Bioerosion caused by the sea urchin *Diadema mexicanum* (Echinodermata: Echinoidea) at Bahías de Huatulco, Western Mexico

T. Herrera-Escalante,[1*] R. A. López-Pérez[2] & G. E. Leyte-Morales[3]

1   Instituto de Pesquerias, Centro Interdisciplinario de Ciencias Marinas, Av. Instituto Politecnico Nacional, Calle Palo de Santa Rita CP. 23090, La Paz, B.C.S., Mexico; phataria_unifascialis@hotmail.com
2   Department of Geoscience, The University of Iowa, Iowa City, Iowa 52242, USA; ramon-lopez-perez@uiowa.edu.
3   Instituto de Recursos, Universidad del Mar, Carretera a Zipolite Km 1.5, Puerto Angel, Oaxaca, Mexico; leyteg@angel.umar.mx.

Abstract: Mexican Pacific sea urchin studies have been focused mainly on species distribution, ecology and fisheries. Reef degradation by sea urchin bioerosion has not been studied previously en these reefs. We investigate the importance of *Diadema mexicanum* as a bioerosive agent of coral carbonate at Bahías de Huatulco, and the relative magnitude of coral accretion and bioerosion. At each of five localities in Bahías de Huatulco, sea urchin density, feeding and mechanical (spine) erosion was determined for three size class intervals. In general, *D. mexicanum* do not exert any significant role on coral reef community structure (live coral, dead coral or algal coverage) at the Huatulco area, probably because they are generally small (2.9-4 cm test size) and few in number (1.0-6.8 ind.m^{-2}). Mean bioerosion rates are consistent with those measured for other diadematoids, as well as other urchin species in various eastern Pacific localities. However, the degree of bioerosive impact depends on species, test size, and population density of urchins. Coral carbonate removal by *D. mexicanum* erosion varies from 0.17 to 3.28 kgCaCO$_3$m^{-2}yr^{-1}. This represents a carbonate loss of < 5% of the annual coral carbonate production at Jicaral Chachacual, San Agustín and Isla Cacaluta, but 16 and 27% at Isla Montosa and La Entrega. On balance, coral accretion exceeds sea urchin erosion at all sites examined at Huatulco. At Bahías de Huatulco coral reef communities are actively growing, though in the coming years, it might be necessary to investigate the local effects of the interaction among erosion, and environmental and human induced perturbations. Rev. Biol. Trop. 53(Suppl. 3): 263-273. Epub 2006 Jan 30.

Key words: *Diadema mexicanum*, sea urchin, bioerosion, Huatulco, western Mexico.

Sea urchins are conspicuous components of marine littoral communities at all latitudes, and frequently exert a decisive role as grazers (Sammarco *et al*. 1974, Levitan 1988, Morrison 1988, McClanahan 1992, McClanahan *et al*. 1996). In shallow coral reef communities, grazing by sea urchins can directly modify the distribution, relative abundance and species composition of algae and corals (Sammarco 1982, Morrison 1988). Sea urchins are able to maintain coral reef cover by grazing heavily on algae that can potentially compete with coral for light and space (Sammarco 1982, Hughes *et al*. 1987, McClanahan *et al*. 1996).

On the contrary, large sea urchin populations such as those observed in Central American reef after the 1982-83 El Niño event, may further increase the biological erosion of reef through feeding and spine abrasion due to their localized grazing (Glynn 1988, Eakin 1992, 1996, Bak 1994).

Both Indo-Pacific and Caribbean coral reef communities have been heavily studied to investigate the effects that sea urchins exert over coral abundance and diversity. On the Mexican Pacific, however, sea urchin studies have been focused on species distribution, ecology and fisheries (Caso 1978, Espino-Barr *et al*. 1996,

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

263

Solís-Marín *et al*. 1997, Cintra-Buenrostro *et al*. 1998). Only one case study has focused on sea urchins importance in coral reef communities (Reyes-Bonilla and Calderon-Aguilera 1999). Bahías de Huatulco is a recently discovered coral reef area (Glynn and Leyte-Morales 1997), and due to its coral reef development, is considered among the most important in the Mexican Pacific (Reyes-Bonilla 2003). While description, species distribution, and community structure and dynamics of the coral reef communities have been the focus of many studies in this area (Glynn and Leyte-Morales 1997, Leyte-Morales 1997, Reyes-Bonilla and Leyte-Morales 1998, Leyte-Morales *et al*. 2001, López-Pérez *et al*. 2002, López-Pérez and Hernández-Ballesteros, 2004), reef degradation by bioerosion has not been studied. The present contribution investigates the importance of *Diadema mexicanum* (Agassiz) as a bioerosive agent, and evaluates the relative magnitude of coral accretion and bioerosion at Bahías de Huatulco.

MATERIAL AND METHODS

Study Area: Bahías de Huatulco is at the edge of one of the most important upwelling areas of the eastern Pacific, the Gulf of Tehuantepec. Between November and April north winds cross the Isthmus of Tehuantepec between two mountain ranges and increase their speed and strength, pushing surface water away from the western coast of México and producing intense and widespread upwelling that can lower surface temperature by 10ºC (Roden 1961, Lluch-Cota *et al*. 1997). Additionally, the area is subjected to perturbations caused by hurricanes and tropical storms that are generated in the Inter Tropical Convergence Zone, especially between May and November (Reyes-Coca and Mejía-Trejo 1991, Glynn *et al*. 1998). Finally, the yearly mean sea surface temperature (including the upwelling period) in the coastal section of Huatulco and surrounding waters is $28.0 \pm 1.5º$ C (Fiedler 1992), among the most suitable for coral reef development in the eastern Pacific.

