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Riverine nutrient inputs to the Mersin Bay, northeastern Mediterranean

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In this study, biochemical (nutrients, total phosphorus (TP), biological oxygen demand) parameters were determined seasonally at downstream points of the five regional rivers (major/small ones: Ceyhan, Seyhan, Goksu, Berdan, Lamas) flowing into wide shelf zone of the northeastern (NE) Mediterranean. Long-term chemical data obtained seasonally in the 2008-2015 period were examined to assess seasonal variations in the chemical concentrations and annual mass influxes to the studied coastal sites, leading to better understanding of impacts of riverine nutrient inputs on the development of eutrophication in the Mersin Bay coastal regions. Expectedly, seasonal and annual variations were recorded in both volume fluxes and nutrient concentrations of the major rivers (Seyhan, Ceyhan, Goksu). The higher nutrient concentrations were consistently recorded in late winter-spring periods. Silicate concentrations, ranging between 95-140 µM in 2008-2011 period, decreased by about 20-40% to 90-110 µM levels in 2012-2015 as the NO_3 consistently increased by about 20%, leading to apparent decreases in the Si/NO_3 ratio due to new dam constructions on the regional rivers and enhanced fertilization and domestic wastewater discharges to the rivers. The total annual nutrient loads of the regional rivers were calculated as TP: 1990 tonnes/yr, PO_4: 1024 tonnes/yr, NO_3: 19420 tonnes/yr and reactive-Si: 38780 tonnes/yr. This long-term decreasing trends in the reactive silicate loads of the nitrate-laden major rivers are very likely to modify Diatom/Dinoflagellate ratio of algal production and abundance in the phosphorus deficient NE Mediterranean shelf waters.

Keywords: Riverine nutrient inputs, eutrophication, Mersin Bay, northeastern Mediterranean

Introduction

The surface layer water of northeastern Mediterranean is saltier than in the western basin due to limited freshwater inflows but excess evaporation during most of the year (Figure 1). The Eastern Mediterranean is a typical example of oligotrophic sea over the world. However, the wide shelf basin of the NE Mediterranean is fed by nitrate and silicate laden regional rivers (major ones: Seyhan, Ceyhan, Goksu; small ones: Berdan, Lamas) contaminated by inorganic and organic pollutants of different origins mainly by domestic and agricultural wastewater discharges and surface runoff during wet winter-spring period (Dogan-Saglamtimur & Tugrul, 2004; Tugrul *et al.*, 2009; 2011; 2016; 2018; MoEU-DGEIAPI & TUBITAK-MRC, 2015; 2016; 2017). Excess nutrient inputs to the semi-enclosed bays on the wide shelf of NE Mediterranean have enhanced eutrophication in the inner bay surface waters of Mersin Bay (Tugrul *et al.*, 2009; 2011; 2016; 2018). Nutrient concentrations of the major rivers measured seasonally between 1995 and 2008 were used to assess annual mass influxes to the sea (Tugrul *et al.*, 2009). Comparison of river fluxes and the domestic wastewater discharges of the Mersin city clearly show that the NE Mediterranean coastal waters are principally fueled by the riverine nutrient inputs (Tugrul *et al*, 2009). However, wastewater discharges have highly influenced the inner part of the bay due to limited ventilation of the shallow inshore waters by the open sea, leading the development of mesotrophic/eutrophic conditions in the Mersin and Iskenderun inner bay waters (Tugrul *et al*, 2018). Ceyhan River waters flow into the outer part of Iskenderun Bay whereas Seyhan, Berdan, Goksu and Lamas rivers feed the oligotrophic waters of the Mersin bay (Tugrul *et al.*, 2018). For the assessment of eutrophication and action plans to sustain healthy ecosystem for the NE Mediterranean coastal region, quantification of terrestrial (natural+anthropogenic) nutrient and organic matter inputs is essential. This study aims to determine seasonal/annual averages of nutrient concentrations and annual fluxes of nutrients carried by the major regional rivers to the entire Mersin Bay and Iskenderun outer bay (Figure 1) occupied by the NE Mediterranean oligotrophic waters.

Material and Methods

Freshwater samples were collected seasonally at the downstream points of five regional rivers (major ones: Ceyhan, Seyhan, Goksu; small ones: Berdan, Lamas; see Figure 1) in the period of 2008-2015. The concentrations of total phosphorus (TP), inorganic nutrients (nitrate (NO_3), nitrite (NO_2), ammonium (NH_4), phosphate (PO_4), reactive silicate (Si)) and biological oxygen demand (BOD_5) were measured by the conventional chemical methods.

