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Review Article

Review on the status of Coral Reefs in the Red Sea

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Abstract

The Red sea has specific unique different features capturing rich biodiversity and aquatic species. The most important geographical and biological values focused on coral reef ecosystems. The shallow regions, as well as the island of Farasan and the tiny islands scattered around it, provide a suitable area for the coral reef distribution and nurture many endemic creatures. This review relied on coral reef association and classification. It dealt with the Red Sea problem and nature with relation to coral reef properties and its impacts. It focused on coral reef threats with future view for economical tourism based on role of coral reefs besides ways for coral reefs conservation. It comprised notes on coral predation, bleaching and diseases. The major hurdle to the coral reefs of this region, resulting in wider areas of coral bleaching, is the rise in temperature due to the global warming phenomenon. This work emphasizes the extent and diversity of red sea corals' natural and anthropogenic issues faced by the coral ecosystems based on published research and technical reports with scoring reviewed data accompanied with tables and figures. Bar and pie graphs were used to analyze the coral reef data to interpret the actual status for all types presented in different countries. At the end of this investigation, conclusion and prediction of coral reefs status besides recommendations for sustainable development applied on utilization of coral reefs were performed.

Keywords: Biodiversity, Coral reefs, Ecology, Red Sea

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Introduction

Coral reef overview on Red Sea

Coral reef ecosystems establish the most attractive framework that are decorative along the whole entire Red Sea coastline. Coral reef demography is studied continuously with dramatic increase due to discovered variety of nature, association, distribution and properties (Fine et al., 2019).

Red Sea nature

The Red Sea encompasses a very long stretch of coral reefs with world's most various corals and a condensed array of endemic species. It is situated in the south warmest parts of the world and harbors organisms adapted to high-temperature conditions (Mohamed, 1939). Most of the world's spreading longest-running coral reef ecosystems is found in the Red Sea (Kleinhaus et al., 2020). The Red Sea is an obvious, long, narrow body of water that connects till the Indian Ocean's northwest arm throughout the Babb El-Mandib Straits, which is 21 miles at narrowest points. It divides all Arabian Peninsula from the northeastern tip of Africa (20.50 mile wide). The Gulf of Aqaba (Eliat) and the Gulf of Suez, that surrounds the Sinai Peninsula, are located at north part of the Red Sea. Eight nations border the Red Sea: Somalia, Djibouti, Eritrea, Sudan, Jordan, Egypt, Yemen and Saudi Arabia, with the largest portion of the Red Sea's shoreline belonging to Saudi Arabian coastal regions.

Red Sea distinguishes with the warmest and saline sea all over the world because of the restricted freshwater inflowing besides limited water exchange incorporated with the Indian Ocean. The salinity of the region is greater than the open ocean but still stable due to reduced freshwater runoff and rainfall, which provide standard ideal surroundings for all coral reef formation along and besides the coastal regions (Sheppard et al., 2012).

The Red Sea located between semi-arid and arid deserts with volume of ~2.5 X 105 km^3, surface area of ~4.6 X 105 km^2, length of ~2000 km, a maximum depth of 3039 m and a maximum width of 355 km (Rasul et al., 2015). There are three distinct depth zones occurred at the Red Sea; shallow zone along its shoreline, less than 100 m depth with nearly 40% of whole Red Sea zones. Deep zone is between 500 to 1000 m. Finally, deeper zone is far from deep one with 1000 to 2900 presented as a long central axis (Thompson et al., 2013). The Red Sea is connected to other marine regions by a narrow shallow strait (Bab-el- Mandeb, 310 m deep) in the South direction latitude. 120 30' longitude. 430 40' E. while a distinct shallow canal (Suez Canal, 25 m deep) in the North direction 29' 36' N., longitude. 350 2' E. (Bowen et al., 2013).

Moreover, the strait measures breadth of 13 mile, the lesser 11 mile; the two together, constitute the entrance to the sea 141 mile, or including the island Perim, which separates them, 16 mile. Its entire circuit measured round both gulfs is 4020 mile, its area 108,154 mile, its cubic content probably about 800,000 mile. Its greatest breadth under the parallel 17' N., which is one-third up the sea, 192 mile and it narrows pretty uniformly towards both end edges, being 72 mile across at Ras-Mahommed (Alnashiri, 2021).

Coral associates and Red Sea biodiversity

The Red Sea occupies a high biodiversity and has over 300 kinds of corals. In addition to over 1,400 fish species, coral reefs have a significant biological variety of other animals and plants (Kotb et al., 2008; Mohammed, 2012). Different kinds of marine microorganisms with biological properties, like antibacterial, anticancer and antioxidant are hosted by coral reefs, both hard and soft (Tahany et al., 2020). Despite the Red Sea's severe climate (based on the highest summer temperature and salt level), a variety of cryptobenthic fish can be found there (Golani and Bogorodsky, 2010; Coker et al., 2017). Aisha (2021) recorded 55 coral fishes belonging to 21 families at Theeran and Dhahek Islands of the Red Sea which nourish the ecosystems of all coral reefs.

Changes present at ecosystem's function as well as coral community composition are frequent indicators to transitions between disturbance regimes (Graham et al., 2014; Mellin et al., 2014; Courtney et al., 2020). Plenty of natural disturbances influence on coral reef ecosystems such as coral predation, bioerosion, sporadic illness mass bleaching and hurricanes can weaken and reduce ecosystem conservation, adaptation and activities (Rogers, 1993; Mallin et al., 1999; Burkholder et al., 2004; Hughes et al., 2018; Steneck et al., 2019). Most of reef fish, long-term habitat degradation, fisheries and a continuous loss in all dimensional structures of coral reefs may have cascading effects (Hoegh et al., 2007; Moberg and Folke, 1999; Alvarez-Filip et al., 2013). There are great threats to coral reefs including dredging for coastal expansion, plastic, destructive fishing methods, shipping, land-filling and other pollutions (David et al., 2020). The Red Sea acquires long been acknowledged to have rich and various biodiversity (Stehli and Wells, 1971) besides endemism (Ormond and Edwards, 1987), contains many genera of hermatypic corals as well as exceeding 1,000 kinds of fish species (Hardeman and Sjoling, 2007; Briggs and Bowen, 2012; Kulbicki et al., 2013; Klunzinger, 1870).

Scleractinian corals are regarded as members of the phylum Cnidaria and are creatures found near the metazoans' origin, originated more than 450 million years ago (Plaisance et al., 2011; Rocha and Bowen, 2008; Huang and Roy, 2015). One-third of all marine creatures find habitat and trophic support on coral reefs, and their biodiversity approaches that of tropical rain forests (Reaka-Kudla, 1997). Living coral reefs are able to support a large biomass in addition to a variety of fisheries with fish, crustaceans, echinoderms and mollusks. They are architecturally complex environments. Small fish can find food and refuge in various microhabitats on coral reefs, including those with soft corals, hard corals, macroalgae, sandy areas or rocky patches (Depczynski and Bellwood, 2004; Beukers and Jones, 1997; Coker et al., 2014; Brooker et al., 2010). Inside their endodermal cells, reef corals harbor symbiotic unicellular algae from the Symbiodiniaceae family (Charles et al., 2021; Lajeunesse et al., 2018).

A natural illustration of a latitudinal gradient in temperature, salinity and nutrient richness is observed in the Red Sea. Allochthonous resources like oceanic and neritic zooplankton and phytoplankton support coral reefs along the Red Sea coastal regions, but not much more is known about how the eco-hydrography links with abundance and plankton richness (Froese and Pauly, 2011).

Corals offer hiding places within the branches, while larger fish might find sanctuary beneath the colony itself (Kerry and Bellwood, 2012). Because they are anticipated that small amount of benthic-associated fish would be highly affected by the habitats that are accessible. Reef fish must comprehend the needs of microhabitats. Globally, coral reef ecosystems provide essential biological diversity and a priceless habitat for many marine living organisms. (More over 800 hard coral species and nearly 4,000 fish species) (NOAA 2019 a, b).

Callum and Rupert (1987) who studied the interrelationship between coral reef habitats and reef fish diversity present on Saudi Arabia's central Red Sea coasts, found that while the live coral cover and fish abundance did not significantly correlate, the biodiversity of the substratum was strongly linked with the diversity of fish species overall. In terms of taxonomy, there are about 30 families that make up the majority of reef fishes. Most of coral reef fish families are classified according to their marine feeding habitats with different major other living groups such as carnivores, herbivores, piscivores, omnivores and planktivores that are recognized (Morton et al., 2008; Cole, 2010; Alevizon and Porter, 2015). A newest collective dataset depicting offshore coral reef communities is presented thorough comprehensive surveys of approximately 40 coral reefs along 683.51 miles of the Saudi Arabian Red Sea coast, which included nearly 100 taxa of fish and 95 benthic categories (Roberts et al., 2016) (Fig. 1).

