BioGill Water Treatment - Aquaculture

Assessment of a BioGill water treatment unit at Port Stephens Fisheries Institute

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1 Executive Summary

A BioGill was installed on one tank at Port Stephens Fisheries Institute (PSFI) Hatchery in May 2012 and has been in continuous operation. Each of the tanks at the Hatchery has an independent water recirculation system to help maintain water quality. Fresh seawater is exchanged at 10% of tank volume per day (i.e. about 3,000 L per day per tank). The BioGill replaced the airlift bioreactor that is normally used as part of this system on all tanks in the Hatchery.

Comparison of the seven months before installation of the BioGill with the same period after installation showed no change in average pH, a smaller minimum and maximum pH range after installation and 2.5 times less buffer being added after installation. The same broodstock were in the tank over this period and are likely to have maintained a steady level of biological demand. A higher than normal water exchange rate was used for the BioGill tank over after installation and this is this period which is a likely contributing factor to the water quality. However, it should be noted that over the last 23 weeks of the Trial water exchange to the BioGill tank was stopped completely without a deterioration in water quality.

Comparison of the tank with the BioGill (Tank 4) and the other two tanks showed equivalent or better performance for control of pH, ammonia and dissolved oxygen. When normalised for the biomass of fish, the BioGill tank required less feed (kg/kg fish) and less buffer (kg/kg fish) compared. The amount of buffer per feed (kg buffer/kg feed) was equivalent to other two tanks. Although the highest level was recorded for buffer/feed when the BioGill tank when water exchange was stopped the level stabilised and approached the level for the other mulloway tank.

The health and breeding performance of the mulloway broodstock in the tank with the BioGill treatment were equivalent to broodstock in the other tank.

Overall, this Trial has demonstrated that BioGills in a recirculating aquaculture system for a hatchery:

- maintained or improved water quality
- allowed zero water exchange in the latter stages of the Trial (23 weeks)
- reduced energy usage
- maintained breeding performance and health of the broodstock.

Acknowledgements

The co-operation and assistance of Dr Stewart Fielder, Mr Luke Cheviot and Mr Luke Vandenberg from the Port Stephens Institute of Fisheries is gratefully acknowledged.

2 Background

Good water quality is one of the most important factors in achieving successful aquaculture. A key issue is to achieve high performance at low operating cost.

The BioGill Water Treatment unit is an above-ground bioreactor that supports the growth of endemic micro-organisms as a biofilm on a patented membrane (www.biogill.com).

Port Stephens Fisheries Institute (PSFI) is located at Taylor's Beach, 40 kms north-east from Newcastle and 150 kms north from Sydney on the coast of New South Wales, Australia. The PSFI is a major aquaculture research facility for the New South Wales Government within the Department of Primary Industries (www.dpi.nsw.gov.au/research/centres /psfi).

The PSFI hatchery maintains a series of tanks for marine fish broodstock with a volume of approximately 30,000 L. Control of water quality is a key factor in a successful breeding program with broodstock and egg viability being particularly sensitive to minor changes. Each tank has independent recirculated water treatment consisting of a rotating drum filter, an airlift bioreactor, then heat exchange followed by split flow between the fish tank and a return to the airlift bioreactor. Fresh seawater is typically added at an exchange rate of approximately 10% of total volume every 24 hrs.

A BioGill Water Treatment unit has been in operation since May 2012 at PSFI replacing one of the airlift bioreactors on a tank for mulloway (*Argyrosomus japonicus*) broodstock (Fig 1). Management of the two tanks was conducted as part of the PSFI's hatchery research program on mulloway breeding by PSFI staff, Dr Stewart Fielder, Mr Luke Cheviot and Mr Luke Vandenberg.

This report provides an assessment of the BioGill water treatment unit at PSFI over the first 12 months of operation, from May 2012 to May 2013.

Figure 1 BioGill Unit (white) as part of the recirculating aquaculture system at PSFI Hatchery

3 Aims

The aims of the BioGill Trial;

- Improve water quality
- Reduce water exchange rate
- Reduce energy and other input costs
- Maintain or improve fish stock breeding performance

4 Results

Both tanks with mulloway were compared for all parameters however an additional tank with a different species (snapper) was included because of differences in biomass between the two mulloway tanks. The tank with the BioGill (Tank 4) had a biomass of 330 kg, whereas the other mulloway tank without the BioGill supported a greater biomass (500 kg). The snapper tank (Tank 2) with a biomass of 152 kg was included to compare the BioGill performance with a tank containing a smaller biomass.

Water quality, the rate of added buffer and fish feed and the rate of water exchange were compared for all three tanks.

An estimate of power consumption for the BioGill tank was compared to the standard recirculating treatment system on the other tanks.

4.1 Water Quality

Routine water quality parameters measured as the PSFI Hatchery were recorded i.e. pH, dissolved oxygen, temperature and salinity. In addition ammonia concentration was recorded for part of the Trial.