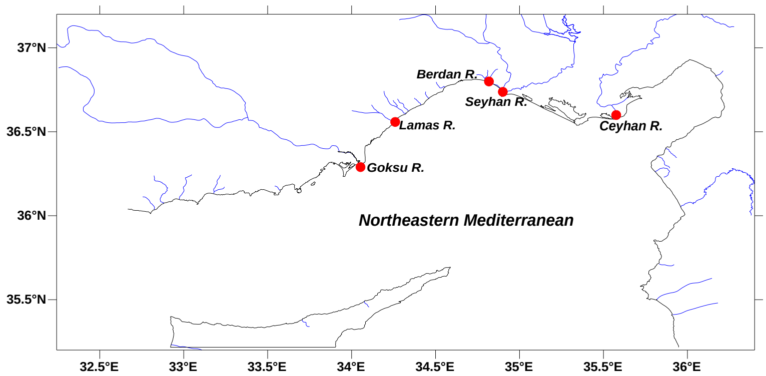

Figure 1. Locations of the studied river stations.

Dissolved inorganic nutrients were determined by the automated colorimetric methods, using a Bran+Luebbe Model four-channel Autoanalyzer (Grasshoff et al., 1983). Water samples for total phosphorus (TP) were digested by perfsulfate oxidation method (Menzel & Corwin 1965). After pH adjustment and reagent addition, the absorbance of each sample was measured manually by the conventional colorimetric method at 880 nm wavelength (Grasshoff et al., 1983). Dissolved oxygen concentrations in river water were measured by a WTW inoLab Oxi 730 Model oxygen meter. Five-day Biological oxygen demand (BOD_5) concentrations, an indicator of biodegradable organic compounds in water, were determined by the changes in dissolved oxygen concentrations of the samples over a five-day period.

Annual chemical (nutrients, TP) fluxes of the monitored rivers were calculated by multiplication of annual averages of chemical concentrations measured seasonally and freshwater discharge rates of the rivers obtained from General Directorate of State Hydraulic Works, Turkey (Kocak et al., 2010).

Results

The seasonal and annual averages of chemical concentrations measured in the five regional rivers for the 2008-2015 period are depicted in Table 1, showing remarkable seasonal variations with the peak values reached in the wet winter-spring seasons. Maximum nutrient concentrations were expectedly recorded in the contaminated Seyhan and Ceyhan Rivers whilst lowest concentrations were determined in the least contaminated Lamas River having the lowest volume flux. Enhanced flow rates and nutrient contents of the major rivers have increased chemical loads of the rivers in late winter-spring periods. Maximum concentrations of seasonal TP (12-33 μM) and PO_4 (3-29 μM) were recorded in Seyhan and Ceyhan Rivers. The least contaminated small Lamas River waters contained lower nutrient concentrations (TP: 0.1-9.6 μM; PO_4: 0.02-1.37 μM). Nitrate and reactive silicate contents of the five rivers are seasonally variable (NO_3: 64.1-167 μM; Si: 84.2-169 μM) with the Si/NO_3 ratio ranging seasonally between 0.73-2.0. Five-day Biological Oxygen Demand (BOD_5) concentrations, an indicator of biodegradable organic matter in water, varied seasonally from 0.95 in the least contaminated Lamas River to 5.89 in the polluted in Seyhan River water in winter-spring periods. The mean annual nutrient loads of the five major rivers in the 2008-2015 period were calculated from the annual nutrient concentrations (Table 2) and annual discharge rates of the rivers as TP: 1990 tonnes/yr, PO_4: 1024 tonnes/yr, NO_3: 19420 tonnes/yr and reactive-Si: 38780 tonnes/yr (Table 3).

Table 1. Concentrations of dissolved inorganic nutrients and BOD_5 values in the five-regional rivers between 2008 and 2015.