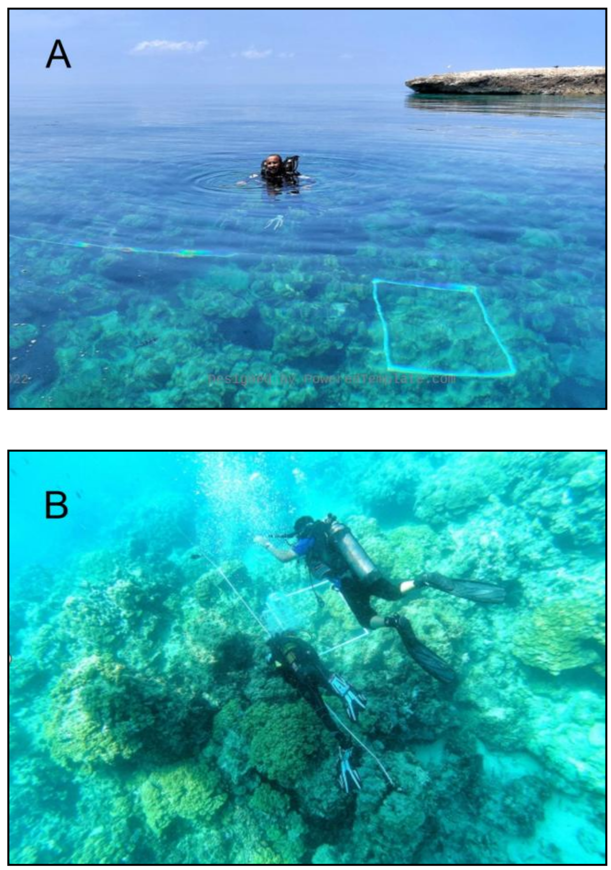

Figure-1. A & B Red Sea Coral Reefs (Photo by Maqbool Kuttyammoo using mirrorless Sony a 7R V underwater camera)

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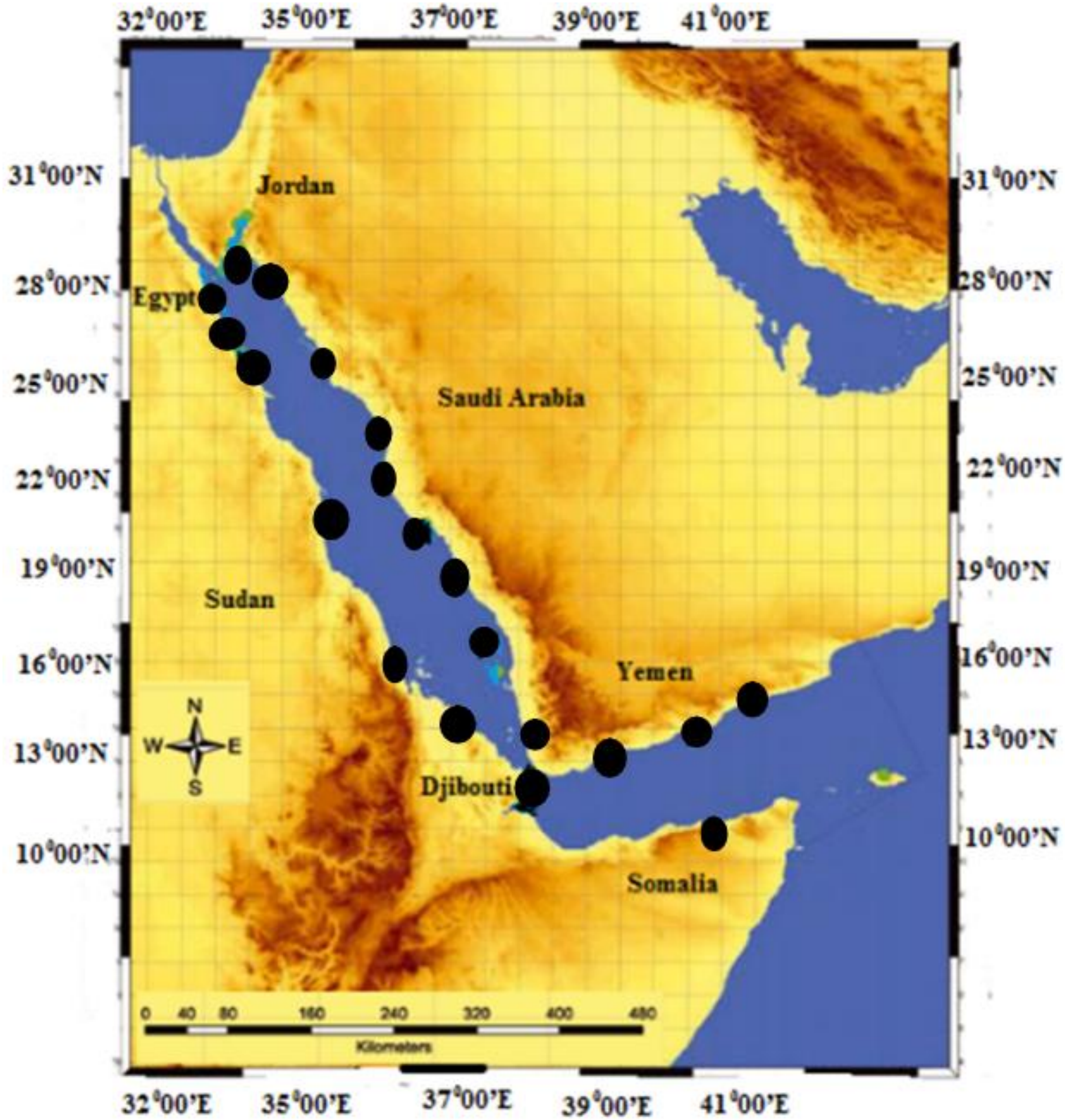
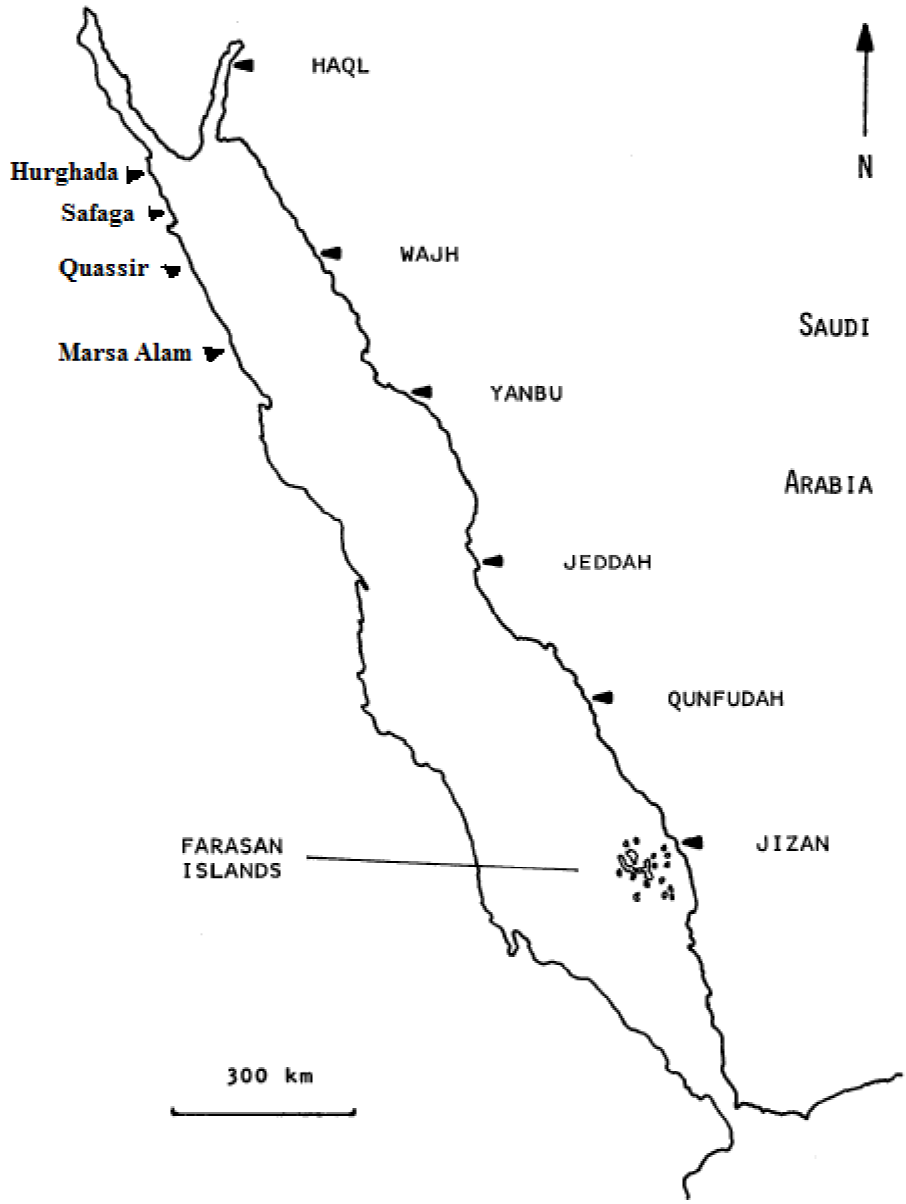
Coral reef distribution & classification

Coral reefs begin northerly distributed near Suez gulf. They extend from Egypt, Palestine and Jordan to the central Red Sea at Saudi Arabia and Sudan. After that they become reduced in size at Djibouti and Somalia till reaching Yemen with rudimentary, shallow reefs or coral communities. (Map 1, 2) (Arnfried et al., 1990; Elenin et al., 2020).



Map-1. The Red Sea map with all reviewed sites (Arnfried et al., 1990; Elenin et al., 2020)



Map-2. The most important sites with majority of coral reefs (Arnfried et al., 1990; Elenin et al., 2020)

From all references included in this review, we stated that the obtained survey of coral reefs included 169 species belonging to 22 families distributed mostly in six countries; eastern coast of Red Sea included Yemen and Saudi Arabia while western coast of Red Sea included Sudan, Egypt, Djibouti and Somalia. Reviewed cites were marked with black circles and arrows on Map (1, 2) respectively. All coral reef species were listed in (Table 1, Plates 1-2). *Acropora* was the most dominant species 19% while *Favia* and *Fungia* recorded each 12%. Furthermore, *Acropora*, *Favia*, *Fungia*, *Favites*, *Pavona*, *Goniopora*, *Leptoseris*, *Psammocora*, *Montipora* and *Porites* recorded 59% of all the coral reefs in the Red Sea. These genera represented by many species more than 3 species per each genus (Fig. 2). The remaining genera, which had less than 3 species each, occupied 41% where monotypic genus more dominant than other genera (Fig. 3). The families had different number of species; Acroporidae was the most dominant 26% while Agariciidae occupied the second level 8%. (Fig. 4). Families which had less than 10 species per each one shown in (Fig 5).

