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Effect of Temperature, Dissolved Oxygen Variation and Evaporation Rate in Marine Aquarium

M. Natarajan, P. Raja, G. Marichamy and S. Rajagopal
Centre of Advanced Study in Marine Biology, Annamalai University,
Parangipettai –608 502. Tamil Nadu, India

Abstract: A marine aquarium was established at Annamalai University 30 km away from the coast with recycled seawater system. The problems faced during the operations were increase in water temperature, consumption of dissolved oxygen and evaporation of seawater. The rate of evaporation of water in entire aquarium was estimated about 128 liters/day. The temperature increase in the aquarium tank was observed as 0.1ºC due to the operation of canister filter, 0.1ºC due to pumps and 1.1ºC due to aquarium lightings. Further the position of aquarium lids leads to a raise in temperature of 0.5ºC. The consumption of dissolved oxygen by eight band butterfly fishes *Chaetodon octofasciatus* was taken as a case study and found to be 2.031×10^{-4} ppm/g of biomass. The optimum stocking density for balanced dissolved oxygen condition was calculated as 0.919 kg of biomass / 1,000 liters of seawater with the aeration of 0.351 ppm/hr.

Key words: Aquarium, *chaetodon octofasciatus*, dissolved oxygen, evaporation, salinity and temperature

INTRODUCTION

Aquarium keeping is a popular hobby around the world, with about 60 millions enthusiast worldwide. Marine aquarium attracts the public globally and marine aquarium setup varies from freshwater aquarium in many ways. In India the practice of ornamental fish keeping started in 1951 with the opening of the Taraporevale Aquarium at Mumbai and the establishment of several aquarium societies in the city. Since then the practice has become widespread in India, with more than hundred varieties of indigenous species and even more of exotic ones. Considering the importance of public aquaria as well as the growing demand on aquarium fishes, a public marine research aquarium was established at Annamalai University attached to the Centre of Advanced study in Marine Biology, Parangipettai. This aquarium was established 30 km inland from Parangipettai, (southeast coast of India) with seawater recycling system.

Water temperature, salinity, dissolved oxygen (DO) concentration, and photoperiod were the parameters that influence the feed consumption, metabolic rate and energy expenditure, and thus, on growth of poikilothermic vertebrates, including fish (Brett, 1979; Elliott, 1982; Dutta, 1994; Bhikajee and Gobin, 1998). All organisms have lethal limits to their temperature range (Hokanson, 1977) and yet within this range they also have optimal temperatures for development of structure and function (Rombough, 1997). Within an ectotherms tolerance limits, variation in temperature will influence metabolism (Rombough, 1997) and therefore related physiological processes, affecting growth (Nicieza and Metcalfe, 1997), development (Koumoundouros *et al*., 2001), and performance encompassing physiological and behavioural capabilities (Fuiman and Higgs, 1997; Koumoundouros *et al*., 2002). It is necessary to keep the temperature of the aquarium waters within the tolerance limit of the species. Fish need oxygen to generate energy for body maintenance, locomotion and metabolism (Van Dam and Pauly, 1995). The relationship between the weight gain and dissolved oxygen was investigated for channel catfish (Buentello *et al*., 2000), largemouth bass (Stewart *et al*., 1967), common carp (Chiba, 1966), coho salmon (Hermann *et al*., 1962), northern pike (Adelman and Smith, 1970) and brook trout (Whitworth, 1968). Increasing dissolved oxygen, up to some level has a limiting value, results in enhancing the growth of fish (Brett and Groves, 1979; Cuenco *et al*., 1985; Neill and Bryan, 1991). It is essential to keep the dissolved oxygen in the aquarium water up to the optimum level for better growth of fishes. Therefore, the changes of these factors in aquariums warrant a thorough investigation. Thus the present study is an attempt to study the variation in water temperature, dissolved oxygen and rate of evaporation of seawater and freshwater. The optimum stocking density of Eight band butterfly fish *Chaetodon octofasciatus* based on the rate of oxygen consumption was estimated and the remedial measures taken.

