Maui Sustainable Reuse Pilot

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Abstract

This vignette describes a pilot wastewater polishing facility to be installed at Haleakala Ranch, Kihei, Maui, Hawaii. This pilot will demonstrate algae farming as a biological approach to reducing nitrogen and phosphorus concentrations in secondary municipal wastewater. The polished water and resultant algal biomass will be used to irrigate and fertilize a collection of native plant mesocosms (the Reuse Forest). Findings from this study will inform the design and operation of an algal water polishing demonstration at the planned Ma'alaea Regional Wastewater Reclamation System.

Introduction

The ecological health of Maui's Maalea Bay ("the Bay") is impaired by excess nitrogen (as nitrate/nitrite and ammonia) leading to unwanted seaweed and algal blooms and turbidity, bacteria such as *Enterococcus* fecal indicators, and other microbes. These pollutants degrade recreational activities such as boating, diving, fishing, swimming, snorkeling and surfing, imposing substantial opportunity costs on the local tourism industry [1]. A major source of these pollutants is the Kihei Wastewater Reclamation Facility (WWRF). The WWRF discharges ~2 MGD of bacterially contaminated, nutrient-rich secondary municipal wastewater (R-2 water) into injection wells, with an additional ~2 MGD of this water, decontaminated with ultraviolet light (R-1 water), distributed through infrastructure known as the R-1 Network, used for landscape irrigation. Current wastewater disposal practices have been found in violation [2], leading to initiation of a $9.5 million project to construct the Maalaea Regional Wastewater Reclamation System.

Here we describe a pilot facility, dubbed the Maui Sustainable Reuse Pilot (MSRP), being developed to demonstrate cost-effective ecologically engineered recycling of nutrient pollution from R-1 water into agriculture. The nutrient recycling component of MSRP works by facilitating the proliferation of native filamentous algae, whose rapid growth efficiently removes the unwanted nitrogen species (N), and additionally phosphate (P) and other substances, from the influent R-1 water. Frequent harvest permanently removes nutrient pollution from the system. The biomass is applied (either directly or after composting) as a slow-release fertilizer/soil amendment to nourish the Reuse Forest, which itself is irrigated using the polished water. The MSRP is funded and as of this writing has received preliminary approval from Maui County and awaits final approval from the Hawaii Department of Health.

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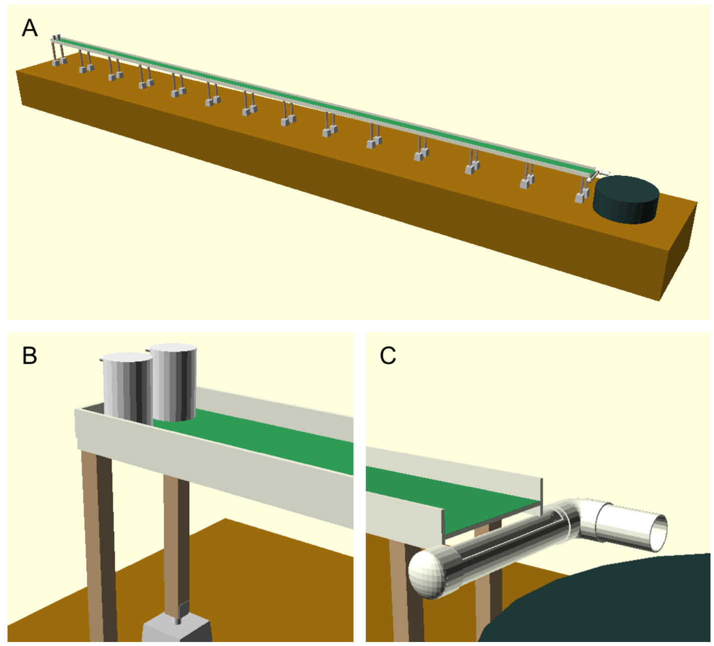

Figure 1: MSRP algal floway. A) View of algal water polishing system. B) Headworks detail showing two pulse generators. C) Tailworks detail showing drainage into 1,550 gal tank.

Description

The MSRP comprises a gently sloped (0.5%), ~2 x 100 ft channel/reservoir tank system for algal cultivation (the floway), described here, and the Reuse Forest, a collection of native plant mesocosms. Figure 1 depicts the overall system along with magnified views of its headworks and tailworks. The floway (Fig. 1A) is constructed from a series of trays fabricated from expanded PVC panels (plastic wood), each ~8 ft long. The trays rest upon a wooden trestle supported by concrete dobie blocks. Two dosing siphons are situated at the headworks (Fig. 1B), delivering pulses of R-1 water from a 1,550 gal reservoir into the headworks. The pulses surge along the slope into the tailworks, draining into the reservoir (Fig. 1C). Submersible pumps within the tank recirculate the R-1 water from the reservoir to the headworks.

Algal Water Polishing

Algal growth converts water, carbon dioxide (CO_2), nitrogen (N) and phosphorus (P) (as well as other nutrients) into algal biomass. Because biomass by definition contains N (mainly in proteins) and P (mainly in nucleic acids and membranes), algal proliferation is accompanied by rapid removal of these nutrients from the growth medium. Frequent (*e.g.* weekly) harvesting permanently removes nutrients from the system.

