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Review

Bacteria that affects coral health with an emphasis on the Gulf of Mexico and the Caribbean Sea

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ABSTRACT. Reefs are the most biologically diverse marine ecosystems; therefore, to conserve the vast array of marine species that depend on them is vital. Many coral reefs around the world are under threat of extinction due to factors related to climate change and anthropogenic action. Studies have shown that specific infections develop at normal ocean temperatures and that warmer temperatures make the disease even more virulent. Also, as temperature increases, the infection in already infected corals becomes lethal. Thermal stress and the presence of pathogenic bacteria from the contribution of organic matter generates pathological affections in coral tissue, such as the White Band, Black Band, Yellow Band, White Plague, and Bacterial Whitening. This stimulates, in the short term, loss of coral cover and in the long term, negative impacts on the faunal composition of marine ecosystems. This review aims to present scientific information generated in the identification of different pathogenic bacteria that affect the health of corals.

Keywords: biodiversity, pathologies, bacterial whitening, climate change, anthropogenic action, *Vibrio* spp.

INTRODUCTION

Coral reefs worldwide protect the high biodiversity of species that over time have been threatened by human activities and settlements in its vicinity (Zamudio-Alemán *et al.*, 2014). The effect of climate change, by impacting with a gradual increase in water temperature, constitutes a threat to the existence of coral reefs. By the end of the century, in 2100, the average global temperature of water could rise from 1.4° to 5.8°C according to the International Panel on Climate Change (IPCC) (Rahman-Sunny, 2017; Abera-Hirpo, 2018). The trend in temperature increase for the present century is an observed value of 0.13°C per decade from 1971 to 2000. For the current period from 2011 to 2040 a trend of an increase of 1.4°C is expected, while for 2041 to 2070 that increment could rise to 2.4°C (Magoni & Mesa-Muñoz, 2018). The gradual increase in temperature shows a relationship with the presence of bacteria, which threatens coral communities causing damage to the polyp-symbiont-holobiont association (coral polyp, zooxanthellae and bacteria) (Maynard *et al.*, 2015), the latter causes loss of coral cover (Jackson *et al.*, 2014; Marulanda-Gómez *et al.*, 2017).

Some pathogenic bacteria are difficult to identify, as are environmental parameters of the ocean that increase the infectious effect. There are not many phenotypic differences in disease in corals and may correspond to different types of infections (Page *et al.*, 2016). Coral species present a difference in their bacterial composition, as well as in species found in the water column. However, there are still studies to be done, in order to know its origin and how pathogenic bacteria act on the coral (Sassi *et al.*, 2015).

Microbiological studies in corals emerge because of the presence of different diseases (Table 1). Some authors have the purpose of identifying the pathogen, fulfilling the postulates of Köch (Puyana *et al.*, 2015). For the identification of pathogens, the most commonly used techniques are microbiology and molecular biology like Polymerase Chain Reaction (PCR) because of their simplicity, low cost, and reliability of results (Sweet *et al.*, 2017).

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Table 1. Pathogenic bacteria in scleractinian corals.

Pathogen	Distribution	Affected corals	Disease	Reference
Halofolliculina corallasia	Caribbean Sea, Mexican Caribbean, Red Sea	Acroporidae, Agaricidae, Astrocoeniidae, Faviidae, Meandrinidae, Poritidae	Eroded skeletal band	Cróquer *et al.* (2005); Iyer (2016)
Oscillatoria sp.	Caribbean Sea, Mexican Caribbean	Scleractinian and octocoral corals	Black band disease	Frías-López *et al.* (2003); Miller & Richardson (2012); Gavio *et al.* (2015).
Vibrio spp.	Caribbean Sea Pacific Ocean Indian Ocean	Scleractinian and octocoral corals	Multiple diseases	Kushmaro *et al.* (1997); Rosenberg & Kushmaro (2011); Mantilla-Galindo (2015); Kemp *et al.* (2018).
Phormidium corallycticum	Caribbean Sea Pacific Ocean	Scleractinian and octocoral corals	Black Band Disease	Frías-López *et al.* (2003); Work & Weil (2016).
Phormidium valderianum	Indian Ocean	*Porites lutea*	Pink Line Disease	Ravindran & Raghukumar (2002); Mantilla-Galindo (2015); Ravindran *et al.* (2016).
Aurantimonas oralicida	Caribbean Sea	*Dichocoenia stokesi*	White Plague Disease	Denner *et al.* (2003); Gil-Agudelo *et al.* (2006); Bruckner, 2016.
Helicostoma nonatum	Caribbean Sea		Brown Band	
Serratia marcescens	Caribbean Sea	Acrocporidae	White Pox	Sutherland & Ritchie (2004); Rodríguez-Villalobos *et al.* (2013).