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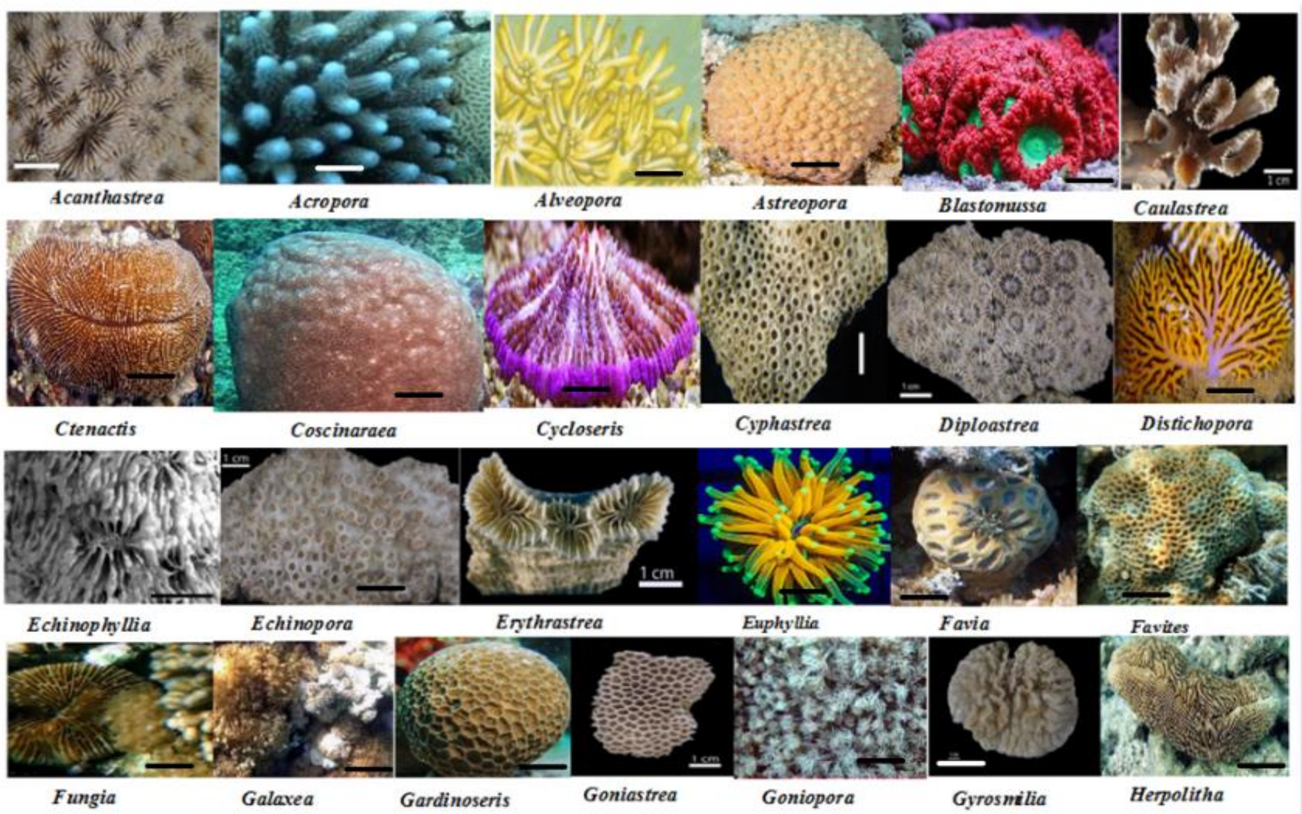

Plate-1. The reviewed coral reef species (alphabetically A-H) (Scale bar 1cm) (Hoeksema and Cairns, 2024)

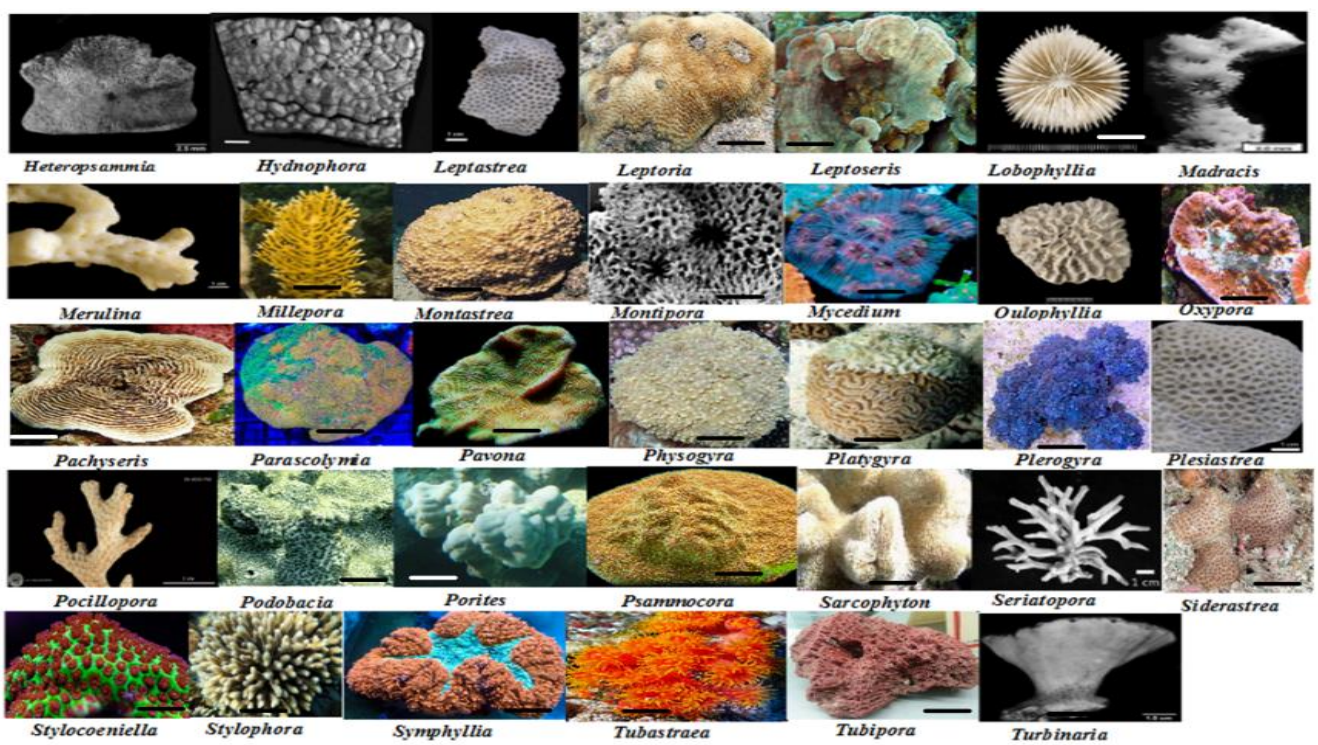

Plate-2. The reviewed coral reef species (alphabetically H-T) (Scale bar 1cm) (Hoeksema and Cairns, 2024)

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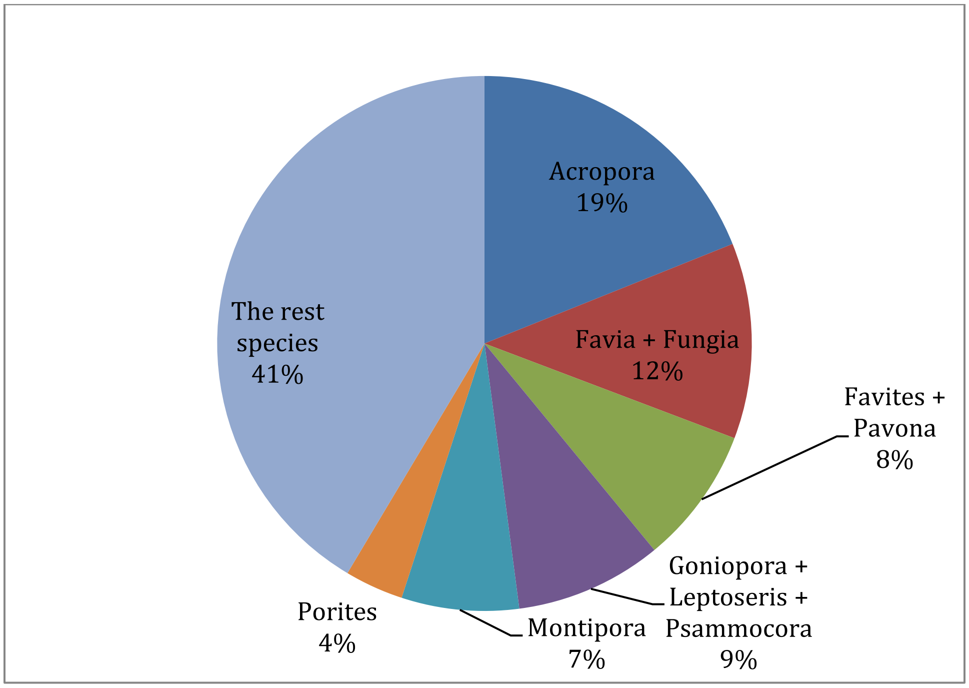

