Seasonal Variation in Photosynthesis, Dark Respiration and Growth Rate of Two Reef Building Corals in the Red Sea Coast

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Abstract

The seasonal variation in photosynthesis, dark respiration and growth rate of two reef building corals, *Seriatopora hystrix* and *Lobophyllia corymbosa* inhabiting the coast of Red Sea was studied during summer and winter. Results showed that there is a little variations in the respiration rates of the zooxanthellae between the two species and season (Summer and Winter). The respiration rates decreases gradually according to the season variations .

Photosynthesis versus irradiance (P v I) curves was obtained and lines fitted to the data using the hyperbolic tangent function. The lower Pgmax values were observed in *Seriatopora hystrix* in winter than in summer, hence sensitive to the temperature variations. Conversely, the Pgmax of *Lobophyllia corymbosa* was higher in summer than in winter, suggesting the possibility of compensatory process of either the lower light-levels or lower water temperature during winter. The growth rate of the two species was lower in the winter than in summer. The light quality and intensity and seawater temperature during summer also affected the growth rate of the two species.

Key words: Coral reefs; zooxanthellae; photosynthesis; dark respiration; the Red Sea

Introduction

Reef-building (hermatypic) corals have a symbiotic relationship with certain dinoflagellate algae that live within the corals' tissues. This zooxanthellae supply supplementary food, Oxygen and enhance the skeleton deposition rate. The coral-algal symbiosis is best adapted to clear, nutrient-poor water (Hallock *et al.,* 1993; Wood, 1993). Reef-building corals are susceptible to a range of stressors, including the effects of global climate change

(Hughes *et al.*,2017). Coral Bleaching is a general stress response of corals, but in recent decades has been most commonly observed during prolonged high temperature anomalies, such as particularly severe El Niño/ Southern Oscillation events. The term bleaching refers to the disruption of the coral-algae symbiosis caused by the loss of photopigments or endosymbiotic dinoflagellates from the animal tissues.(Jones *et al.*,1998 ; Hughes *et al.*,2018)

There are three main metabolic processes in corals (i) Photosynthesis (CO_2 Consumption and O_2 Release), (ii) Respiration (O_2 Consumption and CO_2 Release) and the (iii) Biogeogenic process of calcification (deposition of $CaCO_3$). These processes are interconnected in corals (Al-Horani, 2002). Hermatypic corals are restricted to tropical and sub-tropical seas where the temperature is not lower than 18°C, with optimal reef development between 25° and 29°C and this is expressed in latitudinal patterns of coral reefs distribution and diversity (Wells, 1956; Miller, 1995; Bikerland, 1997).

Growth of scleractinian corals can be divided in two mechanisms: first, skeletal growth due to the deposition of an external skeleton of calcium carbonate by the synthesis of an organic matrix, a process called as calcification, and the second one is the tissue growth. According to the light-enhanced calcification theory (Allemand *et al*., 1998; Gattuso *et al*., 1999), the symbiosis with zooxanthellae is helping the process of skeletal growth. According to this theory, calcification of the coral host is enhanced by photosynthesis of zooxanthellae (Goreau and Goreau 1959; Pearse and Muscatine 1971; Allemand *et al.*, 2004). Certainly, on average, calcification in light is found to be around three times higher than calcification in darkness (Gattuso *et al.*, 1999). Although photosynthesis and calcification are spatially separated processes (photosynthesis occurs in the oral tissue layer and calcification in the aboral tissue layer), they do share a common pool of inorganic carbon inside the coelenteron of the coral host, accounting for the interaction between these two processes. The

exact mechanisms of the enhancement of calcification by photosynthesis are still a matter of debate (Gattuso *et al.*,1999; Furla *et al.*, 2000). Some of the proposed mechanisms include that: (1) photosynthesis provides energy for the energy-demanding processes associated with calcification, such as calcium transport and organic matrix synthesis (Wainwright, 1963), and (2) photosynthesis raises intracellular pH and intracellular saturation state of calcium carbonate, thereby favouring the precipitation of calcium carbonate (Goreau and Goreau 1959; Allemand *et al*., 1998).

The main objective of this study was, to compare the respiration, photosynthesis, growth and their sensitivity range of *Seriatopora hystrix* and *Lobophyllia corymbosa* to the environmental factors during two the seasons (Summer and Winter). Results obtained this study will improve our knowledge on the ecology and physiology of Red Sea Corals.

Materials and Methods

The study was carried out in the onshore laboratory of the Faculty of Marine Sciences, King Abdulaziz University, Jeddah, which is located adjacent to the fringing reefs of an inlet, Obhur creek, away from the north of the City Creek (Figure.1). The study site was located at the mouth of the creek on its northern shore, at the water depth of 3m. Specimens of *S. hystrix* and *L. corymbosa* were collected at this depth.

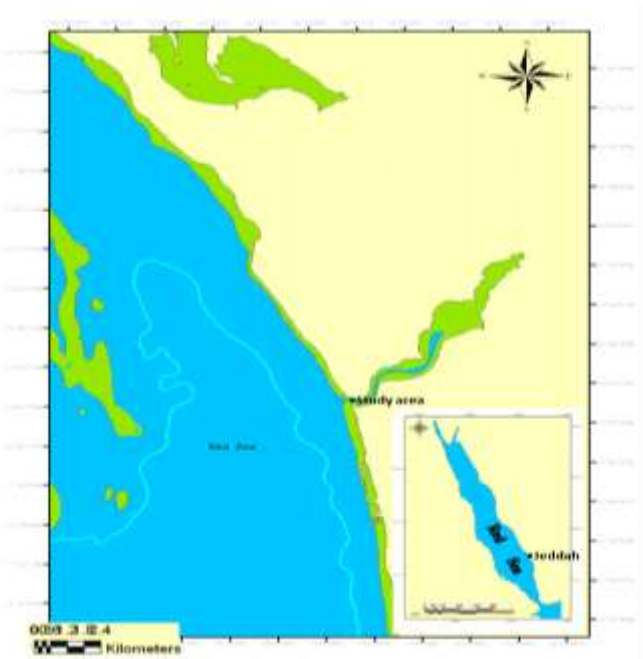

Figure. (1) Red Sea Map and Location of Obhur Creek which lies in the north of Jeddah City. The Study Site is Marked (•) at the Entrance of Obhur Creek.

Measurement of Environmental Parameters

Water temperature was measured *in situ* by using two maximum and minimum thermometers attached to the reef in a shaded location. They were read at monthly intervals from July 2009 to Jun 2010. Underwater down-dwelling UV temperature loggers (HOBO) launch devices (model UA-002-64) were setup in the lab using the HOBOware® Pro software. The sampling intervals were of 15 min and the total recording light is one day in summer 2009 and during winter 2010. The recording time start at 06:00 pm to 06:00 ammeasuring Photosynthetically Active Radiation (P.A.R) between 400 and 700 nm.

