NOTE

Vertical Distribution of Carbohydrate Utilizing Bacteria in Lake Kizaki

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Many investigations have been made on the distribution of heterotrophic bacteria in natural aquatic environments. They have afforded us much information on the occurrence of various functional groups of heterotrophic bacteria in lakes and seas, and on their possible roles (KUZNETSOV, 1970; JONES, 1971; SIEBURTH, 1971). However, relatively little is known as to the relation between their distribution and their participation in the process of organic matter decomposition in natural waters.

In water bodies where a marked thermal stratification is seasonally developed, organic matter production by phytoplankton is generally confined to the epilimnion during the summer. According to OHLE (1962) and SAIJO and SAKAMOTO (1970), the epilimnetic organic matter decomposition is estimated to account for about 80% of the autochthonous organic matter production. It is also responsible for more than 80% of the organic matter decomposition throughout the whole water column. Such a vertical localization of organic matter production and decomposition in natural water bodies suggests that there may be great differences in heterotrophic bacterial population and their ecological roles between epilimnion and hypolimnion.

The present study was conducted to examine such differences of bacterial population and their relations to organic matter decomposition in a stratified water body.

Lake Kizaki was selected for the present

study. It is a typical mesotrophic lake situated in the center of Honshu with a maximum depth of 29.5 meters and a surface area of 140 hectares. From the beginning of May to the end of October, a marked thermal stratification is observed. The present paper is concerned with the results of the surveys performed on June 26 and August 6-8, 1977.

1. Methods

Water temperature was determined with a thermistor (Toho Dentan, ET-3). Water samples for chemical analysis were taken with a Van Dorn sampler, and followed by the filtration through preignited glass fiber filter (Whatman GF/C). The filtrated water was employed for chemical analyses of dissolved organic carbon (DOC: MENZEL and VACCARO, 1964) and of dissolved carbohydrate carbon (DCC: HANDA, 1966). Determination of particulate carbohydrate carbon (PCC: HANDA, 1967) and chlorophyll-a (UNESCO, 1966) was made on GF/C filter samples.

The water for bacterial count was taken with a vacuum glass ampoule sampler (TERAI, 1979). Water samples were diluted decimally to 10^{-3} with sterilized 0.85% sodium chloride solution, followed by blending with a Thermo-Mixer (Thermonics Co., Ltd., Tokyo) for 3 minutes to disperse aggregated or attached bacteria, and five media were inoculated with these samples within several hours of sampling. For the plate count of total aerobic heterotrophic

bacteria, original and diluted samples were inoculated to one-tenth strength nutrient agar medium in triplicate. Incubation was conducted at 20°C for 3 weeks for epilimnetic bacteria and 6°C for 4 weeks for hypolimnetic bacteria. The cell number of several functional groups of heterotrophic bacteria was estimated by the growth responses in the cultures, each of which contained different carbohydrates. The most probable number method using 5 test tubes for each dilution was used for this estimation. A group of bacteria able to utilize cellulose was examined on Dubos medium (RODINA, 1972) in which a strip of qualitative filter paper (Toyo Roshi, No. 2) was added. For xylan utilizer, Augier medium (RODINA, 1972) with the xylan isolated from higher plant (Tokyo Kasei Co., Ltd.) was added. After the incubation of 4 weeks at 20°C, the test of growth response was conducted by the method of RODINA (1972). The estimation of the cell number of bacteria capable of growth on cellobiose or glucose was made on the medium of Dubos in which cellobiose or glucose was added (1g/L) as a sole carbon source. The incubation was conducted at the same temperature as mentioned above. Four weeks after, an optical density at 570 nm was measured. For the

tube on which a significant turbidity was detected, the residual cellobiose or glucose was determined with the phenol-sulfuric acid method (HANDA, 1966). When apparent consumption was detected, the culture was judged as positive.

2. Results and Discussion

The results are graphically presented in Figs. 1 and 2. The amounts of DOC, DCC and PCC were large in the epilimnion and decreased sharply with depth through the thermocline. In the hypolimnion, they were about one-half to one-fifth of those in the epilimnion. It is noticeable that the ratio of PCC to DCC did not show any remarkable change with depth. The fact seems to be interesting from an ecological viewpoint, considering the different significance of particulate and dissolved organic matter to the growth of heterotrophic bacteria. It has been recognized that two modes of bacterial existence occur in natural water body; one is the attachment to particles and the other is a free-living type (FERGSON and RUBLEE, 1978). The growth of heterotrophic bacteria and its relation to the organic matter transformation or consumption would be different for such attached and free-living bacteria because of their different micro-environ-

Fig. 1. Vertical distributions of water temperature, Chl-a, PCC, DCC, DOC and heterotrophic bacteria on June 26, 1977.

Fig. 2. Vertical distributions of water temperature, Chl-a, PCC, DCC, DOC and heterotrophic bacteria on August 6-8, 1977.

ments. The results of detailed examination on this relationship will be reported in a subsequent paper.

Figures 1 and 2 indicate that the cell number for all five groups of bacteria was large in the epilimnion and decreased with depth in a way similar to the vertical change of organic matter. And especially in June the maximum number of each functional group was observed just above the thermocline. The increase in the number of bacteria at the bottom in June is presumably due to a mechanical turbulence at the water-mud surface. The order of each bacterial population in the present studies was as follows throughout the whole water column; total heterotrophic bacteria > glucose utilizer > cellobiose utilizer > xylan utilizer > cellulose utilizer. Cellulose utilizer was not detected in the whole water column in June. The maximum number of each functional group of heterotrophic bacteria did not appear in different layers of the water body.

The grouping of heterotrophic bacteria according to their function in the present study was only tentative. Selection of carbon sources added to the media was made with due regard to the difference in the degree of carbohydrate degradation. The chemical nature of carbohydrates

occurring in a natural lake should be different from that in a given medium. However, the utilization of carbohydrate by bacteria would greatly depend on the difference in their abilities for hydrolysis of carbohydrate polymers. Therefore, we may assess the functional zonation of carbohydrate degradation in the lake, to some extent, from the vertical profile of each functional group of bacteria. The present results unexpectedly revealed almost no possibility of vertical zonation in carbohydrate degradation in a stratified water column. The abundance of every functional group of bacteria in the epilimnion would presumably reflect the active epilimnetic degradation and consumption of organic matter.

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摘 要

本崎湖の夏期成層期を対象に、異なった炭素源を含む培地を用い、水中での有機物代謝に関与する細菌の垂直分布を炭水化物の利用特性の面から調べた。全従属栄養細菌数は表水層で最大値を示し、深度とともに減少した。その垂直分布は、溶存・けんだく態炭水化

物の垂直分布と同様の様式であった。4つの異なった炭水化物（グルコース、セロビオース、キシラン、セルロース）を利用するそれぞれの細菌群の垂直分布も、全従属栄養細菌の垂直分布と同様の様式を示し、それぞれの細菌群が異なった層で最大値を示すということとはなかった。

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