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Baseline

Bio-indicator bacteria & environmental variables of the coastal zones: The example of the Güllük Bay, Aegean Sea, Turkey

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ABSTRACT

In this study bio-indicator bacteria and environmental variable parameters were investigated in the coastal areas of the Güllük Bay, Aegean Sea, Turkey. The seawater samples which were taken from surface (0–30 cm) were tested regarding total and fecal coliform, streptococci and nutrients from May to February in 2012–2013. The primary hydrographic parameters were recorded using multiparameter (YSI 556) in situ at the sampling stations. The highest fecal pollution stress and indicator bacteria values were observed in the period between June and August. The finding showed that bacterial pollution sources of the study area, especially in the summer season, under the control of increasing anthropogenic activities. The finding showed that terrestrial pollution sources carry a potential risk for public and ecosystem health and the sustainable use of living sources. Precautions should be formulated and put into action immediately in order to protect the region from bacteriological risks.

Insufficient urban systems, municipal, domestic, and industrial waste water may lead to growth infectious microorganisms (Wade, 2003; Shikulov, 1987; Fleisher, 1993). Depending on environmental factors such as; human activities, domestic and industrial wastes, the levels of bio-indicator bacteria may rise and pathogen bacteria can grow in coastal areas.

For that reasons, coastal areas have fragile peculiarities with respect to ecosystem dynamics, human and ecosystem health. Monitoring of the coastal marine areas with respect to bio-indicator bacteria have been accepted the most practicable way for protection of these regions (Sanders, 2000; Wheeler, 2002). Additionally, the levels of bio-indicator bacteria are used as a sign of possible pathogens in marine environments. These pathogens are associated with gastrointestinal, skin and respiratory illnesses (Haile et al., 1999; Pruss, 1998; Cabelli, 1983).

Marine transportation relation to the Güllük Harbour (Aegean Sea, Turkey) over population depend on tourism, the aquaculture activities of fish farms which were taken place more than 15 years (the fish farms were relocated away from the coastal region to offshore area in 2009) in the coastal areas and the domestic and industrial pollution inputs are the important environmental factors for the Güllük Bay (Altuğ, 2013).

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Water samples were taken from 11 different stations (Fig. 1) which are located in the coastal area of Güllük Bay (Turkey). Stations were chosen regarding to their environmental risk factors. Water samples were collected under aseptic conditions and transported in cold chain to Istanbul University Aquatic Microbial Ecology Laboratory between May 2012 and February 2013.

The seawater samples were diluted serially and filtered through membrane filters (0.45 μm, Sartorius) by using membrane filtration method. Filters were placed on m-Endo, m-FC and m-Azide for indicator bacteria such as total coliform, fecal coliform and fecal streptococci. The plates were incubated for 24 h (at 37 ± 0.1 °C and 44.5 ± 0.1 °C). The number of bacteria was expressed as colony forming units (CFU 100 ml^{-1} (APHA, 2000)

Temperature, salinity, pH and dissolved oxygen concentration were measured in situ using a portable multiparameter tool (YSI 556). The oxygen sensor was calibrated regarding to air. An oxygen saturation of 100% was considered the oxygen concentration in the air (Lorenti and De Falco, 2004).

4500-NO2$^-$ B. Colorimetric Method for nitrite, 4500-NO3 E. Cadmium Reduction Method for nitrate, 4500-NH3 f. Phenate Method for ammonia, 4500-P E. Ascorbic Acid Method for phosphorus were used regarding to standard methods (APHA, 2000). Spectrophotometric method was performed for chlorophyll-α (Golterman et al., 1978).

The statistical analyses were performed using the SPSS 19.0 software (SPSS, Chicago, IL). One direction variance analysis and Spearman correlation tests analysis were performed to compare

Fig. 1. Location of Güllük Bay and sampling stations.

the influences of seasonal and spatial variations on environmental parameters (Quinn and Keough, 2002). Multidimensional scaling, MDS method was used to find out similarities between seasons and stations regarding to bacteria abundance (Clarke and Warwick, 2001).

