



MICRO-SPATIAL STRUCTURE OF PERIPHYTONIC COMMUNITIES: DETERMINAL FACTORS

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SYNOPSIS

Hydrodynamic factors play an essential role in the formation of micro-spatial structure in the communities since they determine the location of certain organisms on the substrate (depending on the development of adaptations to certain loads). As was shown organisms smaller than 1 mm live entirely within the hydrodynamic boundary layer which formed around the body in a fluid current flow due to the viscosity. Shear stress, integrated force and instability of boundary layer should be mentioned as the most important abiotic factors influencing organisms in a boundary layer. The usual factors such as temperature, concentration of oxygen, dissolved organic matter, etc is essential too. The action of all these factors is different in various parts of boundary layer being conditioned by the spatial structure of the layer.

INTRODUCTION

There are several interpretations of the term "periphyton". However we look up the periphyton as any community of organisms at the "solid body – water" boundary independently of the mode of substrate (Dovgal, 2005). The inhabitants of aquatic animal bodies and vegetative organs of plants are correspondingly attributed to the periphytonic community and was the main object in our investigations. The factors associated with water flow should be rather important for aquatic attached organisms (Koehl, 1984, Silvester and Sleight, 1985, Fenchel, 1987, Dovgal and Kochin, 1985, 1987, Dovgal, 2000, 2005). Influence of these factors may be significant even in stagnant waters due to the current caused by temperature convection (Dovgal and Kochin, 1997). Unfortunately the influence of hydrodynamic loads on the micro-spatial structure of communities forming at the substrates was poorly understood. The paper dealt with brief overview of mentioned factors.

PROCEDURES

The article is based on the original data on ecological and morphological features of sessile ciliates under a variety of conditions at the different substrates. Also various literary data on the sessile microorganism ecology were parsed.

The spatial distribution of the species inhabit at the inanimate substrates was studied by exposition of glass slides. For the purpose ciliates finding on the algae thallus, macrophytes and hosts bodies the vital staining agents may be useful applied, in particular neutral red (0,001%). The macronucleus stained by 0,001% methyl green. The elytra of small aquatic beetles or bugs can be examined using dissecting microscope for the presence of commensals. However it is better to do scraping by blade, scalpel or preparation needle from the surfaces of bodies of large water beetles (for example, *Dytiscus* sp. and *Hydrous* sp.), bugs (*Nepa* sp. and *Ranatra* sp.) and mollusc shells, etc., as well as from vegetative organs of the aquatic plants, but account must be taken of unfailingly loss of the part of material.

In investigations of the peculiarities of sessile protozoan (ciliates) ecology that are inhabitants of body surface of various free-swimming hosts the characteristics of hydrodynamic boundary layer near the body of the latter were size up. The well-studied peculiarities of the host swimming were considered.

It should be remarked that the actual characteristics of the flow around a complicated body, for which the bodies of aquatic invertebrate animals assigned, are highly difficult for estimation. The invertebrate hosts of ciliates (for example, aquatic beetles) are swim irregularly: at the instant of stroke by legs they accelerate, than follows the stage of tranquil swimming (with momentum). Accordingly the boundary layer is unsteady under host surfaces.

Thus we make several admissions for get over the difficulties: only stationary phases of the invertebrate motions and plate rather than three-dimensional boundary layer were examined. This allows as using the theory of laminar boundary layer in calculations (Dovgal and Kohin, 1995, Dovgal, 2005).

RESULTS AND DISCUSSION

As British specialists Silvester and Sleigh in 1985 have shown organisms smaller than 1 mm live entirely within the hydrodynamic boundary layer which formed around the body in a fluid current flow due to the viscosity. Velocity of the current within this layer gradually decreases and near the solid surface drops to zero (i.e. so called sticking of the fluid takes place). There are two types of hydrodynamic loads acting in the layer: the shear stress and the integrated force. First of them force on the basin of the attached ciliate and most common adaptation for the load is extension of the basin area. The integrated force is influence the top of sessile ciliate. Firstly we interested in adaptations of ciliates to these conditions. At that was observed some peculiarities which complicated to explain without using of hydrodynamics.