The Huatulco coral reef area is composed of 17 fringing reefs (Leyte-Morales 1997). Sixteen hermatypic species from three genera have been reported, and most of the reefs exhibited high (30-50%) to very high (60-90%) live coral cover (Glynn and Leyte-Morales 1997, Reyes-Bonilla and Leyte-Morales 1998). Although it is probably one of the best-developed coral reef systems in western México (Reyes-Bonilla 2003), its species richness, species composition, and coral coverage are frequently altered by environmental perturbations (Glynn and Leyte-Morales 1997, Lirman *et al*. 2001, López-Pérez *et al*. 2002, Reyes-Bonilla *et al*. 2002, López-Pérez and Hernández-Ballesteros, 2004). Concerning other specimens, the sea urchins *D. mexicanum*, *Eucidaris thouarsii* (Valenciennes), and *Toxopneustes roseus* (Agassiz), and fishes belonging to the families Pomacentridae and Labridae are important community members at Bahías de Huatulco.

Substrate characteristics and sea urchin abundance: Between November 2000 and October 2001 (except for July), three monthly 50 x 1 m^2 belt transects were conducted in San Agustin (15°41'09" N, 96°14'05" W), Jicaral-Chachacual (15°42'11" N, 96°12'51" W), Isla Cacaluta (15°43'08" N, 96°09'43" W), La Entrega (15°44'34" N, 96°07'35" W), and Isla Montosa (15°45'48" N, 96°04'56" W), in the Huatulco area. All sampling transects (three per month per locality) were haphazardly placed in the reefs inside the bathymetric interval where reefs occur (2-13 m; Glynn and Leyte-Morales 1997). Within each 1 m^2 interval of the belt transect *D. mexicanum* densities and all underlying substrate characteristics including coral, algae, cemented dead corals, and others (rocks and sand) were determined with a quadrat divided into 100 cells of ten cm^2. Additionally, a monthly haphazardly sample of 50 sea urchins per locality was measured (test diameter). Transect surveys were conducted during the day, and therefore, sea urchin densities are conservative since sea urchins are active at night and small individuals are likely to hide in rock or coral crevices. *D. mexica-*

264

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

num densities were checked for deviations of normality and homogeneity of variances utilizing Kolmogorov-Smirnov and Bartlett tests. To distinguish the main effects and possible interactions, densities were analyzed by a two-way analysis of variance to compare time and locality. A simply linear correlation test was performed to assess the relationship between substrate characteristics and sea urchin densities (Zar 1999). All statistical analyses were tested for significance using a p value of 0.05.

Bioerosion: Sea urchin individual grazing rate and spine-induced bioerosion were determined following modifications to the methods of Glynn *et al*. (1979) and Reyes-Bonilla and Calderon-Aguilera (1999). For a more accurate calculation, sea urchin individual grazing rate and spine-induced bioerosion were determined for three size class intervals (< 3 cm, 3-5 cm, and > 5 cm test diameter). First, *D. mexicanum* individual grazing rate was determined by removing and immediately placing ten individual urchins of each size class in plastic containers (20 l) and allowing them to defecate for 24 hours. By doing this it is assumed that ingestion and defecation rates are equal. Although this allowed us to standardize grazing rates for a 24 hr period, there is evidence to suggest that turnover rate in urchins may be greater than 24 hours (Glynn *et al*. 1979). Weight sediment in the control containing no sea urchin was subtracting from individual grazing rate per size class.

In a second phase, a live colony of the coral *Pocillopora damicornis* (Linnaeus) was introduced in the same plastic container as the sea urchin, allowing the sea urchin to mechanically abrade the coral for 24 hr. Individual mechanical sediment production was calculated by subtracting from this both the weight of the sediment from a control container containing only live corals and the individual grazing rate obtained during the previous experiment. For both experiments, the defecated material was collected, rinsed with distilled water and desiccated at 60°C until it attained constant weight. Both sea urchin grazing rate and spine-induced bioerosion were obtained, and reported as dry mass of fecal material and sediments per day. Based on these data, and on the basis of their population densities, proportion of size class and reef size (Leyte-Morales 2001), the total bioerosive effect (feeding activity + mechanical abrasion) of *D. mexicanum* was calculated for one year at each locality.

To assess the bioerosive effect of *D. mexicanum* at each locality, bioerosion rate (kg m^{-2} yr^{-1}) was compared to coral carbonate production rate (kg m^{-2} yr^{-1}). The per-locality annual coral carbonate production was calculated following the method used by Chave *et al*. (1972) and Reyes-Bonilla and Calderon-Aguilera (1999).

