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Influence of sediments and tungsten traces on the skeletal structure of *Pseudodiploria*: a reef building scleractinian coral from the Veracruz Reef System National Park, Mexico

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Abstract: Coral reefs are under intense conditions of stress caused by the anthropogenic activities in coastal areas and the increase of human population. Water effluents from urban and industrial areas carry large amounts of sediments and pollutants affecting corals populations, inducing bioerosion, increasing diseases and promoting the development of algae that compete for space with corals. In the Veracruz Reef System National Park (VRSNP) coral reefs are strongly affected by human activities carried out in the area. Gallega and Galleguilla reefs are among the most affected by wastewater discharges from the industrial (petrochemical and metallurgical) and urban areas in their vicinity. To assess the potential impact of this contamination on corals in the VRSNP, a chemical composition and morphology study of 76 *Pseudodiploria* colonies collected in reefs Gallega, Galleguilla, Isla Verde and Isla de Enmedio, was performed. Fragments of ~10 cm^2 were collected and boric acid at 0.5 % was used to remove tissue from the skeleton; once clean, the morphology of each sample was determined with a scanning electron microscope (SEM). Subsequently, to test the chemical composition, an energy dispersion spectroscopy of X-ray chemical microanalysis (EDSX) was performed in the SEM. We found that corals from Gallega and Galleguilla reefs, located closer to human populations, presented high levels of tungsten and the skeleton exhibited multiple perforations. In contrast, corals from the farthest offshore reefs (Isla Verde and Isla de Enmedio) exhibited lower levels of tungsten and fewer perforations in their skeleton. These results demonstrated that anthropogenic activities in the NPVRS are affecting corals skeleton, highly damaging and promoting their bioerosion. The presence of traces of tungsten in the skeleton of corals is an evidence of the damage that waste discharges are causing to coral reefs. Discharges of large amounts of contaminants promoted the growth of harmful species that grow and develop into the corals skeleton, causing its bioerosion, and making them susceptible to disease and physical damage. This study is the first evidence of the effects of contamination on these species; therefore, further studies are necessary to determine the impact of pollution on their biology and survival. Rev. Biol. Trop. 64 (3): 1077-1089. Epub 2016 September 01.

Key words: sediment, pollution, coral bioerosion, coral reefs, skeletal structure, morphology.

Coral reefs are among the most productive and diverse ecosystems of the world (Jackson, Donovan, Cramer, & Lam, 2014). Millions of humans depend of their resources; in the Caribbean more than 43 million people live within a distance of 30 km from coral reefs (Burke, Reytar, Spalding, & Perry, 2011). However, reefs near human populations are constantly stressed, due to the activities conducted in coastal areas, such as tourism, coastal urban development, pollution, sedimentation and over-fishing (Jackson et al., 2014).

One of the main sources of pollution and degradation in corals reefs is water discharge from terrestrial runoffs (Fabricius, 2005; Bourke, Selig, & Spalding, 2002). Their negative effects on coral reefs are of great importance as they introduce high levels of inorganic and organic nutrients, pollutants and sediments that affect coral development (Carricart-Ganivet & Merino, 2001; Stolarski, 2003). Besides, these anthropogenic disturbances in coral reefs induce bioerosion of scleractinian coral skeletons (Scoffi et al., 1980; Cortes & Risk, 1985; Hubbard, Miller, & Scaturo, 1990; Hodgson & Yau, 1997; Holmes, 2000; Fabricius, 2005), decrease coral cover and diversity (Hodgson, 1990; Hodgson & Walton-Smith, 1993), and reduce coral calcification (Fabricius, 2005). They are also a source of trace metals, nutrients and other substances that corals deposit in their skeleton and tissue (Kayser, 1976; Harland & Brown, 1989; Reichelt-Brushett & Harrison, 2005). Previous studies have reported that high levels of nutrients originated from terrestrial runoffs, have modified the amount of internal macro and micro-bioeroders (Rose & Risk, 1985; Hallock & Schlager, 1986; Hallock, 1988; Cuet, Naim, Faure, & Conan, 1988; Lazar & Loya, 1991; Holmes, 2000; Chazottes, Campio-Alscumard, Peyrot-Clausade, & Cuet, 2002), which can lead to decreased coral skeleton density.

The increase in the amount of pollutants and sediments that are being released in coastal areas is causing deterioration of coral reefs; many contaminants are becoming a serious problem, because they are persistent and may be bio-accumulated (Peters, Gaassman, Firman, Richmond, & Power, 1997). Corals incorporate pollutants into their tissues or skeletons through the substitution of Calcium with pollutants, by trapping sediments during coral feeding, or when the particulate matter with traces of pollutants is included within skeletal cavities (Brown, 1987). Most sediments are introduced to reef systems via rivers; larger sediment fractions are deposited close to the coast, affecting coral communities located near to the river mouth and coastal areas (Golbuu, Victor, Wolanski, & Richmond, 2003); some other documents have also reported that with high sediment rates the coral tissue can be killed in a few days (Riegl & Branch, 1995).

