



Technology Evaluation Report

Testing FloMov Pumping Technology in a Commercial Aquaculture Environment



PROPOSAL:

Testing the Efficacy of FloNergia Pumping Technology in a Commercial Aquaculture Environment

Contract Research Project for:

FloMov pump (A FloNergia Technology)

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1.0 Background:

Increasing the use of sustainable practices in the aquaculture industry is vital to meet the increasing global demands for seafood products. One suggested approach to reduce environmental impacts on wild ecosystems and improve the sustainability of the aquaculture industry is to remove fish production systems from natural bodies of water such as oceans, lakes and rivers. It has been recommended to relocate these production systems to land-based facilities. However, moving fish production systems to land based-tank systems increases the demand for freshwater resources while increasing energy costs due to the requirement to run pumps, aeration and lighting systems. The circulation of water using centrifugal pumps is one of the most expensive parts of a land-based production system.

Compared to centrifugal pumps, airlifts systems are a more cost-effective approach to moving water. Airlift pumps are commonly used in aquaculture systems to circulate water and maintain critical gas levels. To reduce the energy required to operate land-based fish farms, FloNergia Inc. has designed the first gas-driven airlift pump that is able to move heavy fluids and solid-liquid mixture which uses 40% less energy to operate. Additionally, this airlift pump is 70-80% less expensive and requires minimum maintenance compared to conventional mechanically operated pumps.

Previous research by Shallouf et al. (2019) have demonstrated the effectiveness of airlifts in both a laboratory setting and a field setting. The study demonstrated that the numerical velocity in the field setting was comparable to that of the experimental laboratory setting.

However, the effect of these devices on fish and water quality have not yet been studied. It is well documented that water quality, such as high dissolved oxygen and low suspended solids, is essential to optimal fish health and productivity. In addition to simply moving water efficiently, if these airlift pumps can improve water quality parameters such as dissolved oxygen and total suspended solids, fish welfare and productivity can be improved in land-based production systems. Additionally, it is possible that an improved rearing environment may also lead to improved growth and productivity of commercially reared fish. The results of this research will be of value to the growing aquaculture industry.

2.0 Project Objectives:

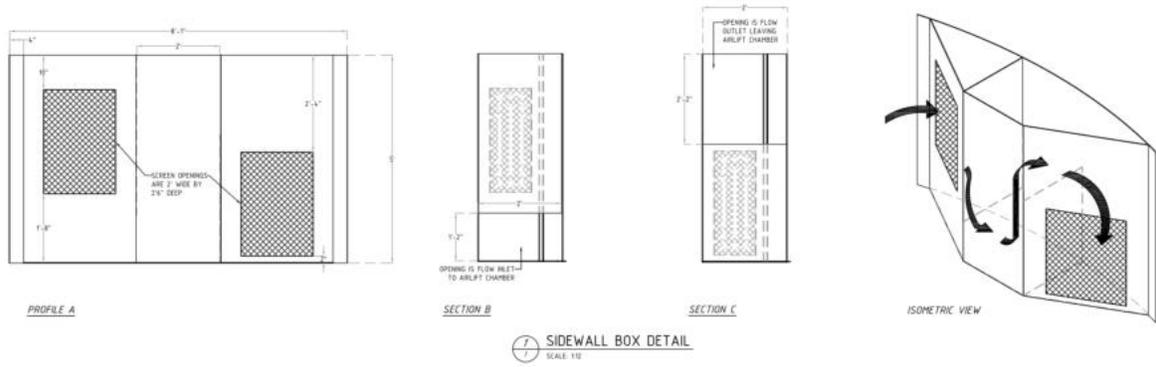
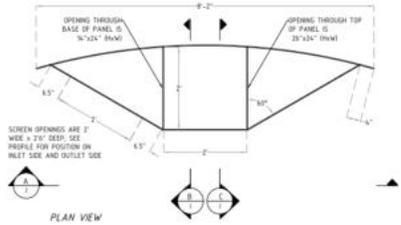
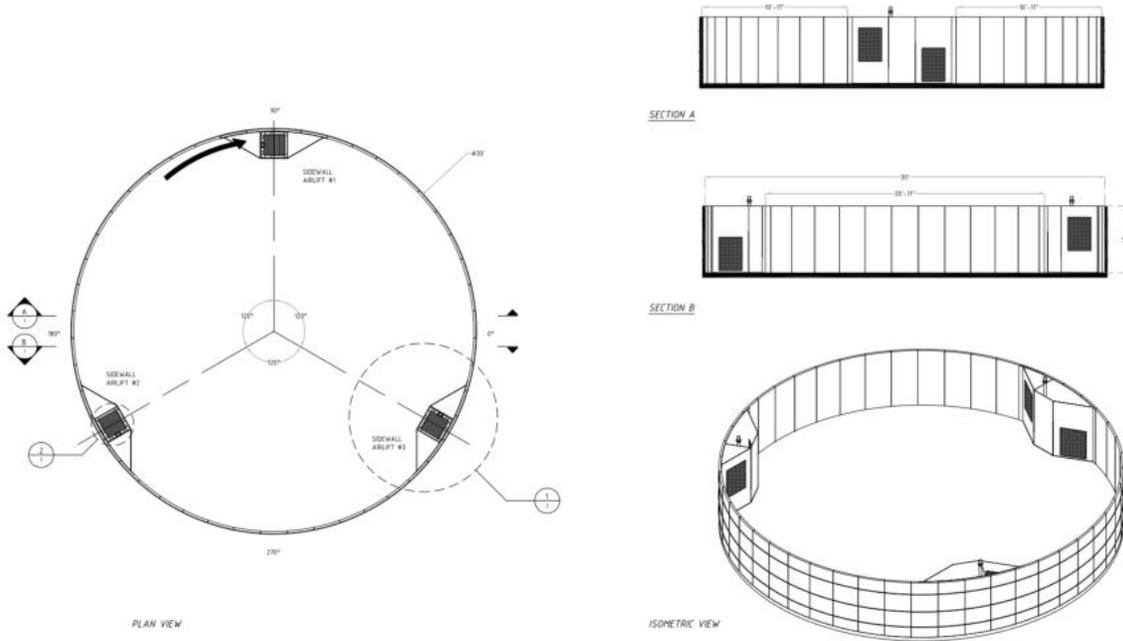
The objective of this project is to evaluate the use of FloNergia airlifts (FloMov) for water quality parameters and fish productivity in a commercial aquaculture setting using an optimized control tank equipped with aerators designed for land-based fish production at Ontario Aquaculture Research Station.

