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ORIGINAL RESEARCH ARTICLE

Spatio-temporal variability of the size-fractionated primary production and chlorophyll in the Levantine Basin (northeastern Mediterranean)

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Summary Spatial and temporal variations in size-fractionated primary production (PP) and chl *a*, in relation to ambient physicochemical parameters, were studied in the three distinct ecosystems of northeastern Levantine Basin namely eutrophic Mersin Bay, mesotrophic Rhodes Gyre, and oligotrophic offshore waters. These ecosystems were visited in July and September 2012 and March and May 2013. Total primary production (TPP) rates ranged between 0.22 and 17.8 mg C m^{-3} h^{-1} within the euphotic zone, whereas depth-integrated TPP rates were in the range 21.5—348.8 mg C m^{-2} h^{-1} (mean: 105.5 ± 88 mg C m^{-2} h^{-1}), with the lowest rates recorded for offshore waters. Similar spatio-temporal variations were observed in chl *a* concentrations, ranging from 2.3 to 117.9 mg m^{-2} (mean: 28.9 ± 24.9 mg m^{-2}) in the study area. The Mersin Bay TPP rates have exceeded almost 8—12 times those measured in the offshore waters and the Rhodes Gyre; however, the chl *a* concentrations measured in coastal waters (0.343 mg m^{-3}) and the Rhodes Gyre (0.308 mg m^{-3}) were only threefold larger than the offshore values. PP and chl *a* were dominated by picoplankton in the study area whereas small nanoplankton, being the most active, displayed the highest assimilation ratio in offshore waters (6.8) and the Rhodes Gyre (2.8). In the upper-layer waters depleted of P (0.02—0.03 μM) of the northeastern Mediterranean, a positive correlation was observed between $NO_3 + NO_2$ and PP (and thus, chl *a*), which strongly suggests that reactive P and inorganic nitrogen are co-limiting factors in the production and biomass distribution of the phytoplankton community in both shelf and offshore waters.

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1. Introduction

The eastern Mediterranean Sea is one of the world's least productive regions, with low nutrient and chlorophyll concentration (Ediger and Yılmaz, 1996; Krom et al., 1991; Psarra et al., 2005; Yucel, 2013). In general, primary production (PP) rate and chlorophyll concentration tends to decrease from west to east and north to south in the Mediterranean (Siokou-Frangou et al., 2010). Increasing oligotrophy toward the east can mainly be attributed to increasing phosphorus limitation (N/P ratio increase from 20 to 29) in the northeastern Levantine waters due to limited inputs of nutrients from external sources and the fact that its deep waters have high N/P (25—26) ratios (Krom et al., 1991, 2010; Thingstad et al., 2005; Yılmaz and Tugrul, 1998; Yucel, 2013). Atmospheric depositions supply a considerable amount of nutrients to the oligotrophic offshore waters (Guerzoni et al., 1999; Koçak et al., 2010; Krom et al., 2004). This atmospheric dry and wet deposition support new production during spring and autumn in the offshore eastern Mediterranean (Herut et al., 2005; Markaki et al., 2003). Primary production in the eastern Mediterranean is principally dominated by eddies and currents that control the distribution of nutrients in the upper-layer waters (Ediger and Yılmaz, 1996). Annual PP is estimated to vary regionally and seasonally between 20.3 and 151.2 g C m^{-2} y^{-1} (Siokou-Frangou et al., 2010 and references there in; Yucel, 2013). The lowest chlorophyll concentrations were recorded in the anticyclonic regions of the Levantine Basin during the dry period, reaching as low as 0.01—0.23 mg m^{-3} (Ediger and Yılmaz, 1996). However, concentrations reach high levels ranging 2.49—3.1 mg m^{-3} in the Rhodes gyre and in the coastal waters enriched by terrestrial inputs (Ediger and Yılmaz, 1996; Yucel, 2013). In the basin, phytoplankton blooms are generally observed in late winter and spring, following the winter convectional mixing (Siokou-Frangou et al., 2010). Up till now, only a few PP rate estimations have been conducted for the Cilician Basin (northeastern Mediterranean) (Ediger et al., 2005; Yayla, 1999; Yılmaz, 2006; Yucel, 2013), all of which highlighted apparent major differences between coastal and offshore waters. Offshore waters are commonly known as oligotrophic (Ediger et al., 2005; Ediger and Yılmaz, 1996; Yucel, 2013). Coastal waters (Mersin and Iskenderun Bays) display a high production capacity (Tugrul et al., 2016; Yılmaz, 2006; Yucel, 2013) due to the input of nutrients from natural and anthropogenic sources (through contaminated rivers and direct discharge of partially treated domestic and industrial wastewaters). Cyclonic systems in the open Levantine Basin differ in terms of their biological, chemical, and physical properties from the surrounding waters owing to the rising of nutrient-rich deep waters toward the base of the euphotic zone (EZ) for most of the year, sometimes reaching the surface during severe winters (Ediger and Yılmaz, 1996; Ediger et al., 2005). Chlorophyll concentrations and PP rates varied between 0.02 and 1.0 mg m^{-3} and 38.5 and 268 mg C m^{-2} day^{-1} in the Rhodes Gyre (Ediger et al., 2005). In severe winter-spring periods, the highest rates of PP and Chl-*a* were recorded in the peripheries of the Rhodes Gyre (Ediger et al., 2005). The coastal waters of the northeastern Cilician Basin are fed by perennial rivers, namely Goksu, Tarsus, Seyhan, Ceyhan, and some other smaller rivers, with associated chemical properties (high $NO_3 + NO_2/PO_4$ ratios and $Si/NO_3 + NO_2$ ratio mostly <1 in the last 2 decades) (Uysal et al., 2008). In the coastal zone, atmospheric and river inputs, winter convectional mixing, and summer upwelling events determine the surface nutrient concentrations and rates of the new and regenerated PP (Ediger et al., 2005; Uysal, 2006; Uysal and Köksalan, 2010; Uysal et al., 2008).