Sediment damage may vary depending on coral species and sediment type; at high sediment rates many species of corals cannot survive, but some species are more resistant and have the ability to adapt to these conditions (Roger, 1990; Fabricius, 2005). In summary, sedimentation may induce changes in coral structure, decreasing colony size, modifying its form and reducing coral growth (Roger, 1990). Nevertheless, there are no studies regarding the effect of sedimentation on the skeletal structure of corals and the implications in coral survival.

In the Veracruz Reef System National Park (VRSNP), Mexican corals of the genus *Pseudodiploria* are among the most abundant in the flat reef zone. However, according to previous reports performed by Horta-Puga and Tello-Musi (2009), locations in the VRSNP that are impacted by water discharges and human activities are also the same locations where higher densities of *Pseudodiploria* colonies are found. The VRNSP is located in one of the most populated coastal areas of the Gulf of Mexico, and an increasing land-based runoff alters the landscape. Several rivers and discharges from industrial areas surrounding this reef system carry large quantities of pollutants, sediments, hydrocarbons and pesticides produced by human activities in the area (ISRS, 2004). In previous field observations in this reef system, we detected several colonies with some degradation (loss of tissue, several white spots and irregular morphology) in their skeletal structure, especially coral species of the genus *Pseudodiploria*. Thus the aim of this work was to perform a morphological analysis of the skeletal structure in *Pseudodiploria* colonies that exhibit damage in their skeletal structure, and to determine if environmental conditions are inducing damage or changes in the corals morphology, in samples taken from four different reefs in the VRSNP. Additionally, a chemical composition analysis was conducted to detect possible pollutants in the coral's skeleton.

MATERIALS AND METHODS

Study area: The Veracruz Reef System National Park (VRSNP) is located in the central portion of the West Gulf of Mexico, in the state of Veracruz (Fig. 1). For this study, four reefs were chosen. Two reefs close to the coastal environment, the coastal reef "Gallega" and the platform reef "Galleguilla" located in North VRSNP. And two offshore reefs: Isla Verde reef, located in the central portion of the North side of the VRSNP, and Isla de Enmedio reef, located in the central portion of the South side of the VRSNP, and near the Jamapa River plume.

The Gallega (near the coast) and Galleguilla (1.5 km from the coast) reefs are widely impacted (due to their location) by anthropogenic activities and terrestrial runoff from industrial and urban areas. Isla Verde reef is located to 6.5 km from the coast, but is not impacted

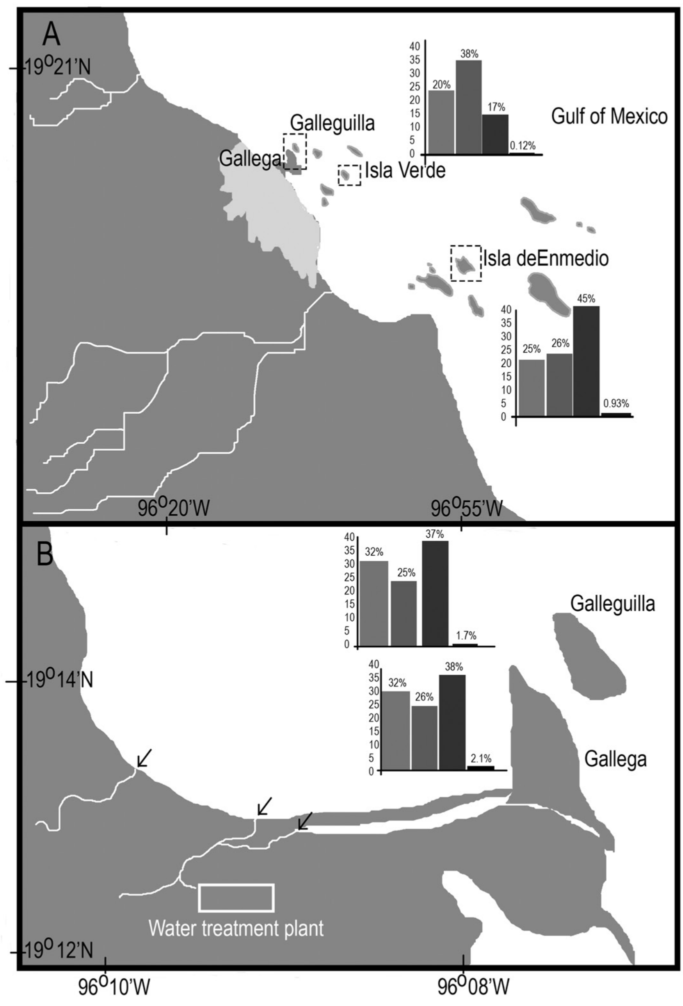

Fig. 1. Veracruz Reef System National Park. **A)** The Jamapa Basin and Antigua Basin in the state of Veracruz, and the average concentration of the chemical microanalysis for Isla Verde and Isla de Enmedio reefs. **B)** The average concentration of chemical microanalysis results for Gallega and Galleguilla. The black arrows indicate industrial and domestic discharges; white polygon: water treatment plant. Dotted arrow, currents in summer. Gray arrows, currents in winter.

directly by runoff discharge or anthropogenic activities. Isla de Enmedio reef is located at 6.8 km from the coast, near the Jamapa river plume. These reefs were chosen in order to assess the effect of terrestrial runoff in coral population. A list with all the possible impacts that affect these reefs is shown in Table 1.

