# THE ASSESSMENT OF ECOLOGICAL QUALITY STATUS OF THE ANTALYA BAY AND DUDEN RIVER

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## ABSTRACT

EU Water Framework Directive (WFD) ensures the evaluation of the ecological status of European rivers, groundwater, estuaries and coastal waters. This article, in accordance with the directive and the methods of some researchers, presents Ecological Quality Ratio and trophic classification in Düden River Estuary which flows into the Antalya Bay. Chl *a* concentration is a good indicator of the nutrient enrichment. Therefore, the nutrients were used in the evaluation of the biological quality and ecological status of the region along with the physicochemical conditions, and reference conditions were formed. The research area shows a mesotrophic characteristic with the effect of the river in spring and autumn months whereas shows an oligotrophic characteristic in summer and winter months. Although a serious ecosystem damage was not observed here, it is remarkable that ecologic indices reached sustainability limits from time to time.

## 1. INTRODUCTION

Evaluating the eutrophication and its risks in the estuaries and coastal waters plays a significant role. While the scale which determines the trophic condition from the threshold values stated for the nutritional elements and chlorophyll was used in the past **[1][2][3][4]**, establishment of a closer correlation between the causal factors and the increase in eutrophication has gained importance with the development of the evaluation tools **[5][6]**.

For the eutrophication, many classifications have been made based on nutrients (phosphate, nitrate and ammonium) and biological elements (such as cell density, chlorophyll *a* concentration, macroinvertebrates and fish) Vollenwedier *et al.* **[7]** proposed trophic index in order to identify the trophic conditions of seawater. This index is the logarithmic combination of 4 variables (Chl *a*, DIN, TP and absolute dissolved oxygen saturation deviation, a%DO). Thus, this composite index is the combination of biological response to nutrient pressure (Chl *a*, representing the biomass) and the environmental degradation (oxygen) in the water quality.

Then, in European Water Directive of Framework (EU WDF, 2000/60/EC) **[8]**, evaluation tools have been presented for phytoplankton, macroalgae and benthos in the ecological classification of the coastal waters. WFD proposed that EQR (Ecological Quality Ratio) which is the relationship between the observed value and the reference value be presented as the numerical values which vary between 1 and 0. ICES **[9]** made an Ecological Quality (EcoQ) evaluation which evaluates phytoplankton indicator types with nutrients, Chl *a* and oxygen concentration. While the evaluations **[3] [10]**, and discussions **[11][12]** continue about the indices formed for benthic invertebrates, the current methods related to the phytoplankton are mostly related with toxic algae or phytoplankton blooms **[13] [14]**. All these regulations conducted for the improvement of European coastal waters, surface waters and seawaters are explained in Water Framework Directive. Member countries are given time until year 2015 to improve their coastal waters and regulate their laws for Ecological Quality Status, EQS.

Although “sensitive areas” or “trophic” status evaluation have just started for the coasts of Turkey which is in the stage of European Union accession talks, legal enforcements have not been formed. In Antalya Bay (Eastern Mediterranean) creates the risk of increase in trophic degree in the coasts due to dense tourism, wastewaters of the city centre, discharge to sea from the wastewater treatment facilities, and nutrient input from the rivers. For that reason, it has been aimed to evaluate ecological and trophic status according to TRIX and EQR indices around the estuary (Düden River) in order to determine the trophic status of the coasts of Antalya and to form the first findings for the region.

## 2. MATERIAL METHOD

### 2.1. *Methods for Water Analysis*

A total of 5 measurement and sampling points have been determined in order to detect water quality of the eastern coasts of Antalya and the effect of continental pollutants. Seawater samples have been taken with Hydrobios water sampler from subsurface, depths of 15m and 30m for 12 months (April 2002-February 2003) (Figure 1). Moreover, temperature, salinity, dissolved oxygen and dissolved oxygen saturation measurements have been performed with intervals in depths varying between 0m and 50m (2.5, 5 and 10m) in the water column. Density has been calculated from the salinity and the temperature measurements.

