Ecological Engineering 75 (2015) 404–412

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Algal turf scrubbers: Periphyton production and nutrient recovery on a South Florida citrus farm

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ARTICLE INFO

Article history:
Received 22 April 2014
Received in revised form 30 October 2014
Accepted 28 November 2014
Available online xxx

Keywords:
ATS
Algal turf scrubber
Periphyton
Phosphorus removal
Nitrogen removal

ABSTRACT

There is a strong need to develop strategies that reduce nutrient loading to Florida's waters. The purpose of this study was to investigate the nutrient-removing ability and growth rate of periphyton, grown on an Algal Turf Scrubber (ATS™) that received runoff from a citrus orchard operated by the USDA in southern Florida. A pilot scale ATS (1.2 m wide × 234 m long; 0.5% declining grade) was constructed and received a continuous flow (227 L min^{-1}) of water pumped from the orchard's drainage canal. Over an 18-month period, PO_4-P, NO_3-N, NO_2-N and NH_4^+ removal averaged 16%, 49%, 19% and 41%, respectively. On average, the entire flow-way yielded 5.5 g m^{-2} day^{-1} (range: 1–16 g m^{-2} day^{-1}) of periphyton (dry weight). However, the upper 60 m yielded 11 g m^{-2} day^{-1} (range: 1–26 g m^{-2} day^{-1}). Over 54% of total production occurred in the upper 26% of the flow-way and growth rate over the entire flow-way, increased 195% during the summer months (June–Aug.) when compared to winter months (Jan.–Mar.). Harvested periphyton contained an average of 24.1% C, 3.8% N, 0.38% P, and 0.003% Si. The harvesting of periphyton from the entire flow-way removed a mean of 0.02 g m^{-2} day^{-1} of total phosphorus, and 0.18 g m^{-2} day^{-1} of total nitrogen. However, the highly productive upstream (1–30 m) section of the flow-way removed a mean of 0.05 g m^{-2} day^{-1} of total phosphorus, and 0.49 g m^{-2} day^{-1} of total nitrogen. During colonization, diatom chains (*Aulocoseira* spp.) along with various pennate diatoms dominated. However, the community was dominated by filamentous Chlorophyta for most of the study. Although this is a preliminary study to provide foundational information necessary for future optimization experiments, nutrient removal observed suggests a potential for the use of ATSs as an effective means of treating agricultural runoff from citrus and other fruit tree orchards while yielding periphyton.

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1. Introduction

The Algal Turf Scrubber® or ATS™ is a solar-driven system that supports periphyton growth and associated nutrient (nitrogen and phosphorus) uptake in order to ameliorate water quality. The system was developed in the early 1980s by Adey (1982); the development and historical uses of algal turf scrubbers are reviewed in Adey et al. (2013). Large-scale ATSs consist of a downward sloping flow-way in which water, or influent, is introduced in a pulsed or continuous manner. The water flows over the length of the flow-way and is then re-circulated or discharged. The ATS is either seeded or naturally colonized by algae and various other organisms that make up the periphyton. Periphyton is defined as a benthic community and includes a matrix of bacteria, fungus, algae, detritus and the fauna that is supported by this matrix.

Agricultural runoff can pollute fresh and coastal waters by introducing excessive quantities of nutrients which can lead to algal blooms, algal toxin accumulation (Paerl and Otten, 2013), aquatic hypoxia and the destruction of healthy ecosystems. Best management practices (BMPs) have been successful in treating nonpoint sources of pollutants (Makarewicz, 2009a,b,b). The primary goal of this study was to explore the utility of an ATS as a BMP for citrus production, one of the major agricultural industries in Florida.

The periphytic community existing on an ATS can positively influence water quality by removing nutrients (Sandefur et al., 2011; Craggs et al., 1996; Adey et al., 1993; Mulbry et al., 2010), breaking down or reducing organic contaminants (Adey et al., 1996), taking up heavy metals (Adey et al., 1996; Perales-Vela et al., 2006; Rothman et al., 2013), increasing pH (Craggs et al., 1996; Sandefur et al., 2011; Adey et al., 2013), and increasing dissolved

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http://dx.doi.org/10.1016/j.ecoleng.2014.11.054
0925-8574/Published by Elsevier B.V.