RESULTS

Substrate characteristics and sea urchin abundance: The sampled localities were composed of seven coral reef species: *Pocillopora damicornis*, *P. capitata* Verrill, *P. verrucosa* (Ellis and Solander), *P. eydouxi* Milne Edwards and Haime, *P. effusus* Veron, *Porites panamensis* Verrill and *Pavona gigantea* Verrill. However, species distribution and abundance varied between localities. Especially low coral cover was found at Jicaral-Chachacual, where a coral mass mortality event probably related to excessive sedimentation (López-Pérez *et al*. 2002), selectively removed *P. damicornis* and the sea urchin *D. mexicanum* at the beginning of February 2001. Coral communities in the Huatulco area exhibited high to very high (43-63%) live mean percent coral cover (Fig. 1). Most of the communities were dominated by *P. damicornis* and *P. capitata*, whereas poritids and agariciids were relatively uncommon. Under normal conditions, algae covers between 1-20% of the substrate at any Huatulco locality; however, following the coral mass mortality at Jicaral-Chachacual, algae increased from 4 to 45% (ANOVA, $F_{8,18}$=6.36, p= 0.00) of occupied substrate space. Cemented dead corals represent ~ 10% of the substrate at San Agustín, Isla Cacaluta and Isla Montosa, but 23% at La Entrega, and a relatively high 32%

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005
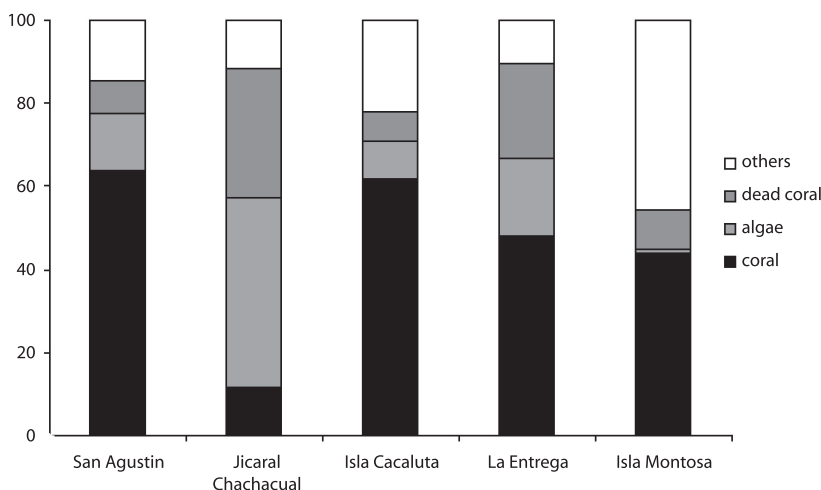
265

Fig. 1. Mean annual percent cover of live coral and other substrata at Bahías de Huatulco, México, from November 2000 through October 2001.

Fig. 1. Cobertura de coral vivo promedio anual y de otros substratos en la Bahía de Huatulco, México, de noviembre del 2000 hasta octubre del 2001.

at Jicaral-Chachacual. Overall, the difference substrata at San Agustín, Jicaral-Chachacual, Isla Cacaluta and Isla Montosa form interdispersed distributed patches in the reef area. At La Entrega, algal mats and cemented dead corals predominated in the deep (5-10 m) zone, while healthy, undisturbed corals predominate in shallow (< 5 m) depths (López-Pérez and Hernández-Ballesteros, 2004).

At all localities, *D. mexicanum* occurred along the bathymetric interval where reefs were present (Glynn and Leyte-Morales 1997). This species was observed living on rock and in coral crevices of the Huatulco coral communities, but rarely on open substrates. It was seen living alone or forming aggregations, commonly from three to eight individuals, distributed randomly in the coral communities; except at La Entrega, where *D. mexicanum* showed a stratified distribution reaching densities of > 11 ind.m^{-2} at the deep zone (5-10 m). *D. mexicanum* was commonly observed grazing over corals, crustose coralline algae, cemented dead corals and dead basal branches of *Pocillopora*.

The mean abundance of the sea urchin *D. mexicanum* (Fig. 2) was low at San Agustín

and Isla Cacaluta (1.0-1.3 ind.m^{-2}), intermediate at Isla Montosa (2.9 ind.m^{-2}), and high at La Entrega (6.8 ind.m^{-2}). These differences were significant among localities (ANOVA, $F_{4,150}$ = 11.97, p = 0.00) but abundance did not vary significantly through time ($F_{10,150}$ = 1.51, p = 0.14). Prior to the coral mortality event, the sea urchin abundance at Jicaral-Chachacual was 0.6 ind. m^{-2}, but by late February no positive record of *D. mexicanum* were find living within the coral area, and only 0.1 ind. m^{-2} was seen in the deep non-coral zone (5-10 m), outside of the previously considered coral area were the surveys described above took place. As illustrated by correlation analysis, the abundance of substrata such as cemented dead coral (R^2=0.01, p= 0.28), live coral cover (R^2=0.003, p= 0.49) or algal cover (R^2=0.001, p= 0.37) were not significantly related to sea urchin abundance.