The study of the different diseases that are presented in corals is of international concern. Investigations that are being developed go from being descriptive to multidisciplinary. These investigations involve aspects of ecology, microbiology, and chemistry (Vogel *et al.*, 2015; May & Woodley, 2016; Meyer *et al.*, 2016). This review aims to present scientific information generated from the identification of different pathogenic bacteria that affect coral's health with an emphasis on the Gulf of Mexico and the Caribbean Sea.

Halofolliculina corallasia (Antonius & Lipscomb, 2001)

Halofolliculina corallasia is a sessile ciliary heterotrichea, although it is not a bacterium, it is the first reported protozoan that affects corals; it is distinguished by its type of reproduction (cell division and conjugation). The cell has two nuclei and at some stage in its life presents cilia (Antonius & Lipscomb, 2001). Coral species that are affected by this ciliary (*Halofolliculina*) have a dark band that surrounds the healthy tissue and on the opposite side a skeleton recently devoid of tissue. The particularity of this affectation is observed in an approach, where independent cilia can be observed, which is found in the dark band (Alder, 2014).

The genus *Halofolliculina* affects 25 species of scleractinian coral from six families in the Caribbean (Acroporidae, Agaricidae, Astrocoeniidae, Faviidae, Meandrinidae, and Poritidae) (Page *et al.*, 2016). These observations include the coasts of Venezuela, Panama, Mexico, Curazao and Puerto Rico (Cróquer *et al.*, 2005). In the Indo-Pacific region, it was suspected that the species *H. corallasia* was the cause of diseases in its coral areas, but it was shown that this ciliate belongs to another species. The disease of the skeletal eroding band (SEB), which manifests as dense aggregations of the ciliate *H. corallasia*, is confused with diseases of the black band. Another disease caused by the bacterium is the Caribbean ciliate infection (CCI) a mottled appearance with black bands on the body of the coral; affecting ten coral species included *Dichocoenia*, *Montastrea*, *Acropora* spp. (Sheridan *et al.*, 2013).

Damage caused by this species is undoubtedly a limiting factor for reef-forming coral species. The mechanisms that develop the disease are still unknown, so further research is needed on this subject (Cróquer *et al.*, 2005).

Oscillatoria sp.

The genus Oscillatoria belongs to the division of Cyanobacteria of the group of autotrophic prokaryotes, which inhabits fresh, brackish and marine shallow waters, is distributed throughout the world although some species are geographically more limited (Gardner, 1932). It is reported by (Myers *et al.*, 2007), as the cause of affectations to scleractinian corals to Black Band Disease (BBD). The BBD is observed and described for presenting the skeleton of a naked coral followed by a dark band, where a consortium of bacteria, including the genus *Oscillatoria*, are the apparent cause of the disease. The band has a thickness of 5 to 20 mm, and after the band is the healthy tissue. The BBD affects more than 19 species of scleractinian corals, data obtained in the Caribbean Sea (Sutherland & Ritchie, 2004). Another disease caused by cyano-bacteria *Oscillatoria* sp. is the Red Band Disease (RBD), affecting coral species such as *Strigosa* sp., *Montastraea annularis, Montastrea cavernosa, Porites astreoides*, and *Siderastrea siderea*, having a range of affectation per day of approximately 1 mm.

