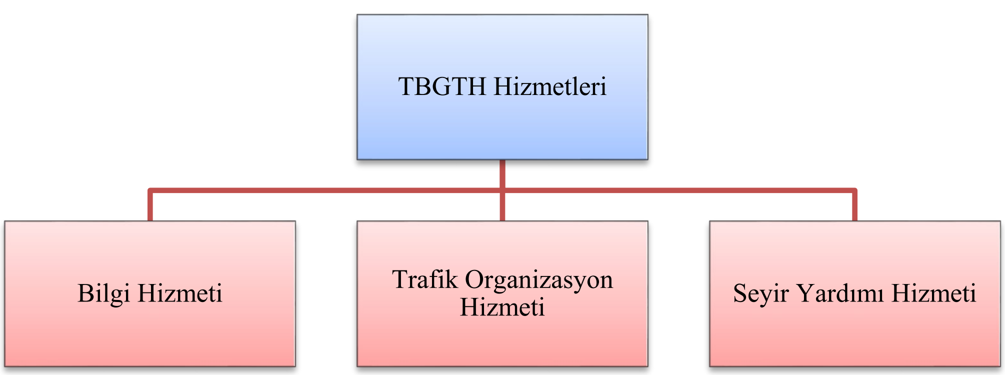
Şekil 5. Türk Boğazlar Sistemi'nde Deniz Trafiğini Düzenleyen Aktörler (Oğuzülgen vd., 2018)

Figure 5. Administrative Organization Scheme for Maritime Traffic in Turkish Straits System

Tablo 4. İstanbul Boğazı Sektörleri ve Haberleşme Kanalları (Türk Boğazları Seyir Rehberi, 2015)

Table 4. VHF Channels in the Strait of Istanbul

Sektör Adı	Çalışma Kanalı	Çağrı İşareti
TÜRKELİ	VHF Kanal 11	SEKTÖR TÜRKELİ
KANDİLLİ	VHF Kanal 12	SEKTÖR KANDİLLİ
KADIKÖY	VHF Kanal 13	SEKTÖR KADIKÖY
MARMARA	VHF Kanal 14	SEKTÖR MARMARA



Şekil 6. TBGTH Hizmetleri

Figure 6. Services provided by VTS

Türk Boğazları Raporlama Sistemi (TÜBRAP)

Türk Boğazları'ndan geçiş belirli prosedürlere tabi olup, geçiş yapacak gemilerin, ilgili IMO kural ve tavsiyeleri uyarınca İdare tarafından kurulmuş olan TÜBRAP'a katılmaları şiddetle tavsiye edilmektedir. Bu kapsamda geçiş yapacak olan gemilerin tabi olduğu prosedürler Türk Boğazları Gemi Trafik Hizmetleri Kullanıcı Rehberi'nde detaylı olarak açıklanmıştır.

1. İlgili GTHM'ye SP 1 ve SP 2 raporu gönderilmesi,
2. Eğer tabi ise Marmara Raporu (MARRAP) verilmesi,
3. İlgili GTHM'ye Çağırma Noktası Raporu vermesi,
4. TBGTH alanı içinde AIS cihazını devamlı çalışır halde bulundurması,
5. TBGTH alanı içinde demirde, driftte veya seyir halinde içinde bulunulan sektörün VHF kanalını dinlemesi,
6. Devamlı olarak ilgili GTHM yayınlarını dinleyerek ve verilen bilgi, tavsiye, uyarı ve talimatları seyir, can, mal ve çevre emniyeti açısından dikkate alması,
7. Seyir emniyeti ile ilgili sakıncalı durumları tespit ettiklerinde GTHM'ye bildirmesi ve Trafik Ayrım Düzeni dışına çıkmayı gerektiren durumlar ile Mevki Raporlarındaki (ETA) 2 saati aşan gecikmeleri ilgili GTHM'ye bildirmesi şeklinde özetlenmiştir (Türk Boğazları Gemi Trafik Hizmetleri Kullanıcı Rehberi, 2018).

Bu prosedürler doğrultusunda, Boğazlardan geçiş yapacak gemilerin düzenlenmesi ve trafik organizasyonunun sağlanmasında rol oynayan en önemli bileşenler SP1 ve SP2 raporları olup, söz konusu raporlar aşağıda sırasıyla açıklanmıştır.

SP1 Raporu: Trafik düzenlemesinin sağlanmasında çok önemli bir aktör olup, zamanında gönderilmeyen raporlar trafikte aksama, gecikme ve beklemelere yol açabilmektedir. Bu nedenle trafiğin etkin şekilde planlanması, geçiş yapacak gemilerin SP1 Raporlarını aşağıda belirtilen kriterler doğrultusunda GTHM'ye yazılı olarak bildirmesi ile sağlanmaktadır.

- Tehlikeli yük taşıyan gemiler ile 500 GT ve daha büyük gemilerin kaptan, donatan ya da acenteleri, gemi Türk Boğazları'na girmeden en az 24 saat önce, tam boyları 200–300 metre arasında ve/veya su çekimleri 15 metreden daha büyük olan gemiler ise Türk Boğazları'na girmeden en az 48 saat önce ilgili GTHM'ye yazılı olarak SP1 Raporunu vereceklerdir.
- Tam boyları 300 metre ve daha büyük olan gemilerle, nükleer güçle yürütülen, nükleer yük veya atık taşıyan gemilerin donatan, acente ya da işleticileri, seferlerin planlanması aşamasında ve 72 saatten az olmamak şartıyla ilgili GTH Otoritesine, geminin niteliği ve yükü hakkında bilgi verecekler ve geminin IMO standartları ve ilgili diğer uluslararası anlaşmalarda öngörülen kurallara uygun nitelikte olduğunu, yükün uygun şekilde taşındığını göstermek üzere bayrak devleti tarafından düzenlenen belgeleri ileteceklerdir.
- Marmara limanlarından kalkacak tehlikeli yük taşıyan gemilerle 500 GT ve daha büyük gemiler, kalkışlarından en az 6 saat önce SP1 raporunu ilgili GTHM'ye göndereceklerdir.

Bu bilgiler doğrultusunda İdare gemilerin boyutları ve manevra yeteneği de dahil olmak üzere tüm özelliklerini Türk Boğazları'nın fiziksel yapısını, mevsim şartlarını, seyir, can, mal ve çevre emniyetiyle deniz trafiğinin durumunu göz önünde bulundurarak, Türk Boğazları'ndan emniyetli geçişi sağlamak için gerekli olan şartları ilgili geminin donatanına, acentesine, işletenine ya da kaptanına bildirmesi zorunlu tutulmuştur (Türk Boğazları Seyir Rehberi, 2015).