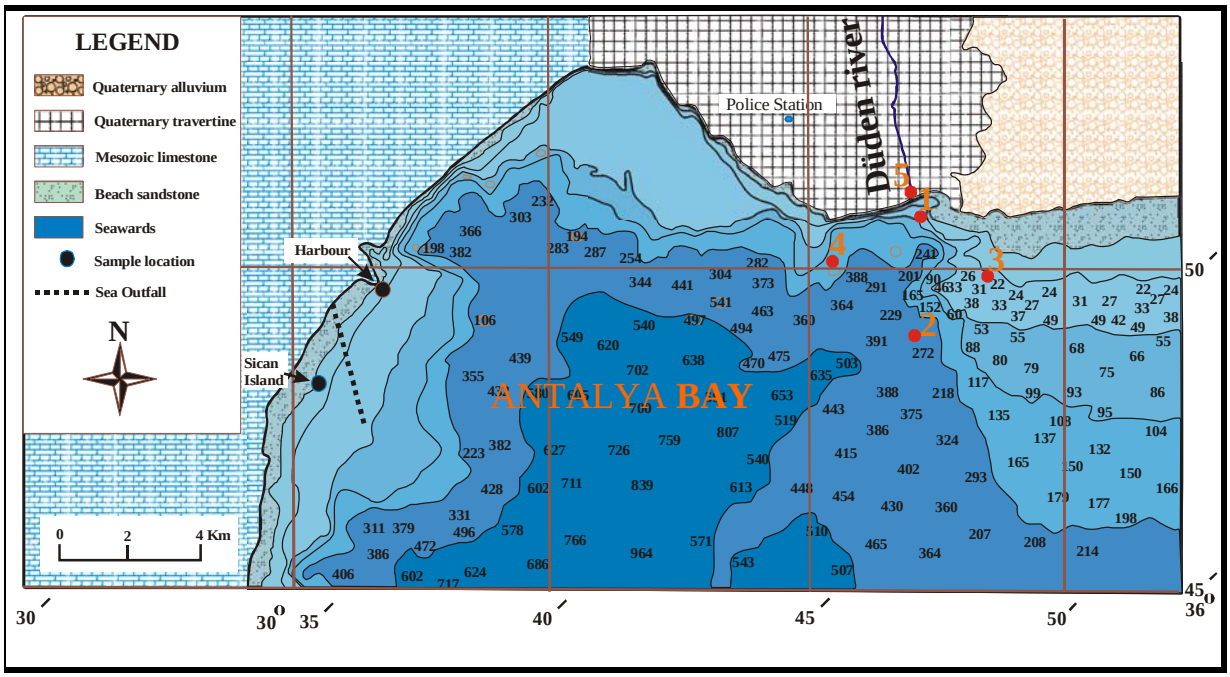



*Figure 1. Research area and sampling stations*

Among nutritional elements, ammonium, nitrate+nitrite nitrogen (Cd-Cu reduction), reactive phosphate, silicate analyses **[15]** have been performed. Measurement limits of the used analysis methods are as follows respectively; nitrate+nitrite nitrogen, reactive phosphate, silicate, 0,1-10 µM, 0,05-45 µM, 0,03–5 µM, 0,1–140 µM, 0,1–140 µM. For the chlorophyll *a* analysis, in the seawater samples which have been obtained only from the sub-surface it has been extracted with the acetone in the filtrate obtained from GF/F type glass filter and it has been analyzed spectrophotometrically. Measurement analysis limit is 0,01 µg/L.

### *2.2 WFD and TRIX Classification*

According to the identification of WDF, the regions in the characterization of the surface water types, especially the ones which are under the influence of the rivers, have been evaluated as the coastal waters. According to the WDF's system A (Annex II, 1.2.4), Mediterranean Sea is located in the 6$^{th}$ ecoregion and East Mediterranean is eurihalin (over salty) and generally deeper than 200m. In the system B, there are physical and chemical factors along with the biological community structure and composition in the evaluation of the coastal waters which must be necessarily determined. Coasts of Antalya have been classified according to the systems A and B which are indicated by WDF and the optional factors stated below. In accordance with this system (Annex V, 1.1.4), (a) water temperature which affects biological processes (T, °C), (b) light transparency as the indication of the turbidity (SD, m), (c) stratification index which defines the mixing property of the region and which is calculated from the difference between the surface and the bottom (SI: it is calculated by extracting the lowest value from the determined highest salinity) **[17]**, (d) water column depth (WD, m) and (e) dilution factor (F%) have been calculated from [S-si/S*100] formula (si is the salinity measured in each station, S is the average saltiness detected in the research area) and it has been accepted as averagely 38.6 **[12]**.