Phytoplankton composition and abundance in the sea are determined by the physicochemical characteristics of upper-water masses, rates of nutrient inputs, and also by the changes in N/P/Si ratios within the euphotic zone. Diatoms have been reported as the most abundant group in the Cilician Basin shelf waters (Eker and Kideyş, 2000; Eker-Develi et al., 2003; Kıdeyş et al., 1989; Polat et al., 2000; Uysal et al., 2003; Uysal et al., 2008). However, in the Levantine offshore waters, small phytoplankton dominate the total biomass and abundance (Li et al., 1993; Siokou-Frangou et al., 2010; Uysal et al., 2004; Uysal, 2006; Yucel, 2013). Recent studies pertaining to flow cytometry and high-performance liquid chromatography have also revealed that in the oligotrophic Levantine open sea, small-sized phytoplankton is the major contributor to the total phytoplankton biomass (Li et al., 1993; Yucel, 2008, 2013). It appears that PP rate data from the Levantine shelf and open sea waters are very limited for the assessment of spatio-temporal variability in the northeastern Mediterranean (Ediger et al., 2005; Yılmaz, 2006; Yucel, 2013). This study aims to enhance the existing knowledge pertaining to PP and size-based standing biomass potential of the basin by comparing and contrasting ecosystems that extend from highly oligotrophic to eutrophic, in relation to ambient physicochemical parameters, on a seasonal basis.

2. Material and methods

2.1. Sample collection and methodology

In this study, five stations were visited for measuring chemical (phosphate, nitrite + nitrate, silicate), biological (size-fractionated chlorophyll and primary production experiments), and physical (salinity, temperature, depth, photosynthetically active radiation (PAR), fluorescence, secchi disc depth [SDD]) parameters of the water column along a transect extending from Mersin Bay to Rhodes Gyre representing the coastal, offshore, and cyclonic areas of the northern Levantine Basin (Fig. 1, Table 1) during July and September 2012 and March and May 2013. Water samples from predefined depths (1, 2, 5, 13, 25 and 39 m for coastal waters and 1, 4, 8, 20, 50, 75, 100, 150 and 200 m for offshore and Rhodes Gyre) were collected on board the r/v *Bilim-2* of the Institute of Marine Sciences (METU) using Niskin bottles fitted onto a rosette sampler, coupled with Sea-Bird Electronics-911 plus CTD (conductivity, temperature, depth) probe. Profiles of temperature, salinity, PAR and fluorescence were obtained using the standard Sea-Bird data processing software.

2.1.1. Nutrient analysis

Nutrient (nitrate + nitrite, phosphate, silicate) samples from the bottle casts were collected into 100 ml high-density polyethylene bottles that were pre-cleaned with