SP2 Raporu: SP1 raporunda gemisinin teknik bakımdan uygun durumda olduğunu beyan eden gemi kaptanları ile "savaş, ticari amaçla kullanılmayan devlet ve yerel deniz trafiği kapsamındakiler" hariç olmak üzere tam boyu 20 metre ve daha büyük gemi kaptanları, İstanbul veya Çanakkale Boğazı'na girişten 2 saat önce ya da Boğaz girişine 20 deniz mili kala, (hangisi önce gerçekleşirse) belirlenmiş VHF kanalından ilgili GTHM'ye SP2 raporu verirler. Boğaz geçişi için hazır olduklarını ilgili GTHM'ye rapor eden gemiler trafik organizasyonuna alınmakta ve GTHM tarafından verilecek bilgileri göz önünde tutarak hareket etmeleri gerekmektedir (Türk Boğazları Seyir Rehberi, 2015).

Mevki Raporu: Türk Boğazları'na girecek olan tam boyu 20 metre ve daha büyük gemilerin, Boğaz girişlerine 5 deniz mili kala VHF sistemi aracılığıyla ilgili GTH sektörüne kendilerini tanıttığı rapor olup, gemi adı ve mevki bilgisini içermektedir (Türk Boğazları Seyir Rehberi, 2015).

Çağırma Noktası Raporu: Türk Boğazları'ndan geçiş yapan Aktif Katılımcı gemilerin, GTH sektör geçişlerinde VHF sistemini kullanarak verdikleri rapor olup, gemi adı ve mevki bilgisini içermektedir. Çağırma Noktası Raporunda verilen mevki geminin ayrıldığı ve dahil olduğu sektör bilgisini de içermelidir (Türk Boğazları Seyir Rehberi, 2015).

Marmara Raporu (MARRAP): Marmara Denizi'ndeki limanlar arasında seyir yapan ve TBGTH alanından geçiş yapacak aktif katılımcı gemiler; TBGTH alanına giriş yaptıkları sektör ile Sektör Marmara – Sektör Gelibolu ve Sektör Gelibolu – Sektör Marmara geçişlerinde hem çıkış hem de giriş yaptıkları sektöre VHF sistemi ile Marmara Raporu (MARRAP) vereceklerdir. Marmara Denizi'nde bir limandan kalkıp Boğaz geçecek gemiler; geçiş yapacakları Boğazı kapsayan GTH Alanından önce diğer GTH Alanına girerlerse, giriş yaptıkları sektöre VHF ile MARRAP vereceklerdir. MARRAP Raporu; Gemi adı, mevkisi, kalkış ve varış limanı bilgisi ile tehlikeli yük durumunu içermektedir (Türk Boğazları Seyir Rehberi, 2015).

2001 – 2015 yılları Arasında İstanbul Boğazı'nda Deniz Trafiğini Düzenleyen Uygulamaların Kronolojisi

1. **Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı (04.09.2002):** 6 kasım 1998'de uygulamaya giren Türk Boğazları Deniz Trafik Düzeni Tüzüğü'nün ana maddelerine ilişkin hükümlerin uygulanması ile ilgili detaylı maddeler barındıran ilk uygulama talimatı 4 Eylül 2002 tarihinde yürürlüğe girmiştir (Oğuzülgen vd, 2018).
2. **Türk Boğazları'nda Karaya Oturma, Arıza ve Diğer Arıza Durumlarında Gemilere Uygulanacak Kurallara İlişkin Uygulama Talimatı (11 Ekim 2004):** Türk Boğazları Deniz Trafik Düzeni Tüzüğü'ne ilişkin gerçekleştirilen ikinci uygulama talimatı karaya oturma, arıza ve diğer kaza durumlarında gemilere uygulanacak kuralları içermekte olup, 11 Ekim 2004 tarihinde yürürlüğe girmiştir. (Oğuzülgen vd., 2018).
3. **Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı (26.12.2006 - 15.11.2011 - 16.10.2012):** Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı ve Türk Boğazları'nda Karaya Oturma, Arıza ve Diğer Arıza Durumlarında Gemilere Uygulanacak Kurallara İlişkin Uygulama Talimatı birleştirilerek tek bir uygulama haline getirilmiş ve 26.12.2006'da Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı olarak revize edilmiştir. Bu düzenlemeyi takiben 15.11.2011'de uygulama talimatında bazı değişiklikler yapılmıştır. Özellikle SP1 raporunda önemli değişiklikler içeren uygulama talimatı 16.10.2012 tarihinde yürürlüğe konmuştur (Oğuzülgen vd., 2018).
4. **İstanbul Liman Yönetmeliği (20.09.2011):** 20.09.2011 tarihinde Resmi Gazete'de yayınlanan 28050 sayılı karar ile İstanbul Liman Yönetmeliği'nde Türk Boğazları ile alakalı düzenlemeler yapılmıştır. Bu kapsamda, demirleme sahaları belirlenmiş, Liman Başkanlığı talimatlarına uyma zorunluluğu getirilmiştir (Oğuzülgen vd., 2018).
5. **Limanlar Yönetmeliği (31.10.2012):** 2012 yılında Resmi Gazate'de yayınlanan 28453 sayılı karar doğrultusunda Liman idari sahasına giren gemilerin veya deniz araçlarının seyir, demirleme veya kıyı tesislerine yanaşma, bağlama veya ayrılmalarında uygulanacak kurallar düzenlenmiştir. Buna ek olarak yük/yolcu tahmil ve tahliye yöntemleri, yer ve zamanları, gemi ve deniz araçlarının bildirimleri, kılavuzculuk ve romorkörcülük ile ilgili gereklilikler, idari sahadaki seyir, can, mal ve çevre emniyeti ile deniz güvenliğinin sağlanmasına ilişkin gereklilikleri ilgili karar doğrultusunda düzenlenmiştir. (Oğuzülgen vd., 2018).

İstanbul Boğazı'ndan Geçiş Yapan Gemi Sayısının Kaza Sayısı Üzerindeki Etkisi

Uluslararası deniz trafiğinin, deniz kazalarına olan etkisini incelemek üzere İstanbul Boğazı'nda 2001 – 2015 yılları arasında meydana gelen deniz kazaları, aynı dönemde yürürlüğe giren düzenlemeler ile paralel olarak incelenmiş, yapılan düzenlemelerin kazaları önleme konusundaki etkinliği araştırılmış ve gemi başına kaza oranı hesaplanmıştır. Bu amaçla söz konusu döneme ilişkin kaza sayısı ile gemi sayısı karşılaştırmalı tablosu (Tablo 5) dikkate alınarak "Geçiş Yapan Gemi Sayısı, Kaza Sayısı ve Gemi Başına Kaza" grafikleri ayrı ayrı çizilmiştir. Bu şekilde söz konusu döneme ilişkin 15 yıllık periyotta geçiş yapan gemi sayısının, deniz kazaları üzerindeki etkisini görmek üzere lineer regresyon modeli oluşturulmuştur.

