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Endangered coral islands: A case study of *Dahlak* in Red Sea

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Abstract: The geo-chemical nature of coral island in relation to the Dahlak archipelago has been revisited. The mechanism behind the symptom of cracks, pot-holes and caves has been discussed in the back-drop of chemical weathering of coral deposits and calcite rock. This study highlights the vulnerability of Dahlak reef ecosystems and calls for protecting the biodiversity hotspot on priority basis.

Introduction

Coral reefs are "the marine rain forests" of the sea. They form the high-productivity marine communities with rich biodiversity (Richmond, 1993). Probably 30-40% of all fish species on earth are found on coral reefs. They represent the tropical islands of the seas and set the most economically important ecosystem supplying seafood, limestone rock and beach sand. Coral colonies provide shelter for a great number of resident organisms and also set the basis for the reef food web. Red Sea harbours greater fish diversity compared to reefs of the Gulf and Gulf of Oman. This probably reflects the scarcity of reef habitat and the extreme environmental conditions (Chiffings, 2003).

Coral reefs stand like rock boulders against waves and cyclones and help protect coastal shores from erosion. Coral reefs very often form the integral part of sea islands (usually upper crest) and sustain the islands from erosion and sinking. The giant reefs are basically built by a group of small crustacean animals known as corals that live in shallow sea water. The shells of these living animals build upon old shells (usually dead) thereby assume a greater proportion of deposits over a period of time what we call coral reef. The hard coral reef builders are mostly from the members of the subphylum Anthozoa (Antonius, 2000).

Coral reefs around the world are dying or dead especially in the vicinity of thickly populated coastal cities, tourism resorts or power plant sites. The escalating pressure on coastal resources due to anthropogenic activities drastically changes the water quality (Xie, 2005), water temperatures, nutrients and by erosion and sedimentation. Mounting to these problems, direct physical damage from dredging, anchoring, destructive fishing techniques take the toll of corals. Though coral reefs are rock-like boulders, they are too fragile owing to the very fact that they are the part of sensitive living things which can easily be killed by environmental changes. The increased global warming, water pollution (through land and air), oil spill, sea-mining and natural calamities (volcanic activity and tsunami like incidents) greatly affect the health of a coral island and its sustenance.

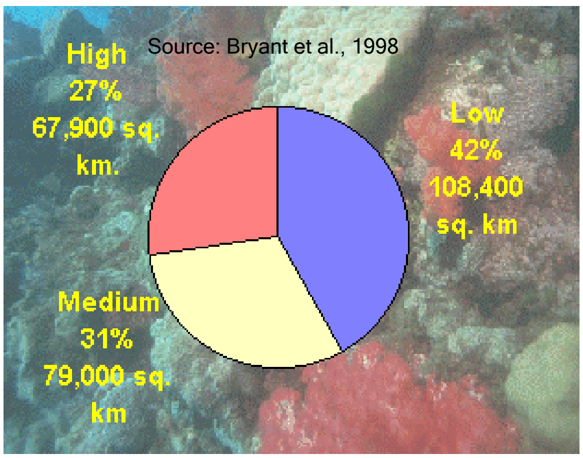
A healthy coral reef grows in size and spread to areas by holding both living and dead components. When reefs become dead they stop growing and eventually degraded.

A massive death of corals has been noticed during the first half of 1998 and attributed to unprecedented hot water conditions then prevailed across the southern Pacific, Atlantic, and Indian Oceans. The consequence was severe declines recorded in fish catches, stocks, sizes, and diversity of fishes, severe erosion of beaches, transformation of coastal structures, and loss of tourism revenues. If coral reefs continue to deteriorate, over 100 coral reef countries will come under severe economic crisis, and several islands could vanish entirely due to rising sea level (Hilbertz & Goreau, 1998). Owing to the Importance of coral reef to the island, Japan made an ambitious plan of planting corals to save its sinking island territory- the rocky isles of Okinotori, 1,700 kilometers south of Tokyo. The outcome of such exercise can be the milestone for coral conservation (Yahoo News, 2007). There is growing fear about the inundation of coral island countries due to global warming and increased natural calamities like Tsunami and cyclonic devastations. The Maldives – a nation of islands faces such a threat which poses the typical challenge for the coral reef conservators (Rioukhina, 2004).

Global scenario

More than a quarter of the world's reefs are reported to be at high risk due to human disturbance (Fig.1). Coral bleaching and other diseases of corals have increased dramatically during the last few decades. Such outbreaks are highly correlated with elevated sea-water temperature, one of the consequences of global warming, which will probably lead to mass destruction of coral reefs. The potential threats to coral reefs can be broadly categorized as overexploitation of marine resources, including destructive fishing practices, and coastal developments. Globally, 36% of all reefs were classified as threatened by overexploitation, 30% by coastal development, 22% by inland pollution and erosion, and 12% by marine pollution. When these threats are combined, over half of the world's reefs are at risk.