The movements of the *Oscillatoria* genus in the BBD and RBD bands appear to be in response to chemical factors and not to luminosity responses. Miller & Richardson (2012) tested Black Bands disease based on the production of toxins, microcystin, and sulfide, produced by the bacterial consortium including the genus *Oscillatoria* under controlled conditions, resulting in tissue lysis when adding the toxins to the coral and a time of the same reaction compared to sick corals by the BBD. In this way, the participation of cyanotoxins by cyanobacteria and sulfide by sulfur reducing bacteria is demonstrated.

***Vibrio* spp.**

The species of *Vibrio* genus are Gram-negative bacteria, of a size of 2 to 3 µm in length, have a polar flagellum that gives them great mobility, are positive oxidase and facultative anaerobes, which support alkaline media as well as high concentrations in a saline medium. Species of bacteria reported as pathogenic are implicated in many diseases in corals. The characte-ristics of the affections are in function of the species-environment-host, causing negative impacts on the composition of marine ecosystems (Castañeda-Chavez *et al.*, 2015). Such is the case of *V. coralliilyticus, V. shiloi* that have been commonly detected in apparently healthy corals, which was studied by Kushmaro *et al.* (1997), revealing that *V. shiloi* affects the *Oculina patagonica* coral, this done in the Mediterranean Sea. Banin *et al.* (2001) further studied this etiology, finding that *V. shiloi* is attracted to the mucus generated by Patagonian coral. *Oculina patagonica* and adheres when temperatures range from 25-28°C. *V. shiloi* produces extracellular toxins that hinder the production of photosynthesis of the zooxanthellae (Ross, 2014).

Dark spot syndrome (DSS) is another disease involving *Vibrio* spp. These organisms in the kingdom Fungi, also affect corals of the genus Montastraea, Siderastrea, Stephanocoenia and even to *Agaricia agaricites*. The disease can be appreciated in the annular part of the coral with purple margins (Sheridan *et al*., 2013).

Shut-down-reaction (SDR) is another condition in corals where *Vibrio harveyi* and *V. alginolyticus* bacteria are involved; these mainly affect the corals *Stephanocoenia intersepta, Siderastrea siderea*, and *Montastraea annularis*, the disease appears as rapid tissue degradation (Sheridan *et al.*, 2013).

Ulcerative white spots (UWS) is caused by *Vibrio* spp. mainly affects species of the *Porites* genus. The appearance of the disease occurs with tissue whitening of 3-5 mm to 5 cm progressing in different patterns mainly in tissue loss (Raymundo *et al.*, 2003).

Black band disease type II (BBD II) affects the coral *Acropora cervicornis*, and it is believed that *Vibrio carchariae* is the cause, as studies by Ritchie & Smith (1995) demonstrated the presence of bacteria in diseased corals and absence in healthy corals. Madigan *et al.* (2003), demonstrates the doubtful participation of bacteria *V. charchariae* in failing to fulfill Koch's fourth postulate (4º the presumed pathogen must re-isolate itself from lesions produced in experimental organisms). There is no doubt that this disease has caused 99% of the death coral in the Caribbean Sea, an event discussed by Gladfelter in 1982 (Gil-Agudelo *et al.*, 2009) and continues to wreak havoc along the Caribbean Sea (González-Ontivero, 2006).

The genus *Vibrio* causes white Syndrome (WS), but the species is unknown. It mainly affects the coral genus *Turbinaria, Acropora, Goniastrea, Pocillopora, Porites, Pavona, Stylophora, Montipora,* and *Faviidae*. The disease characteristics are diffuse areas of tissue loss with an exposed skeleton (Sweet & Bythell, 2012). Yellow band disease (YBD) is caused by *Vibrio* spp. It affects mainly the *Montastraea* genus. The characteristic is spots where the skeleton is exposed, perimeter surrounded by a yellow to white margin (Cróquer *et al.*, 2013).

Some species of the *Vibrio* genus pose risks to corals health, which is undoubtedly demonstrated by the loss of coral cover and affects different coral species. There is a lack of identification of other agents of *Vibrio* spp., which are implicated in diseases of corals and the role of these bacteria in the infectious and etiological role of diseases (Arotsker & Kushmaro, 2016).