MATERIALS AND METHODS

Experiments were conducted in Marine Research Aquarium at Annamalai University. The aquarium houses 24 numbers of 8′ x 4′ x 3′ , 2 numbers of 8′ x 4′ x 2.5′ and 2 numbers of 8′ x 4′ x 2′ concrete tanks covered with ceramic tiles with front glass for viewing. The front side was provided with 8′ length, 4′ height and 19 mm thick toughened glass bent inward by 6″. Each tank has the

Corresponding author: P. Raja, Research Scholar, CAS in Marine Biology, Annamalai University, Parangipettai – 608 502, Tamil Nadu, India. Tel.: +04144 243223; Fax: +04144 243555; Cell: +91 9994545523

Table 1: Water holding capacity of aquarium tanks

S. No.	Description of tank	Length (m)	Breadth (m)	Height (m)	Vol. of water (lit.)
1	Sedimentation tank	4.50	1.45	0.90	6,000
2	Filtration tank	4.80	1.15	0.90	5, 000
3	Storage tank	4.50	3.00	2.20	30,000
4	Overhead tank	3.00	1.00	1.25	5,000
Total volume of water in liters					46,000

capacity to hold about 2,000, 1,700 and 1,100 liters of seawater respectively. The water holding capacity of aquarium tanks were given in Table 1. Three numbers of 5,000 liters capacity 'Syntex' tanks were used for transporting the sea water to marine aquarium.

Temperature variations in aquarium water: The rate and quantum of heat exchange to the aquarium waters were estimated by conducting the following experiments. Four aquarium tanks were selected for the present study equipped with one number canister filter, one number of lift pump, one pair of aquarium lightings and 940 liters of seawater having 35 ‰ salinity. The tank top lid was kept closed in all tanks throughout the experimental period. The operation of canister filter, pumps and lightings were arrested in Tank – 1. Only the canister filter was operated in Tank – 2. The canister filter and the lift pump were operated in Tank – 3. The canister filter, the lift pump and the aquarium lightings were operated in Tank – 4. Temperature of the water was measured by using a digital thermometer with a time interval of 30 minutes and the salinity was measured using a bench top salinometer model E – 2, OSK 2058, Ogawa Seiki Co., Ltd., Japan.

Variations in Dissolved Oxygen:

Oxygen consumption by *Chaetodon octofasciatus*: To estimate the amount of oxygen being consumed by the organisms as well as the solubility of oxygen through the operation of different pumping systems in the aquarium experiments were conducted as detailed below. One aquarium tank was used for the present experiment with 940 liters of seawater having 35 ‰ salinity. 14 numbers of *Chaetodon octofasciatus* with a total weight of 325 g were kept in the tank. The dissolved oxygen in the aquarium water was measured by using YSI model 55 portable digital dissolved oxygen meter with 3 meter cable length connected to the dissolved oxygen probe. Prior to measurement the dissolved oxygen probe was filled with respective electrolyte and calibrated for 35 ‰ salinity as per standard procedure. The rate of consumption of dissolved oxygen was measured by switching 'OFF' the canister filter and lift pump (which are the main source for the atmospheric molecular oxygen to get dissolved in water) and also the aquarium lightings (to avoid raise in temperature). In the marine aquarium no separate aeration devices were used for maintaining the dissolved oxygen. The dissolved oxygen was measured for 12 hours with 10 minutes interval for safe monitoring till the value drops down to 3.75 ppm. The canister filter was kept in operation immediately after this drop of dissolved oxygen and measurement was continued till dissolved oxygen reached the maximum.

Efficiency of canister filter and lift pump on solubility of oxygen: The oxygen solubility in aquarium due to water circulation made by the canister filter and lift pump was studied by selecting two tanks with 940 liters of seawater having 35 ‰ salinity without any biomass. The tank was left without any aeration for few days for obtaining the reduced dissolved oxygen. The dissolved oxygen was measured by operating one number of canister filter in Tank – 1 and one number of lift pump in Tank - 2. The dissolved oxygen was measured for about 5 hours at 10 minutes interval till it reached the maximum value.