According to the Trix index used to determine the trophic status in the Italian, Slovenian, Northern European seas and the coastal waters of Black Sea and Baltic, 2 < TRIX < 4 is defined as Very Good; 4≤ TRIX < 5 is defined as Good; 5 ≤ TRIX < 6 is defined as Fair; 6 ≤ TRIX < 8 is defined as Poor.

Used in the numerical classification of waters in a wide range (1-10) of trophic statuses from oligotrophy to eutrophy, TRIX index is defined as follows: **[7] [18]**,

$$TRIX = \log_{10}[(Chl\ a * |DO\%| * NP) + 1,5]/1,2 \quad [1]$$

where, Chl *a*: chlorophyll *a* concentration (µg/l); |DO%|: the absolute deviation of oxygen saturation percent; N: the dissolved nitrogen (DIN) concentration in µM; P: dissolved inorganic phosphor in µM.

### *2.3. Biological indices*

In the ecological evaluation of the research area, ecological and biotic indices have been used, which have international validity and which are accepted. For that purpose, in the water column between the surface and 15m, species richness Margalef index (D) **[19]**, species diversity Shannon-Weiner index (H') and the evenness of the structure of the community Pielou evenness (J) index **[20]**, species general diversity and species dominance Simpson index **[21]** have been determined.

### *2.4. Trophic Status Classification*

In the ecological classification based on phytoplankton, researchers used different methods in relation with the trophical status and ecological quality classification. Generally, classifications based on biomass are accepted in order to determine the eutrophication status. Simboura et al. **[5]** base this eutrophication scale which was specifically developed for Greece seas on the nutrient concentrations range which includes phosphate, nitrate and ammonium and phytoplankton cell concentration and chlorophyll a concentration parameters. These researchers classified the scale, which they formed by modifying it, as "eutrophic", "high mesotrophic", "low mesotrophic" and "oligotrophic" in order to fit the scale to the ecological quality classes of WFD, and they distributed mesotrophic chlorophyll a values to low mesotrophic range. This has been used to present the nature of the phytoplankton quality elements temporarily for median chlorophyll a in the scale ecological quality classification.

Borja *et al*. **[13]** suggested Chl *a* and indicators for transitional and coastal waters in the evaluation of the biological quality of phytoplankton in Basque region of Spain and they classified the Basque waters. They performed the classification given in the below table by accepting Chl *a* level as 8 µg/l for the coastal waters.

*Table 1. Eutrophication scale comparison according to chlorophyll a concentration.*

| | *Simboura et al. (2005)** | | *Borja et al. (2004)* | | *EU WFD (2000/60/EC)* | |
|---|---|---|---|---|---|---|
| Eutrophication scale | Median Chlorophll *a* (µg/l) | Ecological Quality Status (EQS) | Chl a classification | | Median Chlorophll *a* (µg/l) | Ecological Quality Status (EQS) |
| Oligotrohic | <0,1 | High | <2- | High | 0,1-0,4 | High |
| Lower Mesotrophic | 0,1-0,4 | Good | 2-5 | Good | - | |
| | 0,4-0,6 | Moderate | 6-10 | Moderate | 0,4-0,6 | Good |
| High Mesotrophic | 0,6-2,21 | Poor | 11-15 | Poor | - | |
| Eutrohic | >2,21 | Bad | >15 | Bad | - | Moderate |

*In Greece seas used median Chl *a* values.

EU WFD shows the biological quality elements for the type-specific reference conditions and high surface water type. Reference conditions present a definition of high biological quality elements and ecological quality (EQR) ratios. These ratios must present the relationship between the biological parameters observed for a certain surface water and the acceptable values of the reference conditions in the structure of that water. This ratio must be a numerical value between "0" and "1". It must be "1" for high ecological quality and "0" for bad ecological status (Annex V, 1.4.1 (ii) in WFD). In EQR classification, ratios between "0" and "1" are formed by finding the median value of the available data (reference condition) and dividing the data by the median value (reference value). These ratios must be represented with 5 ecological classes ("high", "good", "moderate", "poor" and "bad").

