Resilience of Coral Reefs at the southern Egyptian Coast of the Red Sea

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ABSTRACT

Twenty nine sites on the reef of the area between House Reef Fantazia Resort to House Reef of Shams Alam Resort, south to city of Marsa Alam, were surveyed. The eleven key resilience factors set by McClanahan *et al*. (2012) were used to evaluate our studied Reef areas. The resilience rank equals the sum of the resistance rank and recovery rank. The highest resistance ranks 2.66 and the lowest one 2.06 recorded in sites 27 and 28, respectively, while the recovery rank ranged between 1.69 and 2.75 in sites 29 and 26 respectively. Dependably, the resilience rank ranged between 3.86 and 5.15 in sites 29 and 19, respectively. Generally, the sites with high recruitment colonies, coral resistance species, herbivores fishes biomass, and lower algal cover, human impacts had higher resilience rank than the others sites.

Keyword: Coral reef, Resilience, Recovery, Resistance, Marsa Alam, Red Sea.

INTRODUCTION

Coral reefs are rare but critically important resources. Although they occupy less than 1.2% of the world’s continental shelf area and only 0.09% of the total area of the world’s ocean, at least 109 countries, territories, and states are directly dependent on the resources and services they provide (Bruckner *et al*., 2011). Unfortunately, many of the world’s coral reefs have been degraded, mainly due to human activities (De'ath *et al*., 2012; Granados-Cifuentes *et al*., 2013). Climate change is now recognized as one of the greatest threats to coral reefs worldwide (Barshis *et al*., 2013; Mumby *et al.,* 2014).

The amount of damage depends on, not only the rate and extent of climate change, but also on the ability of coral reefs to cope with change (Obura and Grimsditch, 2009). Importantly, the natural resilience of reefs, that maintains them in a coral dominated state, is being undermined by stresses associated with human activities on the water and on the land (Brown and Cossins, 2011). Two general properties determine the ability of coral communities to persist in the face of rising temperatures: their sensitivity and their recovery potential (Obura and Grimsditch, 2009). Sensitivity relates to the ability of individual corals to experience exposure without bleaching, and if they bleach to survive (Hughes *et al*., 2003; Baker *et al*., 2008; Obura and Grimsditch, 2009). potential recovery is relat to the community’s capacity to maintain or recover its structure and function in spite of coral mortality (Baker *et al*., 2008; Nyström *et al*., 2008; Obura and Grimsditch, 2009).

Together, they determine the resilience of coral communities to rising sea temperatures. Ecologically, resilience can divided into *Resistance* – when exposed to high temperature and other mitigating factors; the ability of individual corals to resist bleaching, and if bleached to survive, *Recovery* – following mortality of corals, the ability of the reef community to maintain or restore structure and function and remain in an equivalent ‘phase’ as before the coral mortality (Obura and Grimsditch, 2009).

Despite gaps between resilience theory and field observations, the rapid rate of climate change disturbance has elevated demand for immediate solutions and management intervention among coral reef ecosystems (Donner, 2009; Hoegh-Guldberg and Bruno, 2010). The IUCN has developed a protocol for assessing coral reef resilience consisting of 61 factors depending on biological and physical factors in this way to define management priorities (Obura and Grimsdith, 2009). However, having a wide range of physical and biological factors alone is not sufficient to develop sound resilience selection criteria. Factors must also be supported by science with substantial empirical evidence, weighted by the strength of the evidence linking factors to resistance and recovery (McClanahan, *et al*., 2012).

During the 2nd International Marine Conservation Congress (2011), approximately 50 coral reef scientists brought together to address 11 key questions concerning the resilience of coral reefs. Participants were asked to evaluate 61 potential resilience factors used by IUCN. From this, the participants reduced the 61 factors down to 31, based on experience and discussions. Post to workshop, 28 coral reef scientists independently scored the 31 factors based on their perceived importance from personal experience and again based on the empirical evidence from scientific studies in terms of the factors ability to promote resistance to thermal stress and in promoting recovery from any type of disturbance, and depending on scientific literature to evaluate and scale the evidence, and by the end of the discussions they set final list of 11 key factors for resilience management and conservation, ranging from the presence of stress-resistant corals to areas of reduced fishing pressure (McClanahan, *et al*., 2012).