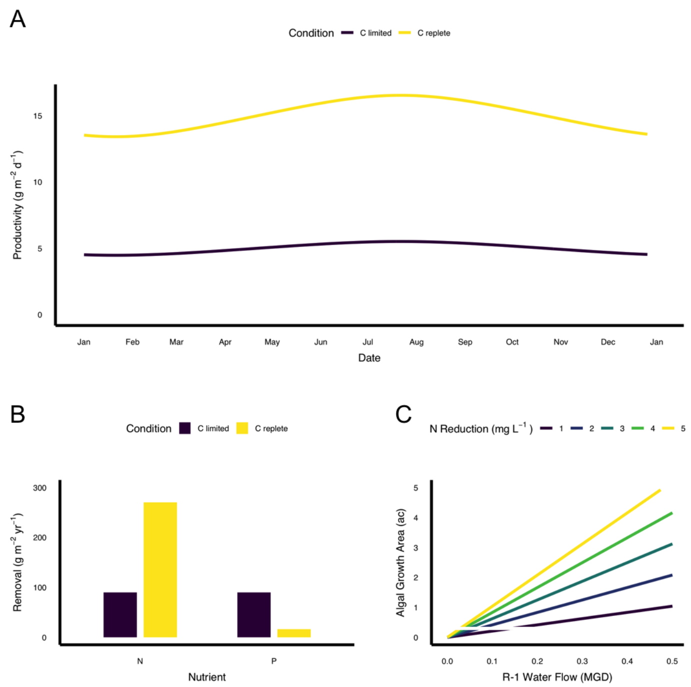

Figure 2: Potential MSRP production and nutrient removal. A) Biomass productivity under carbon-replete and -limited regimes. B) Nutrient removal under the two regimes. C) Tradeoffs between polishing level and algal growth area. Demo system (0.3 ac) indicated by horizontal horizontal white cutout.

An algal floway self-inoculates. Algae cells are ubiquitous, conveyed into the floway as aquatic aerosols or airborne particles with adherent algal cells, or by migrating animals. Anyone familiar with open water bodies knows how hard it is to suppress algal growth. Facilitating its proliferation instead is a matter of providing the appropriate environment. For an algal floway, a high-surface-area substratum submerged under several inches of irregularly flowing water provides this environment, essentially an artificial stream. Algal cells adhere to the substratum and develop into a canopy of attached filaments, removing nutrients from the water as it flows through. A single pass along a several-hundred-foot floway long can remove a few percent of the N and P originally present. Recirculating the water for multiple passes removes additional increments.

Algal growth can consume dissolved CO_2 faster than atmospheric transport replaces it, increasing the water's pH as the water progresses along the floway – essentially the opposite of ocean acidification. Without CO_2 supplementation, a recirculating system becomes increasingly alkaline and carbon limited. A favorable outcome of the high pH is that phosphate salts precipitate chemically within the biomass[1] [3], leading to a substantially higher P content in the harvested biomass compared to typical ratios. Thus, even though N is the major target for this project, total P can potentially also be reduced to very low concentrations. Figure 2 depicts potential biomass production and nutrient removal according to two possible pilot operating schemes (Figs. 2A, 2B).

Reuse Forest

The Reuse Forest will demonstrate utilization of both the polished water and the algal biomass byproduct. A collection of native plant mesocosms will be established prior to constructing the algal floway, initially irrigated with unpolished R-1 water and with no additional fertilization beyond the original soil installation. Once the floway is operational, irrigation will be provided using the polished water and the harvested algal biomass will be applied as a fertilizer/soil amendment, either directly or after composting.

Research

Findings from this pilot will inform the design for the 0.3 acre demonstration algal polishing system planned for the MRWRS. The R-1 output from the enhanced treatment system, projected to range from 5-8 mg L^{-1} total N, will be polished to substantially lower nutrient concentrations. Specific operational features of the pilot will be determined over a range of conditions for one or more complete years of operation. These features include: 1) TN and TP removal rates, 2) biomass productivity and composition, 3) effectiveness of treated water for irrigation and algal biomass as fertilizer/soil amendment, and 4) responsiveness to operational and environmental changes. Features one and two relate to the algal growth area needed to ensure a minimum nutrient removal rate, feature 3 relates to management of the treated wastewater and the algal biomass product, and feature 4 relates to design elements affording the potential to maximize polishing effectiveness. Figure 2C illustrates potential tradeoffs between treatment level and floway size.

Additional Information

The Reuse Forest will demonstrate a circular agricultural nutrient economy utilizing algae-scrubbed R-1 water and algal biomass and as the sole irrigation and soil nourishing components. While N removal is the primary polishing goal, high P removal is also potentially available, as the consumption of CO_2 and HCO_3 drive a high pH and consequent chemical precipitation of P salts. This situation leads to carbon limitation and lower growth rates such that biomass production and therefore N removal may be lower than desired. If additional funding can be secured, we will augment the facility with CO_2 injection technology to manipulate carbon availability and therefore growth rate and N removal in an effort to put the nutrient removal ratio under positive control.

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References

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