Zamansal Değişim

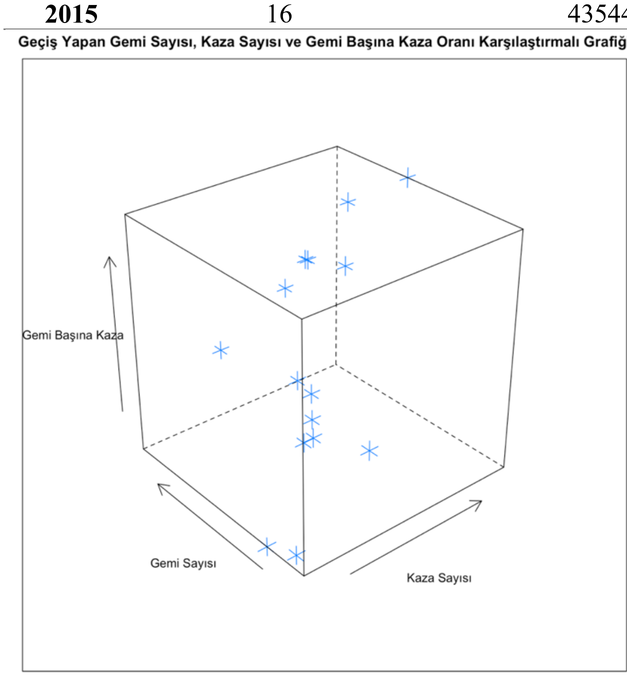
İstanbul Boğazı'ndaki deniz kazaları, 2001 – 2015 yılları arasındaki 15 yıllık süreç içerisinde bölgeden geçiş yapan gemi sayısı, aynı dönemde gerçekleşen kaza sayısı ile eş zamanlı olarak incelenmiş ve geçiş yapan gemi başına kaza oranı hesaplanmıştır. Kıyı Emniyeti Genel Müdürlüğü verileri referans alınarak yapılan bu hesaplamanın amacı bölgede geçiş yapan gemi başına kaza oranını ortaya koymak ve bu oranın zamana bağlı değişimini gözlemlemektir. Elde edilen bulgular Tablo 5'de sunulmuş, Şekil 7 ve Grafik 1'de görselleştirilmiştir.

15 yıllık dönemde, İstanbul Boğazı'nda gemi başına kaza oranının, geçiş yapan gemi sayısı ve bölgede meydana gelen kaza sayısı ile doğru orantılı olarak hareket ettiği Şekil 7'de gözlemlenmiştir.

Tablo 5. 2001 – 2015 Kaza Sayısı & Gemi Sayısı Karşılaştırmalı Tablosu (AAKKM, 2020)

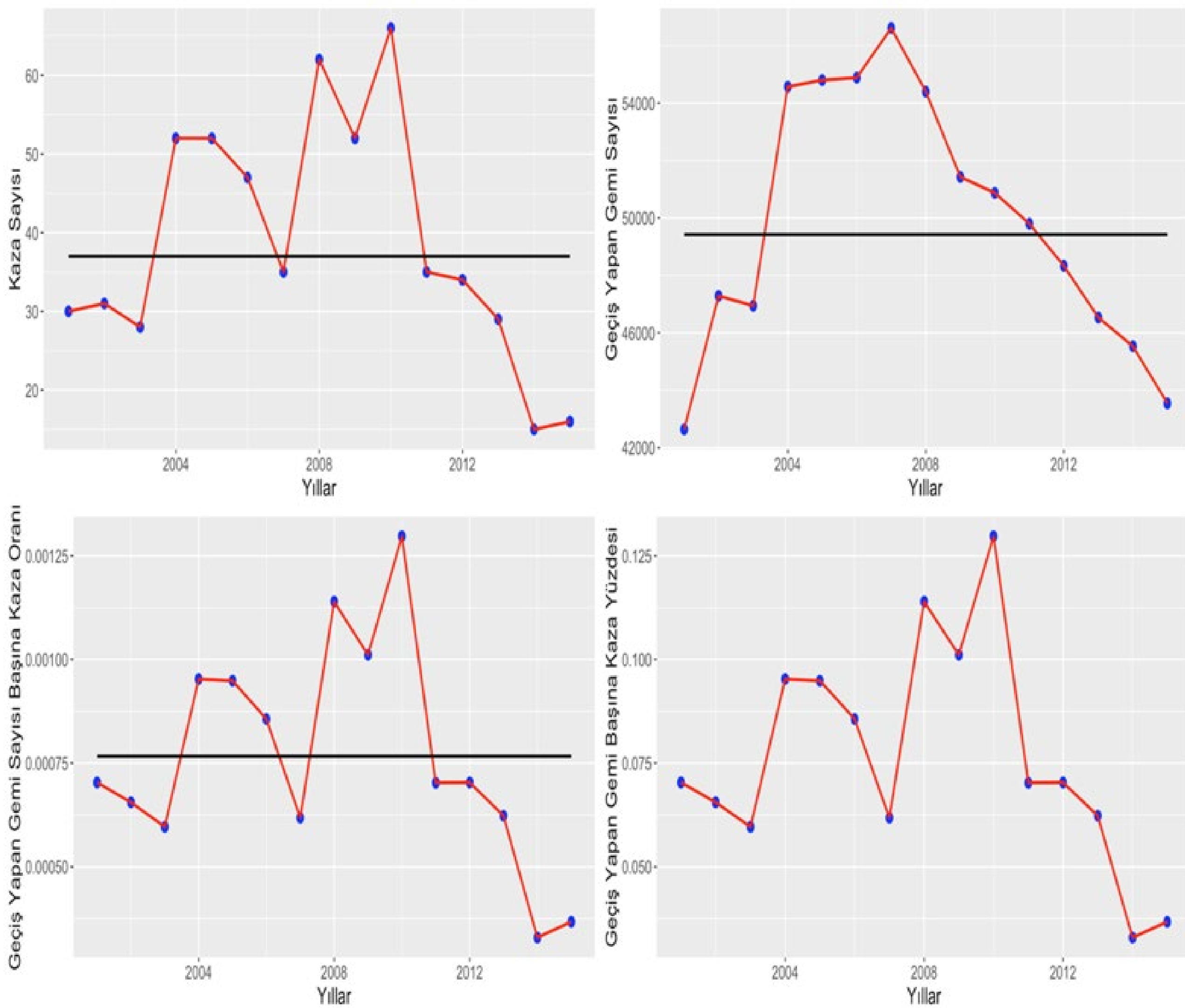
Tablo 5. Comparative Table of the Number of Accident and the Number of Passing Ship (2001 - 2015) (AAKKM, 2020)