Water quality (pH) and buffer addition for the BioGill tank was also compared for the 7 months before and after installation.

4.1.1 Tank 4 - Before and after installation of the BioGill

The pH and addition of buffer (sodium carbonate) are standard measurements at the PSFI Hatchery. Comparison of pH over the period 7 months before and after installation of the BioGill on Tank 4 indicates improved stability. The pH mean and standard deviation over this period prior to BioGill installation was 7.98 ± 0.15 with minimum and maximum values of 7.49 and 8.35 (Fig 2). After installation of the BioGill over the same period, the pH mean was not significantly different but the standard deviation was smaller (7.86 ± 0.15) and the minimum and maximum values were less extreme i.e. 7.66 and 8.23 (Fig 2).

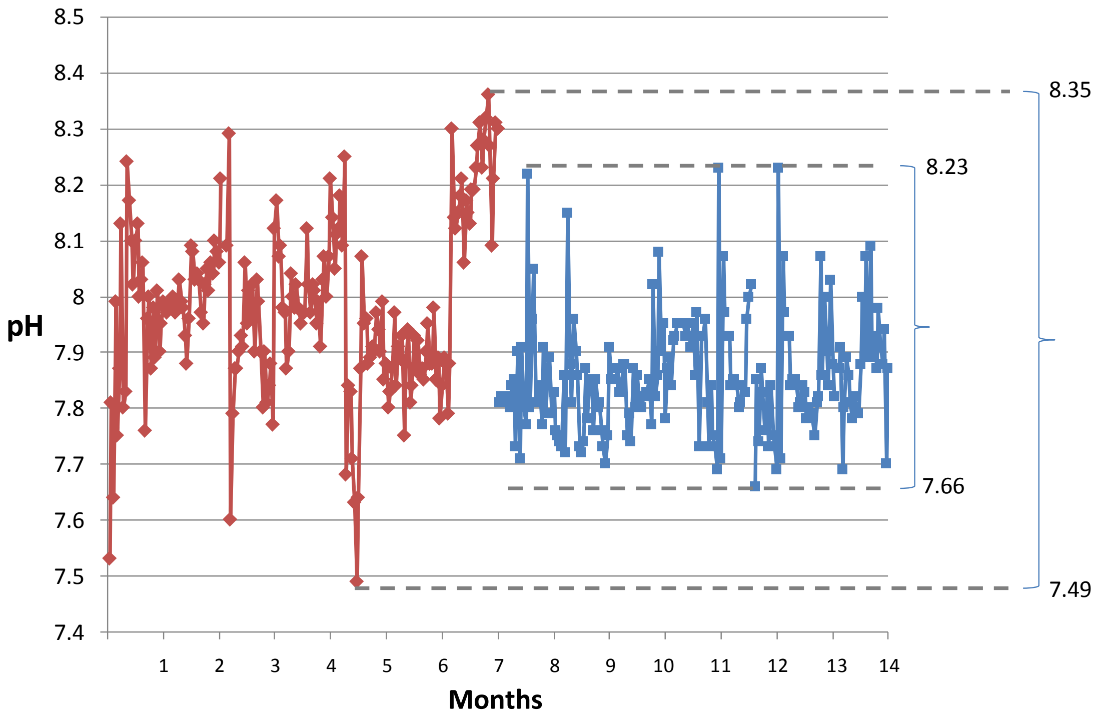


Figure 2 pH for Tank 4

: Before (—) and After (—) installation of the BioGill

Addition of buffer over the 7 months prior to BioGill installation (26.95 kg) was just over 2.5 times more than that required for the 7 months after installation (9.65 kg).

4.1.2 Ammonia

Ammonia was measured over 37 weeks from the start of the Trial for the BioGill tank (Tank 4) and over 26 weeks for the other mulloway tank (Tank 3). The mean ammonia concentration for Tank 3 was 0.4 ± 0.1 ppm with the top and bottom values ranging from 0.2 - 0.6 ppm (Fig 3A) whereas the BioGill had a mean of 0.2 ± 0.1 ppm and a range of 0 to 0.5ppm (Fig 3B). Overall there was significantly lower TAN in the BioGill tank compared to the other mulloway tank.