Small fragments (~10 cm^2) of 76 *Pseudodiploria* colonies were collected from Gallega (20 samples), Galleguilla (20 samples), Isla Verde (20 samples) and Isla de Enmedio (16 samples) coral reefs (Fig. 1) in October 2013, during the rainy season. The sampling protocol for the VRSNP was approved by the Comisión Nacional de Acuacultura y Pesca (Permit Number. PPF/DGOPA-072/13). The *Pseudodiploria* genus is not endangered or protected according to the NOM-059-SEMARNAT-2010. Fragments were taken from the top, middle, and bottom of the colony to test variability and to have a representative sample of the specimen without removing the entire colony. The colonies were located in shallow waters (~3 m depth), and fragments were obtained only from colonies with a diameter of thirty centimeters or more. Fragments were placed in vials with cotton to prevent their damage during transfer to the laboratory.

TABLE 1
Possible impacts that affect the reefs where the samples were taken

Reefs	Possible impacts
Gallega and Galleguilla	Discharges of wastewater from a treatment plant Discharges of water from petrochemical industry Near to the Port of Veracruz Near to human settlements (population of 428 323 people) Near mouth rivers
Isla Verde and Isla de Enmedio	Probably affected indirectly by Jamapa river plume Tourism Fishing

Samples were processed in the laboratory of Ecología de Ecosistemas de Arrecifes Coralinos in the Centro de Investigación y Estudios Avanzados Unidad Merida (Cinvestav-Unidad Mérida). Once in the laboratory, samples were submerged in a one-liter glass with a boric acid solution (0.5 %) for three days, to remove the tissue from the skeleton (Budd & Stolarski, 2009); the remaining tissue was washed away with distilled water. Afterwards, the skeleton fragment was dried in an oven (Isotemp Vacuum Oven, Model 281A, Fisher Scientific) at 32 °C for 24 hrs.

Each fragment was analyzed with scanning electron microscopy (SEM) (EDAX genesis model XL30ESEM, Phillips with SiLi detector) in the National Laboratory of Nano and Biomaterials, at Cinvestav-Unidad Mérida.

Additionally, SEM was used to test the chemical composition of the samples that showed degradation in their skeletal structure through energy dispersion spectroscopy of X-ray chemical microanalysis (EDSX). This technique analyses all of the periodic table elements in samples, with a resolution of 1 μm and a depth of 0.5 to 10 μm. The sample is excited by a beam of accelerated electrons and emits a photon X-ray, which enters the Si-Li detector and becomes a charge pulse. This charge pulse is converted into a voltage pulse and then into a digital signal that forms a histogram or X-ray spectrum. The element’s concentration is determined by the energy of the peaks compared with known X-ray energy peaks. The samples were previously covered with a conductive platinum film for 90 seconds, to optimize the results. Image processing in SEM was carried out using the software Genesis 6.37. Significant differences of each element relative to the reefs were evaluated using an analysis of variance (ANOVA) in the software Infostat. The statistical significance was fixed at $p < 0.05$ at a 95 % confidence level. The concentration of each element was correlated with the reefs and was assessed using a regression analysis.

RESULTS

The half of the sampled *Pseudodiploria* colonies (38 or 50 %) presented perforations in their skeletal structure (mainly in the septa) or an internal hollow in the structure. Colonies from Gallega (Fig. 2 A and Fig. 2 B) and Galleguilla (Fig. 2 C and Fig. 2 D) exhibited the hollow characteristic over the entire length of the septum or even the columella. In contrast, colonies from Isla de Enmedio (Fig. 2 E and Fig. 2 F) and Isla Verde (Fig. 2 G and Fig. 2 H) exhibited little or no damage in their skeletal structures. Seventeen of the twenty colonies

