Evaluation of Surface Water Quality Parameters by Multivariate Statistical Analyses in Northern Coastal Line of Gökova Bay (Muğla, Turkey)

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Abstract: In this study, some physico-chemical parameters of seven selected sampling sites (SSs) along the northern coastal line of Gökova Bay were investigated monthly. Then collected data were evaluated through the multivariate statistical analyses. Monthly distribution of water quality parameters was created using box plot across the SSs. When the parameters were examined with Spearman's rho correlation, the highest positive correlations were found to be between DO (Dissolved oxygen)–SO (Saturated oxygen), EC (Electrical conductivity)–Salt (Salinity), DO–BOD_5 (Biological oxygen demand), SO–BOD_5, TP (Total phosphorus)–PO_4 (Ortho-phosphate), while the highest negative correlations were found to be between WT (Water temperature)–DO, EC–NO_3 (Nitrate nitrogen), Salt–NO_3, WT–SO. When Kruskal Wallis Test was applied to water quality parameters, WT, DO, SO, SUS (Suspended solids), TP, NO_2, PO_4, NH_4, NO_3, BOD_5 differed significantly in terms of sampling months ($p<0.05$), while pH, SO, EC, Salt, NO_2, NH_4, NO_3, Chl-a and BOD_5 differed significantly in terms of SSs ($p<0.05$). Principal component analysis (PCA) was applied to better express the relationship between measured surface water parameters and to identify sources that influence variables. PCA analysis was identified as PC 1 =28.7 %, PC 2 =21.03 % and PC 3 =11.04 %. The result of the study indicates that water quality degradation increases due to environmental pollution caused by intense tourism, overuse of coastal lines, maintenance of ships and daily ship trips.

Keywords: Gökova Bay, physical-chemical parameters, multivariate statistical analyses, coastal line, environmental impacts

Gökova Körfezi Kıyı Hattında (Muğla, Türkiye) Çok Değişkenli İstatistiksel Analizler Kullanılarak Yüzey Suyu Kalite Parametrelerinin Değerlendirilmesi

Öz: *Bu çalışmada, Gökova Körfezi kuzey kıyı şeridi boyunca seçilen yedi istasyonun bazı fiziko-kimyasal parametreleri aylık olarak incelenmiştir. Daha sonra toplanan veriler çok değişkenli istatistiksel analizlerle değerlendirilmiştir. Su kalitesi parametrelerinin dağılımı box plot kullanılarak aylık ve istasyonlar olacak şekilde dağılım grafikleri oluşturulmuştur. Parametreler Spearman's rho korelasyonu ile incelendiğinde en yüksek pozitif korelasyonlar DO (Çözünmüş oksijen)–SO (Doymuş oksijen), EC (Elektriksel iletkenlik)–Salt (Tuzluluk), DO–BOD_5 (Biyolojik oksijen ihtiyacı), SO–BOD_5, TP (Toplam fosfor)–PO_4 (Orto-fosfat) arasında iken en yüksek negatif korelasyonlar WT (Su sıcaklığı)–DO, EC–NO_3 (Nitrat azotu), Salt–NO_3, WT–SO olarak tespit edilmiştir. Su kalitesi parametrelerine Kruskal Wallis Test uygulandığında örnekleme ayları açısından WT, DO, SO, SUS (askıda katılar), TP, NO_2, PO_4, NH_4, NO_3, BOD_5 anlamlı farklılık gösterirken ($p<0.05$) örnekleme noktaları açısından ise pH, SO, EC, Salt, NO_2, NH_4, NO_3, Chl-a ve BOD_5 anlamlı farklılık göstermiştir ($p<0.05$). Ölçülen yüzey suyu parametreleri arasındaki ilişkiyi daha iyi ifade etmek ve değişkenlere etki eden kaynakları belirlemek için Temel Bileşen Analizi (TBA) uygulanmıştır. TBA analizinde PC 1 = %28.7, PC 2 = %21.03 ve PC 3 = %11.04 olarak tespit edilmiştir. Çalışmanın sonucu, yoğun turizm, kıyı hatlarının aşırı kullanımı, gemilerin bakımı ve günübirlik gemi seferlerinin neden olduğu çevre kirliliği nedeniyle su kalitesindeki bozulmanın arttığını göstermiştir.*

Anahtar kelimeler: *Gökova Körfezi, fiziksel-kimyasal parametreler, çok değişkenli istatistiksel analizler, kıyı hattı, çevresel etkiler*