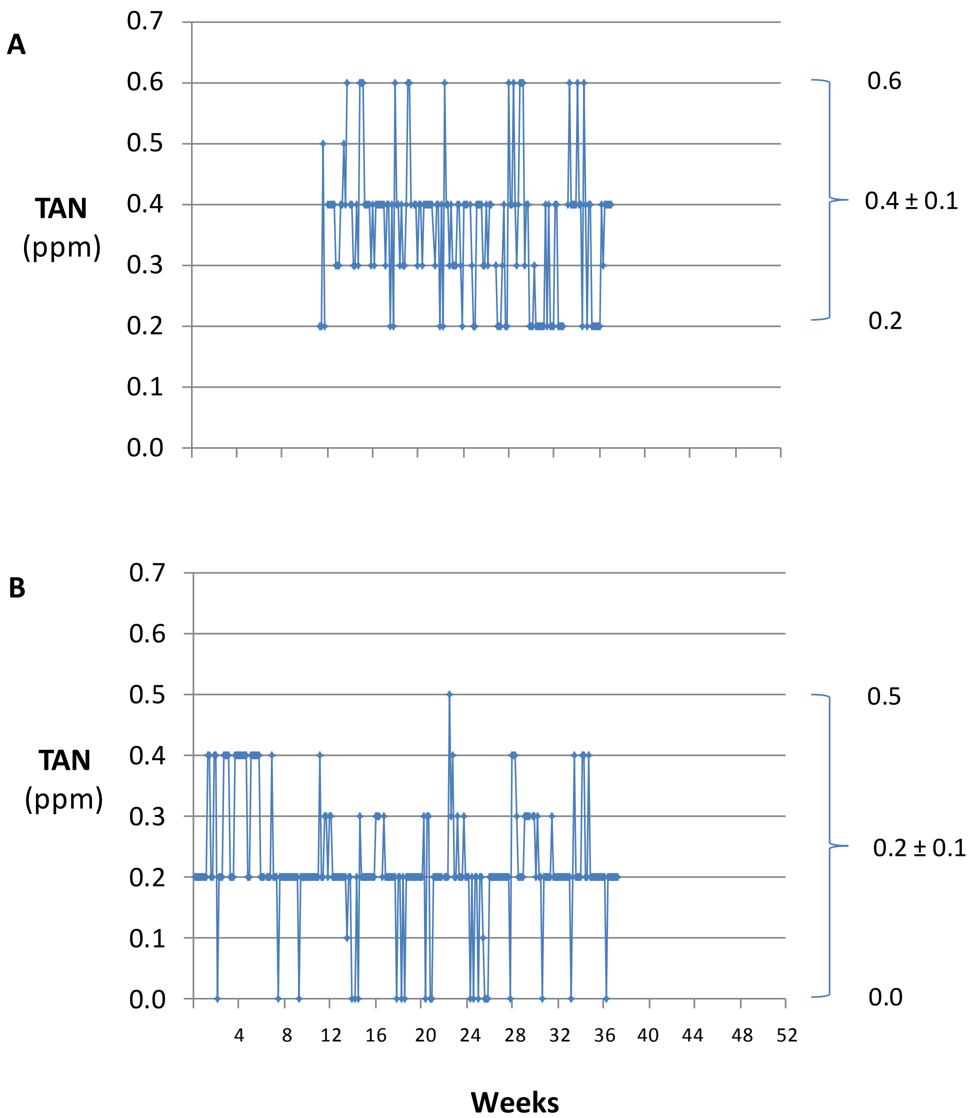


Figure 3 Ammonia (Mean ± SD, max. and min.) in the two mulloway tanks
A. Mulloway tank (Tank 3)
B. Mulloway tank with BioGill (Tank 4)
TAN: Total Ammonia as Nitrogen

4.1.3 pH

pH was measured over the entire 52 weeks of the trial for all Tanks (Fig 4). The mean value for the BioGill tank (7.86 ± 0.11) was similar to the other mulloway tank (7.76 ± 0.14) and the snapper tank (7.87 ± 0.14). The ranges covered by the minimum and maximum values were also comparable however the BioGill tank had the smallest range 7.35 - 8.26.