River (Discharge; m^3/s*)	Season	TP (μM)	PO_4 (μM)	NO_3 (μM)	NO_2 (μM)	NH_4 (μM)	Si (μM)	Si/NO_3	NO_3/PO_4	BOD_5 (mg/L)
Ceyhan (144)	Autumn	4.61	0.97	118.76	4.18	12.06	145.27	1.27	170.9	1.67
	Winter	6.39	3.23	167.07	3.01	17.28	141.29	1.01	147.0	2.85
	Spring	3.82	1.05	141.05	4.12	18.82	135.30	1.05	218.2	2.72
	Summer	2.55	0.97	125.13	6.42	7.94	169.01	1.45	167.5	2.07
Seyhan (168)	Autumn	8.55	6.32	166.73	16.02	40.00	98.84	0.73	43.5	4.93
	Winter	5.06	2.04	92.80	3.12	39.89	91.23	1.57	75.2	5.89
	Spring	6.08	4.04	117.82	8.75	14.89	93.68	1.28	99.6	4.58
	Summer	8.92	4.31	93.88	6.64	8.72	89.92	1.55	97.7	4.75
Berdan (6)	Autumn	5.09	2.48	95.86	4.57	12.68	87.55	1.01	87.5	2.16
	Winter	4.34	1.57	97.36	2.16	23.03	127.74	1.47	115.8	2.95
	Spring	3.68	1.34	100.44	1.12	12.90	87.35	0.97	113.6	2.87
	Summer	4.14	2.22	84.35	3.60	8.39	88.82	1.12	69.5	2.06
Lamas (3)	Autumn	1.57	0.12	94.46	0.74	1.08	86.28	0.95	932.1	1.11
	Winter	1.56	0.08	102.98	0.60	0.69	99.49	1.04	1631.6	1.08
	Spring	2.15	0.28	93.37	0.25	1.84	84.17	0.96	991.9	1.57
	Summer	1.16	0.11	83.96	0.50	1.54	110.14	1.51	1303.4	0.95
Goksu (45)	Autumn	2.06	0.64	64.11	1.40	10.29	126.94	2.00	140.8	1.68
	Winter	3.35	0.53	66.72	0.60	2.82	101.75	1.74	171.0	1.40
	Spring	3.36	0.69	68.17	0.77	3.77	118.26	1.96	152.9	1.45
	Summer	3.17	1.05	72.97	2.31	4.24	108.46	1.67	237.7	1.23

* Discharge rates were retrieved from Kocak *et al.*, 2010.

Discussion

The majority of the nutrient inputs (>90%) to NE Mediterranean shelf are introduced by the major three rivers. The seasonal fluxes reached the maximum levels in winter-spring periods due to enhanced volume fluxes and nutrient concentrations. It should be noted that Si/NO_3 ratio in the river water was apparently variable with season (Table 1), decreasing to very low levels (about 0.1) in the dry late summer-autumn period in the polluted Seyhan River and reaching levels of 2.5-5.2 in wet winter-spring in Berdan, Lamas and Goksu Rivers. Annual averages of long-term silicate data obtained in the rivers display decreasing trend from 95-140 μM in 2008-2011 to 93-110 μM levels in 2012-2015 (Table 2) whilst the annual NO_3 concentrations have consistently increased by about 18-

20% in the same period, leading to apparent decreases in the Si/NO_3 ratio in the river inflow during the last two decades due to dam constructions on the regional rivers and enhanced fertilization. However, the annual averages of NO_3/PO_4 ratio were consistently high (>40) in the regional river waters, leading to development of P-limited algal production in the NE Mediterranean shelf waters fed by nitrate and silicate laden river inflows.

Table 2. Annual mean nutrient concentrations of the regional rivers flowing to the Mersin Bay coastal zone (4 rivers) and Iskenderun outer bay (Ceyhan River) in 2008-2015 period.

Year	TP (µM)	PO_4 (µM)	NO_3 (µM)	NO_2 (µM)	NH_4 (µM)	Si (µM)	Si/NO_3	NO_3/PO_4	BOD_5 (mg/L)
2008	7.48	5.73	146.83	9.13	23.56	137.29	0.94	25.61	2.58
2009	5.35	2.32	101.49	2.35	7.14	113.74	1.12	43.78	1.63
2010	2.46	0.86	103.98	2.70	5.68	139.92	1.35	120.69	1.40
2011	3.03	0.79	65.63	3.06	11.49	95.47	1.45	82.82	
2012	4.56	1.06	92.24	2.51	6.73	93.20	1.01	87.11	1.90
2013	3.55	1.02	86.33	3.16	11.83	104.52	1.21	84.54	2.13
2014	3.02	1.65	99.64	2.86	15.63	100.65	1.01	60.28	3.98
2015	3.11	1.04	123.82	2.86	14.46	109.77	0.89	119.32	3.46
Average	4.07	1.81	102.49	3.58	12.07	111.82	1.12	78.02	2.44

Table 3. The total annual nutrient loads of the regional rivers entering the entire Mersin Bay (Seyhan, Berdan, Lamas, Goksu) and Iskenderun outer bay (Ceyhan River) in 2008-2015 period.

