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Abstract

Viral Effect on Carbon and Nitrogen Cycling in Bloom-Forming Cyanobacteria †

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Viruses can significantly influence the biogeochemical cycling of major nutrients through the infection and lysis of cyanobacteria, a globally important primary producer [1]. However, surprisingly little attention has been given to understanding how viruses alter the metabolism of carbon (C) and nitrogen (N) in bloom-forming cyanobacteria, distributed worldwide in fresh and brackish water ecosystems. Moreover, there is a lack of information about how co-occurring microbial communities respond to the lysis of these primary producers. Therefore, we employed an ecologically relevant filamentous diazotrophic cyanobacteria *Aphanizomenon flos-aquae* [2] and *Nodularia spumigena* [3], and their lytic cyanophages [4,5], as host–virus model systems in combination with a series of incubation experiments, to investigate the effect of viral infection and lysis on photosynthetic activity, nitrogen assimilation and enrichment rates, expression levels of genes involved in photosynthesis, and carbon and nitrogen metabolism, as well as on the concentration of some central and secondary cellular metabolites. In addition, we analyzed the variation in the composition of associated bacterial assemblages in response to viral additions and in relation to uninfected cyanobacterial cultures throughout their cultivation periods. We found that the effect of cyanophages on carbon and nitrogen cycling and cellular metabolism was significant yet varied widely depending on the stage of the infection process (e.g., cyanophage adsorption vs. DNA replication vs. release), and the state of the host culture (culture undergoing infection/lysis vs. recovering culture). Our observations suggest that cyanobacteria underwent a physiological state shift towards lower efficiency carbon and energy cycling, as well as to the reduced nitrogen transport from heterocytes (N-fixing cells) to vegetative cells [6,7]. The lysis of cyanobacterial cells was associated with a release of ammonium and other compounds that promoted changes in co-occurring microbes. The shift in the associated bacterial community was related to the infection rate and increased with higher initial cyanophage density. On the contrary, the initial infection rate, although it affected the timing, had no effect on the magnitude of net population loss or changes in population structure. Our observations indicate that cyanophage infection and lysis have implications across multiple levels of ecological organization, from cell to population and to the entire community [5,6].

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