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WATER QUALITY SEASONAL INVESTIGATION IN THE COASTAL AREAS OF GÜLLÜK BAY (SOUTHEAST OF AEGEAN SEA-TURKEY)

Güllük Bay is potentially important area in terms of marine product within the Aegean Sea. The trophic status classification of coastal waters at the European scale requires the availability of harmonised indicators and procedures. The composite trophic status index (TRIX) provides useful metrics for the assessment of the trophic status of coastal waters. In this study, the trophic status and water quality of Güllük Bay has been evaluated by using the trophic index TRIX. Sea water samples were collected from four coastal regions in the Güllük Bay on seasonal basis, from March, June, September and December 2013.The measurements of some chemical - physical parameters were done in these samples. Results were evaluated by statistical analysis methods. Accordingly, the statistical analyses results, with all parameters differ between seasons indicate statistical sense. In statistical terms isn't determined to the difference between the stations. In addition, N / P and trophic index (TRIX) were calculated with the calculation method. The results of the calculation are of follows: N/P 0,33–29,4 and TRIX index 3,63–6,16. The results show that Gulluk Bay coastal areas has been found to have a high risk of eutrophication.

➢ ***Key Words:*** *Güllük Bay, water quality, eutrophication, TRIX index.*

INTRODUCTION

Coastal regions sustain environmental decline. The problem is especially acute in developing countries. The reasons for environmental decline are very complex, but population factors play a noteworthy role. Today, approximately 3 billion people—about half of the world's population—live within 200 kilometers of a coastline. The pollution from all human activities can affect the coastal environment. For example, more than 90 percent of wastewater and 70 percent of industrial wastes are discharged into coastal waters without being treated in developing countries [1, 2].

The harmful effects of eutrophication on the coastal environment worldwide are well documented. The Urban Wastewater Treatment Directive defines eutrophication as the "enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned". Since marine coastal eutrophication has become more frequent over recent years, words like `oligotrophy', `mesotrophy' and `eutrophy' (a terminology largely developed by limnologists to characterize the trophic conditions of inland waters) have also become more frequent in the marine literature. There is general agreement that oligotrophy means nutrient poor (=low productivity), eutrophy means nutrient rich (=high productivity) waters and mesotrophy waters as moderate conditions. Hypoxia or even anoxia is the last stage of eutrophication [3] and this phase is often characterized as "dystrophic" [4].

The assessment of the risks and impacts of eutrophication in coastal waters is one of the key issues in environmental management [5]. To decrease the nutrients flow and bring down eutrophication the European countries are spending significant efforts aimed at revealing the marine areas that are the most sensitive to nutrient pollution in accordance with the methodology proposed by the Water Framework Directive [6].

The general approach of the WFD to environmental state of sea waters assessment is characterized by quite complex integrated registration of biological communities' functioning and hydromorphological and physicochemical parameters. Recently simple method of coastal water quality integrated assessment using the TRIX trophic index proposed by [7] for some areas of Adriatic Sea is gaining ground more and more for other European seas including the Black Sea and Baltic coastal waters [8]. Mangiala-

jo et al. [9] have used TRIX in a validation process of results obtained applying the CARLIT macrophytic index to assess the ecological status of Ligurian coastal waters (Italy). Loureiro et al. [10] included the trophic index TRIX among a restricted number of tools developed to evaluate the trophic conditions in marine areas [5].

This study aims to study the marine waters trophic state changes using TRIX index in the coastal waters of Güllük Bay in Aegean Sea, to determine the ecological quality of coastal waters in Güllük Bay.

MATERIALS and METHODS

Study Area

The Bay of Güllük is located on southeastern Aegean Sea Coast (Figure 1). The bay is formed basically by four large natural coves and many smaller bays and inlets, and it has a surface area of about 670.5 square kilometers and a coastline of around 262 kilometer. The various materials in the Bay of Güllük are sources of pollution. These can be summarized as; loads originating from domestic waste water, pollution caused by tourism activities, loads brought by the Sari Stream, loads originating aquacultures activities, pollutant loads originating from Güllük Port activities and mining transferred from Güllük Port to the open sea [11, 12].

