Recirculating Aquaculture System

Jackson Estuarine Lab

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Background

- UNH Jackson Estuarine Lab (JEL) is being renovated, greenhouse being converted to a recirculating aquaculture system (RAS)
- Current greenhouse has flow-through tanks and serves as storage space
- Influent water quality from the Great Bay varies in salinity, turbidity, and pathogen load

Striped Bass

Morone saxatilis

Steelhead Trout

Oncorhynchus mykiss

Objectives

- Design a modular RAS that can grow a minimum of 2000 fish to be used for research, teaching, and production that fits within the JEL greenhouse
- Determine the optimal fish species for the system
- Size and source all RAS components, determine electrical load
- Perform a cost analysis for construction and operation of the system

Bio-plan & Flow Rates

- Calculations of growth rate, waste production, and oxygen consumption
- Calculated for when the fish reach 200g, and waste production and oxygen consumption are greatest
- Steelhead trout growth rate[1]: $Y = 21.703e^{0.2722x}$
- Striped bass growth rate[2]: $Y = 15.515e^{0.2307x}$

Waste Production and Oxygen Consumption

- TAN: $P_{TAN} = (Rate_{feed})(Protein\ in\ feed)(\text{Production}_{\text{TAN}})$
- TSS: $P_{TSS} = (Rate_{feed})(Production_{TSS})$
- Carbon Dioxide: $P_{co_2} = (Rate_{feed})(Consumption_{o_2})(Production_{co_2})$
- Oxygen: $P_{o_2} = (Rate_{feed})(-Consumption_{o_2})$