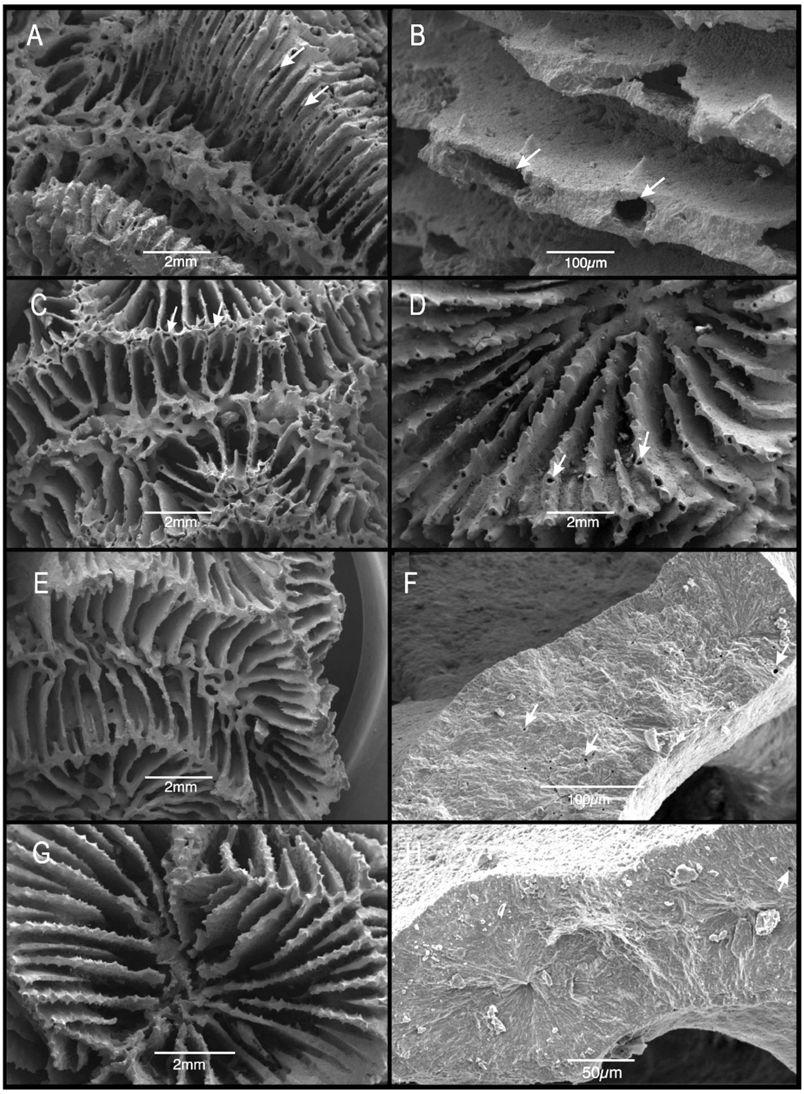

Fig. 2. Scanning electron microscopy images that exhibit damage of corallite and septa of *Pseudodiploria* colonies collected in the VRSNP; Samples from nearshore reefs: Gallega **(A-B)** and Galleguilla **(C-D)**. Samples from offshore reefs: Isla de Enmedio (**E-F)** and Isla Verde **(G-H).** White arrows indicate internal damage (perforations) of the skeletal structure.

from Gallega reef exhibited damage in their skeletal structure, including twelve from Galleguilla, six from Isla de Enmedio, and three from Isla Verde.

The EDSX analysis of the components in the skeletal $CaCO_3$ was performed only for the colonies that exhibit damage in their structure (colonies that did not show damage in their skeleton, exhibited null levels of pollutants). The analysis revealed that colonies from Gallega and Galleguilla (Fig. 3 D) contained high levels of tungsten (Gallega > 2 %; Galleguilla between 1.5-2 %). The samples from Isla de Enmedio showed levels of tungsten between 0.8-1 % (Fig. 3 D). The samples from Isla Verde showed low concentrations (0.3-0.5 %) of tungsten (Fig. 3 D). To compare these results, three samples from the Mexican Caribbean reefs were analyzed, and these samples showed no evidence of pollutants in their skeletal structure. All of the samples were analyzed inside and outside of the perforations;