Figure-2. The percentage of reviewed coral reefs in this study

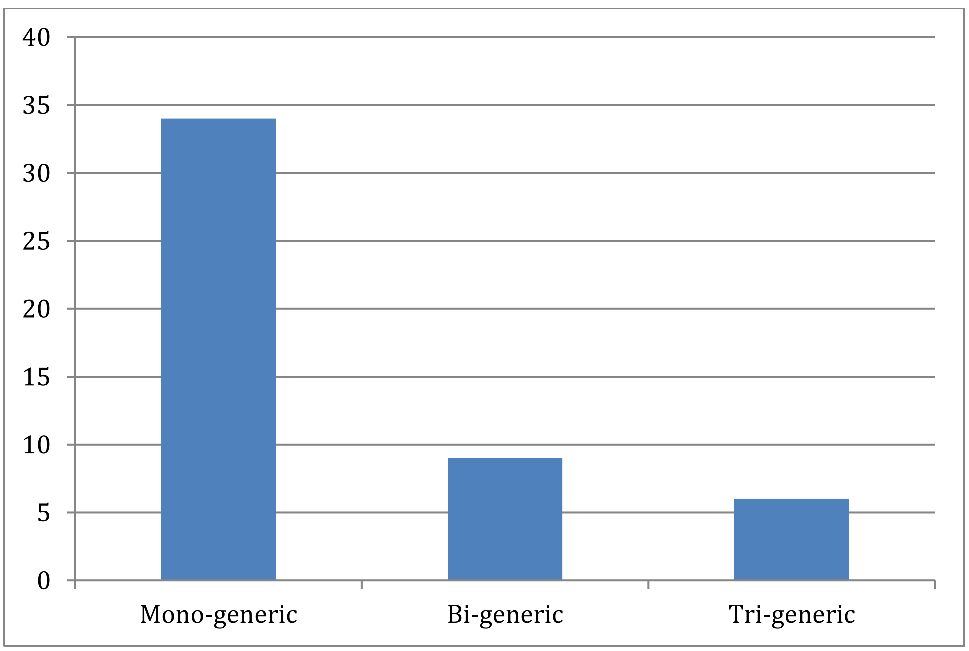

Figure-3. The variation in number of genera

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Table-1. The species of coral reef in this study (Hoeksema and Cairns, 2024)

Subphylum: Anthozoa (Ehrenberg, 1834);

I. Class/ Zoantharia (De Blainville, 1830);

Order/ Scleractinia (Bourne, 1900);

1. Suborder/ Astrocoeniina (Vaughan & Wells, 1943);

1. Family: Astrocoeniidae (Koby, 1890);

Stylocoeniella guentheri (Bass.-Sm. 1890)

2. Family: Thamnasteriidae (Vaughan & Wells, 1943);

Psammocora contigua (Esper, 1795)

P. explanulata (V. D. Horst, 1922)

P. haimeana (M. Edw. & Haime, 1851)

P. nierstraszi (V. D. Horst, 1921)

P. profundacella (Gardiner, 1898)

3. Family: Pocilloporidae (Gray, 1842);

Madracis interjecta (Marenzeller, 1907)

Pocillopora damicornis (Linnaeus, 1758)

P. cf. eydouxi (M. Edw. & H., 1860)

P. verrucosa (Ellis & Sol., 1786)

Seriatopora hystrix (Dana, 1846)

Stylophora pistillata (Esper, 1795)

S. subseriata (Ehrenberg, 1834)

S. wellsi (Schieer, 1964)

4. Family: Acroporidae (Verrill, 1902);

Acropora anthoceris (Brook, 1893)

A. aspera (Dana, 1846)

A. austere (Dana, 1846)

A. cerealis (Dana, 1846)

A. corymbosa (Lanarck, 1816)

A. cytherea (Dana, 1846)

A. danai (M. Edwards & Haime, 1860)

A. digitifera (Dana, 1846)

A. divaricate (Dana, 1846)

A. donei (Veron & Wallace, 1984)

A. echinata (Dana, 1846)

A. eurystoma (Klunzinger, 1879)

A. formosa (Dana, 1846)

A. forskalii (Ehrenberg, 1834)

A. gemmifera (Brook, 1892)

A. granulosa (M. Edw. & Haime, 1860)

A. haimei (M. Edwards & Haime, 1860)

A. hemprichii (Ehrenberg, 1834)

A. humilis (Dana, 1846)

A. hyacinthus (Dana, 1846)

A. intermedia (Brook, 1891)

A. monticulosa (Brueggemann, 1879)

A. nasuta (Dana, 1846)

A. nobilis (Dana, 1846)

A. pharaonis (M. Edw. & Haime, 1860)

A. polystoma (Brook, 1891)

A. scandens (Klunzinger, 1879)

A. secale (Studer, 1878)

A. squarrosa (Ehrenberg, 1834)

A. valenciennesii (M. Edw. & H. 1860)

A. valida (Dana, 1846)

A. vaughani (Wells, 1954)

Astreopora myriophthalma (Lamarck, 1816)

Montipora circumvallate (Ehrenberg, 1834)

M. danae (Bernard, 1897)

M. erythraea (V. Marenzeller, 1906)

M. gracilis (Klunzinger, 1879)

M. informis (Bernard, 1897)

M. monasteriata (Forskal, 1775)

M. peltiformis (Bernard, 1897)

M. spongiosa (Ehrenberg, 1834)

M. tuberculosa (Lamarck, 1816)

M. turgescens (Bernard, 1897)

M. undata (Bernard, 1897)

M. verrucosa (Lamarck, 1816)

2. Suborder/ Fungiina (Verril, 1865);

1. Family: Agariciidae (Gray, 1847);

Gardinoseris planulata (Dana, 1846)

Leptoseris explanata (Yabe & Sugiy, 1941)

L. hawaiiensis (Vaughan, 1907)

L. mycetoseroides (Wells, 1954)

L. tenuis (V. D. Horst, 1921)

L. yabei (Pillai & Scheer, 1976)

Pachyseris speciosa (Dana, 1846)

Pavona cactus (Forskal, 1775)

P. decussate (Dana, 1846)

P. diffluens (Lamarck, 1816)

P. divaricate (Lamarck, 1816)

P. explanulata (Lamarck, 1816)

P. maldivensis (Gardiner, 1905)

P. varians (Verrill, 1864)

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Table-1. Continued……

2. Family: Siderastreidae (Vaughan & Wells, 1943);
Coscinaraea monile (Forskal, 1775)
Siderastrea savignyana (M. Edw. & Haim., 1849)
3. Family: Fungiidae (Dana, 1846);
Ctenactis echinata (Pallas, 1766)
Cycloseris distorta (Michelin, 1843)
C. patelliformis (Boschma, 1923)
Fungia danai (Milne Edwards & Haime, 1851)
F. fungites (Linnaeus, 1758)
F. granulosa (Klunzinger, 1879)
F. horrida (Dana, 1846)
F. klunzingeri (Doederlein, 1901)
F. moluccensis (V. D. Horst, 1919)
F. paumotensis (Stutchbury, 1833)
F. repanda (Dana, 1846)
F. scruposa (Klunzinger, 1879)
F. scutaria (Lamarck, 1801)
Herpolitha limax (Esper, 1795)
Podobacia crustacean (Pallas, 1766)
4. Family: Poritidae (Gray, 1846);
Alveopora allingi (Hoffmeister, 1925)
A. verrilliana (Dana, 1872)
Goniopora ciliatus (Veron, 2000)
G. columna (Dana, 1846)
G. klunzingeri (V. Marenzeller, 1906)
G. planulata (Ehrenberg, 1834)
G. Savignyi (Dana, 1846)
Porites australiensis (Vaughan, 1918)
P. lobata (Dana, 1846)
P. lutea (Milne Edwards & Haime, 1851)
P. nodifera (Klunzinger, 1879)
P. rus (Forskal, 1775)
P. solida (Forskal, 1775)
3. Suborder/ Faviina (Vaughan & Wells, 1943);
1. Family: Faviidae (Gregory, 1900);
Cyphastrea micophthalma (Lamarck, 1816)
C. serailia (Forskal, 1775)
Diploastrea heliopora (Lamarck, 1816)
Echinopora gemmacea (Lamarck, 1816)
Echinopora fruticulosa (Ehrenberg, 1834)
Favia abdita (Elis & Solander, 1786)
F. chinensis (Verrill, 1866)
F. complanata (Ehrenberg, 1834)
F. favus (Forskal, 1775)
F. flexuosa (Dana, 1846)
F. pentagona (esper, 1794)
F. peresi (Faure & Pichon, 1978)
F. laxa (Klunzinger, 1879)
F. pallida (Dana, 1846)
F. stelligera (Dana, 1846)
Goniastrea pectinata (Ehrenberg, 1834)
G. retiformis (Lamarck, 1816)
Hydnophora exesa (Pallas, 1766)
Hydnophora microconos (Lamarck, 1816)
Leptastrea bottae (M. Edwar. & Haime, 1849)
L. purpurea (Dana, 1846)
L. transversa (Klunzinger, 1879)
Leptoria Phrygia (Ellis & Solander, 1786)
Montastrea annuligera (M. Edw. & Hai., 1849)
M. curta (Dana, 1846)
Oulophyllia crispa (Lamarck, 1816)
Platygyra daedalea (Ellis & Soland, 1786)
P. lamellina (Ehrenberg, 1834)
P. sinensis (M. Edw. & Haime, 1849)
Plesiastrea versipora (Lamarck, 1816)
2. Family: Oculinidae (Gray, 1847);
Galaxea fascicularis (Linnaeus, 1758)
3. Family: Mussidae (Ortmann, 1890);
Acanthastrea echinata (Dana, 1846)
A. erythraea (Klunzinger, 1879)
Blastomussa merleti (Wells, 1961)
Lobophyllia corymbosa (Forskal, 1775)
L. hemprichii (Ehrenberg, 1834)
Parascolymia vitiensis (Brueggem., 1877)
4. Family: Pectinidae (Vaughan & Wells, 1943);
Echinophyllia aspera (Ell. & Sol., 1786)
Mycedium elephantotus (Pallas, 1766)
Oxypora lacera (Verrill, 1864)