Specimen Preparation

Freshly collected colonies of the two species (*S. hystrix* and *L. corymbosa*) were used to make coral nubbins (Birkeland, 1976; Davies, 1984; Edmunds and Davies, 1986; Al-Sofyani, 1991). Similar- size regular shaped branch tips of *S. hystrix* were broken

off and the surfaces ground flat to yield tips of 2.5 - 3 cm height. These were attached to pre-weighted 3×3 cm acrylic tiles, using a small quantity of cyanoacrylate adhesive. Similar-sized pieces of *L. corymbosa*, with more irregular growth form, were made in to nubbins in the same way. They were then placed on racks and returned to the reef to recover for at least once in a week.

Dark Respiration

Respiration Oxygen uptake of nubbins was measured in darkness using respirometer cell immediately before the commencement of a photosynthesis run. Respiration rate was linear with production of O_2 over the 100% to 90% saturation levels that were used for the determination. Dark respiration values were added to the net of photosynthesis values to obtain gross photosynthesis.

Respiration rate of zooxanthellae were determined on freshly isolated sample, from nubbins that had been maintained in darkness for 12 h. Coral tissue was removed with a water pick, and the slurry was centrifuged at 2000 *x* g for 1 min. Further separation was achieved with a hand-held potter homogenizer, after which the suspension was centrifuged, washed with seawater thrice and re-suspended in 1 ml of filtered seawater. The rate of oxygen uptake was measured in darkness in an RC 300 respirometer cell (Strathkelvin instrument) with a 1302 Paleographic Oxygen electrode. Zooxanthellae concentrations within the cell were measured on a subsample using Haemacytometer

Photosynthesis

Nubbins were placed in water-jacketed clear acrylic closed Respirometer Cell with a water volume of 128 ml. Oxygen flux was detected by a polarographic oxygen electrode (Strathkelvin Instruments, 1302) connected to a Oxygen meter. Light was provided by a bank of overhead fluorescent lambs whose output was varied between 25 and 300 μE m^{-2} sec^{-1} by mean of a variable transformer. Net Oxygen production rates were normalized to dry weight of coral tissue, mean values derived at each irradiance value

and best fit curves for the plots of net (P v I) were obtained using a hyperbolic tangent function Curve-Fitting Program (Chalker, 1981).

Growth

Nubbins were placed on racks at 3m in the experimental sites on the fringing reef of *S. hystrix* and *L. corymbosa* , after taking the buoyant weight using a precise 120A balance (Davies, 1989). They were returned to the laboratory for reweighing after intervals of approximately seven days.Growth rates were determined in summer 2009 and winter 2010 and were expressed in mg skeleton d^{-1}

The unit reference was dry skeletal weight, which was calculated from the buoyant. The technique involves the weight of the living branches (nubbins) of *S. hystrix* and *L. corymbosa* in seawater and converting the buoyant weight to the dry weight of skeleton by the following equation of Davies (1989):

(i) Dry weight of the object = weight in water ÷ [1- density of water / density of object]

(ii) Buoyant weight of object = weight in air * [1- density of water /density of object]

(iii) Density of water = weight in air-weight in water÷(weight in air/ density of object)

(iv) Density of object=(weight in air *-density of water) / (weight in air-weight in water)

Results and Discussion

Environmental Measurements

The annual mean seawater temperature variations at Obhur creek were lowest in March (2010) at 3 m (27.42°C). However, the maximum mean seawater temperature were observed in August (2009) at 3 m depth (32.67°C) (Figure .2). Floos (2007) observed the lowest seawater temperatures from February to March 2005 (24.5 -24.75°C) in the Obhur creek at 3 m depth and the highest seawater temperature from July to August 2005 (30.25 to 33°C). Similarly, Al- Sofyani (1991) recorded lowest temperatures during February and March (1990) and the highest in July to October 1990 (30°C to 31°C) respectively. In addition, Fadlallah (1985) recorded

similar temperatures at Obhur creek and adjacent Yanbu coast. Temperature change might be expected to influence the metabolic rate of both animal and plant components of the symbiosis, and the rate of photosynthesis.

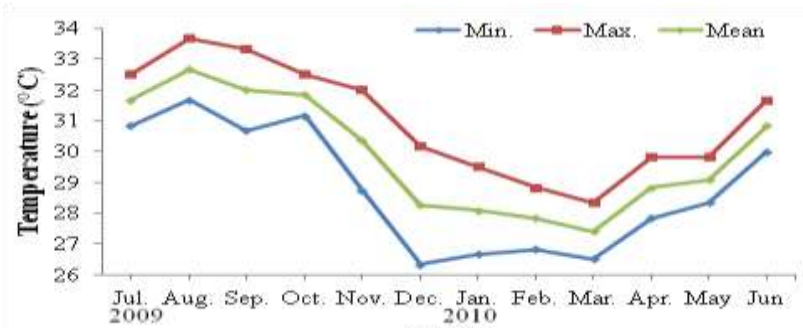

Figure. (2) Monthly Mean Variation of Sea Water Temperature (°C) of Obhur Creek at 3 m Depth from July 2009 to Jun 2010

In summer, the longest duration of sunlight was (12.75 hours) with integrated daily irradiation of (11.26 µE. $m^{-2}.d^{-1}$) at 3 m depth, whereas in winter the day length had shortened to (11.75 hours) and the integrated daily irradiation was (7.32 µE. $m^{-2}.d^{-1}$). This reduction combined with the lower number of winter daylight hours resulted in the total daily irradiance in summer at (11.26 µE. $m^{-2}.d^{-1}$) being more than twice that recorded in winter. The daily maximum variation of light intensity of photosynthetically active radiation (P.A.R) and the duration are shown in the (figures 3 and 4). The P.A.R of daily light curve was maximum in the summer (August 2009) with the value of 512 µE s^{-1} m^{-2} and minimum in the winter (February 2010) with a value of (389 µE s^{-1} m^{-2}) (Figure .3 and 4).