In the last few decades, mankind has destroyed over 35 million acres of coral reefs. Reefs of 93 countries have been damaged by human activity. If the present rate of destruction continues, 70% of the world's coral reefs will be killed within our lifetimes (http://www.coral.org/Threats.html).



Scenario at Middle East and Red Sea

About 8% of the world's mapped reefs are found in the Middle East. In the past, most of the region's reefs have been reported to be in good condition. However due to extensive human interference about 60% of these habitats were assessed as at risk. It is primarily due to coastal development and the oil spills in the heavily trafficked Arabian Gulf and southern end of the Red Sea. Almost two-thirds of Gulf reefs are at risk, largely because over 30% of the world's oil tankers move through this area. In addition, corals in many parts of the Gulf of Aqaba have been degraded due to tourism related developments. Reefs in the northern Red Sea and the Arabian Gulf become extremely vulnerable for degradation subjected to high temperature or global warming. However, one can still find well-developed reefs around the Farasan and Dahlak Islands supporting extensive mangroves. Algae flourish on reefs in the southern Red Sea in low-energy conditions. They form substrate for dense brown algal cover otherwise not possible in sandy areas.

Coral conservation practices

The worldwide decline of coral reefs calls for an urgent reassessment of current management practices (Bellwood *et al*., 2004). Damage to these marine natural heritages is proved to be irreparable loss although many methods are followed to redeem them from the brim of extinction. The practice of creating "artificial reefs" using sunken ships, discarded cars, damaged airplanes, concrete blocks (Jensen, 2002) and rubber tires were proved to be not satisfactory in the attempt of transplanting the corals. We have not yet succeeded in creating habitat for a normal reef ecosystem although a new technology- *mineral accretion* met partial success (Riggs, 2007). This technique uses safe low voltage electrical currents to precipitate dissolved limestone minerals from seawater by creating chemical conditions causing mineral deposition, which would not happen by itself. It favours corals and other animals of limestone skeletons (clams, oysters, etc.) to grow more rapidly (Hilbertz & Goreau, 1998). However the best approach could be the protection of existing coral heritages from further anthropogenic pressure. In this regard, this study identifies the Dahlak archipelago as rewarding site to protect from further danger and also prompts early warning that warrants for suitable mitigation measures from the environmental conservators.

Fig.2

Coastal geography and geology of Red Sea

The main body of the Red Sea lies in a rift valley separating the African and Arabian plates. Plateaus and mountains rise steeply to more than 1,000 m above sea level north of Jeddah and 3,660 m in Yemen. The coastal plain is from 2-50 km wide and slopes up gently to the east until it meets the mountains. The mountains are deeply cut by valleys but streams flowing in the uplands fail to cross the coastal plain to reach the sea. The Red Sea is 180 km wide in the North and widens to 350 km in the south, before narrowing to 28km in the strait of Bab el

Mandeb. As a product of deep-ocean rifting, Red Sea extends for 2,100km from Suez to the Strait of Bab el-Mandeb, which connects it with the Gulf of Aden and the Indian Ocean. It has an average depth of 500m, with a maximum of over 2,000m, and is known for its hottest (exceeding 30°C) and most saline (up to 46o/oo) seawater in the world (Behairy *et al*., 1992). The Red Sea has a barrier reef located 10-40 km off the coast of Saudi Arabia and is about 400 km long and several km wide. The longitudinal series of coral reefs lie along the axis of the Red Sea on ridges resulting from normal faulting and upward movement of underlying salt deposits. These are widespread in the Red Sea. Atolls are also numerous and are found mostly on the ridges. The seabed platform lies at a depth 30-60 m, on which sit many steep-sided patch reefs. Almost continuous marginal coral reefs occur along much of the coast from the Gulf of Aqaba to the Strait of Bab al-Mandeb. A similar description of the reef morphology also applies to the African side of the Red Sea.

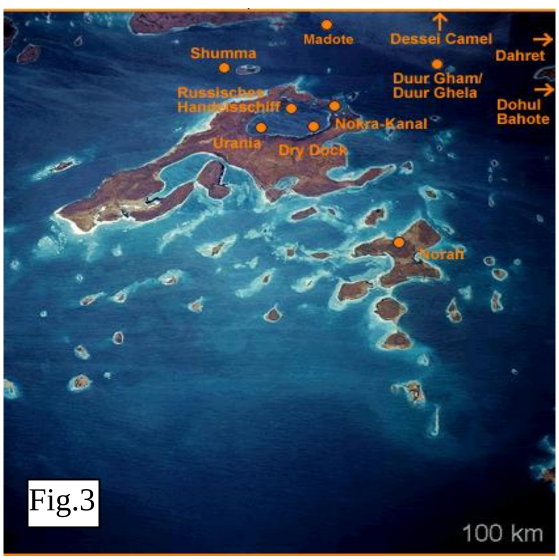


Fig.3

Eritrean coastline and Dahlak archipelago

The length of Eritrean coastline estimated to be 2,234 km total; mainland on Red Sea 1,151 km, islands in Red Sea 1,083 km (CIA, 2003) (Fig.2).

