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Giant Clams as Biofilters

Aquacultured giant clams, *Tridacna gigas* and *Hippopus hippopus*, used as the main biofilter in a saltwater aquarium recirculation system.

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ABSTRACT

Two 1000-litre fibreglass and glass aquaria, each with their own simple filter and reservoir tanks held 3 specimens of the giant clam *Tridacna gigas* and 2 specimens of the giant clam *Hippopus hippopus* as well as an assortment of damselfish. The *T. gigas* weighed up to 40 kg and all the clams were given no nutrients to support their zooxanthellae symbionts other than organic products produced by the fish, invertebrates, and excess fish food. These operated for over 7 months without any problems. Some fish increased to breeding size over this period. The *T. gigas* increased in shell length and total wet weight by 5.5% and 13.4%, respectively, while the *H. hippopu*s increased in shell length and total wet weight by 4.3% and 20.4%, respectively. A larger system holding a total volume of 20,000-litres with 16 T. gigas, 3 *H. hippopus*, 35 *T. crocea*, corals, and a large assortment of damselfish and anemones has opened as a small public viewing aquarium and operated for 2 months trouble-free. The giant clam, particularly the large species *T. gigas* acts as an excellent natural biofilter for large aquariums.

INTRODUCTION

Improved technology for the maintenance of salt-water aquaria has facilitated the holding of many new marine species in aquaria. Much of the improved technology involves the filtration and biofiltration aspects. Cultured giant clams have been shown to take up inorganic nitrogen and phosphate and to speed up their growth rates compared to controls with these nutrient additions (Braley et al., 1992; Fitt et al., 1993). A 75% increase in growth was shown in small *Tridacna derasa* when given 50 uM NH_3 or NO_3 compared to controls (Fitt et al., 1993) and an 88% increase in growth was shown in small *Tridacna gigas* when given 40 uM NH_3 compared to controls in a recirculation seawater system (Braley et al., 1992). Although the smaller giant clam species, *Tridacna maxima* and *Tridacna crocea* have been popular aquarium specimens for some time, the large *Tridacna gigas* has never been purposefully used in an aquarium system as the main biofiltration system. The purpose of this paper is to show the effectiveness of *Tridacna gigas* and other giant clams in this role.

METHODS

Two 1000-litre tanks each with a 250-litre circular plastic tank acting as a combined biofilter and reservoir tank were placed on the pergola of the Aquasearch office. The tanks had 1.8 cm long glass windows on the straight front, while the back and sides of the tanks were semi-circular fibreglass. Sunlight transmission was reduced to about 41% under a high-set (50% light transmission) shadecloth and highly translucent (82% light transmission) plastic material (Solargro). During mid-day in the tropics this equates with about 820 micro-ensteins m^{-2} s^{-1}. The position of the tanks allowed for morning sunlight through about 1400 hrs before the building cut out the direct sunlight. An Eheim model 1060 centrifugal pump (240 v) was placed in each of the reservoir tanks. The flow rate was about 25-litres per minute so over a 24-hr period there were 36 water changes to the main 1000-litre tanks. Water overflowed from one side of the 1000-litre tanks by gravity into a plastic milk carton box full of black plastic biofilter medium (about 48-litre volume; filter media about 150 m^2 / m^3, thus about 7.2 m^2 of biofilter medium per tank). The remainder of the 250-litre circular plastic tank served as the reservoir from which the water was pumped back up to the 1000-litre tank. Aeration was provided inside the 1000-litre tank. Seawater was changed only once over the 7.5 mo. study when a storm caused partial collapse of the solargro canopy and freshwater inundated one tank lowering the salinity. New seawater was immediately changed in both tanks.

The biomass of giant clams, fish, anemones and corals in each tank would have been close to 30 kg of soft tissue (excluding shell). Initial wet weights and shell lengths (cm) of clams were recorded, then recorded again at 3 mo. and 7.5 mo. Fish size increases were approximated from initial introduction at 2 mo. into the study and again at 7.5 mo.

Filamentous algae were regularly cleaned from the aquarium window and irregularly from the fibreglass sides of the tanks.