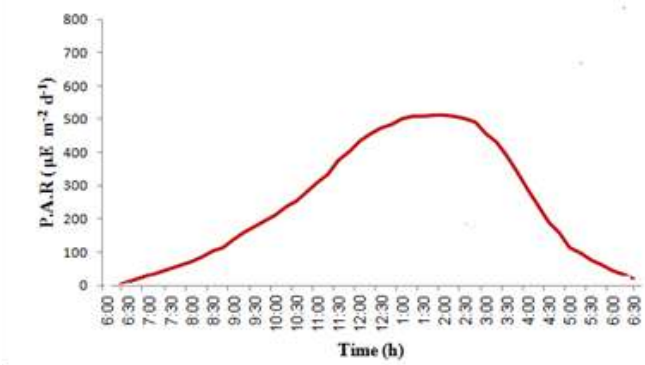

Figure. (3) The Irradiance Intensity Variation of Photosynthetically Active Radiation (P.A.R) in Summer (2009), Recorded at 3m Depths at Obhur Creek

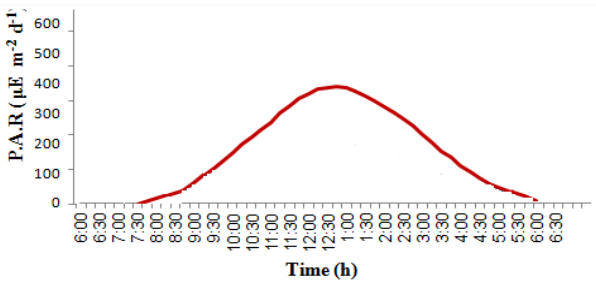

Figure. (4) The Irradiance Intensity Variation of Photosynthetically Active Radiation (P.A.R) in Winter (2010), Recorded at 3 m Depths in Obhur Creek.

Skeleton and Biomass

Skeleton and Biomass Characteristics of *S. hystrix* and *L. corymbosa* are shown in Table (1). The mean density of the skeleton of both species was identical at 2.5±0.16 (10) g.cm^{-3} and 2.75 ± 0.05 (10) g.cm^{-3} respectively, which are compared with 2.78 g.cm^{-3} and 2.77 recorded for both *Pocillopora damicornis* and *Pocillopora Verrucosa*, (Floos, 2007) In addition, skeletal variation of 2.78 g.cm^{-3} was recorded for *Stylophora pistillata* and *Echinopora gemmacea* (Al-Sofyani, 1991), 2.783 g.cm^{-3} for *Pocillopora eydouxi* (Davies, 1984, 1989), 2.822 g.cm^{-3} for *Porites porites* (Edmunds and Davies, 1986) and lowest of 2.95 g.cm^{-3} for *Fungia fungites* (Jan, 2001), 2.78 g.cm^{-3} for *Sariatopora hystrix*

(Al-Sofyani and Niaz, 2007), 2.4 g.cm^{-3} for *Lobophyllia corymbosa* (Al-Lihaibi *et al.*, 1998).

The variations in the skeletal density among the species may be due to the difference in amount of organic matrix in the skeleton (Davies, 1984, 1989). The difference of the skeletal density of both species in the present study may reflect a difference in percentage of the organic matrix in their skeleton.

The mean surface area per g. skeleton was higher in *L. corymbosa* 4.63 ± 2.11(10) cm^2.g^{-1}skeleton than *S. hystrix* 3.58 ± 1.2 (10) cm^2.g^{-1}skeleton with no significant difference. The mean dry tissue weight per g. skeleton in summer at 3m depth was higher in *L. corymbosa* 40.1 ± 12 (10) mg.d.t.g^{-1} skeleton than *S. hystrix* 25.1± 14.4 (10) mg.d.t.g^{-1} skeleton and was significantly different (t-test P ≤ 0.03).

On the other hand the mean dry tissue weight per g. skeleton in winter at 3m depth was higher in *L. corymbosa* 35.8±4.7 (10) mg.d.t.g^{-1} skeleton than *S. hystrix* 13.9 ±6.9 (10) mg.d.t.g^{-1} skeleton and is significantly different (t-test P ≤ 0.001). relative biomass between the two species and two season.

S. hystrix has the lower tissue biomass of 37.12% per mg in the case of dry tissue weight 3m depth in summer than the *L. corymbosa* while in winter, it was 63.96% at 3m depth was lower than the *L. corymbosa* at 3m depth.

Had the lowest tissue biomass than *L. corymbosa* in the case of surface area like 14.83% at depth 3m in summer (Table 1). Similarly, in winter, the biomass of tissue per surface area of *S. hystrix* was lower than *L. corymbosa* 3m depth 49.26%. This may due to the differences in the growth form of the two species or from the tissue location within the skeleton (Davies, 1991; Al-Sofyani, 1991; Floos, 2007).

Floos, (2007) reported that 28.1 mg.d.t.g^{-1}skel and 24.92 mg.d.t.g^{-1}skel for *Pocillopora damic*ornis and *Pocillopora verrucosa* from the Red Sea at 3m depth and Al-Sofyani (1991) reported 10.30 mg.d.t.g^{-1}skel

and 12.86 mg.d.t.g^{-1}skel for *Stylophora pistillata* and *Echinopora gemmace*a from the Red Sea at of 3m depth.

The values remain significantly different when they were expressed on a surface area basis, i.e. 9.27 ± 3.97 (10) mg.d.t.cm^{-2} higher in *L. corymbosa* than *S. hystrix* 7.71 ± 5.82 (10) mg.d.t.cm^{-2} in summer at 3m depth and was not significantly difference. While in winter at 3m depth was higher in *L. corymbosa* 8.16 ± 2.43 (10) than *S. hystrix* 4.14 ± 2.0 (10) mg.d.t.cm^{-2} and was significantly different (t-test $P \leq 0.001$). between the two species and two season, close to the range of 5.56 mg.d.t cm^{-2} to 9.65 mg.d.t cm^{-2} for *Montastrea annularis* at 2m and 10m depths respectively (Davies, 1980). Similarly the surface area range of 2.8 to 12.5 mg.d.t cm^{-2} was observed for six species at 2.5m depth from Barbados, West Indies (Lewis and Post, 1982). Al-Sofyani (1991) reported lower values, 3.52 mg.d.t cm^{-2} for *Stylophora pistillata* and 4.91 mg.d.t cm^{-2} for *Echinopora gemmacea* at of 1m and 3m depths respectively. Floos (2007) recorded lower values, 5.33 mg.d.t cm^{-2} for *Pocillopora damic*ornis and 6.92 mg.d.t cm^{-2} for *Pocillopora verrucosa*, while Edmunds and Davies (1986) showed much higher value of 18.59 mg.d.t cm^{-2} for *Porites porites* at 10m depth. These differences in this present study may due to the growth form or the methods used for measuring surface area (Edmunds and Davies, 1986; Al-Sofyani, 1991)

There was very highly significant difference in the number of zooxanthellae in summer and in winter in 3m depth between the both species on basis of biomass and surface area (t-test $p<0.005$). *L. corymbosa,* had a lower number of zooxanthellae 0.05×10^5 , 0.43×10^5 mg^{-1} dry tissue wt than *S. hystrix*0.19×10^5 , 5.8×10^5 mg^{-1} dry tissue wt in two season respectively (Table 1). This was lower than *Stylophora pistillata*, 2.78×10^5 mg^{-1}d.t and *Echinopora gemmacea* 1.27.mg^{-1}d.t studied earlier (Al-Sofyani, 1991). It was much lower when compared to *Fungia fungites* 6.91×10^5 mg^{-1}d.t (Jan, 2001).

