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Short Communication

Microhabitat hydraulics predict algae growth in running systems

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ABSTRACT

The properties of surface roughness have been considered an important factor in algal growth. The most relevant finding is that rougher surfaces supports higher algal accumulation. However, the stimulatory effects of roughness have not been tested so far. Thus, here we carried out an experiment using an increasing level of roughness in two different flow conditions. Hence, we investigated the roughness stimulatory threshold for algae growth under different flow conditions, in order to assess the effect of hydraulic dynamics. In the slower flow, the stimulatory threshold did not occurred (high algal coverage in all roughness levels), while in the faster one it could be observed (algal coverage varies among roughness levels). The drag force in slower flow flume was lower than in faster flume. The low values of drag force may have reduced the effects of roughness, which was highlighted in the fast flow flume. Therefore, we suggest that hydraulic dynamics can regulate the roughness stimulatory threshold mechanisms and the peak of algal accumulation is directly dependent of these conditions.

1. Introduction

Hydraulic conditions have been considered as one of the major predictors of flora and fauna settlement and distribution in aquatic environments (Brooks et al., 2005; Biggs et al., 2005; Graba et al., 2013). Hydraulic/hydrologic disturbance may negatively affect the effects of refuges provided by complex habitats for stream communities (Brown, 2007). The relation between hydraulic conditions and features of the surface can determine where the organism will most successfully attach (Ditsche-Kuru et al., 2010; Ditsche et al., 2014; Biggs and Hickey, 1994; Tonetto et al., 2014). Therefore, studies focusing on the settlement of aquatic organisms must consider the interaction between hydrodynamics features, such as water velocity, and substrate physical aspects, such as roughness.

The theoretical and empirical framework predicts that freshwater stream algae adhesion is under high pressure and constraints associated with river bed roughness. Stream bottoms are composed of various irregularities such as pits, crevices, moss and other projections (Taniguchi and Tokeshi, 2004). Several studies have shown that higher algal accumulation owes to increased sedimentation efficiency (Johnson, 1994) and protection from

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physical disturbances (Dudley and D'Antonio, 1991; Bergey and Weaver, 2004) provided by rougher substrates. In this context, recent evidence suggests that there is a threshold imposed by surface texture to algae growth and development in rough surfaces. As previously stated, the stimulatory effects of increased texture on algal biomass accrual decrease as roughness increases past a certain point, creating a stimulatory threshold (Murdock and Dodds, 2007).

Nevertheless, the influence of the microhabitat hydrodynamics on the stimulatory threshold of algae settlement has been underexplored. Schneck and Melo (2012) assessed the effects of hydrological disturbance on algal accumulation, but only in two types of surface roughness (smooth vs. rough). Here, our objective was to investigate the surface features in a gradient of roughness in an attempt to find the stimulatory limit for algae accumulation, regarding the interaction between hydraulics and roughness. Hence, we measured hydraulic parameters associated to individual surfaces in order to assess the role of substrate texture properties in algae colonization on various rough surfaces. Indeed, the relationship between the microhabitat hydrodynamics and the accumulation of algal assemblages has been seldom explored. Following Resh et al. (1988), we consider that disturbance of water flow is a dominant organizing factor in stream ecology. Therefore, we hypothesized that increasing disturbance by water flow would change the roughness effect on algae accumulation.

2. Materials and methods

We built two separate flumes (5 m length × 0.15 m width) with different inclination angles to create two different water flow conditions. Water velocity was measured with a Swoffer 3000 flowmeter. The faster flume recorded a mean velocity of 1.33 ± 0.05 m/s, while a mean velocity of 0.81 ± 0.1 m/s in the slower flume. A set of four levels of rougher surfaces (i.e. sand paper of four grain sizes), in an increasing gradient, were fixed at the bottom of both flumes. Thus, we were able to assess the effect of roughness in two different flow conditions.

The rough surfaces were four kinds of sandpaper stripes, measuring 75 × 25 mm (similar to microscopic slides dimensions) and were set up in random positions along the flumes. These sandpaper stripes have known roughness indices (80, 120, 220 and 320 grit), where these values represent the number of sand grains in 1 cm^2. Ten replicates of each kind of sandpaper were used on each flume, totalizing 80 sandpaper stripes. Algae were collected at natural streams in Assis, São Paulo, Brazil (22°38′ S, 50°27′ W; altitude 522 m) and inserted in the system by dropping the water with algae in the water reservoir. Thus, algae were pumped through the system and had equal chances to settle in any part of the flume.

We calculated the drag force for the four roughness levels in each flume. We assumed that drag force was a good predictor of the roughness threshold. Drag force was used to represent the resistance to flow caused by the object (i.e. sandpaper stripes). This force can be related to the permanence of organisms under the object or attached to the surface (Gordon et al., 2004). Drag force is defined in Eq. (1):

$$F_s = C_f W L \rho \frac{V^2}{2} \tag{1}$$

where C_f is the skin friction coefficient which depends of the flow type and is calculated using L and height of the pits and crevices; W and L are width and length of the surface pieces (m) and ρ is the fluid density (kg/m^3). Table 1 shows the drag force variation among roughness level and between flumes. The experiment consisted of four different roughness groups under two different water velocities, hence, a total number of eight treatment groups with different drag forces. The coverage of algae was recorded 10 days after the installation of all surfaces. This period is considered suitable for algal settlement (Danger et al., 2013). The surface area coverage (SAC-%) of the biofilm in the pictures was calculated in a standardized centered area (1 cm^2), to avoid border effects, using Adobe Photoshop (Tonetto et al., 2012). This technique was adapted from Ng et al. (2014), Singer et al. (2006) and recent studies have used percent coverage as an algal metric (Tonetto et al., 2012, 2014).

Differences in algae growth in relation to drag force were analyzed with ANOVA tests. The influence of velocity in algae SAC was analyzed with logistic regression tests, using water flow as a dichotomist variable (i.e. slow vs. fast) and covered area as a continuous variable to assess the probability of algae to settle in slow or fast streams. All statistical analyses were made using the software Statistica 10.

3. Results

The algal community was mainly composed by specimens of the genera *Coelastrum*, *Chlamydomonas*, *Desmodesmus*, *Staurastrum* and few individuals of diatoms (basically the genera *Eunotia*, *Navicula* and *Gomphonema*). Table 1 showed that drag force was lower in the slow flow flume. In slow waters algae are able to attach more easily to the substrates and to stay attached, and thus they can exhibit higher accumulation. Indeed, the results from logistic regression indicate that algae showed more accumulation in the slow velocity flume, and thus a preference for this condition (logistic regression: $X^2 = 31.95$, $p < 0.00001$, Fig. 1). There was a relationship

Table 1
Treatment groups regarding roughness of the sandpapers and drag force acting in each group. The numbers 1–4 indicate the polishing paper in the slow water flume and 5–8 indicate the same roughness variation, but in the fast flow flume.

Treatment group	Roughness (m)	Drag force (Newton)
1	0.000284	1.71E−05
2	0.000232	1.73E−05
3	0.000171	1.78E−05
4	0.000142	1.8E−05
5	0.000284	3.03E−05
6	0.000232	3.08E−05
7	0.000171	3.16E−05
8	0.000142	3.2E−05