Real time monitoring of water quality and mechanisation of pond management to boost productivity and increase profit in Barramundi (*Lates calcarifer*) farming

Clement Pissoat & Dean Jerry

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Abbreviations

Chl *a*: Chlorophyll a

DO: Dissolved Oxygen

TSS: Total suspended solid

POM: Particulate organic matter

GFB: GFB Fisheries.

Pw: paddle wheels

C1: Control 1

C2: Control 2

T1: Treatment 1

T2: Treatment 2

Executive Summary

Maintenance of adequate levels of dissolved oxygen (DO) are critical for the health and production of aquaculture species. In barramundi (*Lates calcarifer*) pond aquaculture the use of 24 hr/7 day mechanical aeration via paddlewheels represents a significant energy cost to companies, although it is not known if the paddlewheels need to be operated continuously to maintain DO at levels that don't affect production outcomes. In recent times DO sensors linked to paddlewheel controllers have been developed and offer the opportunity for savings in energy by turning off paddlewheels when DO levels are above a pre-determined concentration.

The Australian Barramundi Farmers Association (ABFA) is interested in trialling automatic aeration controllers in order to lower their significant energy costs. Accordingly, a field trial over 12 weeks was commissioned on a commercial barramundi farm to evaluate DO sensors linked to paddlewheel controllers and to examine the impact such technology may have on production outcomes and financial savings, along with changes that may occur in the biological and chemical composition of ponds.

This trial ran for 12 weeks over the monsoonal summer (February to May) in two sets of barramundi ponds (two treatment ponds with controllers, 2 control ponds) located at Kelso, Queensland. Growth rate, mortality and FCR was recorded at the beginning and end of the trial, along with measurements three times a week of pH, DO, temperature, chlorophyll, total dissolved solids, oxidation reduction potential, phytoplankton bloom and particulate organic matter). Biological oxygen demand and concentration of heavy metals (zinc, copper, mercury, lead and cadmium) were also measured at the end of the 12-week trial.

Results from the trial showed that automatic aeration controllers turned off paddlewheels on average 26 ± 6.4 hr per week compared to control ponds. This equated to an energy saving of 73 kW per week or 1705kW over the 12 weeks of the trial based on regulating power to four paddlewheels. No statistical differences between any of the ponds were found in water chemistry or biological parameters.

This pilot trial demonstrates that using automatic aeration controllers of aeration has the potential to significantly save on energy consumption, thus lowering production costs. It is recommended, however, that the ABFA consider a larger trial over the entire 18 month production cycle to more fully evaluate the reliability of the automatic aeration controllers and longer terms impacts on FCR and the pond ecosystem.

Key words: Dissolved oxygen, aeration, automatic controllers, barramundi

Introduction

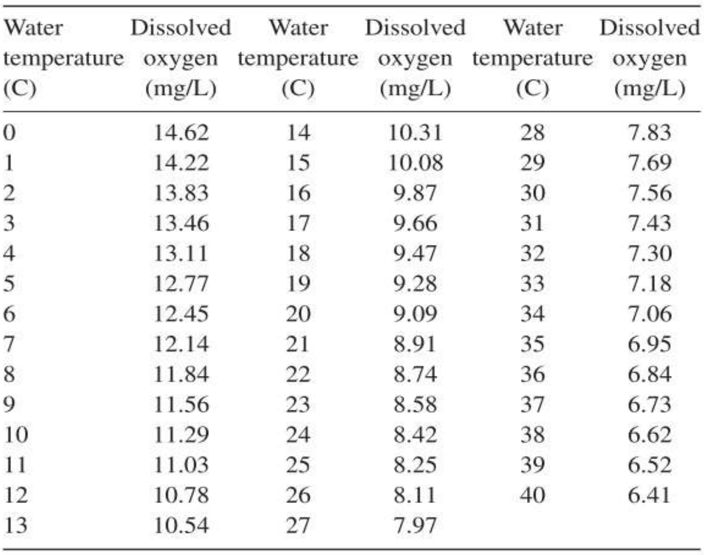
Dissolved oxygen (DO) is considered the most critical parameter to be maintained in intensive aquaculture so that the health and well-being of the species under culture is sustained. Furthermore, in earthen pond aquaculture where there is a complex biological community of phytoplankton and microbes, the healthy maintenance of the entire pond ecosystem is dependent on adequate levels of DO being available (Boyd and Tucker, 1998).

Factors affecting DO in aquaculture ponds

Several factors can determine the concentration of DO in aquaculture ponds. These include temperature, phytoplankton, sediment oxygen uptake, animal respiration and air-water gas transfer.

a) Water temperature: Temperature has a significant effect on the solubility of oxygen in water. In cooler water, DO concentration (mg/L) will be higher at 100% saturation than at warmer temperatures (Table 1) (Boyd, 2015). Furthermore, temperature influences the physiology of the species under culture (such as in fish) wherein cooler water the metabolic rate of the species decreases and accordingly so does oxygen consumption. Inversely in warmer water, metabolic rate increases meaning more oxygen needs to be available for the organism to maintain all physiological functions (Gamble et al., 2014; Killen and Humphries, 2014).

Table 1: Dissolved oxygen in freshwater at different temperatures and in equilibrium with moist air at 760 mm Hg pressure (Boyd et al., 2018).