Table. (1) The Mean Skeletal and Tissue Biomass Colony of *S. hystrix and L. corymbosa* at the Study Site Recorded at 3 m Depth during Summer and Winter.

Characteristic		*S. hystrix*		*L.crymbosa*		t-test	P-value
Skeleton							
Skeletal density ($g.cm^{-3}$)		2.5 ± 0.16	(10)	2.75 ±0.1	(10)	3.17*	0.001
Biomass Colony							
$mg.d.t.g^{-1}$ skeleton	Sum.	25.1± 14.4	(10)	40.1 ± 12	(10)	2.34*	0.031
$mg.d.t.g^{-1}$ skeleton	Wint.	13.9 ±6.9	(10)	35.8±4.7	(10)	4.13*	0.001
$cm^2 .g^{-1}$ skeleton	-	3.48 ± 1.2	(10)	4.63 ± 2.11	(10)	1.32	0.182
$mg.d.t.cm^{-2}$	Sum.	7.71±5.82	(10)	9.27±3.97	(10)	0.53	0.564
$mg.d.t.cm^{-2}$	Wint.	4.14 ±2.0	(10)	8.16 ±2.43	(10)	4.11*	0.001
Zooxanthellae							
$No.10^5 .mg^{-1}$ d.t	Sum.	0.19 ±0.1	(10)	0.05 ±0.02	(10)	6.71*	0.0001
$No.10^5 .mg^{-1}$ d.t	Wint.	5.8 ± 3.12	(10)	0.43 ± 0.18	(10)	4.51*	0.0001

***significance (P≤ 0.05)**

Dark Respiration

The mean percentage of dark respiration rates varied between two species on the basis of milligram dry tissue weight ($mg.d.t.wt.h^{-1}$). The percentage of dark respiration rate of *S. hystrix* (76.4%) was higher than the *L. corymbosa* in summer (32°C). Similarly the respiration rate of *S. hystrix* was as higher (77.69%) than the *L. corymbosa* in winter (30°C) at 3m depth. The respiration rate of *S. hystrix* was significantly higher at 32°C than 30°C during summer, observed in the respiration rate of the freshly isolated zooxanthellae. In *L. corymbosa* summer dark respiration was higher at summer (1.085 µl O_2 $mg^{-1}.d.t\ h^{-1}$) but not much higher than in winter (0.884 µl O_2 $mg^{-1}.d.t\ h^{-1}$). There was a significant difference between the respiration rate of the freshly isolated zooxanthellae during summer(0.2937µl O_2 mg^{-1} .d.t h^{-1}) and winter (0.0894 µl O_2 $mg^{-1}.d.t\ h^{-1}$) (Table 2). The mean respiration rates of this study was compared ($mg.d.t.wt.h^{-1}$) with other published values of this region.

In summer, *Pocillopora damicornis* rate was lower than the present study (1.190 µlO_2 mg.d.t.wt.h^{-1}) and also respiration rate of the *Pocillopora verrucosa* was also lower (1.37 µl O_2 mg.d.t.wt.h^{-1}) at 3m depth of the same study site (Floos, 2007; Al-Sofyani and Floos, 2013). In *Echinopora gemmacea* also the respiration rate was lower (1.37 µl O_2 mg.d.t.wt.h^{-1}) than the present study on *S. hystrix* at the same study area (Al-Sofyani, 1991). Studies on the other regions like Hawaii also showed minimum respiration rates in *Mintipora annularis* (1.65 µlO_2 mg.d.t.wt.h^{-1}) and *Porites lobata* (1.19 µlO_2 mg.d.t.wt.h^{-1}) than the present study (Davies, 1991). The *L. corymbosa* respiration rate was lower than the *S. hystrix* 0.884 µlO_2 mg.d.t.wt.h^{-1}It was *L. corymbosa* even lower in respiration rates when compared to the other studies on *Echinopora gemmacea* (1.21 µlO_2 mg.d.t.wt.h^{-1}) and *Stylophora pistillata* (1.77 µlO_2 mg.d.t.wt.h^{-1}) at the same study site (Al-Sofyani, 1991). This lower respiration rate of *L. corymbosa* of the present study may due to the higher tissue biomass than the *S. hystrix*.

Conversely, in *L. corymbosa* there was small, non-significant increase from winter to summer. In both species, the respiration rate of zooxanthellae was significantly higher in summer than that of winter. However, since the respiration of zooxanthellae contributes only about 10-29% of the colony respiration (Dvies, 1984; Edmunds and Dvies, 1986; Dvies, 1991), the difference in response to seasonal temperatures in the two species is largely due to the animal component of the symbiosis. There was major bleaching in the Red Sea corals in the year 1998. In that period some coral species like *Pocilloporaverrucosa* had found resistant to the bleaching event than the *Pocillopora damicornis* (Al-Sofyani, 2000; Ralph *et al*., 2005). Moreover, Coles and Jokiel (1977) reported very high response in metabolic rate due to temperature changes (19-31°C) in *Pocillopora damicornis*, *Montipora verrucosa*, *Porites compressa* and *Fungia scutaria* in Hawaii and Enewetak. This difference in the metabolic rates may be the indication of compensatory acclimation of the species to the temperature

(Hochachka and Somero, 1984). Acclimation has the effect of increasing metabolic rate during long-term exposure to reduced temperature. If acclimations complete, the metabolic rates when measured at the temperature at which the animals are living are identical. The similarity of respiration rates in summer and winter in *L.corymbosa* may therefore be explained in this way.

Conversely, the lower rate of respiration during the winter demonstrated by *S. hystrix* is indicative of the normal acute temperature response, and compensatory acclimation does not appear to have occurred.

Photosynthesis

The maximum gross photosynthesis values (p^g_{max}) on the basis of mg.d.t.wt.h^{-1} for *S. hystrix* was 8.2865 µl O_2 mg^{-1} d.t.wt.h^{-1} at 3m depth and in the case of *L. corymbosa* it was 2.6941 µl O_2 mg d.t.wt.h^{-1} at the same depthin summer (32°C). These values were lower than the *Stylophora pistillata* (8.81-5.23 µlO_2 mg.d.t.wt.h^{-1}) and higher than the *Echinopora gemmacea* (3.83-3.39) µlO_2mg.d.t.wt.h^{-1} (Al-Sofyani, 1991). When compared to *Porites porites* it was 4.76 µlO_2 mg.d.t.wt.h^{-1} at 10m and in *Porites lobata* it was 4.26 µlO_2 mg.d.t.wt.h^{-1} at 3m respectively, both these species had large tissue biomass (Edmund and Davies, 1986; Davies, 1991).

