PICOPLANKTON DYNAMICS IN A HYPERTROPHIC SEMIARID WETLAND

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Abstract: This study was carried out on a neglected component of wetlands: the picoplankton community. We analyzed the picoplanktonic community patterns and their related environmental factors in a hypertrophic semi-arid wetland located in Central Spain (Las Tablas de Daimiel National Park, TDNP). We determined the bacterial and autotrophic picoplankton (APP) abundance over a three-year period (1996: the end of a long drought period and 1997–1998: after flooding) in five sites of the wetland. The overall range of bacterial abundance was 0.2 × 10^6 to 10 × 10^6 cells/ml. The annual mean abundance increased in the wettest 1997. APP was composed mainly by coccoid phycocyanin-containing cyanobacteria, with the greatest abundance up to 25 × 10^5 cells/ml. The annual mean also increased considerably in wetter 1997–98. Despite the large APP biomass in some sites, its percentage of total phytoplankton biomass was low (the annual average did not exceed 1.5%). We observed spatial heterogeneity in the picoplankton fraction depending on the fluctuating hydrology: bacteria tend to spatial homogeneity after flooding while APP showed only similarity among the output sites. Among the considered predictive variables (temperature, phosphorus, nitrogen, zooplankton, phytoplankton) of the picoplanktonic dynamics, temperature was the most closely correlated to picoplankton, especially to bacterial abundance. Further, in two factorial, coupled-hierarchical laboratory experiments (constant temperature), we searched for control mechanisms of picoplankton. We tested (a) the trophic cascade hypothesis by analyzing the effect of presence/absence of mosquitofish (experiment 1) or directly modifying the zooplanktonic community (experiment 2) and (b) the bottom-up regulation by altering the nutrient conditions (presence/absence of sediment in experiment 1; reducing the nutrient content in experiment 2). Bacterioplankton failed to show any behavior related to trophic cascade direct effects, while nutrients increased its abundance. APP was affected positively by nutrients and negatively by zooplankton grazing.

Key Words: bacteria, filamentous bacteria, autotrophic picoplankton, wetlands, top-down control, bottom-up control, microcosm experiments

INTRODUCTION

The microbial components of aquatic food webs (bacteria, autotrophic picoplankton, heterotrophic flagellates, ciliates) are an important and sometimes dominant part of aquatic ecosystems (Wickham 1998). A great percentage of the total energy represented by primary production in aquatic systems may pass through the detritus food web (Kepner and Pratt 1996) where bacteria play an important role. In the same manner, autotrophic picoplankton (APP) are an available food source for many micrograzers, in contrast to the large filamentous or colonial cyanobacteria that are common in eutrophic wetlands. However, little is known about
the ecological role of APP in eutrophic systems (Jürgens and Jeppesen 2000). Moreover, the high APP growth rates are similar to those of heterotrophic bacteria, making them another important component of the microbial food web in aquatic ecosystems (Weisse 1993, Sommaruga and Robarts 1997).

Many studies have tested the trophic cascade hypothesis following Carpenter et al. (1987), but only a few investigations have also focused on bacteria (Richardson et al. 1990, Wickham 1998) or APP (Rhew et al. 1999). It is not yet clear, therefore, to what extent the trophic cascade links the microbial and classic aquatic food webs. Studies of the cascading effects of metazooplankton on APP and bacteria carried out in lakes have yielded a variety of results, varying from negative to positive or, indeed, no effects at all. Some studies suggest that the trophic cascade is truncated at the level of protozoans (i.e., Richardson et al. 1990, Pace and Funke 1991, Wickham 1998), others postulated a trophic cascade from fish to bacteria (Jürgens et al. 1994), while others have found that the top-down effects on picoplankton may depend on the structure of the metazooplankton community (Jeppesen et al. 1997, Adrian and Schneider-Olt 1999). A reason for these opposing results might be, for example, compensatory mechanisms such as developments of grazing-resistant within the bacterial community (Langenheder and Jürgens 2001), as well as the studied variable: positive effects of nutrients on bacterial growth and negative predator effects on bacterial abundance (Pace and Cole 1996).

Wetlands are important ecosystems in terms of productivity and as sites of bio-geochemical cycling (Johnson and Ward 1997), where sediment plays an important role (Wetzel 1990). However, wetlands are not well-studied with regard to their picoplanktonic (bacteria and autotrophic picoplankton, APP) components (Gsell et al. 1997). Two stressors are common in wetlands: the eutrophication and the high hydrologic variations. Seasonal variation in wetland hydrologic regimes can result in periods of high and low water levels, and this is most noticeable in semiarid countries (Sánchez-Carrillo and Álvarez-Cobelas 2001). Research performed in semiarid wetlands is mainly descriptive, and there is a lack of investigation into the dynamics of planktonic organisms and their trophic relationships (Ortega-Mayagoitia et al. 2000, Rojo et al. 2000). Moreover, few studies of microbial food web dynamics have been carried out in these ecosystems.

In this paper, we report on a combination of field measurements of bacterial and APP abundance over a three-year period in a freshwater hypertrophic wetland and two complementary laboratory microcosm experiments. The recording of long, field data time-series on microbial abundance is infrequent in wetlands. Since one of the major goals in aquatic ecology is the understanding of those factors regulating the biomass of microbial communities, we looked for relationships between the picoplanktic component and (1) abiotic factors (temperature, nutrients: nitrogen and phosphorus) and (2) the other planktonic components (phytoplankton, ciliates, rotifers, and microcrustaceans) from field data. Since those data seemed to suggest some hypotheses on bacterio- and picoplankton functioning in hypertrophic wetlands, we were prompted to search for other mechanisms in lab microcosm experiments. Two coupled-hierarchical experiments of factorial design were conducted to evaluate the effects of inorganic nutrients, sediments, planktivory, and grazing on bacterial and APP populations. We tested to establish the picoplankton variations when either the natural high concentrations of nutrients were diluted or large zooplankton (mainly omnivorous copepods, see Ortega-Mayagoitia et al. 2000) were removed, together with the effect of complex factors such as the presence of sediment or planktivorous fish.

Overall, we intend to describe the temporal pattern of picoplankton dynamics, illustrating the most remarkable relationships with abiotic, as well as biotic, conditions in a wetland, a kind of ecosystem where this planktonic fraction frequently has been neglected. Moreover, we offer data that help to elucidate the controversy on the effect of trophic cascade on the picoplanktonic organisms and also about the relative contribution of autotrophic picoplankton to total planktonic primary producers, depending on the trophic state of the system.

MATERIAL AND METHODS

Study Site

The study was carried out on the plankton community of Las Tablas de Daimiel National Park (TDNP), a semi-arid floodplain located in Central Spain (Figure 1). TDNP is a hypertrophic (OECD 1982), turbid ecosystem with high dissolved organic carbon (DOC) concentrations (annual averages of 4–19 mgC/L and up to 36 mgC/L in some months; Álvarez-Cobelas, unpublished data). The wetland covers about 20 km², receiving its water chiefly from river inputs (Gigüela river, see Figure 1). Its watershed is ~13000 km², underlain by Pliocene limestone, marls, and calcretes, but its discharge into TDNP is low due to water diversion for heavy agricultural irrigation. The water inputs vary greatly, both seasonally (winter rains, Sánchez-Carrillo and Álvarez-Cobelas 2001) and annually. The TDNP suffered a dry period from 1991 until the end of 1996, thereafter increasing its flood area from 7 km² to 14 km² between 1997 and 1998. The highly variable hydrology results in fluctuation.