Water temperature (C)	Dissolved oxygen (mg/L)	Water temperature (C)	Dissolved oxygen (mg/L)	Water temperature (C)	Dissolved oxygen (mg/L)
0	14.62	14	10.31	28	7.83
1	14.22	15	10.08	29	7.69
2	13.83	16	9.87	30	7.56
3	13.46	17	9.66	31	7.43
4	13.11	18	9.47	32	7.30
5	12.77	19	9.28	33	7.18
6	12.45	20	9.09	34	7.06
7	12.14	21	8.91	35	6.95
8	11.84	22	8.74	36	6.84
9	11.56	23	8.58	37	6.73
10	11.29	24	8.42	38	6.62
11	11.03	25	8.25	39	6.52
12	10.78	26	8.11	40	6.41
13	10.54	27	7.97		

b) Primary producers: Phytoplankton are organisms that are mainly composed of green algae (Chlorophyta), euglenophytes, yellow-green and golden-brown algae and diatoms (Chrysophyta), dinoflagellates (Pyrhophyta) and blue-green algae (cyanobacteria) (Horne and Goldman, 1994). These organisms contain chlorophyll pigment (present in all phytoplankton including cyanobacteria) which produce oxygen via photosynthesis. Photosynthesis by phytoplankton during the day can be a significant contributor to levels of DO in the pond (Boyd and Tucker, 1998). However, at night photosynthesis ceases and all organisms in the pond consume available oxygen via respiration.

c) Soil sediment: The amount of oxygen consumed by the sediment is due to various chemical reactions (oxidation reaction of reduced iron, manganese, and sulphite) and respiration of mud-dwelling organisms (Boyd and Tucker, 1998). A significant amount of the available oxygen in a pond is consumed by aerobic decomposition of organic matter by heterotrophic bacteria, oxidation of reduced inorganic substances by autotrophic bacteria such as nitrifying bacteria, and respiration of benthic macroinvertebrates. Measuring accurately the oxygen uptake by sediment is usually difficult. However, by comparing oxygen values at different sites and between ponds on site, it has been assumed that for a pond with an average depth of 1 m, the oxygen uptake is 200 mg $O_2/m^2/h$ which gives an overall loss of oxygen of 2.4 mg/L over a 12 h night-time period (Berthelson, 1992; Boyd et al., 1978; Costa-Pierce et al., 1984; Schroeder, 1975).

d) Species under culture: The amount of oxygen consumed by animals depends on the size and species, water temperature, activity level, time after feeding, and ambient dissolved oxygen concentration. For instance, an adult fish will consume more oxygen than a juvenile fish (Glencross and Felsing, 2006). In addition, as temperature increases by 10 ˚C, the consumption will roughly double; this is known as the Q10 effect (Brett and Groves, 1979). Furthermore, after feeding, the cultured species will increase its metabolic rate in order to digest and metabolise the eaten food; consequently, its consumption of oxygen will significantly increase. In Southern catfish (*Silurus meridionalis*) for example, a postprandial study showed a four-time increase in oxygen consumption after fish were fed (Luo and Xie, 2009). Therefore, during the day, the variation of pond DO can be influenced by the ecophysiological response of the cultured species.

e) Air-water gas exchange: Fundamentally, the exchange of gases between water and air occurs through thin boundary layers at the air-water interface (McKenna and McGillis, 2004). Therefore, to increase diffusion processes of oxygen within the pond system, farmers use mechanical aeration that increases the turbulence at the water surface, which as a result allows for the transfer of large amounts of oxygen. In earthen pond culture, the turbulent motion to increase the diffusion of oxygen into the water is achieved using mechanical aerators such as vertical pumps, pump sprayers, propeller-aspirator pumps, diffused-air systems, tractor-powered aerators, and most commonly paddle wheels (Boyd, 1998). Despite their efficiency to increase the amount of dissolved oxygen, all these devices require significant energy to run resulting in the maintenance of DO in aquaculture being one of the most significant costs to production.

Barramundi (*Lates calcarifer*) aquaculture and aeration

Farmed Australian barramundi (*Lates calcarifer*) was valued at $35 million in 2015/16 (Australian Bureau of Agriculture and Resource, 2016). Most of Australian barramundi production occurs in earthen ponds which require an input of high levels of energy to drive paddlewheels. Due to uncertainties in real-time levels of DO, farms operate paddlewheels continuously to lower the risk of DO depletion in ponds. Whilst this practice is standard, this approach results in pond DO levels being maintained at higher levels than they potentially need to be to maintain a healthy pond ecosystem. If the case, then the energy used to supply excess oxygen to ponds would represent an inefficiency in production cost.

Recently DO sensors linked to paddlewheel controllers have come on the market which potentially allow significant energy savings due to an ability for paddlewheels to only operate once DO in a pond falls below a pre-determined concentration. The Australian Barramundi Farmers Association (ABFA) sees the use of such technology as potentially reducing energy consumption over a production cycle. However, before they employ them on-farm throughout the industry, the ABFA need to understand how reliable the technology is, if controllers save on energy usage, and whether decreasing the amount of time the paddlewheels are operating adversely effects the biological and chemical ecosystem of ponds.

The aim of this pilot study was to investigate in a commercial barramundi farm automatisation of paddle wheels on production outcomes and financial savings, and to determine if reduced use of paddlewheels results in adverse changes in water chemistry and phytoplankton communities.

Objectives

1. Provide metrics to assess the impacts that automated aeration has on energy consumption and fish growth.
2. To evaluate whether automated aeration control results in significant changes to water chemistry and community composition of primary producers.

Location and equipment:

The trial was conducted at the GFB Fisheries (GFB) barramundi grow out freshwater farm located in Kelso (19˚21’24.47” S; 146˚42’19.78” E) (Figure 1). Four ponds for the pilot trials were made available; two controls (C1 and C2) and two treatment ponds (T1 and T2) (Figure 1). The four ponds were equipped with monitoring and controlling devices (Technolab Pond Master System) that recorded dissolved oxygen (DO), temperature, atmospheric pressure, and time/date (every 10 min). The Technolab Pond Master System was installed on-farm on the 7th of February 2018. Within each treatment pond (Figure

2, Figure 3), two paddle wheels were connected to the Technolab Pond Master System which was programmed to switch OFF the paddlewheels between 6 am and 6 pm when DO reached 5.8 mg/L (or above) until DO declined to 5.3 mg/L. At 5.3 mg/L, the controllers switched the paddlewheels back ON until DO increased to 5.8 mg/L or above. The difference of 0.5 mg/L between when the controllers switched the paddle wheels on and off was to prevent the paddlewheels constantly turning on and off as DO fluctuated around 5.8 mg/L. In addition, the Technolab Pond Master System is equipped with alarm devices that will turn the paddlewheels on if DO levels drop below 40% DO saturation.

Figure 1. Satellite image of GFB Fisheries barramundi grow out farm in Kelso (image from Google Earth) showing the location of ponds used during the trial.

