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A Study of Environmental Factors Affecting Coral Species Growth in Western Region of Abu Dhabi – UAE and the Arabian Gulf

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A STUDY OF ENVIRONMENTAL FACTORS AFFECTING CORAL SPECIES GROWTH IN WESTERN REGION of ABU DHABI – UAE AND THE ARABIAN GULF

Khulood Ahmed Eissa Al Ali

This thesis is submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental Sciences

Under the Supervision of Professor Waleed Hamza

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Declaration of Original Work

I, Khulood Ahmed Eissa Al Ali, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*A Study of Environmental Factors Affecting Coral Species Growth in Western Region of Abu Dhabi – UAE and the Arabian Gulf*" hereby, solemnly declare that this thesis is my original research work that has been done and prepared by me under the supervision of Professor Waleed Hamza, in the College of Science at (UAEU). This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this, or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation, and/or publication of this thesis.

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Abstract

This study aims to investigate possible effects of certain environmental factors particularly, high summer water temperature and increase of water salinity on the growth rate of endemic dominant coral species at the west coasts of the United Arab Emirates. The study investigated the dissolved trace elements concentrations and its relation to coral diseases. The methodological investigations have been conducted in a defined two sites at Baraka and Al Saadiyat area. In Barakah, three quadrates of 1.0 m^3 have monitored the growth of *Porites harrisoni* by both photographically as well as by direct measurements of the targeted coral colonies in each frame. That include colonies sizes, coral health, surrounding water temperature and water salinity, and in Saadiyat area, it investigates the coral growth rate of *Acropora downingi* from winter to summer. The obtained results had shown that, there was different growth in the selected colonies branches between winter and spring-summer seasons. In general, the growth rates in Saadiyat *Acropora* colonies was small in winter season, compared to the spring-summer season growth. The most notable growth seen in colony #1 with an 18 mm growth in spring-summer season compared to only 2 mm during the winter season of the same branch. The results have also shown that possible stressors, such as the measured high sulfur concentrations as well as other anthropogenic activities, especially in Barakah area could be responsible about the existing documented coral diseases as well as the loss of *Acropora* colonies in that site. This study has suggested certain recommendations to investigate impact of Sulphur dissolution and its concentration increase effect on the different living coral species. The specific and/or combined factors that lead to each of the reported coral diseases, and to investigate frequent and more intensive studies of growth rates of different corals species and finding the way for mitigation of destroyed areas as well as possible restoration of impacted habitats. These recommendations can be also adopted by other governmental and /or non-governmental agencies responsible about sustainability of marine life in Gulf countries.

Keywords: Coral reefs, Arabian Gulf, coral diseases, coral health, water temperature, water salinity.

Title and Abstract (in Arabic)

دراسة العوامل البيئية المؤثرة على نمو الشعب المرجانية في المنطقة الغربية والخليج العربي

الملخص

الهدف هذه الأطروحة هو دراسة نمو الشعب المرجانية في المنطقة الغربية وكيفية تأثير العوامل البيئية على الشعب المرجانية عن طريق دراسة تأثير درجات الحرارة العالية وملوحة المياة على مستوطنات الشعب المرجانية الموجودة في السواحل الغربية في الإمارات العربية المتحدة. تم دراسة ثلاث مواقع في براكة حيث تم مراقبة نمو الشعب المرجانية (*Porites harrisoni*) عن طريق قياس مربعات (quadrates) حجمها 1 m^3 وذلك عن عن طريق التصوير الفوتوغرافي والقياسات المباشرة للشعب المرجانية المطلوبة في كل إطار، هذه القياسات شملت دراسة حجم الشعب المرجانية، صحة الشعب المرجانية، درجات حرارة المياة المحيطة بها، وملوحة المياة. وفي جزيرة السعديات تم مراقبة نمو الشعب المرجانية (*Acropora downingi*) من الشتاء إلى الصيف. إن النتائج الدراسية استطاعت على قياس معدلات نمو الشعب المرجانية المختلفة في موسمي الشتاء والربيع-الصيف. بشكل عام كان معدل نمو الشعب المرجانية (*Acropora*) في السعديات قليل في موسم الشتاء بالمقارنة بالنمو في موسم الربيع- الصيف. نلاحظ أن النمو في المستعمرة 1# كان بقياس 18 مم في موسم الربيع-الصيف بينما كان النمو بقياس 2مم في موسم الشتاء للتفرع نفسه. نلاحظ أيضاً في النتائج وجود بعض الضغوطات الممكنة من مثل، القياس العالي لتركيز الكبريت وأيضاً بعض الأنشطة البشرية خصوصاً في منطقة براكة التي من الممكن كانت سبب في حدوث الأمراض في الشعب المرجانية الموثقة وأيضاً خسارة الشعب المرجانية *Acropora* في الموقع. هذه الدراسة اقترحت بعض التوصيات استناداً على النتائج التي تم الحصول عليها من أجل الحفاظ على الإستدامة للشعب المرجانية الحية في سواحل دولة الإمارات العربية المتحدة. ومنها دراسة تأثير انحلال الكبريت وزيادة تركيزه على الشعب المرجانية، العوامل التي تؤدي إلى الأمراض في الشعب المرجانية، وعمل دراسات مكثفة لدراسة معدلات النمو في الشعب المرجانية وأخيرا ايجاد حلول لاعادة ترميم ال مناطق المتأثرة. ويمكن أيضا اعتماد هذه التوصيات من قبل الدوائرالحكومية و/أو غير الحكومية الأخرى المسؤولة عن استدامة الحياة البحرية في بلدان الخليج.

مفاهيم البحث الرئيسية: الشعب المرجانية، صحة الشعب المرجانية، الخليج العربي، أمراض الشعب المرجانية، درجات حرارة المياة، ملوحة المياة.

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Dedication

To my beloved parents, husband and family that gave me the required support through my journey in my masters.

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List of Abbreviations

BBD	Black Band Disease
DO	Dissolved Oxygen
PPT	Parts Per Thousand
SP	Species
SST	Sea Surface Temperatures
UV	Ultraviolet
YBD	Yellow Band Disease

Chapter 1: Introduction

Coral reefs have frequently defined as the rainforest of the sea, where one-third of fish species, lives primarily and exclusively, along with other numerous marine species in association with its ecosystems (Knowlton, 2001). The diversity of the coral reef is so vast that even though it covers a small portion of the ocean's floor it harbors 25% of its fish species hence the sub 'tropical rainforests of the oceans (Grimsditch & Salm, 2005). A minimum estimate of reef building corals species has been given at 83,500 species, while an estimate of the biodiversity of reefs organisms has been evaluated at a range of 1-9 million species (Knowlton, 2001). According to Grimsditch and Salm (2005), coral services grant an estimate of US$30 billion to industries worldwide.

The corals are genetically disposed to have zooxanthellae as part of its being. According to Borneman (2002), the relationship starts when a parent coral releases sperm and eggs into the water where it can be externally fertilized to form a cell called planulae. The planulae consume numerous algae from the water to obtain zooxanthellae, and then proceed to find a hard surface to settle, where it metamorphosis to become a small polyp. The zooxanthellae layer can be found mainly in the inner tissue of the coral. Now that the link between the polyp and zooxanthella has been formed, an exchange of benefits occurs. On the one hand, zooxanthellae are providing nutrients to the polyp when the coral metabolize into Carbon dioxide and nitrogen. On the other hand, the algae in the planulae uses the sunlight as a source of energy for photosynthesis. The term "Coral" is usually used for coral both soft and hard (stony) colonies.

Scleractinian is a hard, stony, coral is accountable for the existence of the reef. Scleractinian corals provide habitats for the many organisms. In addition, when Scleractinian corals breakdown of their skeletons during calcium-carbonate accretion, particularly after death, they provide material for rearrangement into the reef framework. The order Scleractinian distributed into 18 artificial families namely the Acroporidae, Astrocoeniidae, Pocilloporidae, Euphyllidae, Oculinidae, Meandrinidae, Siderastreidae, Agariciidae, Fungiidae, Rhizangiidae, Merulinidae, Dendrophylliidae, Caryophylliidae, Muscidae, Faviidae, Trachyphylliidae, and Poritidae that they are all considered as Zooxanthellates. However, only 11 out of the 18 families contain corals that are categorized as true reef building. In some families such as Caryophylliidae and Dendrophylliidae the vast majority of them are azooxanthellate. Moreover, in terms of genetic diversity, the family Faviidea has the highest generic diversity of zooxanthellate reef-builders, while the family Acroporidae is the dominant group of reef-builders (Kleemann, 2001).

Even though Scleractinian corals are the primary builders of the present-day coral reefs, skeletal materials of other groups, both plant and animal are incorporated into the construction of the reef matrix. The contribution of this group to the reef matrix consists of calcite sclerites such as Alcyonacea, soft corals, branched such as Gorgonacea - sea fans, or unbranched Pennatulaceae, sea pens (Kleemann, 2001).

Corals estimated to cover 284,300 square kilometers of coral reefs worldwide. They are limited to a broadband, confined to the tropics and circling most of the globe (Figure 1).

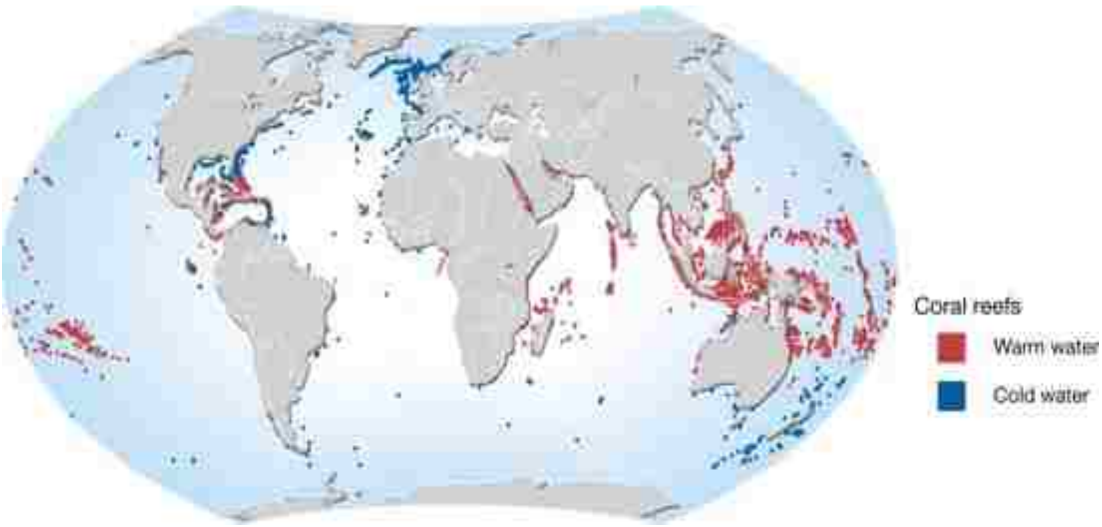


Figure 1: Global distribution of coral reefs (Ahlenius, 2008)

Coral reef not distributed evenly where most of the reefs are located in the remote island regions and offshore areas that are far from major landmasses. Furthermore, studies showed that corals reefs are mainly absent from central Atlantic and the shores of West Africa, however that are present along the western (Pacific) shores of the Americas, and present along the coastline of South Asia from Pakistan to Bangladesh. Furthermore, a great majority of coral reefs are found in the Indo-pacific region that stretches from the Red Sea to the Central Pacific, and less than 8% of the world's reefs are found in the Caribbean and Atlantic (Spalding et al., 2001).

In addition, if look at the coral reefs pattern, it could be understand reefs are often limited in their development in the nearshore waters of large continental landmasses, even though barrier structures are widespread in these areas. They are also, poorly developed close to larger river mouths. However, Coral reefs well established around islands and along the coastlines of drier continental areas (Spalding et al., 2001).

On the other hand, the coral reef demographic distribution in the Arabian Gulf is moderate in number and type of species found in its various areas (Figure 2).