***Phormidium* sp. (Rützler & Santavy, 1983)**

The filamentous cyanobacteria *Phormidium* sp., presents a stratified macro and microscopic growth, is photoautotrophic, its phases (photoautotrophic and heterotrophic) are in the range of other species of cyanobacteria. *Phormidium* sp. causes damage to corals that facilitate the attack of other sulfoxide bacteria (Stal, 1995). Ravindran & Raghukumar (2002) report the cyanobacterium *Phormidium valderianum* (fulfilling the Koch postulates) as the cause of the Pink Line Syndrome (PLS) in the Indian Ocean, affecting the coral *Porites lutea*. The characteristic of this disease is a pink line, which separates dead tissue from living tissue. Ravindran & Raghukumar (2006), report that 20% of the *Porites lutea* colonies were affected by PLS in the Lakshadweep Islands, this in the Arabian Sea in 1996 and the percentage increased by 2000.

Studies were carried out to see the etiology of PLS caused by the cyanobacterium *Phormidium valderianum*, finding other pathogens of the Fungi kingdom (*Aspergillus niger*, *Curvularia lunata*), which together are involved in tissue degradation. In particular, the cyanobacteria attack and inhibit the photosynthesis originated by the zooxanthellae causing the expulsion of the same. In response to the PLS outbreak in coral, it was found that the abiotic factor is the increase of CO_2 in the medium, this, without the presence of agents of the Fungi kingdom (Ravindran & Raghukumar, 2006).

Phormidium corallyticum was described by Rützler & Santavy (1983) after a reclassification of a cyanobacteria, identified as *Oscillatoria submembranacea* by Antonius (1981). *P. corallyticum* was identified as the cause of BBD that attacks scleractinian corals. Frías-López *et al.* (2003) identified three cyanobacteria that in a consortium originate BBD, thus discarding the participation of *P. corallyticum*. The discussion regarding the agents causing BBD is under investigation.

Aurantimonas coralicida (Antonius & Lipscomb, 2001)

Aurantimonas coralicida, an obligate aerobe, belongs to the order Rhizobiales. The family comprises only two species, they are recognized because they have a bacillus form with polar flagella, branched colonies, and obtain its nourishment chemo-heterotrophically. Denner *et al.* (2003) proposed *A. coralicida*, as the putative pathogen of White Plague Disease Type II (WPD II). This bacterium is reported to affect more than 40 different species of corals (Weil *et al.*, 2006). Whereas the bacterial pathogen *A. coralicida*, isolated from *Dichocoenia stokesi*, is the only example for which Koch's postulates have been fulfilled (Denner *et al.*, 2003).

Other studies such as Sunagawa *et al.* (2009) performed the identification of bacteria present in coral *Montastraea faveolata*, healthy and diseased tissue samples with signs of WPD II, not finding the putative pathogen *A. coralicida*. Sunagawa *et al.* (2009) refer that WPD II is probably attributed to a bacterial complex or to different bacteria that may be causing WPD II like signs in many different coral species in both the Pacific and Atlantic regions.

Helicostoma notatum (Kahl, 1931)

The ciliate *Helicostoma notatum* is the possible cause of the Brown band disease (BrBD) that affects corals of the Great Barrier Reef (GBR). The appearance of the disease is a brown colored band that divides healthy tissue from diseased tissue, there is no specific band size, and sometimes there is a white band between healthy tissue and the brown band. The coloration of the band originates from the density of the ciliary *H. notatum*, which in aquarium culture condition; the brown color has a jelly appearance (Borneman, 2001 *apud* Willis *et al.*, 2004).

Serratia marcescens

Serratia marcescens is a Gram-negative Bacillus-like bacterium, growing in temperatures ranging from 5-40°C. They grow in pH levels that range from 5 to 9 (Bennett & Bentley, 2000), it is common to find it in the intestines of animals. It is noted as causing diseases such as the White Pox (WP) that mainly affects corals of the genus *Acropora*. The disease was first observed and described, in the Florida Keys by Holden (1996). The pathological features are irregular white patches surrounded by a necrotic front in the body of the coral simulating smallpox. The disease is also called Patchy Necrosis (Bruckner & Bruckner, 1997).