Evaporation of seawater and increase in salinity: Experiments were conducted to study the rate of evaporation of sea water as well as fresh water in different temperature, relative humidity and wind speed condition by keeping the containers in following different places. 1. Air conditioned (A/C) room (for keeping the water in constant temperature, low humidity and low wind movement) 2. Non air conditioned room (for keeping the water in elevated temperature, higher humidity and low wind movement) 3. Open air in terrace of the building (for keeping the water in elevated temperature, higher humidity and high wind movement) 4. Inside the aquarium building (to measure the actual variation in the existing environmental condition). Two numbers of cylindrical hollow plastic containers of 15 liter capacity was filled with 14 liters of seawater and fresh water respectively and kept open in a safe place in the test site without any disturbances. Initial volume, salinity and temperature of the waters were measured using measuring cylinder, bench top salinometer model E – 2, OSK 2058, Ogawa Seiki Co., Ltd., Japan and a digital thermometer respectively. The relative humidity of the experimental site was measured using a Hair Hygrometer (Huger, West Germany). The temperature and salinity of water and the humidity data were recorded every day. The measurement was taken for 15 days. Final volume of water was measured on the last day and loss of water due to evaporation was estimated.

RESULTS

Variation of temperature: Normally, the working hour of the aquarium was 12 hours from morning 8:00 am to evening 8:00 pm. The canister filter and lift pumps were operated 24 hr. a day and the aquarium lights will be switched 'ON' only during the working hours. Therefore it was proposed to conduct the experiments for 12 hours during day time to observe the changes in temperature in the aquarium tanks and the observed results are shown in Fig.1.

From the results it was inferred that the water temperature in all the tanks started rising with time. The

lowest temperature raise was observed in Tank – 1, where no heat transfer was possible due to any equipments housed in the tanks except the heat exchange due to the surrounding atmosphere. The maximum raise in water temperature due to atmospheric heat exchange was about 0.1ºC over 12:30 hr. In Tank – 2, where only the canister filter was kept in operation, the maximum raise in water temperature was about 0.2ºC. By excluding the heat due to the atmospheric exchange, the raise in water temperature was 0.1ºC over 12:30 hr. The Tank – 3 showed similar trend in raise of water temperature as in Tank – 1 and 2, where in addition to the canister filter the lift pump was kept in operation. The maximum raise in temperature was 0.3ºC. By excluding the exchange due to atmosphere and the canister filter, the raise in temperature observed was 0.1ºC over12:30 hr. In Tank – 4, the trend was totally different. The aquarium lightings exchange maximum heat energy to the surrounding air medium thereby increasing the water temperature in a steady manner. The maximum raise in temperature was 1.1ºC. By excluding the exchange due to atmosphere, canister filter and lift pump, the raise in temperature noted was 0.8ºC over12:30 hr.

It was estimated that the quantum of heat energy received from the surrounding atmosphere, canister filter and lift pump by the aquarium water was about 7.68 kcal. /hr (or) 32.26 kJ/hr. respectively. The heat exchange due to the aquarium lightings was calculated and found to be 61.44 kcal. /hr (or) 258.08 kJ/hr. The higher heat exchange due the lightings may be due to the low air circulation between the lid and water surface since the lid was kept closed throughout the experimental period.

The experiment was repeated by keeping the tank's top lid open. Two aquarium tanks were selected for the present experiment with 940 liters of seawater having 35 ppt salinity. The canister filter the lift pump and the aquarium lights were kept in operation in both the tanks. In one of the tank (Tank – 1) the tank lid was kept closed and in the other tank (Tank – 2) the tank lid was kept open for free air circulation. The temperature of water was measured in a time interval of 30 minutes and the results are shown in Fig. 2. From the results it can be inferred that the water temperature in both tanks started raising with time. In Tank – 2, where the lid was kept open, the rate of raise in temperature was less compared to Tank – 1, where the lid was in closed position. The maximum raise in temperature observed in Tank- 1 was 1.1ºC after 12:30 hours at the same time the Tank – 2 showed an increase of 0.5ºC only. The difference in maximum temperature in both the tanks was 0.6ºC. The results clearly indicate that part of the heat energy emitted from the lights was absorbed by the water and part of the heat was transferred to air in Tank – 2. In Tank – 1, as the top lid was closed, maximum quantum of heat energy released by the light has been absorbed by the water. It can be concluded that the quantum of heat energy received by the water was 354.82 kJ/hr. when the lid was closed and 161.28 kJ/hr. when the lid was open. The