D. mexicanum mean test diameter varied significantly localities, from 2.9 ±0.03 cm at La Entrega to 4 ±0.04 cm at San Agustín, Kruskal-Wallis test ($H_{(4-55)}$= 26.83, p=0.00). Sea urchins at La Entrega, Isla Montosa and Isla Cacaluta had small test diameters, and those at Jicaral-Chachacual and San Agustín
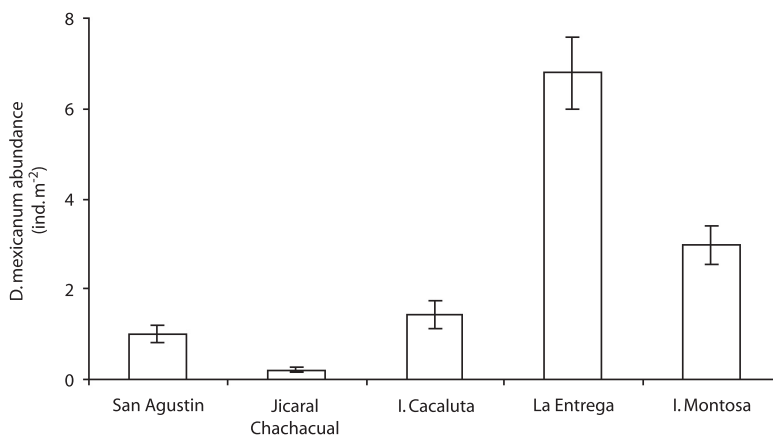
Fig. 2. Mean annual abundance (± SE) of the sea urchin *Diadema mexicanum* (ind. m^{-2}) at Bahías de Huatulco, México, from November 2000 through October 2001.

Fig. 2. Abundancias promedio anuales (± DS) del erizo de mar *Diadema mexicanum* (ind. m^{-2}) en la Bahía de Huatulco, México, de noviembre del 2000 hasta octubre del 2001.

had largest tests (Nemenyi test, $q_{(0.05, \infty, 5)}$= 3.85) (Fig. 3). The patterns of sea urchin test size and density are similar, but not significantly related (R^2= -023, p= 0.09).

Bioerosion: Coral carbonate removal due to both feeding and spine abrasion was *Diadema* test diameter dependent. However, feeding activity removes more CaCO$_3$ than spine abrasion for all size classes. Nevertheless, the

importance of both activities varies with test diameter. For the small size classes, feeding accounts for 87% of the CaCO$_3$ loss, whereas spine abrasion contributes just 13%. Spine abrasion removal becomes more important as test diameter increases (Table 1).

The CaCO$_3$ removed by sea urchins varies among localities (Table 2). At Jicaral-Chachacual, San Agustín and Isla Cacaluta,

TABLE 1

Calcium carbonate erosion by Diadema mexicanum *at Bahías de Huatulco, Mexico. Mean bioerosion ± SE was calculated from 10 independent replicates for each size class. Bioerosion (%) is the portion of the total bioerosion caused by each erosive activity. Mean and total bioerosion are in g CaCO$_3$ind^{-1}d^{-1}*

CUADRO 1

Erosión de carbonato de Calcio causada por Diadema mexicanum *en la Bahía de Huatulco, México. La bioerosión promedio ± DE fue calculada de 10 replicas independientes para clase de tamaño. La bioerosión (%) es la porción es el total de la bioerosión causada por cada actividad. Bioerosión promedio y total están dados en CaCO$_3$ind^{-1}d^{-1}*

Size class	Activity	Mean bioerosion ± SE	Bioerosion (%)	Total bioerosion ± SE
< 3 cm	Feeding	0.47 ± 0.18	87	0.54 ± 0.45
	Spine abrasion	0.06 ± 0.31	13	
3-5 cm	Feeding	1.41 ± 0.26	77	1.83 ± 0.51
	Spine abrasion	0.41 ± 0.26	23	
> 5 cm	Feeding	2.96 ± 0.39	76	3.88 ± 0.74
	Spine abrasion	0.91 ± 0.38	24	

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

267

Fig. 4. Size frequencies of *Diadema mexicanum* at Bahías de Huatulco, México, from November 2000 through October 2001. μ= size mean for site.

Fig. 4. Frecuencia de tallas de *Diadema mexicanum* en la Bahía de Huatulco, México, de noviembre del 2000 hasta octubre del 2001. μ= talla promedio por sitio.

D. mexicanum removes less than 1 kg m^{-2} yr^{-1}, but at La Entrega this amount is greater than 3 kg m^{-2} yr^{-1}. To put these results in perspective, *D. mexicanum* alone eroded less than 6% of the coral carbonate production at Jicaral-Chachacual, San Agustín and Isla Cacaluta annually, but between 16 and 27% at Isla Montosa and La Entrega.