In winter (30°C)for *S. hystrix* the value was 8.7529 µl O_2 mg^{-1} d.t.wt.h^{-1} at 3 m depth and in the case of *L. corymbosa* it was 0.9915µl O_2 mg^{-1} d.t.wt.h^{-1} at 3m depth. The (P^g_{max}) for *L. corymbosa* was lower in winter (30°C) than in summer (32°C) and this could be probably due to the lower water temperature in the winter. However, at 3m depth, the rate of photosynthesis of *S. hystrix* was higher in winter (30°C) than in summer (32°C). In this respect it displayed the normal acute response to temperature change. A similar acute response was demonstrated by Coles and Jokiel (1977) for four species of coral between temperature of (19-31°C)in Hawaii and Enewetak.. However the rate of photosynthesis at any temperature was higher for Hawaiian specimens which had been living at lowered temperature. This suggests an acclimation

response which is similar in effect to the temperature acclimation of metabolic rate noted above. In *L. corymbosa* at Jeddah, there was significant difference in (p^g_{max}) between summer and winter, which again suggests that some form of photosynthesis acclimation to temperature, had occurred.

The I_k values of the (P v I) curve were the indication of the relative efficiency of photosynthesis at low light-levels. Similarly the lower value of I_k was indicating the higher efficiency. The I_k values of *S. hystrix* increased in summer (199.9 µE. m^{-2}. s^{-1}) than in winter (159.29 µE. m^{-2}. s^{-1}) and this might due to the photoadaptation ability of the zooxanthellae. Gattuso (1985) worked on *Stylophora pistillata* and reported that at 1 m the I_k was 318 µE. m^{-2}. s^{-1} and at 10 m it was 158.3 µE m^{-2} s^{-1}. Whilst Porter *et al.*,(1984) found values of 273 µE. m^{-2}. s^{-1}at light adapted and 60 µE m^{-2} s^{-1}) at dark adapted *Stylophora pistillata* respectively. Similarly the I_k values for *L. corymbosa*increased in summer (299.1 µE m^{-2} s^{-1}) than in winter (209.75 µE. m^{-2}. s^{-1}) at 3 m. Previous studies by Davies (1991) reported the values for *Montipora verrucosa* as 176 µE m^{-2} s^{-1} and for *Porites lobata* it was 177 µE m^{-2} s^{-1} at 3 m depth.

Both *L. corymbosa* and *S. hystrix* displayed lower values of I_k in the winter than during the summer indicating the photoadaption to the lower light levels prevailing these months. This appears to be the first report related to the seasonal photoadaption response of Red Sea Corals. The deep-living corals exhibited difference in photosynthetic characteristics, which could be explained by photoadaptation to reduced light by the zooxanthellae. Changes were observed in the shape of the (P v I) curves. Notably the deep corals had lower values of I_k although values for α were similar (Table 2) and (Figure 5 and 6).

Table. (2) The Mean Values of Maximum Mean Gross Photosynthesis (Pg_{max}) of whole Nubbins and the Freshly Isolated Zooxanthellae and Photosynthetic Parameters (I_K, I_C , and $I_{0.95}$) Calculated from the Net PhotosynthesisVs Irradiance of *S. hystrix and L. corymbosa* According 3m Depth and Seasons (Summer and Winter).

	S. hystrix				*L. corymbosa*			
Photo synthesis	**Summer 2009**	**Winter 2010**	**t-test**	**p-value**	**Summer 2009**	**Winter 2010**	**t-test**	**p-value**
Colony P^g_{max} $\mu lO_2 mg^{-1}.d.t\ h^{-1}$	8.2865	8.7529	0.26	0.87	2.6941	0.9915	5.2*	0.001
S.D±	5.14	4.21			0.94	0.22		
α $\mu lO_2 mg^{-1}.d.t\ h^{-1}$/ $\mu E\ s^{-1} m^2$	0.0556	0.0774	1.29	0.229	0.0099	0.0053	2.5*	0.008
S.D±	0.028	0.07			0.005	0.0029		
I_K $\mu E\ s^{-1}\ m^{-2}$	199.9	159.29	1.28	0.249	299.1	209.75	2.1*	0.048
S.D±	78.73	74.09			113.5	75.39		
I_C $\mu E\ s^{-1}\ m^{-2}$	115.1	67.364	3.00*	0.008	116	86	0.5	0.628
S.D±	33.631	42.418			19.488	18.331		
$I_{0.95}$ $\mu E\ s^{-1}\ m^{-2}$	369.662	289.955	1.21	0.249	538.298	371.397	2.1*	0.049
S.D±	117.239	135.744			209.098	138.129		
Respiration R $\mu lO_2 mg^{-1}.d.t\ h^{-1}$	4.594	3.964	1.78	0.099	1.085	0.884	1.0	0.318
S.D±	2.29	1.32			0.47	0.38		
R of zooxanthellae	0.0695	0.7895	9.6*	0.001	0.0894	0.2937	3.4*	0.004
S.D±	0.03	0.27			0.015	0.08		