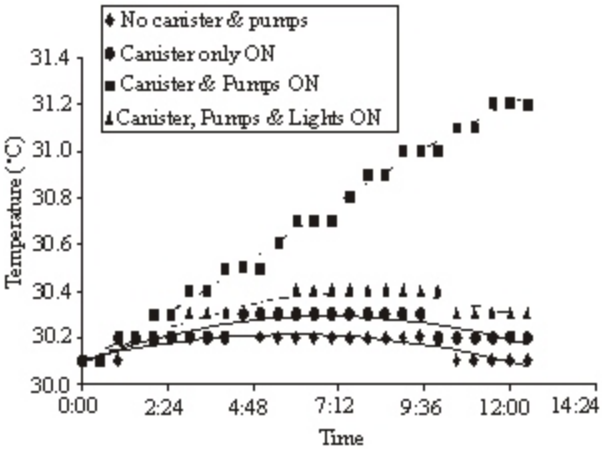

Fig. 1: Change in water temperature with different pumping system

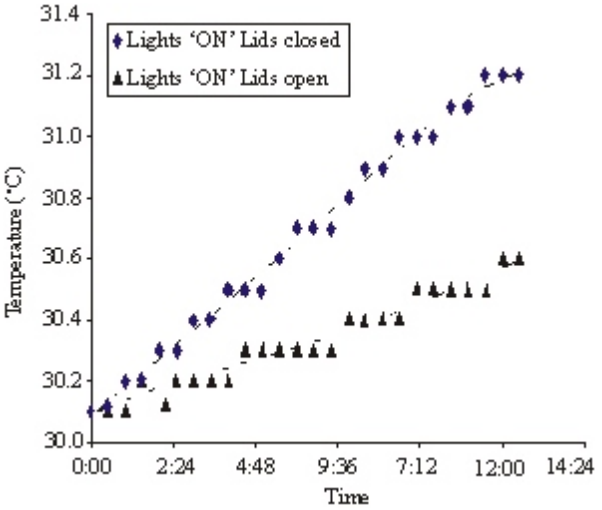

Fig. 2:Change in water temperature with lid position

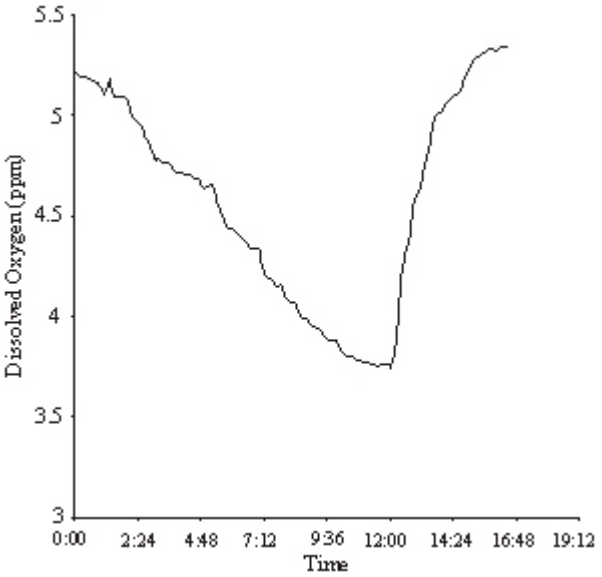

Fig. 3: Variations in Dissolved Oxygen with time

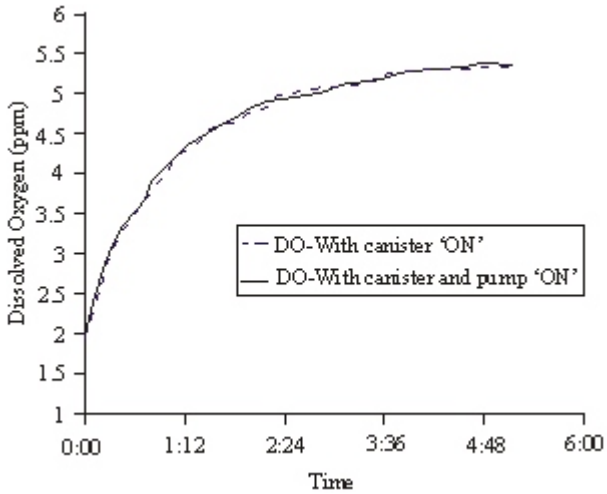

Fig. 4: Rate of Oxygen dissolution in seawater with different pumping system

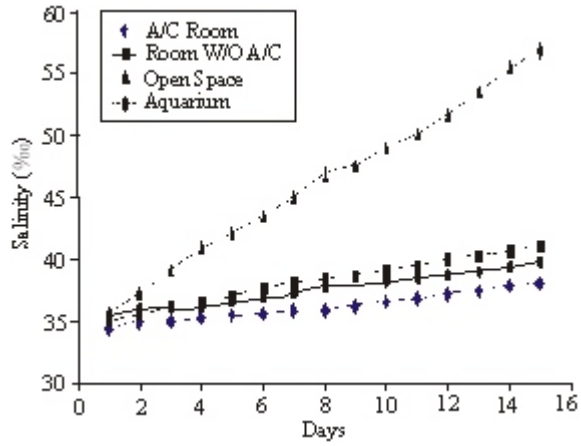

Fig. 5: Variation of salinity due to evaporation at different environment

reasons for raising water temperature in aquarium can be attributed to 1. Heat exchange due to the surrounding atmosphere 2. Heat generated due to the operation of canister filter 3. Heat generated due to the operation of lift pumps and 4. Heat exchange due to the aquarium tank lightings.

Variations in Dissolved Oxygen:

Oxygen consumption by *Chaetodon octofasciatus*: The dissolved oxygen values started decreasing with respect to time almost linearly with a correlation coefficient of 0.9944 Fig.3. It took nearly 12:00 hours to consume 1.58 ppm of oxygen at the rate of 0.132 ppm/hr. After the DO value reached the minimum of 3.75 ppm, the canister filter was switched 'ON' and the dissolved oxygen values started rising and reached a maximum of 5.33 ppm. in 4:30 hours at the rate of 0.351 ppm/hr. From the above it can be estimated that the rate of oxygen consumed was 124.08 mg O_2 / 325 g fish / hr. (or) 0.382 g O_2 / kg fish / hr. The rate of oxygen replenished was 329.94 mg / 940 lit. / hr. The optimum stocking capacity of *Chaetodon octofasciatus* for balanced dissolved oxygen was estimated as 0.865 kg / 940 lit. of seawater. The above findings conclude that 0.919 kg of biomass of *Chaetodon octofasciatus* can be safely stocked in 1,000 liters of seawater with an aeration capacity of 0.351 mg/lit/hr.

