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Zooxanthellae and chlorophyll *a* responses in the scleractinian coral *Montastrea cavernosa* at Triángulos-W Reef, Campeche Bank, Mexico

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Abstract: Samples of *Montastrea cavernosa* were collected from 3 m to 18 m depth, in the leeward slope of Triángulos-W Reef, Campeche Bank, Mexico. Population density of zooxanthellae and chlorophyll *a* contents per square centimeter and per zooxanthellae were determined for each coral colony. These parameters did not differ significantly among depths. The regressions of chlorophyll *a* concentration per square centimeter and per zooxanthellae as a function of population density of zooxanthellae present the same trends of those reported by other authors. It is possible that nitrogen availability controls these parameters in *M. cavernosa* in natural conditions in the reef.

Key words: Campeche Bank, chlorophyll *a*, coral reefs, hermatypic, zooxanthellae.

The hermatypic corals are responsible for the construction of modern reefs, they provide the framework and a good deal of infilling sediments that forms the basic wave resistant structure known as coral reef (Dustan 1979). The importance of the ecological role played by hermatypic corals is due to the evolution of the symbiotic relationship these organisms have with dinoflagellates known as zooxanthellae (Goreau *et al.* 1979).

The responses of zooxanthellae and photosynthetic pigments in relation to depth have been studied by Drew (1972), Dustan (1979, 1982), Titlyanov *et al.* (1980), Zvalinski *et al.* (1980), Falkowsky and Dubinsky (1981), Kinzie *et al.* (1984), McCloskey and Muscatine (1984), Vareschi and Fricke (1986), and in relation to inorganic nitrogen availability by Hoegh-Guldberg and Smith (1989) and Muscatine *et al.* (1989).

The present study was undertaken to determine if zooxanthellae population density and chlorophyll *a* content varied as a function of depth and to observe the relationship between chlorophyll *a* and zooxanthellae population density in natural conditions for *Montastrea cavernosa* (Linnaeus, 1767) at Triángulos-W Reef.

MATERIAL AND METHODS

Samples of *M. cavernosa* were collected with hammer and chisel from the leeward slope of Triángulos-W Reef, which is located at 20° 57'N and 92° 14' W in the Campeche Bank, Mexico (Fig. 1). Samples were collected every three meters depth from 3 to 18 m, three specimens at each depth, with the exception at 3 m were only one colony was found, and were brought to the surface in individual plastic bags. Once on board the dive boat, they were placed in shaded container to maintain a stable temperature and to avoid zooxanthellae expulsion (Dustan 1979, Gil-Turnes and Corredor 1981).

The coral colonies were "waterpicked" (Teledyne Water-Pick) clean of all tissue with filtered seawater (Millipore 0.45 μ), the resulting "blastate" was collected in a clean plastic bag (Johannes and Wiebe 1970). For each

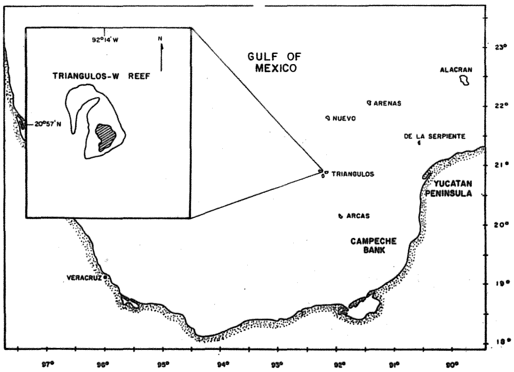

Fig. 1. Location of the Triángulos-W Reef.

sample total "blastate" volume was gently homogenized and recorded.

To determine the population density of zooxanthellae ten replicate cell counts were done in a hemacytometer. The surface area of the skeleton was measured using the aluminium foil method (Marsh 1970).

To extract chlorophyll *a* of each sample 10 ml of "blastate" buffered with $MgCO_3$ to avoid chlorophyll denaturation (Lorenzen and Jeffrey 1978), were centrifugated (five minutes, 5000 rpm), the supernadant was eliminated and the pellet was resuspended in 10 ml of reagent acetone and refrigerated for 36 h (see Lorenzen and Jeffrey 1978). To eliminate skeletal residues extracts were then filtered (Wattman 40), and measurements of optical densities of each one were taken at 630 and 663 nm with a Bausch & Lomb Spectrophotometer (Spectronic 21). These data were then converted to pigment concentrations using the equation of Jeffrey and Humphrey (1975), and chlorophyll *a* concentrations per square centimeter and per zooxanthellae were calculated.

RESULTS

Averages of population density of zooxanthellae and chlorophyll *a* concentrations per square centimeter and per zooxanthellae by depth are presented in Table 1.

Zooxanthellae densities ranged from 1.99 $x10^6$ cells/cm² for corals collected at 3 m depth to 2.72 $x10^6$ cells/cm² for those collected at 15 m depth. One-way ANOVA after outlier rejection showed no differences in cell densities among depths (P=0.94). The amount of chlorophyll *a* per square centimeter (25.44 µg/cm² at 15 m to 15.59 µg/cm² at 3 m) did not differ significantly among depths (P=0.59).

Chlorophyll *a* content per cell ranged from 7.74 $x10^{-6}$ µg/cell for 12 m depth coral samples to 13.04 $x10^{-6}$ µg/cell for those of 9 m depth, and did not differed significantly among depths (P=0.27). The relation between chlorophyll *a* and zooxanthellae population density is shown in Fig. 2; the amount of chlorophyll *a* per cm² increases with the cell density (r= 0.96), opposing this trend is the decrease in the content of chlorophyll *a* per zooxanthellae as the population density increases (r= -0.33).