Dahlak islands: The Dahlak Archipelago is an island group located in the Red Sea near Massawa in Eritrea. It consists of 2 large and 124 small islands. Only 4 of the islands are permanently inhabited. Of which Dahlak Kebir which is located 58 kilometers from Massawa is the largest (643 km²) and most populated (roughly 1,500). Other inhabited islands of this archipelago includes: Dhuladhiya, Dissei, Dohul, Erwa, Harat, Hermil, Isra-Tu, Nahleg, Norah and Shumma, although not all are permanently inhabited (Fig.3).

The constituents and existence of coral islands

An island say *Dahlak* is supposed to be a living entity as its geo-morphology is constituted by the upward growth of coral crown situated on the sinking volcanic body in the deep oceanic sediments. Thus, physio-morphology of Dahlak is governed by the biological and geo-chemical constituents. To make better understanding on island degradation/ erosion, let us know more about the substance by which most sea islands are made of. Most sea islands including Dahlak are composed of coral reef as upper crest and its derived sediment rocks on top of the volcanic sediments. The level of coral depth and its derivatives differ according to the geomorphology and age of islands (Fig.4-10).

To make a rough estimate, for Dahlak, it would have taken about 150,000 years to come to an existence due to volcanic activity. While the subtending volcano sinks into the oceanic bottom due to its own weight, it would have taken 10000 to 25000 years for the corals to build the existing reef on top of the shallow watered island for a height of about 50 to 100 meters. At that point of time, the coral reef building was upward and rapid over the top of the subtending island due to abundance of light and minerals. The reef base and the accredited sand captured by wave action at the top together account for the existing terrain of the island (a detailed investigation is needed). To this date, the growing reef sediments probably compensates with the level of depth the island looses as it sinks to the bottom. Thus, an island like Dahlak sustains for thousands of years since its birth due to the biological sedimentation, rock formation of the coral and the coral reef-captured sand accretion. When coral death occurs, an island too faces its extinction due to the discontinuation in the replacement of its height above the sea. The degradation of biorock and erosion of top soil can hasten the disappearance of an island. In fact, studies were made (AMBIO, 2002) on erosion and recovery after the death of most corals in the central Indian Ocean reefs of Chagos, to 30 m depth. The study revealed the fact that mortality was near-total to 15 m deep in northern atolls, and to >35 m in central and southern atolls. Some reef surfaces have 'dropped' 1.5 m due to the loss of dense coral thickets. Coral bioerosion is substantial, reducing 3-D reef 'structure' and forming unconsolidated rubble. Clearly, living coral can play an important role to keep the surface height of an island.

Lime stone rock: is one of the most common minerals on the face of the Earth, comprising about 4% by weight of the Earth's crust. It is formed in many different geological environments. Calcite can form rocks of considerable mass and constitutes a significant part of all the three major rock classification types: oolitic (Palmer & Jenkyns, 1975), fossiliferous and massive limestones in sedimentary environments. It even serves as the cements for many sandstones and shales. Limestone becomes marble from the heat and pressure of metamorphic events. Calcite is a major component in the igneous rock called carbonatite and accounts for the most portions of many hydrothermal veins. Some of these rock types almost entirely made up of calcite.

The major component of limestone: is a calcium carbonate (CaCO3) mineral called **Calcite**-only one of the non-silicate mineral groups that form the rock. The source of origin of such calcite may vary depend upon the age of the stone and the type of animals dominated at that time. Whatever be the source, lime stones are generally considered as biologically derived organic structure mostly as shells and external deposits of boneless animals. In fact vertebrates (including human) store calcium in the form of calcium phosphate as bone material inside our body. Hence, most of the living organisms have the capacity to nucleate the soluble calcium ions in oceanic solution (liquid) into insoluble form. Thus, calcium as fossil rocks is formed by the action of biological forms once these organisms die. In upper few tens of meters are likely constituted by the living and dead coral deposits and their calcite sediments. The sandwiched sediments between coral and volcanic rocks must have originated from myriads of biological limestone.

Ocean waters are slightly alkaline, about 8.2 on the pH scale, due to the vast amounts of minerals dissolved in them. Ocean creatures, especially crustaceans (lobsters, shrimps and crabs), mollusks (conch and all other shellfish) and corals (both hard and soft), extract these minerals from the seawater to build their skeletons. Thus the corals have the capacity to extract soluble calcium in oceanic water into insoluble rock (skeletal deposit) by special process unique to them (probably they use enzymatic tool and micro-acidic condition inside their body). Reef-building corals precipitate up to 6 tons CaCO3/(km2 per day).

