Biomonitoring of Coastal Pollution Status Using Protozoan Communities with a Modified PFU Method

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Structural and functional parameters of protozoan communities were assessed as indicators of water quality in Korean coastal waters in the summer of 2000. A modified PFU (polyurethane foam unit) method, named the BPFU system, was used in order to carry out the bioassessment. Both parameters suggested that biomonitoring using the BPFU system was more effective than the conventional PFU method in offshore areas. The species number collected by the BPFU system generally decreased as pollution intensity increased at three main stations and was greater than that collected using the PFU method (paired t-test, $t = 4.83$, $p < 0.0001$). The Margalef diversity index coincided well with the water conditions. The diversity index values calculated from the BPFU system were also significantly higher than those from the PFU method (paired t-test, $t = 5.37$, $p < 0.0001$). Furthermore, the functional parameters, i.e. S_{eq}, G and $T_{90\%}$, correlated with the pollution status and could thus clearly discriminate the different classes of water quality.

Keywords: marine; biomonitoring; pollution; protozoa; artificial substrate; modification.

Introduction

Polyurethane foam unit (PFU) is an artificial substrate able to play host to microbial communities in water bodies. PFU may host most protozoans including planktonic, periphytic and benthic protozoan assemblages (Yongue and Cairns, 1973; Lugo *et al*., 1998). Since the 1970s, Cairns and his colleagues have developed the PFU method to monitor pollution levels of freshwater (Cairns *et al*., 1972; Cairns, 1979, 1991; Cairns and Pratt, 1986; Shen *et al*., 1986). The PFU method was introduced to China by Shen (1983) and has been widely used to evaluate freshwater quality (Shen, 1993). Compared with other protozoan communities, using PFU protozoan communities have not only structural but also functional realism for bioassessment. Although the PFU method has been widely used to monitor freshwater quality, to the best of our knowledge, no research has involved marine habitat. This study is the first to use the PFU method for arine biomonitoring. A modified system, named bottled PFU (BPFU) system, was tentatively used for bioassessment in offshore areas. Its efficiency was tested and comparatively studied with the PFU method.

Materials and Methods

Study sites: Four stations in the coastal waters off Inchon, Korea were selected as study area during summer cruises from June 14 through July 4, 2000.

The PFU and BPFU methods : The PFU (polyurethane foam unit) block was about 6 · 6 · 6 cm in size. The PFU blocks were sampled on days 1, 3, 7, 10, 15 and 21 after being soaked in marine water. Each time two PFU blocks were collected for analysis. The apparatus of bottled PFU (BPFU) system is two PFU units bottled by a cylindrical plastic bottle (diameter ca. 7.5 cm; height, 13.5 cm) with four slits (l · w = 12 · 3 cm). The BPFU and PFU systems were soaked at the same water depth and sampled simultaneously. Each time one BPFU was collected for analysis.

Structural and functional parameters : The species diversity index (d) value was calculated according to the formula (Margalef, 1958): $d = (S_t - 1) / \ln N$, where

S_t = number of species at time t and N = total number of individuals per 0.1 ml of sample.

- Colonization process: MacArthur and Wilson's (1967) equilibrium model: $S_t = S_{eq}\,(1\text{-}e^{-Gt})$

was applied to assessing the colonizing process of ciliate and flagellate communities.

- The functional parameters, i.e. S_{eq}, G and $T_{90\%}$, were obtained according to Shen *et al*. (1990). S_t shows the species number at time t. S_{eq} is species number during the equilibrium of colonization. G is the constant value of colonization rate. $T_{90\%}$ is the time taken for reaching 90% S_{eq}.

Environmental factors and statistical analysis : Temperature, salinity, pH and dissolved oxygen (DO) were measured *in situ*. COD, total nitrogen (TN), total phosphate (TP), suspended solids (SS) and Chlorophyll-a concentrations were measured in the laboratory for each sample. SAS (SAS Institute, 1983) programs were used for the statistical analysis.

