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Seasonal changes of the microplankton community along a tropical estuary

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HIGHLIGHTS

- Tempisque River runoff affect abundance and taxonomic composition of microplankton.
- Five microplankton assemblages associated with a seasonal and river–marine gradient.
- 146 microplanktonic taxa were identified, 52 of which were new citations in the area.
- Phytoplankton were mainly limited by light rather than nutrients.
- From ecotone model at the estuary head to ecocline model for the rest of the estuary.

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ABSTRACT

Microplankton organisms are an important link in the transfer of matter and energy between the benthic–pelagic microbial food web and higher trophic levels in estuaries. Although tropical estuaries are among the most productive aquatic systems globally, information on the spatial and seasonal dynamics of microplankton in such systems is scarce. In order to identify which variables control microplankton abundance and community structure a number of environmental variables were measured along the tropical Gulf of Nicoya (Costa Rica) during the rainy and dry seasons (2011–2012). The Tempisque River was a major source of nutrients and turbidity and thus imposing a clear gradient along the estuary. Chlorophyll *a* (chl *a*) concentration was highest in the middle of the estuary (2.7–20 mg m^{-3}), where turbidity decreased. The microplankton comprised mainly diatoms (88%) and dinoflagellates (8%). Multivariate analysis revealed five different microplankton assemblages associated with a seasonal and riverine–marine gradient, and supporting an ecotone model at the estuary head that shifts to an ecocline model for the rest of the estuary. Our results suggest that primary producers in the estuary were mainly limited by light rather than nutrients.

1. Introduction

Estuaries are among the most productive aquatic systems. These areas are important resources for the human population, being sometimes their only source of income for local communities (i.e. fishing). Estuaries are highly dynamic systems, undergoing from daily tidal changes to seasonal changes. This variability in time and space makes estuaries highly heterogeneous and complex ecosystems able to sustain high biodiversity levels (Attrill and Rundle, 2002; Muylaert et al., 2009). Phytoplankton is a key constituent of estuaries, being a primary producer that

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highly influences water quality (i.e. eutrophication). In estuaries, seasonal phytoplankton dynamics are mainly determined by large variations in irradiance, temperature, nutrients, and river runoff (Hitchcock and Smayda, 1977; Cloern, 1987; Alpine and Cloern, 1988; Underwood and Kromkamp, 1999; Eyre and Balls, 1999). In general, tropical estuaries are characterized by higher temperature and irradiance levels year round, and larger variations in river runoff, than temperate estuaries (Nittrouer et al., 1995; Eyre and Balls, 1999). These characteristics lead to high primary productivity rates, with some tropical estuaries being among the most productive aquatic systems globally (Cloern et al., 2013). Despite the importance of tropical estuaries in terms of primary production, current information on the structure, abundance and ecology of the phytoplankton and the factors driving their dynamics in such systems is scarce compared to that for temperate ones (Costa et al., 2009; Cloern and Jassby, 2010; Cloern et al., 2013).

Microplankton are a critical component of the pelagic community of aquatic ecosystems. Microphotoautotrophic primary production is readily transferred to large zooplankton and small fishes (Azam et al., 1983; Costalago et al., 2012), whereas microzooplankton not only graze on microphytoplankton and autotrophic and heterotrophic nanoplankton, but also act as prey to higher trophic levels (Azam et al., 1983; Di Poi et al., 2013). Therefore, microplankton integrate the matter and energy flowing through different pathways along the microbial food web and channels it to higher trophic levels (Calbet and Landry, 2004; Calbet and Saiz, 2005). Microplankton in estuaries also play a major role in benthic–pelagic coupling through consumption by bivalves and other benthic filter feeders (Officer et al., 1982; Werner and Hollibaugh, 1993; Greene et al., 2011). In addition, benthic diatoms are frequently resuspended to the water column, thus contributing to pelagic primary production (Shaffer and Sullivan, 1988; Jonge and Beusekom, 1995). The increasing human pressure on tropical estuaries over the last decades has had a major impact on their ecology and their ecosystem services (Bianchi, 2007; Barbier et al., 2011; Blaber, 2013). Changes in environmental variables due to climate change can also affect phytoplankton communities' structure, zooplankton and fish (Vezzulli et al., 2012). Therefore, understanding seasonal variability and which variables influence the structure and function of microplankton is necessary to be able to predict their future response to anthropogenic and climate changes.

