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Nutrient inputs from two major rivers into the cilician basin of the north-eastern Mediterranean Sea

by

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Abstract

In this study, dissolved nutrients concentrations were measured monthly at downstream points of the two regional rivers (the Berdan and Göksu rivers) flowing into the Cilician Basin of the North-eastern (NE) Mediterranean Sea. The dissolved nutrients data obtained between September 2021 and August 2022 were used to determine riverine nutrient fluxes. This study showed that spatial and temporal variations were recorded in nutrients concentrations of the two regional rivers with the maximum values consistently recorded in the Berdan River having lower volume fluxes. The annual nutrient inputs of the two regional rivers indicated that higher amounts of dissolved nutrients were carried by the Göksu River due to its higher volume flux rate. The calculated molar ratios from total nitrogen (TN) and phosphorus (TP) fluxes ranged from 13 in the Göksu River to 22 in the Berdan River. The higher TN/TP molar ratio compared to the classic Redfield Ratio of N/P in the Berdan River is very likely to modify nutrient dynamics leading to further eutrophication in the shelf waters of the NE Mediterranean Sea.

Key words: Nutrient inputs, eutrophication, Berdan River, Göksu River, North-eastern Mediterranean Sea

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1. Introduction

The estuarine ecosystems, between the riverine systems and coastal waters, are highly influenced by anthropogenic disturbances such as eutrophication driven by wastewater discharges and habitat modifications (Rabalais et al. 2009, Caruso et al. 2010, Gopal et al. 2018, Paula Filho et al. 2020). Determination of riverine nutrient concentrations and their fluxes is essential for the coastal management of marine environments as these nutrient fluxes to the coastal regions highly enhanced primary productivity and coastal eutrophication (Paula Filho et al. 2020). Though the Eastern Mediterranean is an oligotrophic marine environment, the coastal region of the NE Mediterranean Sea is enhanced by nutrients-laden regional rivers highly contaminated by organic and inorganic pollutants mainly by wastewater discharges and surface runoff during the wet winter-spring period (Dogan-Saglamtimur & Tugrul 2004, Tugrul et al. 2009, Tugrul et al. 2011, Tugrul et al. 2016, Tugrul et al. 2019). The nutrient fluxes to the coastal waters of the NE Mediterranean Sea have increased the primary productivity in the inner bays. Surface water Chl-*a* values, for example, in the less saline river-fed coastal waters were documented as high as 3.5 μg l^{-1} but decreased to 0.05 μg l^{-1} levels in the oligotrophic offshore waters (Tugrul et al. 2011).

According to volume fluxes of rivers flowing to the Mediterranean Sea, the 10 largest rivers are the Rhone, Po, Drin-Buna, Nile, Neretva, Ebro, Tiber, Adige, Seyhan and Ceyhan rivers (Ludwig et al. 2009). The continental shelf waters of the NE Mediterranean Sea are fed by nutrient and organic matter inputs from the major rivers (Asi, Ceyhan, Seyhan, Berdan, Göksu, Lamas, Manavgat, Aksu, Eşen Dalaman) and wastewater discharges, leading to the deterioration of water quality and development of eutrophication in the coastal regions.

The Berdan and Göksu rivers are the two important regional rivers flowing into the Cilician Basin of the NE Mediterranean Sea. The Göksu River, about 250 km long, is one of the ecologically important major rivers flowing into the NE Mediterranean coastal region that is highly contaminated by agricultural wastewater discharges (Kılıç 2020). The Berdan River, which passes through the Tarsus district of Mersin, is also one of the important major rivers of the region and is about 124 km long. Berdan River waters are originated from precipitation as rain and snow. The Berdan Dam, constructed on the Berdan River Basin, is used for drinking water needs, agricultural irrigation and electricity production. However, development of eutrophic conditions has been experienced in the Berdan River Basin due to terrestrial inputs originating from agricultural, industrial and domestic wastewater discharges (Özbay et al. 2012). As a result of these organic and inorganic matter inputs, the coastal ecosystem of the NE Mediterranean Sea is significantly altered (Tugrul et al. 2016, Tugrul et al. 2019, Akçay et al. 2022). Therefore, it is of critical importance to quantify terrestrial nutrient and organic matter inputs for the management of eutrophication and action plans to sustain the ecosystem dynamics of the NE Mediterranean shelf waters. This study aimed to determine the current nutrients concentrations and fluxes of the two regional rivers flowing into the Cilician Basin of NE Mediterranean Sea having oligotrophic conditions in its offshore waters (Figure 1).