Records of temperature and salinity were kept during the period of the study. As salinity increased up to 37 ppt, freshwater was added to the reservoir tank to lower the salinity back down to 34-35 ppt. During the austral winter months (May - September) a complete greenhouse was constructed around the tanks by joining Solargro sides and a zip-door to the existing Solargro ceiling. This helped to maintain temperatures in the range of 20^{o}C - 25^{o}C through the winter months, despite ambient air temperatures on the coldest nights reaching as low as 7^{o}C.

Records of nutrient levels in the aquaria were kept. The nutrients tested were ammonia, nitrite, and nitrate. Simple aquarium test kits (Aquasonic) were used. Although these colour-comparison tests are not accurate for fine detail they gave acceptable results for the purpose of this study.

Fish species and numbers, and other organisms kept in the aquaria were as follows:

Tank 1:

10 x *Dascyllus trimaculatus*, three-spot damselfish; 2 x *Chrysiptera cyanea*, blue devil; 6 x *Acanthochromis polyacanthus*, spiny chromis; 2 x *Pomacentrus amboinensis*, ambon damsel. The coral *Goniastrea* sp.; the coral *Turbinaria* sp.; the green macroalgae *Caulerpa sertularioides*; the brown macroalgae *Padina* sp.; filamentous brown algae; filamentous green algae. Note: all fish were 2.5-3.5 cm length at the start.

Tank 2: 10 x *Dascyllus aruanus,* humbug damsel; 6 x *Acanthochromis polyacanthus*, spiny chromis; 2 x *Pomacentrus ambionensis*, ambon damsel; 2 x *Amphiprion melanopus*, red and black anemonefish. The coral *Turbinaria* sp.; the coral *Catalaphyllia jardinei*; the soft coral *Sarcophyton* sp.; the bulb-tentacle sea anemone, *Entacmaea quadricolor*; the green macroalgae *Caulerpa sertularioides*; the brown macroalgae *Padina* sp.; filamentous brown algae; filamentous green algae. Note: all fish were 2.5-3.5 cm length at the start except for the pair of red and black anemonefish which were 5 cm and 8 cm length.

The fish were fed twice per day at about 0800 and 1700 hrs. Food consisted mainly of commercial flakes (Wardley's Total Marine Flakes), but every 3 days a special feeding of pilchard baitfish and small bait-shrimp was given to the fish, the anemone and fleshy tentacled corals.

RESULTS

Clam growth rates are shown in Table 1. The overall (both tanks) mean increase in shell length and wet weight for *T. gigas* was 5.5% and 13.4%, respectively. For *H. hippopus*, the overall (both tanks) mean increase in shell length and wet weight was 4.3% and 20.4%, respectively. When comparing the growth of clams between the two tanks the results were:

T. gigas:

Tank 2 resulted in 68% higher cumulative % increase in shell length and 111.6% higher cumulative % increase in wet weight compared with Tank 1. Testing growth increment resulted in only wet weight being significantly higher ($p=0.028$) in Tank 2 compared with Tank 1 (1-way ANOVA). Shell length was not significant ($p>0.05$).

H. hippopus:

Tank 2 resulted in 110.9% higher cumulative % increase in shell length and 97.8% higher cumulative % increase in wet weight compared with Tank 1. Growth increments tested by 1-way ANOVA resulted in no significant differences between Tank 1 and Tank 2 for either parameter.

Table 2 shows the temperature in the tanks over the period of the study in weekly intervals. Mean weekly temperatures ranged from 21.1 - 30.3^{o} C. The coldest period was in late July.

Table 3 shows the levels of the nutrients ammonia, nitrite and nitrate over time in the tanks. Ammonia was found to be 0.1ppm only about 2.5 weeks after the study began. From the second month onwards the level of ammonia was always less than 0.1ppm. The level of nitrite in the tanks was 1ppm for the first two months and thereafter the levels were Nil. The level of nitrate was 5ppm in the first two months of testing, and on the third month less than 5ppm. From the fourth month of testing onwards the level of nitrate was either almost Nil or Nil. The larger 20,000 - litre volume recirculation system with 7 large aquaria/tanks has been operating for 1.5 months and appears to be following the pattern of nutrient levels seen in the two tanks described above.