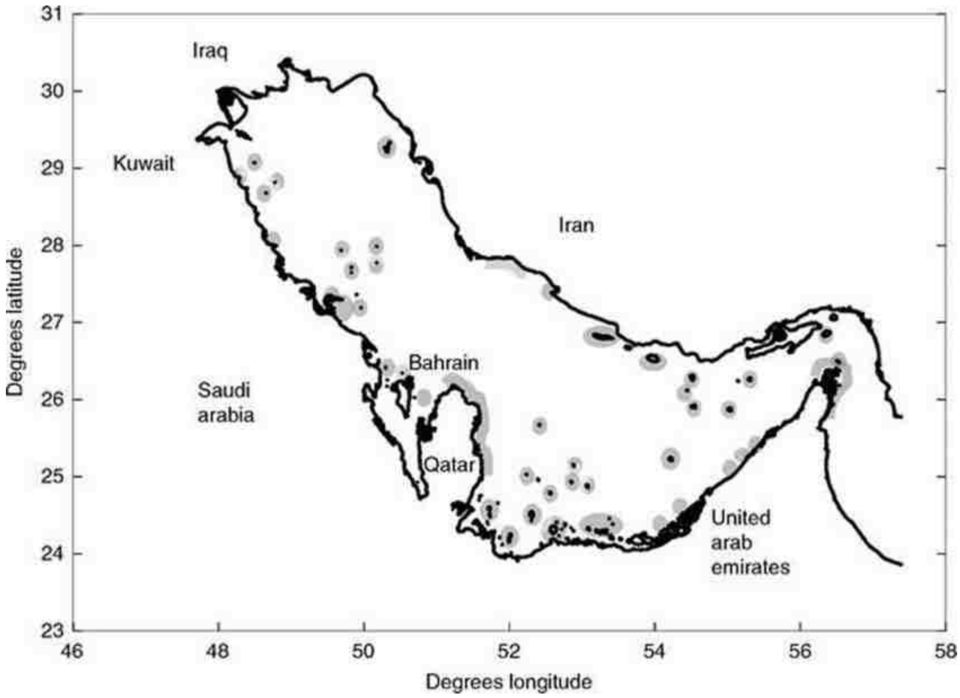


Figure 2: Coral reefs distribution in the Arabian Gulf (Riegl & Purkis, 2011)

The Arabian Gulf features can be described as a marginal sea of approximately 1000 km length, 200-300 km width with an area of 250,000 km^2 (Riegl & Purkis, 2012). It is connected with the Indian Ocean via straits of Hormuz, which is 60 km wide. The gulf's basin is uneven and has an incline with a slope of 35 cm/km on the Arabian side. It harbors extensive coral growth rates due to its high latitude position and its shallow nature. The Arabian side of the Gulf, is slightly sloping and fits the model of a typical carbonate ramp setting, and it receives no riverine input at all, thus marking it salty (Westphal et al., 2010). Moreover, the coastal areas are formed by sabkhas, tidal lagoons, channels, and sandbars, all are water influx to coral build-ups (Hamza & Munawar, 2009).

Although Gulf coral communities are adapted to the extreme environmental conditions, an abnormal rise in the sea-surface temperatures (SST) can have infrequent impacts on the reefs in some areas. To highly sensitive reefs such as the dominate *Acropora* sp., such an infrequent change in marine condition cause a shockingly high mortality of the species. Comparatively, the more tolerant species such as faviids and Poritids varied spatially across the southern basin of the Arabian Gulf; the impact was insignificant to it on the west and around two-thirds of these taxa lost from reefs in the western areas of Abu Dhabi (Burt et al., 2011). However, the *Acropora*'s dominance can be restored once the marine environmental conditions are re-stabilized within 5-10 years. By then, the growth of survivors and juveniles species will provide the support needed for the *Acropora* to survive (Burt et al., 2011). Regardless, many factors affect and contribute to the coral reef distribution in the gulf. Such factors include the local marine environment, wind stress, wave's heights, elevated temperatures, and high salinity

Furthermore, the central gulf along the coast of Saudi Arabia and Bahrain recorded the maximum numbers of species with about 40 species (Coles, 2003). The further south or north from the gulf center we go, the less the number of species are, with 35 species in both Kuwait and UAE. This stark disparity between the two areas is in correspondence with the different environmental factors affecting the corals and subsequently, the diversity of its habitants (Coles, 2003). The sea-surface temperatures (SSTs) in the Arabian Gulf range in summer is between 32-33ºC with a maximum temperature of 37°C while the range in winter is between 14-16ºC with the minimum temperature of 13°C (Burt et al., 2011).

There are numerous coral species in the Gulf. Three endemic coral species have been listed for the Arabian Gulf stated as followed: *Acropora arabensis*, *Acropora downingi* and *Porites harrisoni* (also known as the finger *Porites*, a common species in the Arabian region that was formerly called *Porites compressa*) (Coles, 2003). Hume (2013), on the other hand, suggested that in Abu Dhabi, there are six common gulf coral species found and they are *Cyphastrea microphthalma*, *Favia pallida, Platygyra daedalea, Porites harrisoni, Porites lobata, Porites lutea,* and *Acropora.* (Burt et al., 2011). Reported that *Acropora* sp. is dominant in the southern basin of the Arabian Gulf where it extends over many kilometers while *Porites* sp. is dominant in areas with extreme salinity of more than 35 ppt and is located in a lagoon habitat to the far west of the southern basin of the gulf.

Coral reef species are nowadays facing many environmental stresses that undermines the importance of its existence. Ecosystem resilience is the ability of a system to withstand such environmental stresses and to survive damaging influences to retain basic ecosystem functions (Aeby et al., 2011). Any drastic change that erodes and hinders the resilience in the system, especially that of a coral reef. Hume (2013) suggested that there is currently around 30% of reefs that are damaged, and more than fifty percent might be lost in the next two decades due to climate change. On the other hand, it has estimated that 20% of coral reefs worldwide have been destroyed, while 24% are in danger of eradication and further 26% are under threat of degradation (Grimsditch & Salm, 2005)

Furthermore, Edinger et al. (1998) argue that 30-60% of the coral reef disturbances worldwide are due to destructive human activities. However, Rosenberg and Ben-Haim (2002) stated that the coral’s inability to function, manifest in the form of a disease that coincides with the hottest time of the year and it has been observed that it is most damaging to the corals when the climate is warmer than normal conditions. Indeed, Work et al. (2008) affirm and referred that to the coral’s lack of resilience to resist climate warming as well as deteriorating water quality.

There are certain factors that affect the coral growth around the world some of these factors are belonging to the nature of the area; others are belonging to human activities and its impact on the water quality where corals are living.

This study is focusing on the identified native coral species in the Gulf (i.e., *Acropora arabensis*, *Acropora downing,* and *Porites harrisoni*) to understand the coral's growth performance, and coral diseases that may result from the surrounding environment in the Arabian Gulf.

The main aim of the present study is to better understand possible reasons for coral death, and/or bleaching at the Arabian Gulf basin. Moreover, it also aims to investigate environmental parameters (water salinity, water temperature, dissolved oxygen, and pH levels) and its possible impact on the survival and growth of the studied coral species during winter and spring-summer seasons. In addition to measure the trace elements in the water that plays major role in the skeletal development and growth of the coral reefs. Finally, investigating the impact of surrounding anthropogenic activities (Industrial, overfishing and reclamation) on the water quality surrounding corals ecosystem.

Chapter 2: Literature Review

The coral reefs classified by their geomorphology. It can be either fringing, barrier, or coral atolls (Hopley et al., 2007). Knowledge of how reefs vary over the present ranges of environmental conditions is essential in determining how the coral reefs adapt to the environmental changes occurring in our current environment. Coral reefs have a narrow range of tolerance to variations in the environmental conditions as they are restricted to shallow, warm and saline waters, and also environmental factors such as temperature, salinity, light, carbonate saturation levels, and nutrients within the coral reef environments are essential for effective growth. The factors affecting the coral reef growth can be classified as either first order or second order, and the degree of light penetration through the water, the water temperatures, availability of nutrients, and salinity of water and carbon concentration levels are the first-order factors. Hydrodynamic factor and seawater circulation also play a major role in coral reef growth (Achituv & Dubinsky, 1990). These factors may play a role in coral reef growth, including the wave's strength, frequency of storms, and ocean currents. The hydrodynamic parameters together with larval sources, diversity, and reef disease are referred as the second-order factors. The studies conducted worldwide showed decline in the coral reef and changes in their structure attributed to fish abundance (Hourigan et al., 1988), and structural colony size, that work in cooperatively to cause the changes as no single study showing the level of decline in coral reefs (Hill & Wilkinson, 2004). The multiple stressors identified above are also influenced by the climate change due to global warming as the interaction between various stressors and cumulative outcome effects show the need of the study of environmental effects on coral species (GBRMPA, 2009). Moreover, the environmental factors that threaten the growth of coral species, such as: acidity of the ocean and high water temperatures due to of climate change, increase of coral species disease eruption (Willis et al., 2009), terrestrial sedimentation (Fabricius, 2005), and increased the numbers of crown-of-thorns starfish (Brodie et al., 2005). Furthermore, the increase of development industries along the coastal regions and human population growth worldwide potentiates the threats hence contributing to the severity of the coral species stressors. The coral species, which are more susceptible to bleaching and diseases, are at higher risks of much decline in comparison to other types of species due to death (Roff et al., 2011). In what follows, factors affecting coral species in the Western Region of UAE and within the Arabian Gulf have been reviewed.

2.1 Increase in Ocean Temperatures

Temperature is very vital in support of the marine organism's survival. Indeed, it is vital to coral reef life, and it affects coral reef growth (Agardy et al., 2005). It has been found that when temperatures in the sea raise the narrow warmth limits in which the coral reefs survive are exceeded, and coral reefs are put into stress caused by excess heat elimination; this causes them to release zooxanthellae algae, which reside within their body. Consequently, the algae provide the coral reefs with their color and most of their food and energy resulting in coral bleaching and eventual starvation and death (Van Oppen & Gates, 2006). Because of the increase in ocean temperature, coral reefs may also suffer from disastrous ice melting which causes a rise in the sea levels. The rising in sea level may lead to sedimentation because of erosion of the shoreline, which will negatively affect coral reefs habitats. Changes in oceanic temperatures may also be due to alteration of the oceanic currents that move large amount of heat around the planet. Ocean currents are often altered by shifts in wind, precipitation, temperature, and water salinity as a result of climatic variations as shifts in ocean currents affects the movement and deviating of pollutants routs, larvae transportation, and ultimately affecting the thermally - sensitive coral reefs. A study conducted in the Arabian Gulf region found out that most growing coral reefs in the region ended up bleached or dead due to extremely high temperatures, especially during summer months (Wilson, 2002).

2.2 Water Salinity

On the other hand, is considered the second most important environmental factor in term of distribution of coral spices and the consequent assembly of communities around it, as well as the coral’s potential in having a healthy building. According to Kinsman’s (1964), “Reef corals flourish best in the range 25’-29ºC, within a salinity range of 34-36 ppt”. Coles (2003) praise the coral’s adaptability along the Abu Dhabi coastline and observed that 11 coral species survive temperatures up to 36ºC and the salinity up to 48 ppt.

2.3 Human Activities

The environmental pollution releases nitrogen from sewage, and other agricultural sectors to the ocean waters are responsible about calcification that degrades the coral reef (Baker et al., 2013). Indeed, the increase of dissolved nitrogen levels increases negatively and affects photosynthesis pigments such as chlorophyll, which increases the rate of photosynthesis, hence eutrophication (Fabricius 2005). It has also been found that the nutrients concentration increase enhances the coral diseases and accelerate its transfer rate within the coral community and eutrophication because of increased nitrogen concentration enhances the disease transfer process (Bruno et al., 2003). According to Bayani (2016), the damage resulting from fisheries activities causes the most severe effects. Other human activities such as coastal construction, land-based pollution, recreational activities, oil pollution, and oil and gas extraction affects the coral species in the Arabian Gulf.

2.4 Eutrophication

It has been reported that the Nano plankton growth in the reef regions affected by the river provides a region for eutrophication and survival of the *Acanthaster planci* starfish larvae which later results to *Acanthaster planci* starfish outbreak (Bell, 1992). In his research, Fabricius (2011), has indicated that the Great Barrier Lagoon provides a good atmosphere with nutrients and high algae growth, hence promoting eutrophication. Eutrophication results in increased algae community, the excessive algae growth can block the coral community from accessing the sunlight required for photosynthesis hence increased coral-algae competition. The high nitrogen concentration provides a better environment for the growth of the algae community as opposed to the coral community. Bahrain reefs in the Arabian Gulf have shown a decrease in the coral cover with the algae, which forms approximately 72% of the total cover (Burt et al., 2013).

2.5 Storms

Storms or cyclones in water bodies are disturbances to the coral communities. Storms can break the coral skeletal structure and reduce the coral cover. The severity of the storm determines the intensity of the coral skeletal breakdown and cover loss (Emslie, 2008). This is because the live coral cover is essential for existence and growth of fishes such as obligate corallivores without the live cover, the population of fish and other organisms in the coral reef reduces (Cheal et al., 2002).

2.6 Ocean Acidification

Low Ph levels in the ocean waters are associated with a decrease in the coral reef larval settlements (Nakamura et al., 2011). Furthermore, marine organisms such as oysters and snails have shells that are made of calcium carbonate, just like stone structures of the hard corals. Therefore, access to adequate calcium carbonate is essential for the corals to form their skeleton structures. This is essential, especially in the early stages of a coral polyp's life when it settles on a hard substance and starts building its skeleton. It has been found that ocean acidification has a negative effect on the rate of calcification of coral, meaning that the coral colonies may weaken and become less resistant to other factors affecting their survival. Though, coral reefs are strong to most of the harsh conditions like nutrient and chemical pollution and warm temperatures among others factors, Their ability to re-grow and survive in the seawater is being undermined by ocean acidification as coral animals and plants are being restored by non-calcifying organisms. Climate change is the main factor attributed to ocean acidification whereby most of carbon dioxide that come into the atmosphere disintegrate into the ocean, as its level in the atmosphere decreases, Ph in the ocean decrease thus corals are unable to absorb calcium carbonate thereby resulting to their dissolution (Sabine et al., 2004). Most significantly, the carbon dioxide levels in the Arabian Gulf have been shown to be in the rise manifesting in the acidification, which causes coral bleaching and mortality of the coral species (Uddin et al., 2012).