2. Materials and methods

River water samples were collected monthly at the downstream points of the two regional rivers (the Berdan and Göksu rivers) between September 2021 and August 2022 (Figure 1). The concentrations of nitrate (NO_3-N), phosphate (PO_4-P), total nitrogen

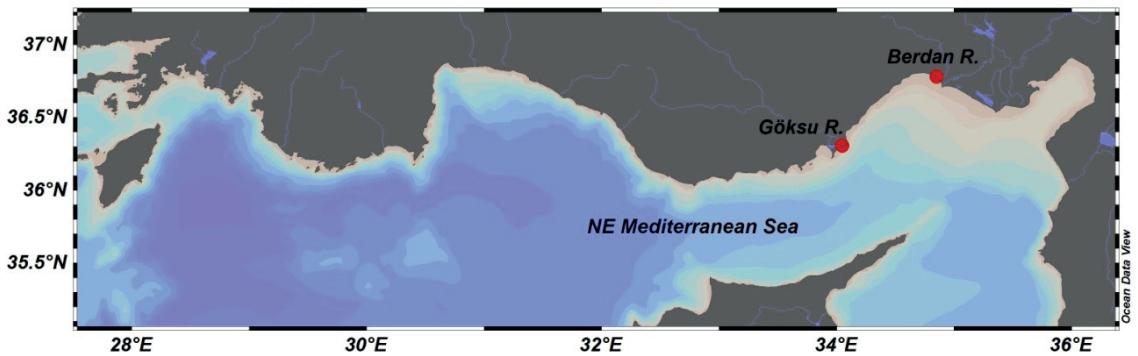

Figure 1

Locations of the studied river stations flowing into the Cilician Basin of the Northeastern Mediterranean Sea

(TN) and phosphorus (TP) were measured by standardised methods (APHA 1998). TN and TP samples were digested by autoclave after addition of persulfate to the river samples. Then, the TN and TP concentrations were determined by colorimetric methods. The measurements of NO_3-N and PO_4-P were also performed by spectrophotometry, but there was no persulfate digestion used for these parameters (APHA 1998). All the spectrophotometric readings were carried out by using Analytik Jena SPECORD 205 Model Spectrophotometer. The annual nutrients fluxes of the two major rivers into the Cilician Basin of the North-eastern Mediterranean Sea were calculated by using annual averages of measured concentrations in this study and discharge rates of the studied rivers obtained from the study of Kocak et al. (2010).

3. Results and discussion

Riverine nutrient fluxes are essential for the coastal management of marine environments since these nutrient fluxes into the coastal regions highly enhance coastal eutrophication (Paula Filho et al. 2020). The study findings showed that nutrients concentrations in the surface waters of the two regional rivers showed remarkable seasonal and regional variations. Maximum concentrations of nutrients were consistently measured in the polluted Berdan River (Table 1). Concentrations of NO_3-N varied between 17.7 and 173 µM whilst PO_4-P concentrations ranged from 2.10 µM in the Göksu River to 54.7 µM in the Berdan River. Similar spatial variability was also recorded for the TN and TP concentrations with the peak values measured in the Berdan River. Concentrations of TP varied regionally from 2.90 µM in the Göksu River to 55.0 µM in the Berdan River. The TN concentrations in the Göksu River ranged between 78.6 and 141 µM reaching to peak values (64.3-643 µM) in the contaminated Berdan River (Table 1).

In this study, riverine nutrient fluxes were calculated from the monthly measured nutrients concentrations (Table 2). It was shown that increased rates of volume fluxes of the two regional rivers have increased nutrients inputs flowing into the Cilician Basin of the NE Mediterranean Sea (Table 2). The mean annual nutrient inputs from the Göksu River in the study period were greater than calculated in the Berdan River due to its higher discharge rate. According to volume fluxes of rivers flowing into the Mediterranean Sea, the 10 largest rivers are the Rhone, Po, Drin-Buna, Nile, Neretva, Ebro, Tiber, Adige, Seyhan and Ceyhan rivers (Ludwig et al. 2009). A recent study performed by Malagó et al. (2019) estimated

Table 1

Concentrations of dissolved nutrients in the two regional rivers between September 2021 and August 2022

Station	Date	NO_3-N (µM)	PO_4-P (µM)	TN (µM)	TP (µM)
Berdan R. Discharge: 6 $m^3 s^{-1}$	Sep 21	127.5	8.42	377.14	8.71
	Oct 21	98.4	54.71	485.71	55.03
	Nov 21	85.5	11.57	642.86	16.13
	Dec 21	90.4	4.21	228.57	9.03
	Jan 22	104.9	19.99	535.71	21.94
	Feb 22	172.6	3.16	207.14	5.48
	Mar 22	167.8	5.26	271.43	6.45
	Apr 22	96.8	5.26	114.29	5.58
	May 22	35.5	3.16	64.29	3.48
	Jun 22	85.5	3.16	157.14	3.48
	Jul 22	137.2	12.62	157.14	12.90
	Aug 22	130.7	10.52	235.71	10.84
Göksu R. Discharge: 45 $m^3 s^{-1}$	Sep 21	17.7	4.21	140.71	24.52
	Oct 21	37.1	2.10	107.14	2.90
	Nov 21	61.3	2.10	100.00	7.10
	Dec 21	67.8	4.21	135.71	4.84
	Jan 22	53.2	6.31	78.57	6.77
	Feb 22	83.9	17.89	84.29	18.06
	Mar 22	56.5	3.16	107.14	3.55
	Apr 22	53.2	4.21	121.43	4.52
	May-22	37.1	4.21	114.29	10.65
	Jun 22	59.7	4.21	135.71	9.68
	Jul 22	62.9	4.21	85.71	4.52
	Aug 22	61.3	4.21	92.86	4.52