Results

Microbial community structure: Both the total number of species and the number of species (S_t) detected with the BPFU system were distinctly higher than those with the PFU system at Stations 1-3, whereas the species number collected by both the BPFU and PFU systems was similar at Station 4. The total number of species at Station 4 was higher than those at Stations 1 and 3. Compared to the other stations, Station 4 was characterized by the highest number of ciliate species. The possible reason is the PFU blocks at Station 4 were tied adjacent to the wall of a floating pier, where *Aufwuchs* or periphytic protozoan communities were very abundant. In the BPFU system, the abundance (N) of ciliates and flagellates fluctuated during the survey. The highest abundance was observed at Station 3 on day 10, Station 1 on day 7 and Station 2 on day 15. Relatively low abundance was detected both by the BPFU and PFU systems at Station 4 indicating that the circulation and tidal current of the marine system might affect the colonization of protozoans. Margalef diversity index (d) : among the BPFU protozoan communities, Station 2 showed the remarkably highest diversity (5.52 in average) in comparison with Stations 1 and 3. The lowest value (3.58 in average) was recorded at Station 3, which was regarded as the most polluted area in the survey. Diversity index values at Station 1 (4.03 in average) were a little higher than those at Station 3. Among the PFU protozoan communities at the three main stations, mean diversity index values at Station 2 were also the highest, followed by those at Stations 1 and 3, respectively. Diversity index values however, were lower than those from the BPFU system.

Colonization process of protozoan communities: The S_{eq} values for Station 1 were a little higher than those for Station 3 and corresponded with their diversity index values. The G value represents the rate of colonization and can be used to discriminate a relatively clean area from a heavily stressed area. The highest G value calculated from the BPFU system was observed at Station 2, which was subsequently followed by Station 1 and Station 3. The G values obtained from the three stations further indicated that water conditions at Station 2 were the best, while water conditions at Station 3 might be the worst among the main stations. The $T_{90\%}$ value is a parameter that positively correlated with G. The lowest value of $T_{90\%}$ calculated from the BPFU system was 5.35 on day 10 and 6.53 on day 15 at Station 2, whereas the highest value was 6.04 on day 10 and 7.13 on day 15 at Station 3. Generally the S_{eq} and G values are low, while $T_{90\%}$ values are high in stressed waters. The highest values of the S_{eq} and G calculated from the PFU system was also for Station 2. However, these values were lower than those from the BPFU system. Both the S_{eq} and G values of Station 1 were lower than those of Station 3. All these further suggested that the functional parameters obtained from the PFU system failed to discriminate the minor differences of water quality in offshore areas, while the BPFU system worked well. The minor differences of the BPFU and PFU functional parameters at Station 4 implied that Station 4 was distinctly different from the other three stations in physical factors and it was therefore hard to conduct comparative studies with the other stations.

Relationships between environmental variables and species diversity : The species diversity decreased with the increase of COD concentrations among the three stations. Station 2 was distinguishable by its low nutrient level and COD concentration and high species diversity. The nutrient level at Station 3 was lower than that of Station 1 during the survey. However, water quality at Station 3 was still worse than the other stations due to its higher heavy metals and organic pollutant levels (Xu *et al.*, 2000). The species diversity index generally indicated that protozoa might give a comprehensive evaluation on pollution status in community level.

Discussion

- The BFPU systems was testified a good for marine biomonitoring . Both structural and functional parameters were verified to correlate with water quality.
- The present study suggested the efficiency of the PFU method in offshore areas was affected by some variables including strong circulation and tide.
- Advantage of the BPFU system include : I) sampling stability, II) structural and functional reality, and III) retaining water volume stable for quantitative comparison.
- Sampling frequency is suggested at days 1, 3, 7, 10/11, 15, while examining BPFU protozoan communities at day 1 or 3 is is thus a rapid, efficient and economic way for routine assay of marine water quality.

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