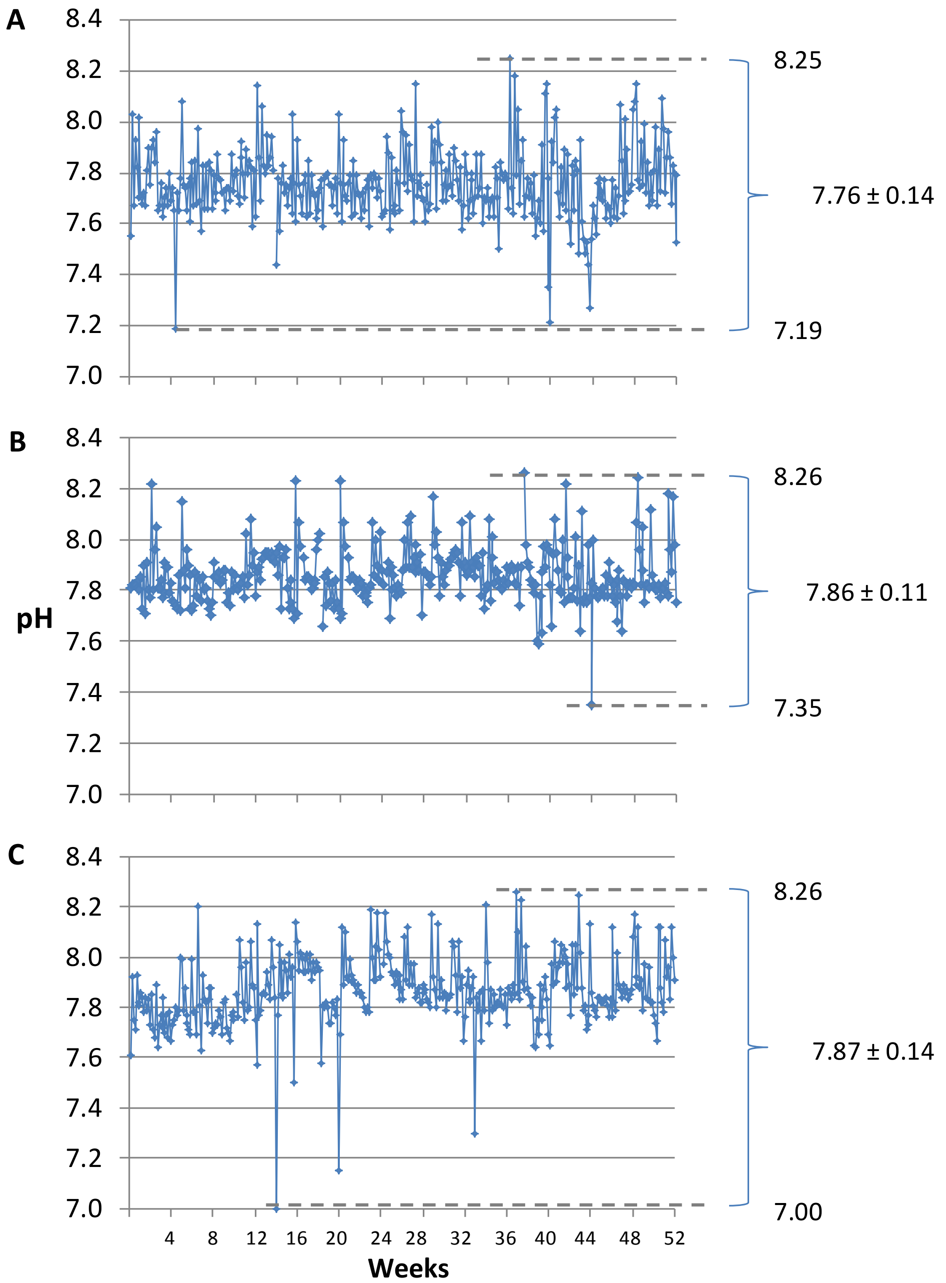


Figure 4 pH (Mean ± SD, max. and min.) over 52 weeks
A. Mulloway tank (Tank 3)
B. Mulloway tank with BioGill (Tank 4)
C. Snapper tank (Tank 2)

4.1.4 Dissolved Oxygen

Over the 52 weeks of the Trial dissolve oxygen across all three tanks are comparable as mean and minimum and maximum levels (Fig 4) i.e. 8.4 ± 1.8 ppm, 6.0 and 14.0 (mulloway tank without the BioGill; Fig 5A), 8.1 ± 1.4 ppm, 4.9 and 14.6 (mulloway tank with the BioGill; Fig 5B) and 8.1 ± 1.4 ppm, 5.8 and 12.6 (snapper tank; Fig 5C).