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Table-1. Continued……

4. Suborder/ Caryophylliina (Vaughan & Wells, 1943);	**Order/ Stylasterina (Hickson & England, 1905);**
Family: Caryophylliidae (Gray, 1847);	Family: Stylasteridae (Gray, 1847);
Gyrosmilia interrupta (Ehrenberg, 1834)	*Distichopora violacea* (Pallas, 1766)
Plerogyra sinuosa (Dana, 1846)	
5. Suborder/ Vacatina (Koby, 1890);	
1. Family: Lobophylliidae (Dai & Horng, 2009)	
Symphyllia erythraea (Klunzinger, 1879)	
2. Family: Merulinidae (Milne Edwards & Haime, 1857)	
Caulastrea tumida (Matthai, 1928)	
Erythrastrea flabellata (Pichon, Scheer & Pillai, 1983)	
Favites abdita (Ellis & Solander, 1786)	
F. chinensis (Verrill, 1866)	
F. complanata (Ehrenberg, 1834)	
F. flexuosa (Dana, 1846)	
F. halicora (Ehrenberg, 1834)	
F. pentagona (Esper, 1790)	
F. peresi (Faure & Pichon, 1978)	
Merulina ampliata (Ellis & Soland, 1786)	
3. Family: Plerogyridae Rowlett, 2020	
Physogyra aperta (Quelch, 1884)	
7. Suborder/ Refertina (Gray, 1847);	
1. Family: Euphylliidae (Milne Edwards & Haime, 1857)	
Euphyllia (Euphyllia) glabrescens (Chamisso & Eysenhardt, 1821)	
2. Family: Dendrophylliidae (Gray, 1847)	
Heteropsammia cochlea (Spengler, 1781)	
Tubastraea aurea (Quoy & Gaimard, 1833)	
T. coccinea (Ehrenberg, 1834)	
T. micranthus (Ehrenberg, 1834)	
Turbinaria mesenterina (Lamarck, 1816)	
II. Class/ Octocorallia (Haeckel, 1866);	
Order/ Stolonifera (Hickson, 1833);	
Family: Tubiporidae (Ehrenberg, 1828);	
Tubipora musica (Linnaeus, 1758)	
Order/ Malacalcyonacea (Stimpson, 1855);	
Family: Sarcophytidae (Gray, 1869);	
Sarcophyton acutum (Tixier-Durivault, 1970)	
III. Class/ Hydrozoa (Owen, 1843);	
Order/ Milleporina (Hickson, 1901);	
Family: Milleporidae (Fleming, 1828);	
Millepora platyphylla (Ehrenberg, 1834)	
M. exaesa (Forskal, 1775)	
M. dichotoma (Forskal, 1775)	

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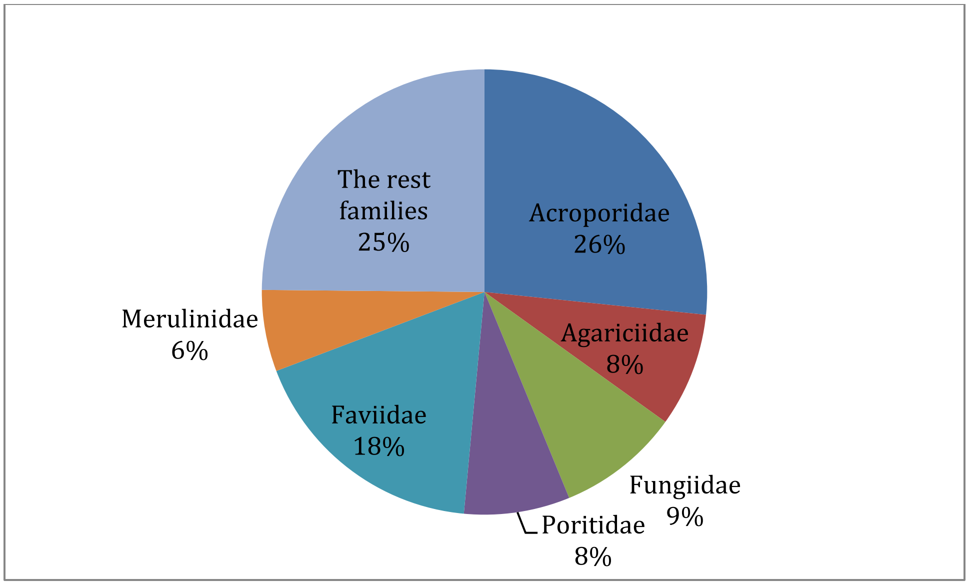

Figure-4. The percentage of the families

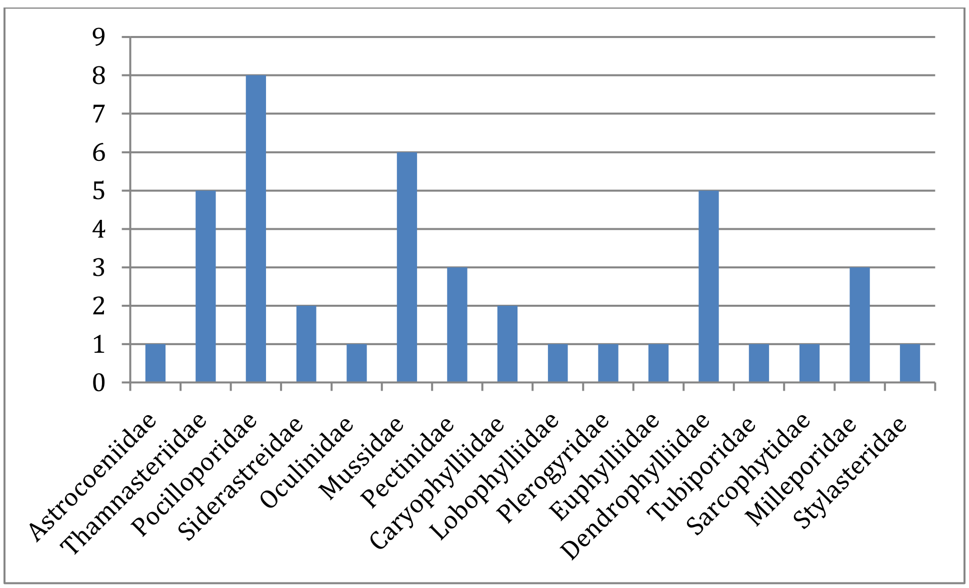

Figure-5. The number of coral reef species per families lower than 10 species

Djibouti was dominate with *Echinophora fruticulosa*, *Acropora hemprichi* and *Porites nodifera* which represented 10% in all sites where they form the coral gardens. Somalia has the highest number of scleractinian and alcyonacean corals and the coral cover constituted a fairly narrow fringing band. Yemen recorded stony, soft and dead corals exist in 50% of the northern and central sites of the Red Sea. Marine diversity is continue along the mainland Gulf of Aden coast, with a low average live coral coverage (17%) and a high median dead coral coverage (34%). On the other hand, Socotra archipelago contained high fauna diversity of coral reefs. In Egypt, coral reefs represented for 55 % of non-sheltered covering regions while 85 % of other sheltered ones. The living coral cover percentage was highly remarkable along the coast. Moreover, coral reefs presented at the northern regions were more various than those at the southern ones, with duplication in coral species and genera. There is no exactly survey data on the status of

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coral reef diversity and cover whether in Palestine, Jordan or Eritrea (DeVantier and Pilcher, 2000; Pilcher and Abou Zaid, 2000; Pilcher and DeVantier, 2000; Pilcher and Djama, 2000). In Saudi Arabia, Species diversity of scleractinian stony corals occupied in the central-northern Red Sea with high degree of homogeneity for coral community composition. Coral reef cover was high on the shallow reef slopes of exposed patch, fringing and barrier reefs. In Sudan, hard live coral reaches at Abu Hashish Jetty situated as 23.5 % at 3.168ft depth besides 50 % at 3.191ft depth, whereas dead coral reefs situated as 2.5 % at 3.168ft depth and null at 15.84ft depth (Pilcher and Krupp, 2000; Pilcher and Nasr, 2000; Pilcher and Al-Moghrabi, 2000).

Coral reef properties

Coral reefs at the Red Sea have an extraordinarily extreme tolerance for the area's rapidly rising saltwater. They can resist changes in water temperature that would kill most other hard corals or cause severe bleaching. The biological mechanisms used by this remarkably resilient reef are likely to be crucial for coral survival as the planet's waters warm. Localized anthropogenic stressors should be rapidly reduced since they exacerbate the effects of rising seawater on corals. The rest shows absolutely experiencing temperatures over alternative thermal tolerance. They have remarkable bleaching although there are benefits from little localized anthropogenic pressures. The nations at the Red Sea boarder must cooperate to ensure the ultimate scientific approaches, conservation and sustainability (Kleinhaus et al., 2020; Majrashi, 2021).

Coral reef problem on Red Sea

The Red Sea faces many challenges that should be overcome and solved. Relatively high and fluctuating water temperatures (2°C in the spring and 34°C in the summer) and high salinity 41.0 psu at the northern Red Sea led some difficulties for scientific research studies to occur (Ormond and Edwards, 1987). Another obstacle is complicated habitats of coral reefs with different sizes and accompanied varied aquatic species found in or around coral reefs having unknown behaviors and performances (Plaisance et al., 2011). Notably, management sustainable approaches are severely lack due to other conflicting political and economic issues that shed light on this world's hottest location cause the shortage of speciation processes and the adaptation of animals and reef systems towards to global climate change (Rocha and Bowen, 2008; Berumen et al., 2013).

The Red Sea is regarded geologically as the young sea owing the Caribbean or the Great Barrier Reef so it needs more world attention for global conservation against human activities and interactions (Augustin et al., 2021).

Coral reef degradation should be studied with different levels because there are different abiotic and biotic factors that influence on it. Abiotic factors include human interference in marine ecosystems by all means whereas biotic factors are the interfering mechanisms between coral reefs and other organisms on known scientific basis like predation and diseases but others are unknown scientific basis that needs more studying like coral bleaching (Lyons et al., 2024).

1. Coral Reef threats

Numerous direct and indirect anthropogenic stressors, both local and worldwide, undergo major threats to coral reefs (Jackson et al., 2001; De'ath et al., 2012; Jessen et al., 2012). Threats applied to ecosystem health due to excessive use of marine resource, damaging fishing methods, and nutrient, sediment runoff from improper land use and unrestrained tourism activities are of particular concern (Wilkinson, 2008; Bruckner et al., 2011; Halpern et al., 2008).

