High Concentrations of Viruses in the Sediments of Lac Gilbert, Québec

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Abstract. Viruses were found to be very abundant in the top layer of the sediments of Lac Gilbert, Québec. Viruses were extracted from the sediments using pyrophosphate buffer, and viruses from the diluted extracts were pelleted onto grids and enumerated using transmission electron microscopy. Viral abundance in the sediments ranged from $6.5 \times 10^8$ to $1.83 \times 10^{10} \text{ ml}^{-1}$, which is 10- to 1,000-fold greater than the number observed in the water column. This increase corresponds well with the 100- to 1,000-fold increase in bacterial abundance in the sediments. Viral abundance differed significantly among the surface sediment samples taken at different bottom depths and among samples taken at different depths of the water column. Viral abundance also varied significantly between the oxic and anoxic zones of the water column and the sediments. The virus-to-bacteria ratio varied greatly among the different sediment sites but not among depths in the water column. Viral abundance in the water column was related to bacterial abundance and chlorophyll concentration, whereas viruses in the sediments were most abundant in sediments with high organic matter content. Elevated viral abundance and their erratic distribution in the sediments suggest that viruses might play an important role in sediment microbial dynamics.

Introduction

Viruses are now recognized as a dynamic component of aquatic microbial communities [3, 10]. Rapid increases and decreases in abundances have been observed on a daily and diurnal basis [4, 14, 20], suggesting that viruses are constantly being produced and removed from these systems. Viruses are obligate parasites. Therefore, to support the population dynamics of viruses seen in aquatic systems, they must control, at least in part, the population densities of their hosts. Lysis induced by viral infection could be responsible for up to 72% of bacterial mortality [12,
Viruses are also believed to be important agents in the mortality of marine phytoplankton [30, 31, 32]. Although viruses seem to occur wherever there is a suitable host [1], viruses have yet to be enumerated in lake sediments. Because bacterial abundance is $10^2$- to $10^3$-fold greater in the sediments than in the water column [6, 29], it is likely that viral abundance would also be greater in the sediments. An increase in viral abundance in the sediments relative to the water column has been observed in marine sediments of a coral reef environment [21]. Although the latter study focused on the presence of coliphage counts as an indicator of anthropogenic pollution, relative to total virus counts in the sediments, coliphage abundance was low, suggesting an active natural sediment viral community.

Sediment bacteria are responsible for the oxidation and decomposition of deposited organic matter and the regeneration of nutrients [7]. In shallow depths, an intimate linkage exists between the level of productivity of the overlying water column and that of the underlying sediments [5]. Sediment microbes may regulate the production of new organic matter in the water column by returning regenerated inorganic nutrients to the water column. Not only may viruses present in the sediments be controlling bacterial numbers or production in the sediments, but the products of bacterial cell lysis by viruses could also be contributing to nutrient cycling in the sediments and subsequently to new production in the water column.

The objectives of this study were to determine if viruses were present in lake sediments, and if so, in what quantity relative to those in the water column. The top 1 cm of lake sediments was sampled at various bottom depths, and we determined whether viral abundance was related to bacterial abundance or percent organic matter at these sites in the oxic and anoxic zones in one lake. A comparison was made between the profile of viral and bacterial abundances and chlorophyll concentrations in the water column of this same lake to gain insight into factors that may influence viral distribution. The results show that unique characteristics of the sediments may allow a study of viral–host dynamics, which is not possible in the water column.

Materials and Methods

Site

Work was done with sediment and lake water samples collected from Lac Gilbert, a small oligo-mesotrophic, dimictic lake (8 ha, maximum depth 14.6 m, elevation 180 m) in the Eastern Townships of Québec, Canada (45° 12' N, 72° 17' W) on 28 August, 1992.

Samples

Water column samples for viral and bacterial enumeration were collected at every meter (0–12 m). Samples were fixed with 2.5% glutaraldehyde (final concentration). All samples were kept at 4°C until processed. Temperature, pH, and oxygen concentration were measured at each depth using a portable Orion pH meter.

The top layer of sediments was collected from several samples taken at different bottom depths (2 m, 4 m, 6–13 m) using a gravity coring device (core tube diameter, 6 cm). The top 1 cm of each core was extruded and fixed with 2.5% formaldehyde (final concentration) and stored at 4°C until processed within 1 month of collection. Two samples were taken at each depth.