Luul resort hotel situated on calcite rock

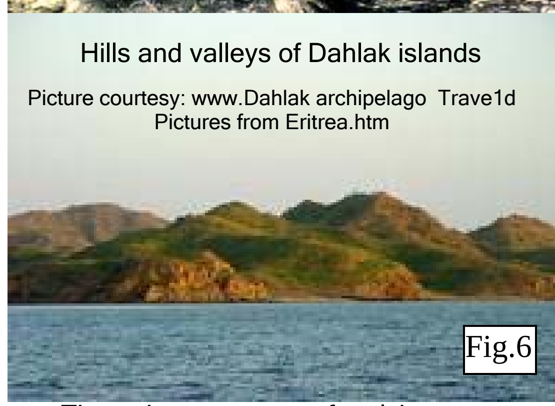
Picture courtesy: http://www.dahlak archipelago - Eritrea.htm

Fig.4

Magnificent calcite structure

Picture courtesy: http://www.dahlak archipelago- Eritrea.htm

Fig.5



Hills and valleys of Dahlak islands

Picture courtesy: www.Dahlak archipelago Trave1d Pictures from Eritrea.htm

Fig.6

The other sources of calcium can come from algae, calcareous sponges, foraminiferids (certain plankton), bryozoa (moss animals), brachiopods (lampshells), echinoderms (starfish, sea cucumbers, sea lilies, sea urchins), mollusks (bivalves, snails, octopus, squid), crustacea (barnacles, crabs, lobsters, shrimp), and pteropods (sea slugs, abalone, cowries, limpets). Oceanic beds over millions and billions of years become the store for such materials (Kastner, 1999). The internal pressure and temperature effectively transform them as rock. Tourists can take note that the pyramids of Egypt are built mainly of nummulitic limestone. Nummulites are large cone-shaped foraminifera (animal) with many chambers arranged in spiral order.

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Threats to the existence:

<u>Coral death</u>: Sewage and chemical pollution can cause overgrowth of algae, oxygen depletion, and poisoning of shallow-water reefs. These reefs are also damaged by scuba divers and boat anchors. Some of the most severe damage appears to be caused by the abiotic factor-thermal stress. Shallow-water reef-building corals live primarily in tropical latitudes (less than 30 degrees north or south of the equator) where the water temperature attains its maximum level that corals can tolerate. Higher temperatures for a longer period will kill the corals outright; the recovery from bleaching may take decades but only if conditions remain favorable.

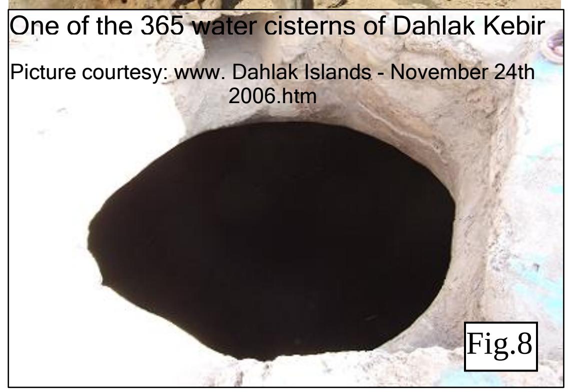
<u>Coral bleaching</u>: Many corals respond to the thermal stress and other infection, by expelling their zooxanthellae. Since the zooxanthellae are responsible for most of the corals' color, those corals that have expelled their algal symbionts appear to be bleached. The key mechanism of coral reef's high productivity is due to the symbiotic mode of life that exists between the coral polyps and the photosynthetic zooxanthellae (a microscopic algae living inside their soft tissues). Millions of these single-celled algae are living as symbionts within their tissues. The zooxanthellae provide the corals with nutrients and oxygen through photosynthesis which are essential for reef building. In turn, the coral provides necessary housing for the algae with basic mineral nutrients *viz:* amino acids, sugars, and other organic compounds that the endo-symbiotic algae absorb directly from the host's tissues. Since zooxanthellae depend on sunlight for photosynthesis, it is believed that reef-building corals are confined to relatively shallow depths where there is enough sunlight to support photosynthesis. Generally, below 150 m deep from the surface of sea, light levels are not adequate to support photosynthesis. However, extensive mounds of living coral do exist in depths from 400 m to 700 m-depths. As the light penetration is minimal at this depth, the corals are devoid of photosynthetic partners. Such deep water coral probably survive by adapting heterotrophic life style by feeding on microscopic animals. Thus, the symbiotic life of coral animal and the algal plant becomes the successful partnership to thrive in extreme condition. Expelling these symbionts can have significant impacts on the corals growth and existence. Corals grow up to three times faster with the help of the zooxanthellae. Coral polyps without such symbiotic relationship become mostly unsuccessful in reef building due to paucity of food in long run. Thus prolonged coral bleaching (over a month) can lead to the death of the polyps and the subsequent loss of coral reef habitats for other marine forms too.