INTRODUCTION

Water is a valuable natural resource for all living organisms (Priscoli, 1998; Yang et al., 2007; Lu et al., 2010; Mandal et al., 2010; Kolawole et al., 2011; Rashid and Romshoo, 2013; Sutadian et al., 2016; Misaghi et al., 2017). However, this resource is in great danger due to the increase in human population and the different demands on water in recent years (Bora and Goswami, 2017). Surface water is the part that is most affected by the pollution in terrestrial areas (Samarghandi et al., 2007). Surface waters are more susceptible to contamination as they are accessible for disposal of wastewater (Ren et al., 2003; Kolawole et al., 2008; Antisari et al., 2010). Recently, awareness and concern about water pollution and scarcity are increasing worldwide. Coastal areas have significant environmental potential (Hernandez-Romero et al., 2004; Barroso et al., 2007). People especially prefer to build industrial and urban centers on the geographic locations where rivers meet seas and oceans. These areas constitute a competitive environment and are used extensively by many sectors. Field competition

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arising from activities such as uncontrolled urbanization, agriculture, industry and tourism (Ferreira et al., 2011) leads to degradation of the environment (Madrid, 2003). In these areas, anthropogenic sources affect adversely the use of the environment by disrupting water quality (Carpenter et al., 1998; Hornberger et al., 1999; Balkis et al., 2010; Şener et al., 2017). The marine environment has a large amount of pollution burden from various sources due to the increase of the population and the commercial industry. Seawater quality has become a serious concern for ecology due to its effects on human health, marine life and water ecosystem (Zhou et al., 2007). The examination on the negative affects of the major activities on water quality is critically important (Russ, 2017).

Humans strongly influence almost the entire large water ecosystem. Increases and deteriorations in nutrient salts within water occur with the activities performed. These inputs have profound and negative impacts on water quality (Smith, 2003). Aquatic organisms (fish) intensively take nitrogen and phosphorus derivatives and people benefit from these organisms. Industrial and domestic waters reach the seas and directly affect the people who live there. On the other hand, water coming from agricultural areas creates eutrophication risk with its high phosphorus, nitrite and nitrate content (Evans et al., 2019). The prevention and control of surface water pollution is based on the identification of contaminant sources (Simeonov et al., 2003; Shrestha and Kazama, 2007). Waters coming from terrestrial areas are a serious factor affecting human health and ecological systems in urban areas because these waters carry a large number of pollutants coming from domestic, industrial, waste water and agricultural areas to the marine zone until they come to coastal area (Zhang et al., 2009).

The Bay of Gökova is capable of harboring many endemic or rare endangered species which are both rich in biological diversity and endangered in the Mediterranean basin and on Earth. The remarkable species in the Bay of Gökova are; sand shark (*Carcharinus plumbeus*), island gull (*Larus audouinii*), fish eagle (*Pandion haliaetus*), the otter (*Lutra lutra*) (Kıraç et al., 2010). Due to its rich biodiversity, the sustainability of water quality in the study area for future generations is very important. Biodiversity, known as plants, birds, animals and other living beings, has recently been endangered worldwide. Some species have become extinct, some are in danger of extinction. Certain regions have been selected in many countries for the purpose of leaving unspoiled rich biological heritage, a healthy and clean environment for future generations, getting sufficient share from world tourism and ensuring sustainable development. In terms of obligation of agreement for protection of Mediterranean against pollution for signatory countries, areas which have economic importance in Turkey and world but are in the risk of extinction due to industry, tourism and structuring have been named with the decision of the board 'special environmental protection area' (Taşlıgil, 2008). Gökova Bay, which is located in the study area, is one of these areas (special environmental protection area). Gökova Bay which located in the connection zone of the Aegean Sea and the Mediterranean Sea, has been declared as “The Private Environment Protection Zone-PEPZ” since 1989. It is one of the eight marine protected areas in Turkey (Akyol et al., 2007). In this bay particularly in summer period, water pollution arises due to tourism. On the north coast of the bay, there are agricultural enterprises, marine activities (yacht and tour boat activities) and the areas where ships are maintained (boatyard). To identify and comprehend pollution loads, water quality parameters should be sampled, analyzed and assessed in each season according to the water quality criteria. This study was conducted to investigate the potential effects of anthropogenic pollution on the surface water quality of the northern coastal coastline of Gökova Bay. In order to determine possible environmental sources affecting the field of study, multivariate statistical analyses were applied and evaluations were made. The results are highly important for decision-makers in order to conduct a sustainable management plan.