Fish species held in the two recirculation systems survived well and grew. Most of the damselfish reached lengths of 4.5-5.5 cm, while the red and black anemonefish reached 6 cm and 9.5 cm length. Several humbug damselfish, *Dascyllus aruanus*, and spiny chromis, *Acanthochromis polyacanthus*, began to reside in terra-cotta flowerpots and to clear patches of filamentous algae on clam shells. This was an indication of sexual maturity and preparedness for spawning and egg laying.

TABLE 1: Giant Clam (*Tridacna gigas* - Tg and *Hippopus hippopus* - Hh) growth rates in two recirculation aquaria over 7.5 months.

Species/Tank / Tag No.	Date	Shell Length (cm) / cumulative % incr.	Wet Weight (kg) / Cumulative % incr.
Tg / 1 / 1	27.12.97	50.3	30.1
“ “	4.4.98	51.0 / 1.4	32.3 / 7.3
“ “	15.8.98	51.5 / 2.4	33.0 / 9.6
Tg / 1 / 2	27.12.98	47.9	31.2
“ ”	4.4.98	49.6 / 3.5	33.0 / 5.8
“ “	15.8.98	50.6 / 5.6	33.5 / 7.4
Tg / 1 / 3	27.12.98	50.4	35.8
“ “	4.4.98	51.7 / 2.6	37.5 / 4.7
“ “	15.8.98	52.5 / 4.2	39.0 / 8.9
Hh / 1 / 1	27.12.98	26.5	6.0
“ “	4.4.98	27.0 / 1.9	6.8 / 13.3
“ “	15.8.98	27.3 / 3.0	7.0 / 16.6

Hh / 1 / 2	27.12.98	28.1	7.4
“ “	4.4.98	28.9 / 2.8	8.0 / 8.1
“ “	15.8.98	29.3 / 4.3	8.2 / 10.8
Tg / 2 / Liz	27.12.98	54.2	38.2
“ “	4.4.98	55.7 / 2.7	40.0 / 2.1
“ “	15.8.98	56.0 / 3.3	43.0 / 12.6
Tg / 2 / 4	27.12.98	45.9	27.6
“ “	4.4.98	47.5 / 3.5	29.7 / 7.6
“ “	15.8.98	51.8 / 12.8	35.0 / 26.8
Tg / 2 / 5	27.12.98	50.6	33.0
“ “	4.4.98	51.0 / 0.8	33.8 / 2.4
“ “	15.8.98	53.0 / 4.7	38.0 / 15.1
Hh / 2 / 3	27.12.98	28.1	7.1
“ “	4.4.98	28.7 / 2.1	7.8 / 9.8
“ “	15.8.98	31.0 / 10.3	9.8 / 38
Hh / 2 / 4	27.12.98	28.9	9.2
“ “	4.4.98	29.8 / 3.1	9.9 / 7.6
“ “	15.8.98	30.4 / 5.2	10.7 / 16.3

TABLE 2: Weekly average water temperatures [°C]in the tanks over the period of the study. Note that temperatures begin in February 1998, not late December 1997.

Dates	Tank 1	Tank 2
1 - 7.2.98	29.9±0.1	30.0±0.2
8 -14.2.98	30.2±0.4	30.3±0.4
15 - 21.2.98	30.0±0.8	30.2±0.7
22 - 28.2.98	30.1±1.1	30.3±1.0
1 - 7.3.98	27.4±1.0	27.8±0.9
8 - 14.3.98	29.7±0.4	29.9±0.6
15 - 21.3.98	29.8±0.2	30.1±0.4
22 - 28.3.98	29.5±0.2	29.8±0.3
29.3- 4.4.98	29.3±0.8	29.7±0.9
5 - 11.4.98	27.5±1.3	26.9±1.5
12 - 18.4.98	28.4±0.6	28.5±0.4
19 - 25.4.98	27.2±0.5	27.3±0.5
26.4- 2.5.98	28.8±2.5	29.2±3.0
3 - 9.5.98	25.7±1.4	25.7±1.2
10 - 16.5.98	25.4±0.9	25.3±0.9
17 - 23.5.98	23.4±1.7	23.0±1.6
24 - 30.5.98	24.2±0.9	24.7±1.0
31.5- 6.6.98	26.7±0.7	26.0±0.8
7 - 13.6.98	25.3±1.3	24.6±1.2
14 - 20.6.98	25.0±1.2	24.6±0.4
21 - 27.6.98	24.0±1.3	23.2±1.3
28.6- 4.7.98	25.4±0.9	25.1±0.2
5 - 11.7.98	25.2±1.8	24.4±1.3