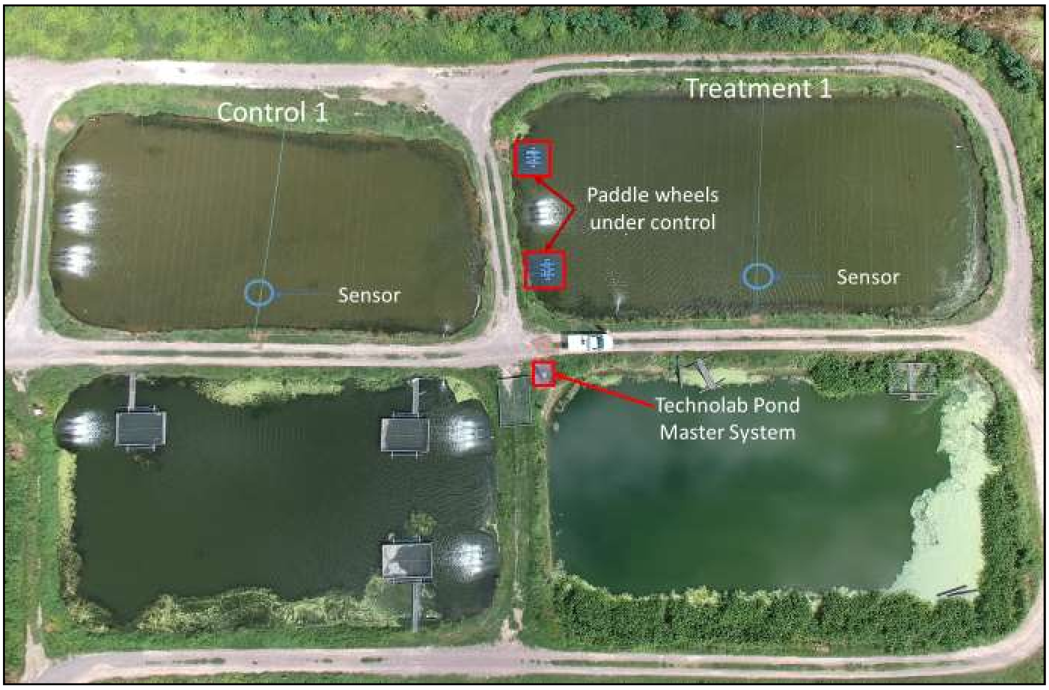


Figure 2: Aerial picture of control 1 (C1) and treatment 1 (T1) ponds, arrow and squares show which paddle wheels are under automatic control and where sensors are located (circles).

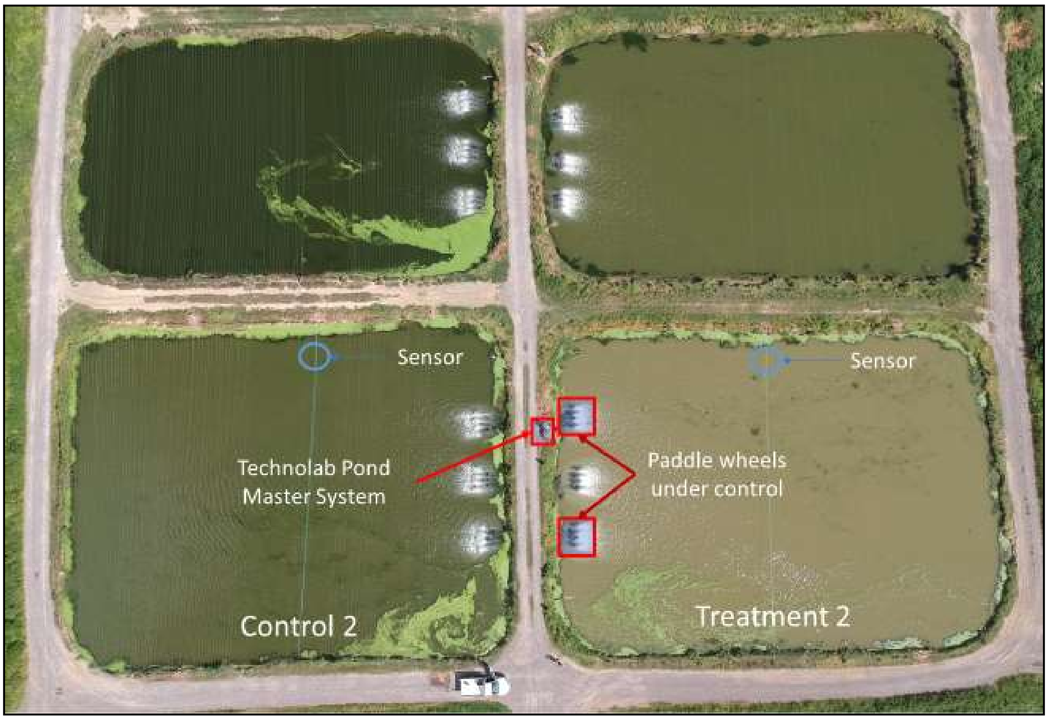


Figure 3: Aerial picture of control 2 (C2) and treatment 2 (T2) ponds, arrow and squares show which paddle wheels are under automatic control and where DO sensors are located (circle).

Pond features and fish cultured

The area of control 1 and treatment 1 ponds measured 1,400 m², with an average depth of 2.3 m, and the area of control 2 and treatment 2 ponds measured 1,700 m², with an average depth of 2.3 m. These ponds each contained ~5000 barramundi, with a mean weight per fish of 3 kg (as determined by the farm thus no variance statistics available). Each pond was filled with water from the same system (groundwater) with a daily water exchange of 10% of pond volume. Feeding occurred once daily between 10:00 and 13:00. Soil composition of ponds is mainly clay (70-80%). Ponds were not fertilized. The initial weight of the fishes within each pond was recorded by the farm before the trial started to estimate average weight and biomass. Feed intake was recorded daily for controls and treatment ponds. During the last week of this trial, a weighted sample (n=600) of barramundi from each control and treatment ponds was performed by the farm's staff to determine growth rate and feed conversion ratio (FCR) in conjunction with feed input data. Here they counted out the 600 fish and weighed them as one in a net with a balance attached (thus again no variance statistics available). Mortality data from each pond during the trial was recorded by GFB staff.