2.7 Sea-level Rise

A global rise in the sea level is majorly caused by thermal expansion. This thermal expansion increase in melting of ice sheets coming from the land-based glacier and sea ice. Sea level rise leads to increased sedimentary processes, which in turn affect photosynthesis, recruitment, feeding and physiological reef processes like sedimentation resulting from shoreline erosion, which smoothens reef by reducing the light needed for photosynthesis (Adger et al., 2005). A calculation of the sea level rise of approximately up to 0.88 meters is a major problem in the Arabian Gulf; this is mainly due to its low-lying nature. With frequent sea-level rise, sedimentation occurs and affects photosynthesis process and consequently affecting the growth and survival of these reefs (Riegl, 2003).

2.8 Terrestrial Sedimentation

Coastal seas are continuously being affected by increased sources of pollution mostly from land due to increase in tree clearing associated with soil loss, increased use of artificial fertilizers, pesticides, and effluent discharged from the industrial (GESAMP, 2001). Pollution combined with bleaching of the coral reef, illegal fishing methods, and excess fishing known as one of the major factors contributing to coral reefs (Spalding et al., 2001). A high volume of fresh water particles releases can kill corals and prevent growth of normal coral reefs even if ocean environment remains uninterrupted by human activities.

Sedimentation on the other hand also causes water turbidity, which reduces light penetration due to suspension of the sediments, and this greatly affects the rate of coral growth and multiplication as they mostly rely on light energy and transparent water to produce energy for their metabolic activities. Therefore, increased direct siltation of corals decreases photosynthesis, growth and increased metabolic processes (Telesnicki & Goldberg, 1995). Ultimately, the depth at which corals survive and maintain active growth is affected (Yentsch et al., 2002).

2.9 Ultraviolet Radiation

Organisms inhabiting in shallow-water tropical environments face the risk of high ultraviolet rays because of the sun's low angle from vertical alignment and the increase in transparency of water column. Solar ultraviolet radiation affects the ecology and biology of the reefs. Increase in the levels of biologically active ultraviolet B radiation, wavelength mostly affected by ozone layer depletion has minimal effects on corals and those that may be seen as changes in the minimum occurrence of important reef taxa like the corals (Banaszak & Lesser, 2009).

Ultraviolet radiation is harmful to many organisms; Arabian Gulf bottom sediments made up of clear and shallow waters and with this, there is penetration of harsh light wavelengths that affects growth and survival of the coral's reefs (Jokiel, 1980). In a study conducted by Al-Hashmi (2012), the Satellite monitoring showed that the region of the Arabian Gulf constantly consists of low Chlorophyll-a.

2.10 Coral Disease

Diseases are natural occurring aspects within the population of coral reefs and are one mechanism by which the numbers of the coral reefs are kept in check. These normally result from an association between three things, i.e., the coral host, the pathogen, and the environment of the coral reef. These diseases can come from fungi, protozoa, either viruses or bacteria and can result to changes in the rates at which they reproduce, grow, their organization, species variations and plenty of organisms associated reef (Abesamis et al., 2014). Recently, coral diseases have increased in terms of their frequency, intensity, and range of the regions they affect, while it remains unclear whether it is due to introduction of novel disease-causing microorganisms or due to changes in the existing microbes that worsen environmental impacts and reduce host resistance.

More so, according to Aeby (2003), coral diseases together with hurricanes affect bleaching of the coral reef and other effects resulting in extensive coral death. Most significant is the understanding of the causes and impacts of coral diseases which is essential in an attempt to apply recent management practices to curb these diseases and also aid in the understanding of how human efforts affects the spread and severity of this menace. Although coral reefs are the most productive ecosystems, their health is at risk. A study done about the coral reefs in the Arabian gulf estimates that 10% of the coral reefs have died due to diseases and about 30% are likely to die in the next 20 years due to primarily viral diseases within the Arabian gulf (Araghi, 2011). The following are the major diseases known for coral's communities

2.10.1 Coral Bleaching

It has been found that coral reef bleaching occurs because of high or low ocean water temperatures (Guldberg, 1999), increased water acidity, and sedimentation stress (Fitt et al., 2001). Moreover, carbon dioxide levels have been on the increase in the past years (Guldberg et al., 2007), and reduced carbon dioxide exchange rates are a cause of increased ocean water acidification majorly due to climate change effect (Feely et al., 2004). The increase in the ocean temperatures is associated with climate change factors and an increase in the ocean pH (Feely et al., 2004). The climate change is also associated with alteration in the aragonite saturation state, sea nutrient levels and sedimentation pattern as high temperatures in the oceans causes increase in water volumes, which degrades the coral cover.

In addition, the rise in water temperatures is reducing carbon dioxide and oxygen solubility in water. Therefore, the coral reefs become deprived of oxygen as toxic sulfite accumulate, resulting in reduced coral community. Corals require light for their photosynthesis reactive radiation phase. At deep sea level, the light penetration reduced, and the coral growth becomes impaired. The coral reef in the Arabian Gulf has the potential of tolerating temperatures as high as 36ºC and as low as 13ºC as high temperatures are major during the summer and low temperatures during the winter. Therefore, the ability of the coral reefs on the Arabian Gulf to tolerate very low and high temperature makes it unique to all gulfs around the world as coral bleaching do occur at the temperatures of 29ºC (Casey, 2015). The low temperatures have been associated with reduction of the coral population in the Arabian Gulf. The low-temperature stress usually results in mortality of algae and reduction in coloration to pale in coral species and finally decadence of corals (Van Oppen & Gates, 2006).

2.10.2 Black Band Disease (BBD)

The black band disease threatens the corals population worldwide, though the most severe loss of corals population have been reported in the wider Caribbean. BBD manifests as a dark, bank-like microbial-mat, at the interference between the normal coral tissue and the freshly exposed skeleton. The progression speed rate depends on host species and seasons; however, it has been reported that the Caribbean corals resulting in the death of the entire coral colonies in a short time frame. The BBD bacterial mat consists of a complex consortium of microorganisms dominated by cyanobacteria that includes sulfate-reducing bacteria, sulfide-oxidizing bacteria, fungi, and other microbes. The cyanobacteria and sulfide-oxidizing bacteria display vertical migration within the microbial mat under varying light environments.

In addition, the presence of very concentrated sulfide and anoxic conditions below the BBD mat is fatal to coral tissue and may be essential to the pathogenesis of BBD. Some other factors have suggested as etiological agents of BBD such as toxins produced by potentially pathogenic heterotrophic bacteria, cyanobacterial penetration of coral tissue, cyanotoxin production, and vibrio protease production. Field observations suggested that interactions among many environmental factors govern BBD abundance including, seawater temperature, water depth, solar irradiance, host population diversity, and anthropogenic nutrients (Sato et al., 2011)

In the gulf, BBD spreads with highest rate and extent of tissue loss in the summer; however, it becomes rare or disappears completely in winter. This disease became rarer after 1996 after the *Acropora* mass mortality; this could be explained by *Acropora* sp. disappearance from the area, which is the disease's preferred host. In the gulf, these following species were confirmed to be affected by the disease. *Acropora downingi*, *A. clathrata*, *A. pharaonic*, *A. valida*, *Favia pallida*, *F. speciosa*, *Platygyra daedalea*, *P. lamellina*, *Cyphastraea microphthalma* (Riegl & Purkis, 2012).

2.10.3 Yellow Band Disease (YBD)

The yellow band disease defines a coral disease the primarily affects faviids in the Caribbean and Indopacific, and *Porites* and *Acropora* in the Gulf, It was first witnessed, and used in Florida in 1994. The yellow band disease that affects the Gulf region has an aggressive affiliation as they are fast spreading on *Acropora*, however, a slow spreading yet persistent on *Porites*. YBD was observed through the Gulf, and it was first reported in 1998 from reefs near Jebel Ali in Dubai, UAE and the following species were confirmed to be affected *Acropora downingi, A. clathrate, A. pharaonic, A. Valida, Porites litea. P. lobate. P.harrisoni, Turbinaria reniformis, Cyphastrea* *microphthalma*. The disease is active in all-seasons which contract with the black band disease that disappears in winter. In addition, the infection process in the summer are faster than the winter, and it is the most common disease on corals in the Gulf.

This disease transfers among certain corals because of a microbial agent, placing of infected colony onto unaffected tissue of a neighboring coral is enough to transfer and spread the disease. Once it is infected, branches are broken and come in contact with healthy tissues. Then, the infection will take place within a week. Disease break is one of the solutions to stop spreading the disease; it is done by removing all live tissues neighboring to the yellow band (Riegl & Purkis, 2012).

Chapter 3: Material and Methods

3.1 Area of Study

The present study carried out along Abu Dhabi Emirates coastal area, at two locations; the first is in Baraka area, western Abu Dhabi Latitude 24.037 longitude 52.3203 (Figure 3), and the second is in Al Saadiyat Island, North of Abu Dhabi city, Latitude 24.584417 longitude 54.499483 (Figure 4).

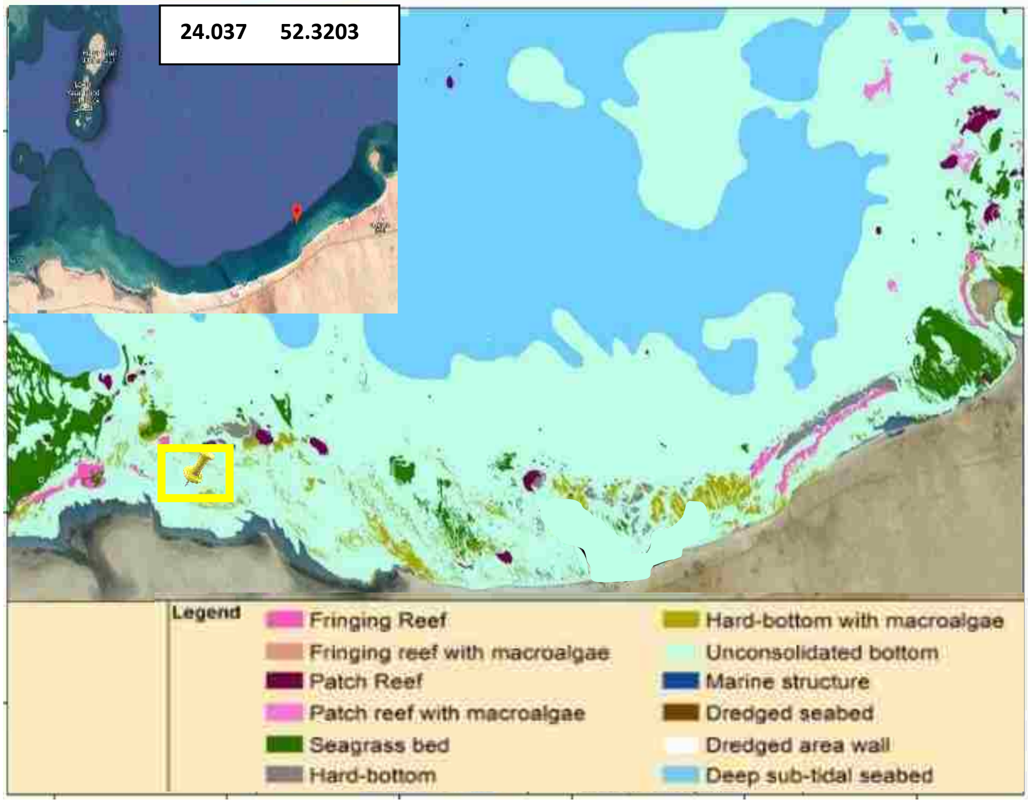


Figure 3: Marine Habitat Map – Abu Dhabi Western region and sampling locations

Figure 4: Al Saadiyat Island study area and sampling locations

3.2 Period of the Study

The study carried during the eight-month period in Barakah from Jan 2016 to August 2016. At Saadiyat Island, it was carried out from October 2016 to May 2017.

Although it was planned to study growth changes in the two coral species (*Acropora* sp. And *Porities* sp.), only at Barakah area (western region of Abu Dhabi) only *Porites* species study was conducted due to the complete death of *Acropora* sp. population during summer of 2017 because of extreme elevation of water temperature at that area (water temperature = 38.5ºC). It has decided to find another *Acropora* sp. colony within Abu Dhabi coastal area. Even it was a pit distance from Barakah, but the colony found at the coastal area of Al Saadiyat Island was in better shape and suitable to carry out and complete the study and its objectives as suggested in the study proposal.

