



WATER
TREATMENT
TECHNOLOGY
ANALYSIS

Estimates of Phosphorus and Nitrogen Treatment Efficiency Aquatic Plant Based Wastewater Treatment System

Hydromentia's Recirculating Aquaculture System – Phase 1A Okeechobee, Florida

Introduction

By mid 1999 Hydromentia completed construction of its Phase 1a recirculating fish aquaculture facility. This facility was designed around the combined use of two aquatic plant based wastewater treatment systems (APBWT)—water hyacinths and algal turf (ATS)—to maintain water quality within a zero discharge aquaculture operation. The targeted fish species were tilapia and hybrid striped bass. By March of 2000 the fish biomass had been brought to the design level of about 900,000 pounds, with feeding at approximately 9,000 pounds daily of a high protein (40%) pelletized feed. Fish production was within 40 individual ¼ acre lined ponds. The APBWT was composed of an 11.35-acre water hyacinth cultivation pond lined with HDPE synthetic liner and a 4.5-acre HDPE lined Algae Turf Scrubber (ATS) sloped at 1%. Water conveyance through the system is through a series of HDPE lined flumes. Two pumping stations ensure effective continuous recycling of water, with each station composed of three MWI axial flow pumps. One of the pumps delivers 15,000 gpm (21.6 MGD) at about 15 ft TDH, with the remaining two at 7,500 gpm (10.8 MGD) at about 15 TDH. Typically flows over the course of a day will equal or exceed 20 MGD, with a hydraulic flushing rate through the system of about 1-2 days.

By March 2000, the hyacinth unit and the ATS unit had been rendered fully operational, with periodic harvesting active in both. Water quality sampling was done on a once monthly basis, with composite samples taken at the influent and effluent of each treatment unit. Sampling continued through September 2000. In addition, fish standing crop, feeding rate, and fish harvest and mortality were monitored closely.

Projected Phosphorus Removal Efficiencies

First order growth models developed for both the hyacinth and ATS systems were used to project the performance for the period March through September 2000, using existing water quality data. The model printouts as noted in Figures A and B indicate a daily projected phosphorus removal rate of 28 lb/day for the hyacinth unit, or a removal rate of 2.44lb/acre-day and a projected phosphorus removal rate of 5 lb-day or 1.1 lb/acre-day for the ATS unit. For the combined system, the projected removal is 33 lb/day of phosphorus with a removal rate of 2.09 lb/acre-day.

Nitrogen removal for the hyacinth unit was projected at 200 lb/day or 17.6 lb/acre-day. For the ATS, nitrogen removal is projected at about 12 lb/day or 2.67 lb/acre-day. The system nitrogen removal performance is projected at 212 lb/day and 12.6 lb/acre-day. The higher nitrogen removal expectations with the hyacinth unit is based upon the active rate of nitrification and denitrification that occur within the hyacinth root mass.

Assessment of System Performance March through September 2000

Actual system assessment was made using two techniques. The first was to do a balance of recycle flow based upon water quality sampling. The findings are as noted in Table 1.

Table 1. Performance Assessment for Period March Through September 2000 Based Upon Water Quality with an Annual Daily Flow of 20 MGD

PHOSPHORUS						
Month	Hyacinth Influent Total P mg/l	Hyacinth Effluent Total P mg/l	ATS Effluent Total P mg/l	Hyacinth Unit TP Areal Removal Rate lb/acre-day	ATS Unit TP Areal Removal Rate lb/acre-day	APBWT (combined) TP Areal Removal Rate lb/acre-day
March	9.33	8.99	8.61	5.0	15.1	7.6
April	10.00	10.20	10.1	-2.9	4.0	-1.1
May	10.20	10.20	10.5	0.0	11.9	-3.2
June	8.18	7.98	7.98	2.93	0.0	6.5
July	8.10	8.26	7.48	-23.51	30.9	2.7
August	6.88	6.78	6.62	1.47	6.35	10.0
September	8.15	7.75	7.20	5.87	21.8	3.5
Average	8.69	8.59	8.36	1.4	9.5	3.5
NITROGEN						
Month	Hyacinth Influent Total N mg/l	Hyacinth Effluent Total N mg/l	ATS Effluent Total N mg/l	Hyacinth Unit TN Areal Removal Rate lb/acre-day	ATS Unit TN Areal Removal Rate lb/acre-day	APBWT (combined) TN Areal Removal Rate lb/acre-day
March	17.08	14.85	14.85	1.6	17.8	17.8
April	17.79	14.70	17.11	45.4	-95.7	1.4
May	22.00	19.79	21.30	32.5	-69.0	-4.4
June	17.38	17.31	16.02	1.0	51.2	0.00
July	22.36	21.84	21.05	7.6	31.4	21.4
August	14.98	13.31	13.69	24.5	-15.1	4.3
September	19.34	17.68	16.47	24.4	48.1	33.1
Average	18.70	17.10	17.20	24.0	-5.5	15.7

The second method of assessment was based upon a nutrient balance, using known inputs and outputs from feed amounts, fish standing crop, and fish harvest and mortality. This assessment is noted as Table 2.