In Eritrea, some coral bleaching and die-off was reported, predominantly from shallow waters, even though recovery was faster. The petroleum hydrocarbons from the oil rich countries probably caused widespread damage to coral reefs through sea water pollution. The levels of oil and its derivatives in the marine environment (source of persistent carcinogens) have been correlated with coral diseases in the Red Sea, especially Black Band Disease (Pilcher, 2000).

Ancient necropolis- Dahlak Kebir

Picture courtesy: www. Dahlak Islands - November 24th 2006.htm

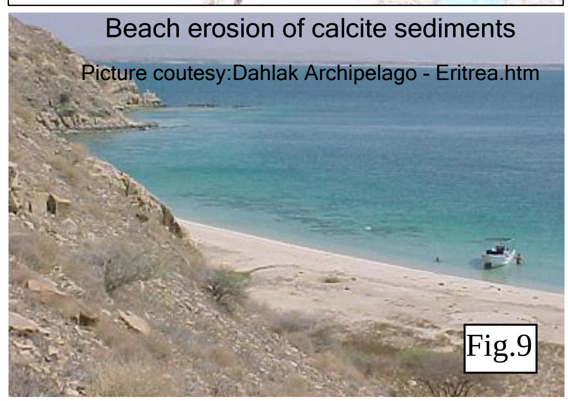
Fig.7



One of the 365 water cisterns of Dahlak Kebir

Picture courtesy: www. Dahlak Islands - November 24th 2006.htm

Fig.8



Beach erosion of calcite sediments

Picture coutesy:Dahlak Archipelago - Eritrea.htm

Fig.9

The biotic factor reported for coral bleaching include: bleaching of *Oculina patagonica* by *Vibrio shiloi*; black band disease by a microbial consortium; sea-fan disease (aspergillosis) by *Aspergillus sydowii*; and coral white plague possibly by *Sphingomonas* sp. In addition, *Vibrio coralyticus* is the aetiological agent for bleaching the coral *Pocillopora damicornis* in the Red Sea. The bacterial and temperature factors leading to yellow blotch/band disease (YBD), which affects the major reef-building Caribbean corals *Montastrea* spp., have been reported. It was observed that YBD affects primarily the symbiotic algae rather than coral tissue (Cervino *et al*., 2004).

Bio-erosion: The bio-erosion of coral reefs by

Nocra Channel: *In the channel of Dahlak Kebir one can dive through a wonderful coral garden with caves which are nothing but the resultant of such coral land weathering process.*

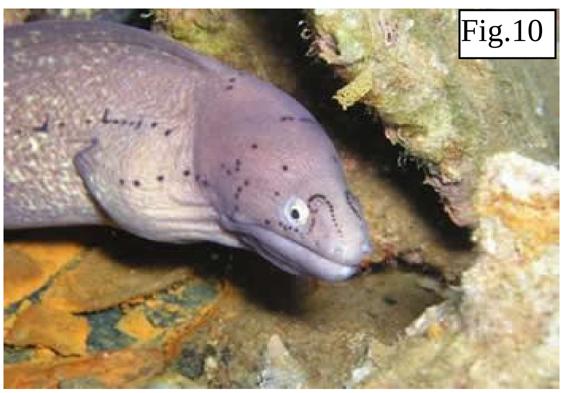


Fig.10

sea urchin (*Echinometra mathaei*) is common in red sea area. The echinoid bioerosion converts to carbonate sediments 7%-11% of the total reef flat calcification and 13%-22% of the total reef slope calcification (Mokady *et al*., 1996; Zundelevich *et al*., 2007).

Dead coral comes under the attack of borers and grazers. Boring agents ranges from bivalves, sponges and worms; along with grazers such as parrotfish and sea urchins devour the coral skeletons. In addition, microorganisms such as algae, cyanobacteria and eubacteria weaken the first few millimeters below the surface of dead coral substrates. The enormous micro passages (340000/cm^2 of coral) created by them contribute considerably to the disintegration process. The bivalves too can play crucial role in drilling the coral reef structure in red sea. They use both chemical process and the mechanical effects. The main consequence of this erosion is that it releases dissolved $CaCO_3$ into the environment. The mineralized coral becomes more vulnerable for acid-water dissolution and ultimately leached into environment as solution.