Sampling Strategy

Sea water samples were collected from four coastal regions in the Güllük Bay. These are village region, port region, summer houses region and a city region (Figure 1). The population of the village and the city are 1.375, 4.114, respectively. But these populations are getting more in tourism seasons. It is the most important issue which there is not the sewerage network in the village. Five sampling stations were selected for each region. Surface sea water samples were collected at sampling stations on seasonal basis, from spring (March), Summer (June), fall (September) and Winter (December) 2013, using Niskin Bottles.

Figure 1. Güllük Bay

Analytical Methods

All water samples were collected with Niskin oceanographic bottles. All physical chemical parameters of water samples were measured by standard methods [13] in Environmental Studies Laboratory of Muğla Sıtkı Koçman University. These methods were applied to the Turkish Accreditation Agency (TÜRKAK) for Environmental Studies Laboratory of Muğla Sıtkı Koçman University. The laboratory analyzes conducted on-site as well as the addition of water, wastewater and sea water sampling within the framework of ISO IEC 17025 Laboratory accreditation are available.

Data analysis

The multivariate index of trophic state TRIX [7] was used to characterize the trophic state of the coastal systems. Oxygen saturation rate, chlorophyll-*a*, dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations were used to obtain this trophic index. These were combined in the following formula in order to quantify the estuary eutrophication:

$$TRIX = \frac{\log(\text{Chl-}a * aD\%O * DIN * TP) - (-1.5)}{1.2}$$

where : Chl *a* : Chlorophyll *a* concentration, (µg L-1) DO2 (%): absolute deviation of measured dissolved oxygen content in % from 100% saturation; TN: Concentration of total N, (µg L-1). TP: Concentration of total P (µg L-1). 1.5 and 1.2 were scale factors based on an extended dataset concerning the northern Adriatic Sea. Table 1 describes the values for describing the systems:

Table 1

List of values and the designations of the TRIX scale [11]

Scale TRIX	State water quality	Level of eutrophication
0–4	High	Low
4–5	Good	Medium
5–6	Bad	High
6–10	Poor	Elevated

The Pearson's correlation analysis and Duncan's multiple range tests were used to compare means of concentrations of physical-chemical parameters in the water samples of study areas by using SPSS. Further analysis was carried out only where there a significant difference at the 5% ($p < 0.05$) and 1% ($p < 0.01$) level of significance.

RESULTS and DISCUSSION

The results of parameters that measured in the study areas is shown in Table 2. The other hand, the results of parameters that measured in the laboratory (Environmental Studies Laboratory of Muğla Sıtkı Koçman University) is shown in Figure 2 and Figure 3. These results are arithmetic averages that calculated from results of each five stations for all study regions.

Table 2

The results of parameters that measured in field area

Parameters	Min-Max
pH	7,42–9,05
Temperature ^{o}C	11,0–28,7
Conductivity (mS/cm)	43,03–61,20
Oxygen Saturation (%)	82,5–165,5

The concentrations of dissolved inorganic nitrogen (DIN = NO_3-N + NO_2-N + NH_4-N) ranged between 0.013 and 0.080 mg/L. The arithmetic averages of concentrations of DIN in all study areas were calculated at 0.031 mg/L for spring (March), 0.021 mg/L for summer (June), 0.031 mg/L for fall (September) and 0.053 mg/L for winter (December).

The concentrations of orthophosphate were not measured at the some coastal stations of Güllük Bay for spring (March), summer (June) and fall (September). The highest value of the concentrations of orthophosphate was measured on fall (September) in the city region of Güllük Bay as 0.018 mg/L. The concentrations of total phosphorous (TP) ranged between 0.001 mg/L and 0.078 mg/L. The arithmetic averages of concentrations of TP in the study regions were observed at 0.023 mg/L for spring (March), 0.013 mg/L for summer (June), 0.015 mg/L for fall (September) and 0.025 mg/L for winter (December).

The lowest and highest arithmetic average rations of N/P were 0,332 and 29,400 in the coast regions of Güllük Bay. The results indicate that N is generally limiting nutrients for the coast regions of Güllük Bay.