On the other hand, the Red Sea is still one of the most important areas that contains beautiful coral communities and are widespread throughout the tropical Indo-Pacific area (Mohammed, 2012). The Red Sea, is of increasing interest to scientists working on climate change and resilience due to its relatively high and variable water temperatures (from 20ºC in spring to 35ºC in summer) and high salinity (c. 40.0 psu in the northern Red Sea) (Edwards, 1987). Consequently, the Red Sea is an ideal model system for understanding how reefs may fare under predicted scenarios of global climate change. Non of the pervious studies which took place in the Red Sea set any rank to the sites of the coral reefs according to the resilience, and this rank is very importance in the conservation and managements of the coral reef in the Red Sea.

Therefore, this study aims to rank some of coral reef sites at the Southern Egyptian Red Sea based on the resilience factors.

MATERIALS AND METHODS

Study area:

This study has been carried out at the Southern Egyptian Coast of the Red Sea, between House Reef Fantazia Resort 29 Km south to City of Marsa Alam to House Reef of Shams Alam Resorts 45 Km south to Marsa Alam city (Figure 1). The study area became well developed in last ten years, where numerous touristic projects (resorts and hotels) were constructed along the shoreline of the area. In total, 29 sites were surveyed, with distance interval of approximately 500m. Out of them, 4 considered as sheltered sites (i.e marsa), namely, House Reef Fantazia Resort, Marsa El-Ghadier, and Marsa El-Fogiera and House Reef shams Alam Resorts at which the

Shams Alam Resort. These four sites are possessed different types of touristic activities, i.e resorts, diving, snorkeling, picnic beaches and mooring for diving boats.

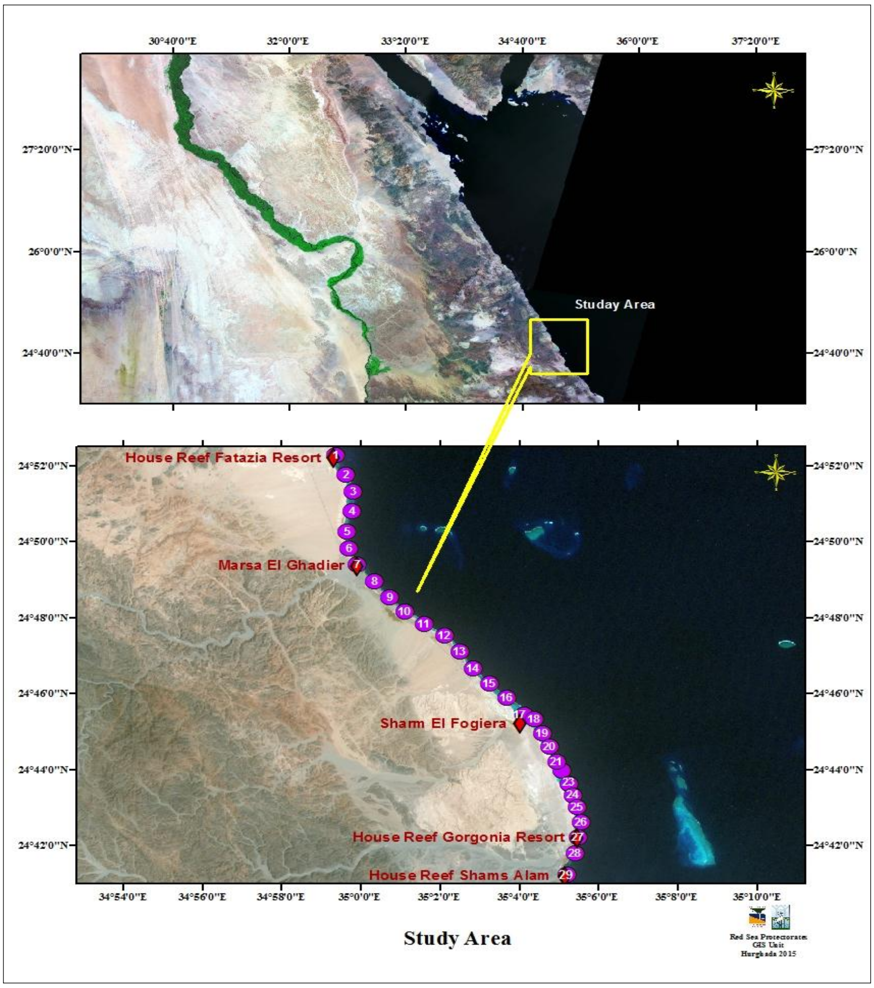

Fig. 1: A satellite map showing the locations of the studied sites in the southern Egyptian Red Sea

Methods:

The eleven key resilience factors set by McClanahan *et al.* (2012) were used to evaluate the studied sites based of the data collected during this study and the pervious information on the study area. At these sites, each of the 11 key resilience factors was given a 5-point Likert scale value (0-none; 5-highest possible) to quantify its level of function and then weighted by its evidence score for resistance and recovery and the resilience rank equal the sum of both categories (McClanahan *et al.*, 2012).