3.0 Methodology:

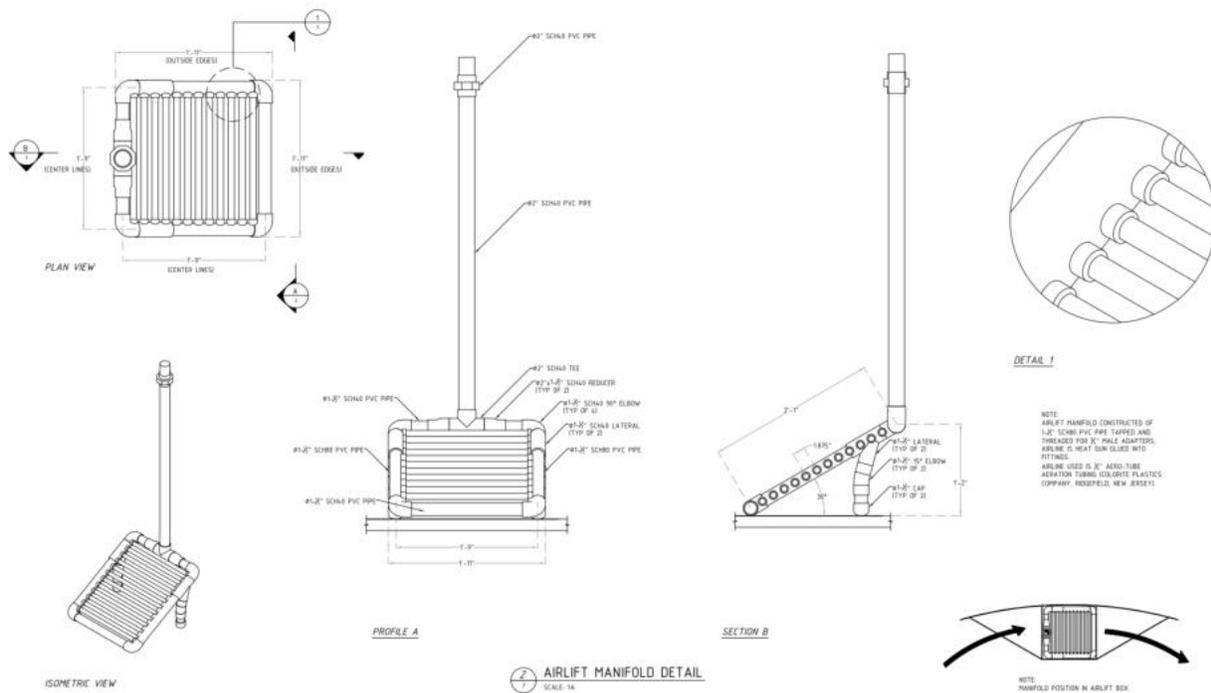
Control Tank Aerators

The aerators used in the existing OARC system are custom built and cannot be ordered off the shelf. These aerators consist of three components: aluminum boxes, perforated tubing and PVC piping. The aluminum boxes were fabricated by a local tool shop (Astron Tool & Machine Ltd, Elmira, Ontario) and the aerators were built by station staff after buying perforated tubing and PVC from Fish Farm Supply

(Elmira, Ontario). The design was originally proposed by Summerfelt and Pfeiffer (2008). The figures below depict the preliminary drawings from the conservation fund freshwater institute of the airlift box system.



SIDEWALL BOX DETAIL
SCALE 1/8"



These aerators were found to provide optimum environmental conditions for the growth and productivity of reared fish. However, they come with their own set of disadvantages:

- 1- High capital cost required to build these devices.
- 2- Since these aerators were custom designed, there is a significant amount of time to construct the equipment, which requires special knowledge and capable staff.
- 3- These aerators require high maintenance. Due to algae growth on the perforated tubing, it was found that it is best to clean this system 2-3 times a week.
- 4- Additionally, after the initial investment in this construction, it was found that the perforated tubing needs to be replaced every few years.

FloMov (FloNergia Airlift Pumping Technology)

The existing system of one of the control tanks was replaced with three 4" dual injection pumps. The system comprises of a pipe clamp that secures the pump to the strut, and a bracket that clamps this pump attachment to the circular tank. For the purposes of this trial test, a 4" pump was utilized. After the pump was secured onto its attachment, it was lowered into the cylindrical tank, and the bracket was then secured to the tank using thumb screws. As can be seen in the engineering drawing assembly of the tank in Figure 1, three of these pumps were connected in accordingly. The pump set up at the field site is shown in Figure 2. The pumps sat a depth of 30 inches under the surface of the water, resulting in a pump submergence of 100%. The setup's components are composed entirely of stainless steel, which resists corrosion.