Sea urchins can modify the distribution, relative abundance and species composition of algae and corals (Sammarco 1982). Sea urchin influence on coral reef communities has been deduced and/or established after natural disturbances or experiments elsewhere in the Indo-Pacific and Caribbean (Hughes *et al*. 1987, McClanahan *et al*. 1996). The influence of sea urchins on eastern Pacific coral communities was first studied in the Galápagos (Glynn *et al*. 1979), and was full established after the El Niño 1982-1983 and its impact in Central America localities. In Panama, Costa Rica and the Galápagos, the large aggregations of sea urchins following the El Niño 1982-1983-- densities were typically 60 to 100 ind.m^{-2} and as high as 156 ind.m^{-2} Glynn 1988a, Guzmán 1988)-- were considered responsible for most of the erosion of the reefs (Glynn 1994, Eakin 1996, 2001, Cortés and Jiménez 2003, Maté 2003). Several studies in the Central American region assigned a subordinate role in structuring eastern Pacific coral reef communities to coral-livores, but a primary role to oceanographic and abiotic factors (Colgan 1990, Glynn 1990, 1993, 1994, Cortés 1997). In the same way, at Bahías de Huatulco no meaningful relationship was found between sea urchin abundance and either the cover of live coral and algal cover, or cemented dead corals. Similar results have been reported for Cabo Pulmo in the Gulf of California (Reyes-Bonilla and Calderon Aguilera 1999), where corallivores, including the sea urchin *Eucidaris thouarsii* are not key factors determining scleractinian abundance. At least in the eastern Pacific, the important role of sea urchins in influencing coral communities is probably due to the synergy between physical disturbance (El Niño), and sea urchins erosion. In addition, it is possible that the sea urchin influence largely depends on the spatiotemporal intensity of the disturbance. For example, at Cabo Pulmo and most of the Bahías de Huatulco communities mild or no physical (natural or human-induced) disturbance has been observed, there was no relation between
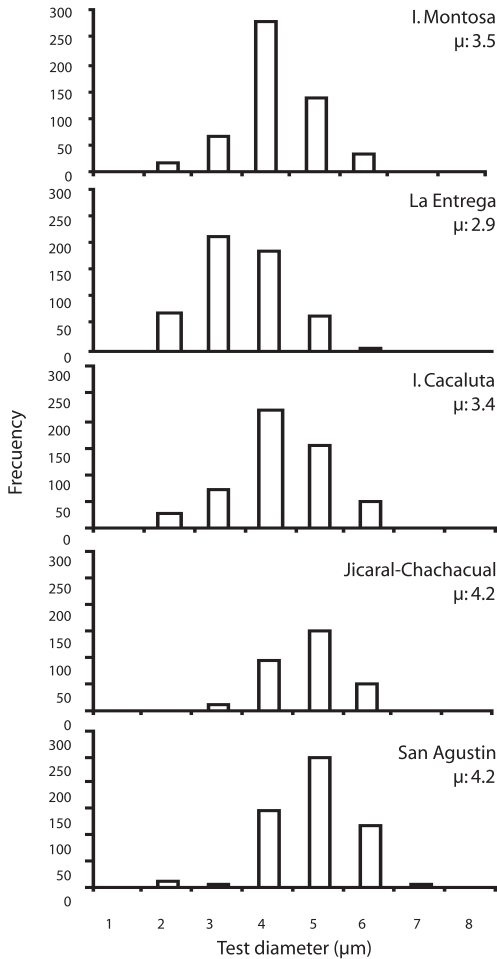
268

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

CUADRO 2

Erosión de carbonato de calcio por Diadema mexicanum *en la Bahía de Huatulco, México.*
El porcentaje bioerosionado es la porción de la producción anual bioerosionada por D. mexicanum *en cada localidad.*
La bioerosión y la producción de carbonato de coral están dadas en kg CaCO$_3$m^{-2}yr^{-1}

Locality	Bioerosion ± SE	Production ± SE	% Bioeroded
San Agustín	0.91 ± 0.15	17.88 ± 3.8	5.08
Jicaral- Chachacual	0.17 ± 0.03	4.15 ± 3.3	4.09
Isla Cacaluta	0.96 ± 0.15	17.28 ± 3.8	5.55
La Entrega	3.28 ± 0.50	12.13 ± 3.3	27.04
Isla Montosa	2.01 ± 0.38	12.11 ± 4.9	16.59

sea urchins and community structure. However, at highly disturbed localities of Central America sea urchins play a major role in the fate of coral communities (Glynn 1994, Eakin 1996, Cortés and Jiménez 2003, Maté 2003).

Diadema mexicanum mean daily bioerosion at Bahías de Huatulco (2.08 ± 0.02 g ind^{-1}d^{-1}) is slightly higher than *E. thouarsii* at Cabo Pulmo (1.83 ± 0.14 g ind^{-1} d^{-1}; Reyes-Bonilla and Calderon-Aguilera 1999), and *D. mexicanum* in Panama (1.98 ± 0.28 g ind^{-1} d^{-1}; Glynn 1988). It is possible that these differences can be explained mainly in terms of sea urchin test size, species, and methodological differences. Test size plays an important role in bioerosion rates at Bahías de Huatulco (Table 1) were there is a direct relationship between test size and individual bioerosion. However, no such consistent relationships between species and methodological differences in daily bioerosion are know. In terms of annual bioerosion, the mean amount of CaCO$_3$ eroded by *D. mexicanum* at Bahías de Huatulco is higher than at Cabo Pulmo (0.11 ± 0.03 kg m^{-2} yr^{-1}; Reyes-Bonilla and Calderon-Aguilera 1999), but lower than at the Galápagos Islands (1.9-18 kg m^{-2} yr^{-1}; Glynn 1988) and Isla Uva in Panama (5.8 kg m^{-2} yr^{-1}; Eakin 1988). This is likely the result of the previously mentioned factors (size, species, methods) and differing sea urchin abundances. Nevertheless, the bioerosion percentages at Jicaral-Chachacual must be considered cautiously since production was low due to the mortality event. Except for La Entrega, at Bahías de Huatulco *D. mexicanum* densities (2.08 ind. m^{-2}) are similar to values reported for Mexican Pacific (1.7 ind.m^{-2}; Espino-Barr *et al*. 1996), whereas *E. thouarsii* are found at low densities at Cabo Pulmo (0.17 ± 0.03 ind. m^{-2}). In the Galápagos Islands and Isla Uva sea urchins densities vary greatly, between 3-156 ind. m^{-2} (Glynn 1988, Eakin 1988). Because of low densities, *D. mexicanum* exerts low to moderate bioerosion at all sites examined in Bahías de Huatulco; that is, coral carbonate production is much higher than the bioerosion caused by *Diadema*. This results in a net positive deposition of coral reef calcium carbonate. Similar results have been reported for Cabo Pulmo (Reyes-Bonilla and Calderon Aguilera 1999), and inferred for the Revillagigedo Islands (Reyes-Bonilla 2003). This inference might be expanded, in general, for the Mexican Pacific where coral reefs appear to be actively growing (e.g., a net positive development of the reefs) (Reyes-Bonilla 2003). By contrast, in the localities of Central America were sea urchins population are high, *Eucidaris* and *Diadema* are considered responsible for most of the erosion of the reefs (Glynn

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

269

2003) and hampered coral reef recovery from stress (Guzmán and Cortes 1992).