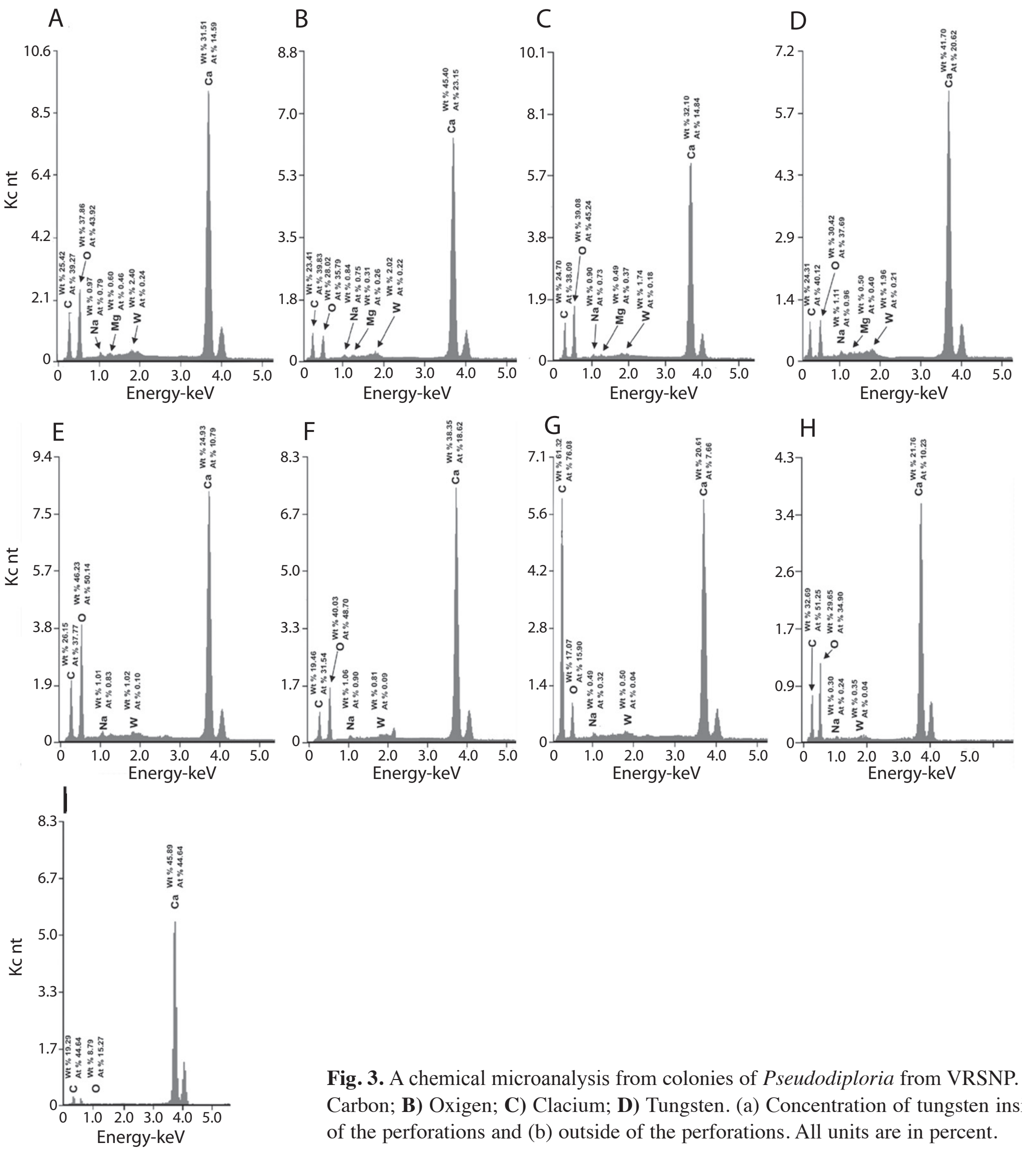

Fig. 3. A chemical microanalysis from colonies of *Pseudodiploria* from VRSNP. **A)** Carbon; **B)** Oxigen; **C)** Clacium; **D)** Tungsten. (a) Concentration of tungsten inside of the perforations and (b) outside of the perforations. All units are in percent.

also we analyzed areas where the skeletal structure did not show any kind of degradation. In most of the cases, tungsten concentration was higher inside (Fig. 3 D, a) than outside the perforations (Fig. 3 D, b), and was the only element detected that could be associated to anthropogenic activities (Table 2). Calcium, Carbon and Oxygen (Fig. 3 A, Fig. 3 B and Fig. 3C) were also detected in the EDSX analysis, and their ratios were similar among reefs.

The mean and standard deviation values of the elements detected in the EDSX analysis are presented in Table 2. The mean concentration of tungsten was high in the nearshore reefs (Gallega and Galleguilla) compared to that found offshore. Additionally, a decreasing gradient was detected in the tungsten concentration with respect to the distance from the coast (Fig. 4). Tungsten (F value: 180.87; $p < 0.0001$) and Oxygen (F value: 4.27; 0.0116) were the elements that exhibited significant differences among the reefs according to ANOVA. Calcium concentration was higher in Gallega and Galleguilla reefs (Table 2). The higher concentrations of tungsten in the Gallega and Galleguilla reefs are probably more affected by pollution, because these reefs are located near the mouth (~3 km) of a water treatment plant that receives waste water effluent from an industrial and petrochemical area (Fig. 1). Samples collected from reefs close to the coast presented also some evidence of boring bivalves in their skeleton (Fig. 5 B and Fig. 5 C), while samples collected offshore reefs did not (Fig. 5 A).

TABLE 2
Mean percentages of each element detected in the samples of *Pseudodiploria* colonies

Reef/Element	C %	O %	W %	Ca %
Gallega	33.51 ± 6.94	35.79 ± 4.84	2.19 ± 0.14	32.08 ± 8.70
Galleguilla	33.71 ± 6.72	41.75 ± 6.4	1.62 ± 0.27	35.70 ± 7.49
Isla de Enmedio	33.25 ± 9.49	42.58 ± 4.48	1.00 ± 0.06	27.33 ± 2.987
Isla Verde	38.47± 9.36	36.97 ± 8.36	0.45 ± 0.05	25.38 ± 4.13