## 3. RESULTS AND DISCUSSION

According to EU WFD, the first step of the ecological quality classification is the water structure and ecoregion identification. These definitions and classifications contain biological elements such as macroinvertebrates, benthos and plankton. Antalya Bay is included in the 6$^{th}$ Mediterranean ecoregion and it has sandy and rocky bottom structure. There are many residential areas and agricultural areas around Düden River which carry the pollution load of the region. The flow rate of the river is 16m$^3$/sc and it reaches the sea by a waterfall.

In this study, a comparison has been made in the ecological quality classification based on phytoplankton by taking into account WFD and the methods defined above (Table 1) and ecological quality ratios have been calculated by forming reference conditions. However, this evaluation is not based on the long term observation but only on a 1 year data set **[22]** which has been regularly studied monthly. The typological classification and the ecological classification of the stations in the research area have been presented in Table 2.

Due to the optical properties, minimum values of the light transparency which controls the biological processes have been observed in winter months and spring blooms period. Values of winter months present the rain effect. Dilution percentage is the indication of the freshwater loading into the seawater and the mixture properties. It has been observed that dilution ratio is significantly low in the point distant to the river and relatively deep regions (S2 and S4). It must be expected that the dilution ratio of especially S2 point which is an open station is much lower. However, the travertine structure of the region proves that ground waters reach the region via undersea caves.

The results of the physical, chemical and ecological conditions show that there is human effect on S1 and S3 stations. Salinity, which arranges the dissolved substance concentration and which is a basic variable in such areas **[23] [24]**, directly affects S1, S3 and S4 points due to surface currents. Open point (S2) presents a relatively good quality compared to other points. The lowest salinity values observed in the surface waters are in 32,9-33,9‰ range (Table 2).

In the course of the history, it is known that estuaries are the most polluted regions and biological elements such as phytoplankton, benthos, fish, etc. constitute the good indicators (**[13] [25] [26] [4]**). The highest values have been observed in S1 point in terms of species diversity, richness and dominance in the biological indices which are given in Table 2 and calculated for phytoplankton. At this point, the high quality of diversity indices (>4) forms the proof that transformations are very mild and they do not affect the phytoplankton community.

In the 1-year research, monthly changes of hydrographic variables, nutritional elements and chlorophyll a and ecological quality and eutrophication scale evaluation according to the results presented with the bottom-surface integration of the data have been presented in Table 3. The researched estuary region is in EcoQ scale “moderate” quality in spring months and early summer; and in “high” quality in summer and winter months. TRIX index expresses that there is no eutrophication risk in the region. However, values larger than <1,5 have been have been reached in spring months and autumn months according to this scale. A mild highness is observed in the TRIX values of S3 (1.99) which is less deep than coast and other stations (Figure 3, Table 3). In this point, dilution percentage (F% 11,2) is higher than phytoplankton biomass, the highest TRIX value and other points. The relative highness of TRIX index in this station caused primary production amount to increase with the waste discharge input and river effect. The increased primary production increases the ecosystem sensitivity by also affecting the physicochemical conditions. These results increase the probability of the formation of eutrophic conditions in the future. According to EcoQ quality standards, all points can be classified as good quality. We can state an increase in the sensitivity in only points 1, 2 and 3.

According to ICES WKEUT **[27]** report, 90th percentile, chlorophyll is in 1-1,5 µg/l range in Spain Basque coastal waters, but it is in 2-4 µg/l range in Basque shelf waters, sub-surface chlorophyll maximum, it is in 2,2-2,3 µg/l range in Cantabrian sea **[25]**, it is in about 10 µg/l range in France shelf sub-surface waters **[28]**. Boundary chlorophyll a value has been determined as 3 µg/l in Spain Cantabrian coasts. This boundary between the high and moderate ecological condition has been accepted as 6 µg/l. For phytoplankton abundance, $5*10^5$ h/l has been determined as the threshold value. It has been stated that there is not enough data for the total cell count and algae blooms, that is because small sized phytoplankton is $10^7$ h/l in the eutrophic Cantabrian sea estuary region and the chlorophyll a values are relatively low although they reach the number of cells **[29]**.