Data from Sutherland & Ritchie (2004), Sutherland *et al.* (2011) show a loss of 87% *Acropora palmata* coral between 1996 and 2002 in the Florida Keys area. *S. marcescens* has been responsible for diseases in terrestrial animals, humans, and insects. The contribution of these bacteria to the marine environment is mainly by the discharge of wastewater that comes in direct contact with corals (Sutherland *et al.*, 2011). The spread of the disease concerning other diseases in corals is slow and may take up to one year to infect another colony (Lesser *et al.*, 2007).

Impact sources causing the presence of pathogenic bacteria in the marine environment

Coral reefs that are located near coastal areas, where there are human activities and settlements, are exposed to the excessive dumping of nutrients, sediments, and bacteria that threaten the growth, reproduction and interaction between important organisms (symbionts) for their subsistence (Fabricius, 2005; Bianchi *et al.*, 2014).

Kaczmarsky *et al.* (2005) conducted a study to measure the relationship between coral diseases (BBD and WP II) and wastewater discharges at two sites, Frederiksted and Butler Bay, in U.S. Virginia Islands finding the highest rate of epizootics at site 1 with 3.7%, while at site 2 the rate was 2.5%. The colonies of corals, most susceptible to diseases were *Diploria clivosa* and *Dichocoenia stokesi*. These results contrast mainly because site 2 is the closest to the coast and has more influence on wastewater discharges, with more variety of colonies unlike site 1. Currents are a physical factor that helps both transport of nutrient sediments and bacteria that disperse all the material through the ocean. Zavala-Hidalgo *et al.* (2003) carried out a study on the behavior of currents in the Gulf of Mexico, finding differences in the pattern of circulation and temperatures during a whole year, which is regarded as a reference for the dispersion behavior of the wastewater discharges over the reef areas.

It has been verified through the study conducted by Gutiérrez-Ruiz *et al.* (2011), that coral reefs are more susceptible both to disease and species diversity when they are close to the coast, in contrast to the more distant reefs. Temperature is another factor that promotes the emergence of diseases and limits the diversity of species. Factors in which, humans have intervened (global warming) causing stress and giving optimal conditions to opportunistic bacteria (Peters, 2015). Such is the case of Cervino *et al.* (2004), who carried out a study to measure the effects of *Vibrio* bacteria at four different temperatures, taking the survival index and disease signs leading to yellow blotch/band disease (YBD) in Caribbean corals *Montastrea* spp., in which, more significant signs of the disease were found at temperatures higher than 25°C. Towards the end of the experiment, it was found that the mean diameter of the yellow lesion increased by 96 h from 0.74 cm at 20°C to 2.2 cm at 33°C. None of the controls developed YBD lesions.

Bruno *et al.* (2003) and Gutiérrez-Ruiz *et al.* (2011), argue that human activities have altered the environmental conditions affecting coral ecosystems, reflected in the increase in the concentration of inorganic nitrogen and phosphorus in the ocean, because of the residual discharges and contributions from rivers. Nutrients increase benefits the increase of fungi population and bacteria and in turn their virulence as pathogens, leading to diseases such as aspergillosis and black band disease among others (Bruno *et al.*, 2003, Pinzón *et al.*, 2014). Fabricius (2005) evaluates the effects of terrestrial runoff on the growth and survival of hard coral colonies, coral reproduction, and recruitment, and organisms that interact on scleractinian coral populations, taking as parameters: increased dissolved inorganic nutrients, enrichment with the particulate organic matter, the light reduction from turbidity and increased sedimentation. Worldwide, the scale of reef pollution estimates that 22% of all coral reefs are classified as at high (12%) or medium (10%) threat from inland pollution and soil erosion. The models also classify 30% of reefs as threatened from coastal development (proximity to cities, mines, and resorts), and 12% at threat from marine pollution (distance to ports, oil tanks, oil wells, and shipping areas). Therefore, on a global scale, coral reefs are threatened by similar contaminations in risk and magnitude (Arellano-Méndez *et al.*, 2016). Hernández-Zulueta *et al.* (2017) emphasize the relationships of bacterial assemblages associated with coral reef species in the Mexican Central Pacific area.