Anthropogenic activity: Corals and reef environments, particularly those in the vicinity of heavily populated areas, are under increased stress from anthropogenic activities. It results in the loss of coral diversity and diseased or damaged corals. In the last few decades,

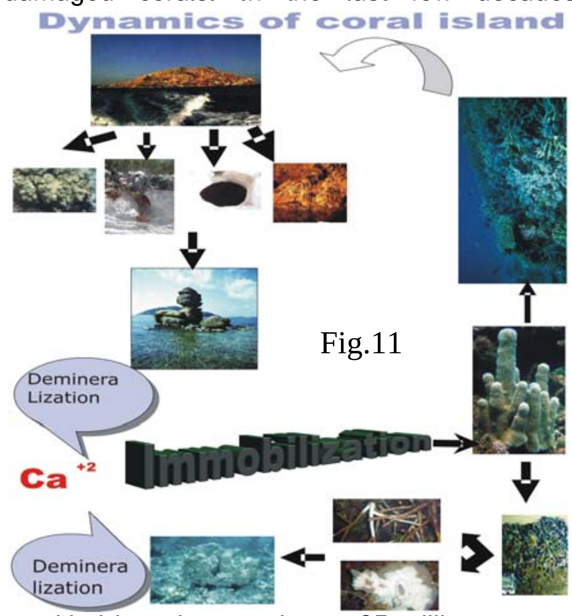


Fig.11

mankind has destroyed over 35 million acres of coral reefs. Reefs of 93 countries have been damaged by human activity. If the present rate of destruction continues, 70% of the world's coral reefs will be killed within our lifetimes.

Thus, the living corals die due to climatic changes, pollution and natural calamities (including cyclone and sand accreditation). Once the corals dead, there are microbial animal consortia to devour the living or dead corals. The coral sedimentary rocks are being dissolved slowly by acid rain as discussed elsewhere. Thus an island like Dahlak can face premature erosion and sink if corals are not restored.

Status of Dahlak islands: What the fissures, cavities, pot-holes, cracks and caves mean for Dahlak?: The major portion of any coral island, including Dahlak, is composed of soft rock-limestone. In Dahlak, the upper (50-100 meter) part of the island seems to be made up of coral reef limestone and the down sediments probably derived from calcites of various biological sources dominated at the time of rock sedimentation process. Coral limestone which is the major part of Dahlak island are being formed at the present day over a large extent of the tropical seas; many existing coral reefs must be of great thickness. The same process has been going on actively since a very early period of the earth's history, for similar rocks are found in great abundance in many geological formations. Some Silurian limestones are rich in corals; in the Devonian there are deposits which have been described as coral reefs. The Carboniferous limestone, or mountain limestones of England and North America, is sometimes nearly entirely coralline, and the great dolomite masses of the Trias in the eastern Alps are believed to be merely the altered coral reefs.

<u>The chemical process of dissimilation of coral reef or dissolution of calcite rock base of Dahlak island</u>: Limestones are often recognizable by their method of weathering. Most limestones which contain fossils show the appearance of fragments of corals, crinoids and shells on the exposed parts of a rock indicating a strong probability that that rock is a limestone. Limestones, when pure, are soft rocks readily can be scratched with a metalic edge, their hardness being *3*. In crystalline limestones or marbles many silicates may occur producing varied colours. Since calcite will dissolve with acid, rain water with slight acidity can dissolve limestone to form caves and Karst. Karst is a Yugoslavian word meaning "internal drainage". Most areas that have karst formations also have heavy rainfall and a thick bed of limestone with a lot of underground flowing water. Thus, in Dahlak, the pits and caves are formed by the disintegration of corals and the dissolution of the animal's underneath sedimentary deposit – limestone or coral rocks.

As we discussed earlier, the carbon dioxide mixed with water forms a weak acid called carbonic acid. The acids can dissolve base (or alkaline; in this case calcite or coral reef) substances. Due to man-made pollution, huge amounts of carbon dioxide being released into the atmosphere, and subsequently dissolved in the sea. In recent decades the emission of fossil fuels in atmosphere is making seawater less and less alkaline over the time. When seawater falls to a pH level below about 7.2, sea creatures including corals cannot make the reef or repair their shells. Some hardier animals might be able to maintain their shells but would be unable to reproduce.

Rainwater seeps down through the soil, becoming slightly acidic as it passes through decaying organic matter such as leaves. The acidic water slowly transforms the calcium carbonate, the predominant mineral in limestone and dolomite (dolomite includes more magnesium than ordinary limestone). The chemical weathering creates calcium bicarbonate, which easily dissolves in water. As the calcium carbonate weathers away, the rock