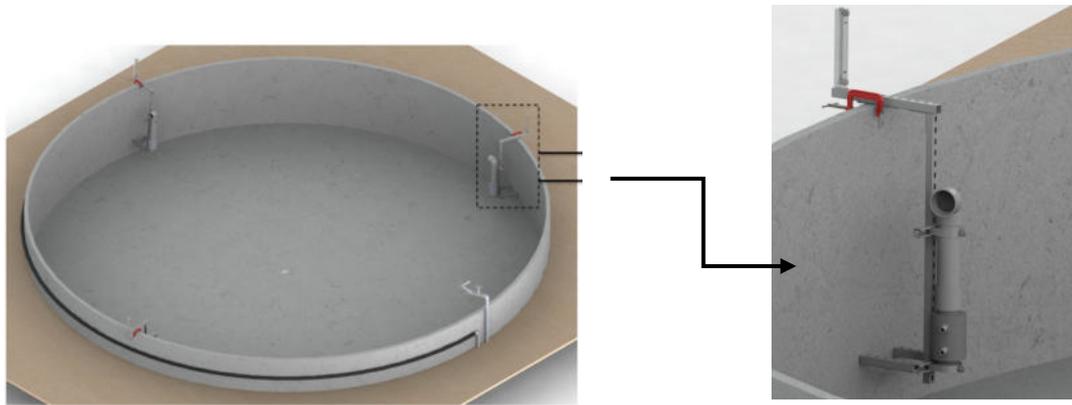


Figure 1. Assembly of the FloMov tank setup



Figure 2. Actual picture of FloMov airlift pump setup

Water Quality and Rearing Environment

Influent water is pumped from six groundwater wells to a central head tank at the Ontario Aquaculture Research Centre (OARC). From there, the groundwater undergoes degassing and oxygenation by passing through five degassing columns with plastic media before being directed the wet laboratories.

Table 1: Water quality characteristics of influent groundwater at the Ontario Aquaculture Research Centre (See appendix I for full water quality report).

Parameter	Value
Temperature	8.5 ± 0.2 °C
Dissolved Oxygen	10.6 mg/L
pH	8.2
Hardness	241 mg/L
Total Suspended Solids	0.29 mg/L
Total Organic Carbon	1.45 mg/L
Chemical Oxygen Demand	<10 mg/L

Aerated water was provided to each tank at a rate of at 380 L/min. Flows were measured weekly and were adjusted as necessary to maintain the desired flow rate. Rearing tanks, approximately 70,000 L in volume, were located in the outdoor lab, an enclosed building with a canvas cover allowing for a natural photoperiod.

Fish and Feeding

The use and handling of fish for this study was performed in accordance with animal utilization protocol #4797 and was reviewed and approved by the University of Guelph’s Animal Care Committee.

Arctic char (*Salvelinus alpinus*) sourced from the OARC were selected for this study. Arctic charr are a cold-water species of salmonid fish native to Northern Canada and aquaculture production is conducted in the Yukon Territory, Manitoba, Nova Scotia, Ontario, Quebec, New Brunswick and Newfoundland.

Mixed sex Arctic char approximately 735 g were randomly distributed in two production-scale rearing tanks (1500 fish/tank) where they were maintained using controlled tank aerators (control) or the FloMov (treatment). Char were fed a commercial diet prepared by Blue Water Fish Feeds (Sharpe Farm Supplies Ltd., Guelph, Ontario). Feed was delivered by hand five times a week (Monday to Friday) during two feeding windows, 9:00 – 11:00 am and 1:00 – 3:00 pm. During these feeding windows, food was

provided to the fish until they stopped showing interest in feeding (no longer coming to the surface to attack the feed, feed accumulation on the bottom of the tank). Feed rations were calculated daily using expected feed conversion and suggested feed rates for this species developed by the OARC. Rations were increased or decreased subjectively, based on the interest in the feed. Fish were fasted for two days a week (Saturday and Sunday) to allow for tank cleaning.

Measurements

Mortality was recorded daily for each tank. A sample size calculator with 95% confidence level and a 5% margin of error was used to determine the number of animals to be measured in the population. After a 14-day acclimation period (day 14), 306 fish from each tank (612 fish in total) were randomly collected by dip net and anesthetized in a 75 mg/L bath of Syncaïne® fish anesthetic (Syndel, Canada). Each of the randomly selected fish was individually weighed to the nearest 0.001 kg and measured for fork length to the nearest 0.1 cm. These measures were used to calculate the condition factor using the following formula: $100 \times \text{weight}/\text{length}^3$. Fish were recovered in an aerated recovery tank and returned to the experimental rearing units. At the conclusion of the 3-month trial (day 84), 306 fish were randomly selected from each tank (612 fish in total) and the measures were repeated. The difference between day 14 and day 84 was used to assess growth and fish condition during the trial period.

Dissolved oxygen (DO) was measured using a Handy Polaris (OxyGuard). Total suspended solids (TSS) were measured by collecting a 1 L grab sample close to the centre drain and then using a gravimetric analysis. A 1.5 µL filter (Whatman Binder-Free Glass Microfibre Filter type 934/AH) was dried for 1 hr at $103^\circ\text{C} \pm 3^\circ\text{C}$ and weighed. The 1 L sample was filtered through the paper. After filtration, the filter paper was dried for 1 hr at $103^\circ\text{C} \pm 3^\circ\text{C}$ and weighed again. The difference between the initial weight the post-filtrated weight was recorded as TSS. Turbidity, reported as Nephelometric Turbidity Unit (NTU), was measured by collecting a grab sample close to the centre drain. The absorptometric method using a HACH 900 Colorimeter was used to quantify turbidity by using a blank (inflow water source) and comparing it to the grab sample. The type and frequency of measurements is summarized in Table 2.

Table 2. Type and frequency of measurements throughout the duration of the experiment.

Parameter	Type	Frequency	Timing
Dissolved Oxygen	Oxyguard	3x / Week	Monday, Wednesday, Friday at 9:00 am
Inflow Measure	Velocimeter	Weekly	Monday 9:00 am
Total Suspended Solids	Grab Sample	2x / Week	Monday 9:00 am; Friday 2:00 pm
Turbidity	Grab Sample	6x / Week	Monday, Wednesday, Friday at 9:00 am and 3:00 pm

Statistical Analysis

Shapiro-Wilk normality test and Levene's Test for Homogeneity of Variance were performed to assess the normality and variance homogeneity, respectively. For normal data (DO, Flow) were assessed using an independent sample T test. Non-normal data (TSS) was transformed to the square root of the

value prior to being assessed using an independent sample T test. Turbidity values continued to fail to pass assumptions for normality, even after log and square root transformation. Therefore, a Mann Whitney U test was performed to determine the significance of treatment (control tank or FloMov) on turbidity. Independent-sample t-test ($\alpha = 0.05$) was used to compare the mean values of parameters for the two systems, control tank versus FloMov.

