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Al-Sofyani, A. A.; Niaz, G. R.

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A comparative study of the components of the hard coral *Seriatopora hystrix* and the soft coral *Xenia umbellata* along the Jeddah coast, Saudi Arabia

Estudio comparado de los componentes del coral duro *Seriatopora hystrix* y del coral blando *Xenia umbellata* en la costa de Jeddah, Arabia Saudita

A. A. Al-Sofyani¹ and G. R. Niaz²

¹Marine Biology Department, Marine Science Faculty, King Abdulaziz University. P.O. Box 53190, Jeddah-21583, Saudi Arabia

²Marine Chemistry Department, Marine Science Faculty, King Abdulaziz University. P.O. Box 53190, Jeddah-21583, Saudi Arabia
Sofyani@hotmail.com

Resumen.- En este estudio se compararon la estructura de los pólipos y los tipos celulares del coral duro *Seriatopora hystrix* y del coral blando *Xenia umbellata*, además de la composición de los ácidos grasos en sus tejidos. *S. hystrix* mostró una aparente carencia de células alimenticias especializadas, particularmente, un pequeño número de células glandulares mucosas y un bajo porcentaje de nematocistos conteniendo veneno. Los P-mastigóforos estuvieron presentes en el 1,52-5,7% de los nematocistos y los B-mastigóforos en el 1,28%. Por el contrario, hubo un alto porcentaje de nematocistos holotricos (24,86 - 55,5%) en los tentáculos y filamentos mesentéricos, respectivamente. Las zooxantelas fueron abundantes en la gastrodermis. Estas características sugieren que *S. hystrix* depende esencialmente de una nutrición autótrofa. Los pólipos de *X. umbellata* no presentaron cnidae, y las glándulas mucosas fueron abundantes, especialmente en la parte más basal del pólipo. La presencia de materia particulada en el celenteron y el bajo número de zooxantelas indican que *X. umbellata* es un suspensívoro, que utiliza mucus para atrapar las partículas en los tentáculos pinados.

Un estudio comparativo de su composición química también reveló diferencias entre ambas especies. *X. umbellata* presentó un alto contenido proteico y lipídico mientras que *S. hystrix* se caracterizó por un alto contenido de carbonato de calcio. En *S. hystrix*, los ácidos grasos fueron predominantemente saturados (87,3%), siendo 16:0 y 18:0 los más abundantes. *X. umbellata* mostró predominancia de ácidos grasos insaturados (77,7%), siendo 16:1 y 18:1 los más abundantes. Las diferencias morfológicas y en composición bioquímica sugieren que *S. hystrix* tiene mayor dependencia de una alimentación autótrofa mientras que *X. umbellata* es mas bien un suspensívoro heterótrofo.

Palabras clave: Tipo cnidae, competencia, arrecifes de coral, estrategias de alimentación, Mar Rojo

Abstract.- In this study, the structure of the polyps and the cell types of the hard coral *Seriatopora hystrix* and the soft coral *Xenia umbellata* were compared, together with the composition of the fatty acids in their tissues. *S. hystrix* displayed an apparent lack of specialized feeding cells, notably the relatively small number of mucous gland cells and the low percentage of venom containing nematocysts. P-mastigophores accounted for 1.52-5.7% and, B-mastigophores for 1.28% of the nematocysts. Conversely there was a high percentage of holotrichs nematocysts (24.86 - 55.5%) in the tentacles and mesenterial filaments respectively. Zooxanthellae were abundant in the gastrodermis. These characteristics suggest that *S. hystrix* relies essentially upon autotrophic nutrition. The polyps of *X. umbellata* were devoid of cnidae, and mucous glands were in abundance, particularly in the lower part of the polyp. The presence of particulate matter in the coelenteron, and low number of zooxanthellae indicate that *X. umbellata* is a suspension feeder, using mucus to trap the particles on the pinnate tentacles.

Differences were also revealed by a comparative study of their chemical composition. *X. umbellata* had a high protein and lipid content, whilst *S. hystrix* was characterized by high calcium carbonate content. In *S. hystrix*, the fatty acids were found to be predominantly saturated fatty acids (87.3%), the most abundant being 16:0 and 18:0. *X. umbellata* showed a predominance of unsaturated fatty acids (77.7%), the most abundant being 16:1 and 18:1. The differences in morphology and in biochemical composition suggest that *S. hystrix* has a greater reliance on autotrophic feeding whilst *X. umbellata* is a more heterotrophic suspension feeder.

Key words: Cnidae type, competition, coral reefs, feeding strategies, Red Sea

Introduction

Corals are ubiquitous in the marine organization. The Red Sea contains about 47 genera of different corals that include about 250 different species of various types of coral (Ditlev 1980). Most of these are stony corals with a few soft corals. They have different types of corallites and therefore exhibit different physiological adaptation to their marine environment. The type of nutritional regime can be studied by chemical and biological examination. The present study was designed to analyze comparatively the chemical and the biological aspects and to study the mode of nutrition in two coral species.

Differences in feeding strategy between two different types of corals, the stony coral *Seriatopora hystrix* Dana, 1846 and the soft coral *Xenia umbellata* Savigny, 1816 were investigated. *S. hystrix* is a widespread species occurring in a variety of habitats from shallow sublittoral down to around 30 m depth. It is most abundant in sheltered lagoon areas where it develops large colonies. In such areas it commonly coexists and competes with *X. umbellata*.

Until now, no comparative studies on the histology and biochemistry of coral polyps have been made in order to relate cell type, size and chemical constitution to different modes of feeding. Most of our knowledge on the feeding behaviour of the polyps has come from observations on ciliary activity and from the morphology of the coral polyp's reef. Corals with a small polyp diameter should be predominantly phototrophic while those species with large polyp or a massive form should show a greater degree of heterotrophism (Wellington 1982). The mucous-gland cells, which secrete the mucus for suspension feeding, occur mainly in the epidermal layer. However, it has been shown that whilst the mucus is used in protection and cleansing, its main use is in food capture (Goldberg 2002).