Table 2. Determination of research area according to values mean, minimum and maximum, and for type-spesific conditions, chemical, physical and ecological conditions in stations.

| St No: | Depth (m) | SD (m) | T (°C) | DO (%) | Salinity (‰) | SI | F% | Chl a (µg/l) | DIN (µg/l) | PO4-P (µg/l) | TRIX | EcoQ - | D | H' | sımpson | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 50 | 10 (1–19) | 22,7 (16.8–28.4) | 89.3 (72.9–99.9) | 38.2 (32.9–39.3) | 0.56 | 41.2 | 2.92 (0.3–9.5) | 32.2 (69.8–9.3) | 2.5 (6.9–0,9) | 1.3 | **2–5 G** | 4.18 | 3.89 | 0.09 | 0.91 |
| **2** | >272 | 10,1 (6–20) | 22,5 (16.8–28.8) | 89,6 (75.4–99.3) | 38,6 (33.9–39.2) | 0.63 | 0.94 | 2.97 (1.3–5.9) | 54.0 (121–6.7) | 2.5 (5.8–0.9) | 1.4 | **2–5 G** | 4.20 | 3.63 | 0.12 | 0.91 |
| **3** | 30 | 12,4 (4–15) | 22,5 (17.3–28.9) | 89,1 (76.4–99.0) | 38,4 (33.9–39.3) | 0.81 | 11.2 | 3.02 (1.0–7.5) | 6.7 (101.1–8.1) | 3.4 (10.4–0.9) | 1.5 | **2–5 G** | 4.27 | 3.61 | 0.11 | 0.94 |
| ***4*** | >200 | 12,4 (2–21) | 23,3 (16.9–28.9) | 89,8 (73.0–99.7) | 38,5 (33.9–39.4) | 0.79 | 9.06 | 2.3 (0.3–6.7) | 57.6 (101.1–11.7) | 3.1 (6.9–0.9) | 1.4 | 2–5 G | 4.30 | 3.62 | 0.12 | 0.88 |

Key: Transparency (SD), Dissolved Oxygen saturation (%DO), Stratification index(SI), Dilution Factor (F%), Ecological quality status(EcoQ), Eutrofication İndex (TRIX), Margalef İndex (D), Shannon-Weiner İndex (H'), Pielou İndex (J). (Öfotik zon için dip-yüzey (0, 15 ve 30 m) integre ortalama değerleridir. Integrated (0, 15 ve 30 m) of deep-surface mean values for euphotic zone.

Table 3. Classification results for biological elements (based on chlorophyll-*a* concentrations) and syntesis of final EQO and T:RIX in Duden river estuary (EU WFD, 2000, Borja et al. 2004).

| | **Station No:** | ***S1*** | | | | **S2** | | | | **S3** | | | | **S4** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | Mounths | EQR | EcoQ | | TRIX | EQR | EcoQ- | | TRIX | EQR | EcoQ- | | TRIX | EQR | EcoQ- | | TRIX |
| 2002 | April | | 6-10 | M | 1,32 | | 6-10 | M | 1,66 | | 6-10 | M | 1,83 | | 2-5 | G | 1,60 |
| | May I | | 6-10 | M | 1,78 | | 6-10 | M | 1,94 | | 2-5 | G | 1,99 | | 2-5 | G | 1,33 |
| | May II | | <2 | H | 1,29 | | 2-5 | G | 1,28 | | 2-5 | G | 1,60 | | 2-5 | G | 1,59 |
| | June | | 6-10 | M | 1,27 | | 6-10 | M | 1,48 | | 6-10 | M | 1,52 | | 2-5 | G | 1,28 |
| | July | | <2 | H | 1,15 | | 2-5 | G | 1,23 | | <2 | H | 1,24 | | <2 | H | 1,20 |
| | August | *HIGH* | <2 | H | 1,23 | *HIGH* | <2 | H | 1,26 | *HIGH* | <2 | H | 1,25 | *HIGH* | <2 | H | 1,24 | *HIGH* |
| | September | | 2-5 | G | 1,56 | | 2-5 | G | 1,30 | | 2-5 | G | 1,57 | | <2 | H | 1,44 |
| | Ooctober | | 2-5 | G | 1,23 | | 2-5 | G | 1,23 | *GOOD* | 2-5 | G | 1,45 | | <2 | H | 1,33 |
| | November | | <2 | H | 1,25 | | <2 | H | 1,27 | | 2-5 | G | 1,25 | | <2 | H | 1,19 |
| | December | | 2-5 | G | 1,54 | | <2 | H | 1,42 | | <2 | H | 1,38 | | <2 | H | 1,25 |
| 2003 | January | | <2 | H | nd | | 2-5 | G | nd | | 2-5 | G | nd | | <2 | H | nd |
| | February | | <2 | H | 1,49 | | <2 | H | 1,30 | | <2 | H | 1,26 | | <2 | H | 1,27 |