Velocity Measurements

Sontek FlowTracker2 device was used to measure the velocity. This device uses the duration between the reflected acoustic signals from water particles to measure the water's velocity. The flow tracker measures its x and y velocities as well as the water's temperature. Figure 3 and 4 shows the velocity measurement device, and the velocity probe sampling direction diagram respectively. For the velocity measurement, data is collected for 16 points inside the circular tank at 2 different diameters in the tank. The schematic of the velocity data collection points can be seen in the Figure 5.



Figure 3. Sontek FlowTracker2

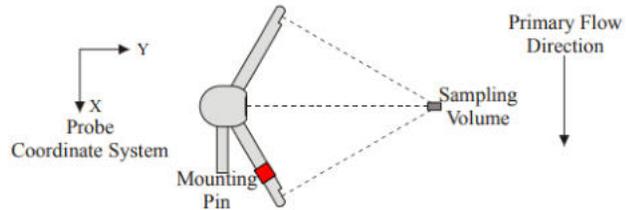


Figure 4. Sontek FlowTracker2 flow direction sampling measurement

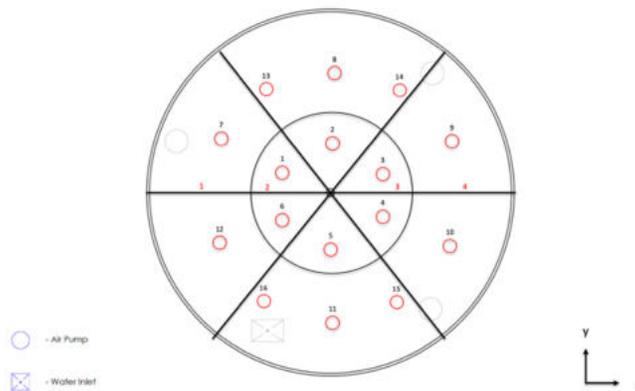


Figure 5. Schematic of velocity measurement data collection locations

Results:

Velocity Measurements/Maps

a) Surface Velocity Map

The surface velocity measurements were collected at an approximate flow rate of 200-300LPM and 700 L/min into the OARC and FloMov circulation systems respectively. The baseline velocities and the velocities at maximum possible flow rate (700LPM) with the fish for the airlift was measured. The baseline condition was denoted Month 0, as no fish were in the tank. Measurements at the 16 locations noted previously, were taken across the FloMov and Alma tank for the next 3 months. These surface velocity magnitude values along with its corresponding vector direction could then be graphically illustrated using a velocity map. The velocity maps for the FloMov tank across the monthly data collection period is shown in Figure 6. Looking at this velocity map timeline across the 3 months, the velocity measurement has increased along the tanks center, from the baseline condition. A side-by-side monthly comparison of the FloMov and OARC tank surface velocity maps can be depicted in Figure 6. It is evident that the FloMov tank has a significantly greater surface velocity when compared to the OARC control tank.

In addition to the surface velocity measurements, depth velocity measurements were also taken and point locations 1 through 4 cross the FloMov tank. These were taken across 3 depths at 1ft increments from the water surface. A velocity profile depiction of the velocities at the tank cross-section for the monthly data collection measurements can be seen in Figure 7. The row noted as '0ft' in the Figure references the associated surface velocity at this point location. Similar to the monthly surface velocity maps, an increase in velocity measurement value is seen at the tanks center across the depth of the tank. In addition, a slight increase is also seen in the velocity along the outer tank at depths greater than the water surface (surface velocity).

An analysis of the flow distribution at the pump entrance and various flow rates was also conducted. Underwater imaging was taken in order to capture the flow at the entrance in order to better quantify the distribution at increased flow rates. The imaging was taken at 2 locations, one parallel and one perpendicular to the flow, at a single depth. The analysis of the flow distribution at the pump entrance and various flow rates was also conducted. Underwater imaging was taken in order to capture the flow at the entrance in order to better quantify the distribution at increased flow rates. The imaging was taken at 2 locations, one parallel and one perpendicular to the flow, at a single depth.

The flow distribution was quantified by measuring the dimensions of the distribution, using the known diameter of the pump within the image as a scaled measurement reference. The length, width, and height of the pumps flow across the different flow rates could then be obtained accordingly. A sample of the imaging flow distribution measurement parameters is in shown in Figure 8. Table 3 presents the complete results of this analysis for all 4 flow rates, for the 3 mention dimensioning parameters with respect to the pumps diameter. As expected, it can be concluded from these results that an increase in the flow rate, corresponds to an increase in size of the flow distribution.