The epidermal cnidae serve a variety of functions: prey capture, adhesion, defense and aggression (Thorington & Hessinger 1990). The two major groups of cnidae involved in feeding are spirocysts, which capture zooplankton by attaching to the surface of the prey, and nematocysts, which are used to capture prey by injection of a toxic substance (Mariscal 1974). Corals can also obtain nutritional benefit from their zooxanthellae. It was observed that corals with symbiotic algae had an increased lipid/protein ratio,

indicating the translocation of photosynthetic product into the host tissue (Szmant-Froelich & Pilson 1980). In addition to this observation it was observed that corals feeding on some prey had greater biomass i.e. it was observed that when two species of coral *Stylophora pistillata* were grown under different conditions, one group was fed with *Artemia* sp. and the second group was kept under starvation. Fed corals exhibited greater biomass compared to starved corals (Reynaud *et al.* 2002).

Zooxanthellae can procure their food via photosynthesis and can pass it on to the animal. When the hard coral *Pocillopora damicornis* was kept in darkness, the tissue biomass was significantly lower than when kept in sunlight, indicating that it was dependant upon energy derived from photosynthesis by zooxanthellae (Clayton & Lasker 1982). Subsequently, it was confirmed that the zooxanthellae are the major sites of lipid synthesis in the light (Kellogg & Patton 1983). It now appears likely that during photosynthesis, labeled carbon is incorporated into lipid, mainly as triglyceride and glycerol. The glycerol is thought to be used as a substrate for respiration by the host cells (Davy & Cook 2001). The nature of the lipid in coral tissues is related to the mode of nutrition. Corals with predominant unsaturated fatty acids relied more on plankton capture, while corals with abundant saturated fatty acids relied more on the photosynthetic products translocated from their zooxanthellae (Meyers 1979). Oku (2003) observed in coral *Montipora digitata* the low molecular weight compounds; sugars and amino acids once translocated from zooxanthellae to host cell were metabolized towards lipogenesis as well as glycerol production. It was studied by a Russian group of workers (Papina *et al.* 2003) that when zooxanthellae were separated from the host animal and their fatty acids were determined separately by GC-MS, it was revealed that the zooxanthellae had a higher percentage of unsaturated fatty acids, so in short it is a point of controversy among the scientists that it is not always necessary that symbiotic algae would always reveal the formation of saturated fatty acids. A comparative light-dark feeding study of the coral *Galaxea fascicularis* showed that in dark the metabolic requirement of the zooxanthellae were in part met from the animal host through a heterotrophic mode of nutrition (Al-Moghrabi 1995), so it is difficult to anticipate that the unsaturated compounds would be predominantly from the host cell, an element of uncertainty is observed.

This study was undertaken therefore to determine whether *S. hystrix* and *X. umbellata* displayed morphological and biochemical composition differences that may reflect differences in their feeding strategy.

Material and methods

Samples were collected from Ubhur Creek (Fig.1) during December 2005, from a depth of 3 m. This creek lies at the north of Jeddah; it is 11 km long, its maximum width is 350 m and the maximum depth is 35 m (approximately in the middle of the creek). The salinity ranges from 39 to 42 psu during most part of the year. Samples for histological examination were relaxed for six hours in solution of 3.5% MgSO_4 and then preserved in 7% sea water/formalin for at least three days. Thereafter, specimens of stony coral were transferred to a 7% solution of nitric acid to decalcify the skeletons. The decalcified hard coral polyps and

soft corals were washed with distilled water and preserved in 70% ethanol for histological study. Parts of the specimens that were to be examined for lipid were post-fixed in potassium dichromate-osmium tetroxide solution (50 ml 2% osmium tetroxide and 50 ml 5% potassium dichromate) for eight hours. Thereafter, the post-fixed samples were washed in running water for two hours and preserved in 70% ethanol.

The preserved specimens were dehydrated in a series of strengths of ethanol, and then cleared in xylene. The cleared specimens were infiltrated and embedded in paraffin wax. Serial sections, 7 μm in thickness, were cut and then stained with Haematoxylin and Eosin. Another series of sections were stained with Alcian Blue and Neutral Red, to differentiate the mucous-glands. The stained sections were cleared with xylene and mounted in Canada balsam.

