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Numerical dynamics of bacterioplankton in shrimp cultural enclosure ecosystems*

Liu Guocai** Li Deshang Dong Shuanglin Lu Jing Chen Zhaobo
(Fisheries College, Ocean University of Qindao, Qingdao 266003)

Abstract Numerical dynamics of bacterioplankton in 5 shrimp cultural enclosure ecosystems were studied. The results were that the number of bacterioplankton fluctuated between 0.41×10^6 ml^{-1} and 10.63×10^6 ml^{-1} with an average of $(4.29\pm2.44)\times10^6$ ml^{-1}, and increased gradually with the lapse of cultural time. Bacterioplankton exhibited an obvious diurnal numerical fluctuation. Bacterioplankton numbers were correlated positively with water temperature, total chemical oxygen demand (TCOD) and dissolved oxygen demand (DCOD), but was not correlated significantly with particulate oxygen demand(PCOD), zooplankton and phytoplankton biomasses.

Key words shrimp culture, enclosure ecosystem, bacterioplankton, numerical dynamics

Study on bacterioplankton in shrimp pond can not only perfect the theory of nutrient structure in its ecosystems, but also provide the theoretical basis of microbial ecology for water management in shrimp culture.

There have been several reports on the study of numerical dynamics of bacterioplankton in shrimp ponds[1-5], but many of them still used the methods of alga culture[1,2] and common microscopy count[3] which can hardly give precise results[6], and moreover, bring difficulties to the comparisons among the bacterioplankton numbers. We used AODC method[7], which was widely used abroad, to count bacterioplankton in shrimp cultural enclosure ecosystems in this study conducted in the shrimp farm of Huanghai Fisheries Group Corporation in Shandong province in 1997.

1 Materials and methods

1.1 Experimental enclosures

The enclosures are 5 m × 5 m land-based ones with a height of 1.5 m (water depth 1.0 m), and are made of plastic-coated polyethylene woven cloth with a frame composed of wood and bamboo poles. In its center, a 90 W water stirrer is fixed to keep the water in dynamics.

The study used 5 enclosures (E1 ~ 5). The stocking density of shrimp in each enclosure was 7.2 ind/m^{-2}. The feed was placed in 2 feed dishes which were fixed in the 2 diagonal ends, each enclosure fed 4 times a day. Chicken manure was put into all enclosures about 1 month before the stocking of the cultured animals to grow feed organisms. Chemical fertilizer was applied according to water transparency,

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** 现为华东师范大学生物系博士后

Postdoctor in the Department of Biology, East China Normal University.

chl - a concentration and nutrient level in the enclosures.

1.2 Numerical dynamics of bacterioplankton

1.2.1 Water sampling Water samples from middle water layer(0.5 m) were gathered and preserved with formaldehyde(2% v/v final volume).

1.2.2 Bacterioplankton biomass AODC method[7] was used to count bacterioplankton. Water samples were stained with 0.01% acridine orange(AO) for 3 min, then filtrated through a 0.2 μm pore nuclepore filter under the pressure below 0.03 Mpa. The filters were soaped in 0.2% Irgalan black with 2% acetic acid for 24 h to eliminate self - fluorescence. The filter was put on a slide, and a drop of particle - free water was added, glass lidded, immersion oil added with lower fluorescence, then at least 10 fields and 200 bacterioplankton were counted for each sample under fluorescence microscopy

1.3 Diurnal fluctuation of bacterioplankton

Diurnal variation of bacterioplankton were measured in the 5 enclosures on Aug. 7～8 1997. Water samples from the upper(0.2 m) and lower (0.8 m) waterlayers (water depth 1.0 m) were taken at 6:00, 12:00, 18:00, 0.00 and again at 6:00, and then fixed with formaldehyde (2% v/v) final volume). Bacterioplankton biomaes were caculated.

1.4 Numerical dynamics of bacterioplankton and main water factors

COD was measured by oxidation method of Basic $KMnO_4$. Dissolved organic matter was separated by filtering water samples through 0.45 μm pore millipore filters.

Phytoplankton and zooplankton were counted by common microscopy. The volume of the species was measured and the biomass was calculated assuming plankton gravity ratio to be 1.

2 Results

2.1 Numerical dynamics of bacterioplankton

Numerical dynamics of bacterioplankton in each enclosure is shown in table 1.