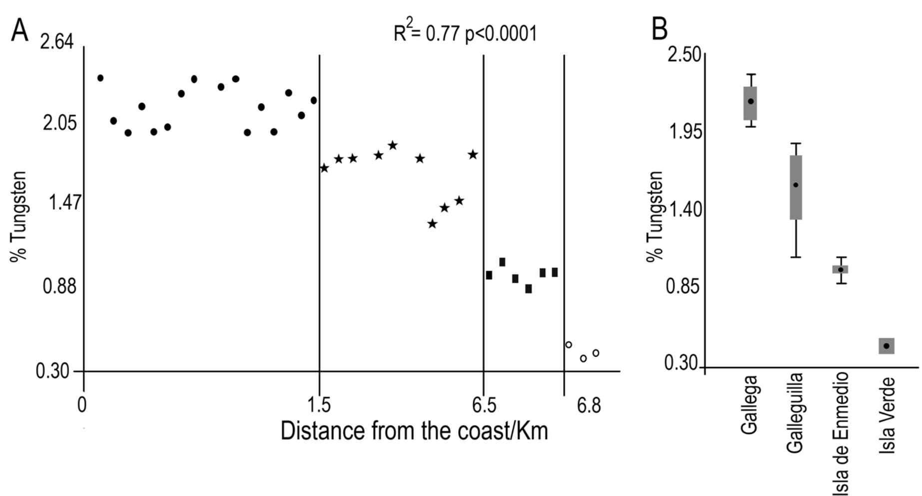

Fig. 4. A) Percentage of tungsten concentration with respect to the distance to coast were samples collected R^2= 0.77. **B)** Boxplot of the differences in tungsten concentration among reefs. Mean in black dots, gray box shows variations of tungsten concentration and whiskers exhibit SD.

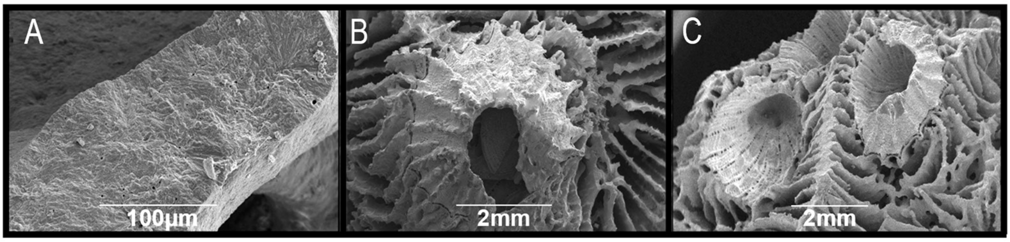

Fig. 5. A) Evidence of damage in the internal structure of $CaCO_3$. **B-C)** presence of bivalve in the skeletal structure of *Pseudodiploria* and the internal damage.

DISCUSION

The increase of sediment and pollutants amount deposited in coastal areas of the NPVRS may cause the damage (perforations, degradation, and weakening) in the skeletal structure of *Pseudodiploria* colonies. The Gallega and Galleguilla reefs are exposed to high sedimentation because they are affected by nearby wastewater and industrial discharges. Samples from these reefs exhibited more damage than those that were located further away from the coastal areas, such as Isla Verde and Isla de Enmedio; a gradient of decreasing skeletal damage in relation to costal distance was observed.

Sediments can be incorporated into the $CaCO_3$ skeletal structure through different ways. Cortes and Risk (1984), reported that when a new coral polyp occupies the free space left by a coral polyp, the sediment could be trapped within cavities of the new skeletal structure. Corals can also incorporate sediments by accidental feeding or by the mucus nets that trap small particles, which are periodically ingested by the coral (Ramos, Inoue, & Ohde, 2004; Corrège, 2006). Another of the possible causes of coral skeleton degradation could be the bioerosion induced by internal macro and micro-bioeroders (molluscs, polychaetes, green and blue-green microalgae), that weaken the $CaCO_3$ structure of corals, and make them susceptible to storm damage (Rose & Risk, 1985; Hallock & Schlager, 1986; Hallock, 1988; Holmes, 2000; Chazottes et al., 2002).

The presence of a boring bivalve in the skeleton of *Pseudodiploria* colonies in the NPVRS was found. Boring organisms remove material from the interior of the skeletal structure through chemical dissolution of the coral substrate or by mechanical abrasion (Lazar & Loya, 1991). Previous reports have found that bioerosion is more common in inshore than offshore reefs (Sammarco & Risk, 1990; Edinger & Risk, 1996), which is consistent with our results. This is due to the fact that the inshore reefs are being influenced directly by the increment of nutrients from the wastewater discharges that carry several pollutants, and problably tungsten compounds that come from industrial (Senesi, Padovano, & Brunetti, 1988) and agricultural areas (Koutsospyros, Braida, Christodoulatos, Dermatas, & Strigul, 2006). In addition, several rivers discharge water to coastal reefs of the VRSNP, affecting reef ecology.