MATERIALS AND METHODS

This study was carried out in Gökova Bay located between 36.90^o – 37.09^o North latitudes and 28.07^o – 28.43^o East longitudes (Figure 1). The length of the bay in the east-west direction is 90 km, and in the north-south direction, its western end is 30 km and the eastern end is 5 km. Gökova Bay, with 24.500 ha land part, has a total area of 52.000 ha (Uluğ et al., 2005; Tarkan et al., 2009). The most important streams that flow to the Gökova Bay are Kadın Azmağı and Akçapınar Azmağı Creeks and Çamlı Stream. The Kadın Azmağı Creek is about 1700 m and 6 m deep in places (Döndü and Özdemir, 2019), the Akçapınar Azmağı Creek is about 7000 m and in a generally slow flow (Tarkan et al., 2009), while Çamlı Stream is about 8000 m and flows throughout the year to the Bay of Gökova (Tuna and Çelik, 2009). Touristic and agricultural activities are particularly intensive during the summer months in the areas where first, fourth and seventh SSs are located. The second SS is located on the pier. The third SS is located in the boat yard. The fifth (SS-5) and sixth (SS-6) SSs are located in main beach area. Between November 2014 and October 2015, the sea surface water samples monthly collected (2.5-3.5 m) from seven selected SSs were analyzed.

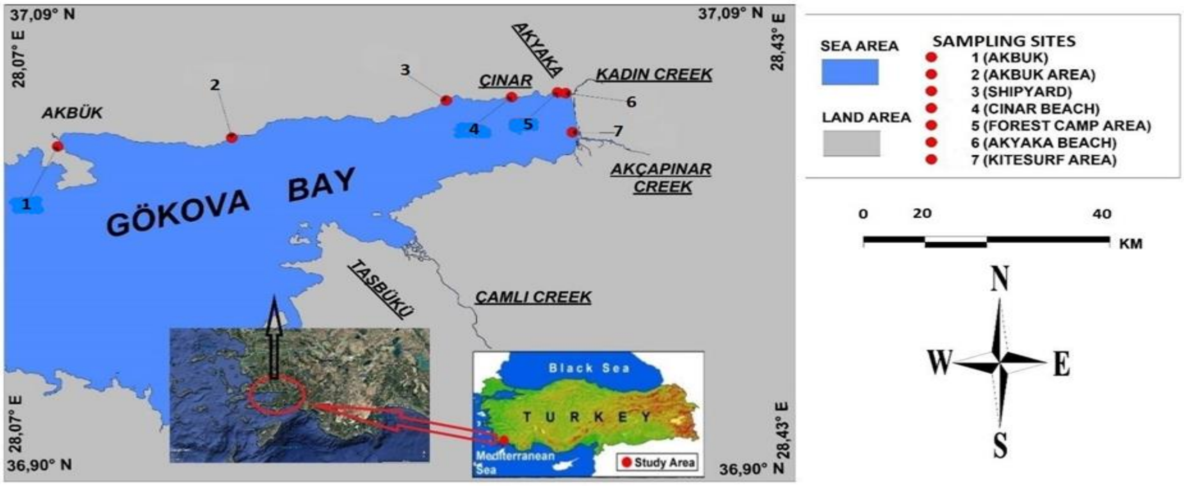

Figure 1. Study area and SSs

Water samples from the designated SSs were filled into polyethylene bottles of 2 L. Samples taken into the bottles were kept in the freezer until they were brought to the laboratory to avoid exposure to microbiological and physchemical disturbances that may be affected by external environmental conditions. Samples that could not be analyzed within an hour were stored in cold chains between 0 and +4 °C under laboratory conditions. All of the reagents and chemicals used in the current study were of analytical reagent grade. EC (mS cm^{-1}), Salt (‰), pH, WT (°C), DO (mg L^{-1}), and SO (%) were measured on site by the YSI 566 multiprop device. Nitrite nitrogen (NO^{-}_{2}-N, mg L^{-1}), NO^{-}_{3}-N (mg L^{-1}), Ammonium nitrogen (NH_4^{+}-N, mg L^{-1}), PO_4^{3-} (mg L^{-1}), TP (mg L^{-1}), Suspended solids (SUS, mg L^{-1}), Chlorophyll-a (Chl-a, mg L^{-1}) and BOD_5 (mg L^{-1}) analyses were performed according to the APHA (American Public Health Association-American Water Works Association-Water Environment Federation, Standard Methods For the Examination of Water and Wastewater, 22nd edition, 2012) methods in Mugla Sıtkı Kocman University, Environmental Problems Research and Application Center, Water Analysis Laboratory (Döndü et al., 2022).

Macro feature of excel package program and IBM SPSS Statistic 22 program were used in data analysis (Coakes, 2009). In the first step of statistical analyses, descriptive statistics of obtained data were completed. Then, the normality (Kolmogorov-Smirnov) test was applied to the variables to determine whether they were normally distributed. Box plot was used to show the distribution of data. Spearman's rho test was used to examine the relationships between data and Kruskal-Wallis test (non-parametric ANOVA) was used to determine the significance of possible water quality values differences between SSs and months. In addition, PCA was used to identify contamination sources.