Yıllar	Kaza Sayısı	Geçiş Yapan Gemi Sayısı	Gemi Başına Kaza Oranı
2001	30	42637	0,000703614
2002	31	47283	0,000655627
2003	28	46939	0,000596519
2004	52	54564	0,000953009
2005	52	54794	0,000949009
2006	47	54880	0,000856414
2007	35	56606	0,000618309
2008	62	54396	0,00113979
2009	52	51422	0,00101124
2010	66	50871	0,001297399
2011	35	49798	0,000702839
2012	34	48329	0,000703511
2013	29	46532	0,000623227
2014	15	45529	0,00032946
2015	16	43544	0,000367444



Şekil 7. İstanbul Boğazı'ndan Geçiş Yapan Gemi Sayısı, Kaza Sayısı ve Geçiş Yapan Gemi Başına Kaza Oranı

Figure 7. Rate of Accidents per Passing Ship in the Strait of Istanbul



Grafik 1. 2001 – 2015 Yılları Arasında Kaza Sayısı, Gemi Sayısı ve Geçiş Yapan Gemi Sayısı Başına Kaza Oranına İlişkin Zaman Serisi Grafikleri

Grafik 1. Temporal change of maritime accidents in the Strait of Istanbul between 2001 and 2015

Grafik 1, İstanbul Boğazı'ndan geçiş yapan gemi sayısının 2007 yılına kadar artış gösterdiğini ve 2007 yılında 56.606 gemi ile tepe noktasına ulaştığını göstermektedir. 2007 yılı itibariyle kaza sayısında istikrarlı bir düşüş eğilimi gözlenmektedir. Değişkenlere ait 15 yıllık ortalamalar siyah çizgi ile ifade edilmiştir. Bu çerçevede 15 yıl boyunca İstanbul Boğazı'ndan geçiş yapan gemi sayısının ortalama 49.417 olduğu, 2011 yılına kadar geçiş yapan gemi sayısının bu ortalamanın üzerinde olduğu, 2011 yılı sonrasında ise 15 yıllık ortalamanın altında seyrettiği gözlemlenmiştir. Bölgedeki kaza sayısı ise yıllar içerisinde dalgalı bir dağılım göstemekle birlikte 2010 yılında maksimum değerine ulaşmıştır. Kaza sayısındaki en sert düşüş 2010 ile 2011 yılları arasında tespit edilmiş olup, 2010 yılı sonrasında düzenli bir düşüş eğilimi gözlemlenmiştir. Geçiş yapan gemi sayısı ile benzer olarak bölgedeki kaza sayısı da 2011 yılı sonrasında 15 yıllık kaza ortalaması olan 37 kazanın altında gerçekleşmiştir. Gemi başına kaza oranı ise bölgeden geçiş yapan gemi sayısı ile meydana gelen kaza sayısının standardize edilmesi sonucu elde edilmiştir. Bu kapsamda her yıl için kaza sayısı bölgeden geçiş yapan gemi sayısına bölünmüştür. Sol alt grafikte görülmekte olan gemi başına kaza oranının 2010 yılında maksimum değerine ulaştığı ve takip eden yıllarda istikrarlı bir düşüş eğilimi sergilediği gözlemlenmiştir. 15 yıl boyunca bölgeden geçiş yapan gemi sayısı başına kaza oranı ortalaması 0.00076 olarak hesaplanmıştır. Bir başka deyişle, 15 yıllık periyodu bir bütün olarak incelendiğinde geçiş yapan her 10.000 gemiden ortalama 76 tanesinin kaza yaptığı gözlemlenmiştir. 2011 yılı ve sonrasında geçiş yapan gemi başına kaza oranı 15 yıllık ortalamanın altında gözlemlenmiştir. Grafik 1'deki sağ alt grafik ise geçiş yapan gemi sayısı başına kaza yüzdesini ifade etmektedir.

Geçiş Yapan Gemi Sayısı & Kaza Sayısı İlişkisi

Regresyon analizi, bir bağımlı değişken ile bir ya da daha fazla bağımsız değişken arasındaki ilişkiyi incelemek için kullanılan istatistiksel bir analiz yöntemidir (Akgüngör ve Doğan, 2010). Doğrusal regresyon ise tahmin yapmak için verileri analiz etmeye yönelik bir modelleme tekniğidir. Bu noktada açıklayıcı değişkene (x) dayanarak yanıt değişkenini (y) tahmin etmek için iki değişkenli bir model oluşturulmaktadır. Bağımlı ve bağımsız değişken arasındaki ilişkiye yönelik elde edilen nokta dağılım grafiği üzerine fit edilen doğrunun denklemi ise tahmin yapmak için kullanılmaktadır (Tranmer vd., 2020). Bu bağlamda lineer regresyon modeli doğrusuna ait denklem, aşağıdaki şekilde tanımlanmaktadır.

$$y_i = \beta_0 + \beta_{1xi} + e_i$$

Burada intercept olarak adlandırılan $\beta_{0,}$ doğrunun y eksenini kestiği yeri ifade etmektedir. Doğrunun eğimi olan $\beta_{1,}$ x'deki 1 birimlik değişim için y'de meydana gelen değişimi ifade etmektedir. Hata terimi olarak adlandırılan e_i ise tahmin edilen değerin gerçek değerden olan uzaklığını ifade etmektedir. Analizin en kritik noktası olan karar aşaması ise olasılık değeri olan ve istatistiksel anlamlılığın varlığını ve var ise tespit edilen ilişki düzeyinin belirlenmesinde kullanılan p – değeri kapsamında gerçekleşmektedir (Kul, 2014: 12). P – değerinin yorumlanmasında izlenecek kriterler aşağıda Tablo 6'da sunulmuştur.

Tablo 6. P değerinin yorumlanması (Kul, 2014)

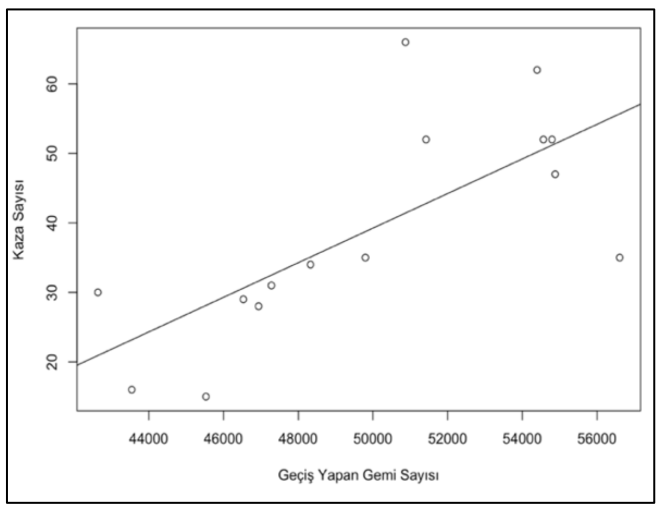
Table 6. Interpretation of the p value

P - Değeri	Yorumu
0.01<=p<0.05	İstatistiksel olarak anlamlılık
0.001<=p<0.01	Yüksek düzeyde istatistiksel anlamlılık
p<0.001	Çok yüksek düzeyde istatistiksel anlamlılık
0.05<=p<0.10	Sınır düzeyde istatistiksel anlamlılık
p>0.10	İstatistiksel olarak anlamlı değil