On balance, calcium carbonate accretion exceeds erosion at all sites examined at Bahías de Huatulco. It is known, however, that urchin distribution patterns can result in varying levels of impact on local scales (Bak 1994, Woodley 1999). At La Entrega, *D. mexicanum* removes annually ~ 27% of the coral carbonate production, thus resulting in a net positive balance. However, its patchy spatial distribution, with fewer individuals at shallow (< 5 m; 0.05 ± 0.16 ind. m^{-2}) than at deep sites (5-10 m; 11.16 ± 3.45 ind. m^{-2}), can exert severe local effects. Recent studies at La Entrega (Hernández-Ballesteros, unpub.) suggest that whereas live mean annual coral coverage (~50%) is higher than dead framework cover (~15%) at shallow sites (< 5 m), the opposite is true (~20 and 70% cover) in deeper reef zones (5-10 m). Glynn and Leyte-Morales (1997), based on *Pavona gigantea* recruiting to pocilloporid reef frames, inferred that the 1987 ENSO event might have caused extensive coral mortality in the deep zone of La Entrega, where large populations of *D. mexicanum* developed later. This implies that the dense concentrations of sea urchins in the deep zone of La Entrega may have severe localized effects preventing recovery of corals following perturbations. In addition, the synergy between *D. mexicanum* bioerosion, intense public use since the early 1990s (Leyte-Morales 2000), and recurrent dredging at La Entrega (at least once a year) since early the 1990s (personal observation) is hampering coral reef recovery and development.

Finally, it is important to note that this study offer a gross estimates of sea urchin bioerosion and its effect on the Bahías de Huatulco coral communities. For example, although *D. mexicanum* has been observe actively grazing on live corals at Bahías de Huatulco and in the Galápagos Islands (Glynn 1988), it also grazes on crustose coralline algae and dead corals. Indeed, Glynn *et al*. (1979) have demonstrated that the gut contents of *Eusidaris* included coralline algae fragments and reworked sediments. In addition, by comparing the values of bioerosion with carbonate production by corals alone, it is assumed that the reef community at Huatulco area is entirely composed of corals, though other calcifying organisms such as coralline algae, bryozoans, mollusks, barnacles, etc. are important members of the reef community. It is important to note that these estimates do not account for any positive, indirect, influences that sea urchins may have on reef production through grazing heavily on algae that can potentially compete with coral for light and space (Sammarco 1982, Hughes *et al*. 1987, McClanahan *et al*. 1996). Also, sea urchins are not the only erosive agents of these reefs, and therefore, erosion values only represent one group of bioeroders. Over 20 invertebrates and vertebrates are know to direct and indirectly affect scleractinian corals in the eastern Pacific (Glynn and Wellington 1983, Guzmán 1993). Their local distribution, abundance and erosive effect on the Huatulco area are still undocumented. In addition, rates of microbioerosion (Tribollet *et al*. 2002) also are undocumented for this region. In the incoming years it will be important to investigate potential interactions between biological, and physical (natural and human-induced) erosive forces, and their effects on the recovery and development of coral reef communities.

ACKNOWLEDGMENTS

270

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

RESUMEN

El estudio de los erizos en el Pacífico Mexicano se ha enfocado en la distribución, ecología y pesquerías. La degradación de estos arrecifes causada por la bioerosión provocada por erizos no ha sido estudiada. Se investigó la erosión de *Diadema mexicanum* como un agente erosivo del carbonato de los arrecifes en Bahías de Huatulco, y la magnitud relativa de la acreción del coral y la bioerosión. En cinco localidades se determinó la densidad de erizos, la erosión por alimentación y por la abrasión mecánica de las espinas, para tres clases de talla. En general, *D. mexicanum* no ejerce un papel significativo sobre la estructura arrecifal (coral vivo, coral muerto o cobertura de algas) en el área de Huatulco, probablemente debido a que los erizos son pequeños (2.9-4 cm) y poco numerosos (1.0-6.8 ind. m^{-2}). La tasa media de bioerosión difiere con otros diademátidos y grupos de erizos en el Pacífico oriental. Sin embargo, el impacto depende de la especie, el tamaño de la testa y densidad de los erizos. El carbonato removido por la erosión varió de 0.17 a 3.28 CaCO$_3$ kg m^{-2} año^{-1}. Esto representa una perdida de carbonato < 5% de la producción anual en Jicaral- Chachacual, San Agustín e Isla Cacaluta, pero del 16 y 27% en Isla Montosa y la Entrega. En cuanto al balance, la acreción del coral excede la erosión provocada por los erizos. En Bahías de Huatulco las comunidades arrecifales están creciendo activamente, por lo que, en los años siguientes es imperativo investigar los efectos locales de la interacción entre la erosión y las perturbaciones ambientales y humanas.