12 - 18.7.98	25.0$\pm$0.0	24.0$\pm$0.0
19 - 25.7.98	25.8$\pm$0.6	25.2$\pm$0.9
26.7- 1.8.98	21.6$\pm$1.3	21.1$\pm$1.5
2 - 8.8.98	22.3$\pm$0.7	22.1$\pm$0.7
9 - 15.8.98	23.6$\pm$0.8	23.8$\pm$1.4

TABLE 3: Nutrient levels in tanks over the study period. Tests were made with Aquasonic Aquarium Test Kits for ammonia, nitrite, and nitrate.

Date	Tank	Ammonia	Nitrite	Nitrate
15.1.98	1	0.1ppm	1ppm	5ppm
"	2	0.1ppm	1ppm	5ppm
15.2.98	1	<0.1ppm	1ppm	5ppm
"	2	<0.1ppm	1ppm	5ppm
16.3.98	1	<0.1ppm	Nil	<5ppm
"	2	<0.1ppm	Nil	<5ppm
14.4.98	1	<0.1ppm	Nil	Almost Nil
"	2	<0.1ppm	Nil	Nil
15.5.98	1	<0.1ppm	Nil	Almost Nil
"	2	<0.1ppm	Nil	Almost Nil
14.6.98	1	<0.1ppm	Nil	Almost Nil
"	2	<0.1ppm	Nil	Nil
14.7.98	1	<0.1ppm	Nil	Nil
"	2	<0.1ppm	Nil	Nil
13.8.98	1	<0.1ppm	Nil	Almost Nil
"	2	<0.1ppm	Nil	Nil

DISCUSSION and CONCLUSIONS

The positive growth seen in the giant clams held in replicate recirculating seawater systems gives an indication regarding the capacity of this animal for use as a biofilter. The small surface area of plastic biofilter material used in the replicate systems was far below the recommended base figure of 0.6 m^2/ 1 kg biomass [3 ft^2/ 1 lb. biomass]. The founder and general manager of the successful Instant Ocean Hatcheries - Aquarium Systems recommended that in a closed system growing tropical reef fish the base figure is minimal and should be doubled to 1.2 m^2/ 1 kg biomass (Hoff, 1996). In comparison, the ratio of filter material perkg of biomass in this study was about 0.24 m^2/ 1 kg biomass. Nutrient levels never reached dangerous levels in the tanks, despite the low ratio of traditional biofilter material, because of the presence of the giant clams.

Giant clams have been shown to uptake ammonia more rapidly than nitrate, but the uptake of nitrate was repressed in the presence of ammonia (Fitt et al., 1993). In that study ammonium nitrate was used and it was found that nitrate became depleted from the tank only after the ammonia concentration dropped below 2.5uM.Also, about half of the ammonia was taken up by the clams and the other half presumably taken up by the algae and other organisms in the tank (Fitt et al., 1993). In the present study this may explain the consistently low ammonia levels while nitrate took longer to drop to almost Nil or Nil.

Fish all grew in size and remained healthy throughout the study. Some fish attained sexual maturity and appeared close to spawning and egg laying.

A larger recirculation seawater system has been operating for about 2 months at the time of this writing. This system includes 7 x 1000 – litre aquaria of the same type as those used in the present study. There is a 1300 – litre sedimentation tank, a 1200 - litre pit, and a 10,500 - litre reservoir tank. In the aquaria there are 16*Tridacna gigas*, 3*Hippopus hippopus*, 35*T. crocea,* corals, and a large assortment of damselfish and anemones. This system is doubling as a small public viewing aquarium and brood stock holding tanks for the clams and fish. There have been no problems to this stage.

Giant clams, particularly the largest species *Tridacnagigas* have proven to be excellent natural biofilters and well-suited to living in large aquaria with natural sunlight. *Tridacna gigas* may be known in future to the marine aquarists as a natural biofilter which is guaranteed to increase in size and filtering capacity over time, a unique case.

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