EQR;Ecological Quality Ratio ……..; EcoQ:Ecological Quality Status

In Düden estuary sub-surface waters, chlorophyll a which has been calculated in 90th percentile is about 1-4 µg/l range. The threshold value for the high and moderate ecological status in this region has been accepted as 4 µg/l. Düden estuary region has higher quality when compared to the boundary values of Spain and France. Figure 2 shows the EQS according to chlorophyll a concentration. Maximum chlorophyll a values (7,5-9.5 mg/l) exceeded the abovementioned threshold values in only spring blooms period. This region has been found as high quality in summer and winter months.

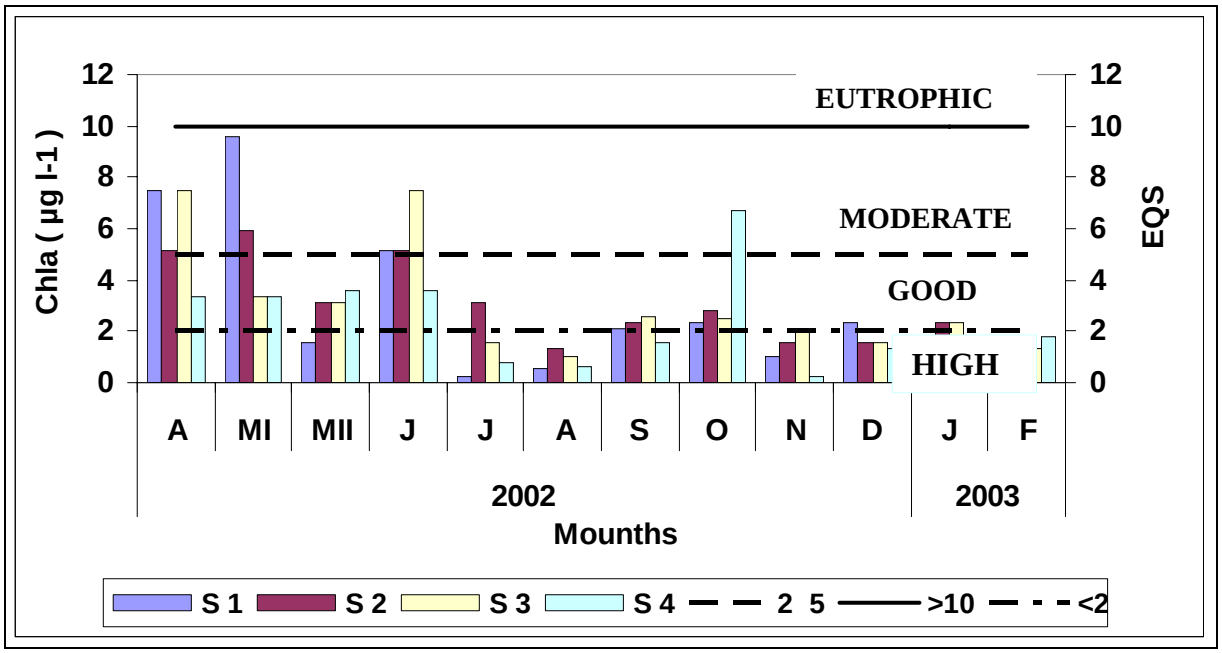



*Figure 2. Classification of Ecological Quality Status based on chlorophyll a concentrations in Duden river estuary.*