TABLE 1

Population densities of zooxanthellae (DZ) and chlorophyll a contents per area (ChlaA) and per zooxanthellae (ChlaZ)

Depth (m)		DZ cells/cm²x10⁶	ChlaA µg/cm²	ChlaZ µg/cellx10⁻⁶
	mean	1.99	15.59	8.72
3	s.e.m.	--	--	--
	n	1	1	1
	mean	2.54	23.82	10.38
6	s.e.m.	1.59	13.23	0.58
	n	3	3	3
	mean	2.01	19.58	13.04
9	s.e.m.	0.93	5.98	2.58
	n	3	3	3
	mean	2.41	15.63	7.74
12	s.e.m.	0.33	4.99	2.44
	n	3	3	3
	mean	2.72	25.44	9.94
15	s.e.m.	0.45	4.98	0.75
	n	3	3	3
	mean	2.42	18.59	9.32
18	s.e.m.	0.68	3.93	4.19
	n	3	3	3

DISCUSSION

Our results showed no signifficant differences in algal population density and chlorophyll *a* per area and per zooxanthellae in relation to depth (P=0.94, P=0.59 and P=0.27, respectively). Possibly the depth range in the

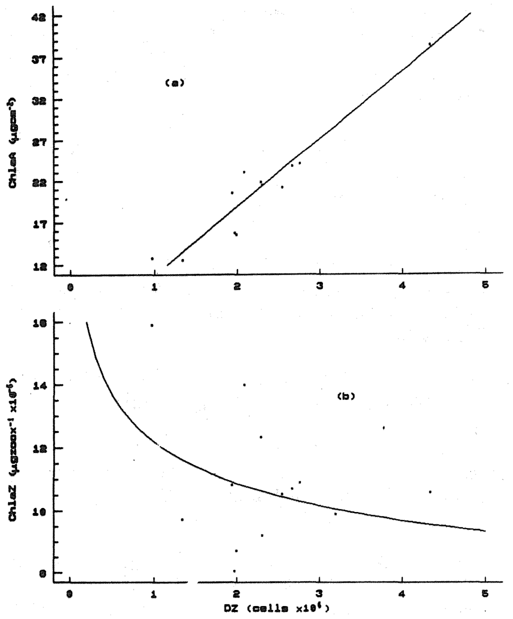

Fig. 2. Amount of chlorophyll *a* (a) per area (ChlaA) and (b) per zooxanthellae (ChlaZ) as a function of the population density of zooxanthellae (DZ). Regression lines are: (a) ChlaA = 2.63 + (8.15 x10^{-6} (DZ)) (r=0.95) and (b) ChlaZ = 1.19 x10^{-4} ($DZ^{-0.16}$) (r=-0.33)

present research was not large enough to observe changes in light intensities and so on these parameters (at sampling time, at 18 m depth the seawater allowed, to the eye of the diver, a visibility of approximately 15 m). McCloskey and Muscatine (1984) reported a decrement in zooxanthellae densities only at light intensities very attenuated by depth.

With respect to the observed trends of the amount of chlorophyll *a* per area and per algal cell as a function of population density of zooxanthellae (Fig. 2), they have been recently reported by other authors, for the first time by Hoegh- Guldberg and Smith (1989) in experimental conditions for *Seriatopora hystrix* with correlations of 0.88 and -0.67 respectively. Muscatine *et al.* (1989) found correlations of 0.88 for the content of chlorophyll *a* per area and 0.35 for the content of the pigment per zooxanthellae as a function of population density in experimental conditions for *Stylopora pistillata*. Beltrán-Torres (1991) obtained correlation values of 0.30 and -0.59 respectively in natural conditions for *M. cavernosa* in La Blanquilla Reef, Veracruz. And Carricart- Ganivet (in preparation) found a correlation of 0.56 for the content of chlorophyll *a* per square centimeter and a correlation value of -0.34 for the content of the pigment per zooxanthellae as a function of zooxanthellae density also in natural conditions for *M. cavernosa* in El Verde Reef, Veracruz.

High correlation values between chlorophyll *a* content per cm^2 and zooxanthellae per cm^2 and low correlation values between chlorophyll a content per algal cell and zooxanthellae population density are indicative of the influence of nitrogen availability, (see Hoegh-Guldberg and Smith 1989, Muscatine *et al.* 1989). So, our results showed that posibly nitrogen availability controls population density of zooxanthellae and amount of chlorophyll *a* per algal cell and per area in *Montastrea cavernosa* under natural conditions in Triángulos-W Reef.

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RESUMEN

Se recolectaron muestras de *Montastrea cavernosa* desde los 3 hasta los 18 m de profundidad en el talud de sotavento del Arrecife de Triángulos-W, Banco de Campeche, México. Para cada colonia de coral se determinaron la densidad poblacional de zooxantelas y los contenidos de clorofila *a* por centímetro cuadrado y por zooxantela. Los parámetros estudiados no difirieron significativamente entre profundidades. Se observó la misma tendencia registrada por otros autores en las regresiones de las concentraciones de clorofila *a* por centímetro cuadrado y por zooxantela en función de la densidad poblacional de zooxantelas. Es posible que la disponibilidad de nitrógeno controle estos pará-

metros en *M. cavernosa* en condiciones naturales en este arrecife.

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