Table 2:Temperature and Humidity at different environment

Description	A/C Room	Non A/C Room	Open space	Aquarium building
Temperature	27-29°C	28-35°C	28-37°C	27-29°C
Relative Humidity	60%	90%	90%	70%

Table 3: Variation of salinity due to evaporation at different environment

	Salinity %			
Days	A/C Room	Non A/C Room	Open space	Aquarium building
1	34.32	35.06	35.51	35.52
2	34.8	35.42	37.23	35.86
3	34.96	36.3	39.04	36
4	35.2	36.52	40.82	36.13
5	35.39	37.04	42.03	36.59
6	35.55	37.64	43.51	37
7	35.76	38.07	45.04	37.3
8	35.81	38.36	46.83	7.75
9	36.21	38.61	47.52	38
10	36.56	39.02	48.98	38.15
11	36.8	39.43	50.12	38.45
12	37.12	40.04	51.59	38.73
13	37.46	40.31	53.51	39.02
14	37.81	40.62	55.48	39.41
15	38	41.02	57.01	39.76

Efficiency of canister filter and lift pump on dissolved oxygen: The results revealed that in both the cases, the rate of increase in dissolved oxygen not showing any considerable variation. The replenishment of dissolved oxygen was observed in two stages. During Stage - 1, the dissolved oxygen values started rising rapidly from 1.97 ppm till it reached 4.52 ppm within 1:30 hr. and then during Stage -2, the rate of increase was slowed down. It took 3:40 hr. to reach 5.36 ppm from 4.52 ppm. The total time taken was 5:10 hours to reach the maximum. The average rate of replenishment of dissolved oxygen was 1.02 ppm/hr. in Stage -1 with correlation coefficient of 0.9631. The average rate of replenishment of dissolved oxygen was 0.229 ppm/hr. in Stage - 2 with correlation coefficient of 0.9393 shown in Fig. 4.