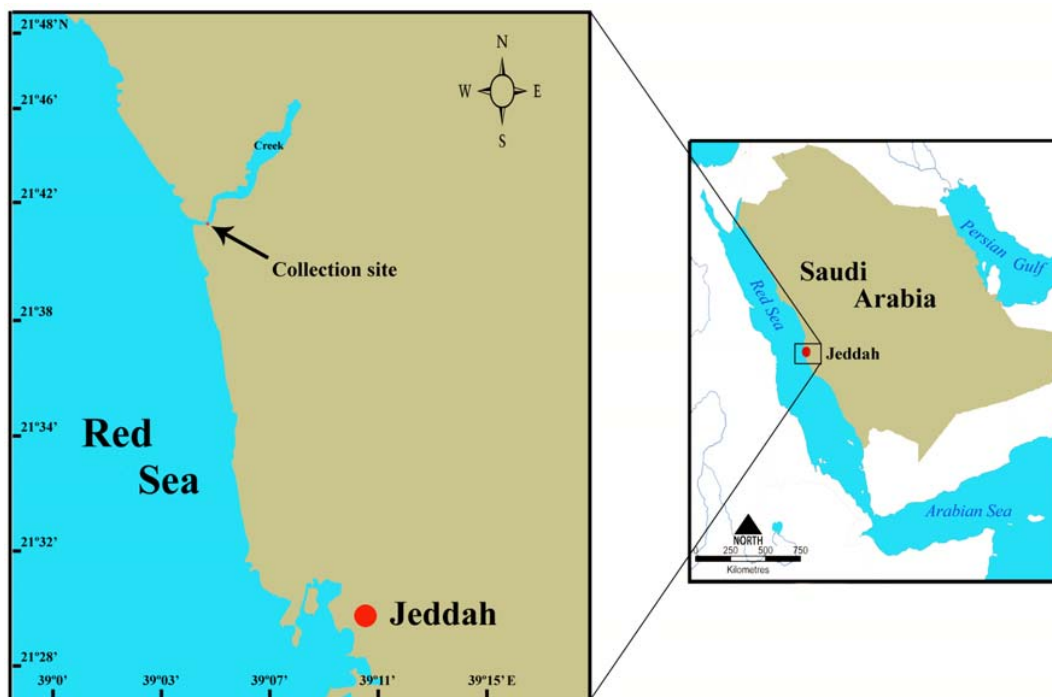


Figure 1

Map of the Red Sea showing the location of the study site at the entrance of Ubhur Creek

Mapa del Mar Rojo mostrando la ubicación del sitio de estudio a la entrada de Ubhur Creek

Samples of tentacle tips, mesenterial filament and oral disc were dissected from the polyps and placed in a solution of 5% potassium hydroxide overnight at a temperature of 5°C. Pieces of tissue were then mounted on a slide and squashed beneath a coverslip. The number, type and size of cnidae were recorded using a microscope with a times 1000 oil-immersion objective. The oral disc was divided into four pieces before counting, and the mesenterial filaments divided into two pieces. Estimates of the total population of cnidae were then made. Biomass measurements were determined according to the method of Davies (1991).

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* in sea water 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)

The skeleton density of *S. hystrix* was obtained by removing the tissue from the skeleton. A group of ten nubbins from *S. hystrix* was left in 10% solution of chlorox and seawater for two days. The skeleton was then cleaned with a water jet to remove any residual tissue. Their buoyant weights were recorded in seawater and its density was measured immediately before buoyant weighing the skeleton. Thereafter, the skeletons were rinsed in distilled water and dried to a constant weight at 60°C. The skeleton density was then calculated from the equation of Davies (1989).

Skeletal weight and dry tissue weight were obtained by a group of 10 nubbins which were buoyant weighed and then fixed in 7% formalin, decalcified in 10% nitric acid and then dried the resultant tissue to constant weight at 60°C. The dry tissue weight was related to dry skeletal weight and expressed as mg dry tissue wt/g skeletal wt. Skeletal weight and number of zooxanthellae were calculated by fixing the nubbins in

formalin, decalcifying in 10% nitric acid and then homogenizing the distilled water-washed resultant tissue with a hand-held potter homogenizer, after which the suspension was centrifuged and distilled water-washed three times. They were resuspended in 1 mL of filtered distilled water and zooxanthellae concentrations within the cell were measured on a sub sample using a haemocytometer. The relationship between the zooxanthellae number and the dry tissue weight was estimated indirectly. Aluminum foil was fitted carefully on to the surface of each nubbin. The fitted foil was then weighed and a value for surface area derived, in order to obtain a relationship between surface area and skeletal weight. The number of polyps per cm² was obtained from the number of calices per cm².

For chemical analysis, the top 2 cm of the branch of *S. hystrix* was used. The skeleton was examined under a stereo microscope, and found to be free from endolithic algae and gall-forming crabs. Water content was determined by drying the coral at 70°C for 48 h till constant weight. Residual matter was estimated by heating in a muffle furnace at 650°C for 48 h till constant weight. These corals were collected at a depth of 3 m. Light is probably the most important factor after temperature as it effects the symbiosis between hermetic coral and zooxanthellae which live within the gastrodermal tissues of the coral and are apparently essential for the calcification, because the light intensity decreases exponentially with increasing depth; active coral reef building greatly diminishes below a depth of 25 m (Levinton 1982). Chlorophyll was determined by dissolving it in 90% aqueous acetone and measuring the absorbance at 665 nm and 645 nm for 'a' and 'b' type chlorophyll, respectively (Lichtenthaler *et al.* 1987).

Lipids were extracted using a modified Folch method (Folch *et al.* 1957). In the case of *S. hystrix*, additional amounts of lipids were obtained by decalcifying the residual matter with 10% formic acid (Harland *et al.* 1993). Methyl esters were prepared by hydrolyzing the lipid with 1 mL ethanol/potassium hydroxide solution under reflux for one hour. It was extracted with ether and partitioned with water. The aqueous layer neutralized with 5 mL hydrochloric acid and the free fatty acids extracted with chloroform. The free fatty acids were dissolved in tetrahydrofuran containing 5% methanolic hydrogen chloride solution. It was refluxed for 2 h. Water containing 5% potassium chloride was added, the

methyl esters were extracted with hexane. The hexane layer was washed with 2% potassium bicarbonate, dried over anhydrous sodium sulphate and the solvent evaporated in a stream of nitrogen. The fatty acid methyl esters were analyzed using gas chromatography (Shimadzu-17A) equipped with a fused silica capillary column (30 m * 0.25 mm i.d.) coated with ergs linked SP-2310. The oven temperature was programmed from 150 to 250°C at 50 min⁻¹, the final temperature was maintained for 5 min. The samples were further analyzed by gas-chromatography mass – spectrometry (GC-MS) on a Shimadzu QP-5000 quadrupole.

Results

Morphology

In *Seriatopora hystrix*, living colonies showed a variety of colours from light brown to brown-green. The polyps were extended during the day. Expanded polyps are 0.1 mm in diameter and up to 0.6 mm in length, with 12 short (0.2 mm) white tipped tentacles.