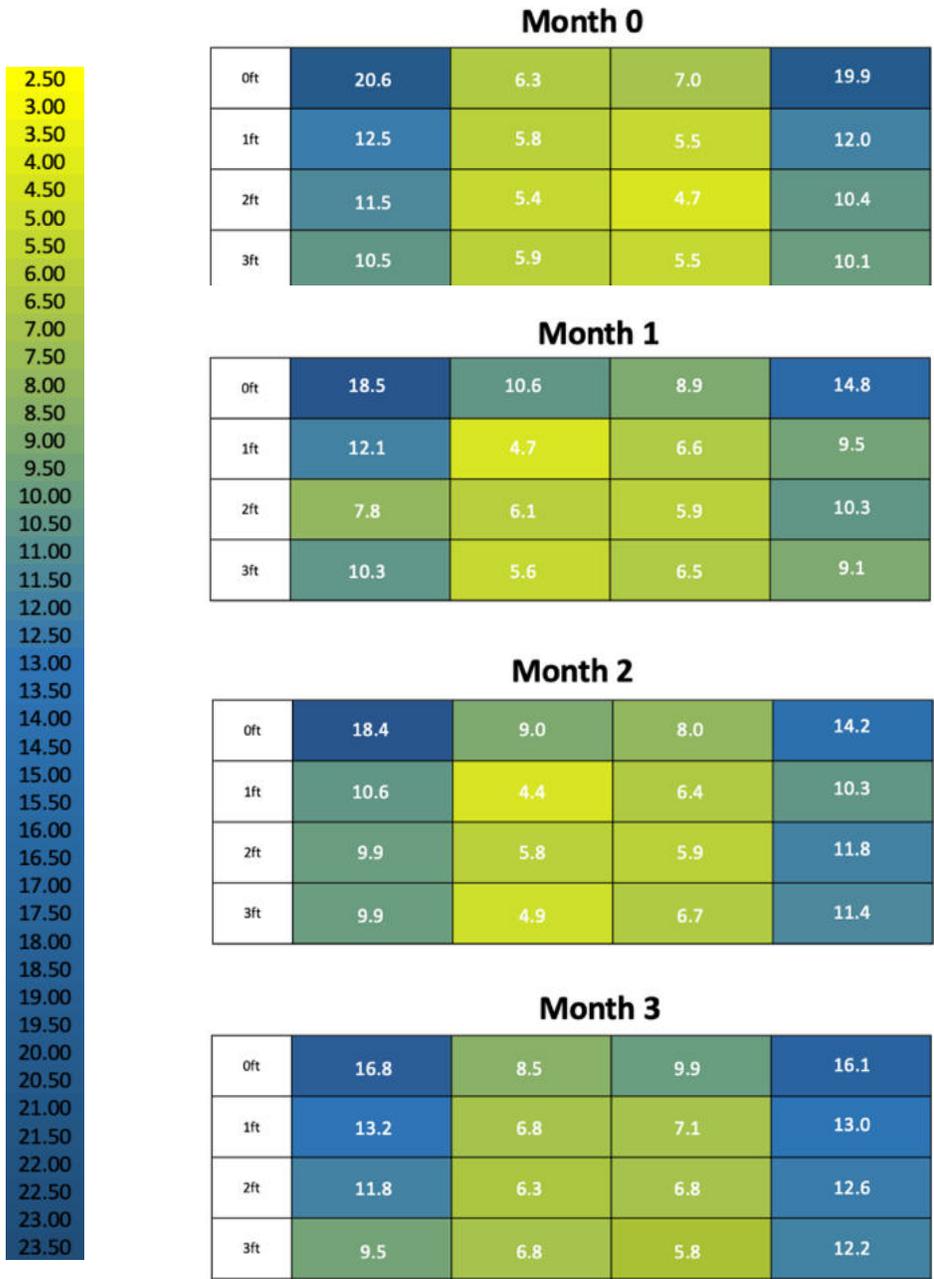


Figure 7. FloMov Tank monthly depth velocity profile

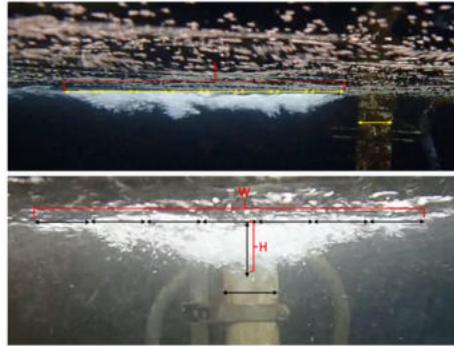


Figure 8. Sample imaging of flow distribution measurement at 500LPM

Table 3. FloMov Tank flow distribution measurement values

Depth	Flow Rate (LPM)	Flow Distribution		
		Perpendicular to Flow		Parallel to Flow
		Width (D/L)	Height (D/L)	Length (D/L)
1.5in	700	6.12	1.21	8.1
	500	4.93	1.15	7.24
	300	3.74	1.28	5.63
	100	3.1	1.2	4.58

b) Fish Performance

Survival was similar in both the OARC control (96.9%) and FloMov treatment (97.5%) tanks (Table 3). At the beginning of the trial, the mean body weight of fish in the control tank were slightly smaller (0.72 kg) compared to the treatment tank (0.75 kg), but this difference was not significant ($p = 0.193$; Table 3). The same trend was observed for mean fork length ($p = 0.073$) and condition factor ($p = 0.344$). However, by the end of the trial, a significant difference was observed in mean body weight ($p = 0.019$) and condition factor ($p = 0.003$) where the fish in the control tank were larger and had a better condition factor compared to fish in the treatment tank. During the three-month trial, the fish in the control tank consumed less feed (532.4 kg) compared to the treatment tank (557.9 kg).

Table 3. Average values for growth metrics (body weight, fork length, condition and cumulative feed intake) plus or minus the standard deviation at the beginning (Day 14) and the end of the experiment (Day 84) for the control tank aerators and the treatment tank (FloNergia airlifts). * denotes significance at $\alpha = 0.05$.

Variable	Control			Treatment		
	Day 14	Day 84	<i>P</i> -value	Day 14	Day 84	<i>P</i> -value
Body Weight (kg)	0.72 ± 0.20	1.09 ± 0.32	0.193	0.75 ± 0.24	1.03 ± 0.35	0.019*
Fork Length (cm)	37.95 ± 2.95	42.15 ± 3.75	0.073	38.47 ± 3.51	41.69 ± 4.20	0.101
Condition Factor	1.28 ± 0.13	1.41 ± 0.16	0.344	1.28 ± 0.12	1.37 ± 0.18	0.003*
Cumulative Mortality	N/A	46	N/A	N/A	37	N/A
Cumulative Feed Intake (kg)	N/A	532.4	N/A	N/A	557.9	N/A

The distribution of size in both tanks at the start and end of the trial are depicted in PDF plots seen in Figure 9. The results of this showed a comparable overall fish length and weight increase across both tanks.