Year	TP (tonnes/y)	PO_4 (tonnes/y)	NO_3 (tonnes/y)	NO_2 (tonnes/y)	NH_4 (tonnes/y)	Si (tonnes/y)
2008	4453	3504	31701	2561	3551	41129
2009	2511	1391	19984	492	1551	45480
2010	1011	432	20201	727	864	46376
2011	1238	360	11666	838	2470	34133
2012	1756	559	16250	724	1987	33452
2013	1581	501	14468	881	3135	39142
2014	1831	1021	17185	775	4760	34018
2015	1539	429	23895	733	4047	36484
Average	**1990**	**1024**	**19420**	**966**	**2796**	**38780**

In conclusion, significant spatial and annual variations were recorded in both volume fluxes and nutrient concentrations of the regional rivers of NE Mediterranean as previously reported by Kocak *et al.* (2010). Silicate content of the major rivers has decreased in the last decade due to damming of Si-enhanced fresh waters at the upstream points (Table 2), leading to apparent decreases in the Si/NO_3 ratio of the major river inflows to the sea. The long-term change in the Si/NO_3 ratio in the major river discharges is very likely to modify Diatom/Dinoflagellate ratio of algal abundance in the phosphorus deficient NE Mediterranean productive shelf waters. The enhanced nutrient inputs from the terrestrial sources with modified N/P/Si ratios have led to development of mesotrophic/eutrophic conditions in the inner bay waters of NE Mediterranean (Tugrul *et al*., 2018).

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References

Dogan-Saglamtimur., N. & Tugrul, S., 2004. Effect of riverine nutrients on coastal water ecosystems: A case study from the Northeastern Mediterranean Shelf. Fresenius Environmental Bulletin, 13, 1288-1294.

Grasshoff, K., Erhardt, M. & Kremlin, K., 1983. Determination of nutrients. In: Methods of Seawater Analysis (2nd ed.), Verlag Chemie Gmbh, Weiheim, Germany, pp. 125-188.

Kocak, M., Kubilay, N., Tugrul, S. & Mihalopoulos, N., 2010. Atmospheric nutrient inputs to the northern levantine basin from a long-term observation: sources and comparison with riverine inputs. Biogeosciences, 7, 12, 4037-4050.

Menzel, D.W. & Corwin, N., 1965. The measurement of total phosphorus in seawater based on the liberation of organically bound fractions by persulfate oxidation. Limnology and Oceanography, 10, 280-282.

MoEU-DGEIAPI & TUBITAK-MRC, 2015. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.14.204 (Mediterranean Final Report, 2014), April 2015, Gebze-Kocaeli.

MoEU-DGEIAPI & TUBITAK-MRC, 2016. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.15.262 (Mediterranean Final Report, 2015), April 2016, Gebze-Kocaeli.

MoEU-DGEIAPI & TUBITAK-MRC, 2017. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.16.332 (Mediterranean Final Report, 2016), May 2017, Gebze-Kocaeli.

Strickland, J.D.H. & Parsons T.R., 1972. A Practical Handbook of Seawater Analysis, 2nd edition. Bulletin of the Fisheries Research Board of Canada, No. 167, 310 pp.

Tugrul, S., Kuçuksezgin, F., Yemenicioglu, S. & Uysal, Z., 2009. Long Term Biomonitoring, Trend and Compliance Monitoring Program in Coastal Areas from Aegean, Northeastern Mediterranean and Eutrophication Monitoring in Mersin Bay (MEDPOL Phase IV). Ministry of Environment and Forestry, Ankara.

Tugrul, S., Ozhan, K. & Akcay, I., 2018. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-018-2529-6.

Tugrul, S., Uysal, Z., Erdogan, E. & Yucel, N., 2011. Changes of eutrofication indicator parameters (TP, DIN, Chl-a and TRIX) in the cilician basin (Northeast Mediterranean). Ekoloji, 20(80), 33-41.

Tugrul, S., Yucel, N. & Akcay, I., 2016. Chemical oceanography of north eastern Mediterranean. In: The Turkish part of the Mediterranean Sea; Marine Biodiversity, Fisheries, Conservation and Governance. (Turan, C., Salihoglu, B., Ozbek, E.O and Ozturk, B). Turkish Marine Research Foundation (TUDAV), Publication No: 43, Istanbul, Turkey, 15-29.

Biochemical quality elements for the assessment of eutrophication in Mersin & Iskenderun Bays (northeastern Mediterranean)

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Eutrophication-related physical and biochemical parameters were measured in shallow coastal waters of both bays located in northeastern Mediterranean during summer and winter for the period 2014-2018 to assess present trophic status of the coastal areas receiving substantial amount of nutrients and organic matter from the local perennial rivers and direct discharges of domestic wastewaters. For this goal, HELCOM Eutrophication Assessment Tool (HEAT 3.0) widely used in the enclosed Baltic Sea has been adapted to the Çukurova basin shelf waters. This tool is based on the determination of Eutrophication Ratios (ERs) of state (nutrients), direct (biomass; chlorophyll-*a*, phytoplankton composition; Diatom/Dinoflagellate ratio, Secchi Disk Depth) and indirect indicators (deep water dissolved oxygen saturation level) measured at selected sites of the two bays, relative to an average "Eutrophication Quality Target" for each indicator by using data sets obtained from the least contaminated offshore ones. The averages of ER values for each parameter were determined to obtain a final ER level from the state, direct and indirect indicators for each station (site) of the visited regions. The present results clearly show that 8 stations (out of 14 stations) in the inner bay waters of Iskenderun and Mersin have been affected from the eutrophication displaying ER values greater than 1.0 while offshore waters display oligotrophic properties (ER<1.0). This study is an initial attempt to use an integrated multi-metric assessment of trophic status in the NE Mediterranean including both direct and indirect indicators of eutrophication.