The highest value of positive factors (Resistance species, temperature variability, coral diversity, herbivores biomass, recruitments) the lowest of negative ones (Coral disease, nutrient pollution, sedimentation, anthropogenic-physical impacts, fishing pressure and algae) at all studied sites gave 5 point and sites evaluated according to the value of each factor at each site. In order to assess the positive and negative factors, the study area was surveyed intensively, using SCUBA diving in March 2013.

At the 29 sites, the substrate elements were analyzed using Point Intercept Transect (PIT according to English *et al.*, 1997). At each studied site, 25m long transect, parallel to the reef edge, was surveyed at depth of 0–5 m. At each distance intervals of 1m, the underness benthic assemblages were recorded, i.e 25 records. The substrate elements included, hard coral (recorded at genus level), soft coral (recorded at genus level), including growth form of each species, associated fauna, associated flora (algae), and dead components.

In addition, at each site, 25m line transect of 5m width was laid at depth 0-5. In each BLT the number of dead colonies (recently and old), bleached colonies (partially and totally), diseased colonies, broken corals, reattached branched) as indicator to physical human impacts and recruitments colonies, were counted and represented as no. of colonies/ 125m^2.

At each of the study site, the herbivores fishes were identified and counted to species level *(FishBase* Froese and Pauly 2003; Cole, 2010; Alevizon, 2014). All the fish counts were done during the daytime in based on visual censes as recommended by (English *et al*., 1997). At each site, herbivores fishes were counted in 500m^3 by swimming on sea surface on the reef slope for 10 minutes which equal to 100m long (Friedlander and DeMartini, 2002), within a transect of 5m width and 1m height. The transect width was estimated visually with 2.5m at each side during swimming, and the counts were expressed as fishes/500m^3.

Herbivores biomass was estimated using the length (L)-weight (M) equation: $M = aL^b$. Constants (a, b) for the most common species according to Froese and Pauly (2003). The length of each species (L) was obtained from the average length recorded at Lieske and Myers (1994) and Fish Base (Froese and Pauly, 2003) and the fish biomass was expressed as g/500^3.

Temperature variability rated was depending on the pervious information on the studied sites. Nutrient pollution, sedimentation, fishing pressure, rated according to the available information and current states during the study.

The data was analyzed statistically using IBM SPSS (V.19. Analysis of Variance (ANOVA) was applied to test the occurrence of significant differences between different studied variables according to the sites.

RESULTS

The One-way ANOVA on the effects of sites on the studied categories showed that, sites had significant influence on the coral diversity, total coral coverage, different coral growth forms, algae, total recruitment colonies, diseased colonies, fishing pressure and herbivores biomass ($p < 0.05$), but it had no influence on the temperature variability, sedimentation and nutrient pollution ($p > 0.05$).

Substrate composition at study area:

The total coral cover in the study area ranged between 52 and 84% in sites 8 and 28, respectively (Figure 2). Generally, branching corals were the dominate growth forms in the most of the studied sites especially the exposed ones, while massive coral had highly percentage in the sheltered sites (marsaes, house reefs). Figure (3) shows that, the highest branching growth forms coverage 52% were recorded in site 19, while the lowest 4% was recorded in site 4. Moreover, the coverage of massive corals ranged between 2 and 56% in sites 3 and 27, respectively. On the other hands, the encrusting corals recorded with highest cover 12% in site 21 and the lowest cover 1% in site 7. The coral diversity (no. of species) ranged between 4 and 13 in sites 27 and 1, respectively (Figure 4). On the other hand, the highest algal cover 28% and the lowest one 2% recorded in sites 12 and 28, respectively, (Figure 5).

The total recruitment colonies increased in the exposed sites than the sheltered ones, and ranged between 11 and 58colonies/125m^2 in sites 7 and 6 respectively,

(Figure 6). Generally, Impacted sites (Marsaes and House reefs) showed more physically damaged colonies than the others sites, where the highest damaged colonies 74 colonies/125m^2 and the lowest one 4colonies/125m^2 in sites 1 and 28, respectively (Figure 7). The coral disease was recorded only in 13 sites, and ranged between 1 and 36 colonies/125m^2, in sites 29 and 20, respectively (Figure 8).