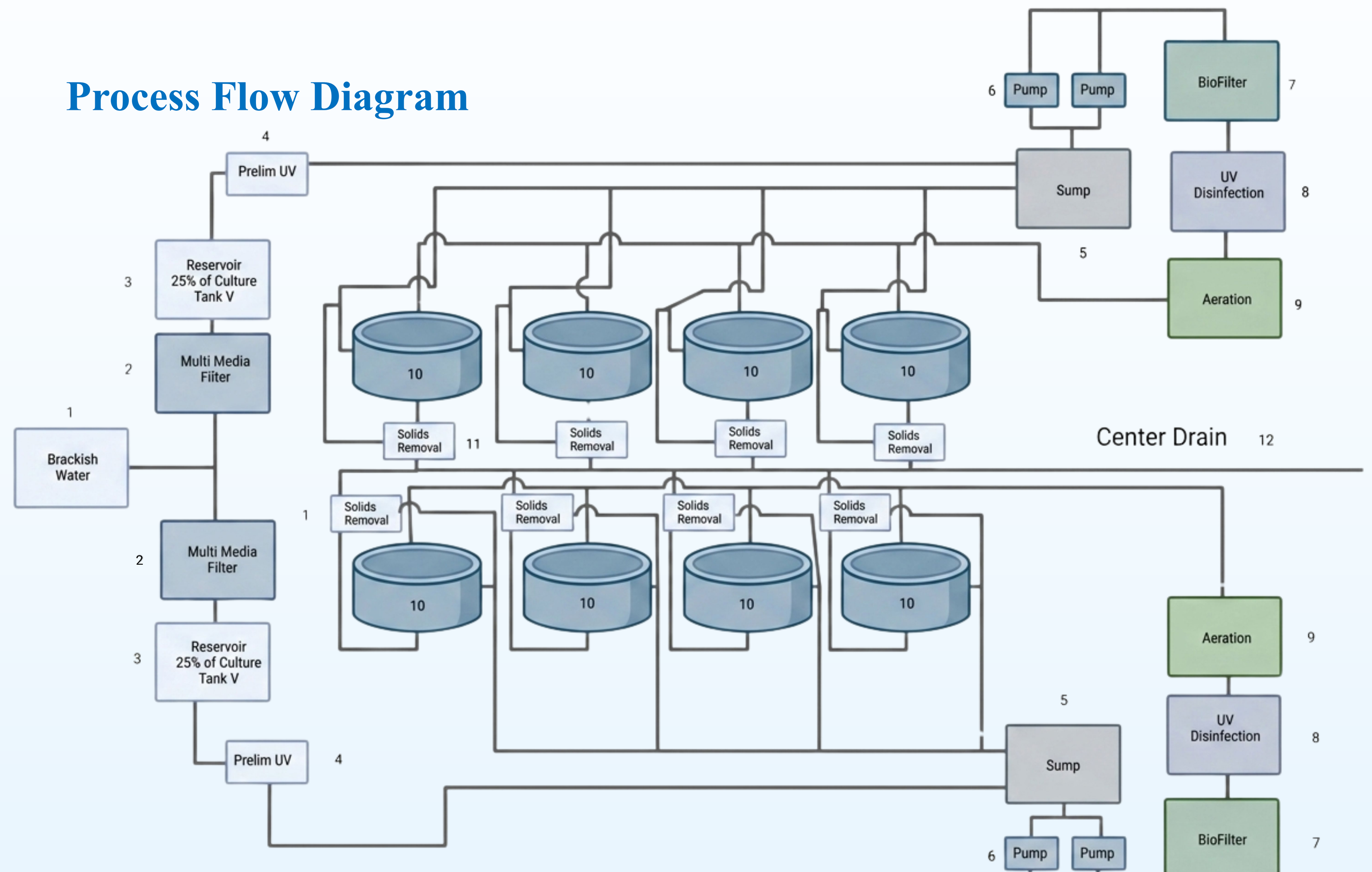
Required Flow Rate

- $C_1 = C_2 + \eta(C_{ideal} - C_2)$
- $Q = -\frac{P}{C_1 - C_2}$
- Flow rates for each product calculated, largest flow rate is the required flow rate when designing the system.

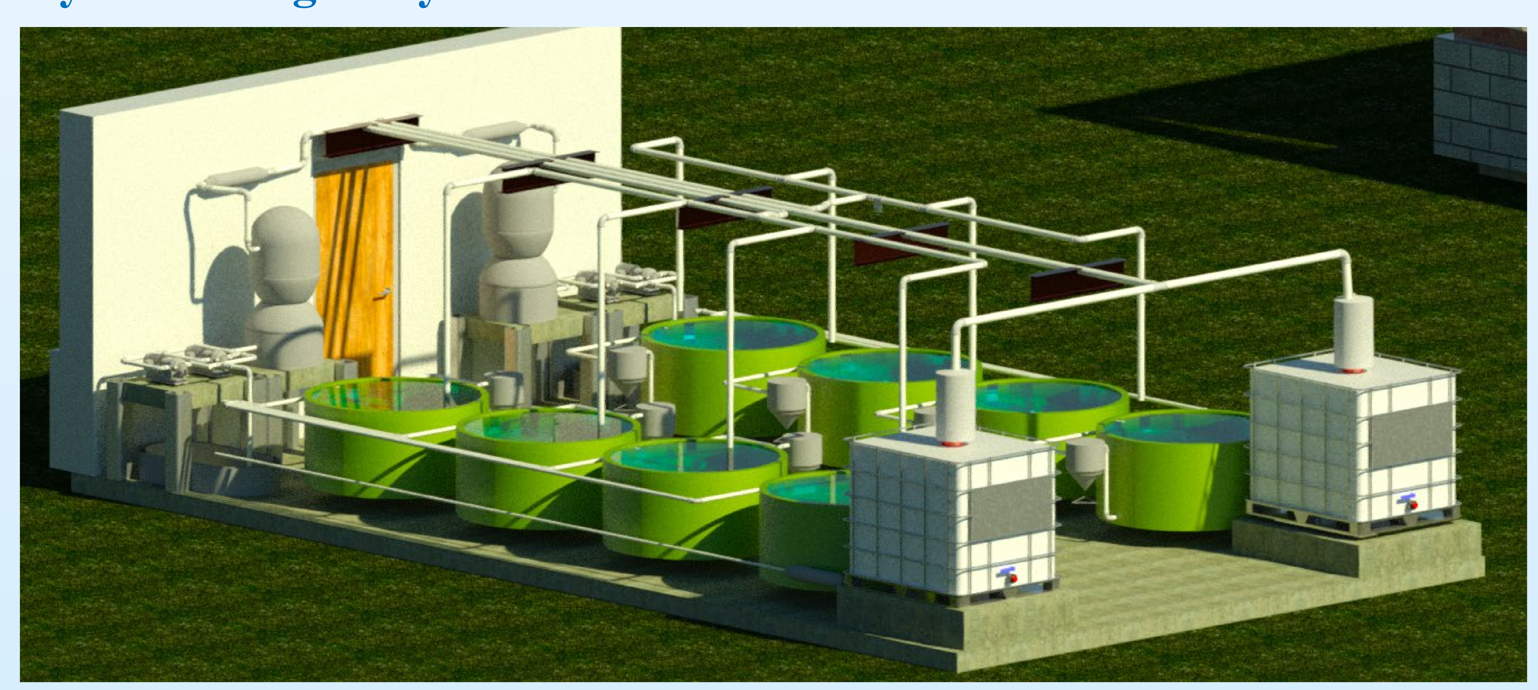
Product	Flow Rate – Steelhead Trout (gpm)	Flow Rate –Striped Bass (gpm)
TAN	60	112
TSS	26	40
Carbon Dioxide	29	44
Oxygen	16	24