RESULTS AND DISCUSSIONS

The study area is affected by many different sources. In summer, especially tourism activities are effective in the sea and terrestrial area. At the same time, the materials brought by the streams from terrestrial areas are directly mixed into the Gökova Bay.

Table 1. Descritive statistics of overall data

	Min	Max	Mean	Sd
WT (°C)	14.9	28.8	21.4	3.94
pH	7.6	9.2	8.0	0.25
DO (mg L^{-1})	4.1	7.0	5.7	0.85
SO (%)	51.2	91.3	73.9	8.45
EC (mS cm^{-1})	23.9	53.9	42.1	9.1
Salt (‰)	13.1	35.7	27.0	6.38
SUS (mg L^{-1})	1.0	143	21.74	27.1
TP (mg L^{-1})	ND	0.026	0.010	0.01
NO_2-N (mg L^{-1})	ND	0.013	0.010	0.01
PO_4 (mg L^{-1})	ND	0.11	0.01	0.02
NH_4-N (mg L^{-1})	0.01	0.15	0.03	0.02
NO_3-N (mg L^{-1})	ND	1.39	0.35	0.27
Chl-a (mg L^{-1})	ND	10.5	2.08	2.46
BOD_5 (mg L^{-1})	0.49	2.99	1.92	0.62

In addition to all this, agricultural activities in the terrestrial area continue throughout the season. Descriptive statistics of water variables are given in Table 1. The data obtained were evaluated according to the Turkish Water Pollution Control Regulation (TWPCR, 2008), Inland Water Resources Classes. According to TWPCR, all the studied parameters (as mean) were determined to be of 1st class water quality except DO, SO and Chl-a. DO and SO values were determined to be of 2nd water quality. Chl-a was found to be above the limit (0.008 mg L^{-1}) value used for recreational purposes which is indicating the risk of eutrophication. Box plot distributions of the data obtained in the study were given in Figure 2. Lines in the middle of the boxes represent the median, round diamonds indicate the arithmetic mean, and circles indicate outliers in Figure 2. In Figure 2a SO, in Figure 2b pH and in Figure 2c NO_3-N values were found to be higher in sampling sites compared to other parameters. Figure 2d–2e–2f displays the distribution of parameters in months (1st month January). There are parallels between air temperature and water temperature data (Figure 2d). Especially in the summer months, the increased anthropogenic activities and the deterioration in some parameters are similar (Figure 2d–2e–2f).