The main physicochemical parameters of the sampling areas such as temperature, salinity, pH, and dissolved oxygen are shown in Table 1.

The levels of nutrients and chlorophyll-α in the samples which were taken from surface water (0–30 cm) were summarized in Table 2.

The levels of total coliform, fecal coliform and fecal streptococci were shown in Figs. 2–4.

The levels of total coliform were ranged between 3 × 101 CFU/100 ml and 2.164 × 106 CFU/100 ml.

The levels of fecal coliform were ranged between 0.1 × 101 CFU/100 ml and 1.46 × 104 CFU/100.

The levels of fecal streptococci were ranged between 0.1 × 101 CFU/100 ml and 2.11 × 104 CFU/100.

Fluctuations in the distribution of total and fecal coliform bacteria were observed throughout the sampling periods, however a distinctive decrease and statistically significant differences was not observed in the bacteria count of all the stations. This situation shows the continuity of point and non-point pollution sources affecting the coastal regions during the study.

In this study, it was possible to isolate indicator bacteria from all the stations, which possessed salinity values between 24.0 psu and 39.3 psu during the study. Total coliform are reliable indicators of sewage contamination. Due to the osmo-regulation systems of the sewage-originated enteric bacteria, they may adapt their metabolism to the new medium against a sudden osmotic shock when they enter seawater. This ability of enteric bacteria aids them in gaining resistance to salt in sea environments and increases their probability of survival (Munro et al., 1989). So, in this study, despite salinity values were changed significantly ($p < 0.001$) due to the fact that fresh water inputs in stations there was no significance ($p > 0.05$) relation between the level of salinity and the number of bacteria. The absence of a significant correlation between salinity concentration and the number of indicator bacteria were linked with adaptation mechanism of indicator bacteria mentioned above.

Between concentration of dissolved oxygen and the level of bacteria no correlation were recorded. This situation were associated with detected oxygen concentrations were not enough to change the level of bacteria radically.

The levels of indicator bacteria were found positively correlated with temperature ($p < 0.001$). This state was linked with rises of the population rate and recreational activities in summer season in the region. Nitrite, nitrate, phosphorus and chlorophyll-a levels were positively correlated with levels of indicator bacteria. This situation showed that increasing nutrient levels is inducing the level of bacterial pollution. Similarly, it was reported that nutrient starvation as a factor influencing the maintenance of bacteria in water (Mitchell, 1968; Munro et al., 1987; Lim and Flint, 1989; Rippey and Cabelli, 1990; Bogosian et al., 1996).

Bacterial pollution of recreational water can lead to health problems because of the occurrence of pathogenic bacteria. Coastal zones such as beach water are under risk of fecal contamination which may cause health problem in polluted waters (Byappanahalli et al., 2008).

Additionally, Güllük Harbor is one of the important potential pollution sources among various factors such as recreational, domestic and industrial activities. It was reported that 2862 unit ships visited from 157 various harbors of the world and carried 4.8 million tones ballast water to the Güllük Harbor in the period 2007–2012 (Olgun, 2013). Although Güllük Bay is open to bacterial contamination risk due to heavy marine transportation, there are no studies to date regarding bacteria related to ballast waters. Consequently, the transportable indicator bacteria load of ships' ballast water for the Güllük Bay has not yet known.

The waterborne disease transmission at recreational beaches has a strong relationship with the abundance of specific indicator bacteria in the water column. It is known that when indicator bacteria levels are higher than standards, fecal contamination may cause health risks and pathogenic problems (Bonilla et al., 2007).

Monitoring regularly of bacterial water quality on coastal areas is necessary to understand anthropogenic impact of pollution sources. Predictions and preventions against pathogens and related

Table 1
Physical and chemical parameters regarding to months.