Keywords: Trophic status assessment, eutrophication, Mersin Bay, Iskenderun Bay, northeastern Mediterranean

Introduction

Offshore waters of the northeastern Mediterranean (Figure 1) are known as one of the highly oligotrophic basins with limited nutrient supply to its surface waters from internal and external sources (UNEP, 1989; Yılmaz & Tuğrul, 1998; Kress & Herut, 2001; Krom *et al.*, 2004). However, its coastal ecosystems composed mainly of shallower Mersin and Iskenderun inner bays (Figure 1) are highly influenced from nutrient and organic matter inputs of terrestrial origin carried by local perennial rivers. Moreover, pollutants of agricultural and industrial origin as well as municipal domestic waste water discharges add more to development of eutrophic conditions in the shallower inner bays (Dogan-Saglamtimur & Tugrul, 2004; Tugrul *et al.*, 2009; 2011; 2016; 2018; MoEU-DGEIAPI & TUBITAK-MRC, 2015; 2016; 2017). Eutrophication-related physical and biochemical parameters were measured in Mersin and Iskenderun bays in the summer and winter periods of 2014-2018 to assess present trophic status of the coastal waters fed by terrestrial inputs during the year. HELCOM Eutrophication Assessment Tool (HEAT 3.0) (Andersen *et al.*, 2015) developed for the highly eutrophic Baltic Sea has been adapted to the Çukurova shelf basin waters using state (nutrients), direct (biomass;

chlorophyll-*a*, phytoplankton composition; Diatom/Dinoflagellate ratio, Secchi Disk Depth) and indirect indicators (deep water dissolved oxygen saturation level) of eutrophication.

Material and Methods

Field surveys in the Mersin and Iskenderun Bay coastal and offshore regions (Figure 1) were conducted using R/V BILIM-2 of METU-IMS. At the selected stations, physical measurements (*in situ* temperature, salinity, density, fluorescence, turbidity) were carried out by a SEABIRD model CTD probe coupled to a 12-PVC Niskin Bottles Rosette System by which seawater samples were obtained from selected depths by remote-control. The Secchi Disk Depth (SDD), a rough estimation of water transparency, was measured at each station during day time (UNEP/MAP, 2005). Dissolved oxygen measurements were carried out by the automated Winkler titration method (Grasshoff *et al.*, 1983; UNEP/MAP, 2005). Dissolved inorganic nutrients (nitrate, nitrite, ammonium, phosphate, silicate) were determined by the conventional automated colorimetric method using a Bran+Luebbe Model four-channel Autoanalyzer (Grasshoff *et al.*, 1983). Total phosphorus measurements were carried out by the colorimetric method at 880 nm wavelength (Strickland & Parsons, 1972; Grasshoff *et al.*, 1983) after persulfate digestion of samples in pre-cleaned glass bottles under high pressure and temperature (2 atm, 100 ˚C) (Menzel & Corwin, 1965). Chlorophyll-*a* (Chl-*a*) measurements were performed by the conventional spectrofluorometric method after digestion of filter samples by 90% acetone solution (vol/vol) (Strickland and Parsons, 1972; UNEP/MAP, 2005) using a HITACHI model F-2500 Fluorescence Spectrophotometer. Diatom/Dinoflagellate ratio was calculated following qualitative and quantitative inspection of glutaraldehyde fixed phytoplankton samples under a phase-contrast inverted microscope.

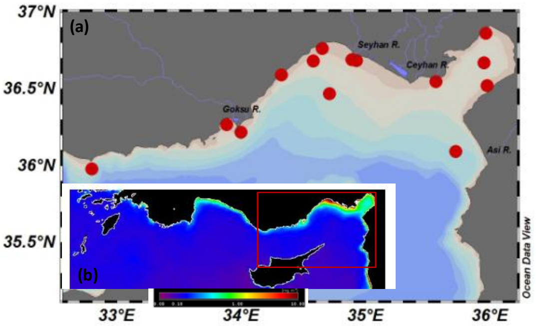

Figure 1. (a) Sampling locations and (b) average surface chlorophyll-*a* (mg/m^3) distribution obtained by Satellite MODIS Aqua in the Cilician basin of the NE Mediterranean in 2009.