2. Impacts on Coral reef

Despite the increasing pressure that global climate change is placing on coral reef worldwide, the Red Sea's present understanding of coral reefs ecology lags well other comparable regions over the globe (Berumen et al., 2013). The Red Sea biota exhibits high rate of endemism accompanied with varying degree of intrusion into the Gulf of Aden as well as it is resilient to significant environmental changes (DiBattista et al., 2015; Alnashiri et al., 2018; Halim, 1984).

a. Temperature impact

According to McWilliams et al. (2005), increasing in seawater temperature has a negative impact on marine ecosystems. It alters biological systems by promoting the increment of toxic algae that are deposited as layers on the water's surfaces and block sunlight. Algae are able to contribute in the death of coral reef with increasing microbial activity besides releasing dissolved chemicals (Smith et al., 2006). Coral reef ecosystems are deteriorating due to these factors and other environmental global changes in marine environments (Pratchett et al., 2014). Extreme sea surface temperatures, high water salinity, enhanced UV radiation, heavy sedimentation, abnormal eutrophication, and thermal pollution are only a few of the stresses of these particularly sensitive habitats (Barber et al., 2001). The consequences of community changes on coral reef ecosystem services may be amplified by nutrient pollution, resulting in the loss of structurally complex habitats with altered nutrient recycling and carbonate dissolution (Roth et al., 2021). According to Brown et al. (2020), the Queensland industry group in charge of aquarium fisheries voluntarily stops harvesting the corals, anemones, and other species are sensitive to bleaching process during years of intense bleaching to aid ecosystem recovery. At collection sites, collectors help monitor the condition of the ecosystem.

Both global and local anthropogenically generated changes affect the physiology of species and ecosystem by changing all the chemical, biological and physical processes that occur on earth (Steffen et al., 2011). Global changes caused the widespread decline of coral reef (Zoccola et al., 2020), similarly, several keys of fish trophic groups abruptly declined when coral reef cover dropped under a threshold of 10 % (Lamy et al., 2016).

Unfortunately, coral reefs have been found to be especially susceptible to environmental changes on a worldwide scale (Gattuso et al., 2015). The shortage of the required photosynthetic micro-algal endo-symbionts and a thermally induced process of coral bleaching are particularly decimating corals. Coral bleaching often happens during El Nino events and is primarily brought on by thermal stress and high temperatures (Podesta and Glynn, 2001). Coral bleaching can be caused by a variety of factors, including marine pollution, hypoxia, fungus, elevated sea acidity, and high salinity. Bleaching could have a very small impact. Although temperature has impact on coral distribution, it may cover vast areas up to hundreds of thousands of square kilometers, relying mostly on the duration of exposure to alteration of water temperature where it lives. The reefs' generally good condition is probably due to regional variations in seawater temperature and bleaching stress (Denley et al., 2020).

b. Urban activity

Both natural and man-made disturbances impact ultimately dynamics and resilience of coral reefs at long-terms. Each significant natural disturbance owned a unique impact on fish composition, resulting in long-term alterations. Urbanization, human activity, and industrial development all substantially impact the Red Sea ecology. Pollution discharges are reduced in impact on the Red Sea ecosystem via prompt detection and control. The Saudi coastal Red Sea fisheries require a significant amount of extensive researches to provide more knowledge and data for sustainability of marine resources (Al Solami, 2020).

Despite being significant from a scientific, ecological and economic standpoint, coral reefs are being harmed by both natural pressures and human activity. Reefs in the Arabian Gulf are degraded significantly in previous decades as a result of effects from industrial pollution, eutrophication, coastal reclamation, dredging, overexploitation and fishing damage (Loya, 2004; Burt, 2014; Jessen et al., 2013; Burt et al., 2014; Rinkevich, 2005; Sheppard et al., 2010; Sale et al., 2011). On the other hand, the frequent natural occurrences that have caused a significant decline in coral reefs inside the Red Sea that have greatly exacerbated these relatively limited impacts. These man-made and natural global stressors have affected reefs in various places individually, but their collective effects led to dramatic changes in coral demography and community structures across all regions (Riegl et al., 2012; Riegl and Purkis, 2015). Overfishing, nutrient runoff from agriculture, sediment runoff from logging and mining, among other local anthropogenic stressors, are among the stresses that corals are subject to.

These ecosystems are generally degrading due to anthropogenic natural disturbances such as climate change, overfishing and habitat (Pandolfi et al., 2005; Bellwood et al., 2004; Mora, 2008; De'ath et al., 2012). The Lakshadweep coral reef system is under stress due to uncontrolled harvesting of coral-associated fishes used as living bait for tuna pole and line fishing stage and unresearched harvesting of herbivorous fishes such as surgeon fish and parrot fish. These regional stresses either directly or indirectly put pressure on the island's coral reef (Babu and Sureshkumar, 2016).

c. Stressors impact

Natural global stressors and multiple anthropogenic are endangering ecosystems worldwide, frequently causing them to transition from desirable to fewer ideal states (Swindles et al., 2018; Hempson et al., 2018; Lercari et al., 2018). Local stresses can force coral ecosystems to adopt the most stress-tolerant life histories, which would be reflected in a loss in morphological and taxonomic richness if they persist or worsen (Bevilacqua et al., 2019).

Over the course of 17 years, Babu et al. (2021) generated baseline data on the coral reefs of Lakshadweep, India, and documented it. They discovered that the reef had seen varying degrees of stress due to changing demographic and lifestyle trends and unrestricted resource extraction from the reefs. Local stressors, including overfishing, sedimentation, and nutrient pollution, along with global ocean temperature rises and ocean acidification, have effectively destroyed 19% of world coral reefs and caused substantial declines in reef health. The other main anthropogenic hazards to the coral reefs of Lakshadweep included sewage, dredging, sedimentation, and coral mining (Wilkinson, 2008).

In especially near lagoonal areas where land-based pollution created by agricultural runoff, sewage and unlawful dumping of garbage are concern. However, these largely limited effects have been made worse by frequent natural occurrences that may have contributed to a wider, more widespread collapse of local coral reefs. There are many mass bleaching occurrences in the Arabian Gulf alone in the last ten years (Riegl and Purkis, 2015), and the Red Sea has had numerous outbreaks resulting from the predatory Drupella gastropods besides the Crown of Thorns starfish (Bruckner and Dempsey, 2015; Schoepf et al., 2010; Riegl et al., 2012).

Coral communities in the Jazan region are becoming threatened locally (by expanding fisheries and developing infrastructure) as well as globally (by dangers like climate change). In general, there are a number of causes for the Jazan region's coral reefs to be degrading. Effects on the destruction of coral reefs Dredging and reclamation over fringing reefs is a result of the rapidly expanding coastal construction activities in the coastal Jazan region, which is causing coral reef ecosystems to deteriorate as caused of more sedimentation and an increment in lagoon temperatures as a result of less flushing (Veron et al., 2009).

Untreated sewage discharged into the ocean resulted in an increase in nutrients and heavy metals. In Jazan City, just 60% of buildings are connected to the city's sewage system; the remainder is dumped into the sea besides herbicides and fertilizers. Sea water of the Red Sea and around Farasan Island, fishing pressure is greater in the southern half than in other areas. However, traditional fishing areas have a greater negative impact on shallower reefs than they do on deeper ones such as Decapoda collecting employing traps. Fishing near coral reefs degrades coral habitats, causing a reduction in coral cover, an increase in bare ground, and a shift in fish dominance away from the area (Alhababy, 2017).

In-depth research by Krueger et al. (2017) on the common reef structure coral at the Northern Red Sea demonstrated minor changes in nitrogen and carbon metabolism at the cellular levels in response to high temperatures. In addition to being under increasing strain from industrial and urban activities, the semi-enclosed Gulf of Aqaba, which is home to sea grass meadows and large fringing reefs underscores the current need to eliminate present stressors. DeCarlo (2020) performed CT scan examinations on Porites at the Red Sea center of Saudi and stress bands were utilized to symbolize previous episodes of bleaching in this area. He concluded that the severity and frequency of bleaching occurrences since 1999 on reefs besides the shore where are unprecedented last century and that it is suggestive of prior bleaching because it caught known bleaching events that happened in 1931, 1978, 1998, 1982, and 2010. The Red Sea's coral reef fish populations are the same distribution like the reefs themselves (Roberts et al., 1992). The reef fish populations are now rapidly degraded by both natural and human interference, such as overfishing, coastal development, the use of destructive fishing techniques and the loss of habitat for nascent fish, oil pollution as well as other pollutants from anthropogenic activity, reef degradation and climate change brought on by natural predators (Bruckner et al., 2011).

Marine environments outperform terrestrial habitats in biodiversity degradation owing to a mix of local and global stressors like pollution, overuse of resources, diseases, and climate change (Eriksson and Hillebrand, 2019). Coral reefs are trend's leaders and are vanishing at an incredible rate, putting them as the biological systems that are most in danger (Gattuso et al., 2015). Over 20 years, reefs' growth rate declined by 15%, and it is believed that the Great Barrier Coral are losing roughly 30% of their population (Hughes et al., 2017; De'ath et al., 2009). According to projections, up to 99% of reefs will be jeopardized and significantly altered by the year 2050, and around 25% of reefs are already gone (Chen et al., 2015).

