Seasonal variations of viral- and nanoflagellate-mediated mortality of heterotrophic bacteria in the coastal ecosystem of subtropical western Pacifice

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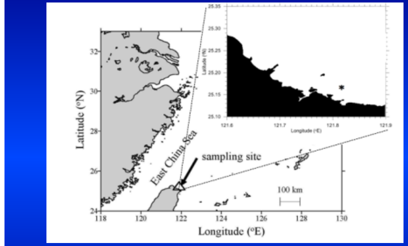
Abstract

Since viral lysis and nanoflagellate grazing differ in their impact on the aquatic food web, it is important to assess the relative importance of both bacterial mortality factors. In this study, an adapted version of the modified dilution method was applied to simultaneously estimate the impact of both viral and nanoflagellate grazing on the mortality of heterotrophic bacteria. A series of experiments was conducted monthly from April to December 2011 and April to October 2012. The growth rates of bacteria we measured ranged from 0.078 h^{-1} (April 2011) to 0.42 h^{-1} (September 2011), indicating that temperature can be important in controlling the seasonal variations of bacterial growth. Furthermore, it appeared that seasonal changes in nanoflagellate grazing and viral lysis could account for 34% to 68% and 13% to 138% of the daily removal of bacterial production, respectively. We suggest that nanoflagellates grazing might play a key role in controlling bacterial biomass and might exceed the impact of viral lysis during the summer period (July to August), because of the higher abundance of nanoflagellates at that time. Viral lysis, on the other hand, was identified as the main cause of bacterial mortality between September and December.

Materials and Methods



Research was conducted aboard the R/V Ocean Research II and Taiwan coastal water samples (*) were collected monthly at the same time of day (1000 to 1100 h) for about 2 years **(Apr-Dec 2011 and Apr-Oct 2013)** (Fig. 1).

Modified Dilution experiments

The regression coefficient resulting from the 0.2 µm dilution series represents only the nanoflagellate grazing rate (mg). Thus, the net growth rate of bacteria (k1) should be calculated as

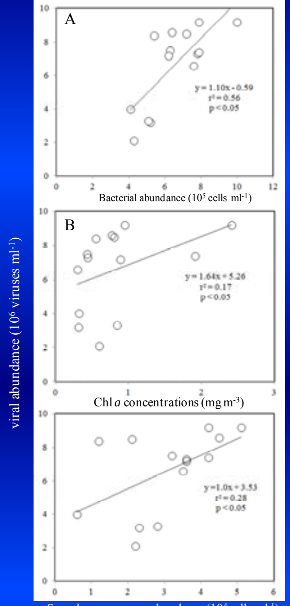
$K1=(\mu-mv)-(mg)\times DF$

If virus-free seawater is used as a diluent (30 kDa filters), the net growth rate of *bacteria* (k2) should be calculated as the difference between growth rate (µ) and mortality due to lysis (mv) and grazing (mg)

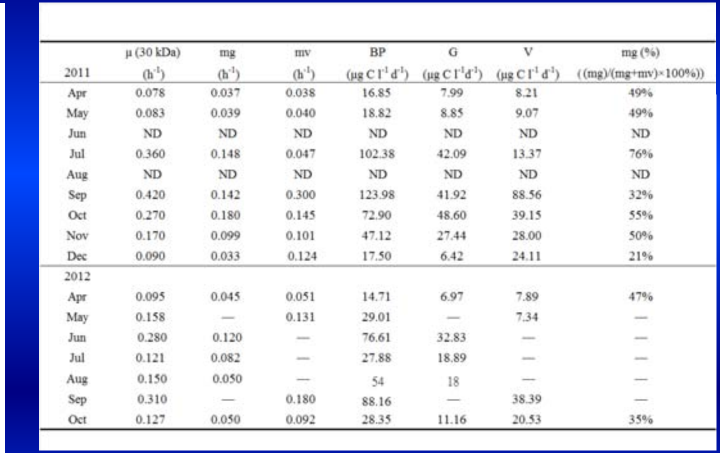
$K2=\mu-(mv+mg)\times DF$

A carbon budget was determined by combining the cellular carbon content estimates and data from the modified dilution experiments. Carbon content for heterotrophic bacteria was based on values reported in Caron et al. (1995) (15 fg C $cell^{-1}$). For bacteria in this study, carbon production (BP in µg C l^{-1} d^{-1}), losses due to grazing (G, µg C l^{-1} d^{-1}), and viral lysis (V, µg C l^{-1} d^{-1}) were calculated using the following formulae: $BP=\mu\times B_0$, $G=mg\times B_0$, and $V=mv\times B_0$, where µ is the dilution-based specific growth (y-intercept of the 30 kDa regression), mg and mv are the dilution-based grazing and viral lysis rates, and B_0 is the heterotrophic bacterial biomass (µg C l^{-1}) at the sampling time.

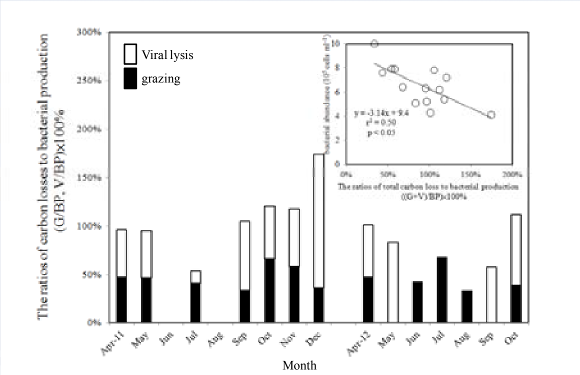
Results



Synechococcus spp. abundance (10^4 cells ml^{-1})



2011	µ (30 kDa) (h^{-1})	mg (h^{-1})	mv (h^{-1})	BP (µg C l^{-1} d^{-1})	G (µg C l^{-1} d^{-1})	V (µg C l^{-1} d^{-1})	mg (%) ((mg)/(mg+mv)×100%))
Apr	0.078	0.037	0.038	16.85	7.99	8.21	49%
May	0.083	0.039	0.040	18.82	8.85	9.07	49%
Jun	ND	ND	ND	ND	ND	ND	ND
Jul	0.360	0.148	0.047	102.38	42.09	13.37	76%
Aug	ND	ND	ND	ND	ND	ND	ND
Sep	0.420	0.142	0.300	123.98	41.92	88.56	32%
Oct	0.270	0.180	0.145	72.90	48.60	39.15	55%
Nov	0.170	0.099	0.101	47.12	27.44	28.00	50%
Dec	0.090	0.033	0.124	17.50	6.42	24.11	21%
2012							
Apr	0.095	0.045	0.051	14.71	6.97	7.89	47%
May	0.158	—	0.131	29.01	—	7.34	—
Jun	0.280	0.120	—	76.61	32.83	—	—
Jul	0.121	0.082	—	27.88	18.89	—	—
Aug	0.150	0.050	—	54	18	—	—
Sep	0.310	—	0.180	88.16	—	38.39	—
Oct	0.127	0.050	0.092	28.35	11.16	20.53	35%



Conclusions
In this study, the ratios of nanoflagellate grazing were generally higher in summer periods. We conclude that grazing transfers production from picoplankton to higher trophic levels, rather than shunting it into the dissolved pool through viral lysis and that viral lysis did the main cause of bacterial mortality between September and December, when it removes between 53% and 137% of the potential bacterial production.

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