# MATERIALIZATION OF THE EFFICIENT CLOSED RECIRCULATING AQUACULTURE SYSTEM FOR RESEARCH PURPOSE

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## Abstract
*Closed Recirculating Aquaculture Systems (CRAS) are increasingly being used for fresh water fish culture. Design and dimensioning of such a facility require attention to flexibility for various experimental designs and the flexibility to vary specific water quality constituents, properties that are not necessary in a standard production plant. A research facility was designed and constructed for the experimental purpose. The each CRAS included four experimental tanks with other filtration tanks. The system was designed so that water from different CRAS or flow-through water sources could be chosen at the level of the culture tanks, thus giving flexibility for proposed experimentation. The present paper explains the theoretical capacities of CRAS design. It is expected that in the present design will be useful in determining the environmental and nutritional requirements of fish reared in CRAS. The experimental performance of the designed CRAS will be revealed in future.*
***Keywords:*** *Aquaculture, CRAS, Fish, Fishery, Recirculating.*

## Introduction
Closed Recirculating Aquaculture Systems (CRAS) are used in home aquaria and for fish production where water exchange is limited and the use of biofiltration is required to reduce ammonia toxicity. Other types of filtration and environmental control are often also necessary to maintain clean water and provide a suitable habitat for fish (Summerfelt and Vinci, 2004 a, b). The main benefit of CRAS is the ability to reduce the need for fresh, clean water while still maintaining a healthy environment for fish. To be operated economically commercial CRAS must have high fish stocking densities, and many researchers are currently conducting studies to determine if CRAS is a viable form of intensive aquaculture (Martins *et al*., 2010; Bendik *et al*., 2013). Hence, designing such CRAS facility is to achieve semi-commercialized results like to achieve optimal performance, health and welfare of farmed fish during research (Vandeputte and Reuver, 2011; Michael and David, 2014). In addition, the research facility had to be accurately dimensioned, and its performance documented, such that good experimental designs can be developed in research projects. Furthermore, the growth rate of the studied fish species, at control group conditions, should be higher or at least comparable to growth rates obtained in the aquaculture industry (Carlos and Daniel, 2019). The project development, facility design and dimensioning, described here may be of use to other research institutions that intend to establish similar or related facilities.

## Materials and methods
A pre-project survey was performed to determine the requirements that the facility should fulfill, and the overview of the design and dimensioning necessary to meet these requirements. Subsequently, entire construction facility was supervised as to achieve theoretical capacities of CRAS design.

### *CRAS dimensioning and design*
Dimensioning of the reuse systems was done according to mass-balance principles, as outlined by earlier authors (Vinci *et al*., 2004; Eding *et al*., 2006; Timmons and Ebeling, 2007). Dimensioning of multi-chambered rearing chambers and filtration units followed that of Drennan *et al*. (2006) and Rusten *et al*. (2006). Suggestions of Summerfelt *et al*. (2000) were used for calculations of packing height, flow distribution and required countercurrent air flow in the degassers.

### *Water quality standards*
The water analysis is performed according to APHA (2005). The aquarium water was aerated continuously during experimental tenure. The water composition and characteristics were maintained within the effective range (Bhatnagar and Devi, 2013) is given in Table 1.

**Table 3.2.1: water quality standards**

| Sr. | Characteristics | Mean |
|---|---|---|
| 1 | Temperature | 28.5±2.5 |
| 2 | pH | 8.1±0.5 |
| 3 | Total dissolved solids (mg/L) | 240.5±19.5 |
| 4 | Dissolved Oxygen (mg/L) | 4.42±0.24 |
| 5 | Biological oxygen demand (mg/L) | 1.70±0.20 |
| 7 | Free $CO_2$ (mg/L) | 13.4±1.3 |
| 8 | Alkalinity (mg/L) | 65.3±5.0 |
| 9 | Hardness (mg/L) | 123.20±16.76 |
| 10 | Ammonia (mg/L) | 0.55±0.01 |
| 11 | Nitrate (mg/L) | 0.136±0.28 |
| 12 | Nitrite (mg/L) | 11.39±0.37 |
| 13 | Salinity (ppt) | 0.3±0.1 |

## Results and discussion

### *Design and dimensions*

A series of treatment processes is utilized to maintain water quality in intensive fish farming operations. These steps are often done in order. After leaving the vessel holding fish the water is first treated for solids before entering a filtration units to convert ammonia, next degassing and oxygenation occur, often followed by heating/cooling and sterilization. Each of these processes can be completed by using a variety of different methods and equipment, but regardless all must take place to ensure a healthy environment that maximizes fish growth and health. The design and dimensions of the Closed Recirciltaing Aquaculture System (CRAS) is shown in Figure 1-4.