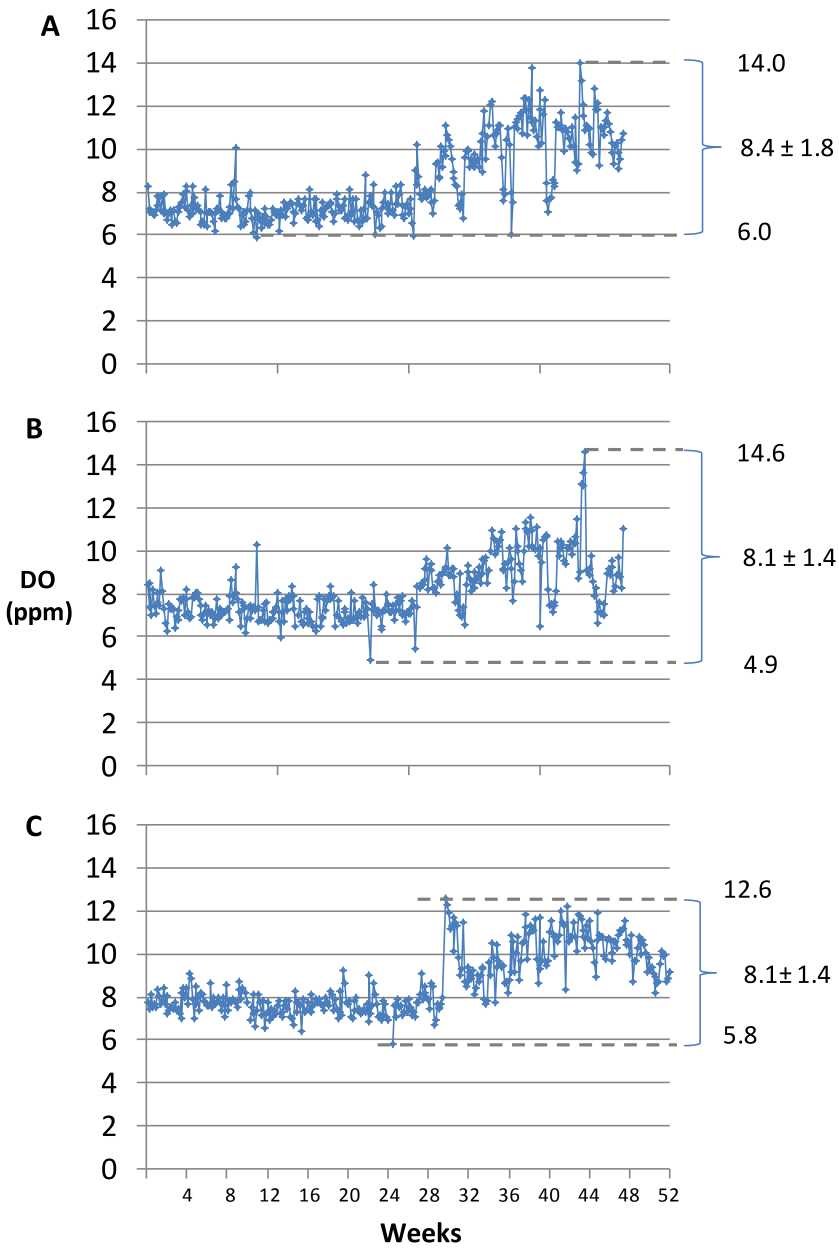


Figure 5 Dissolved oxygen (Mean ± SD, max. and min.) over 52 weeks
A. Mulloway tank (Tank 3)
B. Mulloway tank with BioGill (Tank 4)
C. Snapper tank (Tank 2)

4.1.5 Temperature and Salinity

The temperature profile for the two mulloway tanks was the same over the 52 weeks and also had the same mean, standard deviation and minimum and maximum range (Table 1). The snapper tank was slightly cooler and with a smaller minimum and maximum range.

The salinity profile the two mulloway tanks was similar and had the same mean with Tank 3 having a slightly greater standard deviation and minimum and maximum range. The snapper tank had a similar profile, mean, standard deviation and range as the mulloway tanks (Table 1).

Note that the complete data set for temperature and salinity is available in the data file.

Temperature and salinity are not considered to be significant factors for the BioGill trial.

Location - Tank #	**Temperature (°C)**		**Salinity (ppm)**	
	Mean ± SD	Min - Max	Mean ± SD	Min - Max
Mulloway - 3	17.0 ± 1.5	10.6 - 24.6	31.2 ± 4.2	13.8 - 35.8
Mulloway, BioGill - 4	"	"	31.2 ± 3.2	15.9 - 38.1
Snapper - 2	16.5 ± 0.8	14.2 - 18.8	31.2 ± 3.2	17.7 - 39.2

Table 1 Temperature and salinity over the Trial period for all three tanks

4.2 Feed and Buffer Addition

Sodium carbonate was added to all tanks as a buffer for pH. Feed and waste from the fish can lead to problems (i.e. a reduction in pH) with maintenance of the pH and the buffer helps to reduce this effect.

The total weight of fish in the mulloway tank with the BioGill was less than the other mulloway tank, 330 and 500 kg, respectively (Table 2). Over the 52 weeks of the trial period less feed was added to the BioGill tank (90.2 kg) than the other mulloway tank (319.6 kg). When normalised by the weight of fish, less food was consumed by the fish in the BioGill tank compared to the other mulloway tank, i.e. 0.27 and 0.64 kg/kg fish respectively.

The highest consumption rate was for the snapper tank but this may well be due to species difference and is not considered relevant to this study.

Buffer addition to the tanks showed a similar trend with the least buffer and buffer per fish wt. being observed for the BioGill tank compared to the other mulloway tank and the highest levels occurring for the snapper tank.

Location - Tank #	**Fish (kg)**	**Feed kg**	**(kg/kg fish)**	**Buffer (kg)**	**(kg/kg fish)**
Mulloway - 3	500	319.6	0.64	192.7	0.39
Mulloway, BioGill - 4	330	90.2	0.27	41.9	0.13
Snapper - 2	152	125.0	0.82	61.0	0.40

Table 2 Total Feed and Buffer added to Tanks over the 52 week Trial period

Buffer per kg of fish plotted per 4-weekly intervals (Fig 6) shows a pronounced spike in the ratio for the BioGill tank for weeks 36 to 40 (Fig 6B). This occurred in the same period as the reduction in water exchange for the BioGill tank down to zero (see the following Section). However the level dropped and stabilised to 1 - 1.5 kg/kg fish by week 48 compared to 0.8 kg/kg fish for the other mulloway tank. (Fig 6).