System Design

Process Flow Diagram



System Design Layout



Cost Analysis

RSMeans[3] Installation and Materials Costs

Description	Quantity	Cost
Tank, 250-500 gal	2	$804.32
Tank, 130-240 gal	8	$282.85
Pump, sump	4	$141.44
Pipe, 2"-3" diameter	160	$339.20
Air Compressor	8	$6,371.83
Swimming pool equipment, filter system	2	$937.20
Components	-	$55,221.08
	Total	**$64,097.94**

Operating Costs

Component	Power (kW)	Running Time Per Day (hours)	Energy (kWh/day)	Electricity Cost[4] ($/kWh)
Pump	6.4	24	153.6	0.08
UV Disinfection	0.24	24	5.76	
Blower	2	24	48	
Prelim UV	0.05	24	1.2	
LED lightbulbs	0.32	12	3.85	
			Total	**$17 per day**

Component Selection

Component	Governing Criteria & Equation	Discussion
Multi-Media Filter	Based on Influent flow,	• Water Media Filtration MF-300 • Made of fiberglass reinforced plastic; does not corrode in salt
Preliminary UV Filter	Dosage $Q_{filter}D_{filter} = Q_{req}D_{req}$	• Sized using influent flow and required UV dosage • Dosage of 30 $\frac{mj}{cm^2}$ for effective bacterial inactivation
Culture Tank	Ideal Diameter to Depth Ratio 2:1-4.5:1	• Diameter to depth ratio of 2:1 required • Eight 210 gal Duracast tanks selected
Sump & Pump	Head Loss $H_{L\ total} = \left(f\frac{L}{D}\frac{v^2}{2g}\right) + \left(K\frac{v^2}{2g}\right) + (h_{su} + h_{st})$	• Total dynamic head loss of the system is 12.4 ft • Sparus pump with constant and adaptable flow technology • Hastings 97gal sump was chosen
Swirl Separator	Hydraulic Retention Time $HRT = \frac{V}{Q}$ Hydraulic Loading Rate $HLR = \frac{Q}{A_B}$	• HLR of 1 min • HRT of 4.8 $\frac{gpm}{ft^2}$ • Eight 15 gal Norwesco swirl separators • Removes solids prior to filtration
Bubble Bead Filter	Volume of Media $V_{media} = \frac{R_{feed}}{v_f}$	• Fingerling system • Volume of media is 14 ft^3 • AST HHPG 25 selected
Aeration	Power $P = \frac{Production\ of\ O_2}{Standard\ Aeration\ Rate}$	• Power required for blower is 0.024 hp • 0.33hp AMTREK blower and FlexAir 9" Air diffuser
Primary UV Filter	Dosage $Q_{filter}D_{filter} = Q_{req}D_{req}$	• Sized using required flow rate through system • Doseage of 30 $\frac{mj}{cm^2}$ for final disinfection.
Reservoir Tanks	Given criteria $V = 25\%\ of\ Culture\ Tank\ Volume$	• 25% accounts for the 5-10% estimated system losses each day in each tank • Two 275 gal tanks with steel pallets from ULINE

Conclusion

- Design incorporates two independent RAS, each with 4 replicate tanks to enhance statistical reliability while maintaining experimental control
- System supports 1554 steelhead trout at a stocking density of 50 kg/m^3 to a harvest weight of 200g in 6 months.

References & Acknowledgments

[1] Pepe-Victoriano, Renzo, et al. "Growth of *Oncorhynchus Mykiss* (Rainbow Trout) through a Recirculation System in the Foothills of the Extreme North of Chile." *Animals: An Open Access Journal from MDPI*, U.S. National Library of Medicine, 3 Sept. 2024, pmc.ncbi.nlm.nih.gov/articles/PMC11394614/#animals-14-02567

[2] Kenter, L. W. (2018). *Strain evaluation of striped bass (Morone saxatilis) cultured under different salinities.* Aquaculture, 491, 1–10. https://doi.org/10.1016/j.aquaculture.2018.300644

[3] https://www.rsmeansonline.com/

[4] https://www.eversource.com/docs/default-source/rates-tariffs/nh-summary-rates.pdf?sfvrsn=eefadaef_39

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