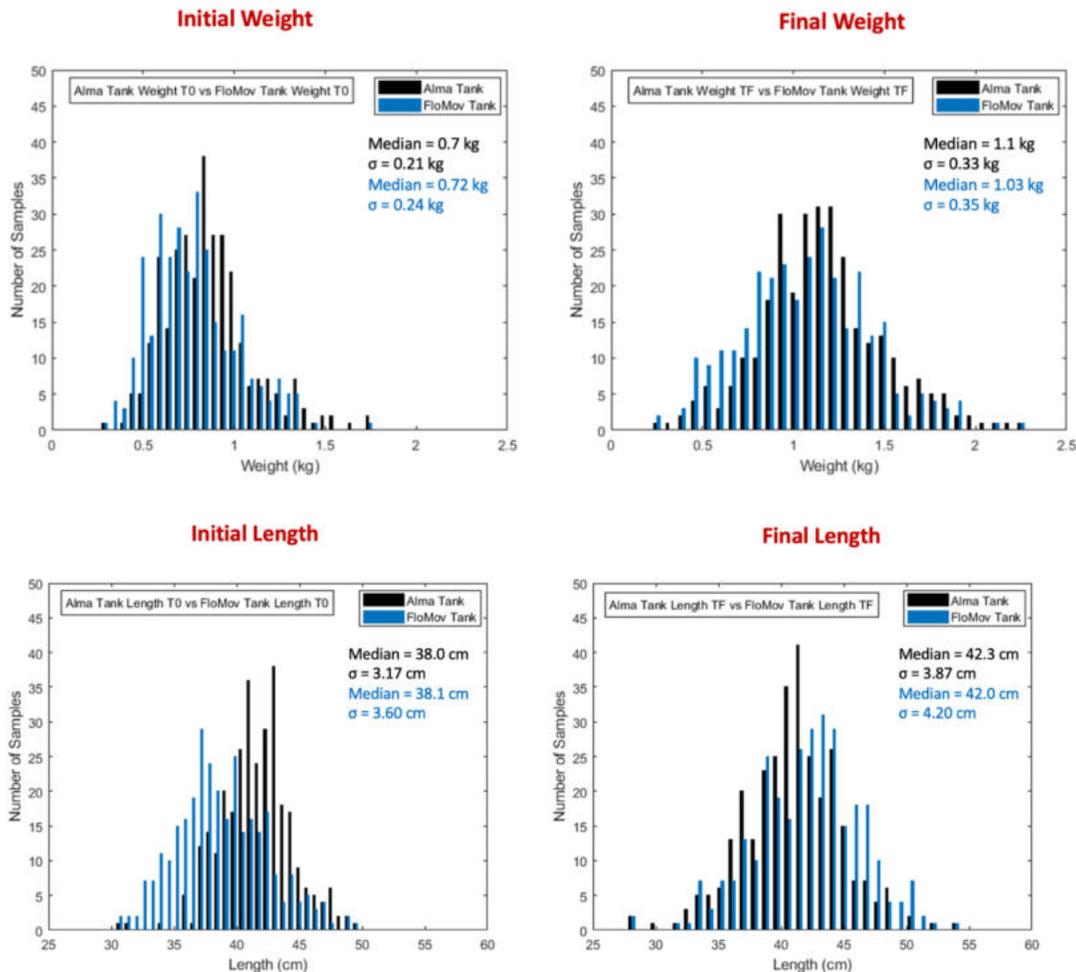


Figure 9. FloMov Tank and OARC Control Tank Fish Growth PDF plots

c) Water Quality

Inflow water did not vary between the control (383.19 L/min) and the treatment tanks (383.32 L/min) during the trial. There was no difference in turbidity between the control and treatment tanks, regardless of the time of measurement (morning versus afternoon; Table 4). Significant differences were noted in two water quality parameters, dissolved oxygen and the measurement of total suspended solids (morning measurement only; Table 4). Dissolved oxygen was greater in the treatment tank (8.68 mg/L) with the FloMov system compared to the control tank (8.023 mg/L; $p = 0.002$). The morning measurement of total suspended solids were greater in the control tank (0.90 mg/L) compared to the treatment tank (0.45 mg/L) with the FloMov airlifts ($p = 0.004$). No significant difference was observed for the afternoon measurement of total suspended solids ($p = 0.169$); Table 4.

Table 4. Average values for water quality parameters (inflow, dissolved oxygen, total suspended solids and turbidity) plus or minus the standard deviation for the control tank areators and the treatment tank (FloNergia airlifts). * denotes significance at $\alpha = 0.05$.

Parameter	Control	Treatment	P-value
Inflow (L/min)	383.19 ± 10.15	383.32 ± 9.90	0.793
Dissolved Oxygen (mg/L)	8.23 ± 0.65	8.68 ± 0.47	0.002*
AM Total Suspended Solids (mg/L)	0.90 ± 0.36	0.45 ± 0.34	0.004*
PM Total Suspended Solids (mg/L)	0.82 ± 0.35	0.63 ± 0.52	0.169
AM Turbidity (NTU)	0.69 ± 1.37	0.50 ± 1.01	0.491
PM Turbidity (NTU)	0.64 ± 1.32	0.50 ± 0.99	0.768

The results of the dissolved oxygen readings as well as the saturation was plotted over the duration of the trial can be seen In Figure 10 and 11 respectively. As can be seen from the results, the FloMov airlift was able to better oxygenate the water compared to the OARC control tank, for both the metrics of total oxygen dissolved and saturation. A side-by-side plot of the percent increase of the FloMov tank when compared to the OARC control tank is also displayed.