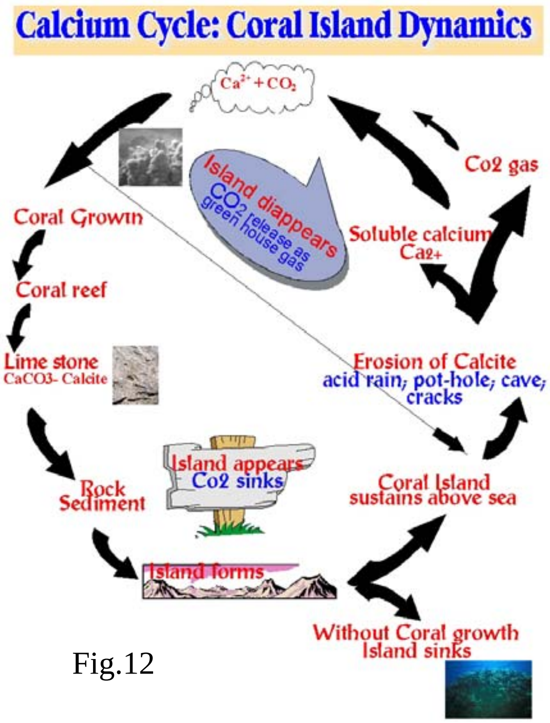


Fig.12

will erode and create a "karst" landscape with springs, sinkholes and caves. Acid rain may also be speeding up the creation of caves.

The chemical weathering process is invisible to us when it occurs underground. Water created caves by dissolving limestone in Virginia is well known as eroded remnants of cave systems at Natural Bridge, Natural Tunnel, and Natural Chimneys. When calcite reacts with acid water it will effervesce (bubble) as it disintegrates. The reason for the bubbling is in the formula below:

$CaCO_3$ + 2H(+1) -------> Ca(+2) + H_2O + CO_2

The carbon dioxide gas (CO_2) is given off as bubbles and the calcium dissolves in the residual water.

In detail:

$CaCO_3 + H_2CO_3 = Ca^{+2} + 2HCO^-_3$ [1]

where:

- $CaCO_3$ is a solid - calcite
- H_2CO_3 is carbonic acid - a relatively weak naturally occurring acid that forms by the reaction between water and carbon dioxide:

  $H_2O + CO_2 = H_2CO_3$ [2]
- Ca^{+2} Calcium is a positive ion (cation) in solution and
- $2HCO^-_3$ is a negative ion (an anion) in solution - the so-called bicarbonate ion

The process of limestone weathering can be summarized into a few steps:
1. CO_2 in the air is absorbed by rain water and reaches the ground.
2. The CO_2 dissolved water act as a very weak acid called carbonic acid.
3. The weak acid comes into contact with limestone as it finds its way through the cracks.
4. The acid dissolves the limestone (which is made of calcium carbonate or calcite) causing the cracks to become larger into caves and passages. As the bedrock dissolves and "fills" with holes, it forms a type of terrain called *karst*. Karst usually consists of sinkholes above the ground and a large network of underground streams. A sinkhole sets as depression on the terrain through which water can quickly enter the limestone bedrock.

It is common for any tourists to diagnose the Dahlak Island with its fissures, pot-holes, cavities and caves in many places. Such marks can be construed as mineralization process of the island overtaking the immobilization by corals and thus accounts for the weakening of the island (Fig. 11).

Calcite is intricately tied to carbon dioxide in another way. Since many sea organisms such as corals, algae and diatoms make their shells out of calcite, they absorb dissolved carbon dioxide from the sea water to accomplish this in a near reverse of the above stated reaction (http://www.Calcium Carbonate.htm). This way of immobilizing the carbon dioxide, a green house gas, helps to reverse the "green house gas effect". By pulling carbon dioxide out of the sea water, this biological activity allows more of the carbon dioxide in the air to dissolve in the sea and thus acts as a carbon sink for the planet (Fig. 12). Destruction of coral probably interferes with the natural carbon balancing process.

Precautions and conservative measures

Coral reefs provide 25% of the fish catch of the developing countries. Dahlak corals already experience the threat of low level to medium level (Fig.13). In order to achieve success in Integrated Coastal Management (ICM), participatory planning and decision making at National and international levels are the need of the hour to protect our precious coral islands and sustainable management of coastal resources.

Most countries recognize the value of their coastal and marine biodiversity and have gazetted marine and wetland protected areas to ensure their sustainability. There is a need to develop an integrated management approach to the use of the marine environment and the coastal areas which will allow the achievement of environmental and development goals in a harmonious manner. It is fact that the waters of the Red Sea and Gulf of Aden by oil and other harmful or noxious materials arising from human activities on land or at sea, especially through indiscriminate and uncontrolled discharge of these substances, presents a growing threat to marine life, fisheries, human health, recreational uses of beaches and other amenities (RCCRSGA, 1982). The uncontrolled tourist activities damaging the corals and destruction of key habitats of the Gulf have been realised (PERSGA 2004; UNEP, 2003). The protection and restoration of Africa's coastal and marine ecosystems and their services are long-term objectives for local to global communities.

<u>Recommendations (conservation plan)</u>:
1. Dahlak island as National Biopark must get all its due considerations.
2. To draw National level Policy and implementation of Wet-land biodiversity conservation set by UNEP.
3. To enter into integrated coral reef management with the Red Sea stakeholders.