Stations	Months	Temperature (°C)	Salinity (‰)	pH	Dissolved O_2 (mg/l)
Station 1	May 2012	24.4	15.76	6.06	7.52
	June 2012	27.6	9.72	7.77	3.85
	July 2012	29.5	5.81	7.86	10.08
	Aug. 2012	25.9	5.72	7.66	6.77
	Sept. 2012	25.2	7.72	7.85	5.68
	Feb. 2013	15.4	3.64	8.85	7.23
Station 2	May 2012	24.4	38.2	8.25	11.59
	June 2012	30.3	38.5	8.28	11.39
	July 2012	32.6	38.7	8.39	13.07
	Aug. 2012	28	38.4	8.22	8.96
	Sept. 2012	26	38.4	8.12	6.5
	Feb. 2013	15	38.3	8.93	10.94
Station 3	May 2012	24.2	38.4	8.8	9.08
	June 2012	29.9	38.4	8.2	9.94
	July 2012	32.2	39.1	8.34	11.34
	Aug. 2012	27.4	38.8	8.2	7.67
	Sept. 2012	26.2	38.5	8.16	6.4
	Feb. 2013	15.7	38.5	8.95	8.98
Station 4	May 2012	24.7	38.8	8.21	9.66
	June 2012	29.9	38.3	8.21	9.28
	July 2012	31.6	38.8	8.26	9.33
	Aug. 2012	27.3	39.1	8.18	7.55
	Sept. 2012	26.3	39.1	8.08	7.12
	Feb. 2013	16.7	38.5	8.92	8.52
Station 5	May 2012	24.9	38.8	8.19	9.15
	June 2012	30.4	39.2	8.22	9.2
	July 2012	31.5	39.1	8.24	9.47
	Aug. 2012	27.6	39.1	8.19	7.32
	Sept. 2012	26.4	39.1	8.07	7.2
	Feb. 2013	16.2	39.2	8.01	8.59
Station 6	May 2012	23.9	38.4	8.13	9.11
	June 2012	29.2	38.2	8.19	8.31
	July 2012	31.3	39	8.2	7.26
	Aug. 2012	27.1	38.6	8	7.12
	Sept. 2012	26.1	38.6	8.11	7.75
	Feb. 2013	16.6	38.7	8.03	8.4
Station 7	May 2012	23.9	38.7	8.21	10.05
	June 2012	29.4	39.1	8.24	9.24
	July 2012	31.2	38.4	8.22	8.22
	Aug. 2012	27.4	38.6	8.14	7.42
	Sept. 2012	26.4	38.8	8.14	6.68
	Feb. 2013	16	38.7	7.88	8.75
Station 8	May 2012	24.9	38.9	8.17	9.46
	June 2012	31	39.1	8.24	10.83
	July 2012	32.9	38.8	8.27	8.38
	Aug. 2012	28.1	38.6	8.21	7.12
	Sept. 2012	26.1	38.7	8.1	6.87
	Feb. 2013	16.3	39.2	8.07	8.71
Station 9	May 2012	24.1	39.1	7.81	9.39
	June 2012	29.7	38.8	8.07	8.86
	July 2012	29.2	38.6	7.75	6.58
	Aug. 2012	23.9	39.2	6.99	6.18
	Sept. 2012	26.5	39.1	8.14	7
	Feb. 2013	15.4	39.1	7.28	7.61
Station 10	May 2012	22.9	39	8.15	9.67
	June 2012	29	39.3	8.06	8.4
	July 2012	28.2	39.2	8.11	6.64
	Aug. 2012	25.4	38.8	8.07	7.11
	Sept. 2012	25.4	38.8	8.03	7.03
	Feb. 2013	14.2	38.9	7.31	8.62
Station 11	May 2012	22.6	38.3	7.98	9.82
	June 2012	26.4	38.2	8.1	8.52
	July 2012	27.2	38.5	8.14	6.95
	Aug. 2012	24.4	38.5	8.1	7.07
	Sept. 2012	25.6	39.7	8.1	7.05
	Feb. 2013	15.5	39.3	8.1	8.8

Table 2
Nutrient and chlorophyll-α values regarding to months.