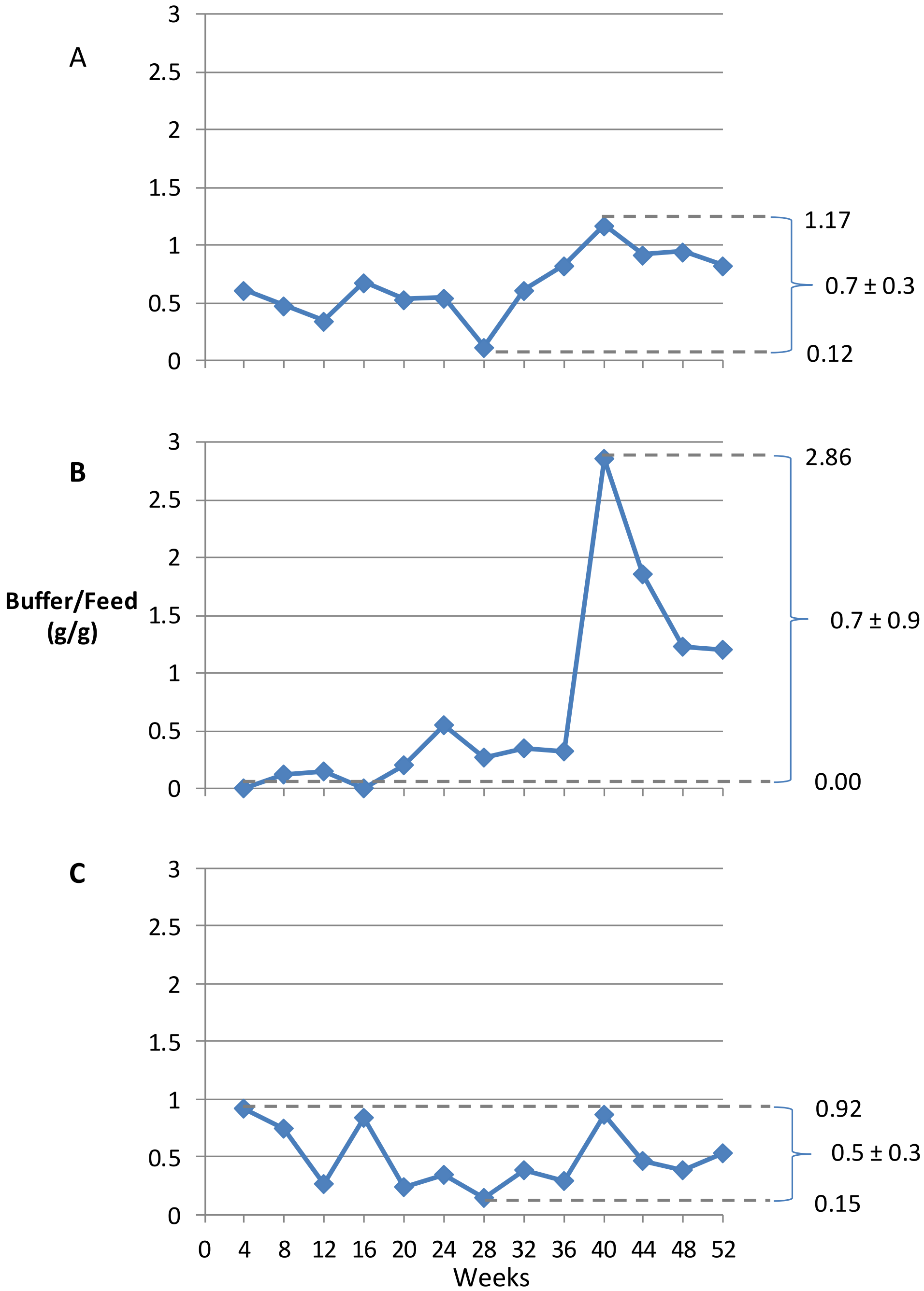


Figure 6 Buffer per Feed (by weight) over the Trial period

A. Mulloway tank (Tank 3)
B. Mulloway tank with BioGill (Tank 4)
C. Snapper tank (Tank 2)

4.3 Water exchange

Water exchange was kept at a constant 125 L/hr (3,000 L/day) for all tanks in the Hatchery apart from the BioGill tank (Fig 7). The rate at the start of the Trial was kept high (540 L/hr) as a precaution and was then decreased to 270 L/hr for most of the following 28 weeks when exchange was completely stopped for the BioGill tank. There is no water exchange for the BioGill tank up to the present.