<u>Specific recommendation (assessment of the health of the Dahlak islands)</u>:
1. Assessing the level of living & dead corals.
2. Degree of damage to the coral reef (physical assessment of coral and water analysis for coral leakages; the rate of coral bleaching and recovery).
3. Assessing the phytoplankton levels and sea weeds over many seasons.
4. Geo-physical characterization of island rock.
5. Environmental health watch of coastal water and coastal resources.

Conclusion

Dahlak is a coral island with the base made up of limestone rock which can be demineralised into soluble calcium by polluted acidic water. The replenishment of such loss should be met by continued coral growth as it immobilizes the calcium and ultimately add to the rock making process. Thus a living island makes the balance of its loosing height with the coral deposits. Hence the pit-holes, caves and cracks on Dahlak need careful monitoring; any sign of further weakness or aggravations should be addressed diligently. Such pit-holes and cracks not only precarious to runways and roads but also emancipates the island. Globally, coral and coral reef-islands are subjected to the onslaught of anthropogenic activities. Coral bleaching is often the first sign of stress. Such incidents have already been recorded in Red sea of this region. Prevention of coastal erosion, pollution abatement and coral conservation are the few mitigation measures to conserve the coral reefs of Dahlak and the island itself from destruction.

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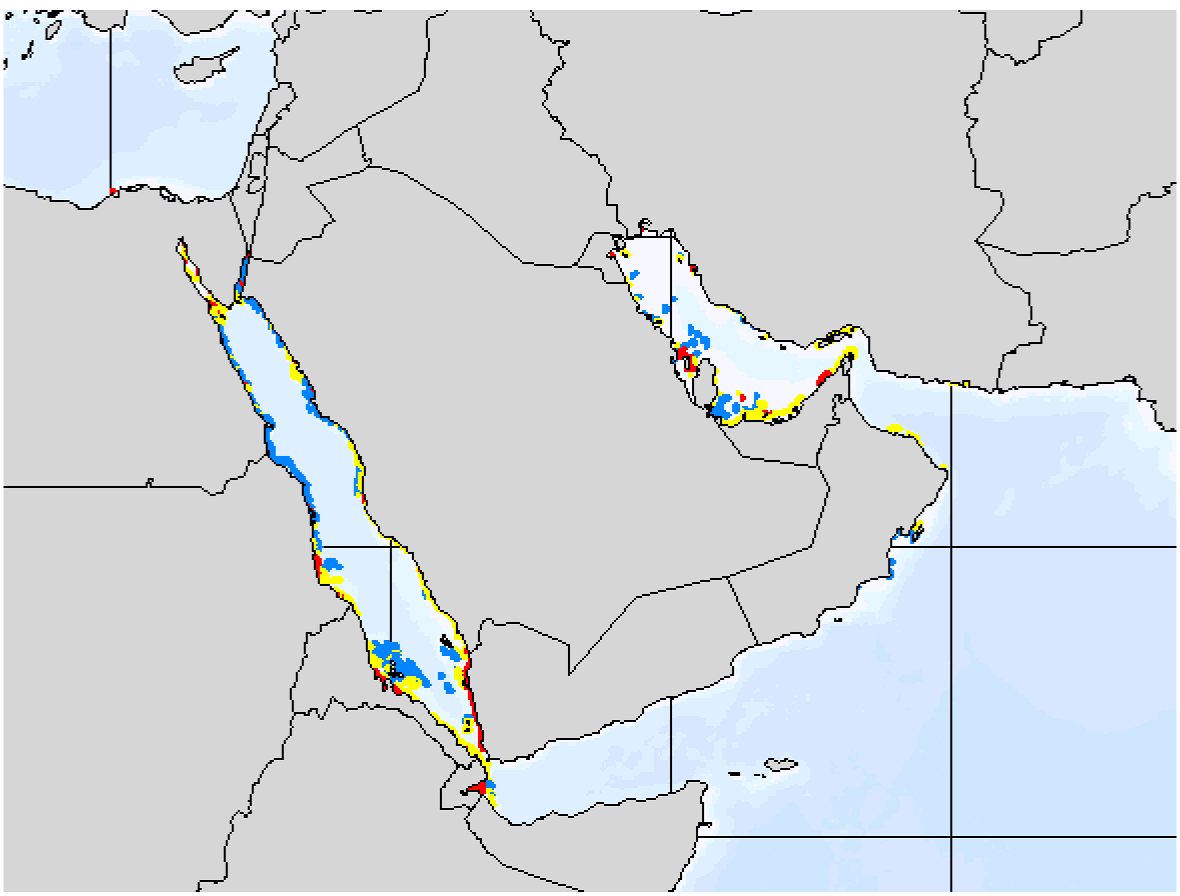

Fig.13. Estimated Threat to Coral Reefs: low medium high (Bryant *et al.*,1998)

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