Table 2

Mean annual nutrients fluxes of the two regional rivers flowing into the Cilician Basin of the Northeastern Mediterranean Sea

Station	NO_3-N (ton y^{-1})	PO_4-P (ton y^{-1})	TN (ton y^{-1})	TP (ton y^{-1})	TN/TP (molar)
Berdan R.	294	69	768	78	22
Göksu R.	1079	224	2158	373	13

the nutrient discharges into the Mediterranean Sea as 1.87 Tg y^{-1} for total nitrogen (TN), 1.22 Tg y^{-1} for NO_3-N, 0.11 Tg y^{-1} for TP and 0.03 Tg y^{-1} for PO_4-P, respectively, leading to high biological productivity and eutrophication in the river-influenced coastal regions. The study results showed that the contribution of the riverine nutrient fluxes carried by the Berdan and Göksu rivers to total nutrient inputs flowing to the Mediterranean Sea was calculated as 4.10‰ for TP, 9.77‰ for PO_4-P, 1.56‰ for TN and 1.13‰ for NO_3, respectively, highly enhancing coastal eutrophication in the inner bays affected by these regional rivers (Figure 2).

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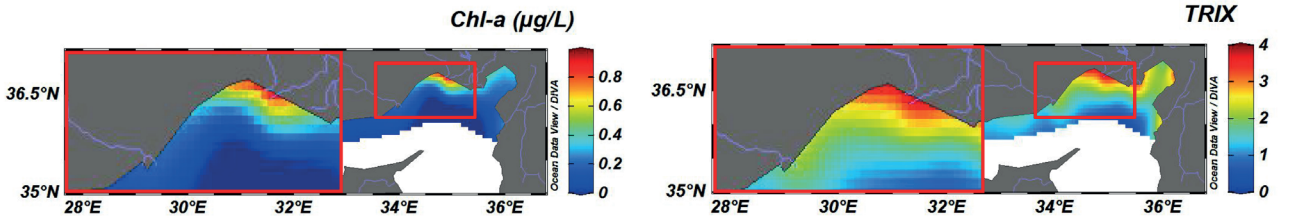

Figure 2

Concentrations of chlorophyll-*a* and current trophic status of NE Mediterranean shelf waters reported by Tugrul et al. (2019)

The fluxes of nutrients in the Berdan and Göksu Rivers were comparable with the nutrient inputs carried by other major rivers reported previously by Kocak et al. (2010), Özbay et al. (2012), Kılıç et al. (2018), Kılıç (2020), and Akcay et al. (2021). The results of previous studies performed in the regional rivers flowing into the shelf region of NE Mediterranean Sea also showed spatial variability in the nutrients concentrations of major rivers (Kocak et al. 2010, Özbay et al. 2012, Kılıç et al. 2018, Kılıç 2020, Akcay et al. 2021). The study findings with the previously reported riverine nutrients data showed that nutrient concentrations and fluxes of the Seyhan and Ceyhan Rivers were greater than recorded in the other regional rivers flowing into the NE Mediterranean coastal region as these rivers pass through highly populated urban areas hosting local industrial and domestic wastewater treatment facilities that discharge to these rivers (Kılıç et al. 2018). Higher concentrations of nutrients carried by the regional rivers have led to development of coastal eutrophication in the NE Mediterranean coastal waters (Tugrul et al. 2019, Akcay et al. 2022) (Figure 2). The calculated molar ratios from total nitrogen (TN) and phosphorus (TP) fluxes ranged from 13 in the Göksu River to 22 in the Berdan River (Table 2). The higher TN/TP molar ratio compared to the classic Redfield Ratio of N/P in the Berdan River is very likely to modify nutrient dynamics and hence lead to further eutrophication in the shelf waters of the NE Mediterranean Sea.

4. Conclusions

In this study, fluxes of nutrients from the two major rivers flowing into the Cilician Basin of NE Mediterranean were determined. The study findings showed significant spatio-temporal variations in nutrient concentrations and fluxes. Large amounts of nutrients were carried by the Göksu River due to its higher volume flux rate. The calculated molar ratios of the nutrient fluxes indicated a higher TN/TP molar ratio compared to the classic Redfield Ratio of N/P in the Berdan River that is very likely to modify nutrient dynamics in the NE Mediterranean shelf waters. Determination of current nutrient loads presented in this study is, therefore, critical for the eutrophication management efforts in this section of the Mediterranean Sea.

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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