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RESEARCH ARTICLE

ECOLOGICAL STATUS ASSESSMENT OF LITANI RIVER, LEBANON USING CHLOROPHYLL A

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ABSTRACT

Eutrophication of Litani River, the most important water resource in Lebanon, has become a pressing national concern. In spite of the intensive efforts on studying the physiochemical properties of its water, not enough attention has so far been given to the biological quality elements and trophic status of the river. Considered as the most sensitive indicator for nutrient enrichment and algal biomass, seasonal levels of sestonic chlorophyll-a (Chl-a) were determined in this study at five stations of Litani River during 2013 and 2014 and the relationship with transparency (Secchi disk), nutrients and mineralization levels was tested. Findings revealed statistically significant spatial variations in chlorophyll-a between the stations under study with Upper Litani River forming a homogenous subset characterized by hypereutrophic levels (54.54±38.61 µg/L in Rayak; 57.39±42.67 µg/L in El Marj and 67.21±60.94 µg/L in Jib Janine), while oligotrophic levels were observed at the Lower Litani River (2.60±2.82 µg/L in Dellafi and 3.14±1.49 µg/L Khardali). Correlation coefficients between chlorophyll-a and levels of phosphates, nitrites and ammonia were significantly positive. Negative correlation was revealed with Secchi disk readings and nitrate levels, yet no statistical significance was reached with nitrates. It is concluded that phosphates and both nitrites and ammonia have positive influences on algal proliferation and eutrophication of Upper Litani River. However, the negative correlation with nitrates suggests that Chl-a did not relate to nitrates and it may be a poor criterion for assessing the ecological status and nutrient-related problems of the river possibly due to the complex nitrogen cycle dynamics of the river. Thus, it is of importance to explore total nitrogen and total phosphate and their relationship with chlorophyll-a as potentially a more reliable tool.

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INTRODUCTION

Deterioration of ecological status of Upper Litani River, largest and most important river in Lebanon, is a pressing national concern. The heavy load of plant nutrients (phosphorus and nitrogen) that usually stimulate algal proliferation and cultural (man-made) eutrophication of aquatic ecosystems can be attributed to the increased urbanization pressure, inappropriate agricultural practices, a wide range of industrial activities coupled with climate change and surge in demand by the influx of Syrian refugees (Assaf and Saaheh, 2008; BAMAS, 2005; MoE and UNDP, 2011; LRBMS, 2012a and b). Findings from several extensive studies show serious progressive elevations in a wide range of contaminants including nutrients, heavy metals and bacterial contaminants in the last a few decades (BAMAS, 2005; Haydar *et al*., 2014; Ismail *et al*., 2009; Baydoun et al., 2016).

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The levels of many contaminants and associated nuisance high prevalence of algae and other aquatic vegetation (macrophytes) have exceeded the natural assimilative capacity of the river. These deterioration conditions have resulted in the decline of the ecological services of the river basin, aggravated the socioeconomic constraints on the Lebanese nation and caused major adverse effects on public health. The magnitude of these effects can range between annoyances to very serious when irrigation water demand substantially increases during the long rainless Summer seasons under current climate change conditions (Farajalla, 2009; Khouri *et al*., 2014; MoE, 2016). In eutrophic aquatic ecosystems, taste and odor problems, reduced sunlight penetration, dissolved oxygen (DO) depletion leading to aquatic habitat destruction and total loss biological activity are among the many effect associated with nutrient enrichment. Algal cyanobacterial toxins can affect animal and human health (WHO 1999, 2003). Low DO can increase the availability of toxic metals from sediments and build up of toxic substances like ammonia and hydrogen sulfide in water column contaminating habitats of aquatic life (EPA, 2000a and b).