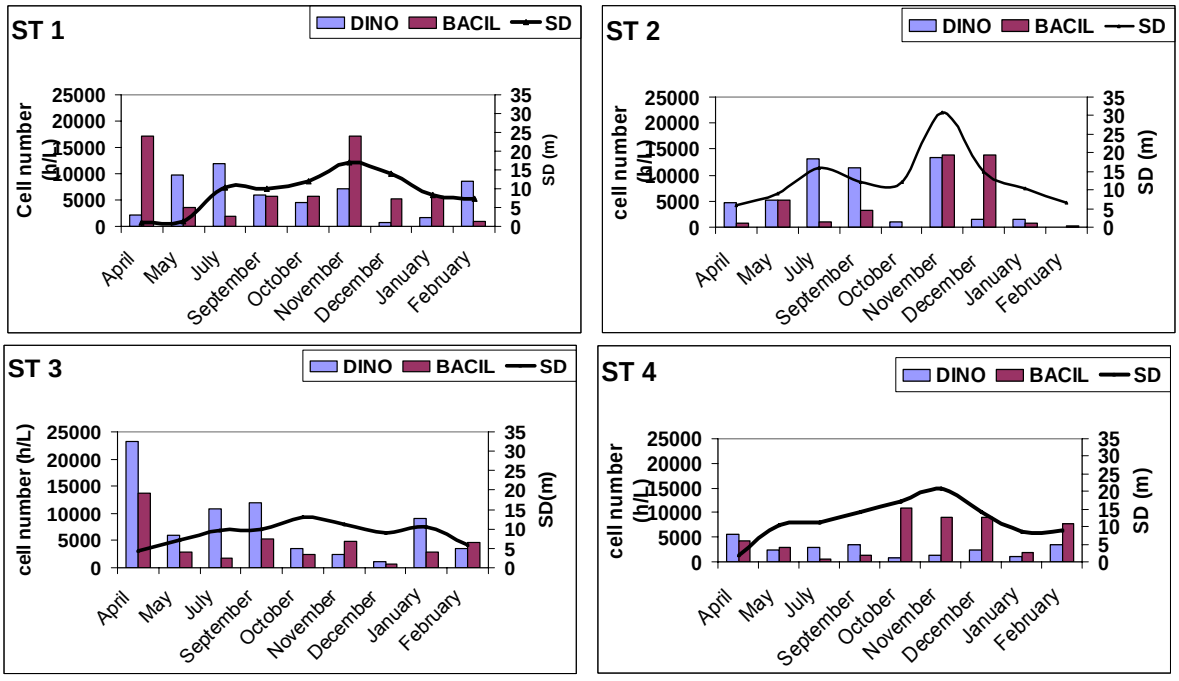



*Figure 3. Cell concentrations and light transparency in the entire sampling period.*

## 4. CONCLUSION

The research area shows a mesotrophic characteristic with the effect of the river in spring and autumn months whereas shows an oligotrophic characteristic in summer and winter months. Although a serious ecosystem damage was not observed here, it is remarkable that ecologic indices reached sustainability limits in the spring blooms period.

It has not been found strong between Trix index and chlorophyll a ($r=0.15$, $p< 0.01$). EcoQ which has been calculated based on Chl *a* concentration has been a more precise scale. EQR scale varies between "high" and "good" quality, and the highest variability has been observed in spring months. Although a precise evaluation has not been possible due to the fact that data set has been for 1 year, it is considered that it will be a reference for the classification of the region according to WFD rules. Consequently, the points under the river effect have been found as moderate quality which coincides with the spring blooms in this case; and they have been found as high quality according to the general condition. According to the criteria of water framework directive, a long term observation study is required to evaluate more precisely the quality of Antalya Bay estuaries and the seawater.

**Acknowledgements:** This study was supported by The Scientific and Technical Research Council of Turkey (Project no: 101Y065) (TUBITAK).

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