3.3 Methodology and Measurements

In order to monitor growth changes in the studies coral species; variations in both physical and chemical parameters of the seawater at the studied two areas carried out. That coincided with in-situ measurements of coral growth with different techniques as follows:

3.3.1 Water Quality Measurements and Analyses

Seawater parameters were measured at designated sites within the study area in order to indicate both spatial distribution and stratification differences. The water depth at these stations ranged from 6.3 m to 16.9 m.

Measurements have recorded using a Hydrolab DS5 Multiparameter probe (Figure 5), lowered and raised through the water column, with readings taken at the surface (-1 m), mid-water and seabed (+1 m) depth intervals (where water depths allowed). The following parameters have recorded at each location and depth intervals:

- Dissolved Oxygen (mg/l).
- pH (Alkalinity).
- Salinity (ppt).
- Temperature (°C).

Figure 5: Hydrolab DS5 multiparameter seawater probe

3.3.2 Water Sample Collection and Trace Metals Analyses

The sampling programs for seawater analyses were carried out in two seasons. The first Sample collection occurred during the winter season on 27/01/2016 in the western region area, where, 15 water samples were collected. While, the second samples collection was during the summer on 31/08/2016 where 15 water samples were collected.

In addition, four Seawater samples were collected from Al Saadiyat Island site during summer and winter, the first water sample collection was on 02/10/2016, and the second water samples were collected on 07/08/2017.

To test the trace elements in the seawater in both locations, 500 ml water samples were collected and analyzed on-site for the physical parameter, and at the UAE University Laboratories for the trace metals analyses. To ensure the quality of sample transportation, water samples were transferred using a plastic bottle that preserves metals. These plastic bottles are then stored, using ice blocks and carried in ice and cool box to maintain the quality of the seawater to the UAEU Laboratories. Trace metals analyses at UAEU laboratories were carried out within 48 hours of the arrival of the sample, using ICP analyzer.

3.3.3 In-situ Coral Growth Measurements

To monitor live coral cover over time, transects have been set up on the specified locations to allow repeatable visits to quantify change to live coral cover and to set up a visual guide to any changes in coral cover and health.

A total of (6), stations at Barakah and (1) station in Al Saadiyat Island were investigated, using scientific diving survey techniques, which involved

(2) Scuba divers (Scubapro/aqualung) with underwater cameras (canon G15) and calipers/rulers in measuring the branches. The temperature logger used a 'Hobo Water Temp Pro v2' was anchored to the seabed on a patch of sand and maintained upright with a submerged float

At each station, 1 m^2 photo-quadrats were taken every 1 m along a 50 m transect line, in an area representative of habitat conditions at the surveyed site, utilizing the methodology established for habitat mapping and remote sensing by Roelfsema (2007). Each transect at each location consists of six replicates that are each 25 m in length, making a total of 150 m for each transect that is located on the fringing reef (CT001, CT002, and CT003, CT004, CT005, CT006) as shown in Figure 6. These replicates have placed to identify the type of corals that exist in the area.

Figure 6: Diver setting up transects line, transect marker and quadrate replicates

Each location of 25 m in each transect has been defined by two metal rebar stakes (Figure 6), that have been molded with a loop on the end and placed into the reef at locations seemed suitable in that they do not damage live coral or other sessile organisms to ensure that the stakes stay in place. The start and end of each replicate were marked by a sub-surface fishing float, to denote the beginning and end marker stakes and to aid in relocation.

The transect line itself used was a 30 m tape-measure, attached and the start rebar marker and tied off at the second fixed rebar position at 25 m as shown in Figure 7. Survey elements are then undertaken along the line (UVC, benthic flora/fauna, photo quadrats) this equates to a total of 25 photo quadrats per replicate and therefore 125 photo quadrats per transect. The distance between each replicate is no more than 10 m.

Figure 7: Photo of the tape measure attached with the start of rebar marker

3.4 Coral reef Growth Measurement

The species of coral that were selected for this study are *Acropora* sp. and *Porites* sp. These two species were selected because *Acropora* sp. is dominant in the southern basin of the Arabian Gulf where it extends over many kilometers, while *Porites* sp is dominant in areas with extreme salinity of more than 35 ppt and is located in a lagoon habitat to the far west of the southern basin of the gulf. These two species have selected also since it known to be endemic species in the Arabian Gulf.

3.4.1 *Acropora* sp. Growth Measurements

During the first visit for water sampling collection in the western region (Barakah site), it was found that the *Acropora* population had no remaining living colonies. Therefore, another location was chosen (Al Saadiyat island) to further investigate the *Acropora* sp. growth and study the relationship between the seawater temperature and its growth (Figure 8).

The *Acropora* sp. growth measurements were conducted only in Al Saadiyat Island where, ten branches of *Acropora* sp. measured to mm scale using Vernier caliper to measure from the stem to the branch's tip (Figure 9).

The separate stems named AC1, AC2, and AC3, each with a different number of branches measured (Figure 9). The marking of the selected branches has done using special underwater seawater marker and with colored tags. First measurement Oct, 2016 and second measurement was in January 2017 to represent winter season growth. To represent growth in spring-summer season third measurements have carried out firstly February 2017 and the second measurement was on May 2017.

Figure 8: Al Saadiyat Island *Acropora* site

Figure 9: Measurement of the *Acropora* branches' dimensions

3.4.2 *Porites* sp. Growth Measurements

Quadrat photographs that were placed in Barakah were subsequently analyzed using Coral Point Count with Excel extension to measure *Porities* sp. Growth (Kohler & Gill, 2006). This allows for accurate habitat mapping as well as the determination of species abundance, species richness, Shannon-Weiner diversity index (Shannon &

Weiner, 1949), density and coverage change between the dates from Jan 2016 until September 2016.

On the other hand, observations made in the field to include an assessment of the physiological status, including indicators of stress, disease, and ecological disturbance at each station. These data are essential to compare with previous studies and to analyze coral health and growth.

Estimates of relative abundance were made according to life history and population traits utilizing SACFOR (Superabundant, Abundant, Common, Frequent, Occasional, Rare) classifications (JNCC, 1990) as shown in Table 1. Abundance data from all quadrats were combined to give an overall species density per m^2, which were then classified using the appropriate SACFOR scale for an estimated mean species size

Table 1: Abundance scales for marine organisms

Class		Sessile species[1] (% cover)	Size class of individual / colony			
			< 1 cm	1-3 cm	3-15 cm	> 15 cm
			Maximum density per m^2 unless otherwise stated			
S	**Superabundant**	> 64%	> 10,000	> 1,000	> 100	> 10
A	**Abundant**	36-64%	10,000	1,000	100	10
C	**Common**	16-32%	1,000	100	10	1
F	**Frequent**	4-16%	100	10	1	1 / 10 m^2
O	**Occasional**	1-4%	10	1	1 per 10 m^2	1 / 100 m^2
R	**Rare**	< 1%	1	1 per 10 m^2	1 / 100 m^2	1 / 1000 m^2

Source: (JNCC, 1990)
Note: Statistical analysis was used to compare the results of seawater trace elements to show if any significant changes between summer and winter. That have done by using t-test analysis using (SPSS) software tool.

Chapter 4: Results

4.1 Environmental Parameter

In this study, *Porites* sp. colonies were involved in measuring the variation in coral growth. Colonies have been found at Barakah site depth of 8 m. The multi-sensory readings showed a notable variation in water temperature, water salinity, and water pH and dissolved oxygen. A comparison between the three colonies made to measure their growth variations, taking into consideration the above-mentioned environmental parameters.

4.1.1 Water Temperature at Barakah Site

There was a remarkable change in water temperature throughout the study period. A gradual drop in water temperature started early in January and reached its lowest point early in February with a reading of 17ºC. On the other hand, a gradual increase in water temperature has observed in mid-April, reaching a culmination of 30ºC early in May and announcing by this the beginning of summer (Figure 10).

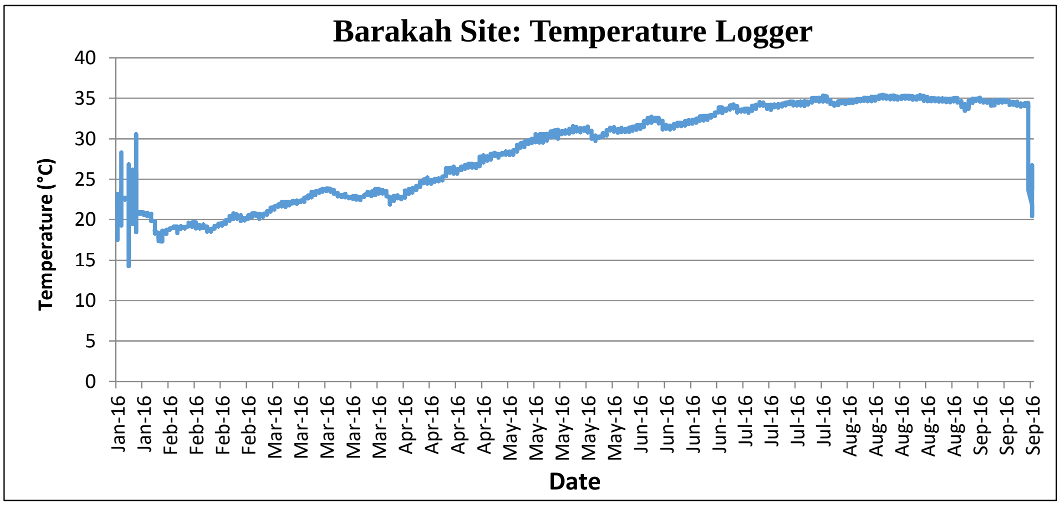


Figure 10: Monthly variation in water temperature during the study period at Barakah Site

4.1.2 Water Temperature at Saadiyat Site

On the other hand, a gradual drop in water temperature started from November 2016 and reached its lowest point early in February 2017, with a reading of 19ºC. While a gradual increase in water temperature has observed, reaching a highest of 32.3 early in May 2017 and announcing by this the beginning of summer, this was taken in a different timeline from Barakah site (Figure 11).

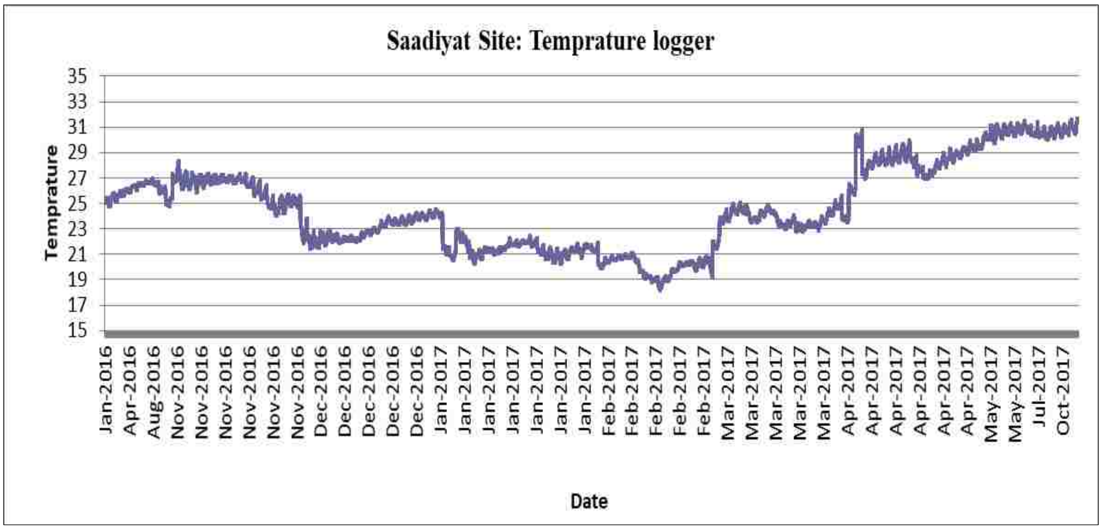


Figure 11: Monthly variation in water temperature during the study period in Saadiyat

4.1.3 Water Salinity in Barakah Site

There were slight variations in water salinity across the study period at different stations in Barakah. The six water samples tested in summer (Aug) for salinity in Barakah, have an average of 43.11 ppt. On the other hand, the six water samples tested in winter (Jan) for salinity, have an average of 43.48 (Table 2).