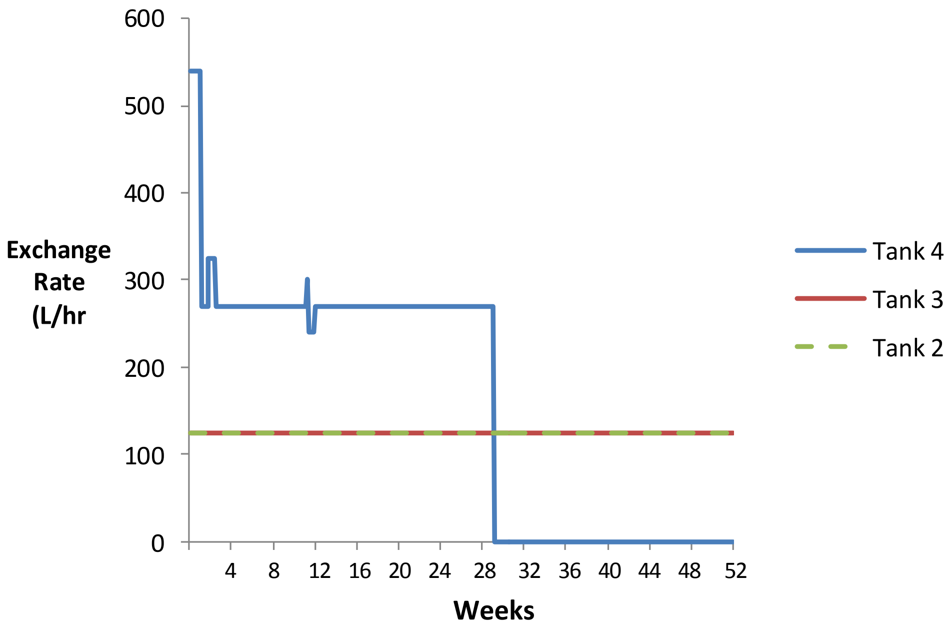


Figure 7 Daily water exchange rate for each Tank

4.4 Electricity consumption

With installation of the BioGill, energy consumption was reduced by the removal of the air blower required for the airlift bioreactor and by eliminating water exchange for the last 23 weeks of the trial. Both systems are run continuously on the standard recirculation system configuration at the Hatchery.

A 2HP (1492 Watts) electric pump is used for water exchange of all six tanks operated at the Hatchery. Electricity consumption would be a total of 13,000 kWh/yr and on a pro-rata basis 2,200 kWh/yr for each Tank.

4.5 Broodstock health and performance

Dr Stewart Fielder stated that broodstock performance and quality of the spawn for mulloway in the BioGill tank was equivalent to that for the control tank (airlift bioreactor).

5 Conclusions

This trial provided a reasonable first test of the BioGill capacity to perform as part of a recirculating water treatment system for hatchery aquaculture. The trial took place over an extended period and in a facility that was operated to high standards.

Water quality for the mulloway tank supported by the BioGill was equivalent to or better than water quality for the other two tanks in the Trial. Ammonia concentration was measured only for the two mulloway tanks and the BioGill kept to levels below or equivalent to the other tank.

The most direct comparisons were with the other tank containing mulloway and between the 7 months period before and after installation of BioGill. The lack of a control tank containing the same number and size of mulloway fish was overcome by stopping water exchange to the BioGill tank in the last 23 weeks of the Trial. The increase in the buffer to feed ratio at this point may have been a precautionary measure and in any case the water quality indicators remained stable and comparable to the other two tanks in this trial.

Comparison of pH and buffer addition for the 7 months after installation to the same period before installation showed an improvement in water quality with a small range of minimum and maximum values and significantly less buffer being added. It should be noted that the same broodstock were in the tank over the entire period.

Electricity requirements for the BioGill were lower than for the standard recirculation systems due mainly to the stopping of water exchange for the BioGill tank in the latter part of the trial.

Overall, this Trial has demonstrated that BioGill in a recirculating aquaculture system for hatchery was able to maintain or improve water quality, reduce water, energy and buffer consumption while maintaining breeding performance and health of the broodstock.

6 Future work

Future work may include:

- determination of the minimum time and water exchange rate required for the BioGill recirculation system before stopping water exchange completely
- stopping water exchange to another tank at the Hatchery that has an airlift bioreactor

7 Method

A BioGill water treatment unit replaced an airlift bio-reactor on a tank stocked with mulloway broodstock and started operation on 23 May 2012 (Tank 3). Performance of the BioGill was compared over 52 weeks with another tank with mulloway broodstock that was fitted with an airlift bio-reactor (Tank 4). Apart from replacement of the airlift bioreactor the only other change to the Tank fitted with the BioGill was to remove the pressurised air supply that was required for the airlift bioreactor.