Eutrophication status of Mersin and Iskenderun inner bays and offshore regions was determined by the third version of the HELCOM Eutrophication Assessment Tool (HEAT 3.0) (Andersen *et al.*, 2015) in which Eutrophication Ratios (ERs) were calculated using Eutrophication Quality Target (ET) values defined in the studied region of NE Mediterranean. The "good/moderate" boundaries (unaffected/affected by eutrophication) for eutrophication indicators defined for the NE Mediterranean were obtained from the results of Tugrul *et al.* (2018).

Results

Surface layer salinity in the Mersin and Iskenderun Bays varied regionally and seasonally between 37.3 and 39.8 with lower values in the river-fed coastal sites in wet winter periods. Surface salinity values were higher in the offshore during summer due to limited effect of freshwater inflows and increasing evaporation (Table 1). Similar spatio-temporal variations were observed in the SDD measurements, ranging <0.5 m in the nearshore zone to 39 m in the offshore waters in summer (Figure 2). Dissolved inorganic nutrient concentrations measured in surface waters of the visited sites displayed remarkable spatial and temporal variations (Table 1; Figure 2). Peak values were observed in the coastal waters fed by riverine and wastewater inputs. Summer nutrient concentrations were consistently lower than the wet winter values due to apparent decreases in river inflows and atmospheric wet deposition during dry summer period. NO_x (referred to NO_3+NO_2) concentrations varied regionally from 0.04-4.35 μM in summer to 0.07-24.50 μM in wet winter; higher NO_x values were observed in less saline coastal waters (S<39.0). Dissolved inorganic nitrogen (DIN=NO_3+NO_2+NH_4) concentrations ranged between 0.13 to 46.7 µM in surface waters of the two bays, with peak values in the polluted inner bay waters and river-fed less saline shallow zones. Surface PO_4 concentrations displayed similar spatial pattern in the NE Mediterranean shelf waters; lower values in the offshore waters (0.02-0.04 µM) increasing to 0.29 µM in the less saline coastal waters.

Table 1. The winter and summer results of eutrophication-related parameters measured in the Mersin and Iskenderun Bays during the 2014-2018 period.

Winter	Salinity	TP (µM)	PO_4 (µM)	NO_x (µM)	DIN (µM)	Si (µM)	DWDO (% sat.)	Chl-*a* (µg/L)	SDD (m)	Diatom/Dinoflagellate
Mean	38.96	0.19	0.05	1.54	1.87	2.29	99.06	0.42	11.21	52.8
Std. Dev.	0.40	0.10	0.03	3.21	3.33	3.08	2.69	0.38	6.28	55.1
Min.	37.27	0.08	0.02	0.07	0.23	0.62	87.39	0.09	0.10	0.3
Max.	39.43	0.85	0.29	24.50	25.24	24.07	106.22	1.70	28.00	233.1
N	113	113	113	113	113	113	113	113	112	36
Summer	Salinity	TP (µM)	PO_4 (µM)	NO_x (µM)	DIN (µM)	Si (µM)	DWDO (% sat.)	Chl-*a* (µg/L)	SDD (m)	Diatom/Dinoflagellate
Mean	39.33	0.19	0.04	0.41	1.10	1.78	98.30	0.33	12.80	15.4
Std. Dev.	0.28	0.08	0.03	0.61	3.78	1.40	7.00	0.48	8.09	20.3
Min.	38.31	0.06	0.02	0.04	0.13	0.50	74.96	0.02	1.00	0.5
Max.	39.78	0.65	0.21	4.35	46.72	7.98	113.27	4.65	39.00	96.0
N	158	156	158	158	158	158	158	157	155	47