Table 2: Sea water salinity in Barakah (summer vs. winter 2016)

Site ID	Date & Time	Site Depth (m)	Profile	SAL (ppt)	Date & Time	Site Depth (m)	Profile	SAL (ppt)
CT001	21 Aug 2016 8:11	5.8	Surface	43.11	31 Jan 2016 13:23	6.1	Surface	43.95
			Middle	43.10			Mid-water	43.88
			Near Bottom	43.08			Near Bottom	43.92
CT002	21 Aug 2016 8:01	5.6	Surface	43.22	31 Jan 2016 13:18	7.2	Surface	43.65
			Middle	43.18			Mid-water	43.76
			Near Bottom	43.16			Near Bottom	43.70
CT003	21 Aug 2016 7:47	9.2	Surface	43.26	31 Jan 2016 13:10	9.6	Surface	-
			Middle	43.20			Mid-water	43.52
			Near Bottom	43.20			Near Bottom	43.56
CT004	21 Aug 2016 8:42	12.9	Surface	42.86	31 Jan 2016 9:53	6.2	Surface	43.18
			Middle	42.79			Mid-water	43.19
			Near Bottom	42.77			Near Bottom	43.18
CT005	21 Aug 2016 9:11	8.5	Surface	42.76	2 Feb 2016 10:21	8.9	Surface	43.14
			Middle	42.74			Mid-water	43.14
			Near Bottom	42.71			Near Bottom	43.15
CT006	21 Aug 2016 9:37	6.0	Surface	43.49	2 Feb 2016 10:52	8.2	Surface	43.39
			Middle	43.55			Mid-water	43.38
			Near Bottom	43.79			Near Bottom	43.45

4.1.4 Water pH in Barakah Site

The pH of the water samples collected during summer (August 2016), from the six studied locations in Barakah has shown a pH ranged from 7.99-8.06 with an average of 8.03 (Table 3). However, in winter (February 2016), the six sites measurements average pH level recorded was 7.98 (Table 3). Statistical analyses have shown no significant variations between the pH values at both seasons within the different stations (P = 0.09).

Table 3: Records of pH measurement in Barakah during summer and winter

Site ID	Date & Time	Site Depth (m)	Profile	pH	Date & Time	Site Depth (m)	Profile	pH
CT001	21 Aug 2016 8:11	5.8	Surface	7.99	31 Jan 2016 13:23	6.1	Surface	8.04
			Middle	7.99			Mid-water	8.03
			Near Bottom	8.00			Near Bottom	8.04
CT002	21 Aug 2016 8:01	5.6	Surface	8.01	31 Jan 2016 13:18	7.2	Surface	8.04
			Middle	8.03			Mid-water	8.03
			Near Bottom	8.02			Near Bottom	8.03
CT003	21 Aug 2016 7:47	9.2	Surface	8.04	31 Jan 2016 13:10	9.6	Surface	8.03
			Middle	8.05			Mid-water	8.01
			Near Bottom	8.01			Near Bottom	8.00
CT004	21 Aug 2016 8:42	12.9	Surface	8.06	02 Feb 2016 09:53	6.2	Surface	7.70
			Middle	8.07			Mid-water	7.94
			Near Bottom	8.07			Near Bottom	8.01
CT005	21 Aug 2016 9:11	8.5	Surface	8.06	02 Feb 2016 10:21	8.9	Surface	8.03
			Middle	8.06			Mid-water	7.58
			Near Bottom	8.06			Near Bottom	7.96
CT006	21 Aug 2016 9:37	6.0	Surface	8.03	02 Feb 2016 10:52	8.2	Surface	8.08
			Middle	8.04			Mid-water	8.07
			Near Bottom	8.02			Near Bottom	8.07

4.1.5 Dissolved Oxygen (DO) in Barakah

A slight variation in the dissolved oxygen concentration in water was observed from summer to winter.

In the summer of Aug 2016, the six sites in Barakah have an average of 5.15 mg.L^{-1} dissolved oxygen. The maximum-recorded value of (DO) during that period was 8.70 mg.L^{-1} (Table 4). On the other hand, in winter (Feb 2016) the average (DO) concentration has reached 6.97 mg.L^{-1}, while the maximum-recorded value of (DO) during this period was 8.08 (Table 4). In Barakah, based on the t-test, there is no significant change between (DO) between summer and winter.

Table 4: Records of DO measurement in Barakah during summer and winter

Site ID	Date & Time	Site Depth (m)	Profile	DO $mg.l^{-1}$	Date & Time	Site Depth (m)	Profile	DO $mg.l^{-1}$
CT001	21 Aug 2016 8:11	5.8	Surface	4.28	31 Jan 2016 13:23	6.1	Surface	6.99
			Middle	4.19			Mid-water	7.10
			Near Bottom	4.11			Near Bottom	7.03
CT002	21 Aug 2016 8:01	5.6	Surface	4.73	31 Jan 2016 13:18	7.2	Surface	6.96
			Middle	4.69			Mid-water	7.06
			Near Bottom	4.67			Near Bottom	7.17
CT003	21 Aug 2016 7:47	9.2	Surface	5.24	31 Jan 2016 13:10	9.6	Surface	-
			Middle	5.21			Mid-water	6.94
			Near Bottom	4.92			Near Bottom	6.99
CT004	21 Aug 2016 8:42	12.9	Surface	5.71	02 Feb 2016 09:53	6.2	Surface	6.85
			Middle	5.69			Mid-water	6.85
			Near Bottom	5.64			Near Bottom	6.83
CT005	21 Aug 2016 9:11	8.5	Surface	5.82	02Feb 2016 10:21	8.9	Surface	6.85
			Middle	5.74			Mid-water	6.83
			Near Bottom	5.72			Near Bottom	6.78
CT006	21 Aug 2016 9:37	6.0	Surface	5.64	02 Feb 2016 10:52	8.2	Surface	7.03
			Middle	5.50			Mid-water	7.06
			Near Bottom	5.13			Near Bottom	7.15

4.2 Seawater Trace Element

The study measured different trace elements: (Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sr, V, and Zn) in the two studied locations In Barakah site 15 samples were collected while, in Saadiyat Island only 4 samples were taken.

The comparison made is to test the variation of trace elements concentrations in summer (Table 5 and Table 6) and winter (Table 7 and Table 8). The t-test shows no significant changes in reading between summer and winter in Barakah water sampling in Al ($P=0.13$), Ni ($P=0.215$), and Zn ($P=0.46$). While in Saadiyat trace elements no significant difference were shown in copper (Cu) concentrations between summer (average 5.5 $mg.L^{-1}$) and winter (average 4.25 $mg.L^{-1}$), where $P= 0.1955$, not significant for Ni ($P=0.19$) and Zn ($P=0.44$).

Table 5: Barakah seawater trace elements concentrations in seawater (winter, 2017)

Sample ID	mg/L (ppm)																			
	Al	As	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sr	V	Zn
Sample 1	0.015	<0.009	584.9	<0.001	<0.003	<0.005	0.009	<0.017	453.7	1821.4	<0.009	<0.018	11475.0	0.003	0.015	<0.011	1321.5	3.69	0.003	0.007
Sample 2	0.020	<0.009	585.2	<0.001	<0.003	<0.005	0.009	<0.017	453.3	1820.6	<0.009	<0.018	11527.0	<0.003	0.024	<0.011	1362.2	3.82	0.003	0.006
Sample 3	0.017	<0.009	579.5	<0.001	<0.003	<0.005	0.009	<0.017	451.4	1818.5	<0.009	<0.018	11384.0	<0.003	0.010	<0.011	1329.4	4.00	0.003	0.003
Sample 4	0.011	<0.009	565.8	<0.001	<0.003	<0.005	0.008	<0.017	440.5	1775.9	<0.009	<0.018	11170.1	<0.003	<0.010	<0.011	1295.1	4.06	0.002	0.007
Sample 5	0.014	<0.009	571.2	<0.001	<0.003	<0.005	0.008	<0.017	450.4	1803.3	<0.009	<0.018	11285.8	0.004	0.028	<0.011	1326.8	4.14	0.002	<0.001
Sample 6	<0.010	<0.009	557.8	<0.001	<0.003	<0.005	0.008	<0.017	426.1	1734.7	<0.009	<0.018	10947.6	0.005	0.025	<0.011	1279.2	4.22	0.002	0.006
Sample 7	0.015	<0.009	567.9	<0.001	<0.003	<0.005	0.007	<0.017	455.8	1805.5	<0.009	<0.018	11391.9	0.003	0.026	<0.011	1330.8	4.38	0.003	0.005
Sample 8	0.019	<0.009	566.8	<0.001	<0.003	<0.005	0.007	<0.017	453.3	1789.7	<0.009	<0.018	11340.3	0.004	0.029	<0.011	1331.1	4.20	0.003	0.003
Sample 9	0.021	<0.009	563.6	<0.001	<0.003	<0.005	0.007	<0.017	452.4	1794.5	<0.009	<0.018	11362.8	0.006	0.028	<0.011	1306.9	4.13	0.003	<0.001
Sample 10	0.021	<0.009	579.9	<0.001	<0.003	<0.005	0.007	<0.017	473.6	1850.8	<0.009	<0.018	11555.8	0.005	0.023	<0.011	1354.5	4.31	0.003	0.006
Sample 12	0.016	<0.009	560.3	<0.001	<0.003	<0.005	0.007	<0.017	447.8	1772.4	<0.009	<0.018	11181.5	<0.003	0.028	<0.011	1310.6	4.15	0.003	0.007
Sample 13	0.021	<0.009	564.5	<0.001	<0.003	<0.005	0.006	<0.017	451.0	1775.9	<0.009	<0.018	11296.8	0.006	0.031	<0.011	1332.5	3.87	0.003	<0.001
Sample 14	0.022	<0.009	557.1	<0.001	<0.003	<0.005	0.006	<0.017	441.5	1752.9	<0.009	<0.018	11102.2	0.004	0.017	<0.011	1309.8	4.10	0.003	0.006
Sample 15	0.020	<0.009	559.9	<0.001	<0.003	<0.005	0.006	<0.017	446.0	1774.2	<0.009	<0.018	11216.2	0.004	0.015	<0.011	1312.7	3.68	0.004	0.007

Table 6: Barakah seawater trace elements concentrations in seawater (summer, 2017)

Sample ID	mg/L (ppm)																			
	Al	**As**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sr**	**V**	**Zn**
Sample 1	0.014	0.019	578.6	<0.001	<0.003	<0.005	0.009	<0.017	512.3	1701.5	<0.009	<0.018	11696.2	0.007	<0.010	<0.011	1307.7	3.62	0.002	0.006
Sample 2	0.010	0.020	590.3	<0.001	<0.003	<0.005	0.010	<0.017	518.4	1711.0	<0.009	<0.018	11707.4	<0.003	0.013	<0.011	1335.3	3.73	0.002	0.006
Sample 3	0.014	0.019	593.6	<0.001	<0.003	<0.005	0.011	<0.017	540.0	1781.4	<0.009	<0.018	11950.9	0.003	0.021	<0.011	1378.3	3.69	0.002	0.003
Sample 4	0.017	<0.009	591.7	<0.001	<0.003	<0.005	0.010	<0.017	540.6	1772.2	<0.009	<0.018	11945.7	0.004	<0.010	<0.011	1394.9	3.67	0.003	0.010
Sample 5	0.015	0.022	581.6	<0.001	<0.003	<0.005	0.010	<0.017	524.6	1729.5	<0.009	<0.018	11893.8	<0.003	<0.010	<0.011	1345.4	3.52	0.002	0.005
Sample 6	0.011	<0.009	599.7	<0.001	<0.003	<0.005	0.010	<0.017	554.8	1793.7	<0.009	<0.018	12218	0.004	0.011	<0.011	1373.1	3.60	0.003	0.006
Sample 7	0.030	<0.009	597.2	<0.001	<0.003	<0.005	0.009	<0.017	537.2	1776.8	<0.009	<0.018	11990.5	0.004	0.013	<0.011	1396.0	3.65	0.003	0.006
Sample 8	0.025	0.010	590.4	<0.001	<0.003	<0.005	0.008	<0.017	532.7	1743.7	<0.009	<0.018	11921.9	0.006	0.014	<0.011	1360.0	3.46	0.003	0.004
Sample 9	0.014	<0.009	606.3	<0.001	<0.003	<0.005	0.008	<0.017	539.1	1778.0	<0.009	<0.018	12105.7	<0.003	0.012	<0.011	1426.0	3.31	0.002	0.006
Sample 10	0.008	0.025	591.1	<0.001	<0.003	<0.005	0.008	<0.017	535.0	1741.5	<0.009	<0.018	12031.6	0.003	0.017	<0.011	1383.5	3.61	0.004	0.001
Sample 11	0.013	0.009	647.0	<0.001	<0.003	<0.005	0.006	<0.017	598.6	1887.0	<0.009	<0.018	12987.4	0.016	<0.010	<0.011	1495.6	3.15	0.002	0.006
Sample 12	0.005	0.031	604.8	<0.001	<0.003	<0.005	0.008	<0.017	542.0	1745.3	<0.009	<0.018	12119.5	0.004	0.023	<0.011	1411.7	3.44	0.002	0.010
Sample 13	0.021	<0.009	613.5	<0.001	0.003	<0.005	0.006	<0.017	551.8	1782.1	<0.009	<0.018	12284.6	0.003	0.017	<0.011	1419.9	3.28	0.004	0.008
Sample 14	0.012	0.019	634.2	<0.001	<0.003	<0.005	0.007	<0.017	582.2	1869.0	<0.009	<0.018	12715.3	0.005	0.011	<0.011	1478.6	3.37	0.003	0.005
Sample 15	0.012	0.021	647.7	<0.001	<0.003	<0.005	0.006	<0.017	596.4	1919.5	<0.009	<0.018	12915.9	0.009	0.015	<0.011	1482.2	3.48	0.002	<0.001

The result from Tables 7 and 8 showed concentrations of the trace elements in the water from summer and winter in Saadiyat location. There is a noticeable increase in Sulfur (S) element concentration in Al Saadiyat from summer 2017 to winter 2018 to winter (Figure 12). The statistical analyses indicated significant changes (P= 0.0001481) in the sulfur element concentration.