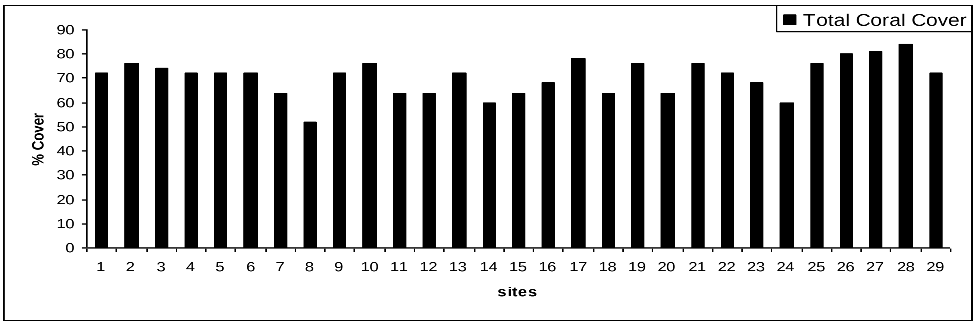

Fig. 2: The total coral percentages cover recorded at the 29 studied sites.

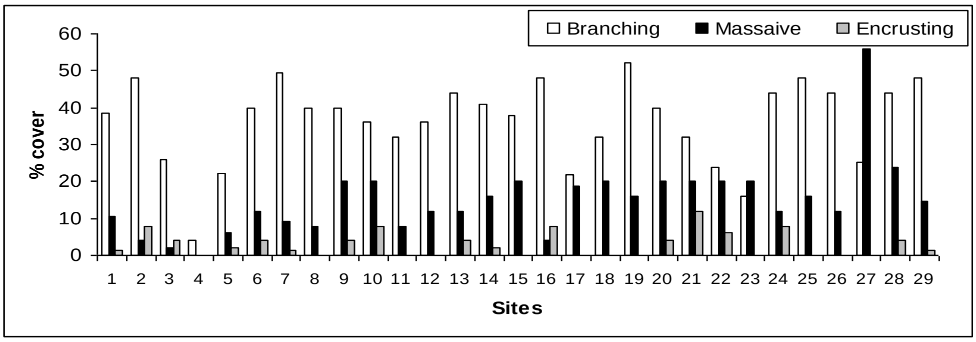

Fig. 3: The different coral growth forms percentages cover recorded at the 29 studied sites.

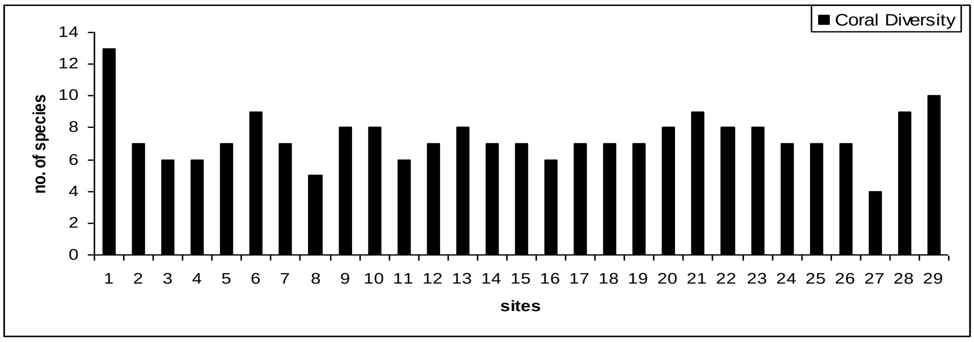

Fig. 4: The coral diversity (no. of species) recorded at the 29 studied sites.