Çalışma kapsamında geçiş yapan gemi sayısının, kaza sayısı üzerindeki etkisini tahmin edebilmek için lineer regresyon modeli kurulmuş olup, analiz dahilinde anlamlılık düzeyi 0.05 olarak kabul edilmiştir. Oluşturulan lineer regresyon modeline ilişkin elde edilen sonuçlar Şekil 8'de sunulmuştur.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -85.217926  33.339720  -2.556  0.02392 *
Ships         0.002489   0.000666   3.738  0.00248 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 11.16 on 13 degrees of freedom
Multiple R-squared:  0.518,    Adjusted R-squared:  0.4809
F-statistic: 13.97 on 1 and 13 DF,  p-value: 0.002485
```

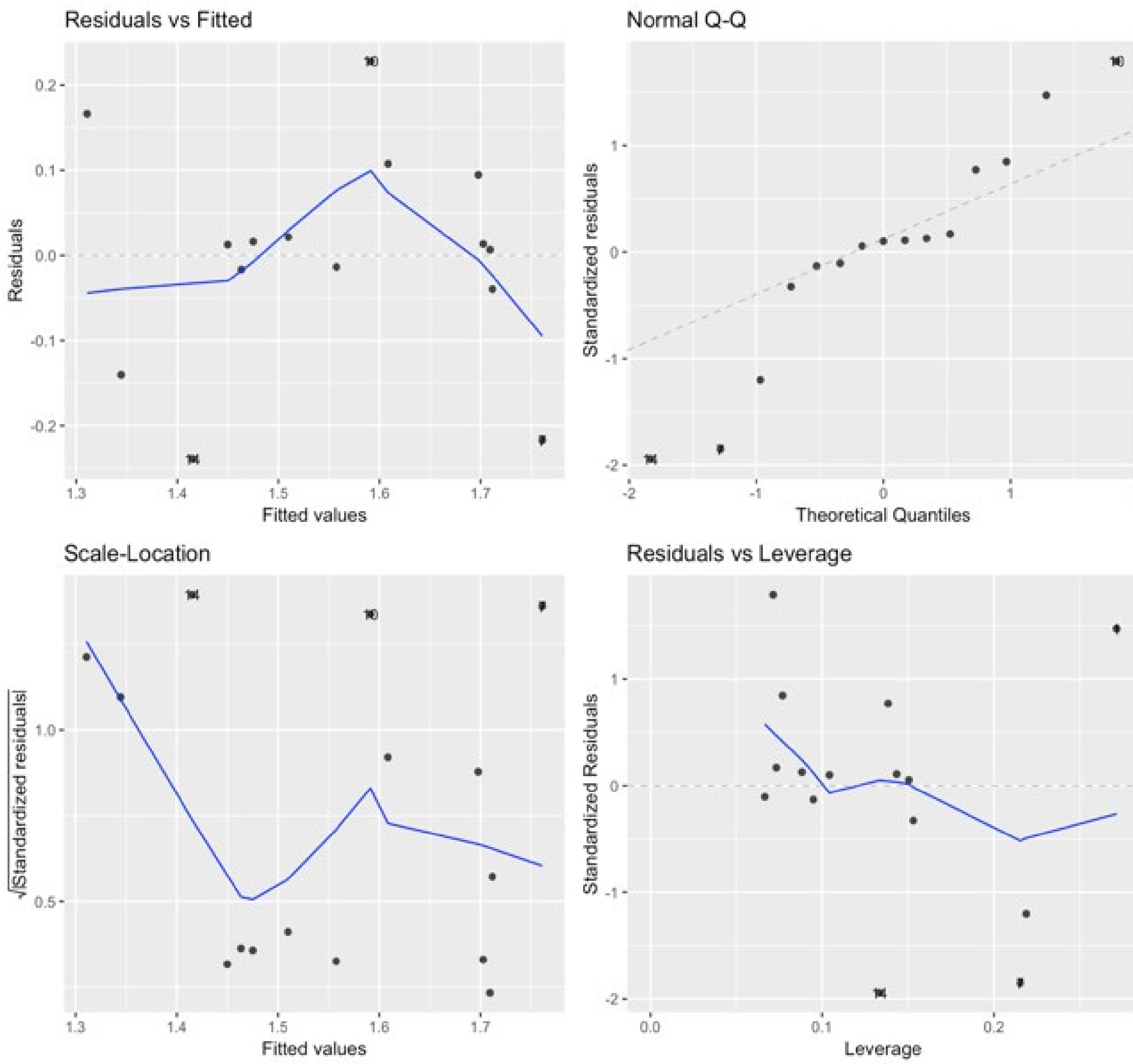


Şekil 8. İstanbul Boğazı'ndan geçiş yapan gemi sayısının kaza sayısına etkisi lineer regresyon modeli sonuçları

Figure 8. Results of the linear regression model

Kurulan doğrusal regresyon modeli sonucunda hem "overall p-value" değeri hem de "individual p – value" değerleri anlamlılık düzeyi olan 0.05'den küçük olarak hesaplanmıştır. Böylelikle İstanbul Boğazı'ndan geçiş yapan gemi sayısının kaza sayısı üzerinde istatistiksel açıdan anlamlı bir etkisi bulunduğu ve uluslararası gemi trafiğinin kazalar üzerinde açıklayıcı gücü olduğu sonucuna ulaşılmıştır.

Regresyon modeline ilişkin çizdirilen tanımlayıcı grafiklerde, "Residuals vs Fitted grafikleri" verilmiştir. Bu grafiklerde hata terimlerinin "-0.2 ile + 0.2" arasında random olarak değiştiği görülmüş, ikinci grafikte veri dağılımının teorik normal dağılım hattına oldukça yakın olduğu gözlemlenmiş ve regresyon modelinin varsayımlarının karşılandığı saptanmıştır.



Grafik 2. Tanımlayıcı Grafikler

Grafik 2. Diagnostic Plots

Buna göre multiple R square sonucunun anlamlı olduğu, geçiş yapan gemi sayısının İstanbul Boğazı'ndaki kaza sayısını "%51oranında" açıkladığı sonucuna varılmıştır. Bu doğrultuda kurulan regresyon modelinin formülü;

"Kaza Sayısı = -85.21 + 0.002 x Geçiş Yapan Gemi Sayısı" olarak elde edilmiştir.

Oluşturulan lineer regresyon modeli sonucunda İstanbul Boğazı'ndan geçiş yapan gemi sayısının kaza sayısı üzerinde istatistiksel açıdan anlamlı bir etkisinin bulunduğu, bir başka deyişle uluslararası gemi trafiğinin bölgedeki kazalar üzerinde büyük ölçüde açıklayıcı gücü olduğu tespit edilmiştir.

Elde edilen bulgular, kazaları önlemede etkili olan düzenlemelerin profilini çıkararak yeni tedbirlerin geliştirilmesine referans olacağı düşünülmüştür. Şimdiye kadar yapılan çalışmalarda geçiş yapan gemi sayısı ile kaza sayısı arasında bir korelasyon olduğu belirtilmiştir. Bu çalışmada ise sözkonusu ilişkiye yönelik katsayılar lineer regresyon modeli dahilinde hesaplanmıştır. Böylelikle trafik hacmindeki artışın bölgedeki kazalar üzerindeki açıklayıcı gücü sayısal olarak belirlenmiştir. Elde edilen sonuçların, gelecek yıllarda geçiş yapan gemi sayısına bağlı olarak seyir emniyetini arttırmaya yönelik yapılacak yeni düzenlemelerin gerçekleştirilmesi için istatistiksel açıdan anlamlı bir kriter olarak değerlendirilmesi hedeflenmiştir.

Sonuç

Bu çalışma kapsamında, Dünya'nın en işlek ikinci su yolu olan İstanbul Boğazı'ndaki deniz kazaları, geçiş yapan gemi sayısı ve deniz trafiği ile ilgili yapılan düzenlemeler doğrultusunda incelenmiştir. Bu amaçla Türk Boğazları Gemi Trafik Hizmetleri' nin (TBGTH) bir parçası olarak İstanbul Boğazı'na kurulan sistemin hizmete açıldığı 2003 yılı sonrası deniz kaza istatistikleri dikkate alınmıştır. Böylelikle, bölgeye yönelik yapılan düzenlemelerin deniz kazaları üzerindeki etkileri belirlenmiş ve uygulamaların seyir emniyeti üzerindeki etkisi değerlendirilmiştir.

Bu amaçla kaza sayısı ile geçiş yapan gemi sayısı lineer regresyon modeli çerçevesinde karşılaştırılmıştır. Elde edilen bulgular, veri dağılımının teorik normal dağılım hattına oldukça yakın olduğunu göstermiş ve kurulan lineer regresyon modelinin, model varsayımları ile büyük ölçüde uyuştuğu tespit edilmiştir.

Oluşturulan lineer regresyon modeli sonucunda İstanbul Boğazı'ndan geçiş yapan gemi sayısının kaza sayısı üzerinde istatistiksel açıdan anlamlı bir etkisinin bulunduğu, kurulan lineer regresyon modeli doğrultusunda intercept değerinin 0.02392, individual p – value değerinin 0.00248 ve overall p – value değerinin 0.002485 olarak hesaplandığı ve elde edilen multiple R-Square doğrultusunda, geçiş yapan gemi sayısının kazalar üzerinde % 51 oranında açıklayıcı gücü olduğu tespit edilmiştir. Günümüzde küresel ticaretin %90'ının deniz yoluyla gerçekleştirildiği ve Birleşmiş Milletler Ticaret ve Kalkınma Konferansı Raporu'na göre dünya deniz ticaretinde 2018 ile 2023 yılları arasında yıllık yüzde 3,8'lik bir oranla büyüme beklendiği düşünülürse; artan deniz ticaretinin doğal sonucu olarak, uluslararası deniz trafiğinin de artış göstereceği aşikardır. Çalışma kapsamında elde edilen bulgular; geçiş yapan gemi sayısının deniz kazaları üzerindeki etkisini ortaya koymuş ve 2023'e kadar öngörülen bu büyümenin İstanbul Boğazı için kaza riskini arttıracağını göstermiştir.