Table 2. Performance Assessment for Period March 2000 through September 2000 Based upon Nutrient Balance

	NITROGEN	PHOSPHORUS
PERIOD BEGIN	POUNDS	POUNDS
Fish Stock	28,464	11,860
Water Column	4,954	2,872
TOTAL	33,418	14,732
PERIOD END	POUNDS	POUNDS
Fish Stock	26,986	11,244
Water Column	5,494	2,402
TOTAL	32,480	13,646
INPUTS(+)/OUTPUTS(-)	POUNDS	POUNDS
Feed	86,928	14,847
Groundwater	60	10
Rainfall	30	4
Fish Harvest and Mortality	-21,541	-5,386
TOTAL	65,477	9,475
APBWT REMOVAL	POUNDS	POUNDS
TOTAL REMOVAL	66,415	10,561
DAYS IN PERIOD	214	214
APBWT ACRES	15.80	15.80
AVERAGE AREAL REMOVAL RATE LB/ACRE-DAY	19.6	3.1

Comments:

A comparison of the results of the two methods and to the projected values indicates reasonableness as noted in Table 3. It is notable that the water quality results indicate poor nitrogen removal through the ATS system, suggesting that perhaps some nitrogen fixation occurred. While cyanobacteria certainly are capable of nitrogen fixation, it is felt this is unlikely in the nutrient abundant situation within the recycle system. Rather, the infrequency of sampling and the variation in recycle flow rate reduce the confidence range associated with the water quality method. The nutrient balance method is likely more reliable, and the numbers for system performance probably more closely reflect true performance.

Table 3. Comparative Nutrient Removal Rates

	Projected Model APBWT lb/acre-day	Actual Water Quality Based APBWT lb/acre-day	Actual Nutrient Budget Based APBWT lb/acre-day
Nitrogen Removal Rate	12.6	15.7	19.6
Phosphorus Re- moval Rate	2.1	3.5	3.1

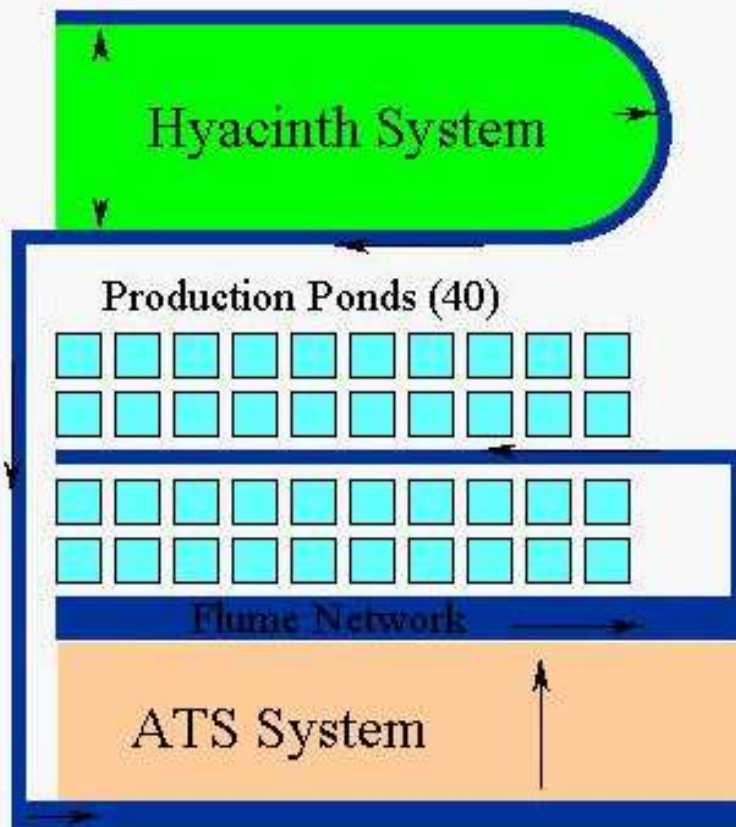
These removal rates are very high, and cannot be expected when concentrations are lower. For example, consider a system designed to reduce total phosphorus from 500 ppb to 40 ppb, as noted in Figures C and D. The system areal phosphorus removal rate at these concentrations would be projected at 0.96 lb/acre-day (suggesting a 50 Ton-P/year system would require less than 300 acres of water surface between the ATS and the Hyacinth System.) This is still considerably higher rate than what would be expected of a passive wetland system at perhaps 0.02 to 0.05 lb/acre-day, or for a 50 TPY system 5,500 to 13,700 acres of treatment area.

It is suggested that a prototypical system be established of sufficient size, with a flow through dynamic at lower nutrient concentrations to establish critical design and operational information for a regional APBWT.

Review of Existing Application

Closed Recirculating Integrated Aquaculture System

Nutrient Budget January-June 2000



	NITROGEN	PHOSPHORUS
TOTAL INPUTS	POUNDS	POUNDS
FEED	68,140	18,621
FISH STOCK	70	21
GROUNDWATER	60	10
RAINFALL	30	4
TOTAL	68,300	18,656
CHANGE IN STORES	POUNDS	POUNDS
FISH INVENTORY	3,736	1,121
HYACINTH STANDING CROP	1,054	238
ALGAE STANDING CROP	84	34
SEDIMENTS	6,208	2,491
WATER COLUMN	812	662
TOTAL	11,894	4,546
TOTAL OUTPUTS	POUNDS	POUNDS
FISH HARVEST	38,560	11,568
FISH MORTALITY	2,355	707
HYACINTH HARVEST	6,650	1,455
ALGAE HARVEST	504	180
DENITRIFICATION	7,337	0
OTHER OUTPUTS (LARVAL EMERGENCE ETC.)	1,000	200
TOTAL	56,406	14,110

HYDROMENTIA, INC.