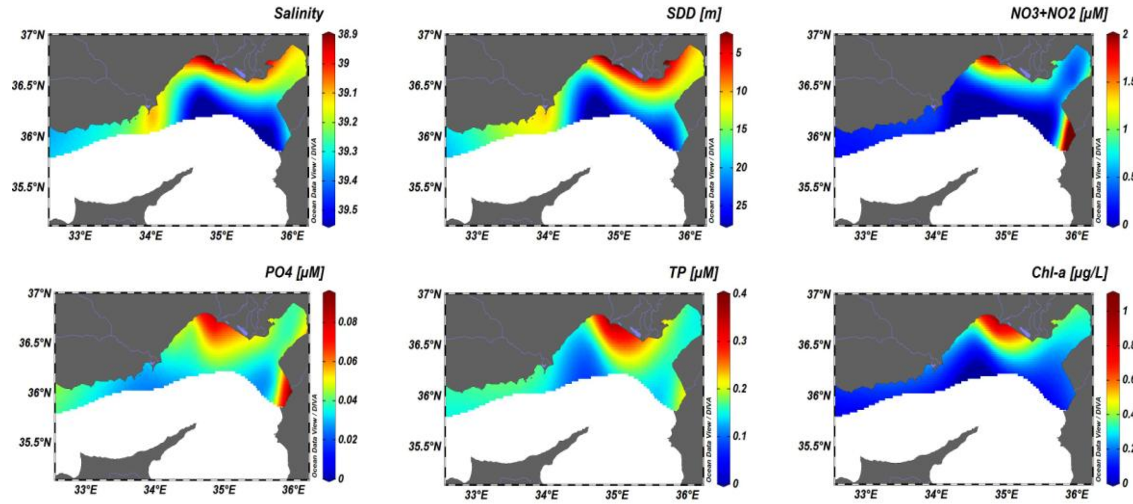

Figure 2. Surface layer (0-10 m average) distributions of summer-winter average values of eutrophication indicator parameters in the Cilician Shelf including two bays for the 2014-2018 period.

Surface Si concentrations were markedly low in the offshore (0.50-1.0 µM) reaching peak values (8-24 µM) in the river-fed delta waters. Expectedly, dissolved inorganic nutrients and TP values measured within the study period displayed similar spatio-temporal variations; increasing apparently in wet winter period (Table 1). Nutrient inputs from external sources enhanced algal biomass (in terms of Chl-*a*) in the coastal waters. Chl-*a* values varied from 1.0-4.65 µg/L in less saline coastal waters to 0.02-0.10 µg/L in the offshore waters of the two bays. No oxygen deficiency (suboxic condition) was observed in the bottom waters of Mersin and Iskenderun Bays (Table 1; Figure 2). Diatom/Dinoflagellate ratios based on individual cell counts varied between a summer minimum of 3.3 and a winter maximum of 116.6 in the region indicating direct role of changes in nutrient concentrations relative to each other as well as temperature regulating spatial and temporal heterogeneity in phytoplankton group assemblages in the area (Figure 3).

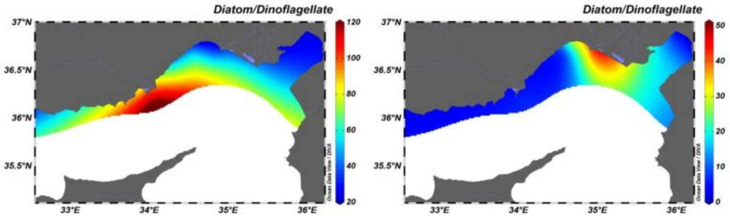

Figure 3. Winter (left) and summer (right) average values of Diatom/Dinoflagellate ratios at surface waters of both bays for the 2014-2018 period.

Discussion

Surface layer concentrations of eutrophication-related biochemical parameters displayed apparent decreases from inner bay/river delta to offshore waters (Figure 2). The present results are in agreement with the recent studies conducted in these bays and wide shelf waters of NE Mediterranean (Dogan-Saglamtimur & Tugrul, 2004; Tugrul *et al.*, 2009; 2011; 2016; 2018; MoEU-DGEIAPI & TUBITAK-MRC, 2015; 2016; 2017). Impacts of terrestrial inputs on nutrient and Chl-*a* concentrations were markedly high in the less saline coastal zone and inner bay waters of Mersin and Iskenderun Bays, leading to apparent decrease in SDD values.

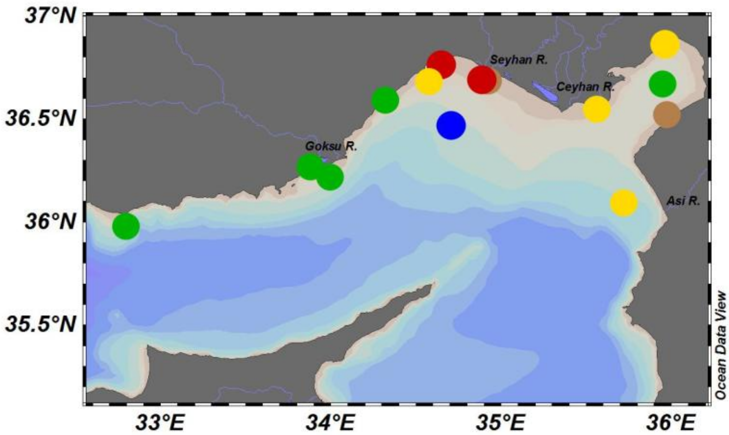

Figure 4. Present eutrophication status of the Cilician shelf including Mersin and Iskenderun Bays, NE Mediterranean, assessed by the HEAT 3.0 (color codes; Blue: High, Green: Good (unaffected by eutrophication), Yellow: Moderate, Brown: Poor, Red: Bad (affected by eutrophication).