Considered as the most sensitive indicator for nutrient enrichment and algal biomass, chlorophyll-a (Chl-a) has long been used in the application of as an index of the productivity and trophic condition of water bodies (Dodds, 2006; Boyer *et al*., 2009; Solimini *et al*., 2006). Although many factors can influence algal biomass in rivers and streams, including hydrodynamics, riparian shading, toxic compounds, climate change, introduced species among others, control of nutrient input remains the most effectively manageable factor to mitigate problems of excessive algae. Actually, the relationship between annoyance algal growth and nutrient enrichment in river and stream systems has been well-documented in the literature (Welch et al., 1992; Van Nieuwenhuyse and Jones, 1996; Dodds *et al*., 1997; Chetelat *et al*., 1999, Dodds and Oakes, 2004).

The nutrient enrichment issue of Litani River is not new but, to date, not enough efforts have been made to assess its ecological status based on chlorophyll-a nor to develop nutrient criteria for improving water quality and habitat of the river. The present study aims at the preliminary assessment of seasonal levels of Chl-a in Litani River and testing relationships between nutrient input and Chl-a response. The study is a first step towards setting a nutrient criteria for mitigating cultural eutrophication and protecting the river's ecosystem.

MATERIALS AND METHODS

Study sites

Situated within the boundaries of Lebanon, Litani River runs for about 170 km through Bekaa Valley in a south- westerly direction to meet the Mediterranean Sea (Figure 1).

Figure 1. Study sites at Upper and Lower Litani River Basins, Lebanon. Source Baydoun *et al*. (2016) adopted of https:// strikehold.files.wordpress.com/2009/10/bekaa-valley-map.gif

It forms a catchment of around 2,000 km^2 area That is divided into two sub-basins by Qaraoun dam which was constructed in 1960s for water storage and electricity generation. The Upper Basin stretches between the source until the dam at altitudes ranging between 800 to 1000 meters with an estimated area of approximately 1,500 km^2. The Lower Basin of about 500 km^2 area is formed as the river exits the reservoir and takes a steep slope sharply dropping within 60 km from an altitude of 800 m to its outlet at sea level. Characterized by different hydrological and geomorphological features as well as the type and magnitude of anthropogenic pressures and land use, five sites distributed along both the Upper and Lower River Basins were selected for the study (Figure 1). The sites of Upper Litani Basin were situated at the towns of Rayak, El Marj and Jeb Janine, while the sites of Lower Basin were positioned at Dellafi and Khardali.

Chlorophyll assessment

Water samples were collected at a 30 cm depth of water surface during nine seasonal sampling campaigns of 2013 and 2014. Chl-a was extracted by filtration of 500 ml of water, digestion of particulate organic substance by dimethyl sulfoxide and acetone and then spectrophotometric measurement (Jeffrey and Humphrey, 1975; Burnison, 1980). Statistical analysiswere performed by ANOVA (PAWAS Statistics 18). Correlation analysis with the in parallel assessed nitrates, nitrites, ammonia, phosphates and Secchi disk readings previously reported in Baydoun *et al*. (2016) was also examined.

RESULTS AND DISCUSSION

Figure 2 illustrates the seasonal variation in Chl-a assessed at the five studied stations of Litani River indicating variable algal growth responses to both anthropogenic and natural influences on the river. Chl-a mean values of the study duration of 2013 and 2014 ranged between 54.54 µg/L and 67.21 µg/L at the Upper Litani stations and 2.60 µg/L and 3.14 µg/L at the stations of the Lower River. The maximum Chl-a levels were obviously reached during the dry months of Summer and Autumn of both years. The significant variance in rainfall between typically dry summer and wet winter and increased freshwater demand for urban and agricultural uses are believed to have resulted in higher Chl-a values in the dry seasons of the study duration. Higher levels of Chl-a were noted at the Upper Litani River in 2014 as compared to 2013. This can be mostly attributed to the sever drop in precipitation and high temperatures witnessed in the drought year of 2014 which was described as one of the harshest droughts in the last 50 years with a 57% decrease in precipitation in Upper Litani Basin while nationally a decrease between 40-50% was reported (http://www.setsintl.net/index.php/drought-in-lebanon -this-past-year-was-one-of-the-driest-on-record). With a usual average of 812 mm, annual precipitation levels hit an all-time low level of 431 mm. The stabilized lower Chl-a at Lower Litani River may further confirm the relatively better quality conditions of this part of the river reported in our previous work at the same stations of the river (Baydoun *et al*., 2016). This can be mainly due to the trapping effect of Qaraoun reservoir, nitrogen cycling discontinuity and possible dilution effect of water springs at the bottom of reservoir (US Department of the Interior Bureau of Reclamation for the Foreign Operations Administration, 1954; Friedl *et al*., 2004; Teoduru and Wernli, 2005; Von Schiller *et al*., 2016).

