Microbial Biomass on Particulate Organic Matter in Seawater of the Euphotic Zone

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Microbial biomass on suspended organic matter in seawater of the euphotic zone of Saanich Inlet was investigated. The viable microorganisms were measured by the glucose-uptake method. Microbial carbon on particulate organic matter in seawater was determined to be, on the average, 9.9 μg of C/liter, and there was a regression relationship as \( y = 0.0062x - 1.79 \) with an unbiased variance \( V_{xy}^{1/2} = 0.38 \), where \( x \) = particulate organic carbon in seawater (micrograms of C/liter) and \( y = \log \) of microbial carbon (micrograms of C/liter).

As the climax state of succession of the marine ecosystem would be reached when primary producers are converted completely into bacterial cells, matured detritus in seawater should be composed chiefly by living and dead cells of bacteria. As reviewed by Nishizawa (6, 7), detritus can also be formed from dissolved organic matter that originates from the production of phytoplankton. Such matured detritus can be observed predominantly not only in the aphotic zone but also in the euphotic zone of the sea, where phytoplankton and zooplankton can also be found.

The predominance of detritus in the food of marine animals clearly indicates the importance of bacteria and allied microorganisms to detritus in the food chain of the sea (2, 3, 5, 11, 12). The importance may be better stressed by the fact that most detritus feeders are not primarily dependent on organic debris but on the microorganisms which attack the debris (1, 5).

On the other hand, many studies suggest that food selectivity of animals is associated more with the physical state of the food, such as its shape and size, rather than its chemical composition. Actually, most microorganisms in the sea are on detritus, and detritus feeders can take up microorganisms associated with detritus more efficiently than those in the free-living condition. Such animals swallow or filter detritus indiscriminately and assimilate only digestible parts.

From these points of view, estimation of the microbial biomass relevant to the standing crop of particulate organic matter in seawater is of primary interest for solving the food chain problems of aquatic systems.

MATERIALS AND METHODS

Sample collection. Microbial investigation was conducted to measure viable cells of heterotrophic microorganisms relevant to the standing crop of particulate organic matter in seawater at Saanich Inlet (48° 38' N, 123° 30' W), British Columbia, Canada, during May, June, and July 1968. Seawater samples were collected aseptically by use of Cotet sterile samplers from depths of 0.5, 2, 10, 15, 20, and 30 m. All of the microbiological treatments were finished within 0.5 hr of their collection aboard the C. N. A. V. Deperm barge YBD3.

Estimation of microbial biomass. Glucose uptake by microorganisms in natural seawater was measured by the method of Parsons and Strickland (10). Incubation was for 4 hr at the in situ temperature, and concentrations of 250 mg of C of D-glucose per m³ of water sample containing 2 μCi of ¹⁴C-D-glucose were used. The radioactivity taken up by the microorganisms was determined in a liquid scintillation counter (Nuclear-Chicago Corp.) after filtration on HA filters (diameter, 25 mm; Millipore Corp., Bedford, Mass.). The relative biomass of the heterotrophic microorganisms on suspended matter in seawater was calculated on the basis of the result that the glucose-uptake rate of a pure marine Vibrio sp. was (5.0 ± 0.3) × 10⁻¹¹ μg of C per cell per hr (13). The Vibrio was isolated from the water of Saanich Inlet by using medium 2216(15). The uptake rate was measured in autoclaved seawater under the same conditions as those used for the natural flora.

Particulate organic analysis. Particulate carbon in seawater was determined after filtration on glass fiber filters by the semimicro Pregl method as modified by use of the Coleman carbon analyzer (14).

RESULTS

The microorganisms on particulate matter in seawater of Saanich Inlet were investigated by the
concluded that the microbial biomass in seawater was, on the average, about 9.9 \( \mu g \) of C/liter and that the microbial fraction of the organic particles was about 2%.

During this study, the concentration of organic particles in seawater was generally higher than the threshold of the feeding concentration for marine copepods according to the approximate estimations of Parsons and Seki (9).

**DISCUSSION**

To study the role of bacteria and allied microorganisms as a bridge between phytoplankton and filter feeders in the food chain of the sea, an investigation was conducted to estimate the viable microbial biomass relevant to the standing crop of particulate organic matter in seawater. Since most of the bacteria and allied microorganisms in seawater exist as clumps or in aggregates, the measurement of their biomass has been almost impossible. As was reviewed and discussed by Seki (13), respiration, glucose uptake, and adenosine triphosphate (ATP) content of microorganisms may become the best parameters for the estimation of the viable microbial biomass in the sea. However, as respiration or ATP analysis (4) would show all of the viable biomass, it cannot be a useful parameter for the biomass estimation of bacteria and allied microorganisms in the eucheptic zone of the sea because respiration or ATP of phytoplankton may also interfere. Thus, glucose uptake is considered to be a good parameter for the estimation of only viable heterotrophic microorganisms.

Parsons (8) has shown that the total organic matter in the eucheptic zone approximates the following distribution: soluble organic, 100; particulate detritus, 10; phytoplankton, 2; zoo- plankton, 0.2; fish, 0.002; expressed on a relative scale based on 100 for the amount of soluble organic matter. As a result of this study, microorganisms in Saanich Inlet that can utilize glucose should be 0.2. Although the value may be low compared to that of total heterotrophic microorganisms, because glucose is not considered to be metabolized by all marine heterotrophs, the value measured at the eucheptic zone of Saanich Inlet was nearly the same as that estimated at the aphotic zone of the ocean; i.e., Holm-Hansen and Booth (4) estimated the bacterial biomass in the Pacific Ocean on the basis of ATP concentration and showed that a few per cent of living cells on total particulate organic matter were often measured at the aphotic zone where biomass of phytoplankton does not interfere. In conclusion, it can be suggested that the viable biomass of bacteria and allied microorganisms contains a

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**Table 1. Regression analysis of microbial biomass to particulate organic matter in seawater (data from Fig. 1)**

| Source of variation | Sum of square | Degree of freedom | Mean square | \( F_0 \) |
|---------------------|---------------|------------------|-------------|-----------|
| Linear regression   | 1.75          | 1                | 1.75        | 11.9**    |
| Residual            | 16.5          | 112              | 0.147       |           |
| Total               | 18.25         | 113              |             |           |

**Probability level \( F(1, 112; 0.01) = 6.9. **

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**Fig. 1. Viable microorganisms on particulate organic matter in seawater of Saanich Inlet during the summer of 1968.** The line represents the regression relationship between the microbial carbon and particulate carbon in seawater.

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The suspended organic matter in seawater of Saanich Inlet was highly variable in content of viable microorganisms that can utilize glucose. From the statistical analysis (Table 1), a regression relationship was found between the logarithm of microbial biomass (micrograms of C/liter) on suspended matter \( x \) and the concentration of particulate organic carbon (micrograms of C/liter) in seawater \( y \) as \( y = 0.0062 x - 1.79 \) with an unbiased variance \( V_{xy}^{1/2} = 0.38. \) From this analysis, it is
few per cent of the total particulate organic matter in the sea.

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