The first case was connected with water beetle *Hyphydrus ovatus* (Linnaeus,

1761), at which body abundant suctorian ciliates *Discophrya lichtensteinii* (Claparede et Lachmann, 1859) are living. It has been found that the stalk length of these ciliates naturally rise in individuals which living nearer of the end of beetle body. This observation was confirmed by measuring and processing the data by means of ANOVA. The results encouraged us to suppose correlation between the stalk length and parameters of the boundary layer forming around the surface of the beetle's body during swimming. Estimation of the boundary layer parameters made possible to distinguish 3 zones along the body of a beetle (Dovgal and Kochin, 1995).

The first one covers the head, the thorax and anterior part of elytrae (Fig. 1). Specimens of *D. lichtensteinii* settled in this zone are beyond the displacement thickness (where the water velocity is about zero) and they are subjected to the shear stress as well as to the integrated force. The 2nd zone covers the middle part of elytrae. Here specimens of ciliates are placed entirely within the displacement thickness and are influenced only by shear stress. The 3rd zone begins at the point of the boundary layer separation and covers the hind one third of the beetle body (Fig. 1). Ciliates within this area are exposed to the water fluid with high turbulence. Thus, each specimen settled on the surface of moving host is located within the specific area heterogeneous both in the longitudinal (from anterior to posterior end) and the transversal (normal to the body surface) directions.

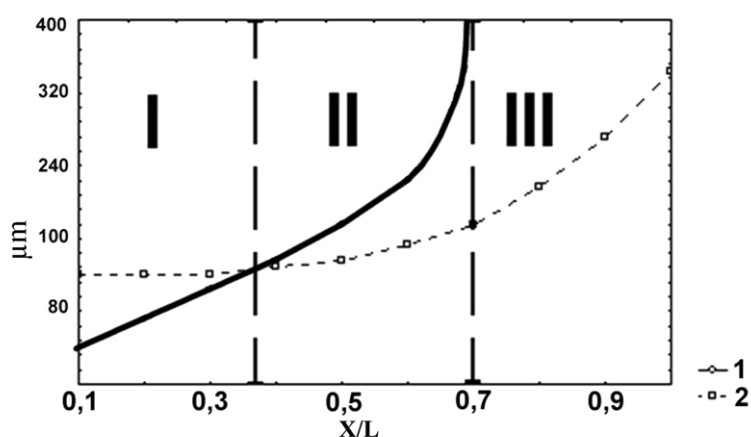


Fig. 1. The boundary layer parameters and *Discophrya lichtensteinii* (Claparede et Lachmann, 1859) body height at the upper surface of the *Hyphydrus ovatus* (Linnaeus, 1761) body. 1 – displacement thickness; 2 – ciliate body height; L – length of the beetle body; X – distance from the forward end of the beetle body; I-III – zones.

The second case was connected with water bug *Ranatra linearis* (Linnaeus, 1758) on which live the suctorian ciliate *Discophrya elongata* (Claparede et Lachmann, 1859) that has flattened cell body. At the upper surface of the bug leg the individuals of ciliate equally aligned whereas at the lateral surface of the leg their randomly arranged (Fig. 2). For our opinion this is due to the fact that when *Ranatra* move the stream is in one direction at the upper surface of leg and ciliates successfully bring down the load deflecting in plane. Whereas near lateral side the

stream is vortical therefore ciliates have not any definite orientation. The latter observations to make it clear that the nonstationarity (instability) of the boundary layer is also important factor influencing the organisms living at the solid surface.