3. Coral Predation

There are natural predators for coral reefs. Gastropods, starfish and aquatic fish are the main predators. They predominately distribute in Farasan islands, Ras Al-Qasabah, Tiran island at Saudi, Socotra at Yemen and Khor Ambado at Djibouti. These natural predators feed on different types of coral reefs. *Coralliophila* gastropods predate on *Porites* and *Stylophora* besides *Drupella* gastropods can impact on *Pocillopora* and *Acropora* (Riegl et al., 2012). Nevertheless, *Acanthaster* is the main thorns starfish predator in the Red Sea. It feeds on *Echinopora* and *Porites* Moreover, other creature plays the predation role as Damselfish algal lawns that feed on *Platygyra* and *Porites* while parrotfish records general spot biting on several coral reefs; *Porites*, *Pocillopora*, *Leptoria*, *Galaxea*, and *Porites* (DiBattista et al., 2016).

4. Coral Bleaching

Coral bleaching is a physical natural process where coral colonies lose coloration and become white. The breakdown or expulsion of zooxanthellae brings by this. High seawater temperatures cause coral tissues to lose beneficial algae, which causes bleaching. Bleaching affects coral's ability to reproduce much less, alters the makeup of the coral communities, and ultimately kills coral reefs (Douglas, 2003; Brown and Ogden, 1993; Depczynski et al., 2013) Abiotic factors are identified as the major important determinants for coral reef illness, despite the degrees of coral reef bleaching fluctuating according to different causes. These factors might include freshwater dilution, acidity, sedimentation, cyclones, solar irradiation, sub-aerial exposure, seawater temperature and storms (Van Hooidonk et al., 2014; Anthony et al., 2007). Hurricanes and high storms can also reduce and disrupt marine ecosystem services and functions (Monroe et al., 2018; Simmons et al., 2021).

Due to high temperatures after exchanging the Indian Ocean with limited little freshwater flow, coral bleaching is increasing in the Red Sea these days. This increment exceeds 1ºC annually that influenced on coral cover throughout the Red Sea. Interpretation of bleaching-related mechanism is not understood till now. There is a relation between spreading of coral diseases and lesion with bleaching events however; it is not discussed deeply in the recent publications. The degree of coral bleaching distribution is concentrated at the southern Red Sea with different levels appeared on coral reef species (Hoegh et al., 2009; Bruno and Selig, 2007).

5. Collection/Disease

Coral disease is typically identified by their macroscopic and microscopic symptoms with comments on the degree of tissue color, loss, and coral skeleton exposure helping with naming and diagnosis. The bulk of illnesses' etiologies are still unknown besides coral epidemiology is still ignored, despite their reported importance in reefs worldwide (Garrett and Ducklow, 1975). Numerous microbes, including viruses, bacteria, protozoa and fungi are thought to be able to ensure coral disease, according to the bulk of published literature. To be sure, abiotic variables like UV, temperature, exposure, pollution (like agricultural pesticides and heavy metals) or predation obvious scars are frequently cited as the original cause of disease (Antonius, 2008). It has been demonstrated that coral diseases affect both managed marine protected areas, like those used as examples, and unmanaged reefs. Despite the grave consequences of coral disease, some geographic regions are less widely studied and documented than others. In stance, illnesses influence on corals throughout the Red Sea are among the least thoroughly documented and investigated. Coral diseases have significantly reduced coral populations worldwide during the past 40 years (Rosenberg and Loya, 2004; Wilkinson, 2008). One such disease is the pervasive black band disease, initially discovered on a reef in Belize region in the early 1980s. A contagious illness known to affect corals everywhere (Willis et al., 2004). BBD is affected by several variables, including water temperature, depth, water clarity, light intensity and acidity (Kuta and Richardson, 2002). The surface mucus of the healthy corals contained gammaproteobacterial such as *Vibrio* spp., that regarded as opportunistic and commensal coral pathogens. Numerous *Vibrio* species have been shown to exhibit significant proteolytic activity. It's likely that this group's pathogenic species, some of which were found in the mat, contribute significantly to the breakdown of host tissue (Arotsker et al., 2009).

Challenges and expected prospective goals from Coral Reef on Red Sea

According to major biodiversity and biological initiatives, coral reefs are listed as the most important headline indicator for global change in the post-2020. Therefore, scientists try to apply consistent sustainability and conservation of coral reefs through estimating their beneficial roles on different aspects

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like environment, economy, medicine etc. (Ghafari, 2024).

1. Economy and the Role of Reefs in Red Sea Tourism

Nearly 240 million people live in the Red Sea region, with continuous increment residing in metropolitan areas and along the shore to take advantage of the economic advantages of maritime navigation, fisheries, recreation and tourism (Chen et al., 2015; David et al., 2020). More than 600 million individuals worldwide rely directly on coral reefs for existence, making coral reefs economically crucial for many human communities and their biological significance (Spalding et al., 2017; Moberg and Folke, 1999; Wilkinson, 2008). World coral reefs are accounted to be worth more than USD 29 billion annually (Chen et al., 2015; Cesar et al., 2003; Costanza et al., 1997).

One of the most popular tourist sites on the world is the Red Sea. With contributions of more than 3.5% of Egyptian GDP up to date, seaside tourism is primarily focused besides eastern Egypt shore (Hilmi et al., 2018). Centuries of explorers and naturalists have long been drawn to the Red Sea's clear blue water, an abundance of life, and proximity to Europe (Berumen et al., 2013; Head, 1987), they noted the tremendous endemism and variety of these reefs. Some Red Sea nations make significant money just from reef-related tourism.

The money spent by international tourists significantly influences directly on the contribution of tourism and travel industry. Visitor exports to Egypt totaled EGP 57.5 billion in 2015 (20.7% of the total). By 2026, 15,738,000 international visitors are expected to come to Egypt, spending an estimated EGP 103.7 billion, a growth of 6.5% annually. According to Saudi Arabia's Vision 2030 economic strategy aims to diversify its economy as well as lessen its dependence on oil revenue through an eco-friendly Red sea tourism project. Given the lengthy shoreline and several spectacular coral reefs along its coast, together with the care taken to maintain the coral reefs, tourism, notably coastal tourism, is thought to be the most valuable component of the kingdom's categorization plan (Fattouh and Sen, 2016; Gazette, 2016).

2. Corals as a Source of Bioactive Natural Compounds

A wealth of potential marine natural products, food sources and tourism prospects can be found in areas with high biodiversity. Marine natural bi-products are metabolic bioactive components found in various marine species and act as parameters against pathogens and illness. Although many of these substances serve as a rich supply of therapeutic substances and useful components, less than 9% of coral reef community is thought to be known, and only a small portion of the reported species has been investigated as potential sources of bioactive chemicals (Bruckner, 2002). The coastlines of Aqaba Gulf, Palestine besides Hurghada, Egypt were determined to be the richest in bioactive natural chemicals found in the Red Sea. Numerous biological actions, such as cytotoxicity, antiproliferative, antiviral, and anti-inflammatory properties, were detected in hundreds of chemicals extracted from Red Sea species (El-Ezz et al., 2017).

3. Recent Research and Coral Reef Restoration

The marine active restoration is the process of supporting a damaged, destroyed or degraded environment in its recovery (SER, 2004). Once it is established that the normal healing of corals is hampered, it can become occasionally necessary on coral reefs. Any restoration effort aims to eventually create sexually reproducing, self-sustaining populations with sufficient genetic diversity to allow them to adapt to their environment. Coral reef rehabilitation may be especially crucial when coral species are threatened to be extinct. In the past, the two main reef-structure species in the Caribbean; *Acropora cervicornis* and *Acropora palmate* were widely dispersed. Both species have suffered loss in covering throughout the Caribbean since the 1970s. As a result, they are now classified as Highly Critically Endangered on the International Union for Conservation of Nature (IUCN) Organization’s Red List (Aronson and Precht, 2001). Reef-building Coral reef ecosystems, the most significant biogenic structures in the world, are built on the foundation of corals, which play a critical role in marine ecosystem. As a result, we must set up interventions. To keep maintenance for the long-term viability of the restoration efforts, socio-cultural objectives and social-economic are important progressively that incorporated into coral restoration programs. Educational and reef resource stewardship opportunities have been demonstrated to enhance active participation in coral restoration initiatives (Ceccarelli et al., 2020).

The rehabilitation of coral reef involves the employment of several methods. The most often used strategies rely on asexual procedures such as micro-fragmentation, coral gardening, and direct transplantation (Bayraktarov et al., 2019). Larval propagation is an alternate method that relies on collecting gametes and subsequent cultures of embryos and larvae. At around one month old, the coral spit is cultivated in ex situ aquaria to greater and higher colonies and out-planted onto damaged and deteriorated reefs (Barton et al., 2017). Direct coral transplantation is one of the earliest methods for restoring coral reefs (Edwards and Clark, 1998); this entails taking coral colonies from a donor location, transplanting them right away to a restoration sites, or reattaching colonies which were moved by ships running aground (Precht and Robbart, 2006).
Ex situ and in situ actions may be used to preserve or/and rebuild coral reefs and each has benefits and drawbacks. To retain a species' genetic information or specific genotypes, the first methods used in corals involved building a "vault" to restore germinal cells from several coral reef species. Successful cryopreservation of dissociated embryonic cells and coral spermatozoa cells (Hagedom et al., 2012). Cryopreservation, however, has been found to decrease the success of fertilization, and the procedures are not readily available; instead, they need to be improved to be used uniformly and widely (Hagedom et al., 2012). Additionally, more investigation is required to evaluate and comprehend potential success and long-term repercussions. Ex situ culturing enhances the conservation efforts currently made by aquariums and zoos for threatened vertebrate and invertebrate populations (Maitland, 1995; Mascarelli, 2013). To preserve coral species, produce coral material without diminishing wild supplies for study, and provide a multispecies tests bed for the interaction and function of altered coral reefs prior to ex-situ culturing outdoor tests that are regarded as a novel approach was devised using a network of aquariums (Rinkevich and Shafir, 2000).