Table 1 Dynamics of bacterioplankton in the experimental enclosures 10^6 ml^{-1}

date	05-30	06-06	06-10	06-16	06-20	06-28	06-29	07-14	07-20	07-24	07-29	08-05	08-11	08-15	08-17	08-24	08-25
E1	0.41	1.81	1.76	2.54	3.87	4.64	3.14	5.10	3.31	3.97	4.92	5.81	5.86	6.87	5.50	8.59	9.14
E2	1.36	1.40	1.13	3.46	2.53	5.17	3.57	6.43	4.26	7.37	6.22	2.81	3.32	3.99	3.38	3.21	3.29
E3	0.98	1.55	1.08	2.57	1.87	5.62	6.09	9.23	7 48	9.17	9.43	4.17	4.26	3.42	3.51	5.10	6.38
E4	0.42	0.87	1.59	2.07	2.52	4.57	9.88	10.63	8.13	2.32	2.70	4.61	4.51	4.24	4.11	2.77	3.15
E5	0.72	2.15	2.13	4.44	3.15	7.16	7.63	9.53	7.10	4.10	5.60	3.15	3.22	4.24	4.24	5.19	5.36

The number of bacterioplankton fluctuated between 0.41×10^6 and 10.63×10^6 ml^{-1} with an average of $(4.29\pm2.44)\times10^6$ ml^{-1} in 5 enclosures, and increased gradually with the lapse of culture time.

2.2 Diurnal variation of bacterioplankton

Diurnal variation of bacterioplankton are shown in table 2.

The number of bacterioplankton fluctuated noticeably within a day; their deviation coefficients varied from 0.49 to 0.88(upper waterlayer) and 0.47 to 0.74(lower waterlayer). The large deviation coefficients indicated that the production and consumption rates of bacterioplankton in shrimp cultural enclosures was high.

Table 2 Diurnal variation of bacterioplankton numbers in the experimental enclosures on Aug. 7～8, 1997

10^6 ml^{-1}

simpling place		time					deviation coefficient
		6:00	12:00	18:0	0:00	6:00	
E1	upper waterlayer	0.73	1.78	3.11	3.46	3.90	0.50
	lower waterlayer	3.80	0.43	4.26	1.47	2.48	0.64
E2	upper waterlayer	4.68	1.99	1.64	2.35	1.39	0.55
	lower waterlayer	4.16	1.23	1.68	0.49	1.72	0 74
E3	upper waterlayer	5.57	0.83	2.56	0.65	1.70	0.88
	lower waterlayer	4.12	1.15	2.20	0.67	2.07	0.65
E4	upper waterlayer	0.72	1.56	2.15	0.62	1.47	0.49
	lower waterlayer	1.79	1.19	1.78	0.20	1 10	0 41
E5	upper waterlayer	1.99	0.87	2.25	0.43	0.71	0 65
	lower waterlayer	0.60	0.56	1.57	0.28	1.57	0.67

2.3 Correlation between numerical dynamics of bacterioplankton and main water factors

Water temperature, COD and plankton biomass in each enclosure are shown in tables 3 and 4.

Table 3 Variations of COD in the experimental enclosures mg·L⁻¹

date	E1			E2			E3			E4			E5		
	TCOD	PCOD	DCOD	TCOD	PCOD	DCOD	TCOD	PCOD	DCOD	TCOD	PCOD	DCOD	TCOD	PCOD	DCOD
05-30	4.83	1.00	3.83	4.82	0.92	3.90	5.27	1.44	3.83	5.27	1.68	3.59	4.85	1.05	3.80
06-10	5.40	1.37	4.03	4.95	0.98	3.97	5.03	0.99	4.04	5.20	1.16	5.04	5.43	1.43	4.00
06-20	6.23	1.01	5.22	5.71	1.33	4.38	5.60	0.83	4.77	5.52	1.40	4.12	5.85	1.17	4.68
06-29	6.25	1.16	5.09	6.07	1.37	4.70	5.42	0.83	4.59	5.96	1.63	4.33	5.63	0.89	4.74
07-14	6.22	0.81	5.41	5.52	0.89	4.63	5.14	0.85	4.29	5.64	1.23	4.41	5.61	1.09	4.52
07-24	6.18	1.25	4.93	5.57	1.05	4.52	5.26	1.05	4.21	5.67	1.08	4.59	4.98	0.69	4.29
08-05	5.49	1.04	4.45	5.47	0.94	4.53	5.73	0.95	4.78	5.19	0.64	4.55	4.93	0.52	4.41
08-15	5.85	1.00	4.85	5.54	0.75	4.79	5.50	0.69	4.81	5.19	0.46	4.73	5.18	0.77	4.41
08-25	6.19	1.50	4.69	5.74	1.26	4.48	5.12	0.92	4.20	5.03	0.73	4.30	4.76	0.40	4.36

TCOD: Total COD; PCOD: Particulate COD; DCOD: Dissolved COD.