An overhead water tank with capacity 400L is used as a source of water. Four rearing tanks are used fish cultivation during experiment. Filtration unit receive water of recycling from rearing tank through drainage channel. The filtration unit is equipped with sedimentation tank, gravel filter tank, sand filter tank and biofilter tank of 250L each. The collector tank is also having capacity of 250L. Filtered water is again pump into overhead water tank. The scaling and the number of replicates can be manipulated as per fish size and stocking density.

### *Biofiltration*

System relies on biofiltration to convert ammonia excreted by the fish into nitrate. Ammonia is a waste product of fish metabolism and high concentrations (>.02 mg/L) are toxic to most finfish (Emparanza, 2009). Nitrifying bacteria are chemoautotrophs that convert ammonia into nitrite then nitrate. A biofilter provides a substrate for the bacterial community, which results in thick biofilm growing within the filter (Pfeiffer and Wills, 2011). Water is pumped through the filter, and ammonia is utilized by the bacteria for energy. Nitrate is less toxic than ammonia (>100 mg/L), and can be removed by a denitrifying biofilter or by water replacement (Mathieu et al. 2014). Stable environmental conditions and regular maintenance are required to ensure the biofilter is operating efficiently (Wenchang *et al.*, 2020).

### *Solids removal*

In addition to treating the liquid waste excreted by fish the solid waste must also be treated, this is done by concentrating and flushing the solids out of the system (Summerfelt and Chris, 2005; Kolarevic *et al.*, 2012). Removing solids reduces bacteria growth, oxygen demand, and the proliferation of disease. The simplest method for removing solids is the creation of settling basin where the relative velocity of the water is slow and particles can settle at the bottom of the tank where they are either flushed out or vacuumed out manually using a siphon (Paulo, 2015). However, this method is not viable for RAS operations where a small footprint is desired. Typical CRAS solids removal involves a sand filter or particle filter where solids become lodged and can be periodically backflushed out of the filter (Nesar and Turchini 2021).

### *Oxygenation / Aeration*

Reoxygenating the system water is a crucial part to obtaining high production densities. Fish require oxygen to metabolize food and grow, as do bacteria communities in the biofilter (Summerfelt *et al.*, 2000; Fivelstad *et al.*, 2003). Dissolved oxygen levels can be increased through two methods, aeration and oxygenation. In aeration air is pumped through an air stone or similar device that creates small bubbles in the water column, this result in a high surface area where oxygen can dissolve into the water (Summerfelt *et al.*, 2003; Summerfelt and Sharrer 2004). In general due to slow gas dissolution rates and the high air pressure needed to create small bubbles this method is considered inefficient and the water is instead oxygenated by pumping in air/oxygen (Moran, 2010; Colt *et al.*, 2012). Various methods are used to ensure that during oxygenation all of the oxygen dissolves into the water column. Careful calculation and consideration must be given to the oxygen demand of a given system, and that demand must be met with either oxygenation or aeration equipment (Paula *et al.*, 2018).

### *pH control*

System pH must be carefully monitored and controlled. The first step of nitrification in the biofilter consumes alkalinity and lowers the pH of the system. Keeping the pH in a suitable range is crucial to maintain the health of both the fish and biofilter (Kristensen *et al.*, 2009). The pH is typically controlled by the addition of alkalinity in the form of limeor sodium hydroxide (Kolarevic *et al.*, 2011). A low pH will lead to high levels of dissolved carbon dioxide, which can prove toxic to fish. pH can also be controlled by degassing carbon dioxide in a packed column or with an aerator, this is necessary in intensive systems especially where oxygenation instead of aeration is used in tanks to maintain oxygen levels (Gutierrez *et al.*, 2011).