The epidermal layer comprised elongated columnar cells, nematocysts and a few mucous-gland cells (Fig. 2A, B). The mucous-gland cells were present in small

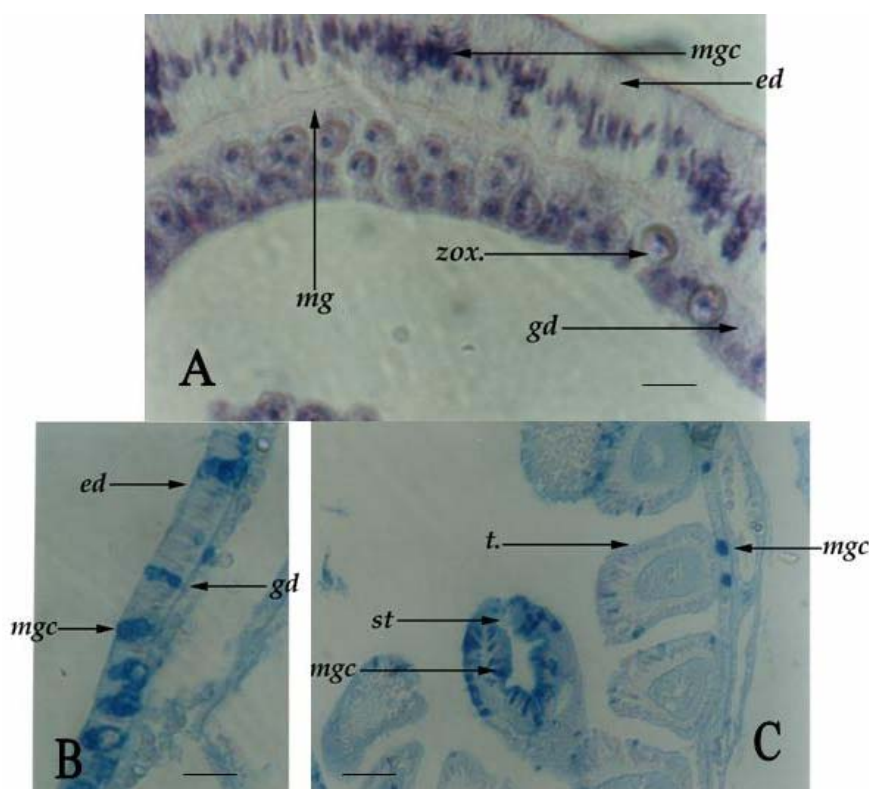


Figure 2

Histological sections through the polyp of *S. hystrix*. A. Cross-section through coenosarc, showing details of cell types occurring in each layer; ed, epidermis; gd, gastrodermis; mg, mesogloea; mgc, mucus-gland cell; zox, zooxanthellae. B. and C. Cross-section through the polyp. Note the shape and the color of mucus-gland cells when stained with Alcian Blue at pH 1. st, stomodaeum; t, tentacle

Cortes histológicas a través del pólipo de *S. hystrix*. A. Sección transversal a través de un coenosarco, mostrando detalles de los tipos celulares de cada capa; ed, epidermis; gd, gastrodermis; mg, mesoglea; mgc, célula glandular mucosa; zox, zooxantelas. B. y C. Corte transversal a través del pólipo. Note la forma y el color de las células glandulares mucosas al ser teñidas con azul alcian a pH 1. st, estomodeo; t, tentáculo

numbers in all tissues except the oral disc where they were present in large numbers. They are flask-shaped or elongated about 15.6 μm in length (Fig. 2 B.C.). Lipid was stained black in osmium-tetroxide-fixed tissue. It was observed as black particles ranging from 6.0 to 19.5 μm in diameter between the zooxanthellae,

and in the gastrodermis of the lower half of the polyp (Fig. 4A.B.). Lipids were never observed in the epidermal layer.

Holotrichs and spirocysts were the predominant cnidae in the tentacles of *S. hystrix* (Fig. 3A). Their

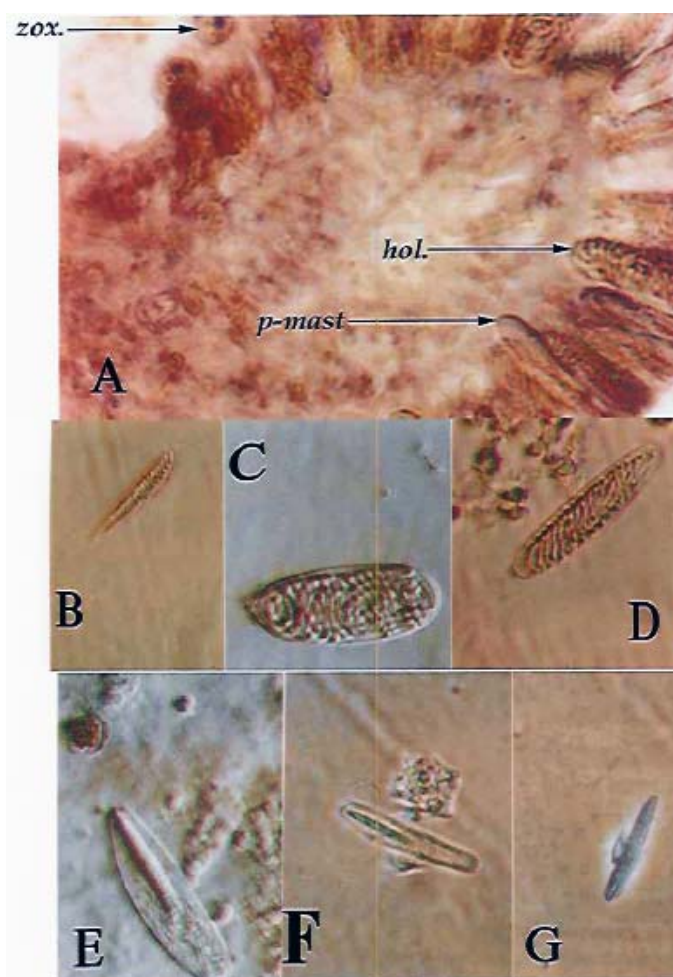


Figure 3

Longitudinal section through the tentacle of *S. hystrix*, showing cnidae types. A. hol., holotrich; p-mast, p-mastigophore. B-G. Types of cnidae found in. B, spirocysts; C, holotrich in tentacles; D, holotrich in stomodaeum; E, p-mastigophore in tentacle; F, p-mastigophore in stomodaeum and G, b-mastigophore in stomodaeum