Palabras claves: *Diadema mexicanum*, erizo de mar, bioerosión, Huatulco, México occidental.

REFERENCES

Bak R.P.M. 1994. Sea urchin bioerosion on coral reefs: place in the carbonate budget and relevant variables. Coral Reefs 13: 99-104.

Caso, M.E. 1978. Los equinoideos del Pacífico Mexicano; Parte segunda. Ordenes Stiriodonta y Camarodonta. Anal. Centro Cien. Mar Limnol UNAM. Publ Esp. 1: 1-224.

Chave, K.E., E.S. Smith & K.J. Roy. 1972. Carbonate production by coral reefs. Mar Geol 12: 123-140.

Cintra-Buenrostro, C.E., H. Reyes-Bonilla & O. Arizpe-Covarubias. 1998. Los equinodermos (Echinodermata) del arrecife de Cabo-Pulmo, Pacífico de Mexico. Rev. Biol. Trop. 46: 341-344.

Colgan, M.W. 1990. El Niño and the history of eastern Pacific reef building, p 183-232. *In* P.W. Glynn (ed.). Global ecological consequences of the 1982-83 El Niño Southern Oscillation. Elsevier, Amsterdam.

Cortés, J. 1997. Biology and geology of eastern Pacific coral reefs. Proc. 8th Int. Coral Reef Sym. Panama 1: 57-64.

Cortés, J.C. & Jiménez. 2003. Corals and Coral Reefs of the Pacific of Costa Rica: history, research and status, p. 361-385. *In* J.Cortés. (ed.). Latin American Coral Reefs. Elsevier, Amsterdam.

Eakin, C.M. 1988. Avoidance of damselfish lawns by the sea urchin *Diadema mexicanum* at Uva Island, Panama. Proc. 6th Int. Coral Reef Sym. Australia 2: 21-26.

Eakin, C.M. 1992. Post-El Niño panamanian reefs: less accretion, more erosion and damselfish protection. Proc. 7th Int. Coral Reef Sym. Guam 1: 387-396.

Eakin, C.M. 1996. Where have all the carbonates gone? A model comparison of calcium carbonate budgets before and afer the 1982-83 El Niño at Uva Island in the eastern Pacific. Coral Reefs 15: 109-119.

Espino-Barr, E., R. Cibrían & A. García. 1996. Estructura y densidad de la población del erizo tinta *Diadema mexicanum* en el litoral rocoso del estado de Colima. Cienc. Pesq. 12: 60-67.

Fiedler, P.C. 1992. Seasonal climatologies and variability of Eastern Tropical Pacific surface waters. NOAA Tech Rep NMFS. 109 p.

Glynn, P.W. 1988a. El Niño warming, coral mortality and reef framework destruction by echinoid bioerosion in the eastern Pacific. Galaxea 7: 129-160.

Glynn, P.W. 1988b. El Nino-Southern Oscillation 1982-1983: Near shore population, community, and ecosystem responses. Annu. Rev. Ecol. Syst. 19: 309-345.

Glynn, P.W. 1990. Coral mortality and disturbances to coral reefs in the tropical eastern Pacific, p. 55-126. *In* P.W. Glynn (ed.). Global ecological consequences of the 1982-83 El Niño Southern Oscillation. Elsevier, Amsterdam.

Glynn, P.W. 1993. Coral reef bleaching: ecological perspectives. Coral Reefs 12: 1-17.

Glynn, P.W. 1994. State of coral reefs in the Galápagos Islands: natural versus anthropogenic impacts. Mar. Pollut. Bull. 29: 131-140.

Glynn, P.W. 2003. Coral communities and coral reefs of Ecuator, p. 449-472. *In* J.Cortés (ed.). Latin American Coral Reefs. Elsevier, Amsterdam.

Glynn, P.W. & G.E. Leyte-Morales. 1997. Coral reefs of Huatulco, west Mexico: reef development in upwelling Gulf of Tehuantepec. Rev. Biol. Trop. 45: 1033-1047.

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

271

Glynn, P.W.& G. M. Wellington. 1983. Corals and coral reefs of the Galápagos Islands. Univ. California Press, Berkeley. 330 p.

Glynn, P.W., G.M. Wellington & C. Birkeland. 1979. Coral reef growth in the Galápagos: Limitation by sea urchins. Science 203: 47-49.

Glynn, P.W., D. Lirman, A.C. Baker & G.E. Leyte-Morales. 1998. First documented hurricane strikes on eastern Pacific coral reefs reveal only slight damage. Coral Reefs 17: 361.

Guzmán, H.M. 1988. Distribución y abundancia de organismos coralívoros en los arrecifes coralinos de la Isla del Caño, Costa Rica. Rev. Biol. Trop. 36: 191-207.

Guzmán, H.M. 1993. Arrecifes coralinos del Pacifico oriental tropical: revisión y perspectivas. Rev. Biol. Trop. 41: 535-557.

Guzmán, H.M. & J. Cortés. 1992. Cocos Island (Pacific of Costa Rica) coral reefs after the 1982-83 El Niño disturbance. Rev. Biol. Trop. 40: 309-324.

Hughes, T.P., D.C. Reed & M.J. Boyle. 1987. Herbivory on coral reefs: community structure following mass mortalities of sea urchins. J. Exp. Mar. Biol. Ecol. 113: 39-59.