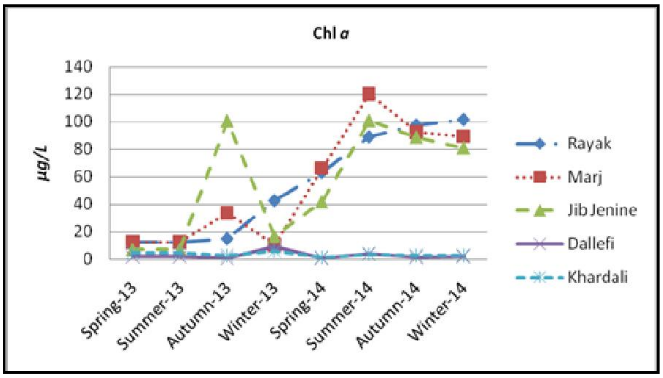

Figure 2. Significant spatial and seasonal variations in Chl-a between the stations of Upper and Lower Litani River

The statistically significant spatial variations shown in Table 1 indicate different algal growth levels and trophic conditions between stations under study.

contrast, the observed oligotrophic conditions of the Lower River may be attributed to the relatively less anthropogenic pressure and possible influence of Qaraoun reservoir.

Nutrients (nitrites, ammonia, phosphates) as presented in Table 2 revealed significant positive correlation (r= +0.338, +0.482 and +0.305 at p<0.01, respectively). Whereas, the correlation was negative with SD (r= -0.556 at p<0.01) and nitrates (r= -0.158). However, statistical significance was not reached with NO_3^- indicating that this nitrogen species did not relate to algal biomass of the river. Given the frequently reported high levels of toxic NH_3 and dissolved oxygen deficiency in the Upper River, it is expected that the denitrification is the main factor influencing N forms (Hamilton *et al*., 2001). Actually, the relationship between Chl-a and N as well as P is not simple and can be influenced by both natural processes, biogeochemical cycles and anthropogenic inputs (Deflandre and Jarvie, 2005). A series of nutrient addition experiments carried out over a four-year period to assess the role of nutrient loading on algal biomass on Blackwater Streams, USA showed that N enrichment over 200 µg N/l led to an increase in phytoplankton biomass, whatever the form of nitrogen, whereas no impact of P enrichment was shown (Mallin *et al*., 2004).

Table 1. Mean values ± SD (n=27) of Chl-a levels at the five studied sites of Litani River in 2013-2014, Superscript a, b, c indicate homogenous value subsets that significantly differ by ANOVA

Parameter	Rayak	El Marj	Jeb Janine	Dellafi	Khardali
Chl-a (mgL^{-1})	54.54±38.61^a	57.39±42.67^a	67.21±60.94^a	2.60±2.83^b	3.14±1.49^b
SD (cm)*	14.85±14.80^a	16.15±14.68^a	32.22±15.30^b	>300^d	130.04±59.33^c
PO_4^{-3} (mgL^{-1})*	16.19±11.21^c	9.27±5.40^b	7.60±9.53^b	0.60±0.86^a	0.45±0.51^a
NO_2^- (mgL^{-1})*	0.39±0.26^a	0.38±0.25^a	0.67±0.42^b	0.28±0.15^a	0.30±0.24^a
NO_3^- (mgL^{-1})*	7.04±3.19^{a,b}	6.22±2.62^a	7.81±3.33^{a,b}	8.11±2.50^b	6.89±3.42^{a,b}
NH_3 (mgL^{-1})*	34.33±18.37^c	33.97±17.92^c	9.82±4.57^b	0.23±0.18^a	0.22±0.11^a

* Source Baydoun *et al*. (2016).