Corte longitudinal a través del tentáculo de *S. hystrix*, mostrando los tipos de cnidae. A. hol., holotricho; p-mast, p-mastigóforo. B-G. Tipos de cnidae encontrados. B, espirocistos; C, holotrichos en tentáculos; D, holotrichos en estomodeo; E, p-mastigóforo en tentáculo; F, p-mastigóforo en estomodeo y G, b-mastigóforo en estomodeo

numbers were 1636 ± 103 and 736 ± 54 per polyp respectively (Table 1). The mean number of P-mastigophore (100 ± 15) and B-mastigophore (84 ± 10) were relatively low. However, spirocysts were absent in the oral disc, and P-mastigophore, holotrichs and B-mastigophore were considerably lower in number.

Mesenterial filaments were devoid of spirocysts and B-mastigophores, while holotrichs were abundant (3620 ± 775) and P-mastigophores were present but in lower number (378 ± 34) (Fig. 3B-G). The distribution of the zooxanthellae was uniform throughout the polyp. Their average number was $1.57 \times 10^{-5} \text{ mg}^{-1}$ dry tissue (Table 2).

Table 1

Average number, size and percentage distribution of cnidae type per polyp in each tissue type in *S. hystrix* (mean \pm standard deviation and sample size). Where size was uniform no standard deviation is given

Número promedio, talla y porcentaje de distribución de tipo de cnidae por pólipo en cada tipo de tejido en *S. hystrix* (media \pm desviación estándar y tamaño de muestra). Cuando la talla fue uniforme no se incluye la desviación estándar

Cnidae type		Tentacle	Oral disc	Filament
Spirocysts	Mean	736.00	*	*
	\pm s.d.(n)	53.96(10)	*	*
	Size μm	15.60	*	*
	Percentage %	11.18	*	*
P-mastigophores	Mean	100.0	18.0	378.0
	\pm s.d.(n)	14.96(10)	1.41(5)	34.2(5)
	Size μm	27.3	23.4	31.2
	Percentage %	1.52	0.27	5.7
B-mastigophores	Mean	84.00	9.60	*
	\pm s.d.(n)	9.79(10)	19.5(5)	*
	Size μm	19.5	19.5	*
	Percentage %	1.28	0.15	*
Holotrich	Mean	1636.0	*	3620.4
	\pm s.d.(n)	102.9(9)	*	775(5)
	Size μm	31	*	31.2
	Percentage %	24.86	*	55.0

* Not observed

Table 2

The mean skeletal and tissue characteristics of *S. hystrix* and *X. umbellata* at the study site

Principales características esqueléticas y del tejido de *S. hystrix* y *X. umbellata* en el sitio de estudio

Characteristics	<i>S. hystrix</i>	<i>X. umbellata</i>
Skeleton		
Skeletal density $\text{g}\cdot\text{cm}^{-3}$	$2.78 \pm 0.006(10)$	*
Biomass		
Colony		
$\text{mg}\cdot\text{d.t.}\cdot\text{g}^{-1}$ skel.	$12.50 \pm 1.10(10)$	
$\text{mg}\cdot\text{d.t.}\cdot\text{g}^{-1}$ wet weight	-	$7.78 \pm 0.55(10)$
$\text{cm}^2\cdot\text{g}^{-1}$ skeleton	$0.06 \pm 0.39(10)$	*
$\text{mg}\cdot\text{d.t.}\cdot\text{cm}^{-2}$	$0.81 \pm 0.58(10)$	*
N° polyps cm^{-2}	$34.38 \pm 0.00(10)$	*
Zooxanthellae		
$\text{N}^\circ 10^5 \text{mg}^{-1}$ d.t.	$6.02 \pm 1.42(10)$	$1.57 \pm 0.19(10)$