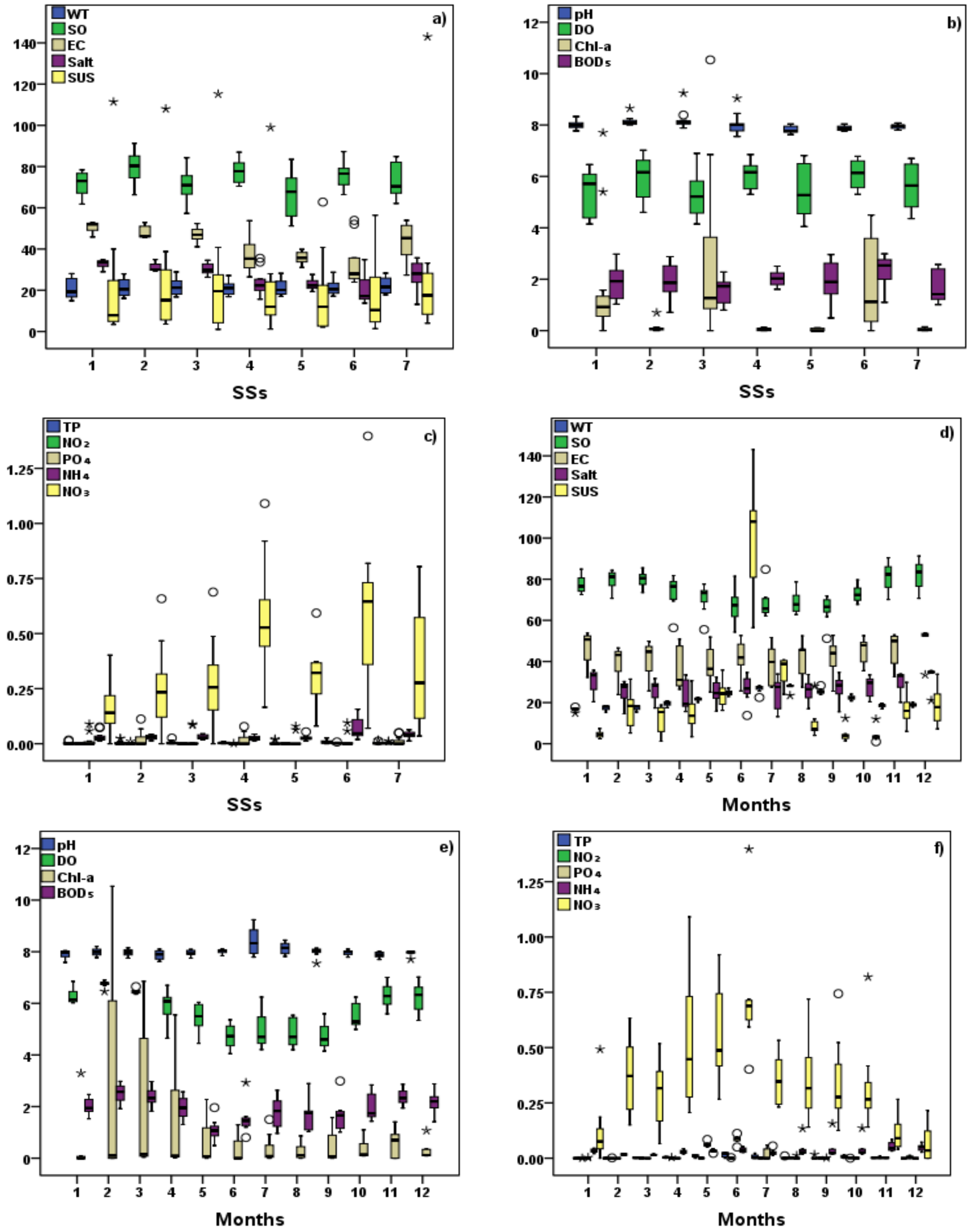

Figure 2. Distribution of water quality parameters

Table 2. Spearman's rho correlation results

	WT	pH	DO	SO	EC	Salt	SUS	TP	NO_2	PO_4	NH_4	NO_3	Chl-a	BOD_5
WT	1													
pH	0.3^{**}	1												
DO	-0.8^{**}	-0.3^{*}	1											
SO	-0.6^{**}	−0.1	0.9^{**}	1										
EC	−0.1	0.4^{**}	−0.1	0.1	1									
Salt	−0.1	0.4^{**}	−0.1	0.2	0.9^{**}	1								
SUS	0.2	0.2	−0.2	−0.1	0.1	0.1	1							
TP	0.2^{*}	−0.1	−0.2	-0.3^{*}	-0.3^{**}	-0.3^{**}	0.2^{*}	1						
NO_2	0.4^{**}	−0.1	−0.1	−0.2	−0.1	−0.1	−0.1	0.1	1					
PO_4	0.3^{**}	0.1	-0.3^{**}	-0.2^{*}	−0.1	−0.1	0.4^{**}	0.6^{**}	0.1	1				
NH_4	0.1	−0.2	−0.1	−0.1	0.1	0.1	−0.1	0.1	0.5^{**}	0.3^{*}	1			
NO_3	0.4^{**}	−0.1	−0.1	−0.2	-0.7^{**}	-0.7^{**}	0.2	0.5^{**}	0.1	0.4^{**}	−0.1	1		
Chl-a	−0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	−0.1	−0.1	−0.1	1	
BOD_5	-0.5^{**}	-0.3^{**}	0.7^{**}	0.6^{**}	−0.2	−0.2	−0.2	−0.2	0.1	-0.3^{**}	−0.1	−0.1	0.1	**1**

**Correlation is significant at the 0.01 level (2-tailed),*Correlation is significant at the 0.05 level (2-tailed).

Table 3. Kruskal-Wallis test results

Test Statistics[a,b]

	WT	pH	DO	SO	EC	Salt	SUS	TP	NO_2	PO_4	NH_4	NO_3	Chl-a	BOD_5
Chi-Square	74.8	14.0	56.6	39.7	18.0	18.5	58.9	31.8	23.3	57.0	40.7	44.7	8.5	32.0
Asymp. Sig.	0.000	0.228	0.000	0.000	0.080	0.071	0.000	0.001	0.016	0.000	0.000	0.000	0.665	0.001

a. Kruskal Wallis Test
b. Grouping Variable: Months

Test Statistics[a,b]