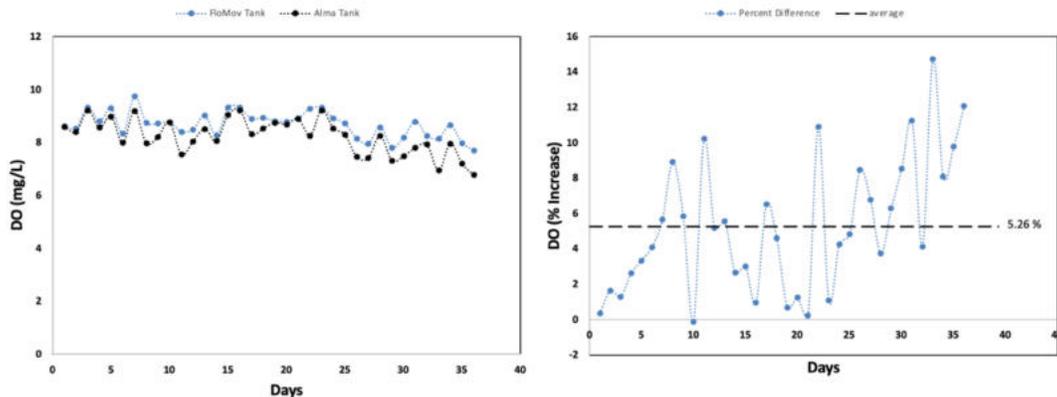


Figure 10. FloMov Tank and OARC Control Tank total dissolved oxygen results

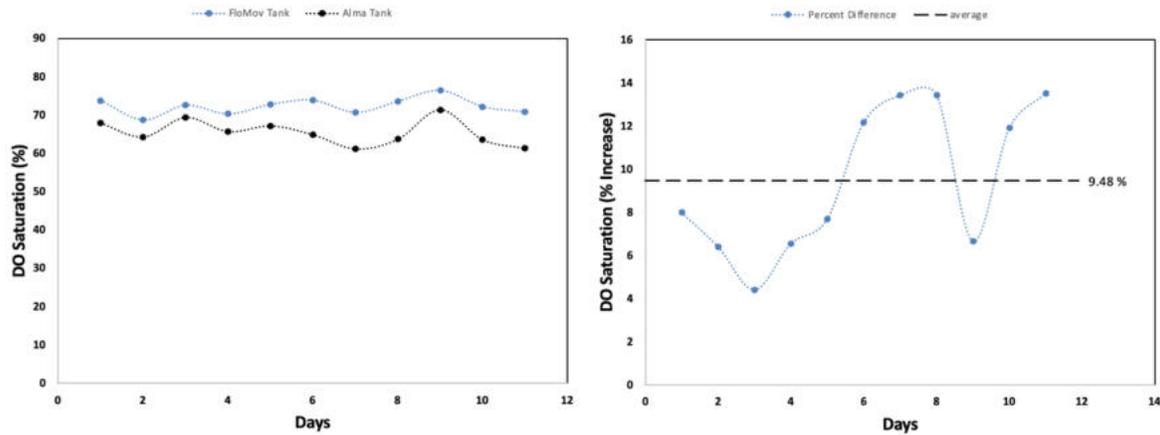


Figure 11. FloMov Tank and OARC Control Tank dissolved oxygen saturation results

Total suspended solids (TSS) are the dry weight of undissolved suspended particles in a water sample that can be captured by a filter and measured using a filtering device as discussed by Campbell (2021). TSS is a measure of water quality that is used to evaluate the quality of a sample of any kind of water or water body. Although bacteria and algae can also be categorized as TSS, inorganic materials make up the majority of TSS (Schumann and Brinker (2020)). High TSS can affect water quality by lowering naturally occurring dissolved oxygen levels and raising water temperature. This might make it difficult for aquatic organisms, like fish, to survive. For this reason, it is ideal to minimize measured TSS within the tank. Underwater imaging of both tanks can be seen in Figure 12 and 13. Observing both imaging of both tanks, it is evident that the OARC control tank had significantly more floating solids within the tank when compared to the FloMov tank. The results of the measurements of TSS of both tanks over the trial period supports this notion. As can be seen in Figure 14, from the plot of both tanks measured TSS, as well as their percent difference from these measurements, The FloMov tank has an average of 38.26% less TSS over the trial period.



Figure 12. Underwater FloMov Tank imaging



Figure 13. Underwater OARC Control Tank imaging

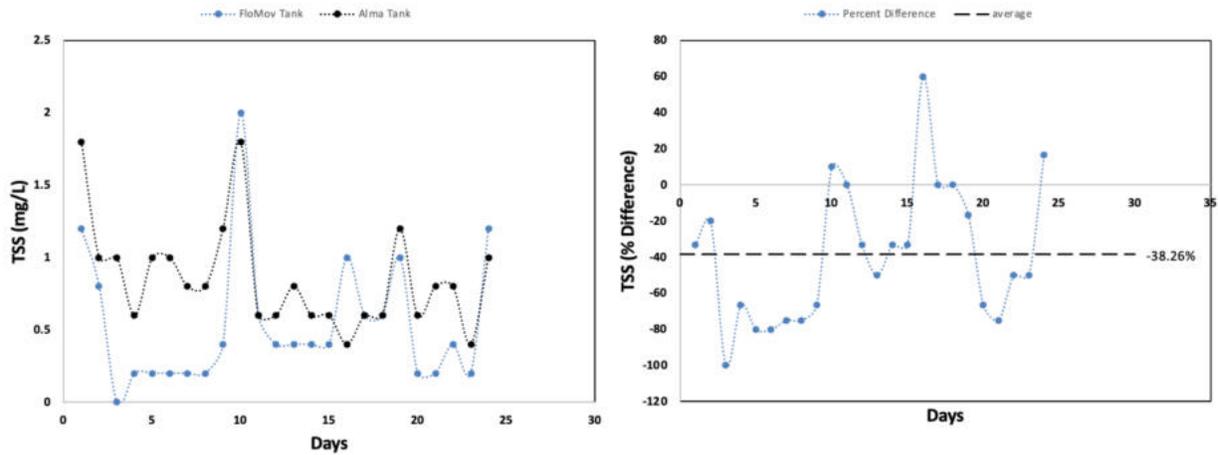


Figure 14. FloMov Tank and OARC Control Tank total suspended solids (TSS) results

Discussion:

Airlift pumps have been successfully utilized in various aquaculture operations, including recirculating systems, raceways and land-based tanks due to their ability to aerate, degas and circulate water (Loyless & Malone, 1998; Arani & Agh, 2020). In this study, the inflow water supply was the same in both the control and treatment tanks throughout the trial, therefore any differences in the water quality parameters are believed to be due to the effect of the aeration device, the OARC control tank aerators (control) or the FloMov airlift (treatment).