* Polyp does not have skeleton

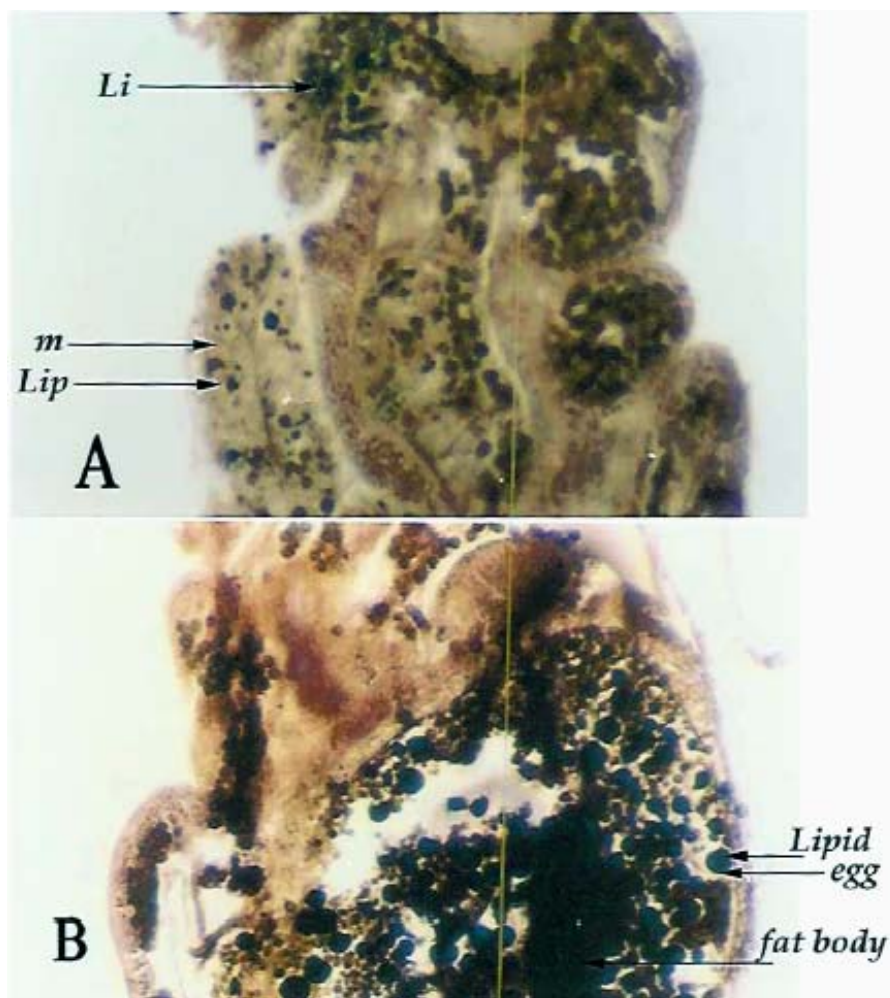


Figure 4

Longitudinal section through the mesentery of *S. hystrix*, showing black-stained lipid, lip; m, mesentery (A) and black-stained lipid, and fat body in the egg (B)

Corte longitudinal a través del mesenterio de *S. hystrix*, mostrando los lípidos teñidos de negro, lip; m, mesenterio (A) y los lípidos teñidos de negro y el cuerpo graso en el huevo (B)

In *Xenia umbellata*, the color of the living colonies ranged from light to dark brown. The polyp, which has eight long pinnate tentacles (8.0 mm), was 2.6 cm long and 16 mm in diameter. The polyp was found to be completely devoid of cnidae. The epidermis of the polyp wall was comprised of columnar epithelial cells, along with bean shaped mucous-gland cells 23 μ m long (Fig. 5B, C). The number of mucous-glands was high in the lower part of the polyp and did not stain blue

with Alcian Blue at pH 1.0. The mucous-glands found in mesoglea of mesentery were oval in shape (15 μ m long), and stained reddish with Alcian Blue at pH 1.0 (Fig. 5A). Cross sections through the coelenteron of *X. umbellata* indicated that it was filled with mucus and unidentifiable small food particles and a small crustacean (Fig. 6A, B). The small food particles contained lipids that were stained black in osmium-tetroxide (Fig. 7B).

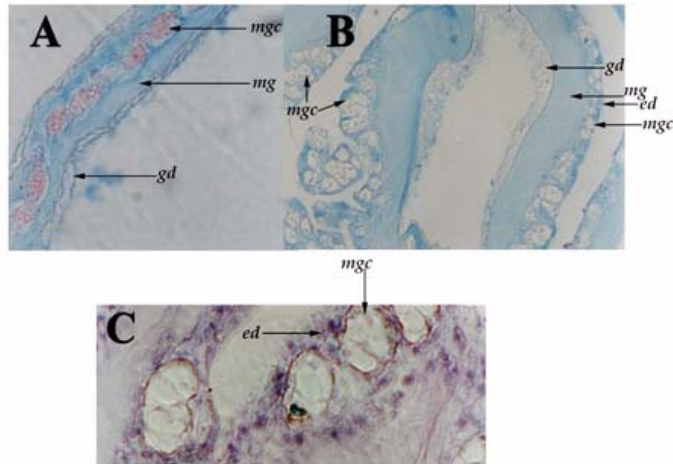


Figure 5

Longitudinal section through the lower part of *X. umbellata* polyp, showing the shape and the distribution of mucus-gland cells, when stained with Alcian Blue at pH 1.0. mgc, mucus-gland cell; gd, gastrodermis; mg, mesogloea; ed, epidermis

Corte longitudinal a través de la parte más baja del pólipo de *X. umbellata*, mostrando la forma y la distribución de las células glandulares mucosas teñidas con azul Alcian a pH 1,0. mgc, células glandulares mucosas; gd, gastrodermis; mg, mesoglea; ed, epidermis

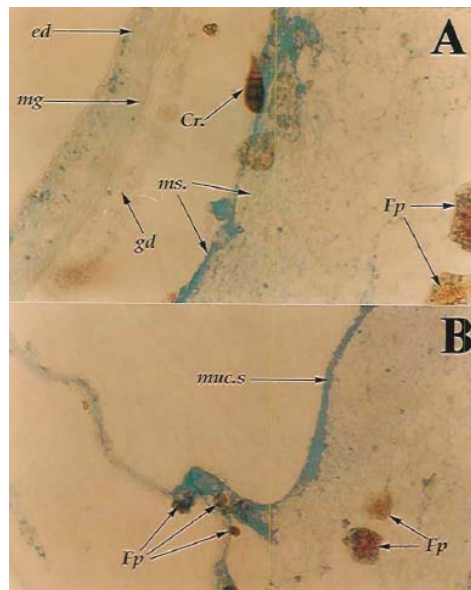


Figure 6

Cross sections (A, B) through the coelenteron of *X. umbellata* polyp, showing mucus sheet (mucus with food particles (Fp)), crustacean (Cr.), mucus sheet (ms., muc.s), epidermis (ed.), mesogloea (mg.), gastrodermis (gd.) and mucus-gland cell (mgc.)