Bu doğrultuda, çalışma yapılan dönem olan 2001 – 2015 yılları arasında bölgedeki deniz trafiğini düzenleyen uygulamalar araştırılmış ve bu uygulamalar sırasıyla;

- Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı (04.09.2002)
- Türk Boğazları'nda Karaya Oturma, Arıza ve Diğer Arıza Durumlarında Gemilere Uygulanacak Kurallara İlişkin Uygulama Talimatı (11 Ekim 2004)
- Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı (26.12.2006 – 15.11.2011 – 16.10.2012) İstanbul Liman Yönetmeliği (20.09.2011)
- Limanlar Yönetmeliği (31.10.2012) olarak belirlenmiştir.

İstanbul Boğazı'nda gerçekleşen kaza sayısı, bölgedeki deniz tarfiğini düzenleyen uygulamalar perspektifinde incelendiğinde ise; yapılan düzenlemelerin kazaları önlemede büyük ölçüde başarılı olduğu ve özellikle 2010 yılı sonrasında kaza sayılarında istikrarlı bir düşüş tespit edilmiştir.

2002 yılında yürürlüğe giren "Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı" ile kaza sayısında 2002 ile 2003 yılları arasında düşüş gözlenmiştir. Buna karşılık 15 yıllık periyotta kazalardaki ilk gözle görülür artış 2003 ile 2004 yılları arasında görülmüş ve 2004 yılında gerçekleşen kaza sayısı 54 olarak kaydedilmiştir.

Bu doğrultuda 11 Ekim 2004 tarihinde Türk Boğazları'nda Karaya Oturma, Arıza ve Diğer Arıza Durumlarında Gemilere Uygulanacak Kurallara İlişkin Uygulama Talimatı yürürlüğe girmiş ve 2004 – 2007 yılları arasında kaza sayısında gözle görülür bir azalma kaydedilmiştir. 2007 yılında ise kaza sayısı 15 yılın kaza ortalamasının altına düşmüştür. Bununla birlikte kaza sayısındaki ikinci artışın 2007 ile 2008 yıllarında gerçekleştiği ve 2010 yılına kadar genel artış eğilimi gösterdiği tespit edilmiştir.

2010 yılında gerçekleşen kaza sayısı 66 olup, bu sayı 15 yıl boyunca bölgede gerçekleşen en yüksek kaza sayısıdır. 20.09.2011 tarihinde yürürlüğe giren "İstanbul Liman Yönetmeliği" ve 15.11.2011 tarihinde revize edilen "Türk Boğazları Deniz Trafik Düzeni Tüzüğü Uygulama Talimatı" düzenlemeleri gerçekleştirilmiştir. Yapılan bu iki düzenlemenin kaza oranına etkisi, kaza grafiğinde çarpıcı bir etki olarak görülmüş ve 2011 yılı itibariyle kaza sayısında keskin bir düşüş yaşanmıştır.

2011 itibariyle kaza sayısı, 15 yıllık kaza ortalamasının altına düşmüş ve takip eden yıllarda da azalmaya devam etmiştir. 2012 yılında "Limanlar Yönetmeliği" kapsamında yapılan düzenlemelerin de devreye girmesiyle kaza sayısında yeniden keskin bir düşüş yaşanmış ve yıllık kaza sayısı 30'un altına inmiştir. Grafik 1'de elde edilen sonuçlar, özellikle VTS hizmetleri sonrasında yürürlüğe konulan uygulamaların, İstanbul Boğazı'nda gerçekleşen kaza sayısında gözle görülür bir düşüş sağladığını göstermiştir.

Şimdiye kadar yapılan çalışmalarda geçiş yapan gemi sayısı ile kaza sayısı arasında bir korelasyon olduğu bilgisine genel bir ifade olarak yer verilmiş ancak bu korelasyonun sayısal değerine odaklanılmamıştır. Bu çalışmada ise söz konusu ilişkiye yönelik katsayılar, lineer regresyon modeli dahilinde hesaplanmıştır. Böylelikle trafik hacmindeki artışın bölgedeki kazalar üzerindeki açıklayıcı gücü sayısal olarak belirlenmiştir. Bu oran, gelecek yıllarda geçiş yapan gemi sayısına bağlı olarak yeni düzenlemelerin gerçekleştirilmesi için istatistiksel açıdan anlamlı referans bir kriter olarak kullanılabilecektir.

Etik Standart ile Uyumluluk

Çıkar çatışması: Yazarlar herhangi bir çıkar çatışmasının olmadığını beyan eder.

Etik kurul izni: Bu çalışma için etik kurul iznine gerek yoktur.
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Teşekkür: -

Açıklama: -

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Short Communication

First report of *Alvania scuderii* Villari, 2017 (Gastropoda: Mollusca) from Tyrrhenian Sea: Some biogeographic implications

Walter RENDA[1], Salvatore GIACOBBE[2]

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[1] Via Bologna 18/A, 87032 Amantea (CS), Italy
[2] Messina University, Department ChiBioFarAm, Viale Stagno D'Alcontres, 98166 Messina, Italy

ORCID IDs of the author(s):
W.R. 0000-0003-3944-6758
S. G. 0000-0002-4619-4862