### *Temperature control*

All fish species have a preferred temperature above and below which that fish will experience negative health effects and eventually death (Wood, 2001). Warm water species such as Tilapia and Barramundi prefer 24°C water or warmer, where as cold water species such as trout and salmon prefer water temperature below 16°C (Svobodová *et al.*, 2005). Temperature also plays an important role in dissolved oxygen (DO) concentrations, with higher water temperatures having lower values for DO saturation. Temperature is controlled through the use of submerged water warmer/heater. It helps the system for operating at the optimal temperature for maximizing fish production (Summerfelt, 2006).

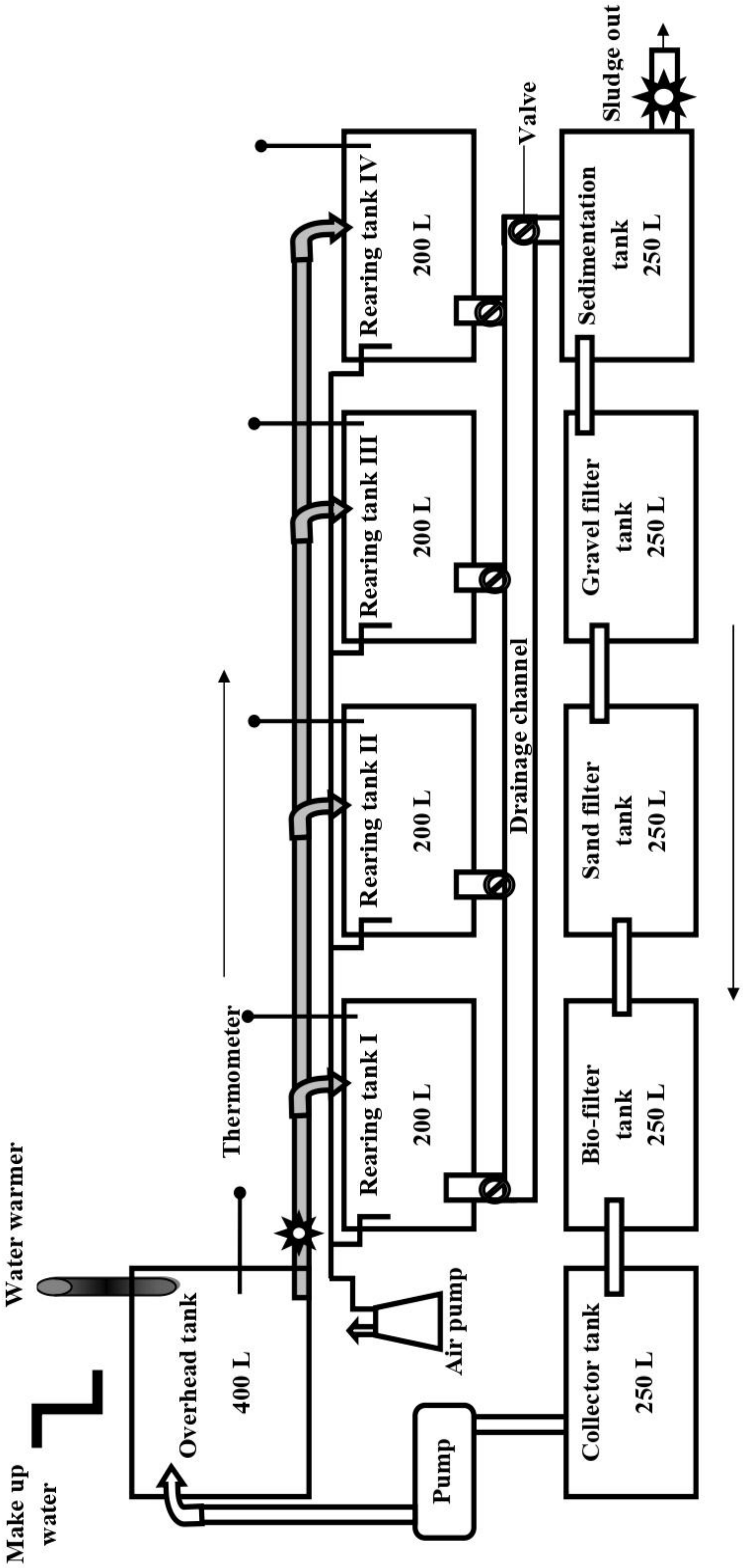


**Figure 1: Closed Recirculating Aquaculture System: Experimental / Rearing unit**

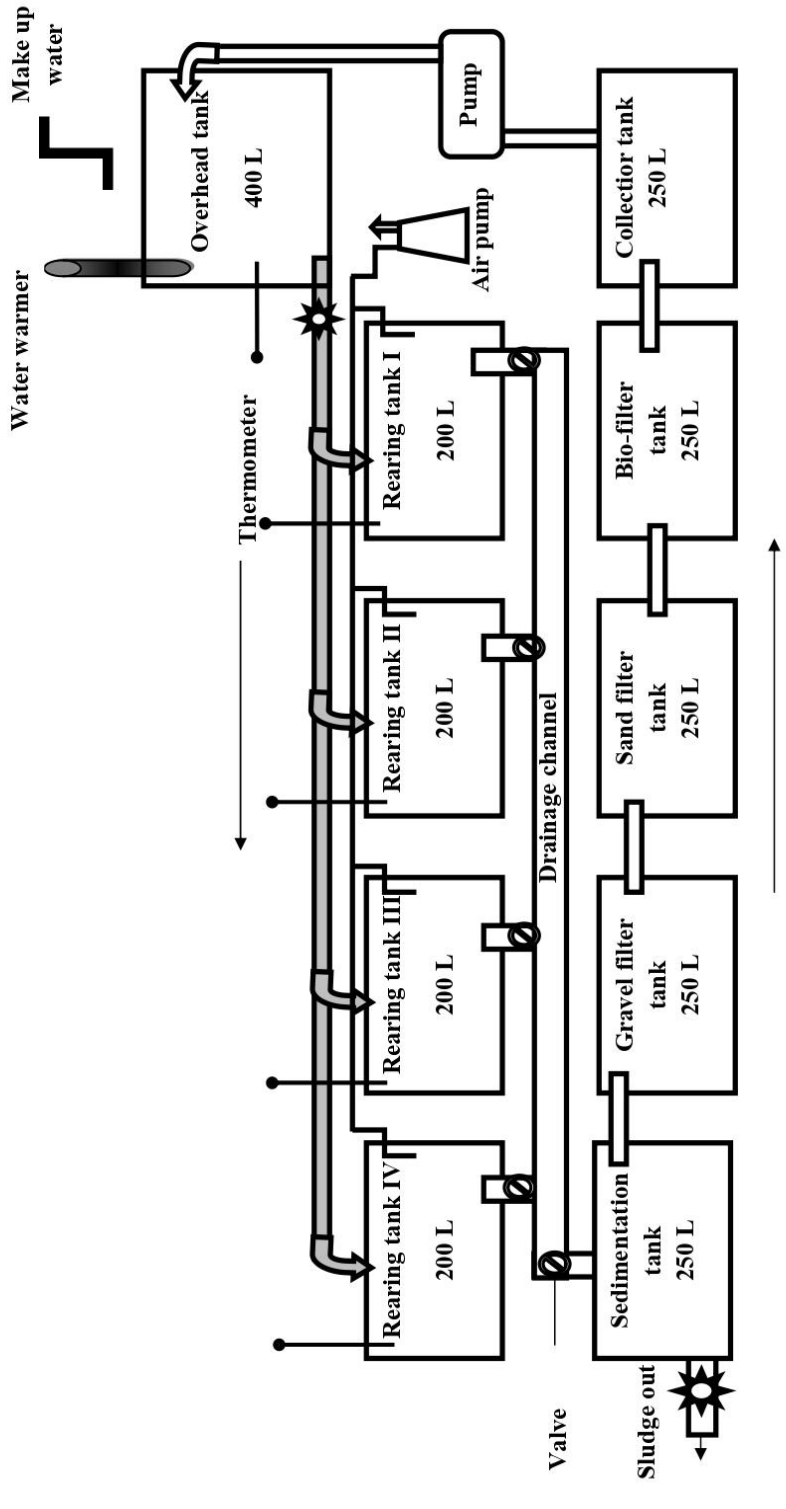


**Figure 2: Closed Recirculating Aqua. System: View towards water treatment unit**

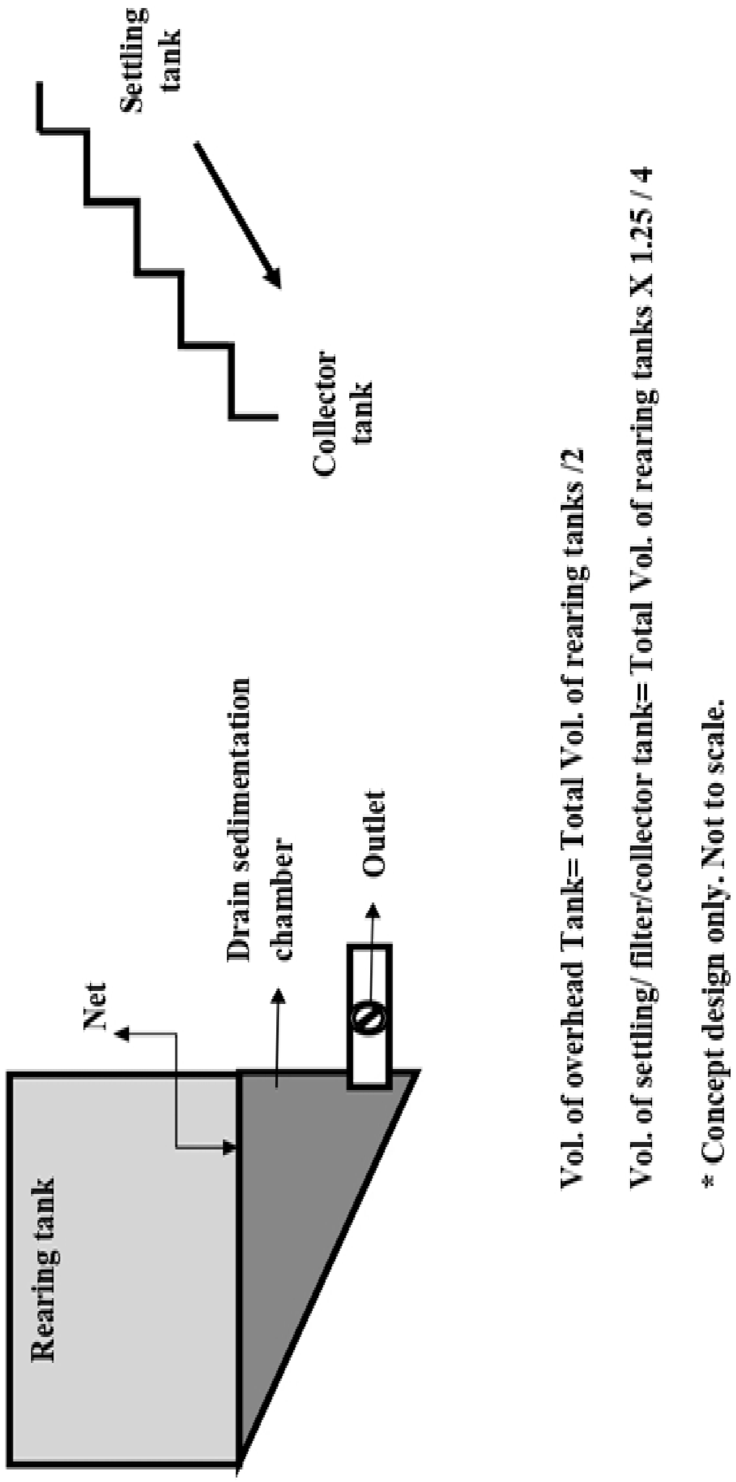


**Figure 3: Closed Recirculating Aquaculture System: Specification**

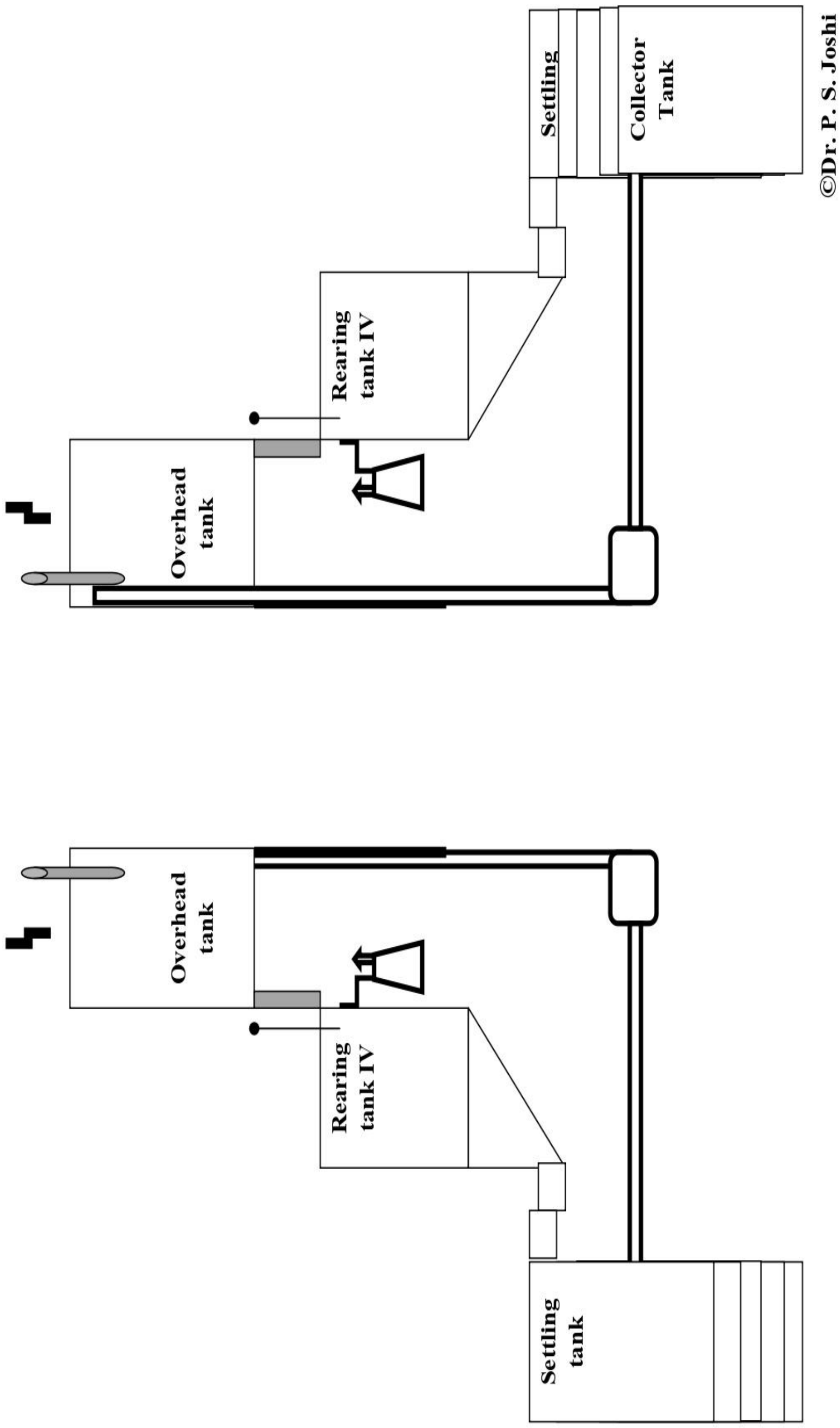


**Figure 4: Closed Recirculating Aquaculture System: Side view and tank arrangement**

***Biosecurity***

Disease outbreaks occur more readily when dealing with the high fish stocking densities typically employed in intensive CRAS (Wright and Fyhn, 2001). Outbreaks can be reduced by operating multiple independent systems with the same building and isolating water to water contact between systems by cleaning equipment and personnel that move between systems (Chen *et al.*, 2006; Terjesen 2008). Also the use of an Ultra Violet (UV) or ozone water treatment system reduces the number of free floating virus and bacteria in the system water. These treatment systems reduce the disease loading that occurs on stressed fish and thus reduce the chance of an outbreak (Lunda *et al.*, 2019; Nesar and Turchini, 2021).

## Conclusions

The Closed Recirculting Aquaculture System described here was built for scientific research purposes and for focus on the environmental requirements of freshwater farm fishes. A major goal when constructing the facility was to offer sufficient flexibility for experiments and for doing such experiments on a semi-commercial scale. It helps to reduced water requirements as compared to raceway or pond aquaculture systems. It also reduced land needs due to the high stocking density. It provides site selection flexibility and independence from a large, clean water source. It helps in reduction of wastewater effluent volume and increased bio-security and ease in treating disease outbreaks. The Closed Recirculting Aquaculture System has ability to closely monitor and control environmental conditions to maximize production efficiency. Similarly it is independence from weather and variable environmental conditions.

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