Cortes transversales (A, B) a través del celenteron del pólipo de *X. umbellata*, mostrando una capa de mucus (mucus con partículas de alimento (Fp)) y crustáceo (Cr.), capa de mucus (muc.s., muc.s), epidermis (ed.), mesoglea (mg.), gastrodermis (gd.) y célula de glándula mucosa (mgc)

The distribution of the zooxanthellae was not uniform throughout the polyp. They tended to be concentrated in the gastrodermal layer of the pinnate tentacles (Fig. 7A), whilst in the gastrodermal layer of the polyp wall, they were scarce. Their average number was $1.57 \times 10^{-5} \text{ mg}^{-1} \text{ d.t.}$ with a mean diameter of $7 \mu\text{m}$ (Table 2). Lipid was again concentrated in the

gastrodermal layer of the pinnate tentacles only (Fig. 7A).

Tissue lipids

The total lipid content of *S. hystrix* and *X. umbellata* was found to be and 3.37 mg g^{-1} and 6.23 mg g^{-1} respectively of dry weight of coral (Table 3).

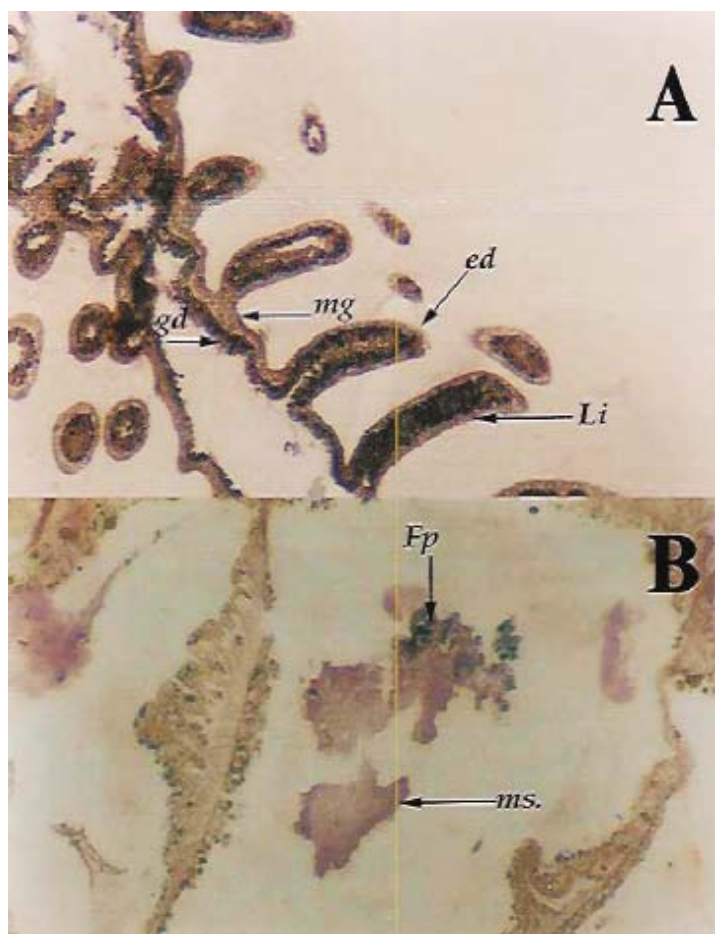


Figure 7

A. Longitudinal section through the pinnate tentacles of *X. umbellata*, showing black-stained lipid and black stained zooxanthellae when post-fixed in Potassium dichromate tetroxide solution. **B.** Cross section through the gastrovascular cavity of *X. umbellata*, showing food particle (Fp) stained black in the mucus sheet (ms.)

A. Corte longitudinal a través de los tentáculos pinados de *X. umbellata*, mostrando lípidos y zooxantelas teñidos de negro cuando son post-fijados en una solución de tetróxido dicromato de potasio. B. Corte transversal a través de la cavidad gastrovascular of *X. umbellata*, mostrando partículas de alimento (Fp) teñidas de negro en la capa mucosa (ms.)

In *S. hystrix*, the unsaturated fatty acids were found to be 13.7% of the total. The major saturated fatty acids were palmitic acid 16:0, stearic acid 18:0, making a sum of 86.2% of the total fatty acids (Table 4). Among the methyl esters it was found that the major fatty acids in *X. umbellata* were palmitoleic acid 16:1; oleic acid 18:1 and arachidonic acid 20:4. The unsaturated fatty acids constituted 77.9% of the total fatty acids. The

presence of 14:3 is unusual and has not been detected in other marine organisms like corals or sponges so its presence can be considered with some doubts. It was also surprising that the carbon chain was up to 20 carbon atoms, C₂₀ or C₂₂ were found to be absent or may be they were below detectable limits as these have been reported in other corals (Zhukova & Titlyanov 2003).

Table 3

A comparative study of chemical components of *S. hystrix* and *X. umbellata* at the study site (mean \pm S.D., n = 3)

Estudio comparado de los componentes químicos de *S. hystrix* y *X. umbellata* en el sitio de estudio (media \pm D.E., n = 3)

Components	<i>S. hystrix</i>	<i>X. umbellata</i>
Dry matter	91.36% \pm 1.510	18.56% \pm 2.41
Ash content	53.79% \pm 0.870	1.79% \pm 0.53
Organic matter	46.21% \pm 0.850	98.21% \pm 1.53
Chlorophyll "a" $\mu\text{g}\cdot\text{g}^{-1}$	5.36 \pm 0.17	4.72 \pm 0.17
Chlorophyll "b" $\mu\text{g}\cdot\text{g}^{-1}$	4.65 \pm 0.05	8.33 \pm 0.36
Carbohydrates (water soluble) $\mu\text{g}\cdot\text{g}^{-1}$	43 \pm 1.41	176.0 \pm 37.01
Lipids $\mu\text{g}\cdot\text{g}^{-1}$	3.37 \pm 0.21	6.23 \pm 0.24
Protein $\mu\text{g}\cdot\text{g}^{-1}$	55.52 \pm 3.31	141.37 \pm 6.45
Cholesterol $\mu\text{g}\cdot\text{g}^{-1}$	1.24 \pm 0.15	0.366 \pm 0.11