These results show the development of eutrophication in the coastal and inner bay waters of the studied sites. For this goal, HELCOM Eutrophication Assessment Tool (HEAT 3.0) was used to assess the current trophic status of the studied regions. The averages of calculated ER values for each parameter are depicted in Figure 4, exhibiting the "bad" trophic conditions developed in the inner bay waters of Mersin Bay and coastal waters polluted by Asi River inflow enhancing markedly in winter period.

In conclusion, the present classification results clearly show that 8 stations (out of 14 stations) in the inner bay waters of Iskenderun and Mersin have been affected by eutrophication (both natural and human-induced nutrient inputs) having ER greater than 1.0 while offshore waters display oligotrophic properties (ER<1.0) (Figure 4). This study is an initial attempt to use an integrated multi-metric assessment of trophic status in the NE Mediterranean including both direct and indirect indicators of eutrophication.

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References

Andersen, J.H., Carstensen, J., Conley, D.J., Dromph, K., Fleming-Lehtinen, V., Gustafsson, B.G., *Josefson, A.B., Norkko, A.,* Villnäs, A. & Murray, C., 2015. Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. Biological Reviews. doi: 10.1111/brv.12221.

Dogan-Saglamtimur., N. & Tugrul, S., 2004. Effect of riverine nutrients on coastal water ecosystems: A case study from the Northeastern Mediterranean Shelf. Fresenius Environmental Bulletin, 13, 1288-1294.

Grasshoff, K., Erhardt, M. & Kremlin, K., 1983. Determination of nutrients. In: Methods of Seawater Analysis (2^{nd} ed.), Verlag Chemie Gmbh, Weiheim, Germany, pp. 125-188.

Kress, N. & Herut, B., 2001. Spatial and seasonal evolution of dissolved oxygen and nutrients in the Southern Levantine Basin (Eastern Mediterranean Sea). Chemical characterization of the water masses and inferences on the N:P ratios. Deep-Sea Research I, 48, 2347-2372.

Krom, M. D., Herut, B. & Mantoura, R.F.C., 2004. Nutrient budget for the Eastern Mediterranean: Implications for phosphorus limitation. Limnology and Oceanography, 49(5), 1582-1592.

Menzel, D.W. & Corwin, N., 1965. The measurement of total phosphorus in seawater based on the liberation of organically bound fractions by persulfate oxidation. Limnology and Oceanography, 10, 280-282.

MoEU-DGEIAPI & TUBITAK-MRC, 2015. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.14.204 (Mediterranean Final Report, 2014), April 2015, Gebze-Kocaeli.

MoEU-DGEIAPI & TUBITAK-MRC, 2016. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.15.262 (Mediterranean Final Report, 2015), April 2016, Gebze-Kocaeli.

MoEU-DGEIAPI & TUBITAK-MRC, 2017. Integrated Marine Pollution Monitoring Project (2014 – 2016). ECPI 5148704, Report No. ÇTÜE.16.332 (Mediterranean Final Report, 2016), May 2017, Gebze-Kocaeli.

Strickland, J.D.H. & Parsons T.R., 1972. A Practical Handbook of Seawater Analysis, 2nd edition. Bulletin of the Fisheries Research Board of Canada, No. 167, 310 pp.

Tugrul, S., Kuçuksezgin, F., Yemenicioglu, S. & Uysal, Z., 2009. Long Term Biomonitoring, Trend and Compliance Monitoring Program in Coastal Areas from Aegean, Northeastern Mediterranean and Eutrophication Monitoring in Mersin Bay (MEDPOL Phase IV). Ministry of Environment and Forestry, Ankara.

Tugrul, S., Ozhan, K. & Akcay, I., 2018. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-018-2529-6.

Tugrul, S., Uysal, Z., Erdogan, E. & Yucel, N., 2011. Changes of eutrofication indicator parameters (TP, DIN, Chl-a and TRIX) in the cilician basin (Northeast Mediterranean). Ekoloji, 20(80), 33-41.

Tugrul, S., Yucel, N. & Akcay, I., 2016. Chemical oceanography of north eastern Mediterranean. In: The Turkish part of the Mediterranean Sea; Marine Biodiversity, Fisheries, Conservation and Governance. (Turan, C., Salihoglu, B., Ozbek, E.O and Ozturk, B). Turkish Marine Research Foundation (TUDAV), Publication No: 43, Istanbul, Turkey, 15-29.

UNEP, 1989: State of the Mediterranean Marine Environment. MAP Technical Series No. 28, UNEP, Athens.

UNEP/MAP, 2005: Sampling and analysis techniques for the eutrophication monitorıng strategy of MED POL, MAP Technical Reports Series No. 163, Athens.

Yılmaz, A. & Tuğrul, S., 1998. The effect of cold- and warm- core eddies on the distribution and stoichiometry of dissolved nutrients in the northeastern Mediterranean. Journal of Marine Systems, 16, 253-268.