The Northern region of the VRSNP is affected by La Antigua river runoff (annual discharge of 2.88×10^6 m^3/year) and is located ~18 km from the Gallega and Galleguilla reefs; the Jamapa River discharges (annual discharge of 1.89×10^6 m^3/year), at the center of the VRSNP, and is located ~16 km from the Isla de Enmedio reef and ~12 km from the Isla Verde. The Papaloapan River discharges affect principally the Southern part of the VRSNP; the nearest reef to this river is the Cabezo at ~30 km. The Papaloapan River is one of the largest rivers in Mexico (Tamayo, 1999) with an annual discharge of 36.19×10^6 m^3/year. River plumes can extend several kilometers into coastal waters; due to the effect of ocean currents, the plumes of the Jamapa, Antigua and Papaloapan Rivers are oriented Southward during the winter and Northward during the summer (Krutak, 1997). A total of 89.8 % of the surface water of the Jamapa River basin is used by several industries (metallurgy, wood, food, textile, among others), and 6.88 % is used for agriculture (CNA, 2014). A 44.87 % of the water from the Antigua River basin is used by the industry, while 49.81 % is used for agriculture. A total of 38.7 % of the water in the Papaloapan River basin is used for industry, and 56.9 % is used for agriculture (Consejo del Sistema Veracruzano de Aguas, 2014). These rivers cross urban, agricultural and industrial areas, and increase the probability to transport pollutants, such as tungsten, which are deposited in the coastal waters near the VRSNP (Cruz-Abrego, Flores-Andolais, & Solís-Weiss, 1991). These water discharges alter environmental conditions by introducing pollutants and terrigenous sediments, producing eutrophication and changing marine chemistry. Previous studies have reported concentrations of contaminants in Veracruz coastal waters (Vázquez-Botello, Villanueva-Fragoso, & Rosales-Hoz, 2004) that exert a negative influence on coral communities. The Gallega reef presents the highest sedimentation rates: 653.30 cm^3/m^2 during rainy season, 1 854.82 cm^3/m^2 during dry season, 2 693.76 m^3/m^2 during North season; in decreasing order, it was followed by Galleguilla reef with respective values of 299.86 cm^3/m^2, 766.07 m^3/m^2 and 1 377.59 m^3/m^2; Isla Verde with 435.76 cm^3/m^2, 530.32 m^3/m^2 and 983.89 m^3/m^2; and Isla Enmedio 174.20 m^3/m^2, 186.51 cm^3/m^2 and 353.87 m^3/m^2, respectively (Mendel-Albarado, 2014). The high rates of sedimentation in the Gallega and Galleguilla reefs may be product of water discharges of urban and industrial origin, due to the proximity of these reefs to the costal line.

The concentration of tungsten and the reefs distance from the shoreline were found to have significant positive correlations (r^2= 0.77, F= 117.72, p <0.0001), and a descending gradient in tungsten concentration from the coast to the open water in the VRSNP was found. The Gallega and Galleguilla reefs exhibit the highest tungsten values due to their proximity to the coastal area of Port of Veracruz, whereas Isla Verde and Isla de Enmedio showed low levels. Similarly, tungsten concentration was higher inside than outside the perforations found on corals. This is most likely because the particulate matter containing traces of tungsten was trapped in the skeleton. Once in the water, tungsten compounds are found as ions (WO_4^{2-}) or insoluble ions, and can adsorb suspended solids and sediments in the water column (Tanizaki, Shimokawa & Nakumura, 1992). This probably has facilitated the incorporation of sediments with tungsten particles in the coral skeleton during skeletogenesis.

There are no reports of maximum permissible concentrations of tungsten in corals, water or sediments, however, some studies have reported that concentrations of tungsten in seawater are 0.12 µm/Kg (Ishibashi, Fujimawa, & Kwamoto, 1961) and in sediments 10-60 µm/Kg (Pilipchuk & Volkov, 1966; Kunzendorf & Glasby, 1992). According to Newbury (2008), maximum levels of trace metals (tungsten) in a sample of either soil or water should be less than one percent. A previous study has reported the presence of heavy metals (Cd, Cu, Ni, Pb, Va, Cr) in water and sediments from Gallega and Galleguilla reefs (Cerón-Alvarado & Rosales Hoz, 2007). Additionally, previous works have found that metals concentrations were higher in sediments than water (Rozalez-Hoz, Carranza-Edwards, Cerón-Alvarado, & Celis-Hernández, 2010) mainly related by the waters coming from the urban and industrial areas of the Port of Veracruz. Corals from Gallega and Galleguilla reefs exhibited levels of tungsten >1 %, while in corals from Isla Verde and Isla Enmedio reefs tungsten levels were less than one percent, which is indicative that tungsten concentrations in Gallega and Galleguilla reef are high. The presence of tungsten in the $CaCO_3$ structure of corals is very important because tungsten exerts an inhibitory effect on nitrogenase activity, replacing Molybdenum in the enzyme's structure and inhibiting its enzymatic activity (Kakefuda, Duke, & Duke, 1983). This may affect the development and survival of zooxanthellae and/or coral, because they use nitrogen for nutrients production. Additionally, elevated levels of tungsten stimulate the growth of many types of microorganisms (Kletzin & Adams, 1996) that may harm corals survival.