***significance (P≤ 0.05)**

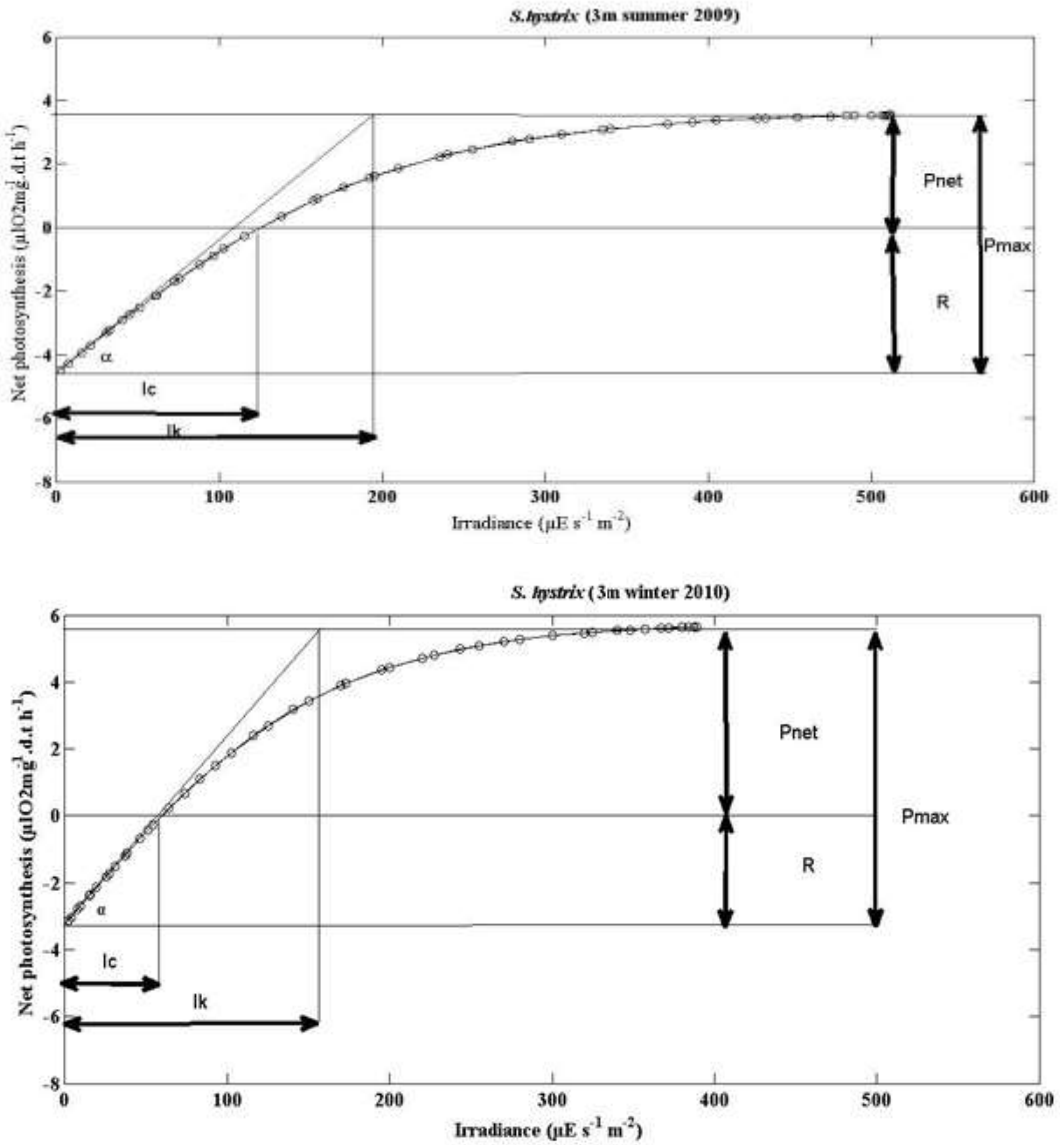

Figure. (5) Relationship Between Light Intensity (I) and Photosynthesis (P) for *S. hystrix* at 3m Depth during Summer and Winter.The Curves were Derivedfrom the Mean Values of Photosynthesis Parameters Using the Following Equations:

S. hystrix $P_{net} = P^{g}_{max.} \tanh (I/I_K) - R$ **Chalker (1981)**

$P_{net} = 8.2865 \tanh (I/199.9) - 4.594$ **3m winter 2010**

$P_{net} = 8.7529 \tanh (I/159.29) - 3.964$ **3m summer 2009**

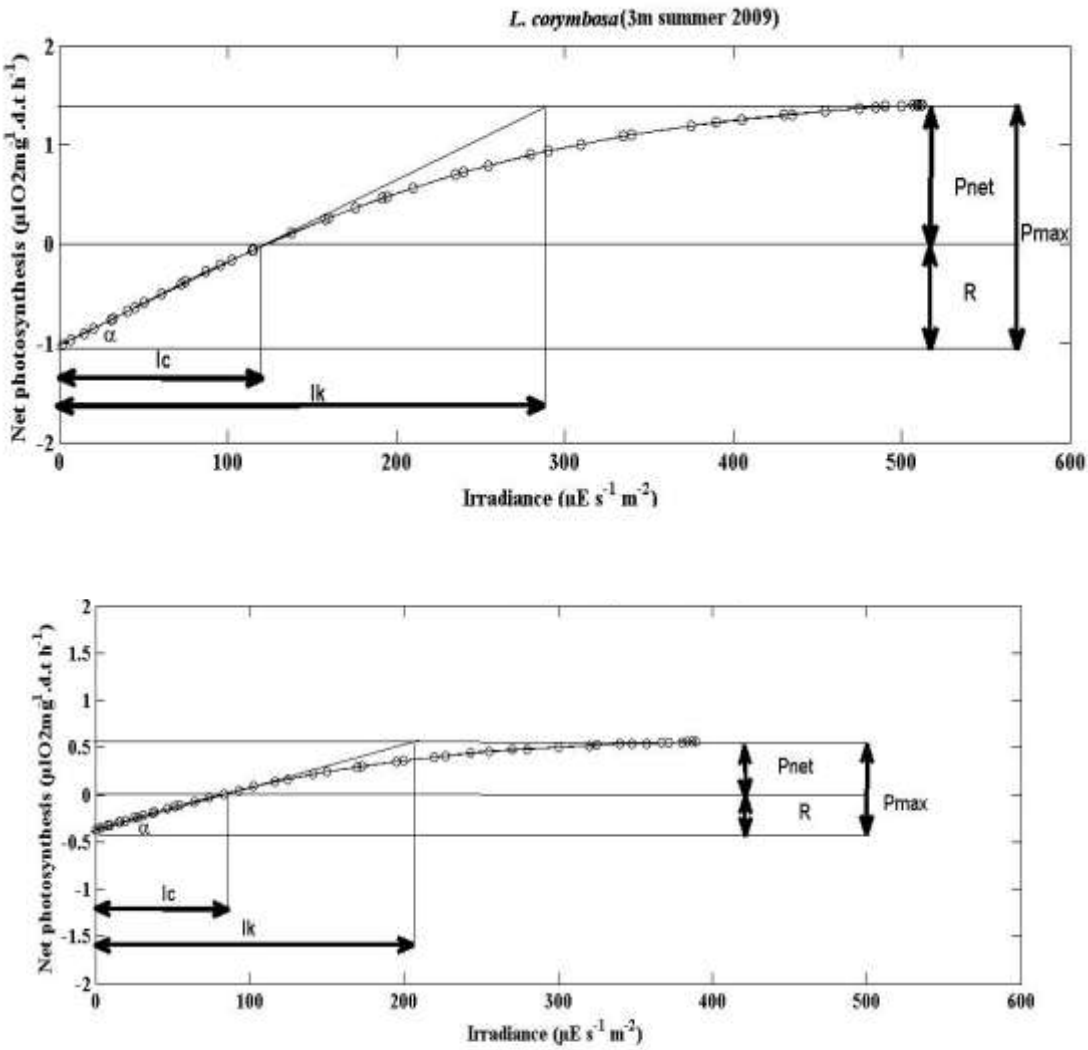

Figure. (6) Relationship Between Light Intensity (I) and Photosynthesis (P) for *L. corymbosa* at 3m Depth during Summer and Winter. The Curves were Derived from the mean Values of Photosynthesis Parameters using the Following Equations:.