Fig. 1. View of ATS head showing influent pipe and flow-way. Influent poured directly onto the flow-way at 227 L min^{-1}. The photo was taken 3 weeks after the influent pump was turned on.

oxygen (DO) (Craggs et al., 1996; Sandefur et al., 2011). The above effects result from a combination of physiological processes and complex ecological interactions. These processes and interactions, in turn, are influenced by external parameters (e.g., flow-rate, temperature, sunlight) and self-induced micro-environmental changes that occur as a result of community metabolism and growth (e.g., influences on turbulence, self-shading, and the release of organic compounds such as phosphatases). Potential commercial use of the harvested periphyton include use as a fertilizer and soil amendment (Mulbry et al., 2005, 2006), an animal feed supplement (Kebede-Westhead et al., 2004, 2006), or a feedstock for bio-energy production (Adey et al., 2013; Mulbry et al., 2010). Incorporation into biodegradable materials such as bioplastics has also been suggested (Zeller et al., 2013) and many other applications can be envisioned, especially if the community can be controlled to produce biomass with desirable characteristics.

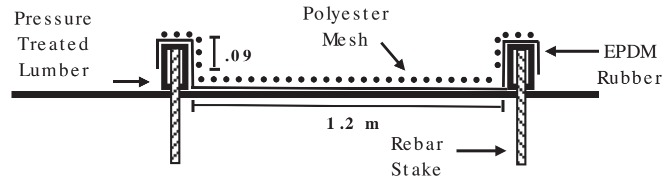

Fig. 2. Cross section of the flow-way. Flow-way edging consisted of pressure treated lumber, which was secured to the ground by rebar stakes. The EPDM rubber was layered on the flow-way and over the wood edging while the polyester mesh was laid on top on the EPDM rubber. The EPDM rubber and mesh were secured with staples.

In this study we set up a simple, low maintenance, continuous flow (non-surging), self-seeded ATS system, fed by drainage canal water, on a South Floridian citrus farm. In addition to evaluating periphyton growth and nutrient removal, we determined the elemental composition of the periphyton biomass.

2. Methods

2.1. Location and construction

The ATS was constructed on a small research farm operated by the USDA-Agricultural Research Service (ARS) in Ft. Pierce, FL. Adjacent land use is predominantly bedded citrus groves that are ground fertilized 2–3 times per year, foliar fertilized 6–8 times per year, and treated (as needed) with pesticides including glyphosate, copper sulfate and copper hydroxide. Pesticide/fertilizer applications are typical for agricultural management in southern Florida.

The ATS was 234 m long, 1.2 m wide, and 0.09 m deep; it was constructed by laying 1.14 mm thick sheets of ethylene propylene diene monomer (EPDM) rubber on a floor of compacted crushed limestone with a 0.5% declining grade. Pressure-treated lumber (4 cm by 9 cm by 3.7 m) served as track edging under the EPDM. A layer of polyester mesh (pore size: 0.5 cm^2) was placed on top of the EPDM to function as a periphyton attachment substrate (Fig. 2). The ATS received 227 L min^{-1} of agricultural drainage canal water. Influent from the drainage canal entered through a Sure Flow Self Cleaning Strainer (SCS4-DD, Sure-Flo Fittings, Ann Arbor, MI) and was pumped by a STA-Rite Self Priming Centrifugal Pump (Model: DHJ3 5HP, Pentair, Delavan, WI) through 10 cm PVC piping to the head of the ATS, where the influent poured from an open-ended pipe falling about 0.5 m onto the ATS (Fig. 1). After passing down the length of the flow-way, the effluent drained into a grated concrete catch basin and then into a different drainage canal, creating a continual flow-through system (Fig. 3). The average

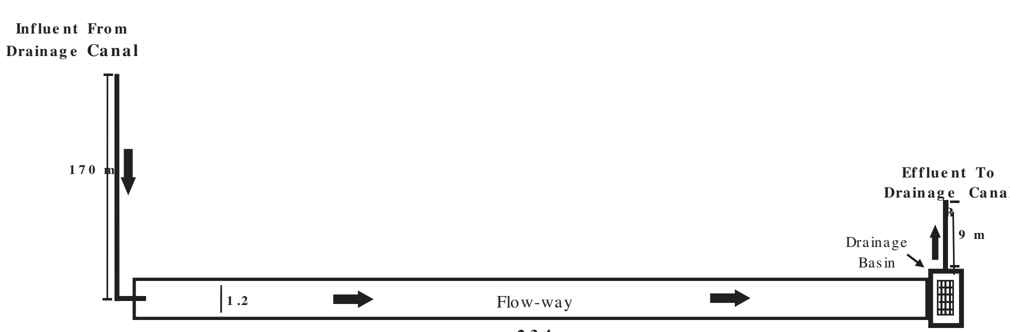

Fig. 3. Aerial diagram of flow-way: influent was pumped from drainage canal A, traveled 170 m through PVC piping, poured onto the flow-way and traveled 234 m flowing into a grated concrete drainage basin. From the drainage basin, effluent drained into canal B.