4. Extremes Weather Events, Cyclones, and the Red Sea Reefs

Upwelling is supposed to be a key factor in regulation of the Red Sea's temperature. With thousands of coral reefs spread across 9941.94 $mile^2$ and some of the warmest water temperature of any coral-reef location, the Farasan Islands within the south Red Sea are homely to tens of coral reefs (DeCarlo et al., 2021). Cyclonic winds and floodwaters can severely impact the ecosystems of coral reefs. Floodwaters entering coral reefs can stress inshore ecosystems by reducing salinity, increasing turbidity, and concentrating agricultural pollutants and nutrients. Some species, especially connected organisms like corals and seagrasses, can succumb to prolonged exposure. Many other species including fish and turtles depending on corals and sea grass for shelter and food, so their loss might have a cascading effect across the ecosystem (Spalding et al., 2007).
Although coral reefs naturally can recover from the effects of extreme weather, they are no longer able to live. Climate scientists expect that extreme weather events like powerful cyclones and devastating rains will occur more frequently due to climate change. Recent extreme weather occurrences have brought attention to the necessity for good management and ongoing monitoring. Tropical cyclones have caused noticeable loss of coral reefs worldwide and stark declines in reef health (Wilkinson, 2008).
Coral ecosystem services are crucial to maintaining biodiversity, productivity, and structural complexity and are endangered by warming climate change phenomenon and acidification of the oceans. Additionally, the great threat posed by global climate change to coral reefs and related ecosystems around the world is new and growing (Barshis et al., 2013; Alnashiri, 2021). Coral is quite delicate and requires a marine environment that is somewhat stable. Despite the possibility that some coral species may possess genomic and physiological characteristics that increase their resistance to warm stress, a sizable reduction of corals and the reefs that they support is unavoidable (Kersting and Linares, 2019). According to a source, there was a super cyclone and significant toxic algal bloom in the Gulf of Oman and the Arabian Sea (Burt et al., 2016).

5. Predictions on the Status and Health of the Red Sea Coral Reefs

The Red Sea may be a crucial natural lab to help us understand what coral reefs in other sides of the world can expect in the near and far future, given current estimates of global climate changes. Thus, the growing scientific focus on Red Sea research has the high potential to impact beyond the basic accumulation of knowledge peculiar to the region.
The Red Sea area shares with reefs worldwide the same dangers posed by overfishing, climate change, coastal development, etc. One important

exception is that, in many Red Sea localities, terrestrial impacts from freshwater intake & nutrient runoff are minimal or insignificant because of insufficient rainfall and estuaries. (Berumen et al., 2020). In the Philippines, 206 bordering reefs were recently assessed nationally, and it was found that none of them met the criteria for the outstanding condition because of the loss of one-third of the hard-coral covering. These results highlight the urgent need for conservation and management action, especially in light of previously published studies and reviews revealing that marine protected areas (MPAs) alone are not adequate to safeguard corals and coral reefs against the different effects of global climate change (Ainsworth et al., 2015).

Reefs must be managed and protected against the direct effects of human activity through ongoing monitoring, mapping, and national and local government intervention. In light of the reflections, regulations and laws must be evaluated and revised.

According to Hamilton et al. (2021) recruitment overfishing is improbable if there are reefs that are only moderately exploited up to 52.82 mile distant from a heavily fish area and marine protected zones (MPZs) (less than 0.62 mile^2) are insufficient to safeguard this species. Natural experiments showed that coral communities could thrive on the reef flats in which there were hard substrata segregated within the regions of rubble by the big coral colonies that were growing successfully on few large limestone blocks spread on all reef flat. Sadly, according to recent national assessment findings, nearly a third of the corals in these reefs have been lost. Management and conservation efforts prior to this loss had been restricted to the creation of MPAs and a restriction on the harvesting and export of reef-building corals (a policy that is currently being revisited). Therefore, none of the 206 stations surveyed could be considered "good" health.

Reefs may be better able to recover from local disruptions like cyclones and bleaching if local stressors are lessened by applying rules to safeguard fish supplies and lower nutrient levels. Local environmental considerations cannot fend against global repercussions like extreme bleaching occurrences (Hughes et al., 2017). Even more concerning, the Intergovernmental Panel on Climate Change (IPCC) published a special report named "Global warming of 1.5°C," on 2018, predicts that, under a warming scenario of +1.5°C, corals will likely lose 90% of their ability to build reefs by 2100 and will likely lose nearly all of their population (>99%).

Due to their strong thermotolerance, Red Sea reefs are anticipated to be one of the last reefs to bleach where seawater temperature rise. They emphasize the necessity of regional marine natural scientists and governments working to include UN fishing scientists in the assessment and implementation of all regional surveillance and conservation effort as well as the need for UNESCO to state that specific areas of the Red Sea can be recognized as Global Biosphere Reserves. They also stress the necessity of seeking UN supporting for a long-term researching scientific monitoring program at the Red Sea. The vital regional scientific world collaboration can be promoted via the Transnational Red Sea Center, housed at the Swiss Federal Institute of Technology Lausanne Organization (EPFLO) (Grimsditch and Salm, 2006).

6. Coral Reef conservations

The maintenance of nutrient delivery as well as regeneration is one way that the pioneer communities contribute significantly to keep the health of coral reef ecosystems at good manner (Roth et al., 2020).

The Red Sea is considered one of the world's most marine biodiverse coral reef ecosystems and may have a significant impact on how we understand the nature and habitat of coral reefs globally, as well as how to provide thermo-tolerant species for transplantation and restoration.

As part of the effort to lessen the effects of global climate change on coral reefs and their ability to function, the preservation & restoration of the mangrove ecosystem should also continue to be a top priority (Rogers and Mumby, 2019). It is positive that the local administration took the first step toward creating an MPA. However, because of relatively profitability of Dulong fishing that is illegal and out of laws, there is still substantial community opposition to the formal establishment of marine protected areas (Marine et al., 2019).

Although it has been claimed that coral reef restoration is excessively expensive and difficult in terms of spatial size, time, and success, the initiatives shown below have demonstrated that many of these obstacles have already been removed. Many initiatives, such as the construction of such marine protected area (MPA), intensive coral restoration programs, and aided evolutionary initiatives, are emerging to combat the predicted extinction of coral reef at the end of 20th century. Due to the increasing coral loss, researchers

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have urged the preservation of coral reefs and needed to reduce the negative impact of environmental pressures on coral reef ecosystems, giving rise to the concept of constructing marine protected zones (Salm and Price, 1995; Bridge et al., 2013; Mumby and Steneck, 2008). However, this approach might not be enough to lessen ecological and human hazards, especially for reefs at risk. Efficient spatial planning, no-take zones, enforcement, sewage treatment and preserving neighboring marine ecosystems like mangroves are all management measures (Cortes-Useche et al., 2019; Andersson et al., 2019).

Conclusion

There is definitely a need to reduce pollution that harms coral, such as those caused by plastics, sewage, and runoff from agriculture. In many places, solving these issues can benefit coastal communities in other ways, such as greater sanitation due to improved sewage treatment. This demonstrates the necessity of ongoing coral reef health monitoring (Walsworth et al., 2019).

A rapid effort is necessary to control and remove local stressors to secure northern portions of the Red Sea. To identify areas of coral inhabitation and those with potential for coral expansion it is essential to conduct a comprehensive and accurate mapping of the Red Sea's benthos. Additionally, destructive activities such as bottom trawling should be regulated or prohibited in these areas. For effective management, the scientific knowledge base must be strengthened, and regional cooperation on environmental issues must be promoted.

According to a literature review, studies on the extent, diversity, and current issues facing coral reefs are either fragmentary or limited in scope. However, the Red Sea lags significantly behind comparable places worldwide regarding the current understanding of coral reef habitats. The in-depth data on diversity and the current condition of red sea coral reefs will crucial for effective management and the development of species-specific conservation plans.

The Red Sea could have significant impact on the coral reef ecosystem. Numerous scientists have suggested that corals in the Red Sea may provide insights into into adaptation processes and tolerant to high temperatures, as reefs face increasing pressure from global climate change. The system may aid in understanding specific processes and other factors fostering and preserving marine biodiversity on coral reefs with the Red Sea's young age and high endemism of its fauna. We anticipate that future scientific research will strategically understand different significant knowledge gaps because the Red Sea has high scientific resources that are mostly untapped and have a lot of potentials.

By Comparing to the GBR and the Caribbean, the Red Sea received 1/6th and around 1/8th of the research, respectively. Additionally, the Gulf of Aqaba, a small region (less than 3% of the Red Sea's total areas) in the far northern Red Sea has been the source of more than 60% of the published studies and reviews from the Red Sea.

Recommendations for Future

We must conduct regular, routine reef monitoring. More importantly, this monitoring must be linked to national and local management initiatives (e.g., restrictions on anchoring and access to bleached reefs, increased oversight of road development on rivers and slopes leading to the sea). Assessments can highlight our losses; but efficient monitoring can provide actionable data for management. Laws and regulations must also be reviewed and updated, beginning with those that define environmentally significant areas and impose limitations on government infrastructure projects particularly port construction and coastal reclamation that have an impact on these areas.

To gather statistically sound data on corals' diversity, abundance, and sizes, scientists must enhance their reef assessment and monitoring methodologies. The images and data produced by these new approaches must be integrated at the national level, and they should be image-based. Identifying well-developed reef boundaries requires a multidisciplinary effort from scientists, who must also study and map them. To prioritize reef for protection, additional criteria must be applied, such as the presence of rare species. When observing reefs, tracking the abundance of these species is essential.

The importance of monitoring, early warning, and swift, strategic action is evident. Since the most recent national assessment, several people from regional educational institutions, local governments, and national organizations have been trained to conduct more thorough assessments and the monitor reefs. Scientific infrastructure, staff, and institutions are also being developed to support management initiatives.

Despite the size of its coral reefs, the biodiversity and endemism they support, and the important work done by early natural historians, the Red Sea remains severely understudied. The Caribbean and Australia's

Great Barrier Reef each have six and eight times as many published studies as the Red Sea on the topics we looked into as a whole. In many cases, the lack of information present significant barrier to management and conservation efforts in the area.

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