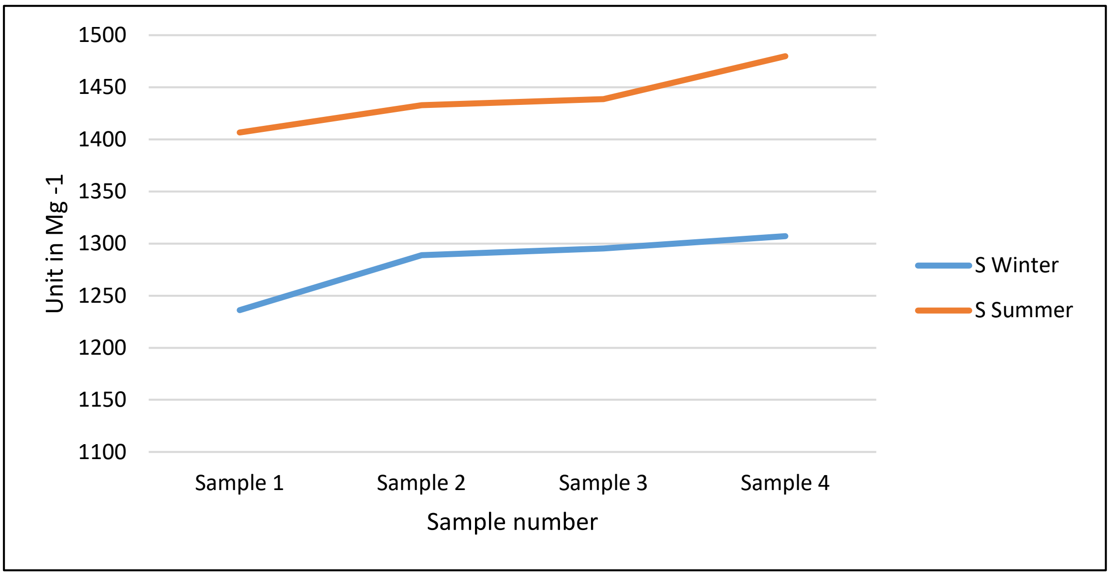


Figure 12: Sulfur concentrations in summer and winter at Saadiyat Island

Table 7: Seawater trace elements concentrations at Saadiyat Island (winter, 2017)

Sample ID	**mg/L (ppm)**																			
	Ca	**K**	**Mg**	**Na**	**S**	**Al**	**As**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Mo**	**Ni**	**P**	**Pb**	**Sr**	**V**	**Zn**
Sample 1	**573.1**	**462.9**	**1860.8**	**13474.3**	**1236.1**	**0.013**	**<0.009**	**<0.001**	**<0.003**	**<0.005**	**0.004**	**<0.017**	**<0.009**	**0.009**	**0.002**	**0.018**	**<0.011**	**3.95**	**0.003**	**0.006**
Sample 2	**584.9**	**485.4**	**1961.3**	**14053.7**	**1288.9**	**0.017**	**<0.009**	**<0.001**	**<0.003**	**<0.005**	**0.005**	**<0.017**	**<0.009**	**0.010**	**0.003**	**0.013**	**<0.011**	**3.86**	**0.002**	**0.007**
Sample 3	**582.2**	**488.1**	**1952.7**	**14322.6**	**1295.2**	**0.011**	**<0.009**	**<0.001**	**<0.003**	**<0.005**	**0.005**	**<0.017**	**<0.009**	**0.010**	**0.003**	**0.017**	**<0.011**	**3.64**	**0.003**	**0.007**
Sample 4	**585.1**	**488.6**	**1964.9**	**14326.8**	**1307.1**	**0.019**	**<0.009**	**<0.001**	**<0.003**	**<0.005**	**0.006**	**<0.017**	**<0.009**	**0.011**	**0.002**	**0.022**	**<0.011**	**3.78**	**0.003**	**0.005**

Table 8: Seawater trace elements concentrations at Saadiyat Island (spring-Summer, 2017)

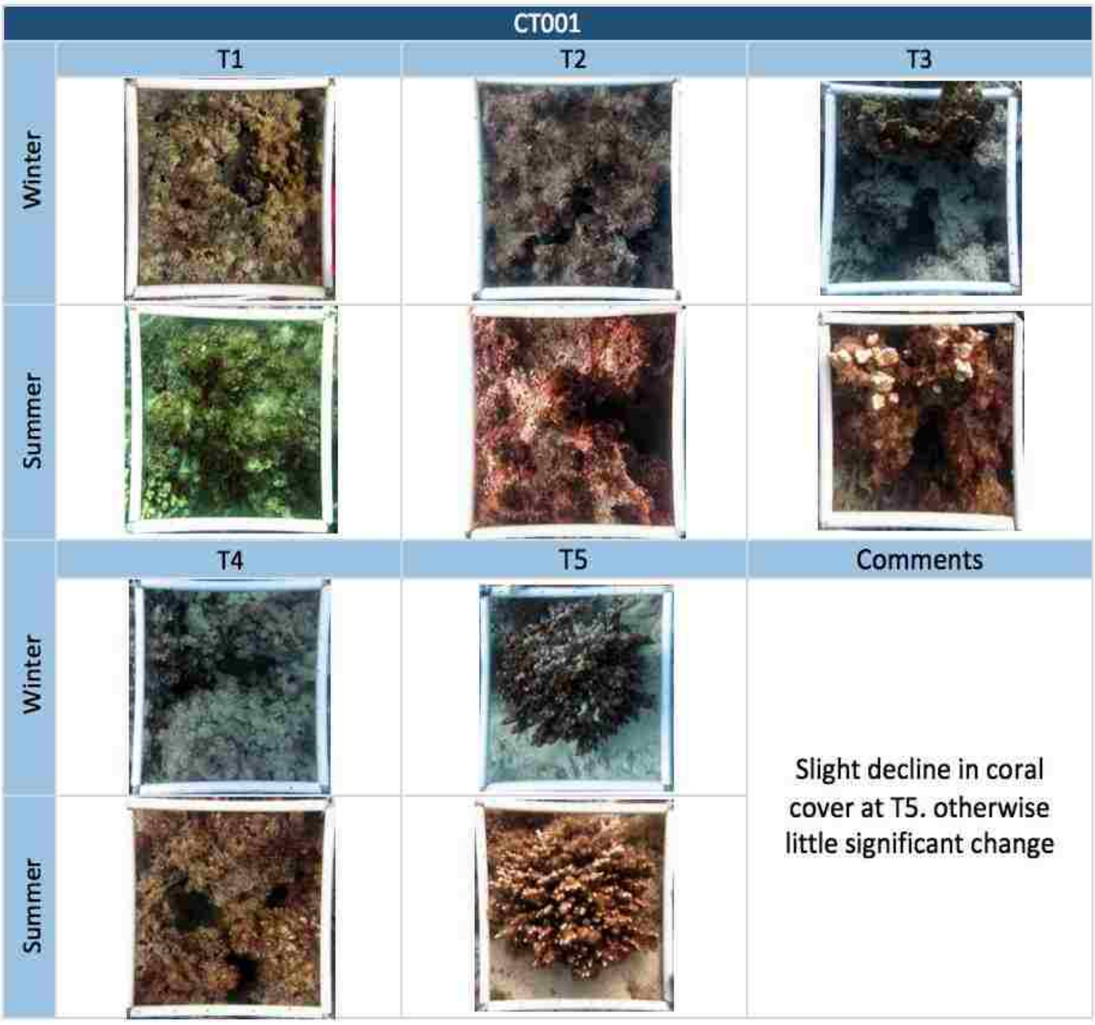
Sample ID	**mg/L (ppm)**																			
	Al	**As**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sr**	**V**	**Zn**
Sample 01	**0.028**	**<0.009**	**611.0**	**<0.001**	**<0.003**	**<0.005**	**0.006**	**<0.017**	**567.8**	**1789.6**	**<0.009**	**<0.018**	**12434.8**	**<0.003**	**0.014**	**<0.011**	**1406.6**	**3.39**	**0.003**	**<0.001**
Sample 02	**0.032**	**0.011**	**621.8**	**<0.001**	**<0.003**	**0.026**	**0.005**	**<0.017**	**589.1**	**1840.9**	**<0.009**	**0.024**	**12626.4**	**0.121**	**<0.010**	**<0.011**	**1432.8**	**3.47**	**0.002**	**0.013**
Sample 03	**0.021**	**0.010**	**615.7**	**<0.001**	**0.004**	**<0.005**	**0.005**	**<0.017**	**579.1**	**1813.3**	**<0.009**	**<0.018**	**12670.6**	**0.006**	**<0.010**	**<0.011**	**1438.5**	**3.28**	**0.003**	**0.003**
Sample 04	**0.044**	**0.031**	**639.5**	**<0.001**	**0.003**	**<0.005**	**0.006**	**<0.017**	**583.5**	**1853.6**	**<0.009**	**<0.018**	**12810.9**	**0.008**	**<0.010**	**<0.011**	**1479.8**	**3.23**	**0.002**	**<0.001**

4.3 Coral Growth

4.3.1 *Porites* sp. Growth Measurements at Barakah

Table 9 shows the differences in *Porites* colonies investigated during summer and winter seasons at the Barakah site. CPCe analysis had conducted on all photo quadrats and combined to provide details of the benthic coverage at the coral sites. CPCe analysis showed that live coral cover across all sites was 35.2% during the winter; this was noticeably lower during the summer at 21.6%. Table 9 provide *Porites* sp. coral cover for each site, comparing winter and summer results.

Table 9: Comparison of quadrat photos CT001 in both summer and winter seasons at Barakah site



Estimates of relative abundance were made according to life history and population traits utilizing SACFOR (Superabundant, Abundant, Common, Frequent, Occasional, Rare) classifications (JNCC, 1990), as shown in Table 10. In Table 10, abundances data from all quadrats have combined to give an overall species density per m^2, which were then classified using the appropriate SACFOR scale for an estimated mean species size

Table 10: *Porites* cover from CT001 to CT005 at Barakah site

Scientific name	CT001a		CT001b		CT001c		CT001d		CT001e		CT002a		CT002b		CT002c		CT002d		CT002e		CT003a		CT003b		CT003c		CT003d		CT003e	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Porites sp.	R		R		R		R			R	R	O	R	O	R	R	R	R	R	O	R		R		R		R		R	
SACFOR Scale: S = Super Abundant / A = Abundant / C = Common / F = Frequent / O = Occasional / R = Rare / W = Winter / S = Summer																														

Scientific name	CT004a		CT004b		CT004c		CT004d		CT004e		CT005a		CT005b		CT005c		CT005d		CT005e	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Porites sp.	F		F		F		F		F		F		F		F		F		F	
SACFOR Scale: S = Super Abundant / A = Abundant / C = Common / F = Frequent / O = Occasional / R = Rare / W = Winter / S = Summer																				

4.3.2 *Acropora* sp. Growth at Saadiyat Island

Due to the bleaching, of the *Acropora* in Barakah (Figure 13), three *Acropora* colonies were selected from Saadiyat Island to track down and compare the variation between winter and summer seasons. Branches growth have shown significant distinguished variations between its branches (Table 11).

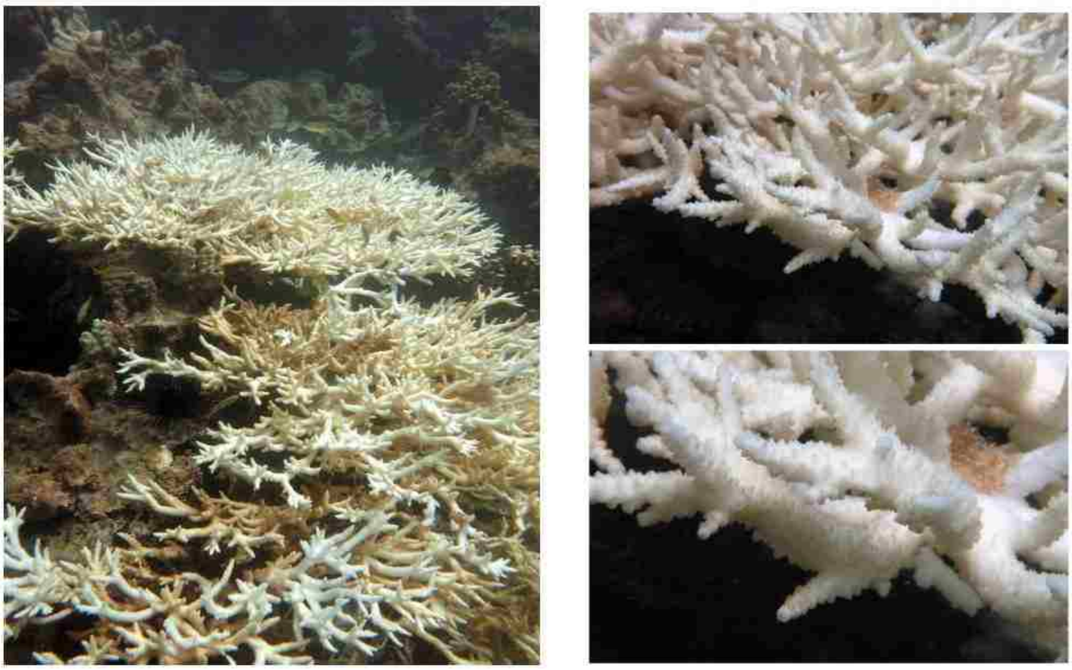


Figure 13: *Acropora downingi* bleaching in Barakah site CT002 (summer 2016)

In Saadiyat *Acropora* colonies, there was different growth in the selected colonies branches between winter and spring-summer seasons. In general, the growth was small in winter season, compared to the spring-summer season growth. The most notable growth has seen in colony #1 with an 18 mm growth per season in spring-summer season compared to only 2 mm per season during the winter season of the same branch (Table 11).