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Correspondence:
Walter RENDA
E-mail: w.renda1@tin.it

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ABSTRACT

The cryptic gastropod *Alvania scuderii* Villari, 2017, recently described from the Strait of Messina as new species inside the *A. scabra* (Philippi, 1844) group, was known by restricted areas of eastern and southern Sicily. Some records from the type locality and south-eastern Tyrrhenian sea, which provided new data on habitat and bathymetric range, also enlarged northward, in a further basin, the known areal. Such areal, that overlaps a Mediterranean western-eastern biogeographic boundary, may be considered a further clue of an hydrological front that is responsible of a West-Mediterranean footprint more marked than in nearby North-westernmost areas.

Keywords: Motile fauna, Hard bottom, Rissoidae, Alvania, Biogeography, Mediterranean sea

Introduction

The recently described *Alvania scuderii* Villari, 2017, is a cryptic gastropod species belonging to the taxonomically problematic *A. scabra* (Philippi, 1844) group (Villari, 2017; Villari & Scuderi, 2017). The new species, described on specimens from the Strait of Messina was initially related to "a peculiar sciaphilous environment of the Eastern Sicilian coasts", before other living specimens from S. Giovanni Li Cuti, near Catania, expanded the known habitat about 100 km to the south (Amati et al., 2020). Shells from Scilla testified the occurrence of *A. scabra* in the other side of the Messina Strait, whilst dead specimens from some localities of Linosa Island (Amati et al., 2020; Scaperotta et al., 2019) indicated a wider distribution which included the Strait of Sicily.

The present report of living specimens both from type locality and southern Tyrrhenian Sea, further expanding the known areal of this poorly known species, suggests some considerations about the western-eastern Mediterranean boundary line.

Material and Methods

Samples of motile macrofauna have been collected from the Strait of Messina and nearby localities of southern Tyrrhenian sea, in the framework of different research programs (MeBE; NIRS) Two sampling techniques have been employed, according to the main purposes of each investigation. In particular, qualitative samples have been collected by brushing of vegetated hard substrata, 1-4 m depth, while quantitative sampling have been carried out by scraping of 20x20 cm hard bottom surface at 3-6 m, 12-16 m and 24-32 m depth. Samples have been washed on a 0.5 mm mesh sieve and the retained rapidly fixed in 70% ethanol. Mollusc fauna was sorted under stereomicroscope and specimens determined at the species level, as far as possible. Most species were photographed under stereomicroscope.

ACRONYMS

BEL: Benthic Ecology Laboratory, Messina University, Italy.

CWR: Collection Walter Renda, Amantea, Cosenza, Italy

MeBE: The Strait of Messina Benthic Ecosystem Project

NIRS: Ecology and Spatial Dynamics of Marine Not Indigenous and Rare Species Project

Results and Discussion

Samplings carried out in the type locality, Cape Peloro, altogether provided 32 *A. scuderii* living specimens, all collected from the sheltered side of breakwater artificial reefs, 1-4 m depth, located at 38°15'43"N - 15°38'20"E (two specimens, repository code: BEL147Faro2019As1-5), and 38°15'35"N - 15°37'44"E, 200 m northward (22 specimens, repository codes: BEL147Gran2019As1-17 and CWR147-3121B1-5). In both sites, the sampled vertical surface was characterized by a dense algal covering, dominated by fleshy red algae under a brown algae canopy.

The other five specimens (BEL147Spez2019As6-10) were collected along a transect orthogonal to the line coast (38°15'46.66"N - 15°38'33.11"E), in a vegetated rocky bottom characterized by patch distributed fleshy and calcareous red algae, at 15 m (3 specimens) and 26 m depth (2 specimens).

Outside of the type locality, two specimens (Figure 1) have been collected near Briatico (VV) (38°43'37.65"N - 16° 1'20.67"E), about 4 m depth, from a rocky substrate partially covered by Cystoseiracee brown algae (repository code: CWR147-3121A1-2).

In both type and new localities, *A. scuderii* was always found sympatric with the close congeneric *A. scabra* (Philippi, 1844).

Size ranged between 1.2 mm and 2.0 mm for Messina specimens and between 1.8 mm and 1.9 mm for Tyrrhenian specimens (Figure 1).

Figure 1. Ventral and dorsal view of a *Alvania scuderii* Villari, 2017 specimen from Briatico, South-eastern Tyrrhenian sea Scale bar: 1 mm