Parameters measured on site:

Three times per week, water quality parameters were measured at the farm including dissolved oxygen (to ensure that the automatic device has a correct reading of DO), pH, oxidation-reduction potential (ORP), turbidity, ammoniacal nitrogen (NH_3-N) and photographic reference of pond blooms. Other indicators of water quality, including several heavy metals and biological oxygen demand (BOD) were measured at the end of the trial (TropWater JCU). Sampling tools and frequency of sampling are provided in Table 2.

Table 2:Weekly abiotic parameters measured within the control and treatment ponds.

Parameters	Days measured	Comments/equipment
Dissolved oxygen (DO)	Monday, Wednesday, Friday	YSI DO probe
pH	Monday, Wednesday, Friday	pH meter
Oxidation reduction potential (ORP)	Monday, Wednesday, Friday	ORP meter
Turbidity	Monday, Wednesday, Friday	Secchi disk
Ammoniacal Nitrogen	Monday (student), Thursday (farm staff)	Photometer
Photographic reference of pond bloom	Friday (when weather permits)	Drone usage
Biological oxygen demand (BOD)	End of trial (week 12)	Trop WATER
Heavy metals: -zinc -copper -mercury -lead -cadmium	End of trial (week 12)	Trop WATER

Samples collection and suspended solids procedure:

Water samples were collected from the four trial ponds over a 12-week period. Water was sampled using a 2 m x 50 mm pipe equipped with a valve. Then 4×2 L bottles were filled with pond water separately. Bottles were stored on ice until the filtration procedure (storing time of 2 h before lab procedure). Six replicates from each 2 L bottle were filtered through glass microfiber filter paper (GFP) (membrane 0.7 µm). From the six replicates, three replicates were kept for chlorophyll extraction and stored in the freezer until analysis with a known volume of water filtered through microfiber filter paper. The three remaining microfiber papers were dried at a constant temperature of 60 ˚C, with the weight of microfiber papers recorded before filtration to estimate total suspended solids (TSS). Then, filters with retained solids were incinerated for 60 min in a muffle furnace at 550 ˚C and the residue reweighed. The weight loss on ignition represented the particulate organic matter (POM) concentration.

The composition of phytoplankton was divided into five categories: Diatoms, cyanobacteria, dinoflagellate, chlorophytes, and unknown microalgae. The identification was conducted through microscope counting where a relative proportion was determined by counting between 100 and 200 cells from 20 µL subsamples (preserved into 1% Lugol's solution); 1000x magnification under oil immersion was used (Leica DMLB light microscope).

Chlorophyll extraction and analysis:

The solvent used to extract pigment from filters was methanol, which was previously prepared with the addition of 1N sodium bicarbonate solution per litre (Ritchie, 2006). Each filter sample was folded and displaced into a 20 mL glass vial with 5 mL of methanol solution. Then vials were closed with caps and put into a sonicator for 15 min and then stored in fridge for 1 h. To clarify the solutions, solution from each vial was transferred into a 15 mL centrifugal Falcon tube to centrifuge for 20 min at 1000 g. Following centrifugation, 1 mL of each sample was analysed by spectrophotometry (SPECTROstar Nano® by BMG LABTECH) in Kuvetten Cuvettes. To calculate concentration of chlorophyll a, b and c, the values obtained by the spectrophotometer at OD665, OD649 and OD629, were added into the following equation:

Chl a [mg/L] = (13.53 (OD665 - OD750) – 5.2 (OD649 -OD750) - 5.64 (OD629 – OD750)) x extraction volume(L) / Volume filtered (L) x pathlength (cm)

Chl b [mg/L] = (22.43 (OD649 – OD750) – 7.07 (OD665 - OD750) – 2.61 (OD629 – OD750)) x extraction volume (L) / Volume filtered (L) x pathlength (cm)

Chl c [mg/L] = (27.26 (OD649 – OD750) – 5.02 (OD665 – OD750) – 5.2 (OD649 -OD750)) x extraction volume (L) / Volume filtered (L) x pathlength (cm)

To determine the amount of phaeophytin a in the sample to establish the correct Chlorophyll a, a solution containing 1N HCl with distilled water was added to the cuvette and after 1 min of acidification the measurement was taken at OD 665. The concentration was found by using the following formula:

Correct Chl a [mg/L] = (29.62 (OD665b – OD665a)) x extraction volume (L) / volume filtered (L) x pathlength (cm)

Phaeophytin a [mg/L] = (20.7 (OD665a)) – OD664b) x extraction volume (L) / volume filtered (L) x pathlength (cm)

(OD665b = OD665 – OD750 measured before acidification; OD665a = OD665 – OD750 measured after acidification)

Climate conditions:

Forecast data for each day of the pilot trial was obtained from the Townsville branch of the Bureau of Meteorology. Solar exposure (MJ/m^2), cloud cover (oktas), rainfall (mL), and atmospheric pressure (hPa) were analysed in relation to the abiotic parameters and phytoplankton data collected from the ponds.

Economic model regarding energy use and cost savings:

The mean of potential saving is determined by the weekly average of time the paddle wheels were turned off in the treatment ponds according to the following formula:

$$Equation\ 1: A = \frac{1}{n}\sum_{i=1}^{n} ai = \frac{1}{n}\ (a1 + a2 + \cdots + an)$$

A = mean time savings per week (hours)

a = weekly average of time paddle wheels was switched off

n = number of weeks

To establish the amount of dollars saved per week per pond, the solution of equation 1 above (A) is used in the equation below:

$$Equation\ 2: B = A \times Pw(\alpha) \times \beta$$

Where B = mean savings per week per pond ($)

Pw = number of paddle wheels connected to Technolab Pond Master System in one pond, in our case two Pw were connected to the device

α = energy used by one paddle wheels (Kilowatts)

β = cost of one kilowatt ($) – a fixed rate of one kilowatt costing $0.22 was used

Then, by using equation 2, the potential savings per growth cycle:

$$Equation\ 3: C = B(number\ of\ ponds) \times Growth\ cycle\ (weeks)$$

Where C = potential savings per year ($)

Growth cycle in the commercial ponds is the number of weeks required to grow barramundi from 450 g to 3 kg.