The most notable change has seen in colony # 1 branch 3 with a growth of 18 mm per season. Moreover; colony # 2 showed a similar change in branch (3) at a growth of 15 mm per season in spring-summer season compared with only 4 mm growth per season during the winter season. While colony # 3 showed no change at all, due to limited number of branches tracked Resulted from tags and marking loss (Tables 11 and 12).

Table 11: *Acropora* growth rates comparison of the three *Acropora* sp. Colonies and its branches growth in winter and spring-summer seasons in Saadiyat location

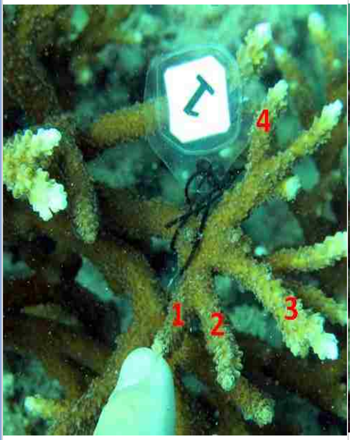
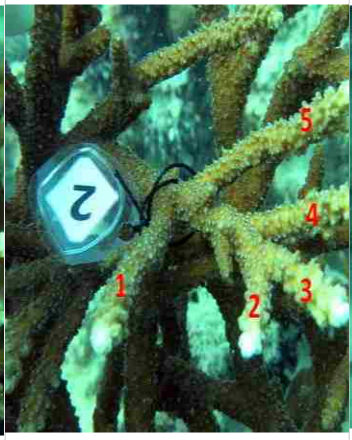
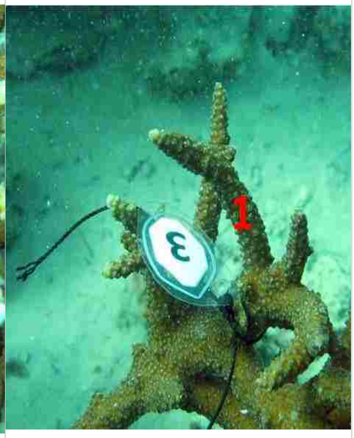
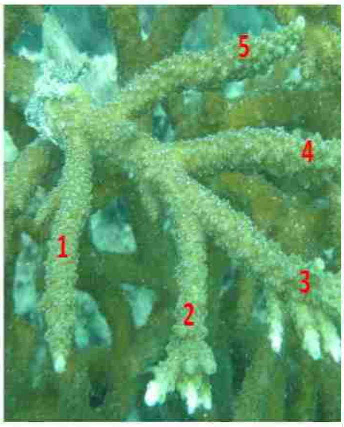
Acropora branches length in			
	Sample 1	Sample 2	Sample 3
Winter (Jan 2017)			
Summer (May 2017)			

Table 12: *Acropora* branches' growth rate comparison in summer and winter

	Branch	Original length	Winter (Oct-Jan) Length (mm)	Spring-Summer (Feb-May) Length (mm)
Sample1	AC1(1)	18	20	20
	AC1(2)	21	25	30
	AC1(3)	40	42	60
	AC1(4)	22	25	28
Sample 2	AC2(1)	50	50	50
	AC2(2)	15	19	31
	AC2(3)	22	26	41
	AC2(4)	40	45	51
	AC2(5)	58	58	58
Sample 3	AC3(1)	45	46	46

Statistical comparison analysis of the growth rate of *Acropora* branches in winter (October-January 2016) with the original branches sizes has shown non-significant (P=0.0008). Furthermore, the statistical comparison between *Acropora* branches growth rate with the original sizes has shown non-significant (P=0.004) during spring/ summer season (February-May 2017). Furthermore, the statistical comparison between winter and spring-summer measurements in sample 1 and 2 of the *Acropora* branches shown to be significant (P= 0.09).

4.4 Coral Disease Assessment

Barakah site showed the most degraded habitat of the dense coral and specifically for both *Acropora* and *Porites* species were the most suffered ones *Acropora* spp. colonies have completely bleached and almost demolished from this site. Despite heavy mortality, some populations of other coral still exist, but with some notable unhealthy status Figure 14. shows some underwater photographs in Barakah studied areas within and outside the studied colonies where signs of yellow band disease infecting some of the existing colonies of *Porites harrisoni* (Figure 14 A) other colonies of the same species have overgrowing of serpulid worm (Figure 14 B). Also, it shows a completely dead *Acropora* sp. colonies (Figure 14 C), with signs of yellow band disease.

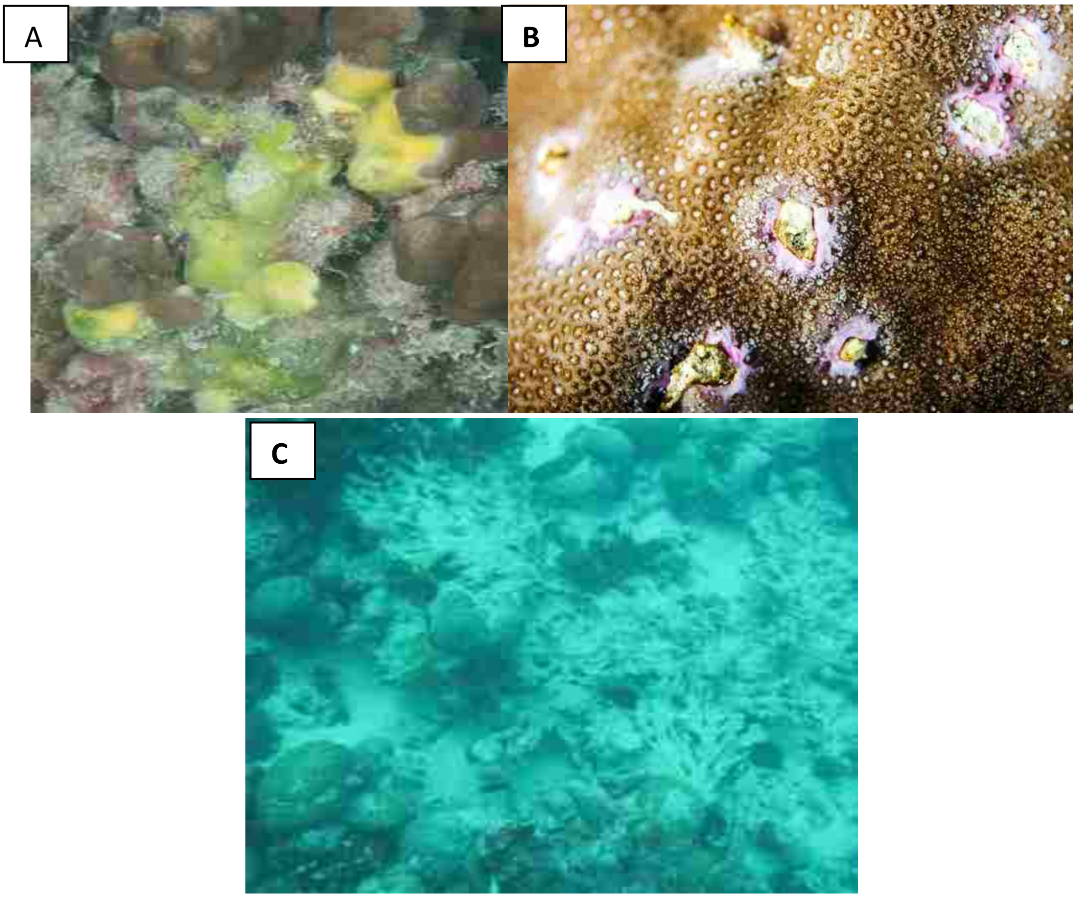


Figure 14: Underwater photographs from the Barakah site showing diseases affecting corals. (A) *Porites harrisoni* affected by yellow band disease, (B) Serpulid worms growing over *Porites* species and (C) Old dead *Acropora* colonies. That seems to be dead from yellow band disease as some yellow.

Chapter 5: Discussion

More than two decades earlier, it was mentioned that the health of coral reefs has deteriorated, and many corals died in 1997 and 1998 in Abu Dhabi (Environment Agency Abu Dhabi, 2017). Guest et al. (2014) explained that the main cause of the death and bleaching of corals are the results of deteriorating in water quality and seawater warming.

Rising sea temperatures caused by climate change have become the greatest danger to coral reefs. In the past few decades, corals faced difficult environmental conditions; high temperature and high salinity were among the factors that negatively affected corals. During the present study, water temperature ranged in Barakah site between 17ºC in winter and 36ºC in summer. That may look normal for the coral species living in the Gulf area. It has been mentioned that the coral reef in the Arabian Gulf has got the potential of tolerating temperatures as high as 36ºC and as low as 13ºC as high temperatures are major during the summer and low temperatures during the winter. Therefore, the ability of the coral reefs on the Arabian Gulf to tolerate very low and high temperature makes it unique to all gulfs around the world as coral bleaching do occur at the temperatures of 29ºC (Casey, 2015). It seems that, due to human activities in Barakah area in 2016 water temperature increased and lead to the mass bleaching of *Acropora* species in the area. However, the measurement carried in this study during 2017, has recorded normal temperature levels that is suitable for the growth of *Porites* and *Acropora* species. On the other hand, the appearance of Yellow band disease and worm infection of *Porites* colonies endorse the suggestion of the presence of other factors to be responsible for such finding in that site.

Although the growth measurements were done for the *Acropora* colonies at Saadiyat site did not cover the hot summer months; but the colonies measured during the study period (October 2016-May 2017), with a water temperature ranged between 17ºC, and 31ºC, and were found to be in good shape. That also may indicate that the water quality at Barakah site is unsuitable for a healthy growth of coral communities in general and *Acropora* species in particular. That could be due to human activities in that area that influenced its water quality and could be responsible for the damages happened to coral community at that site.

Water Salinity is also a factor that helps in the distribution of corals species as well as the assembly communities around it. Moderate temperature and salinity have a key role in coral calcification. According to Kinsman's (1964), "Reef corals flourish best in the range 25ºC-29ºC, within a salinity range of 34-36 ppt". Coles (2003) praised the coral's adaptability along the Abu Dhabi coastline and observed that 11 coral species survive temperatures up to 36ºC and the salinity up to 48 ppt. According to the measurements of water salinity of Abu Dhabi coral habitats done both 7 years ago until the present study.

The salinity along the coast of Abu Dhabi is often around 40-43 ppt" with conditions of extreme in the shallow southern basin where the depth is less than 20 m (Riegl & Purkis, 2012). Since the Gulf has no rapid turnover of oceanic waters, temperature and salinity become high. Therefore, it is affirmative that corals in

Arabian Gulf, most especially the *Porites* sp. and *Acropora* sp. are growing in extreme environmental conditions, at elevated temperature and salinity.

Corals such as the *Porites* sp. can adapt to areas with extreme salinity of more than 35 ppt but the *Acropora* sp. cannot survive in a high salinity water body. Although *Porites* can survive in an extreme salinity area when there is a great increment in temperature due to climate change, the zoothanthelli, which supply energy to corals, will die. That will result in bleaching and death of corals. In the present study, the salinity levels in Barakah site in summer was (43.11 ppt) and in winter (43.48 ppt), which are within the average of *Porites* sp and *Acropora* sp. survival. However, zoothanthelli or unicellular algae associated with corals may not be able to fulfill its symbiotic performance with the coral polyps.

Coral reefs of the United Arab Emirates were once extensive, but have declined dramatically in recent decades as a result of the different stress factors such as high temperatures and low winds (Riegl & Purkis, 2012) 90% of Abu Dhabi's coral cover bleached and are still struggling to survive (Bardsley, 2019).

Moreover, the corals in Arabian Gulf reefs declined up to 50 percent (Zaman, 2014). According to Environment Agency - Abu Dhabi, 98% of Abu Dhabi's corals have died in the past because of prolonged positive seawater temperature anomalies.

