THE ROLE OF EUTROPHICATION AND OMNIVORY ON AIR-WATER CO$_2$ FLUXES IN A TROPICAL LAKE

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INTRODUCTION

Traditionally, ecologists have considered either the importance of bottom-up (resource based) or top-down (predation driven) forces in structuring ecological communities, but clearly both resources and predation may act simultaneously (review in McCollum et al., 1998). Net ecosystem production (NEP) is the budget between carbon dioxide (CO2) fixation by primary production and CO2 release by respiration. Thus, NEP strongly influences air-water CO2 fluxes in aquatic ecosystems. Numerous papers assessed the main regulating factors on the air-water CO2 fluxes in lakes, but experimental studies considering the importance of both nutrients availability and predation are not common, especially in tropical food webs. In a global scale, tropical lakes are broadly distributed (Downing et al. 2006) and show relevant peculiarities due to the high annual solar incidence and temperature.Dissolved organic carbon (DOC) availability acts as a relevant bottom-up control on CO2 production by heterotrophic bacteria. DOC sources in lakes are mainly algae, aquatic macrophytes and terrestrial inputs. Nitrogen (N) and phosphorus (P) inputs have often human origin in the watershed (Arbuckle and Downing 2001). Eutrophication influences air-water CO2 fluxes in lakes because N and P are resource for both autotrophy and heterotrophy.

In relation to top-down control on food webs, trophic cascades are the extreme form in which top predators suppress their prey and cause alternate control by and release from predation across successively lower trophic levels, ultimately to the level of primary producers (Vadeboncoeur et al. 2005). The importance of top-down control by omnivorous fishes on air-water CO2 fluxes is less studied, despite the large abundance of these organisms in tropical lakes.

We tested two hypotheses in experimental mesocosms: (a) eutrophication enhances CO2 evasion from lake due to high organic carbon availability (humic condition), and (b) omnivorous fishes introduction does not change these fluxes.

MATERIAL AND METHODS

The experiment was performed in sixteen 5600 L cylindrical polyethylene mesocosms (2 m in diameter and 2 m in depth).These mesocosms included the whole water column from the surface to the bottom sediment in Cabiúnas lagoon (22o 17' 51.7" South e 41o 41' 20.3" West). This lagoon is inside a conservation area of restinga vegetation (Restinga de Jurubatiba National Park).The study included four experimental treatments: control (CTR), fish (FIS), nutrients (NUT) and nutrients associated to fish (NUFI). We introduced the omnivorous fish Hyphessobrycon luetkeni in FIS and NUFI treatments, maintaining during the whole experiment time its density similar to often observed in other lakes in this region. These mesocosms were enriched with inorganic nutrients (Nitrogen and Phosphorus) keeping a 5:1 N:P ratio during whole experiment.

DOC concentrations were quantified with a TOC-5000 Shimatzu Analyzer by high temperature catalytic oxidation method. Coloration (COLOR) was measured from absorption coefficient at 430 nm and transparency by Secchi disk. Water samples for nutrients were frozen before analysis according to Standard Methods (APHA 1992). Chlorophyll-a concentrations were determined by a fluorescent method as described in (Beutler et al. 2002). CO2 concentrations were quantified by pH-alkalinity method in the field, following (Stumm and Morgan 1996). Air-water carbon fluxes (FCO2 in mmol m-2 h-1) were estimated according to Cole & Caraco (1998).

To compare the results, was performed a repeated factorial ANOVA with Tukey's HSD post-hoc.

RESULTS AND DISCUSSION

In FIS treatment, omnivorous fishes feeding both autotrophs (algae) and heterotrophs (zooplankton)

at ambient nutrient availability reduced trophic cascade strength. FIS mesocosms did not change air-water CO_2 fluxes in comparison to control during the whole experiment (repeated factorial ANOVA, p<0,05). This result complemented the conceptual model in which zooplanktivorous fishes might reduce CO_2 evasion, while piscivorous fishes might enhance it in lakes.

In contrast, the nutrients addition in NUT treatment changed CO_2 evasion with respect to CTR and FIS (repeated factorial ANOVA, p<0,05), but caused different trends along the time. CO_2 evasion was reduced during the first weeks after eutrophication. This result was caused by phytoplankton and periphyton growth (pelagic and periphytic chlorophyll-a, respectively). Despite the persistence of higher total chlorophyll-a concentrations during the first weeks, the decreasing trend for CO_2 evasion in NUT mesocosms was shifted after three weeks of experiment (repeated factorial ANOVA, p<0,05). Response time of heterotrophs as zooplankton and snails are longer than algae, probably contributing for this delayed increase in CO_2 evasion. The delayed increase of CO_2 evasion in NUFI treatment was less than found in enriched fish and nutrients mesocosms (NUFI treatment) probably due to higher algae biomass growth. The zooplankton predation by omnivorous fishes in mesocosms with ambient nutrient levels (FIS treatment) did not result in algae growth due to nutrient limitation (oligotrophic). On the other hand, the strength increase of top-down control by omnivorous fishes on zooplankton and snails reduced CO_2 concentrations in NUFI treatment, favoring algae growth under high nutrientavailability.

 Therefore, tropical humic condition contributed to increase CO_2 evasion in nutrient enriched mesocosms (NUT treatment), but only during the last weeks of experiment. Omnivorous fish introduction under ambient nutrient levels did not significantly change air-water CO_2 fluxes with respect to control mesocosms. In eutrophic condition (NUFI treatment), the studied omnivorous fish increased algae growth and reduced CO_2 evasion. In conclusion, the isolated eutrophication might favor the net heterotrophy in very humic tropical lakes due to high organic compounds availability, while omnivorous fishes may cause different effects on NEP depending of lake trophic status. Then, more studies are still needed to assess the effects of eutrophication on CO_2 air-water fluxes in tropical lakes with different DOC concentrations and food webs. We concluded that the synergism between bottom up and top down forces may be crucial for CO_2 air-water fluxes in tropical lakes.

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