Correlation and statistical analysis:

Spearman correlations were used to establish relationships between parameters and environmental condition. The Pearson correlation was used to show similarity in variation for the same parameters within each different pond. A T-test was performed to test the difference in parameters between control and treatment ponds, using S-plus statistical software (TIBCO Software Inc., California, USA).

Results

Energy consumption

Throughout the trial the mean number of hours per week paddle wheels were switched off by the controllers was 26 ± 6.4 hr (figure 4). This equated to a reduction of energy consumption across the trial of 73 kW (or $16.6 per week). Therefore, over the term of the 12-week trial use of the controllers on four paddlewheels saved 1705kW or $375.

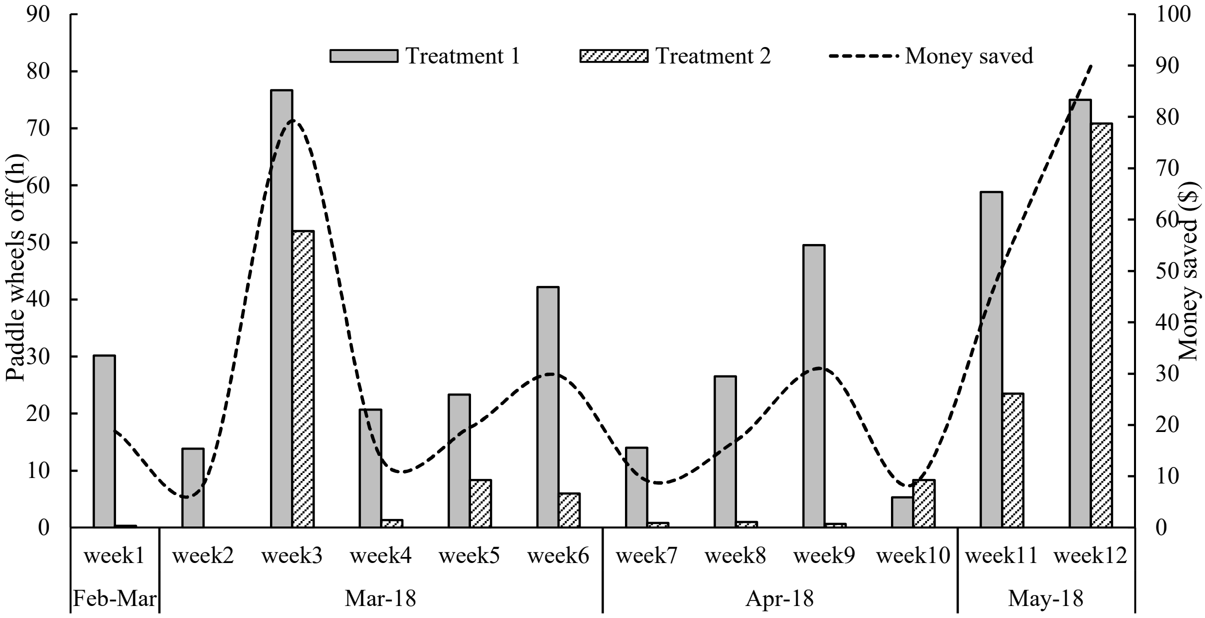


Figure 4: Absolute time paddles wheels in each treatment pond were off on a weekly scale, dash line represents the money saved from reduced energy consumption.

Production parameters

Barramundi in the treatment ponds on average exhibited a higher FCR than control ponds. However, with the limited statistical power available for the analyses FCR was not significantly different between control and treatment ponds, with a mean of 1.54 ±0.004 and 1.68 ±0.128, respectively (n=2, df=1, p>0.05) (Table 3). Pond T2 (treatment 2) had the highest FCR value (1.8) (table 3). The average growth rate was 8.8 g per day, where C2 had the highest growth and T2 the lowest growth (10.5 g and 7.6 g, respectively) (Table 3). However, a T-test revealed that growth rate was not significantly different between Barramundi cultured in treatment and control ponds (n=2, df=1, p>0.05). Mortality was also similar between control and treatment ponds where C1 and T1 had less mortality (8.5 ±0.5 fishes) compared to C2 and T2 which had twice as many deaths (Table 3) (n=2, df=1, p>0.05).

Table 3: Production results regarding barramundi growth rate, feed intake and mortality.

Pond	FCR	Growth (g/day/fish)	Mortality (individual fish) during trial
C1 (control)	1.54	8.91	8
T1 (treatment)	1.55	8.31	9
C2 (control)	1.55	10.5	16
T2 (treatment)	1.80	7.6	16

Water quality

The weekly changes of abiotic parameters such as pH, temperature, and ORP between ponds were found to be not significantly different ($p > 0.05$) between ponds. Both pH and ORP fluctuated over the experiment between 9.5 and 7.7, and 153 mV and 5 mV, respectively. The overall temperature revealed a decline over time the trial was run (Figure 5), which correlated with atmospheric temperature ($p<0.01$, R2=0.74). This decline was expected due to the change of season during the experiment from summer to winter. The overall concentration of ammoniacal nitrogen observed during this trial was quite high, where concentration fluctuated between 0.8 and 5.8 mg/L (Figure 6). Ammoniacal nitrogen between control and treatment ponds, however, did not show any significant difference ($p>0.05$).