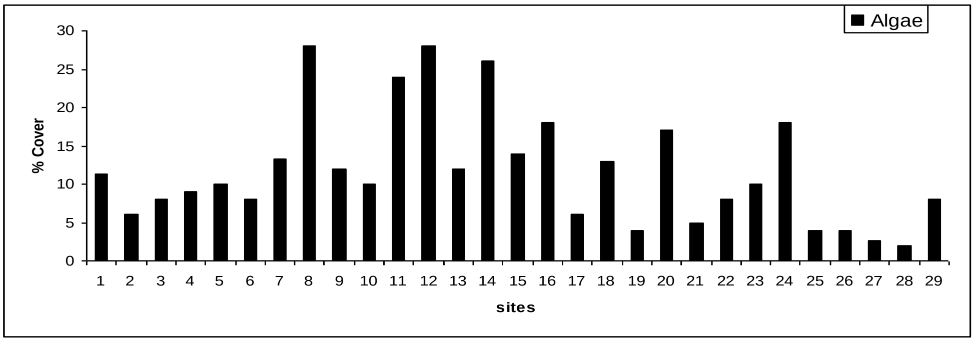

Fig. 5: The algal percentages cover recorded at the 29 studied sites

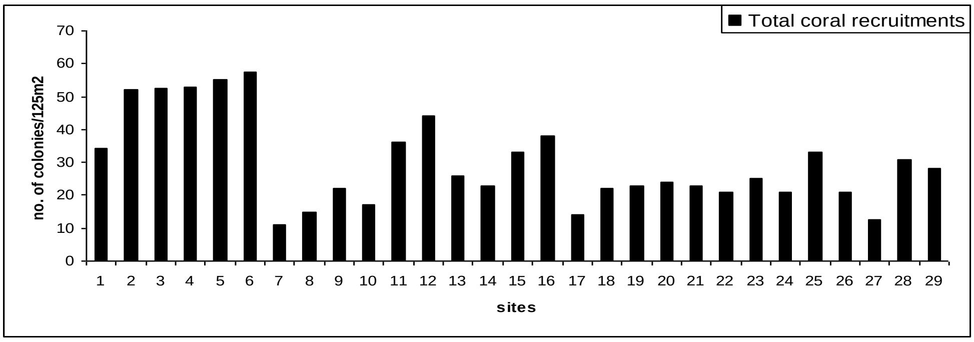

Fig. 6: The counted numbers of total recruitment colonies recorded per $125m^2$ in the 29 studied sites

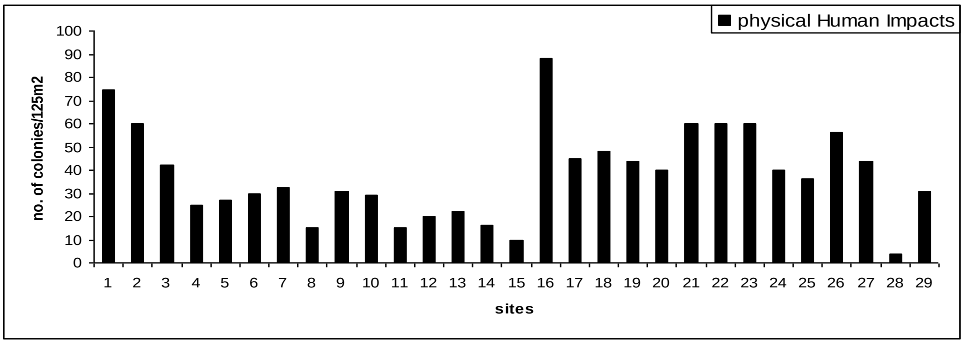

Fig. 7: The physical human impacts recorded per $125m^2$ in the 29 studied sites

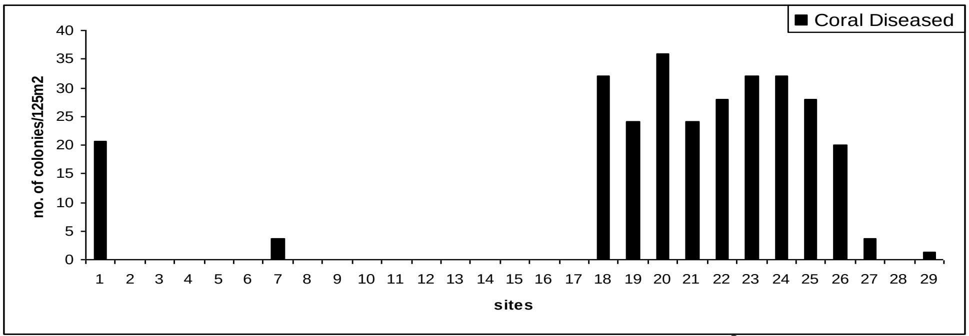

Fig. 8: The counted numbers of diseased colonies recorded per $125m^2$ in the 29 studied sites

Herbivores Biomass

Eighteen herbivores species were recorded in all study sites, belonged to seven families of coral reef fishes. The herbivores abundance ranged between 2 and 342fishes/$500m^3$. Figure (9) shows the herbivores biomass at the studied sites, where the highest herbivores biomass 186747g/$500m^3$ was recorded in site 27 and the lowest one (1092g/$500m^3$) was recorded in site 21.