L. corymbosa $P_{net} = P^{g}_{max.} \tanh (I/I_K) - R$ **Chalker (1981)**

$P_{net} = 2.6941 \tanh (I/299.1) - 1.085$ **3m summer 2009**

$P_{net} = 0.9915 \tanh (I/209.75) - 0.884$ **3m winter 2010**

Growth

The rate of skeletal growth of *S.hystrix* in summer was 1.9 mg skeleton d^{-1} and during winter, a value of 1.8 mg skeleton d^{-1} was observed. By contrast, the rate of growth of *L. corymbosa* was 7.9 mg skeleton d^{-1} in summer and 5.9 mg skeleton d^{-1} during winter (Table 3) and (figure 7, 8 and 9).

Linear growth rates studies in this two species can be interpreted that, it may rapidly increase at the tips of the nubbin rather than lateral (Rinkevich and Loya, 1984; Davies, 1984; Al-Sofyani, 1991; Wellington and Glynn, 1983; Floos, 2007 Al-Sofyani and Floos, 2013.The growth rate of hermatypic corals is influenced generally by the external factors like light intensity, sedimentation (Wellington and Glynn, 1983; Al-Sofyani, 1991; Miller, 1995; Atkinson *et al*., 1995; Floos, 2007 Al-Sofyani and Floos, 2013). The temperature is also another important parameter that can affect coral growth. In tropical corals, several studies showed that a 1°C increment in mean annual temperature may resulted into the increase in the coral calcification rate by 3.1% especially when temperatures increased above the upper threshold limit of corals (McNeil *et al*., 2004: Orejas, *et al*., 2011).

In *L.corymbosa* also, the growth rate was reduced by the internal factors such as reproduction, genetics, growth form of colony, number or type of zooxanthellae and production of mucus tunics by species. The light quality and intensity and seawater temperature during summer also affected the growth rate of *S. hystrixa*nd *L.corymbosa*. Hence, the mean respiration rate of zooxanthellae increased dramatically with an increasing temperature. The reduction in coral respiration rates with an increasing temperature was associated with a reduction in number of zooxanthellae. It may be possibly due to the translocation of organic material from the algae due to decrease in photosynthesis, in addition to decrease the growth rate of skeleton during winter.

The respiration of the corals was consumed the most important portion of the energy input (Al-Sofyani, 1991; Edmunds,

1986). However, both species, especially the *S. hystrix* seemed to be more sensitive to exogenous and endogenous factors. This was evidenced by the mean growth rates which recorded in the summer for *S. hystrix* and *L. corymbosa*. In compared the mean growth with other studies, showed that the mean growth rate was 1.9 mg. skel. d^{-1} for *S. hystrix* and 7.9 mg. skel. d^{-1} for *L. corymbosa* at 3m in summer respectively. It was more or less similar to the growth rates of *P. damicorni* (3.90 mg. skel. d^{-1}) and also of *Pocillopora verrucosa* (5.40 mg. skel. d^{-1}) at 3m. But it was lower than the *Echinopora gemmacea* (13.46 mg. skel. d^{-1}) and *Stylophora pistillata* (56.03 mg. skel. d^{-1}) of even at 1m from the Red Sea (Al-Sofyani, 1991). In winter, the mean growth rates of *S. hystrix* was (1.8 mg. skel. d^{-1}) and for *L. corymbosa* it was 5.9 mg. skel. d^{-1}at 3m respectively.

Hence, the growth rate of the corals in the present study were higher in summer than in winter. But it was still lesser than the other studies which fallen within the range of 12.5 mg. skel. d^{-1} to 51.6 mg. skel. d^{-1} for several other coral species from 2 to 10m depths (Davies, 1984; Edmunds and Davies, 1986; Davies, 1989, 1990 and 1991; Al-Sofyani, 1991). Another study by Al-Sofyani and Floos, 2013 showed that the values in winter were 6.08 mg. skel. d^{-1} and 7.44 mg. skel. d^{-1} for *Pocillopora damicorni*s and *Pocillopora verrucosa* respectively.

Table. (3) The Daily Mean Skeleton Growth Rate of *S. hystrix* and *L. corymbosa* Recorded at 3 m Depth during Summer and Winter .

	S. hystrix				*L. corymbosa*			
Growth Rate Skeleton	**Summer 2009**	**Winter 2010**	**t-test**	**p-value**	**Summer 2009**	**Winter 2010**	**t-test**	**P-value**
mg Skeleton. d^{-1}	1.9	1.8			7.9	5.9		
S.D±	0.6	0.8	0.23	0.82	3.5	2.9	1.9	0.06
n	(21)	(20)			(17)	(27)		

***significance (P≤ 0.05)**

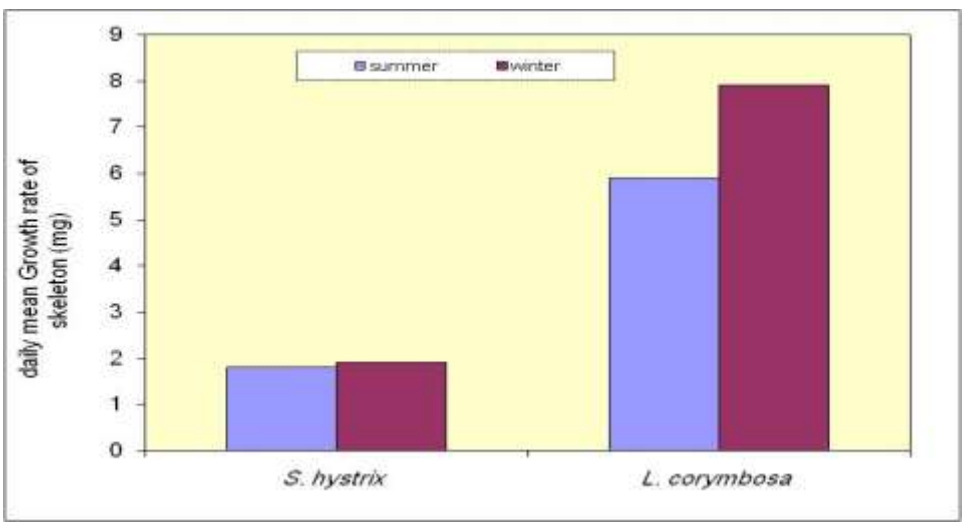

Figure. (7) Comparison of the Daily Mean Skeleton Growth Rate of the Two Species at 3m Depth during Summer 2009 and Winter 2010.