Levitan, D.R. 1988. Algal-urchin biomass responses following mass mortality of *Diadema antillarum* Philippi at Saint John, US Virgin Islands. J. Exp. Mar. Biol. Ecol. 119: 167-178.

Leyte-Morales, G.E. 1997. La colección de corales de la Universidad del Mar. Ciencia y Mar 1: 3-16.

Leyte-Morales, G.E. 2000. Perturbaciones naturales y antropogénicas en las comunidades coralinas de Oaxaca (1977-1998). XII Congreso Nacional de Oceanografía. Huatulco, México. 5 p.

Leyte-Morales, G.E. 2001. Estructura de la comunidad de corales y características geomorfológicas de los arrecifes coralinos de Bahías de Huatulco, Oaxaca, México. MSc Dissertation, Universidad del Mar, Oaxaca.

Lirman, D., P.W. Glynn, A.C. Baker & G.E. Leyte-Morales. 2001. Combined effects of three sequential storms on the Huatulco coral reef tract, México. Bull. Mar. Sci. 69: 267-278.

Lluch-Cota, S., E.S. Álvarez-Borrego, E.M. Santamaría-del Ángel, F.E. Muller-Karger & S. Hernández-Vázquez. 1997. El Golfo de Tehuantepec y áreas adyacentes: variación espaciotemporal de pigmentos fotosintéticos derivados de satélite. Ciencias Marinas 23: 329-340.

López-Pérez, R.A. & L.M. Hernández-Ballesteros. 2004. Coral community structure and dynamics in the Huatulco area, Western México. Bull. Mar. Sci. In press.

López-Pérez, R.A., L.M. Hernández-Ballesteros & T. Herrera-Escalante. 2002. Cambio en la dominancia de la comunidad arrecifal en Chachacual, Bahías de Huatulco, Oaxaca, México. Ciencia y Mar 16: 33-38.

Maté, J.L. 2003. Coral and coral reefs of the Pacific coast of Panama, p. 387-418. *In* J.Cortés (ed.). Latin American Coral Reefs. Elsevier, Amsterdam.

McClanahan, T.R. 1992. Resource utilization, competition and predation: a model and example from coral reef grazers. Ecol. Model. 61: 195-215.

McClanahan, T.R., A.T. Kamukuru, N.A. Muthiga, M. Gilagabher & D. Obura. 1996. Effect of sea urchin reductions on algae, coral, and fish populations. Conserv. Biol. 10: 136-154.

Mokady, O., B. Lazar & Y. Loya. 1996. Echinoid bioerosion as a major structuring force of Red Sea coral reefs. Biol. Bull. 190: 367-372.

Morrison, D. 1988. Comparing fish and urchin grazing in shallow and deeper coral reef algal communities. Ecology 69: 1367-1382.

Reyes-Bonilla, H. 2003. Coral reefs of the Pacific coast of México, p. 387-418. *In* J.Cortés (ed.). Latin American Coral Reefs. Elsevier, Amsterdam.

Reyes-Bonilla, H. & L.E. Calderón-Aguilera. 1999. Population density, distribution and consumption rates of three corallivores at Cabo Pulmo reef, Gulf of California, Mexico, Mar. Ecol. 20: 347-357.

Reyes-Bonilla, H. & G.E. Leyte-Morales. 1998. Corals and coral reefs of the Puerto Angel region, west coast of México. Rev. Biol. Trop. 46: 679-681.

Reyes-Bonilla, H., J.D. Carriquiry, G.E. Leyte-Morales & A.L. Cupul-Magaña. 2002. Effects of the El Niño-Southern Oscillation and the anti-El Niño event (1997-1999) on coral reefs of the western coast of México. Coral Reefs 21: 368-372.

Reyes-Coca, S. & A. Mejía-Trejo. 1991. Tropical perturbations in the eastern Pacific and the precipitation field over northwestern México in relation to ENSO phenomenon. Int. J. Climatol. 11: 515-528.

272

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

Roden, G.I. 1961. On the wind driven circulation in the Gulf of Tehuantepec and its effect upon surface temperatures. Geofis. Int. 1: 55-72.

Sammarco, P.W. 1982. Echinoid grazing as a structuring force in coral communities: whole reef manipulations. J. Exp. Mar. Biol. Ecol. 61: 31-35.

Sammarco, P.W., J.S. Leviton & J.C. Ogden. 1974. Grazing and control of coral reef community structure by *Diadema antillarum* Philippi (Echinodermata: Echinoidea): a preliminary study. J. Mar. Res. 32: 47-53.

Solis-Marín, F.A., H. Reyes-Bonilla, M. D. Herrero-Pérezrul, O. Arizpe-Cobarrubias & A. Laguarda-Figueras. 1997. Sistemática y distribución de los equinodermos de la Bahía de la Paz. Ciencias Marinas 23: 249-263.

Tribollet, A., G. Decherf, P. A. Hutchings & M. Peyrot-Clausade. 2002. Large-scale spatial variability in bio-erosion of experimental coral substrates on the Great Barrier Reef (Australia): importance of microborers. Coral Reefs 21: 424-432.

Woodley, J. D. 1999. Sea urchins exert top-down control of macroalgae on Jamaican coral reefs. Coral Reefs 18: 192-193.

Zar, J. H. 1999. Biostatistical analysis. Prentice Hall, New Jersey. 718 p.

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 3): 263-273, December 2005

273