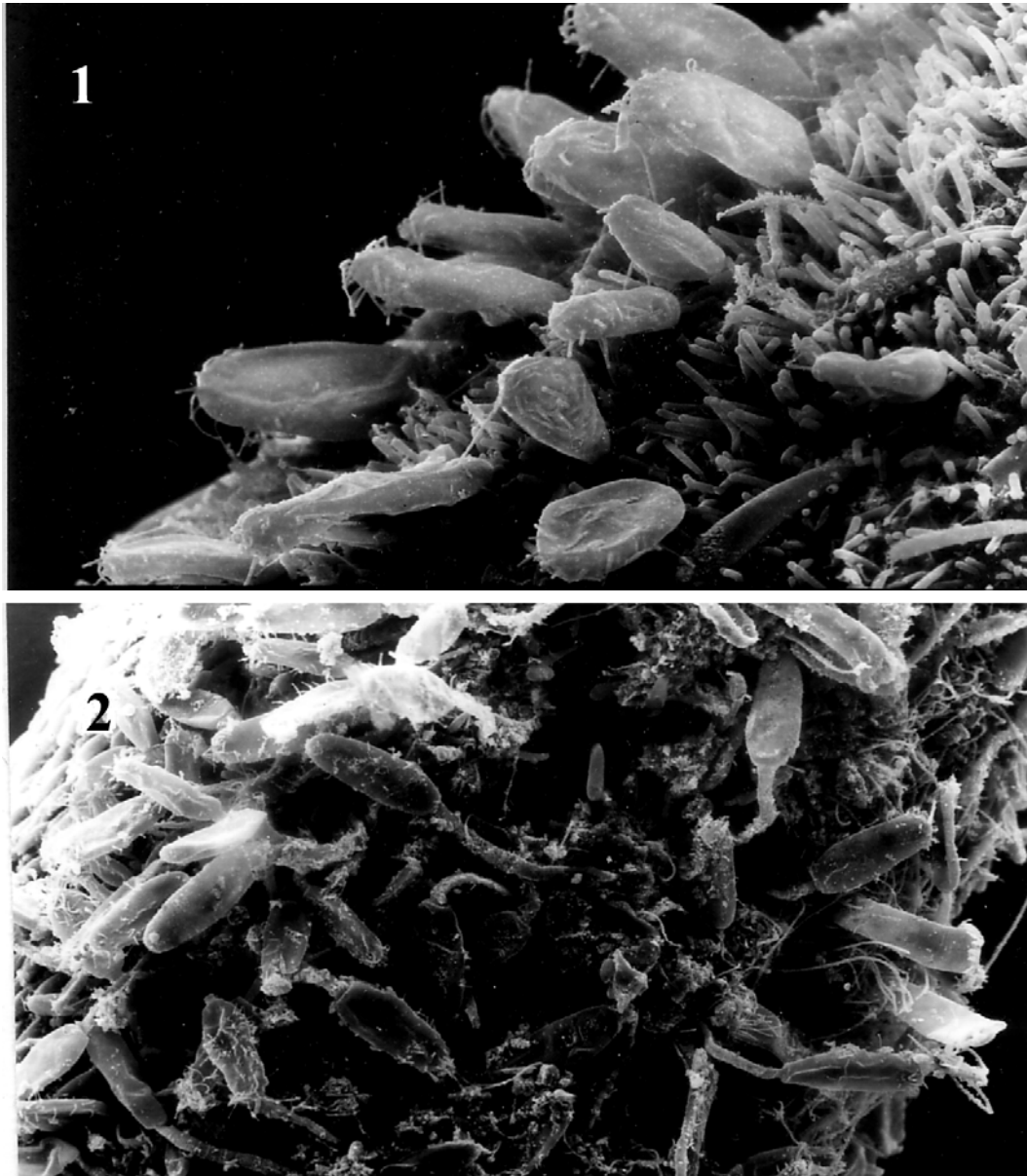


Fig. 2. The orientation of *Discophrya elongata* (Claparede et Lachmann, 1859) at the upper (1) and lateral (2) surfaces of the leg of bug *Ranatra linearis* (Linnaeus, 1758). Scanning electron microscopy (1 - $\times 600$; 2 - $\times 200$).

Thus our observations and literary data as well as results of investigations of boundary layer peculiarities near surface of aquatic invertebrates bring us to following concept (Dovgal, 2005):

1. Small sessile organisms live within the hydrodynamic boundary layer.
2. Boundary layer has a specific spatial structure that stable at different types

of substrates.

3. The presence of that spatial structure to create the necessary prerequisites for sessile organisms in order to forming of various adaptations to the factors which influencing in different localities of the boundary layer. These factors are responsible for spatial heterogeneity of the boundary layer which represents a complex of potential habitats for organisms. These considerations substantiate the concept of boundary layer as adaptive zone for sessile organisms (protists).