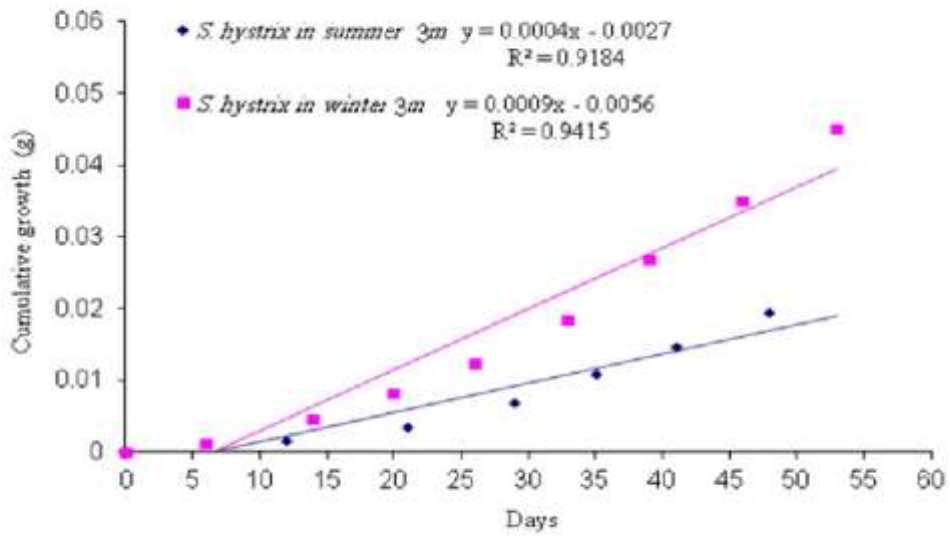

Figure.(8) Cumulative Skeleton Growth rate of *S. hystrix* at 3m Depth during Summer 2009 and Winter 2010.

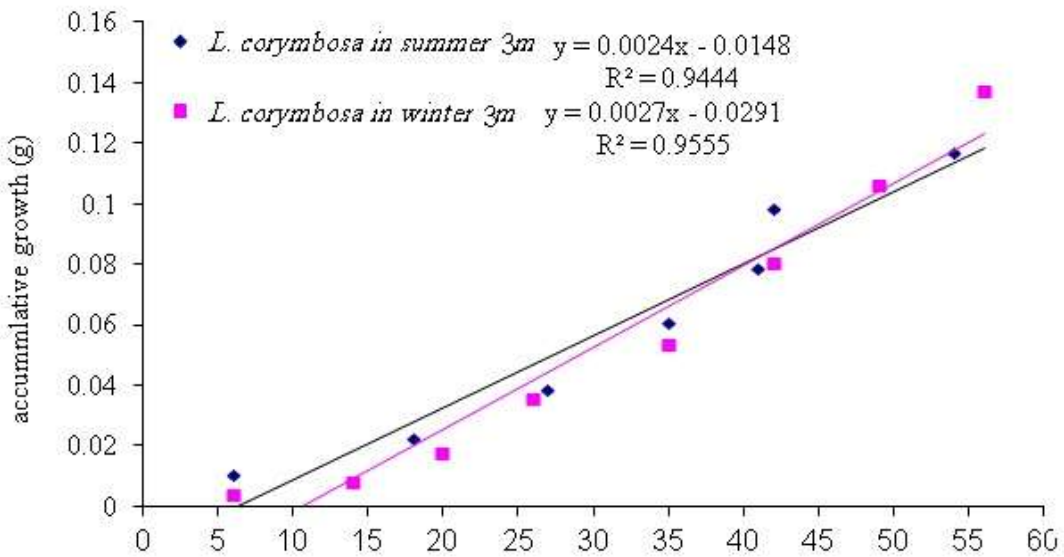

Figure. (9) Cumulative Skeleton Growth Rate of *L. corymbosa* at 3m Depth during Summer 2009 and Winter 2010

Conclusion

The lower respiration rate of *L. corymbosa* of the present study may be due to the higher tissue biomass which is not active than the *S. hystrix*..

The mean maximum gross photosynthesis (Pgmax) on the basis of biomass were higher in *S. hystrix* than in the *L. corymbosa*. This may be due to the higher number of zooxanthellae when expressed on both biomass.

The reduction in coral respiration rates with an increasing temperature was associated with a reduction in number of zooxanthellae .It may be possibly due to the translocation of organic material from the algae due to decrease in photosynthesis, in addition to decrease the growth rate of skeleton.

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Seasonal Variation in Photosynthesis, Dark Respiration and Growth Rate of Two Reef Building Corals in the Red Sea Coast

الاختلافات الموسمية في معدل عملية البناء الضوئي ، معدل التنفس المظلم ومعدل النمو لنوعين من المراجين البانية في ساحل البحر الأحمر

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المستخلص

تم في هذه الدراسة جمع نوعين من المراجين الصخرية سريتوابورا هستريكس ولوبوفيليا كرمبوسا من ساحل البحر الأحمر لدراسة معدل عملية البناء الضوئي و معدل التنفس المظلم ومعدل النمو في الصيف والشتاء. وأظهرت النتائج اختلافات قليلة في معدل التنفس لطحالب الزوكزانثيلا بين النوعيين وينخفض معدل التنفس بشكل تدريجي في كلا النوعين طبقا لاختلاف الموسم. ترتبط شدة الإضاءة في المرجان بعلاقة رياضية غير خطية حيث نجد أن المنحني يمثل معادلات رياضية متعددة لوصف العلاقة بين البناء الضوئي وشدة الإشعاع (P v I) لوحظ انخفاض معدل البناء الضوئي الكلي في نوع سرياتوبورا هيستريكس في الشتاء مقارنة بالصيف ولهذا السبب فهي حساسة للتغيرات في درجات الحرارة . وعلي العكس فان معدل البناء الضوئي الكلي في نوع اللوبوفيليا كرومبوسا اعلى في الصيف مقارنة بالشتاء. وقد يعود السبب في ذلك إلي انخفاض مستويات الإضاءة والى انخفاض في درجة حرارة مياه البحر. تؤثر نوعية وكثافة الإضاءة ودرجة حرارة ماء البحر أثناء الصيف علي معدل النمو لسريتوابورا هستريكس ولوبوفيليا كرمبوسا ولهذا السبب متوسط معدل التنفس للطحالب يزداد اتماتيكي مع ازدياد درجة الحرارة فالانخفاض في معدل تنفس المرجان مع ازدياد درجة الحرارة صاحب انخفاض في عدد الطحالب الزوكزانثيلا .