	WT	pH	DO	SO	EC	Salt	SUS	TP	NO_2	PO_4	NH_4	NO_3	Chl-a	BOD_5
Chi-Square	1.5	35.7	9.8	16.3	37.5	35.6	1.6	9.5	22.1	1.4	17.4	24.2	46.9	13.8
Asymp. Sig.	0.953	0.000	0.130	0.012	0.000	0.000	0.947	0.146	0.001	0.960	0.008	0.000	0.000	0.032

a. Kruskal Wallis Test
b. Grouping Variable: Sampling Sites

PCA analysis is often used to assess the relationships and similarities of possible sources of pollutants. Kaiser-Meyer-Olkin (KMO) – Bartlett's test and Varimax with Kaiser normalization (Rotation Method) were applied to determine whether the data set was suitable for PCA. KMO – Bartlett test was $p<0.001$, which illustrated that PCA could be used in dimensionality decompositions. Three main components (3 components extracted), whose eigenvalue was greater than 1 and constituted 60.77 % of the total variance, were identified (Figure 3). While DO, SO, Chl–a and BOD_5 are positively loaded on PC 1, WT is negatively loaded. NO_3 negatively is loaded while pH, EC and Salt are loaded positively on PC 2. In PC 3, SUS, TP and PO_4 are loaded positively (Figure 4).

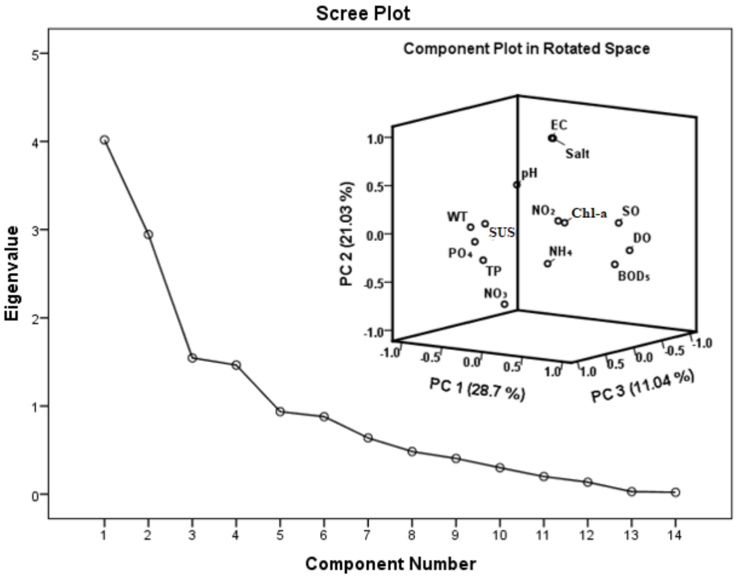

Figure 3. PCA graph for parameters

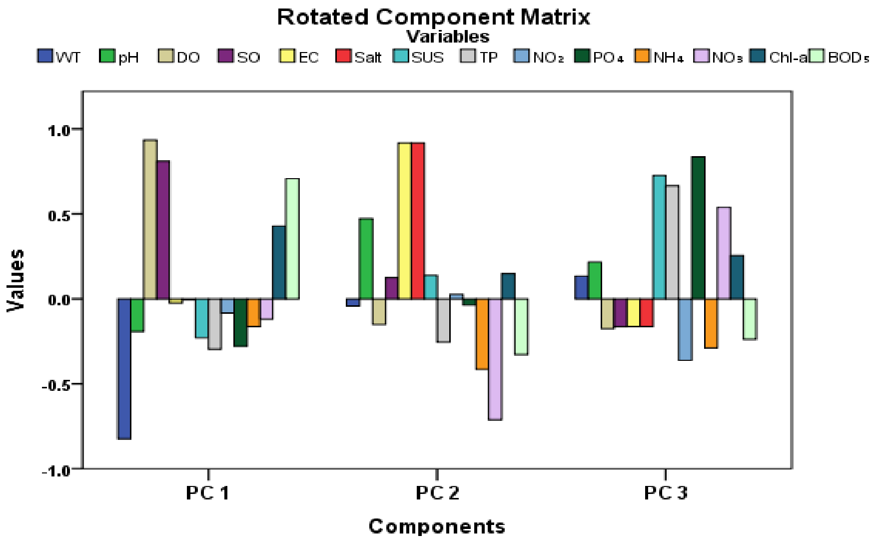

Figure 4. Rotated component matrix

In the northern coastal line of Gökova Bay, the number of studies in which water quality is evaluated by statistical analysis is low. In this regard, it is thought that our work will contribute to sustainable use by funding scientific studies.

WT is a very important criterion in water quality because most quality parameters (physical, chemical and biochemical) are temperature dependent (Cluis, 1972; Zhu and Piotrowski, 2020). WT values are depended on weather temperature values. During the summer, water temperature values increase, while in winter they reduce. The highest water temperature was 28.8 ^{o}C at the third SS in August (Figure 2a–2d). The most fluctuation was observed at 6th and 7th SSs, which are directly linked to the streams (Kadın and Akçapınar Creeks). WT is particularly negatively correlated with DO, SO and BOD_5 (Table 2). DO, SO and BOD_5 parameters decrease during the months when temperature increases. Kruskal-Wallis test found that WT differed significantly across the months ($p<0.05$), but did not differ across the SSs ($p>0.05$) (Table 3).