Stations	Months	Nitrite (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Phosphorus (mg/l)	Chlorophyll-α (μg/l)
Station 1	May 2012	0.0325	17.6624	0.6868	0.4849	0.8150
	June 2012	0.0325	15.8169	1.4638	0.6744	0.0718
	July 2012	0.0295	14.0735	1.5126	0.7288	0.1969
	Aug. 2012	0.0355	16.9917	0.9779	0.6201	0.3875
	Sept. 2012	0.0182	17.3683	0.0032	0.8571	0.3978
	Feb. 2013	0.0351	20.0165	0.6598	1.3340	0.2145
Station 2	May 2012	0.0255	6.6166	0.7121	0.4105	0.7812
	June 2012	0.0177	2.3106	0.3543	0.0241	0.3802
	July 2012	0.0165	3.8229	0.4154	0.2113	0.2137
	Aug. 2012	0.0195	4.7892	1.0053	0.1046	0.2659
	Sept. 2012	0.0205	10.4396	0.0365	1.8149	0.1337
	Feb. 2013	0.0243	7.3728	0.7188	0.6922	0.3793
Station 3	May 2012	0.0252	6.3436	0.4386	0.0986	0.9708
	June 2012	0.0178	2.8357	0.2289	0.0262	0.2892
	July 2012	0.0270	3.6759	0.4252	0.1972	0.4583
	Aug. 2012	0.0194	4.4741	0.3992	0.0744	0.3135
	Sept. 2012	0.0271	6.8012	0.0397	1.8732	0.7317
	Feb. 2013	0.0257	5.4824	0.4979	0.6720	0.2758
Station 4	May 2012	0.0256	5.2093	0.1875	0.0724	0.2220
	June 2012	0.0146	2.8147	0.1264	0.1247	0.1240
	July 2012	0.0180	3.2138	0.3862	0.1972	0.0062
	Aug. 2012	0.0252	4.1170	0.8216	0.1006	0.3013
	Sept. 2012	0.0178	6.4651	0.0383	2.0101	0.3708
	Feb. 2013	0.0200	4.6211	0.3971	0.6881	0.4425
Station 5	May 2012	0.0267	4.6632	0.3044	0.1227	1.1494
	June 2012	0.0207	3.8650	0.2493	0.2676	1.0341
	July 2012	0.0193	3.1718	1.2426	0.2093	0.2078
	Aug. 2012	0.0176	4.0540	0.5499	0.0684	0.3484
	Sept. 2012	0.0344	6.4981	0.0411	2.0905	0.9633
	Feb. 2013	0.0345	6.5326	0.3989	0.6600	0.2829
Station 6	May 2012	0.0232	5.3773	0.3739	0.0785	0.0268
	June 2012	0.0195	3.5919	0.1801	0.1046	0.3041
	July 2012	0.0148	2.9197	0.4529	0.2354	0.2913
	Aug. 2012	0.0189	4.9572	0.6907	0.1992	0.3822
	Sept. 2012	0.0239	7.4651	0.0418	2.0121	0.4050
	Feb. 2013	0.0320	7.2048	0.4063	0.7626	0.2696
Station 7	May 2012	0.0239	4.2010	0.2820	0.1590	0.2995
	June 2012	0.0305	3.1088	0.0906	0.1046	1.0131
	July 2012	0.0170	5.1253	1.0084	0.1972	0.0913
	Aug. 2012	0.0170	3.9910	0.6338	0.1328	0.2798
	Sept. 2012	0.0236	6.4021	0.0267	2.1308	0.8710
	Feb. 2013	0.0282	6.4066	0.3308	0.6720	0.4161
Station 8	May 2012	0.0183	5.3143	0.1980	0.1408	0.3615
	June 2012	0.0126	2.3316	0.1752	0.1851	0.1357
	July 2012	0.0192	3.6759	0.3399	0.2254	0.3714
	Aug. 2012	0.0198	4.7262	1.1243	0.1549	0.6273
	Sept. 2012	0.0239	7.5199	0.0411	2.0503	0.0406
	Feb. 2013	0.0312	9.7674	0.6166	0.7988	0.3300
Station 9	May 2012	0.0192	11.8259	0.1464	0.1127	0.2407
	June 2012	0.0193	16.1110	0.1935	0.1348	0.1279
	July 2012	0.0293	14.3256	0.3237	0.2072	0.0459
	Aug. 2012	0.0228	13.0172	0.9340	0.5654	0.9844
	Sept. 2012	0.0235	19.8633	0.0344	1.9879	0.7426
	Feb. 2013	0.0179	21.6938	0.2612	0.7163	0.2701
Station 10	May 2012	0.0213	5.5874	0.1359	0.0765	0.1851
	June 2012	0.0179	3.4869	0.0305	0.2897	0.4057
	July 2012	0.0213	4.6211	1.1805	0.1650	0.4530
	Aug. 2012	0.0193	5.6084	0.6060	0.4165	0.3739
	Sept. 2012	0.0210	9.3053	0.0404	1.9960	0.6440
	Feb. 2013	0.0137	3.6759	0.1970	0.5372	0.1223
Station 11	May 2012	0.0198	4.3901	0.1489	0.1167	0.1825
	June 2012	0.0156	3.0248	0.0762	0.2475	0.1409
	July 2012	0.0310	3.1508	0.4572	0.2294	0.0391
	Aug. 2012	0.0295	4.7262	1.0485	0.5674	0.3543
	Sept. 2012	0.0411	9.7757	0.0383	1.8471	0.4837
	Feb. 2013	0.0242	3.1088	0.4136	0.5674	0.2626