Evaporation of seawater and increase in salinity: Evaporation occurs when water molecules move fast enough to escape their liquid state and become vaporous. The major factors controlling the rate of evaporation are temperature, surface area of water column, wind speed and relative humidity. From the results represented in Table 2 and 3 as well as in Fig. 5. It can be inferred that the rate of evaporation of sea water is slightly higher in the containers kept in the aquarium than in the A/C room. As the temperature and humidity of both the environment were same, the higher rate of evaporation may be due to air circulation in the aquarium building. The evaporation rate was slightly higher in containers kept in non A/C room, may be due to the elevated temperature (35ºC). The

Table 4: Rate of evaporation of water

Place	Initial vol. of water lit.	Final vol. of water	Loss of water lit.	No. of days	Loss of water lit.lit./day	Diameter of the container m	Rate of evaporation lit./m^2/day
Sea water							
A/C room	14	12.758	1.242	15	0.0828	0.285	1.297
Non A/C room	14	11.321	2.679	15	0.1786	0.288	2.740
Open space	14	6.500	7.500	15	0.500	0.287	7.726
Aquarium	14	11.916	2.084	15	0.1389	0.285	2.177
Fresh water							
A/C room	14	12.663	1.337	15	0.0891	0.288	1.367
Non A/C room	14	10.625	3.375	15	0.225	0.285	3.526
Open space	14	4.809	9.191	15	0.6127	0.283	9.737
Aquarium	14	11.816	2.184	15	0.1456	0.29	2.203

container kept in open space exhibited highest rate of evaporation due to high temperature associated with free air circulation in the open space. The loss of water due to evaporation in all the experiments were tabulated in Table 4 along with the net rate of evaporation in lit./m^2/day .The rate of evaporation was found increased from A/C room to open space in the following order in both sea and fresh water

A/C room < Aquarium < Non A/C room < Open Space: Further the rate of evaporation of fresh water was higher than that of sea water in all the places. Water evaporates as some of the water molecules get enough energy to break away from the rest of the water molecules in the liquid. The higher the temperature more molecules to escape and the water evaporate in faster manner. Adding substances such as salt to water causes the water to evaporate more slowly at a given temperature. This is because the salt molecules form a bond with several surrounding water molecules. It takes extra energy to break this bond and that slows down the evaporation. This may be the reason for the faster evaporation of fresh water than the seawater.

The wind is also playing a major role in evaporation. The rate of evaporation increases with wind speed since the energy imparted by the wind is much more than the energy due to change in temperature. The above experiment clearly shows the higher rate of evaporation in open space both in fresh water and seawater. The total water bound area in all the 28 numbers of tanks has been calculated as 58.97 m^2. In the present investigation the total loss of water due to evaporation was calculated to a maximum of 128.38 liters/day. The loss of water due to evaporation leads to increasing salinity. To avoid this it is suggested that fresh water, preferably water treated through Reverse Osmosis technique, may be added to compensate the loss and dilute the salinity. This will avoid the complications which may arise due to increased chlorine content, dissolved gases and other pollutants if the tap water or the ground water is used. The total fresh water required to keep the salinity constant was estimated to be 128 liters per day for all the tanks. This may be added directly to the sump in a phased manner and mixed thoroughly before pumping in to the overhead tank.

DISCUSSION

From this study we concluded that the aquarium lightings deliver more heat energy to the aquarium waters and increase the water temperature. This may be avoided by replacing present aquarium top lid with a perforated one for release of heat generated by the lightings to the atmosphere. Further the perforation may be covered with nylon mesh to avoid unwanted entry of insects. This will also provide fresh air above the water surface and the dissolved oxygen may be maintained to the optimum. The rate of consumption of oxygen by *Chaetodon octofasciatus* was estimated as 0.3815 g O_2 / kg fish / hr. and recommended to stock 0.919 kg of biomass (37 numbers) of *Chaetodon octofasciatus* in 1,000 liters of seawater with the aeration capacity of 0.351 mg/lit/hr. with a free swimming volume of 27 liters/fish.

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