Studies conducted in the Gulf of Mexico and the Mexican Caribbean

The following is a summary of some work done in important reef areas of the Gulf of Mexico and the Mexican Caribbean, regarding pollution, diseases and anthropogenic factors. In which, a significant environmental deterioration is reported; where the specific factors that degrade the environmental quality are directly related to the discharges of wastewater with high levels of nutrients, toxic substances and sedimentation of particles. Therefore, regional and global anthropic impacts are a probable cause of this deterioration (Daszak *et al.*, 2001).

Bruno *et al.* (2003), conducted a study on nutrient uptake and severity in coral diseases in the Yucatan Peninsula (Akumal), based on environmental changes caused by human activities. It also shows evidence of increased nutrients in the environment and identifies two diseases, aspergillosis in the coral *Gorgonia ventalina* and the yellow band disease in *Montastraea annularis* and *M. franksi*. They propose water quality management to minimize nutrient enrichment, as well as identify other global aspects that may influence disease dynamics.

Jordán-Dahlgren *et al.* (2005) accomplished a study on the prevalence of clinical signs of disease and mortality in colonies of *Montastraea annularis* in the northeastern Caribbean and the Gulf of Mexico. It was proved that a higher prevalence of these parameters is constant when they are close to point sources of contamination.

Experiments were performed on three types of the reef, one isolated, another with urban influence and a third one influenced by industrial pollutants. The results show that concerning diseases in *M.an nularis*; no significant differences were found in relation to urban and industrial influence, so that the isolated reef presented prevalence in the diseases, thus rejecting their hypothesis. Jordán-Dahlgren *et al.* (2005), opens the possibility that other environmental and/or global factors may be playing another important role in the prevalence of coral diseases in the Caribbean and Gulf of Mexico. Pathogens in reefs show a high level of connectivity, such as circulation patterns, pollutants from inland, and warming of the sea surface that stresses corals.

Ward *et al.* (2006) analyzed the diversity of diseases in the Yucatan Peninsula. They quantified the prevalence of diseases and coral diversity, as well as the prevalence of these diseases and the relationship with octocorals and scleractinian corals. They also found species variability (71 species of corals) and documented six diseases for scleractinian corals that remained constant between 2002 and 2004, with a higher prevalence for octocorals. Therefore, no association was found between scleractinian corals and octocorals. These diseases, no doubt, become susceptible to coral's diversity. The present paper is the first study to measure the prevalence of diseases in the long term.

Aguirre-Macedo *et al.* (2008) studied the discharge of ballast water of the freighters that transit on the Cayo de Arcas Campeche Reef System (CACRS). The discharge of ballast water carries nutrients, phytoplankton, and pathogenic bacteria that may place the CACRS area at risk. Thirty oil tankers of PEMEX (Mexican Petroleum Company) and reference sites in the reef area were evaluated. The results indicate that ballast water discharges contain pathogenic bacteria, both for humans and for corals (70% of oil tanks). However, the evaluation of reference sites in the coral reef area did not show the presence of more pathogenic bacteria, beyond the presence of total coliforms, having with this good water quality. It is concluded that there is no detrimental effect regarding ballast water discharges to the Cayo de Arcas Campeche Reef.

Horta-Puga *et al.* (2008) analyzed the current state of Punta Gorda Reef in the Veracruz Reef System. The sampling of Punta Gorda reef included the geomorphological zones of the coral reef plain and windward slope. Thirty-three transects were positioned in the reef plain in which no coral was recorded, whereas in the windward area, 55 transects were positioned recording four species of scleractinian corals. Having through this, the data corresponding to the coral cover with a 0.39% for the slope of windward. Punta Gorda reef as shown in the study by Horta-Puga *et al.* (2008), is a profoundly impacted area that dates to colonial times (La Villa Rica de la Veracruz). To date, this reef no longer has the richness of species and the typical characteristics of one in function. It should be mentioned that this study was implemented to consider the possible expansion of the Port of Veracruz (API-Veracruz).