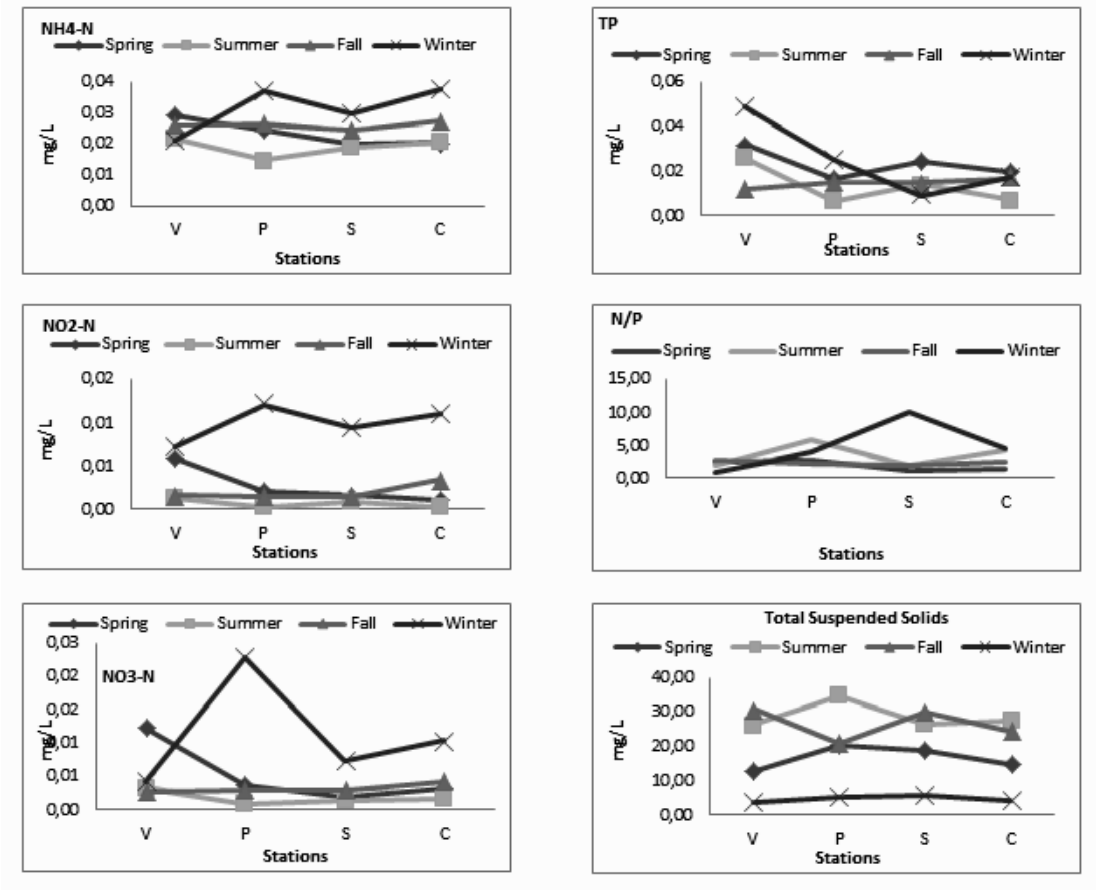

Figure 2. The results of some parameters that measured at the laboratory: V – Village Region, P – Port Region, S – Summer House Region, C – City Region