Table 4 Fluctuations of plankton biomass in the experimental enclosures mg·L⁻¹

date	temp./℃	E1		E2		E3		E4		E5	
		PB	ZB	PB	ZB	PB	ZB	PB	ZB	PB	ZB
05-30	21.5	-	-	-	-	20.18	2.73	11.03	2.51	-	-
06-10	23.5	5.65	1.43	8.50	0.86	4.57	0.72	7.44	0.41	6.85	0.64
06-20	25.0	3.60	2.45	4.30	1.70	4.29	0.95	10.43	1.28	4.12	0.61
06-29	26.9	2.63	2.69	7.44	2.08	2.53	0.83	2.70	1.01	1.46	2.96
07-14	28.3	4.12	2.16	15.37	1.21	6.52	0.74	8.17	0.29	3.72	0.66
07-24	30.9	5.67	0.66	7.05	0.87	7.67	1.24	10.10	0.52	15.68	0.25
08-05	28.7	5.00	1.16	4.73	0.12	4.91	0.03	1.97	2.52	1.99	2.93
08-15	29.9	12.87	1.70	4.18	2.66	5.15	0.41	5.87	2.38	0.73	1.94
08-25	29.5	4.21	1.29	7.05	2.07	1.60	1.11	4.09	0.89	0.70	1.16

PB: Phytoplankton biomass; ZB: Zooplankton biomass.

Bacterioplankton biomasses were positively correlated with water temperature ($r = 0.5987$, $n = 45$), TCOD ($r = 0.3093$, $n = 45$) and DCOD ($r = 0.2948$, $n = 45$), but were not significantly correlated with PDOC ($r = 0.0357$, $n = 45$), phytoplankton ($r = -0.1819$, $n = 42$) and zooplankton biomasses ($r = -0.1360$, $n = 42$).

3 Discussion

3.1 Numerical dynamics of bacterioplankton

Bacterioplankton numbers fluctuated significantly in the 5 enclosures during the study period. The fluctuation was related to water temperature, plankton, detritus and inorganic nutrient, and was assumed to be the result of multiple effects of physical, chemical and biological factors.

Compared with natural waterbodies (salt and fresh), shrimp ponds are small ecosystems with large community biomass and high concentration of organic matter, which make the interaction among physical, chemical and biological factors in shrimp ponds sophisticated and varied frequently. As bacteria are typical substrate-limited organisms[8] with high surface/volume ratio and high reproduction rate, they reacted quickly to the frequent variation of the physical, chemical and biological factors and showed larger fluctuation. Numerical dynamics of bacterioplankton in this study was consistent with those in natural waterbody (bacterioplankton numbers could increase several times as many within a few days) reported by Gude[9].

Bacterioplankton fluctuated between 0.40×10^6 and 10.63×10^6 ml^{-1} in the 5 enclosures during the cultural period, which is consistent with the results once reported as $(8.30 \sim 25.70) \times 10^6$ ml^{-1}[4], $(0.40 \sim 3.60) \times 10^6$ ml^{-1}[5] and $(0.36 \sim 13.15) \times 10^6$ ml^{-1}[3].

There was an obvious diurnal fluctuation of bacterioplankton numbers, which indicated that both bacterioplankton diurnal reproduction and consumption rates were high.

3.2 Relationship between numerical dynamics of bacterioplankton and main water factors

The numbers of micro - organisms is correlated significantly with water temperature and organic matter concentration[10]. The relationship between bacterioplankton numbers and water temperature, organic matter concentration in the study was consistent with the results above, which indicated that with the high rates of phytoplankton reproduction and artificial feed and fertilizer put into the pond, the organic matter concentration increased, and the high organic matter conentration and temperature could make bacterioplankton grow faster. This increase of bacterioplankton numbers was consistent with the results of sea water shrimp ponds reported by Guo et al[2], Gao et al[1], Lu et al[11] and Liu et al[2], and of fresh water shrimp ponds reported by MacLean et al[12].

There was not a significant correlation between bacterioplankton numbers and PCOD because the ratio of bacterioplankton biomass to total particulate organic matter was low (bacterioplankton carbon was 11.94 percent of total POC①). The fluctuation had no obvious effect on the variation of total suspending particulate organic matter.

Bacterioplankton numbers were not correlated significantly with phytoplankton and zooplankton biomasses due to the complicated relationship of nutrition among them, and the frequent changes of many factors affected these processes. The insignificant correlation between bacterioplankton numbers and phytoplankton, zooplankton biomasses were also found in fresh water fish ponds[13].

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对虾养殖围隔生态系浮游细菌的数量动态

刘国才　李德尚　董双林　卢　静　陈兆波

(青岛海洋大学水产学院,青岛 266003)

摘　要　对5个对虾养殖围隔生态系浮游细菌的数量动态进行了研究。结果表明:浮游细菌数量波动在$(0.41 \sim 10.63) \times 10^{6}\ ml^{-1}$之间,平均为$(4.29 \pm 2.44) \times 10^{6}\ ml^{-1}$。随着养殖时间的推移,细菌数量逐渐上升,细菌数量昼夜间呈现较大波动。细菌数量与水温、总有机质的化学需氧量(TCOD)、溶解态有机质的化学需氧量(DCOD)呈现显著正相关,与颗粒态有机质的化学需氧量(PCOD)、浮游动、植物生物量无显著相关性。

关键词　对虾养殖,围隔生态系,浮游细菌,数量动态