Gutiérrez-Ruiz *et al.* (2011), carried out a study on anthropic disturbances on the diversity of stony corals in the Veracruz Reef System National Park (VRSNP), between reefs, located close (Sacrificio Reef) and far away (Santiaguillo Reef) of the port of Veracruz, México. Taking as indicators, the diseases present in corals and the diversity of species in each area of study. Gutiérrez-Ruiz *et al.* (2011) found that the predominance of diseases was higher at Sacrificios than at Santiaguillo; and the coral diversity was lower at Sacrificios than at Santiaguillo. Concluding that the northern area of the VRSNP is near the coast of Veracruz and the port traffic, consequently, they have been strongly impacted, while the Antón Lizardo area is better preserved, as it is further away from the city, and away from navigation routes to the port. However, the authors recommend the search for factors and diversity that originate diseases in the reef areas.

Hayasaka-Ramírez & Ortiz-Lozano, (2014**)**, studied the generation of specific indicators linked to stranding events in the Veracruz Reef System National Park (VRSNP). In search of information on the subject, 126 events of this nature were described, as well as the causes and sites where they were performed, resulting in useful information given the demographic explosion in Veracruz Port.

Castañeda-Chávez *et al.* (2015), made a diagnosis of bacteria of the genus *Vibrio* spp. in corals of the VRSNP. With the support of the National Commission of Natural Protected Areas (NCNPA), they obtained samples of 12 fixed transects distributed within the polygon of the reef. A positive presence in a 42.3% of *Vibrio* complex, *V. coralliilyticus* and *V. shilonii* was observed in the coral tissue of *Colpophyllia natans, Montastraea cavernosa, M. faveolata, Porites astreoides*, and *Siderastrea siderea*. It was concluded that the presence of pathogenic bacteria comes from the contribution of organic matter from anthropogenic sources discharged directly into the area. Causing pathological affections in coral tissue, such as White Band, Black Band, Yellow Band, White Plague, and Bacterial Bleaching, are stimulating, in the short term, loss of coral cover and, in the long term, negative impacts on the faunal composition of the Veracruz Reef System (VRS).

Celis-Hernández *et al.* (2017), conducted a study on sediment and pollution on the coast of Veracruz in four study sites, taking as reference the influence exerted by two rivers: Jamapa and La Antigua. The results present the potential to be taken as a baseline concerning future anthropic interventions in the specific treatment of heavy metals of greater toxicity and their possible effects on the biotic activities of goods and services as well as commercial activities carried out in that area.

CONCLUSIONS

The following pathogenic bacteria are identified as the main responsible for endangering the health of corals: *Aurantimonas coralicide, Halofolliculina corallasia, Helicostoma nonatum, Oscillatoria* sp., *Phormidium corallycticum, Phormidium valderianum, Serratia marcescens*, and *Vibrio* spp. It was concluded that the presence of pathogenic bacteria comes from the contributions of organic matter from anthropogenic sources that discharge directly into reef areas; generating pathological affectations in coral tissue, such as White Band, Black Band, Yellow Band, White Plague, and Bacterial Whitening. The preceding stimulates, in the short term, loss of coral reef cover and, in the long term, negative impacts on the faunal composition.

It is defined that other causes can cause the existence of affectations in corals, such as those related to climate change and global warming, being stressors, stimulators of growth and the activity of several pathogens in corals, which give rise to diseases known as: White Plague, Black Band, Yellow Band, and aspergillosis among others.

The design of conservation strategies with the support of public policies, as is being done in some countries that have this problem becomes a must. As well as managing which key areas for their high marine biodiversity, should be called protected natural areas and therefore receive support for their surveillance. It is necessary to strengthen efforts, with non-invasive techniques, for the restoration of reefs in the Caribbean and the Gulf of Mexico. The future will depend on the joint decisions made by humanity in the coming years to limit and stop the emission of greenhouse gases, which will reduce the increase in temperature and corals may have a better chance of survival.

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