Hydrodynamic factors play an essential role in the formation of spatial structure in the periphyton communities since they determine the location of certain organisms on the substrate (depending on the development of adaptations to certain loads). For example the species possessing attaching organelles can colonize the sites closer to the fore part of an extended flow around the substrate than organisms merely adhering to the substrate with mucus. Inhabitants of the encrusting communities can be divided into several groups in accordance with the body height (Bereczky, 1990), and this is associated with the loads functioning in the boundary layer (Dovgal, 2005).

Thus on a substrate extended along the water flow, the density of the organism can substantially increase towards the rear edge, i.e., the fringe effect of periphyton is observed, and its expression is associated with the parameters of the boundary layer (Railkin, 1998). In the course of colonization of sterile substrates, the types of loads effect the organisms change depending on the elevation above the substrate, localization, spatial orientation, etc.

Thus, the following sequence of the developmental stages appears (Dovgal, 2005):

1. The formation of a film (two-dimensional) community (Fig. 3). The stage begins with settlement of bacteria as well as diatoms and ciliates lacking with adhesive structures. Such small organisms occurred within the diffuse boundary layer, where they obtained nutrients by molecular diffusion only.

The main hydrodynamic factor at this stage is the shear stress. The species adopted to its different values (components of the fouling communities) allocated within the sites of the substrate with different values of τ , because of the fringe effect, formed the colonies with the density increasing towards the rear edge of substrate and characterized by a horizontal (two-dimensional) community structure.

2. The formation of three-dimensional community (Fig. 3). The stage comes when the migratory stages of sessile protists (generally swimmers of ciliates) completed the metamorphosis and formed their adhesive structures (stalks in ciliates). As a result organisms rising in the zone of convective diffusion with rate that considerably higher than the rate of molecular diffusion.

The integrated force is the main hydrodynamic factor at the stage. Having developed the adaptations to the integrated force, some species colonized the sites which enabled them to be in the displacement thickness where the force has the lowest values; the other species possessing relatively more effective systems of protection from the load, extended outside the displacement thickness and acquired more comfortable conditions of mass transfer. Thus, adaptations to the integrated

force (in addition to adaptations to the shear stress) resulted in the formation of a three-dimensional spatial structure of communities.

3. The formation of macroperiphyton community (Fig. 3). Since attached colonial organisms (and subsequently, multicellular algae and sedentary multicellular animals) appeared, the community of the encrusting macroorganisms formed. The spatial structure become complicated at the expense of relatively large organisms at the surfaces of them forming the secondary communities. At this stage, the characteristics of the water flow around substrates became substantially complicated, and hydrodynamic factors retained only an indirect role in the community development.

It should be mentioned that nonstationarity of the boundary layer is sufficient at all listed steps.

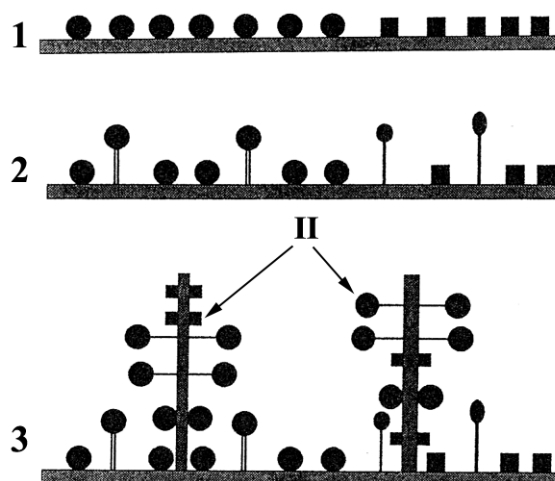


Fig. 3. The stages of the micro-spatial structure of periphytonic community development (schematic). 1 – the step of a film community; 2 – the step of a three-dimensional community; 3 – the step of a macroperiphyton community. II - secondary communities.

Thus the micro-spatial structure of periphytonic communities is appreciably become formed in connection with parameters of hydrodynamic boundary layer near the substrate surface. The manifestation of this property is further intensifying by the diversity of surface textures and physical properties. The heterogeneity of the layer as well as its instability creates prerequisites for the forming at the substrates of highly productive and diverse communities of organisms.

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