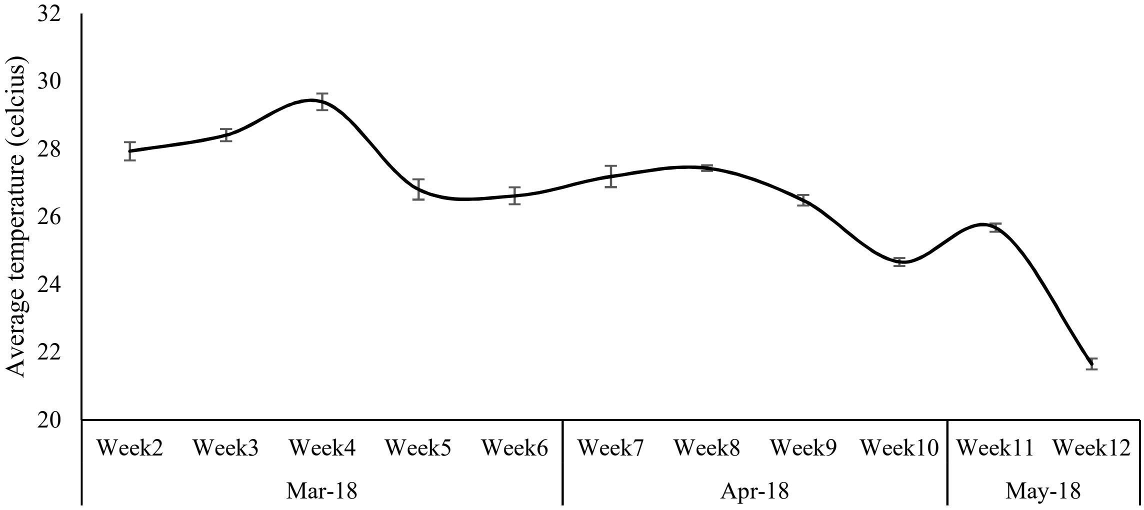


Figure 5: Overall weekly temperature of ponds over time of the 12 week trial (±SE).

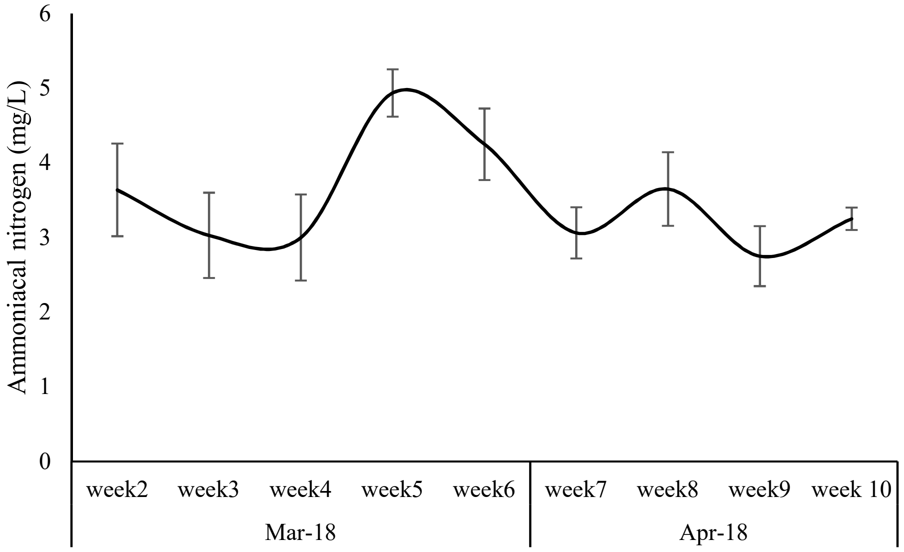


Figure 6: Weekly ammoniacal nitrogen detected in ponds the 12 weeks of the trial (±SE).

TSS, POM and chlorophyll a concentration all showed no significant differences between control and treatment ponds (n=2, df=1, $p > 0.05$) (Figure 7, figure 8). T2 had the highest TSS compared to the other ponds and the highest turbidity (figure 8). Chlorophyll a concentration from C1 and T1 demonstrated a positive correlation ($p < 0.01$, R2=0.81), which meant that these two ponds showed the same changes of chlorophyll a concentration during the experiment (Figure 7). Similarly, chlorophyll a concentration from T1 and T2 also showed a positive correlation ($p < 0.05$, R2=0.66), which meant that they also correlate in term of changes over time of the trial (Figure 7). Concerning these changes, the four ponds showed peaks in chlorophyll a concentration at week 3, 6, 9 and 12 (figure 7). Overall, T2 had the lowest concentration of chlorophyll a fluctuating between 16 mg/L and 43 mg/L. In contrast, C1 and T1 had the highest concentration where they varied between 48 mg/L and 129 mg/L, and between 31 mg/L and 129 mg/l, respectively (Figure 8). BOD data revealed that C1 and T1 had a higher BOD (15 mg/L and 12 mg/L, respectively) than C2 and T2 (8 mg/L and 6 mg/L, respectively), but variation between treatments and controls were similar ($p < 0.05$).