Table 2. Correlation coefficients between water quality parameters of studied stations at Litani River during 2013 and 2014

Indicator	SD *cm*	PO_4^{3-} *mg/l*	NO_2^- *mg/l*	NO_3^- *mg/l*	NH_3 *mg/l*	Tur *ntu*	Chl *a µg/l*
SD *cm*	1						
PO_4^{3-} *mg/l*	-0.509**	1					
NO_2^- *mg/l*	-0.282**	0.323**	1				
NO_3^- *mg/l*	0.080	0.010	0.279**	1			
NH_3 *mg/l*	-0.612**	0.608**	-0.054	-0.179*	1		
Chl-a *µg/l*	-0.556**	0.305**	0.338**	-0.158	0.482**	0.515**	1

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

Based on the trophic classification scheme for streams and rivers developed by Dodds *et al*. (1998) using the value of 10 µg/L as oligotrophic-mesotrophic boundary and value of 30 µg/L as mesotrophic-eutrophic boundary, the stations of Upper Litani River formed a homogenous subset characterized by eutrophic conditions (54.54±38.61 µg/L at Rayak; 57.39±42.66 µg/L at El Marj and 67.21±60.93 µg/L at Jib Janine), whereas oligotrophic conditions were revealed in the stations of Lower Litani River (2.6±2.82 µg/L in Dellafi and 3.14±1.49 µg/L Khardali). The increased algal productivity and eutrophic conditions of Upper Litani may be primarily explained by the heavy nutrient loading resulting from extensive agricultural land use and domestic activities dominating this part of the river (MoE and UNDP, 2011). By

On the contrary, in a more recent study on five agricultural streams mandated by USEPA in Illinois, no or only a weak positive correlation between Chl-a and dissolved N and P was reported suggesting that Chl-a is a poor criterion for assessing and managing eutrophication problems in the studied streams (Morgan *et al*., 2006). Nitrogen and P occur in different forms in rivers and streams, including dissolved inorganic forms and particulate organic material that also releases plant-available inorganic nutrients to water column increasing nutrient levels either locally or downstream. Thus, measuring the levels of dissolved N and P forms only may not be very effective in the monitoring and management of eutrophication (Dodds and Welch, 2000, Dodds, 2006). It follows that the quantification of total nitrogen, total phosphorus and stoichiometry (ratios of nutrients) and exploring their relationship with Chl-a are necessary in assessment of trophic status and development of suitable nutrient management goals (EPA, 2000a).

Conclusion

This study presents for the first time information on the ecological status of Litani River using Chl-a and tests the relationship between Chl-a on one side and nitrates, nitrites, ammonia and phosphates on the other. Significant spatial variations between the zones of river are revealed with the Upper Litani River forming a homogenous subset characterized by hypereutrophic levels, while oligotrophic levels were observed at the Lower Litani River. The relationship between Chl-aand the nutrient species nitrites, ammonia, phosphates was revealed significantly positive. Whereas, the correlation with nitrates was negative with no reach of statistical significance suggesting that Chl-a may be a poor criterion for assessing and managing the eutrophication problems of the Upper Litani River. Considering the importance of both organic and inorganic N and P forms in aquatic ecosystems, the quantification of total nitrogen, total phosphorus and their relationship with Chl-a are necessary for a more fundamental and holistic understanding of the trophic state in Litani River for both the basic ecological value and practical management implications.

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