Calcium concentration was higher in inshore reefs than offhore reefs; calcium concentration in seawater can be affected by several factors (temperature, light, nutrition, salinity, pH and water saturation) that can limit or make it available for corals during calcification (Allemand, Tambutté, Zoccola, & Tambutté, 2011). Calcium can be added to the marine environment by river runoff and atmospheric deposition. Human activities increase calcium levels in rivers waters by industry and agriculture (Jorgensen, 2010); and changing land use for agriculture and the use of fertilizers can increase calcium levels in the water (De la Rocha, Hoff, & Bryce, 2008). In the case of the PNSAV, this water is deposited in coastal areas of Gallega and Galleguilla reefs, which can increase the amount of available calcium for corals, and thus, calcium precipitation rate may be higher in inshore than offshore reefs. Also, in areas were nutrients and particulate loads are high, corals present higher concentrations of photosynthetic pigments, due to an increase in the number of zooxanthellae, causing a rise in calcification (Tomascik & Sander, 1985). Environmental conditions in the Gallega and Galleguilla reefs may probably have had higher calcium availability compared with offshore reefs.

Several papers have reported the effect of sedimentation on corals growth and morphology (Foster, 1979; Hubbard et al., 1990; Roger, 1990; Stanfford-Smith & Ormond, 1992). However, this study contribution is to report, for the first time, the damage that water effluents with high levels of suspended sediments/polluants can cause on corals. Coral reefs are also being degraded by other human activities such as poor land-use practices that cause nutrient and sediment pollution; besides, industry, high and increasing population, tourism, and coastal pollution contribute. Our results provided direct evidence of how anthropogenic activities can directly affect the skeletal structure of coral populations located nearby urban areas. Human activities are affecting the environmental conditions in the VRSNP, promoting reef degradation and accelerating the degradation of the $CaCO_3$ structure of coral skeleton. Additional research needs to be done in order to test the effect of other environmental conditions, pollutants and anthropogenic activities on scleractinian corals. New surveys should include other reefs of the VRSNP, in order to measure all of the possible effects that human activities may cause in the corals skeletal structures.

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RESUMEN

Influencia de los sedimentos y trazas de tungsteno en la estructura del esqueleto de ***Pseudodiploria*** **un coral escleractinio constructor de arrecifes del Parque Nacional Sistema Arrecifal Veracruzano, México.** Los arrecifes de coral se encuentran bajo condiciones intensas de estrés causado por las actividades antropogénicas y el incremento de las poblaciones humanas en las zonas costeras. Las descargas de aguas de origen urbano e industrial transportan sedimentos y contaminantes que afectan a las poblaciones de corales, induciendo la bioerosion, el aumento de enfermedades en los corales y promueven el desarrollo de algas que compiten por espacio con los corales. En el Parque Nacional Sistema Arrecifal Veracruzano (NPVRS) los arrecifes de coral son afectados fuertemente por las actividades humanas que se llevan a cabo en la zona. Los arrecifes Gallega y Galleguilla son de los más afectados por las descargas de aguas residuales provenientes de la industria (petroquímica y metalúrgica) y de áreas urbanas que desembocan sus aguas en las proximidades de los arrecifes. Para evaluar el posible impacto de las descargas de aguas en los corales del NPVRS, se realizó un estudio de la composición química y morfología de

76 colonias de *Pseudodiploria* en los arrecifes Gallega, Galleguilla, Isla Verde e Isla de Enmedio. Se recolectaron fragmentos de ~10 cm^2, el tejido del esqueleto fue removido utilizando ácido bórico al 0.5 %. Una vez limpia la muestra, la morfología fue analizada con un microscopio electrónico de barrido (SEM), posteriormente, para analizar la composición química de las muestras, realizamos una espectroscopia de dispersión de energía o micro-análisis químico de rayos X (EDSX) en el SEM. Encontramos que los corales de los arrecifes Gallega y Galleguilla que se encuentran ubicados cerca de poblaciones humanas, presentan altos niveles de tungsteno y el esqueleto exhibe múltiples agujeros. En contraste, los corales de los arrecifes más lejanos (Isla Verde e Isla de En medio) mostraron niveles más bajos de tungsteno y un menor número de agujeros en su esqueleto. Nuestros resultados demuestran que las actividades antropogénicas en el NPVRS, están afectando el esqueleto de los corales y promueven la bioerosión. Las descargas de grandes cantidades de contaminantes hacia las zonas costeras, promueven el crecimiento de especies dañinas que crecen y se desarrollan dentro del esqueleto de los corales, causando bioerosión del esqueleto, haciéndolos susceptibles a enfermedades y daños físicos. Debido a que este estudio es la primera evidencia de los efectos de la contaminación sobre esta especie de corales, son necesarios más estudios para determinar el impacto de la contaminación sobre su biología y la supervivencia de los corales.

Palabras clave: sedimentación, contaminación, bioerosión del coral, arrecifes de coral, estructura del esqueleto, morfología.

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