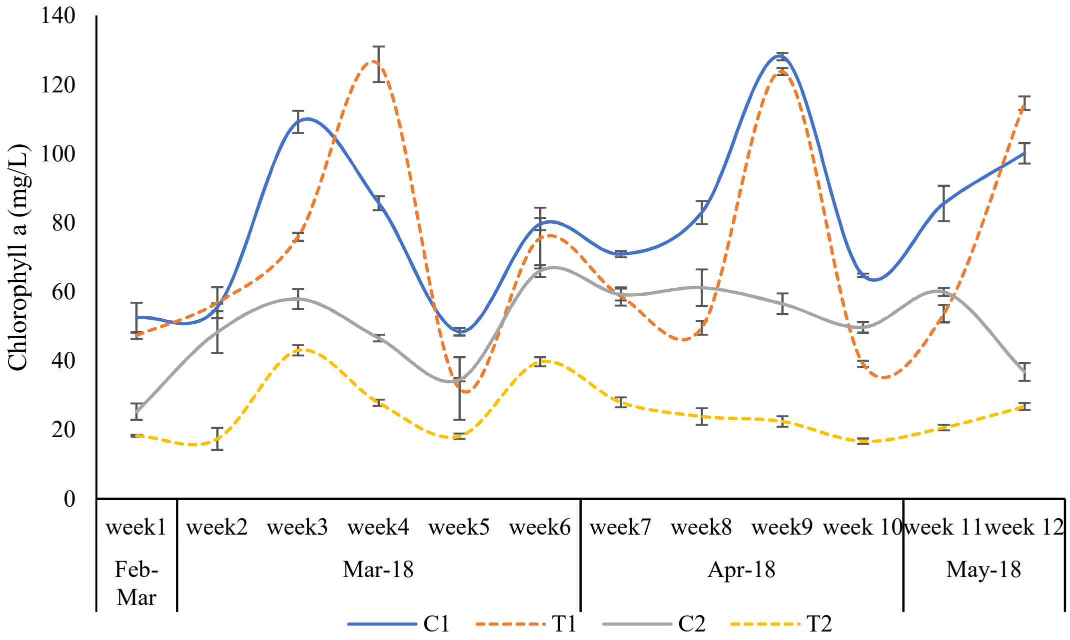


Figure 7: Concentration of chlorophyll a (mg/L) between the different ponds, dashed lines represent treatments, the others represent the controls (C1=control 1, C2 =control 2, T1=treatment 1, T2=treatment 2), errors bars shows standard error between subsamples.

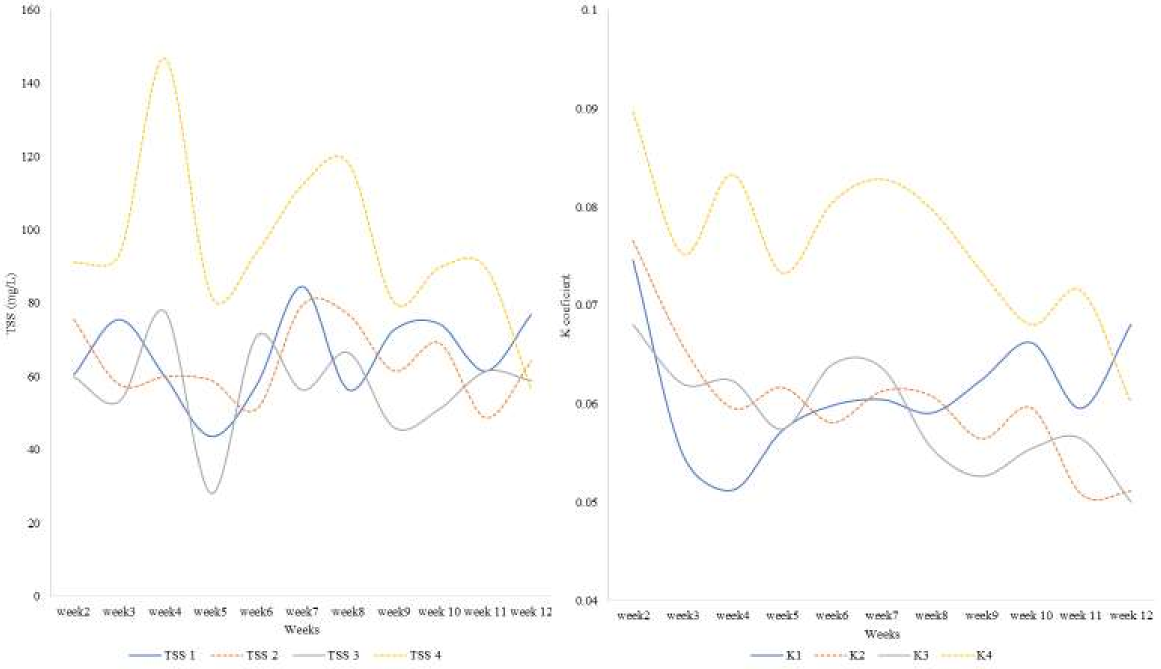


Figure 8: Total suspended solid (TSS) (left) and extinction coefficient of light (K) (right) over time of experiment. (TSS1 and K1 =P1, TSS2 and K2=P2, TSS3 and K3=P3, TSS4 and K4=P4).

Overall, the phytoplankton community composition in the four ponds was shown to be dominated by cyanobacteria (70-80%), which in turn were predominately composed of *Microcystis aeruginosa*. Most of the remaining phytoplankton were roughly divided equally between green algae and diatoms. The composition of green algae observed during this trial included Scenedesmus, Coelastrum, Pediastrum, and Radiococcus. Diatoms were composed of mainly centric (Cyclotella spp. and Chaetoceros spp), and pennate (Cylindrotheca spp). While the overall concentration of phytoplankton changed in ponds over the course of the trial, the relative quantity of each species compared to one another and the species composition remained relatively unchanged.

Discussion

The results of this study revealed that using the automatic aeration controllers did not appear to significantly affect the growth and the health of Barramundi, or the underlying pond biota or water chemistry. In addition, savings in power usage were found. Based on the economic model developed during the 12 week trial when projected over a typical growth cycle of Barramundi (baseline 15 months), the potential savings per pond of installing the controllers is $1042 (in the situation where only two paddle wheels are connected to the devices).

The DO sensors and automatic controller proved to be quite efficient in terms of monitoring DO where every 10 min the DO was recorded. This device offers a great solution for farmers where DO can be recorded in real time, which reduces labour and routine inspection of DO overnight. In fact, if DO drops to a critical level, the alarm of the device will go on at the pond location, but also in the office (or staff station). Therefore, monitoring DO becomes simpler and more accurate. However, DO sensors are known to loss efficiency overtime and become fouled producing false readings. Thus for the system it will be important to maintain sensors, and/or see how they perform over a longer period in the pond environment.