Furthermore, percent cover of the *Acropora* coral has declined in the Abu Dhabi coast due to seawater warming that may contribute to the physiological stress of reef corals (Chilcoat, 2004).

Another study by Crossland (1984) mentioned that lower wintertime temperatures and low light levels did not limit the calcification rates of *Turbinaria* *reniformis* corals. At locations where temperatures exceeded the long-term summer maxima, coral growth was equivalent or a little lower than winter (Anderson, 2017).

In the present study, the growth of *Porites* sp. in Barakah is more visible during winter (35.2%) than in summer (21.6%). This corresponds to the research carried out by Riegl and Purkis (2012) on Abu Dhabi's coastline, indicating that the coral reefs are growing more in the winter, although, they grew in summer as *Porites* have great tolerance to elevated temperature and salinity. In addition, from research carried out from 2013 to 2016 by Environment Agency - Abu Dhabi, its report showed an increase in live coral cover during winter across Abu Dhabi, from the three-year period there is evidence of recovery from previous bleaching events.

On the other hand, the growth rate measured at Saadiyat for the *Acropora* colonies and their branches showing better growth during the spring-summer (February-May 2017), compared with the winter (Oct. 2016-January 2017). In fact, the growth rate in the spring – summer period has ranged between 1 mm and 20 mm (P=0.004), while in winter the growth rate ranged between 1 mm and 5 mm (P=0.0008) (Table 12). This growth rate found to be good when compared with similar studies done at Abu Al Abyad Island (UAE), coastal water in a coral nursery, where the growth rate found to be around 6 mm during the period Oct-Dec. 2012-2013 and around 15 mm during the period Jan – Mar 2013. Moreover, 22 mm measured during the period April-June 2013 (Sen & Yousif, 2016). In a study done in the Caribbean Staghorn, it has documented that the annual growth rate measured for *Acropora cervicornis* in both nursery and reef has ranged between 14 mm and 64 mm (Lirman et al., 2014).

In the present study, there were no hot summer month's growth measurements for the *Acropora* colonies in Saadiyat; that was also due to limited time. However, it seems that the high growth rate measured during the spring-summer occurred during the months where temperature was favorable for optimum growth. In fact, at that period the water temperature ranged between 18ºC and 31ºC. In their study, Sen and Yousif (2016) have reported that *Acropora clathrata* in the tree nursery of Abu Al Abyad Island (UAE), which is few kilometers from Saadiyat (present study site) have less survival in July-September period compared to April-June period. This confirms that high temperature during hot summer months (June-September), are not favorite for better growth in Abu Dhabi coastal area.

On the other hand, it has documented that corals need trace elements in water since it plays a major role not only in the skeletal development but also in the physiological roles and functioning of photosynthetic organisms. One of the essential elements requires by coral in trace amount is Copper (Cu). Using the Copper baseline ranges between (0.01 mg.L^{-1} and 1.0 mg.L^{-1}) by Howard et al. (1986), the values of Cu in the Barakah and Saadiyat (both in winter and summer) is less than the baseline. Supported by a research conducted by Sabdono (2009), on the exposure of coral *Galaxea fascicularis* to copper concentration of 0.001ppm the coral's conditions were normal. However, Copper can cause partial bleaching of the corals if it was in high concentrations. A study conducted by Jones (1997) has shown from a high concentration of metals can reduce the reproductive level of corals (Reichelt & Harrison, 1999).

In addition, Manganese (Mn) is also a key trace element for coral symbioses; it helps corals to resist heat stress-induced bleaching and does not reduce coral’s photosynthesis and calcification (Biscéré et al., 2018). However, at higher concentrations, these heavy metals, including mercury and many other trace elements can lead to toxic effects on coral reefs (Kim et al., 2008).

The other trace elements values that recorded in water for Al, Ni, Zn, Cd, Fe and Pb in Barakah and Saadiyat sites were found normal, within range and are suitable for the growth of coral reefs. Furthermore, the values of Zn, Ni and Cu in the study areas are lower when compared with values found in different locations around the world.

Table 13 summarize the main trace metals concentration found around the Porities and the *Acropora* colonies in the present study in Barakah and Saadiyat, respectively with different concentrations found around other coral habitats around the world. This comparison showing that the trace metals concentrations in the studied areas are within the normal conditions found elsewhere.

Table 13: Comparison of trace metals concentrations (mg/l) in different *Porites* Corals from previous research reports worldwide with the study areas

Location	*Porites Species*	Cr	Mn	Ni	Cu	Zn	Cd	Pb	Reference
Barakah	*Porites sp.*	-	-	0.215	0.0002	0.46	-	-	Present Study
**Saadiyat	*Acropora*	-	-	0.19	0.1955	0.44	-	-	Present study
Florid Keys	*Porites*	<2	4	2	2	<2	-	<2	(Livingston & Thompson, 1971)
Heron and Wistari Reef (Great Barrier Reef)	*Poritidae*	-	-	0.17	0.28	2.4	0.054	0.27	(John, 1974)
Alina's Reef (Florid keys)	*Porites astreoides*	-	-	-	33.7	-	<0.3	9.3	(Glynn et al., 1990)
Bache Reef (Florid Keys)	*Porites astreoides*	-	-	-	33.7	-	<0.3	<1.0	(Glynn et al., 1990)
Red Sea	*Porites lutea*	-	0.667	0.15	0.83	9.28	0.058	51	(Hanna & Muiri, 1990)
Punta Brava (Venezuela)	*Porites astreoides*	0.797	-	-	16.33	10.67	-	0.208	(Bastidas & Garcia, 1999)
Bajo Caiman (Venezuela)	*Porites astreoides*	1.952`	-	-	12.52	9.12	-	1.037	(Bastidas & Garcia, 1999)
Misima Island (Papua New Guniea)	*Porites sp.*	-	0.19-1.6	-	-	0.68-36.5	-	0.24 - 1.22	(Fallon et al., 2002)
Ulan (Marinduque Island, Philippines)	*Porites lobata*	-	1	-	3.1	1.8	-		(David, 2003)
Dafangi Island (China)	*Porites lutea*	1.08	4.27	9.5	11.7	16.9	0.097	1.02	(Peng et al., 2006)
Gulf of Aqaba (Jordan)	*Porites sp.*	-	8.22	-	5.36	5.52	5.15	1.02	(Al-Rousan et al.,2007)
TuticornCoast (India)	*Porites andrewsi*	5.23	8.53	72.2	10.56	2.51	7.21	28.3	(Jayaraju et al., 2009)

Source: (Song et al., 2014)

Additionally, several studies done on trace elements concentrations in coral reefs concluded that Iron (Fe) decreases growth rate and causes bleaching (Biscéré et al., 2018). Moreover, Reichelt and Harrison (1999) showed that cadmium and zinc high concentration had no effect on the fertilization success of gametes from the scleractinian coral, another research conducted by Reichelt and Harrison (2005), showed that zinc and nickel had a significant reduction in the fertilization success for *Aliciella tenuis* gametes.

From another perspective, the appearance mass destruction of *Acropora* in Barakah site with bleaching and the Yellow band and warm diseases is seen in *Porites* colonies cannot only referred to the increase in water temperature.

Although, there is a wide agreement between all researchers that temperature is the first most important environmental factor not only does it affects the coral reef distribution, community structure but also the spreading of disease; human activities could be another important factor that can accelerate such phenomenon. In their research (Bruno et al., 2007), revealed that bleaching could make corals more susceptible to diseases. They added that ocean warming due to climate change is a major factor that increases infectious coral disease outbreaks by increasing pathogen virulence.

The first reported coral disease in the Arabian Gulf was located in the Gulf of Oman (Coles 1994). The diseases observed were Black Band, White Band Diseases, and Yellow Band Disease (Antonius, 1973; Bruno et al., 2007; Brandt & McManus, 2009).

Yellow Band disease (YBD) defined as a coral disease that primarily affects faviids in the Caribbean and Indo pacific, and *Porites* and *Acropora* in the Gulf. It was first witnessed in Florida in 1994. The Yellow Band disease first record in the Gulf region had an aggressive affiliation that is fast spreading on *Acropora*, however a slow-spreading but persistent on *Porites* (Korrubel & Riegl, 1998). It was observed through the gulf, and it was first reported in 1998 from reefs near Jebel Ali in Dubai, UAE and the following species were confirmed to be affected *Acropora downingi, A. clathrate, A. pharaonic, A. valida, Porites litea. P. lobate. P.harrisoni, Turbinaria reniformis, Cyphastrea microphthalma*. The disease is active in all-season which contract with the Black Band disease that disappears in winter. In addition, the infection process in the summer are faster than the winter and it is the most common disease on corals in the Gulf.

Moreover, there is no work done to identify possible etiologic agents that confirms the connection to environmental factors. This disease transferred among certain corals because of microbial agent, placing of infected colony onto unaffected tissue of a neighboring coral is enough to transfer and spread the disease. When infected benches were broken off and came in contact with a healthy tissue then the infection will take place within a week. Disease break is one of the solutions to stop spreading the disease. It is done by removing all live tissues neighboring to the yellow band (Riegl & Purkis, 2012).

Moreover, a study of Rosenberg and Ben-Haim (2002) found records implicating summer seawater temperature of 29-30ºC to be the cause of mass bleaching. They concluded that disease in the coral system correlates with high seawater temperature, they also observed that coral diseases coincide with the hottest time of the year. By correlating their study with the observations of the present study at both Barakah and Saadiyat sites summer seawater temperatures are high and with further increase in temperature that could result in bleaching and in-turn disease outbreak.

Other than the fact that mankind is increasing its population, and as a result, pressure on the environment through economic growth, human activities, whether direct or indirect, are the most damaging to coral reef species. These human activities include over-fishing, deforestation, nutrient enrichment, burning of fossil fuel, and use of toxic chemicals (Knowlton, 2001). The damage can be observed on weak coral skeletons where the weakness is due to 17-35% decreases of calcification (Grimsditch & Salm, 2005). There is a correlation between carbon dioxide and calcification; the more carbon dioxide there is in the ocean, the less calcification there is in corals. By engaging in activities that increase carbon dioxide in the ocean, humans indirectly reduced corals growth rates and inflicted diseases that plague the coral reefs (Knowlton, 2001). Rosenberg and Ben-Haim (2002), mentioned that black band disease is correlated with polluted waters, suggesting that human sewage contributes to the deterioration of corals.

Furthermore, it has found that other environmental factors that threaten the growth of coral species include acidity of the ocean (Willis et al., 2009). Currently, the average pH of ocean water is about 8.1, and the pH below (5) can threaten the growth of corals (Strahl et al., 2015). On average, the pH of the water samples collected during summer in Barakah is 8.03 in winter is 7.98. However, the finding of high Sulphur concentrations in summer (Figure 12) may be related to increasing the water acidity in the studied area. Although there is no investigation done during this study to verify the impact of this element on the water pH and consequently on the coral growth; it seems that human, activities at Barakah site could be a major stressor on the coral habitat. In fact, the dredging activities and building of power station plants could have negatively stressed the living biota in the area. That is in addition to possible thermal pollution that results from the discharged cooling water of the power plants, which considered a major threat to the living corals.

Chapter 6: Conclusion, Recommendation, and Directions for Future Researchers

In general, the present study has succeeded in determining the growth rates of the studied species in both sites, and also documented the existing status of the coral species colonies and analyzed the possible stressors that may influence the growth and survival of the main endemic coral species in the Arabian Gulf.

The measurements of coral growth rate carried in situ in the present study, for *Acropora* sp. in Saadiyat, and for *Porites* sp. at Barakah is a reference in the Arabian Gulf that can transfer to other researchers in the region, since it deals with natural colonies that living in its natural habitat.

Although of the arid conditions of the area that lead to high water temperature and increase of water salinity of the Arabian Gulf, the coral's communities have always lived with specific adaptation to the surrounded environmental conditions. There is no doubt that recent degradation in coral communities in the Arabian Gulf in general and particularly, in the studied areas could not only attribute to seawater warming. Other human activities impacts have led to water quality degradation with negative consequences that increased the stress on corals and its associated biota.

Here, it is important to document that, the destruction of such biome and the loss of its services that has never valuated by investors as well as environmentalists is difficult to be restored in short time if humans continue to increase its activities with the same rhythm.

From the present study results, it seems that there is a need to do more investigations on certain topics; such as:

1- Impact of Sulphur dissolution due to human activities and its concentration increase effect on the different living coral species.

2- The specific and/or combined factors that lead to each of the reported coral diseases.

3- Frequent and more intensive studies of growth rates of different corals species and finding the way for mitigation of destroyed areas as well as possible restoration of impacted habitats.

Finally, it is important to conclude that, in order to maintain healthy coral habitats, there is a bad need for a national non-stop monitoring plan for the water quality and coral habitats along with the coastal areas of UAE as well as the whole Gulf countries. National Environmental Research Institutes should be responsible for the status of the water and marine resources. They should also have a mechanism and contingency plans to face any abnormalities occur in their area of responsibility.

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