Total suspended solids and turbidity are influenced by feeding; therefore, these parameters were measured in the morning before feeding and in the afternoon following the cessation of feeding. Many of the water quality parameters, including afternoon total suspended solids and turbidity did not differ between the treatment and the reference control tank. This suggests that the effect of feeding increased the total suspended solids for a period of time following the cessation of feeding regardless of the airlift design. However, when total suspended solids were measured in the morning, a significant difference was observed, indicating that the FloMov cleared the tank of solids at a faster rate than the control tank aerators. Significant differences were also observed in dissolved oxygen between the control and treatment tank, indicating that the FloMov system was more efficient at oxygenating the tank water. While the mean dissolved oxygen of the water was statistically greater in the FloMov tank, both treatment and control tanks recorded measures above the minimal level required by the facility's standard operating practices and therefore fish were not at risk of stress due to low oxygen.

Notably, while not significantly different, the average weight of the fish in the control tank was slightly smaller compared to the average weight of the fish in the treatment tank at the beginning of the experiment. At the conclusion of the experiment however, the reverse was true. After 84 days of growth,

the fish in the control tank were significantly larger compared to the fish in the treatment tank, despite more feed being presented to the fish in the treatment tank. During the trial, the technicians stopped feeding when the fish stopped showing interest in feed, by observing behavior such as swimming to the surface to aggressively strike at the pelleted feed or observing an accumulation of uneaten feed on the tank bottom. Fish having greater access to feed should grow larger than those having access to less feed. Because the fish in the control tank were provided with less feed but grew larger than the treatment tank, we suspect that the FloMov system affected the growth rate of the fish. The FloMov tank was observed to have a significantly greater surface velocity when compared to the OARC control tank which may have caused a number of effects which could have contributed to the reduction in body size.

1. Increased water velocity may cause the fish to expend more energy swimming against the current and maintaining their position in the water column.
2. As the feed sank through the water column, increased water velocity may have moved uneaten feed towards the bottom of the tank and the drain at a faster rate compared to the aerators in control tank, making it more difficult for the fish to access the feed.
3. The disruption of the surface of the water may have made it more difficult for the fish to see the feed provided, which may have contributed to accessing the feed.

While improved water quality in a commercial aquaculture operation is desirable as water quality has an impact on animal health and product flavor, the rearing environment must be appropriate to support fish growth. This includes the correct current speed to and access to feed. Feed is one of the most costly parts of any aquaculture operation. Therefore, producers strive to avoid over feeding fish as waste feed cannot be recovered and uneaten feed is economically costly. Additionally, waste feed has the potential to affect the receiving environment by increasing the amount of total suspended solids and total phosphorus in the effluent water.

Conclusion:

This study tested the effect of FloNergia airlifts (FloMov) on water quality parameters and fish productivity in a commercial aquaculture setting compared to traditional aeration devices utilized for land-based fish production. The FloMov were simple to install and operate. Additionally, the devices did not experience much biofouling during the trial. This study found that the FloMov system significantly improved some water quality parameters, such as velocity, dissolved oxygen and total suspended solids measured in the morning. However, because the fish in the treatment tank with the FloMov airlifts were smaller at the end of the trial even though they had been provided with more feed compared to the control tank, it is recommended that these airlifts should be adjusted to create an environment which better meet the needs of the fish. Specifically, the FloMov airlift should be altered to reduce the water velocity in the tank and the inflows should be relocated below the surface of the water to reduce the disruption of the surface.



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Appendix I

Ontario Aquaculture Research Centre Water Quality Characteristics

	Result	Detection Limit	Units
Physical Tests			
Colour, Apparent	<2.0	2	CU
Conductivity	506	3	umhos/cm
Hardness (as CaCO ₃)	241	10	mg/L
pH	8.21	0.10	pH units
Total Dissolved Solids	311	20	mg/L
Total UV Transmittance	99	--	%T
Turbidity	0.13	0.10	NTU
Anions and Nutrients			
Alkalinity, Total (as CaCO ₃)	242	10	mg/L
Ammonia, Total (as N)	<0.020	0.020	mg/L
Chloride (Cl)	7.72	0.50	mg/L
Fluoride (F)	0.199	0.020	mg/L
Nitrate (as N)	0.482	0.020	mg/L
Nitrite (as N)	<0.010	0.010	mg/L
Orthophosphate-Dissolved (as P)	<0.0030	0.0030	mg/L
Sulfate (SO ₄)	31.6	0.3	mg/L
Organic / Inorganic Carbon			
Total Organic Carbon (TOC)	1.45	0.50	mg/L
Aggregate Organics			
Chemical Oxygen Demand (COD)	<10	10	mg/L
Total Metals			
Aluminum (Al)-Total	<0.010	0.010	mg/L
Antimony (Sb)-Total	<0.00010	0.00010	mg/L
Arsenic (As)-Total	0.00016	0.00010	mg/L
Barium (Ba)-Total	0.0836	0.0002	mg/L
Beryllium (Be)-Total	<0.00010	0.00010	mg/L
Bismuth (Bi)-Total	<0.000050	0.000050	mg/L
Boron (B)-Total	0.033	0.010	mg/L
Cadmium (Cd)-Total	<0.000010	0.000010	mg/L
Calcium (Ca)-Total	54.5	0.5	mg/L
Cesium (Cs)-Total	<0.000010	0.000010	mg/L
Chromium (Cr)-Total	<0.00050	0.00050	mg/L
Cobalt (Co)-Total	<0.00010	0.00010	mg/L
Copper (Cu)-Total	<0.0010	0.0010	mg/L



	Result	Detection Limit	Units
Iron (Fe)-Total	<0.050	0.050	mg/L
Lead (Pb)-Total	<0.00010	0.000	mg/L
Magnesium (Mg)-Total	24.4	0.05	mg/L
Manganese (Mn)-Total	0.0942	0.0005	mg/L
Mercury (Hg)-Total	<0.000010	0.000010	mg/L