A LOW RUNNING COSTS AND EASY-CARE RECIRCULATING AQUACULTURE FROM AN INTERGRATED MULTI-TROPHIC SYSTEM INCLUDING FIVE VALUABLE COMMERCIAL SPECIES

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Introduction

Integrated multi-trophic aquaculture (IMTA) is used to reduced waste from aquaculture by co-cultured species (Troell et al., 2003). In this study, we tested an experimental IMTA in a recirculating aquaculture system to drastically reduce water supply. European seabass (*Dicentrarchus labrax*) were raised with co-cultured sea urchin (*Paracentrotus lividus*), deteritivorous polychaete (*Hediste diversicolor*) used to feed on particulate matter, macroalgae (*Ulva lactuca*) used to uptake dissolved nutrients, gastropod (*Phorcus turbinatus*) used to cleaning tanks from fouling. We designed a recirculating multi-trophic aquaculture system which requires low energy consumption and easy-care. The present study examined during one month the efficiency of the system to recycling water and produce biomass.

Materials and methods

Experimental systems were conducted in triplicate. A single system in composed by 4 tanks with an air-lift to recirculate water (in 3 hours) and 5% renewal water per day (Fig. 1). First a 400 l tank with fish at a density of 1.5 kg.m^{-3} was followed by another 400 l tank with sea urchin at 10 kg.m^{-3}. Then a 220 l cylindroconical tank with polychaete at 2.6 kg.m^{-3} was followed by a 900 l tank with macroalgae at 3.3 kg.m^{-3}. Gastropod were added to 250 g.m^{-3} and 575 g.m^{-3} in fish and macroalgae tanks respectively. Fish were fed with commercial pellets at 2 % of their body weight. Fish, sea urchin, polychaete and gastropod were weighed at the end of the experiment while macroalgae were weighed twice a week and their density has been reset to the initial value. A part of excess algae was used to fed sea urchin at 2 % of their body weight.
Dissolved oxygen, pH, salinity, temperature and amount of sunshine were measured daily. Once a week, water samples were collected at the outlet pipe of each tank and analyzed for total suspended solids (TSS), biochemical oxygen demand (BOD5), phytoplankton estimation and ammonia, nitrite, nitrate and phosphate concentrations.

Mean values are ± standard deviation and presented statistics are two-way ANOVA followed by Tukey's multiple comparisons test.
Fig. 1. Experimental recirculating multi-trophic aquaculture system

Results

Specific growth rate (SGR) of fish was 0.77 % ± 0.31 d^{-1} with a food conversion ratio (FCR) of 2.3 ± 0.59. SGR was 0.31 % ± 0.12 d^{-1} for sea urchin with a FCR of 3.49 ± 1.63. A high mortality of *H. diversicolor* was observed but another small polychaete appear in accumulated organic matter in cylindroconical tanks with an approximate final density of 339 ± 183 g.m^{-3}. Mean macroalgae growth rate was 3.74 % ± 1.44 d^{-1} with variability between sampling. In two experimental systems, an important decrease was observed after 3 weeks followed by a return to initial growth rate. 3.0 ± 0.22 kg of macroalgae were extracted during the experiment among which 40 % were used to fed sea urchin. Some gastropods escape from tanks but growth rate and young juvenile compensate this unexpected mortality, meaning initial and final density were similar.

Dissolved nutrients stay low (at a maximum of 2.4 $mg.l^{-1}$ and 5.3 $mg.l^{-1}$ for nitrate and phosphate respectively) or under the detectable threshold (for ammonia and nitrite) during the experiment. BOD5 increased 2.2 folds after 2 weeks (adjusted p value = 0.005) then decreased 1.8 folds in 2 additional weeks ($p = 0.02$). BOD5 slightly decreased between fish and macroalgae tanks ($p = 0.03$). TSS highly increased 42.5 folds after 3 weeks ($p = 0.003$) then slightly decreased at the end of the experiment. After 3 weeks, a phytoplanktonic bloom appears in 2 systems of the triplicate then rapidly decreased.

Discussion and conclusion

The experimental recirculating multi-trophic aquaculture system allows to produce in one-month biomass of fish (157.7 ± 59 g), sea urchin (393.7 ± 164 g), polychaete (75 ± 40 g from the new species), macoralgae (3.0 kg including 1.2 kg used to fed sea urchin) and gastropod (numerous of growing young juveniles) from 343.6 ± 28 g of dry commercial fish food.
Dissolved nutrients were always at a low or undetectable value meaning the system was efficiently able to assimilate them. Macroalgae were often used to assimilate dissolved inorganic nutrient (i.e. Huo et al. 2012). We show that macroalgae was able to treat a part of the BOD5 produced by fish. BOD5 and TSS concentrations seems to indicate an acclimation time of the system during 2 or 3 weeks but a longer experiment should be performed to confirm that trend. We observed that TSS and phytoplankton were the measured parameters the hardest to managed by our system. Variation in phytoplankton concentration seems to be linked to high decrease in macroalgae production maybe du to nutriments competition. Filter feeders were often used to regulate particulate organic matter (Montalto et al., 2016) and should be added to our system.
During the experiment, we limited our human action by (1) adding fish diet on an automatic feeder every day, (2) resetting macroalgae biomass twice a week and fed sea urchin at the same time, (3) assessing water quality and (4) controlling a single air-lift flow every week. No cleaning or complex maintenance was performed. However, at the end of the experiment, fouling in fish tank slightly appear and outlet pipe of one replicate conducted to cylindroconical tank was partially clogged. In the absence of physical filtration in this recirculating multi-trophic aquaculture system, air-lift, with low energy consumption, was enough to allow water circulation between tanks. Presented system was easy-care but more gastropods should be adding to fish tank for a better cleaning of fouling. We showed that a low running cost recirculating system using only bioremediation was able to efficiently treat classical aquaculture pollutants and producing biomass of various valuable commercial species.

References

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