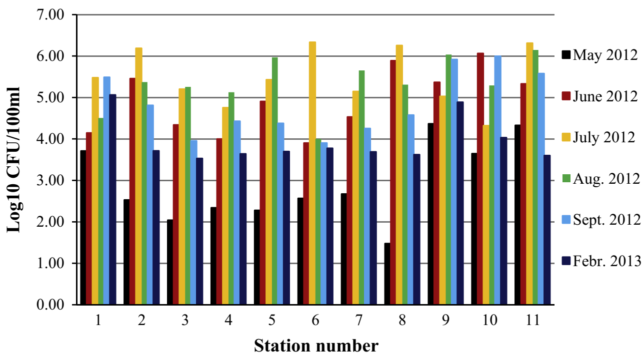

Fig. 2. The levels of total coliform.

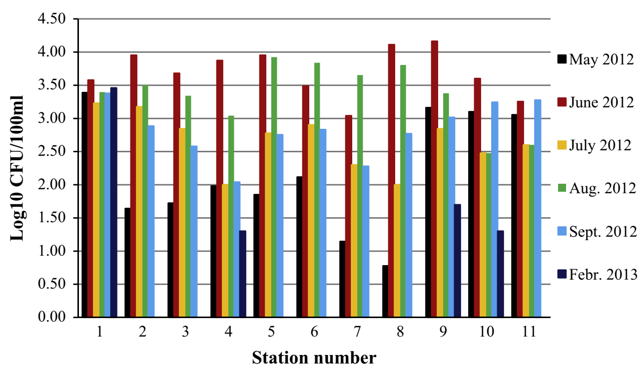

Fig. 3. The levels of fecal coliform.

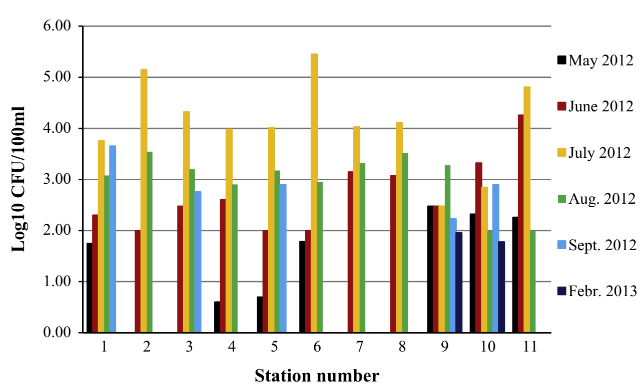

Fig. 4. The levels of fecal streptococci.

water-borne disease may improve more efficiently for public and ecosystem health and the sustainable use of living sources.

In this study the count of indicator bacteria of the seawater samples which were taken from coastal areas of the Güllük Bay of the Aegean Sea were found higher than the standard values. The results showed that bacterial pollution sources in the region should be decreased. The precautions methods, which are used to reduce the level of bacteria input to the region, should put into action immediately.

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