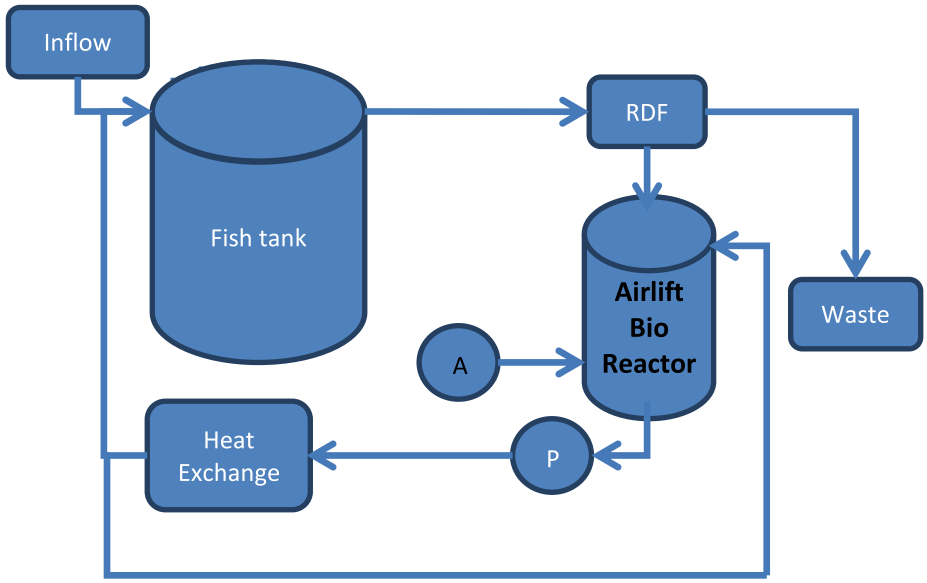
The recirculation treatment cycle is from the Fish Tank to the Rotating Drum Filter (RDF), Airlift Bio-Reactor (Tank 3) or BioGill (Tank 4), heat exchanger and then split flow to the Fish Tank and Airlift Bio Reactor or BioGill. The configuration of both systems is shown at Figure 7.

The parameters monitored for both Tanks were: Total Ammonia Nitrogen, pH, dissolved oxygen, temperature, salinity, water exchange rate, buffer addition and feed for the broodstock.

Water quality for Tank 3 was also compared for the 6 months before and 6 months after installation of the BioGill unit for pH and amount of buffer added (sodium bicarbonate).

Fresh seawater is supplied directly to the tanks from the local estuary via a series of sand filters (Inflow). The inflow rate determines the exchange rate and this was set to 10% of total volume in 24 hrs at the beginning of the trial for both Tanks.

A



B

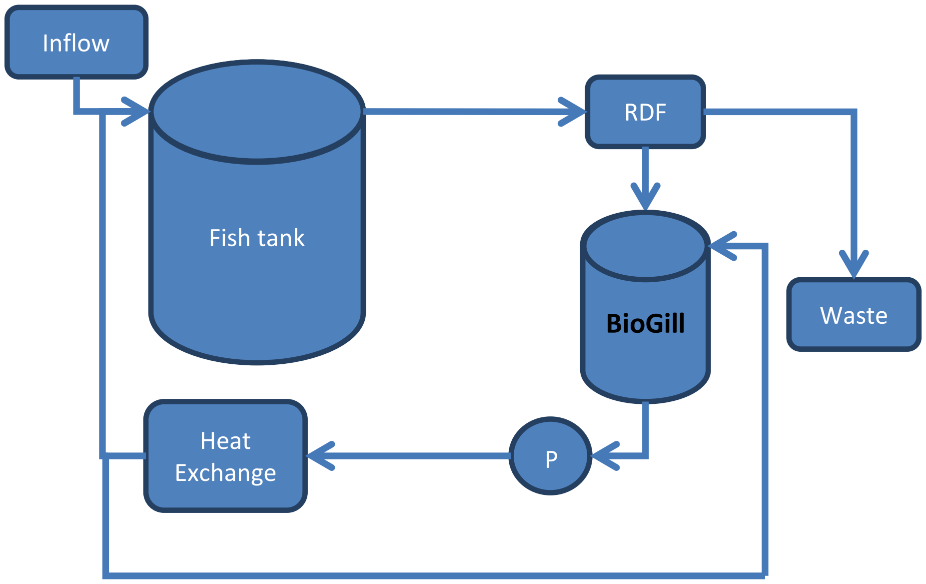


Figure 8 Water treatment process for the two Tanks in the PSFI Hatchery Trial
A. Standard PSFI Hatchery configuration (airlift bioreactor) including Tank 3 (mulloway) and Tank 2 (snapper)
B. Tank 4, BioGill
Legend: A - Airpump; P - Water pump; RDF - Rotating Drum Filter.