The new records of *A. scuderii* provide further information about habitat and depth range of this rarely reported gastropod. The species, that Villari (2017) indicated as preferentially sciaphilous, colonizing both "rocky and very shallow waters, between algae on stones", in present investigation has been found associated to different typologies of photophilic algal covering and, deeper, to variously vegetated rocky bottoms. Depth range was wider than initially described, since the species occurs at least from 1 m to 26 m depth. Deeper records of living specimens, in general, agree with some reports of empty shells from Linosa, whilst dead specimen from 43-44 m depth, at Scilla (Amati et al., 2020), might be displaced from shallower rocky bottoms. Although poor information is available on the related mollusc assemblage, present data at least confirm that *A. scuderii* is normally sympatric with the close *A. scabra*, which is always more abundant, in agreement with Amati et al. (2020).

The present records of *A. scuderii* (Figure 2), confirming the stable settlement of this species in the type locality, also expand northward the known areal, in the nearby Tyrrhenian basin. Such distribution, defining an almost continuous corridor, which connects the Tyrrhenian Calabrian coasts to the Strait of Sicily, throughout the Strait of Messina and Ionian coasts of Sicily (Figure 2), might suggest an areal restricted to the eastern boundary of the western Mediterranean, as it is drawn in Bianchi & Morri (2000), and in accordance with the local hydrology.

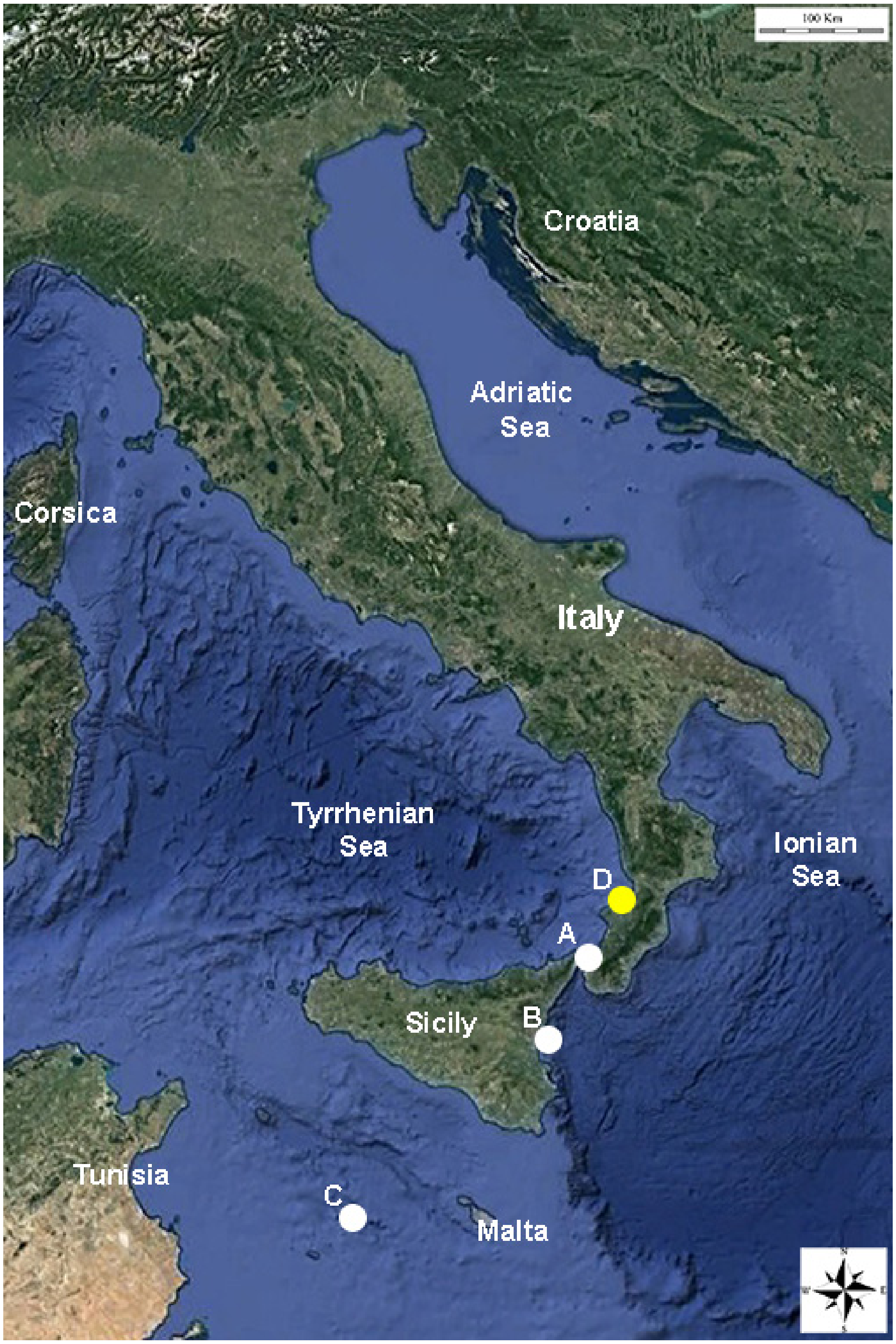

Figure 2. *Alvania scuderii* Villari, 2017 distribution. **A** –Strait of Messina (Type locality); **B** –San Giovanni Li Cuti; **C** – Linosa Island; **D** – Briatico (present record)

Satellite thermography's, in fact, show a well distinct "cold strip" superimposed to the southern and eastern Sicily shelf, and overflowing into the southern Tyrrhenian sea through the Messina Strait (Bôhm et al., 1987), which determines a substantial continuity throughout the whole *A. scuderii* areal. Such coastal waters, that are colder than the close Ionian and Tyrrhenian typical water masses, have different origin, since southward they are tied to a wind-induced upwelling regime (Levi et al., 2003), whilst northward the effect of the Messina Strait tidal upwelling is recognizable (Bôhm et al., 1987). The records from the isle of Linosa, although concerning an area that is almost peripheral in respect to the core of such peculiar water-masses, can be explained by the Atlantic-Ionian Current pathway, one branch of which originates an anticiclonic gyre circling around Linosa, before flowing towards Sicily (Reyes Suarez et al., 2019). We may suppose, in agreement with Cuttitta et al. (2016), that mesoscale oceanographic structures play a key role in shaping the actual distribution of *A. scuderii*. This species, in fact, whose paucispiral protoconch indicates a non-planktotrophic larval development (Nützel, 2014), has a moderate dispersion capacity, on turn conditioned by the effectiveness of lateral supply and availability of neighboring steppingstones. In this respect, we suggest that *A. scuderii* might almost continuously occur throughout the completely southern and eastern coast of Sicily, up to a southeastern Tyrrhenian area which is still affected by the Strait of Messina tidal regime. Such distribution, whose effectiveness is however conditioned by the recent splitting of *A. scabra* in a rich species complex which includes *A. scuderii* (Amati et al., 2020), contributes to a patchiness of closely related species which together, but also individually (*A. scabra*), cover the whole Mediterranean western basin.

Conclusion

The occurrence of *A. scuderii*, in particular, contributes to define a Mediterranean western-eastern biogeographic boundary line, which however cannot be considered as an ecotone, but as a front whose oceanographic features allow a West-Mediterranean footprint more marked than in nearby North-westernmost areas.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: Approved by institutional, regional and national animal ethical statements.

Funding disclosure: -

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Disclosure: -

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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 10.10.2015)
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 10.10.2015)
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