The pH values indicate seasonal and even daily changes in seawater as a result of temperature and biological activities (Demirak, 2003; Ustaoğlu et al., 2020). The pH values were detected as the highest at the sampling site 3 which is located on the boat yard. pH was found to differ significantly, especially across the SSs ($p<0.001$). This indicates that each SS is affected by different levels of environmental resources. It is deduced that the use of chemical materials (painting, polishing, sanding, etc.) on the boat yard is the main cause of this increase.

Adequate DO in the water column is essential for aquaculture processes and is routinely monitored (Price et al., 2015; Heddam and Kisi, 2018). The highest DO value was 7.0 mg L^{-1} at the second SS in December. DO is particularly highly correlated with SO and BOD_5 (Table 2), and DO distributions differ significantly across the months ($p<0.05$). The lowest annual average values were also found in the boatyard zone and annual average of DO was 5.7 mg L^{-1}. This value is under the criteria required for the waters used for recreation purposes (TWPCR, 2008). This situation may pose potential ecological and health risks to aquatic creatures living in the region in the coming years. SO values are generally in parallel with the dissolved oxygen values ($r=0.9$). The water quality parameter (SO) used for recreation purposes remained below the limit value (TWPCR, 2008). The highest SO value was determined in December at the second SS, as was the DO value. The precipitation in these months and fresh water from the terrestrial area cause an increase in these parameters (DO and SO). SO values differ significantly in terms of both months and sampling points ($p<0.05$).

Salinity is an important factor that controls the distribution of biota in water systems (Bayly, 1972; Ueda et al., 2000; Venâncio et al., 2019). Most multicellular organisms in the water have been adapted to live in either saltwater or freshwater conditions (Herlemann et al., 2011). Salinity in water is under the influence of various factors such as rocks, rains, and evaporation in the aquatic environment. The annual average of salinity was 27 $‰_0$ and the annual average of electrical conductivity was 42.1 mS cm^{-1}. Salinity and EC values are in parallel with each other (Figure 2a and 2d) ($r=0.9$). Both salinity and EC values differ significantly across SSs ($p<0.05$).

The tendency to increase nitrogen levels due to anthropogenic sources is a worldwide problem because it can contribute to algae bloom and eutrophication. Nitrite nitrogen is intermediate in nitrification, denitrification and reduction of nitrate to ammonium (Philips et al., 2002). Nitrite nitrogen was not detected at some SSs, while the highest value (0.013 mg L^{-1}) was detected at the seventh SS in December. The reason why nitrite nitrogen was fluctuating throughout the study is that nitrite is a by-product. Atmospheric events in winter, the potential for freshwater to carry nitrite to the Bay and nitrite fertilizers used for agricultural purposes in the region may be the reasons for the increases (Anderson et al., 2006). Nitrite nitrogen differs significantly across both months and sampling points ($p<0.05$).

In the study area, ammonium nitrogen was 0.03 mg L^{-1} and nitrate nitrogen was 0.35 mg L^{-1}. Nitrate nitrogen values increase in the mid seasons and summer months (Figure 2d). Nitrate nitrogen differs significantly across both months and SSs ($p<0.05$). Ammonium in the water can be originated from humans and animals (Demirak, 2003; Demirak et al. 2012). Ammonium nitrogen differs significantly across both months and SSs ($p<0.05$), while it also has a positive relationship with nitrite nitrogen ($r=0.05$). This is thought to be due to nitrification and denitrification relations. Ammonium nitrogen values increase in the coastal part of Akyaka where tourism and agricultural activities (the use of nitrogen-containing fertilizers) are concentrated. The reason for higher nitrogen values can be explained with the amount of environmental waste from freshwater sources flowing to the Gökova Bay, the seasonal activities of the boatyard, the discharge of bilge waters to sea, and especially in summer months the intensive use of beaches for touristic purposes.

Phosphorus is generally lesser in marine waters, but it can lead to an increase in eutrophication through anthropogenic effects (Cloern, 2001; Nordvarg and Hakanson, 2002; Ngatia et al., 2019). In this study, the annual total phosphorus value was 0.010 mg L^{-1}, and the orthophosphate value was determined as 0.01 mg L^{-1} on average. Positive correlation was detected between total phosphorus and orthophosphate values ($r=0.6$), and both parameters differed significantly between the months ($p<0.05$). Anthropogenic activities in the region, especially in summer months (especially domestic waste mixing with water and agricultural studies) are the sources that have eliminated phosphorus increase. Total phosphorus concentration in Güllük Bay was 0.03–0.07 mg L^{-1}. Demirak (2003), in the same study area, determined the orthophosphate concentration as 0.06–0.36 mg L^{-1}.