During the whole experiment DO level never dropped below critical levels. In fact, it has been claimed that using moderate aeration is more beneficial in terms of enhancing FCR and water quality (Boyd, 1998). In addition, using heavy aeration increases erosion of pond bottoms and the inside slopes of embankments. Therefore, this technology can be classified as a moderate aeration through automatisation of paddle wheels, which reduces erosion and cost of electricity by simply using less mechanical aeration when the pond ecosystem does not require an external addition of DO (likely as primary productivity helps sustains the ecosystem largely during day hours. Furthermore, having constant and heavy aeration running all the time increases turbidity due to the resuspension of settled particles that are mixed back in the water because of the current created by the paddle wheels (Hollerman and Boyd, 1980; Steeby et al., 2004). In fact, in this study T2 had lower DO during the beginning than toward the end of the experiment. This low DO concentration could be explained by the higher TSS in T2 which was due to a large proportion of inorganic matter (clay) within the pond that was resuspended because of constant aeration. As the temperature cooled down the DO concentration in the four ponds tested increased, in addition, barramundi are likely to have significantly reduced their consumption of oxygen at the cooler water temperature (Gamble et al., 2014). Consequently, the paddle wheels were off more often which decreased the rate of aeration, and therefore result in less turbid water in treatment ponds (T1 and T2) at the end of the trial (week 12). Compared to other studies where they established a strong and moderate correlation between chlorophyll a and turbidity (Almazan and Boyd, 1978), in this study it seems that at this site location turbidity is linked to TSS where T2 had shown a strong correlation ($R^2 = 0.88$). In contrast, C1, C2, and T1 did not have a significant relationship between turbidity and TSS, and between Chlorophyll a and turbidity. It was established that this difference can be due to the amount of clay present in the soil (Teichert-Coddington et al., 1992), where clay comprises between 70% and 80% of the substrate of ponds at GFB.

Conclusion

In conclusion, this trial revealed no adverse effects from automatic aeration controllers on the chemical and biological factors of the pond ecosystem and on the health of a barramundi (although the trial was for a short period and replication of treatments were low). In addition, the use of this technology allowed the barramundi farm to reduce the cost of energy due to the use of mechanical aeration. Therefore, this pilot study has shown that this technology has potential to be implemented on-farm which can provide a useful tool to monitor and manage DO in real time while also providing potential savings in energy cost. Further study should focus on evaluating this technology in different farms with larger replication, this would give a clearer picture of the benefits of using an automatic controller for aeration.

Implications

This trial has shown that the use of aeration controllers can reduce energy input costs to farms without severe adverse impacts. Furthermore, this trial was conducted during the hottest months and monsoonal period in North Queensland when water temperatures were high and where cloud cover is highest; thus the mg/L saturation in water and production of oxygen via primary producers would have been lower than during the dry, cooler months. Despite these challenges to maintain DO in such conditions, the automatic aeration controllers still proved effective to keep DO above 5.8 mg/L while achieving an average saving in power usage of 16% per week. If the results from weeks 11 and 12 are indicative of how often the paddlewheels are turned off during the day, then potential saving between 25% and 43% may be achievable.

Recommendations

This study is considered a pilot study as the number of pond replicates for each treatment was only two. Whilst results are positive in that energy savings were observed and no adverse negative effects in fish growth and the pond ecosystem found, caution is recommended on the long-term reliability and impacts of using automatic aeration controllers. The trial was not able to validate how sensors and the technology perform over longer periods, or if the subtle differences seen among ponds increase in their magnitude. A larger trial involving more replicates, perhaps involving farms in different geographical locales, and over the entire production cycle is recommended.

Extension and Adoption

The results of this study will be communicated to the ABFA through this report, and also at their annual R&D meeting.

Pond Master – Practicality and evaluation from the test farm’s perspective (Tim Bade – GFB Fisheries)

This trial was conducted when water temperatures were high and with volatile weather patterns in the back half of the wet season from February to May. Ponds selected were at high biomass with fish at a 3kg+ size grade at the trials commencement. These ponds were selected to examine the potential benefits of the Pond Master system at a time when dissolved oxygen requirement was highest and management at its most critical. The reasoning behind this was that any benefits and return on investment would only be enhanced in more favourable conditions, effectively this was designed from the farms perspective to be a worst-case scenario trial (i.e. when high oxygen demand required virtual continuous operation of paddlewheels). As believed, enhanced benefits were observed towards the end of the trial when water temperature decreased and the average time the aeration was switched off started to increase. Following the conclusion of the trial GFB Fisheries has continued to collect the data from the Pond Masters and continues to evaluate their performance.

From mid-June, with decreased water temperature the Pond Master was adjusted to control the aerators for an extended period of the day (6 am-12 midnight as opposed to 6 am-6 pm for the trial period). This showed to have significant reduction in the need for mechanical aeration in the 3 weeks following the change. Pond Master controlled aeration, on average was off for 65% of the control period for the 3 weeks (15.6 hrs/day). The following week it was decided to give the Pond Master 24 hr control to see if further savings could be achieved. At the time of writing, the results had just been obtained for the first week following the change to 24 hr control. In that time on average, Pond Master controlled aeration was off for 86.5% of the time in a 24 hr period (20.76 hr/day with daily pond water temperature for this period averaging 21.1 ˚C). This represents a significant increase in return on investment with cooler water temperature than what was observed in the trial period with higher water temperatures.

Maintenance on the system has been low and has minimal impacts to the day to day running of the farm. Probes are cleaned twice a day on the farms scheduled water quality monitoring laps. Cleaning is a very simple procedure of pulling the probe to the bank and giving it a quick wipe with a damp cloth or sponge. This is more than required cleaning, however, we are already at the location twice per day (recommended cleaning is every day or two depending on levels of biofouling and time of year). The probes have been very robust and reliable to date. Probes are checked for calibration once a week whilst data is being downloaded from the Pond Master unit and field calibrated in air if necessary. Probes have been installed 5 months and have required minimal membrane changes or calibration in this time.

Based on the observed results following the conclusion of the trial; during winter the return on investment may be significantly greater than observed in the trial through summer/autumn. Further trialling over an extended period would give a clearer picture of the potential return on investment.

It is important to also mention the added level of stock security that real time oxygen monitoring through the Pond Master offers. Return on investment is a great way to value add, but enhanced stock security is also important for farm management. The fact that a pond fitted with this technology has 24 hr a day oxygen monitoring is highly valuable for stock security in my opinion. It also has the potential to eliminate the need for manual measurement of dissolved oxygen as to date the Pond Master system has proved accurate and reliable.

In conclusion, the Pond Master has proved reliable and suited to pond-based farming. Valuable insights have been discovered in relation to the requirements of mechanical aeration and the benefits this system has to offer. In our experience with the Pond Master's there have only been very minor issues initially getting used to operating the equipment and adapting the system to our farms operational structure.

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