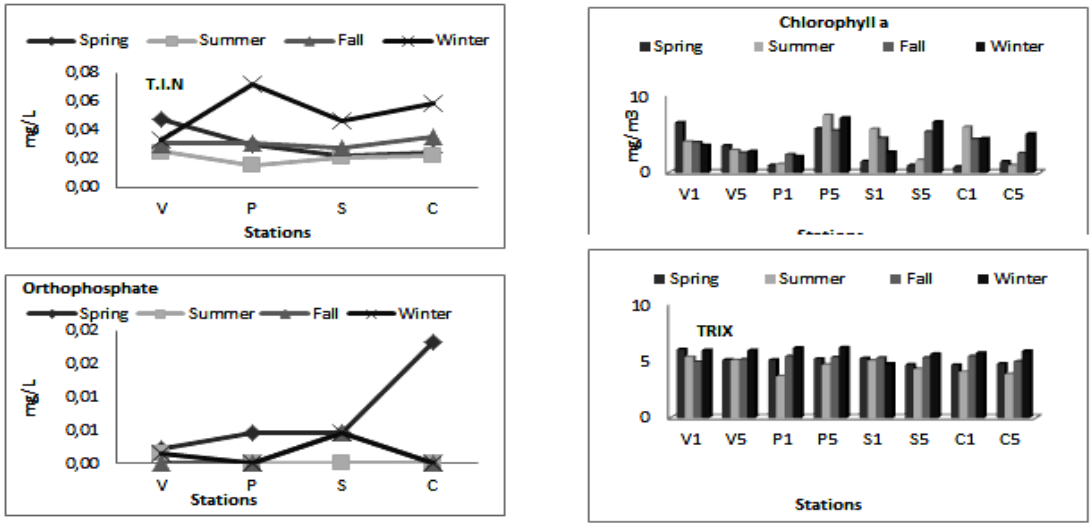

Figure 3. The results of some parameters that measured at the laboratory: V – Village Region; P – Port Region; S – Summer House Regioon; C – City Region; V1, V5 – Village Region Station; P1, P5 – Port Region Station; S1, S5 – Summer House Region Station; C1, C5 – City Region Station

According to some study [14], the limits of average concentration in chlorophyll *a* are <0.5 μg L-1 for oligotrophic, 0.5-1.0 μg L-1 for mesotrophic and >1.0 μg L-1 for eutrophic waters. According to chlorophyll *a* results obtained from the coast regions of Güllük bay. The Bay has mesotrophic conditions. Moreover, it shows eutrophic conditions in some periods.

The TRIX trophic state index is a multivariate tool used to characterize systems with anthropogenic enrichment. The trophic state of a system depends on the availability of nitrogen and phosphorus for primary production, the determination of phytoplankton biomass (Chl *a*) and the saturation of dissolved oxygen [15].

Table 3 shows the trophic classification resulting from the TRIX in the in the coastal regions of Güllük Bay.

Table 3

Trophic classification results in the coastal regions of Güllük Bay, according to TRIX values

	Spring (March)		Summer (June)		Fall (September)		Winter (December)	
V1 (Village Region)	5,9872	B, H	5,3329	B, H	4,8752	G, M	5,9072	B, H
V5 ((Village Region)	5,0674	B, H	5,0371	B, H	5,0999	B, H	5,8977	B, H
P1(Port Region)	5,0731	B, H	3,6282	H, L	5,3785	B, H	6,1222	P, E
P5 (Port Region)	5,1572	B, H	4,6438	G, M	5,2702	B, H	6,1608	P, E
S1 (Summer House)	5,2157	B, H	4,9918	G, M	5,2513	B, H	4,7335	G, M
S5 (Summer house)	4,6358	G, M	4,2551	G, M	5,2403	B, H	5,5922	B, H
C1 (City Region)	4,6216	G, M	4,0100	G, M	5,3823	B, H	5,6789	B, H
C5 (City Region)	4,7222	G, M	3,8270	H, L	4,9334	G, M	5,8329	B, H

Water quality: H = High, G = Good, B = Bad, P = Poor
Level of eutrophication: L = Low, M = Medium, H = High, E = Elevated

Statistical analysis

According to Duncan's multiple range test and Pearson's correlation, significant differences were not observed in the concentrations of physical- chemical parameters of the water samples between the four stations ($p > 0.05$). The results show that the Güllük Bay is affected by the same contaminants.

The Pearson's correlation analysis was performed on concentrations of physical- chemical parameters in the water samples of study areas between the periods study.

Significant differences were observed in the mean concentrations of physical-chemical parameters of the water samples between the periods study ($p < 0.05$) except pH ($p > 0.05$).

CONCLUSION

- The Trix represents a synthesis system of fundamentals trophic parameters with easy numerical values.
- We can be classify and identify quality of the coastal water of Güllük Bay with TRIX.
- We can make information comparable over a wide range oftrophic situation with TRIX, while avoiding the subjectivity in the usage of traditional trophic terminology.
- We can develop for the Turkish coastal waters to provide information useful for assessing eutrophic conditions and a scale of water quality will have been established, compatible to the European Water Framework Directive.
- It is influenced the coastal areas of Güllük Bay in the winter by rain water and land-based pollutants which transported from the open sea.
- As result of study, it can be said that the main pollutant sources in study area are municipal waste, increasing tourism activities and intense maritime traffic in spring, summer and fall seasons.
- The study realized the current state of water quality in the coastal regions of Güllük Bay.
- The study can be used as main source in determining possible changes in these regions in the future.
- Effective waste water management including nutrient control have been required for effective pollution prevention program in these regions.
- According to TRIX, it has been found to have a high risk of eutrophicatin in the study area.