SUS, which has organic or inorganic origin and transported by streams, reduces the light permeability to water by increasing the blur. SUS values were most at SS 7 (June, 143 mg L^{-1}). The reason for this is the substances carried with Akçapınar Creek and the samplings in mid seasons. In addition, SUS shows significant distribution difference between months ($p<0.05$). SUS values were identified as 21.74 mg L^{-1} on average.

BOD_5 is the amount of oxygen that bacteria need to break down organic matter in oxygenated conditions. The annual average of BOD_5 values was determined as 1.92 mg L^{-1}. BOD_5 shows a positive correlation with DO and SO ($r=0.7$, $r=0.6$), while it correlates negatively with WT ($r=-0.5$). In aquatic environment, low BOD_5 is good quality water and high BOD_5 is an indicator of polluted water (Effendi and Wardiatno, 2015). The concentration of DO is generally thought to decrease when the BOD_5 rises (Basatnia et al., 2018).

However, when BOD_5 increased in the study, the DO level (r=0.7) also increased. This may be because the sampling sites in the study area are at shallow water level (as well as calm water close to land) and surface water samples are used regardless of depth. For these reasons, it is thought that a positive correlation occurs between BOD_5 and DO. The DO-BOD_5 correlation we obtained in our study is parallel to the study by Basatnia et al. (2018). BOD_5 differs significantly across both months and SSs ($p<0.05$). The maximum increase found on the sixth sampling site. The beach has a small area and is an intensely used point, so the lack of infrastructure system and mixing of the residual wastes directly to the water affect the beach negatively.

Chl-a is the most important photosynthesis pigment and available as the main pigment in all plants. Pigment analyses are also used to determine the trophic structure of phytoplankton communities (Barlow et al., 1997). Also Chlorophyll-a is an important index that shows the eutrophic level in the waters and is used to express the biomass of ambient (Demirak, 2003; Mamun et al., 2019). Chl-a values are especially intense in the spring months when temperatures first start to rise (Figure 2e). This indicates increased eutrophic conditions with temperature increase, dissolved oxygen decrease and nutrient increase. In recent studies, researchers discussed the relationship between Chl-a and the increase of nutrients and the formation of mucilage, which is one of the important problems of today (Ergul et al., 2021). Chl-a distributions differ significantly between sampling points ($p<0.001$). In the study, the annual average of Chlorophyll-a was determined as 2.08 mg L^{-1}. The average Chl-a value is above the limit value used for recreational purposes which is indicating the risk of eutrophication.

The results obtained by PCA analysis are given in Figure 3 and Figure 4. Factors are classified as "strong" (>0.75) "medium" (0.75–0.50) and "weak" (0.50–0.30) according to their impact size (Li et al., 2011). PC 1 is 28.7%, with DO and SO strong, BOD_5 medium, Chl-a weak load and WT negative strong load (Figure 4). This indicates that WT acts inversely proportional to other parameters within the same factor during periods of increase or decrease. In particular, the results in correlation analyses support this situation (Table 2). PC 2 accounts for 21.03%, EC and Salt are strong, pH is weak positive loading, nitrate nitrogen is medium, ammonium nitrogen and BOD_5 are weak. The inclusion of BOD_5 in both components is considered an indication that it is affected by similar sources. Wastes caused by agricultural and tourism activities in the field of study may have affected nitrogen and its derivatives, causing an increase in the factors that are strong in this variance. PC 3 accounts for 11.04%, orthophosphate is strong, SUS, TP and nitrate nitrogen show moderate load. Strong correlations of organic matter and phosphorous compounds support this condition (Table 2). Large increases in organic matter from agricultural areas and domestic (household wastewater, sewage, detergent waste, etc.) areas may have led to an increase in the factors affecting this variance.

CONCLUSION

Evaluation of water quality parameters by statistical analyses is very important for the ecosystem. In this respect, our study is the first study conducted with the use of statistical analysis on the northern coastal coast of the Bay of Gökova. In the statistical analyzes, it is seen that PCA is very effective and rivers have significant effects on the study area. According to TWPCR (2008); DO, SO and chl-a were detected in second class water quality. In addition, some parameters deteriorated especially towards the spring and summer months. There was an increase in chl-a during the spring months when biological activity was high, and increases in NO_3-N concentrations at the fourth, sixth, and seventh sampling points where agricultural areas were concentrated.

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AUTHOR CONTRIBUTION

Nedim Özdemir: Data collection, writing original draft, reviewing, and editing. Mesut Perktaş: Collection of data, laboratory studies, original drafting, reviewing, and editing. Mustafa Döndü: Collection of data, laboratory work, validation, writing original draft.

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