The Gulf of Nicoya, located in the Pacific Coast of Costa Rica, is a highly productive estuarine system (Peterson, 1960; Gocke et al., 2001; Cloern et al., 2013) supporting important fisheries, particularly in its inner basin (Vargas, 1995; Palter et al., 2007). The hydrographic structure and dynamics of the water column in the inner basin of Nicoya Gulf are strongly influenced by seasonal changes in freshwater flow from the Tempisque River (Lizano, 1998; Brenes et al., 2001). These seasonal changes in the river runoff are likely to affect the biological community and the flow of matter and energy in the estuarine ecosystem, including water column productivity and phytoplankton taxonomic composition (Sin et al., 2000; Smayda and Reynolds, 2003; Costa et al., 2009; Cloern et al., 2013). Changes in the species that dominate the estuary can lead to harmful algal blooms, such as those already reported in the Gulf of Nicoya (Hargraves and Víquez, 1985, Vargas-Montero and Freer, 2004, Vargas Montero et al., 2008). In the inner basin of Nicoya Gulf, important changes in inorganic nutrients, oxygen, and chl *a* concentrations have been reported along the river–sea gradient (Kress et al., 2002; Palter et al., 2007). However, similar to other tropical estuaries, there is scarce information on how the different components of the planktonic community respond to seasonal changes in the environmental conditions (Cloern and Jassby, 2010; Cloern et al., 2013). Previous studies in the Gulf of Nicoya provided a general taxonomic description of the microphytoplankton community, showing that the community composition differs from that in other areas of the Pacific Central America coast (Hargraves and Víquez, 1981; Hargraves and Víquez, 1985). Changes in phytoplankton taxonomic composition together with the physicochemical properties and chl *a* concentrations, have been studied in only a single point in the inner gulf (Brugnoli-Olivera and Morales-Ramírez, 1999, 2001, 2008). Therefore, as yet, no single study has considered all the environmental variables, phytoplankton abundance and taxonomy during the two tropical seasons along the inner Gulf, and therefore established the possible drivers of the tropical estuarine phytoplankton composition. In addition, understanding spatial and seasonal dynamics of microplankton in tropical and subtropical estuaries is essential to evaluate the contribution of estuaries to global biogeochemical cycles; however, such studies are largely biased towards temperate European and North American estuaries, with warmer estuaries being largely under-represented (Cloern and Jassby, 2010; Cloern et al., 2013).

Here we study the abundance and composition of the microplankton community in the inner part of a tropical estuary, the Gulf of Nicoya, where changes in the main river runoff was expected to be the greatest influence. Estuaries are a transition zone and can be differentiated into two main types of boundary model: ecotone, when the transition is a narrow ecological zone that separates two relative homogeneous zones, and ecocline when the transition is gradual (Attrill and Rundle, 2002). We hypothesized that there is a seasonal shift of the microplankton community and question whether it fits an ecotone or ecocline model along the river–sea gradient. We examine patterns of variability and potential environmental factors influencing microplankton abundance and species composition in tropical estuaries as model of gradient aquatic ecosystems. The results provide new insight into the relationship between species and environmental variables in tropical estuaries in order to identify management strategies that protect these important coastal ecosystems.

2. Material and methods

2.1. Study area

The Gulf of Nicoya is a mid-sized tropical estuary located in the northwest Pacific coast of Costa Rica (10°N 85°W) (Fig. 1). The estuary is 80 km long from the mouth of the Tempisque River to the Pacific Ocean and 50 km wide at its southernmost extension, having a total surface area of 1543 km^2. Based on its bathymetry, the gulf can be divided into two regions: the inner gulf, from the river mouth to the Puntarenas Channel, with a maximum water depth of ∼20 m, and the external gulf, with depths down to ∼200 m (Fig. 1). Sand and rocky cliffs border the external gulf, whereas mangroves border the inner gulf (Voorhis et al., 1983; Palter et al., 2007). The gulf is classified as mesotidal estuary (tidal range 2–4 m) (Davies, 1964). Tides are semidiurnal with mean amplitude of 2.28 m (Lizano, 2006). Freshwater inputs from the Tempisque River produce intense salinity gradients in the inner gulf; mean discharge rates range between 333.3 and 157.9 m^3 s^{-1} during the rainy (May–November) and dry seasons (December–April), respectively (Kress et al., 2002). The mean values of precipitation in the sampled months were inside normal historical conditions (INM, 2009).

2.2. Satellite imagery

Satellite imagery is a powerful tool that provide a quasi-synoptic measurements of chl *a* and sea surface temperature (SST). Here we processed monthly climatology images from 2002 to 2011, with a spatial resolution of 4 × 4 km, to produce climatological seasonal images.