Table 4

A comparative study of fatty acid esters of *S. hystrix* and *X. umbellata* (determined by GC-MS)

Estudio comparado de los ésteres de ácidos grasos de *S. hystrix* y *X. umbellata* (determinado por GC-MS)

Esters fatty acids	Molecular weight	Carbon chain	<i>S. hystrix</i> %	<i>X. umbellata</i> %
Tetradecatrienoic acid C ₁₃ H ₂₁ COOCH ₃	236	14:3	1.24	4.40
Tetradecanoic acid C ₁₃ H ₂₇ COOCH ₃	242	14:0	7.00	0.88
Pentadecanoic acid C ₁₄ H ₂₉ COOCH ₃	256	15:0	--	0.94
Palmitoleic acid C ₁₅ H ₂₉ COOCH ₃	268	16:1	5.32	23.55
Palmitic acid C ₁₅ H ₃₁ COOCH ₃	270	16:0	55.56	10.23
Heptadecanoic acid C ₁₆ H ₃₁ COOCH ₃	284	17:0	--	0.30
Oleic acid C ₁₇ H ₃₃ COOCH ₃	296	18:1	7.33	33.55
Stearic acid C ₁₇ H ₃₅ COOCH ₃	298	18:0	15.70	8.05
Arachadonic acid C ₁₉ H ₃₁ COOCH ₃	318	20:4	--	10.57
Eicosenoic acid C ₁₉ H ₃₇ COOCH ₃	324	20:1	--	5.90
Eicosanoic acid C ₁₉ H ₃₉ COOCH ₃	326	20:0	7.96	0.33
Saturated fatty acid			86.22	20.73
Unsaturated fatty acid			13.77	77.97

Discussion

The morphology of the polyps and their cells types are different in the two species. *S. hystrix* has small diameter polyps (0.1 mm) with 12 short tentacles expanding during the day and night. The colony has a large surface area to volume ratio due to the thin and sharply pointed branches. Furthermore, *S. hystrix* contains large numbers of zooxanthellae which were dispersed throughout the polyp wall, the coenosteum and the tentacles. These characteristics suggest that *S. hystrix* is more autotrophic (Porter 1976). On the other hand, *X. umbellata*, which has large diameter (8.0 mm) polyps with eight long pinnate tentacles, contains a lower number of zooxanthellae.

The pinnate tentacles often pulsate in a rhythmic opening and closing motion. This increases the water flow over the tentacles, and this together with mucus production provides an efficient mean for suspension feeding. The presence of food particles and crustaceans in the coelenteron indicates that *X. umbellata* has a more heterotrophic nutrition as in other soft corals (Lewis 1992). Symbiotic dinoflagellates from the coral release droplets *in vitro*; putative droplet secretion is taken as an evidence for lipid translocation from algae to the host tissue in hospite in symbiotic cnidarians (Muscatine *et al.* 1994). It was further studied by Patton & Burris (1983) that when symbiotic algae were isolated from the coral *Stylophora pistillata*, maximum translocation occurred during the daylight i.e. from 2.00 to 7.00 pm.

The absence of specialized feeding cells in *S. hystrix* was shown by the histological data. Notably there are a relatively small number of mucus gland cells, a low percentage of venomous P-mastigophore (1.52-5.7%) and B-mastigophore nematocysts (1.2-0.0%). Conversely there is a high percentage of holotrichs nematocysts (24.86-55.0%) in the tentacles and mesenterial filaments. P-mastigophore and B-mastigophore are used in defense and prey capture, whilst holotrichs are thought to participate in aggressive interactions (Mariscal 1974). It seems very likely therefore that this species uses these nematocysts for defense and aggression, but not for feeding. In *X. umbellata*, cnidae are absent from the polyp, their place being taken by the large number of enlarged mucous glands found in the outer layer of the coenosac, the lower part of the polyp and the mesenterial filaments. Mucus has been reported to function in food capture in corals (Al-Sofyani 1991). The mucous-gland cells of the two species reacted the same way

to the Alcian Blue stain. This stain reacts with mucopolysaccharides to yield a blue colour, whilst neutral mucopolysaccharides are stained a reddish colour (Durry & Wellington 1980).

The distribution of lipid in the gastrodermal cells, particularly those in the lower part of *S. hystrix* polyp, is very similar to that described for Hawaiian and Arabia Gulf corals (Stimson 1990). In the *X. umbellata* polyp lipid was distributed in the gastrodermal cells of the pinnate tentacles only. It appears that most of the photosynthetically-fixed carbon in the gastrodermal cells of the pinnate tentacles is used as an immediate energy supply for their metabolically high activity in feeding. It has been mentioned by other workers (Muscatine 1973 and Davies 1984) that the photosynthetic products, as a result of autotrophism, are gradually passed on to the host cells (coral) and used as a part of their nutrition. Corals tend to maintain a balance between heterotrophy and autotrophy.

Meyer (1979) had studied 45 samples of coral species and analyzed their fatty acid composition; he concluded that the corals that rely predominantly on symbiotic algae produce more saturated fatty acids. The differences in mode of feeding between the two species are further strengthened by differences in the fatty acids in the tissues. It has been postulated that unsaturated fatty acids may be derived from dietary zooplankton, fish feces, small food particles, etc., and the saturated fatty acids from zooxanthellae (Patton *et al.* 1977). In our study it was observed that in *S. hystrix* the two major fatty acids were the saturated fatty acids, palmitic and stearic acids (71.2%). The predominance of unsaturated fatty acids in *X. umbellata* (77.7%) along with the lipid droplet study points towards the dominance of heterotrophic feeding.

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