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REFERENCES

1. Creel, L. (2003). Ripple effects: Population and coastal regions. (policy brief). Washington DC: Population Reference Bureau.

2. Balkis, N., Aliçli, B.T., Balci, M. (2012). Evaluation of Ecological QualityStatus with the Trophic Index (TRIX)Values in the Coastal Waters of the Gulfs of Erdek and Bandırma in the Marmara Sea**.** Ecological Water Quality – Water Treatment and Reuse.

3. Gray, S. J. (1992). Eutrophication in the sea. In: Marine eutrophication and pollution dynamics, Colombo, G. and Viviani, R. (Eds), Olsen&Olsen, Fredensborg.

4. Karydis, M. (2009). Eutrophication assessment of coastal waters based on indicators: a literature review. Global NEST Journal, 11(4), 373–390.

5. Pettine, M., Casentini, B., Fazi, S., Giovanardi, F., Pagnotta, R. (2007). A revisitation of TRIX for trophic status assessment in the light of the European Water Framework Directive: Application to Italian coastal waters . Marine Pollution Bulletin 54 (2007) 1413–1426

6. Kovalova, N., Medinets, V., (2012). Comprehensive Assessment of Long-Term Changes of the Black Sea Surface Waters Quality in the Zmiinyi Island Area Turkish Journal of Fisheries and Aquatic Sciences 12: 485–491.

7. Volleinweider, R.A., Giovanardi, F., Montanari, G., Rinaldi, A. (1998). Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics 9, 329–357.

8. Baytut, O., Gonulol, A., Koray, T. (2010). Temporal variations of phytoplankton in relation to eutrophication in Samsun Bay, Southern Black Sea. Turkish Journal of Fisheries and Aquatic Sciences, 10, 363–372.

9. Mangialajo, L., Ruggieri, N., Asnaghi, V., Chiantore, M., Povero, P., Cattaneo-Vietti, R.(2007). Ecological status in the Ligurian Sea: The effect of coastline urbanisation and the importance of proper reference sites. Marine Pollution Bulletin 55, 2007.

10. Loureiro, S., Newton, A., Icely, J. (2006). Boundary conditions for the European Water Framework Directive in the Ria Formosa Lagoon, Portugal physico-chemical and phytoplankton quality elements. Estuarine, Coastal and Shelf Science 67, 382–398.

11. Demirak, A., Balcı, A., Tüfekçi, M., (2006) Environmental Impact of the Marine Aquaculture in Güllük Bay, Turkey, Environ Monit and Assess,123, 1–12.

12. Arisoy, Y., Guzel,Y-G., Pazi,I. (2012). Relocation of the fish farms in Güllük Bay. . Water resources and wetlands, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan* Conference Proceedings, 14-16 September 2012, Tulcea – Romania.

13. APHA**,** AWWA, WEF, (2012) Standart Methods for The Examination of Water and Wastewater, 22st Edition, American Public Health Association, Washington, 4-103 – 4–169.

14. Ignatiades, L. (2005). Scaling the trophic status of the Aegean Sea, eastern mediterranean. Journal of Sea Research., 54, 51-57.

15. Alves, G., Flores-Montes,M, Gaspar, F., Gomes, J., Feitosa, F. (2013) Eutrophication and water quality in a tropical Brazilian estuary. Journal of Coastal Research**,** Special Issue No. 65

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Регион Гуллук Бэй на берегу Эгейского моря является одним из основных районов заготовки морепродуктов Турции. Основной задачей данной работы является изучение комплексного трофического индекса (КТИ) оценки трофического статуса и качества прибрежных вод района Гуллук Бэй. Были отобраны образцы воды из четырех прибрежных пунктов региона Гуллук Бэй в течение четырех сезонов 2013 года – в марте, июне, сентябре и декабре. Были проведены физико-химические исследования, результаты которых оценивались с применением статистических методов. Все исследованные параметры имеют сезонные колебания, и различия между станциями не обнаружены. Результаты расчета представлены следующим образом: N / P 0,33–29,4 и КТИ индекс 3,63–6,16. Результаты показывают, что прибрежные районы региона Гуллук Бэй имеют высокий риск эвтрофикации. Сделан вывод о том, что основным источником загрязнения прибрежных вод являются муниципальные отходы, расширение туристической деятельности и интенсивное судоходство в весенний, летний и осенний периоды года.