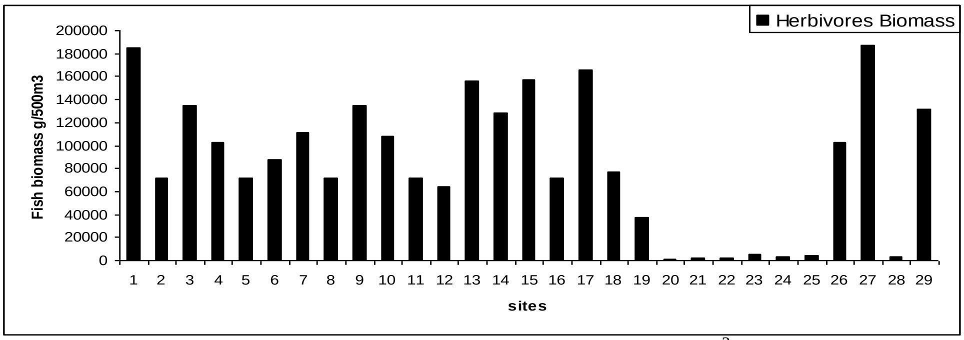

Fig. 9: The biomass of herbivores fishes recorded per $500m^3$ in the 29 studied sites

Resilience rank to the study sites:

The highest resistance ranks 2.66 and the lowest one 2.06 recorded in sites 27 and 28, respectively, while the recovery rank ranged between 1.69 and 2.75 in sites 29 and 26 respectively. Dependably, the resilience rank ranged between 3.86 and 5.15 in sites 29 and 19, respectively, (Figure 10). In general the impacted and sheltered site had lowest resilience rank than the exposed and un-impacted sites.

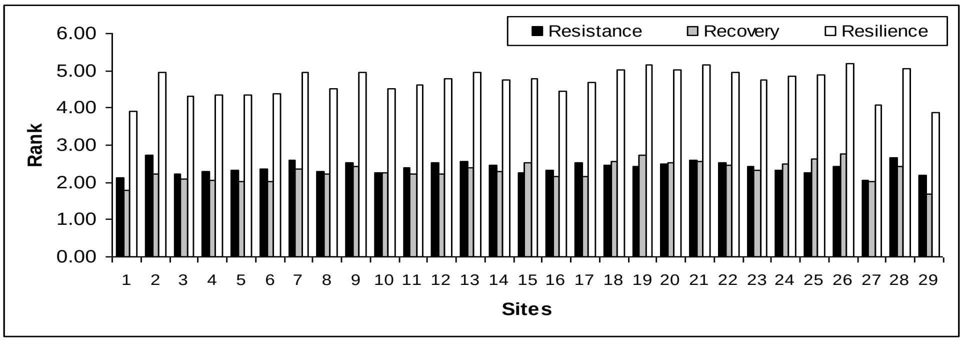

Fig. 10: The rank of resistance, recovery and resilience recorded in the 29 studied sites

DISCUSSION

Ecological resilience can be defined as the capacity of an ecosystem to absorb recurrent disturbances or shocks and adapt to change, while retaining essentially the same function and structure (Scheffer *el al*., 2001). There were difference in the coral coverage between studied sites and impacted sites (Marsa and House Reefs) had less coral coverage than the others sites. The differences in coral community structures in many coastal areas have been controlled by different factors; the most important one was the human impact such as coastal development and diving activities (Dar *et al*., 2012; Jackson *et al*., 2014).

Massive coral consider as the most resistance species and often not impacted by disturbance and a high abundance of resistant species, by definition, confers resistance (Foster *et al*., 2011). In additional, massive species, that remain after a disturbance can continue to grow and reproduce to promote recovery, although these are often slow-growing species and coral recovery may depend more on the recolonization of fast-growing branching and plating species (Riegl and Purkis, 2009). The most dominate growth form in studied sites was branching coral in the exposed site and massive coral tend to increase in the sheltered ones. That is because corals can adapt themselves with the current and wave, where the branching growth form dominated in the exposed sites, while the coral colony was modified to be corymbose or massive forms in sheltered sites. Attalla (2011), Mohammed (2012) and Dar *et al*., (2012) found that in the exposed sites, branched forms estimated higher percentage than in the sheltered sites, in contrast, the massive growth forms at the sheltered sites showed higher occurrence than that of the exposed sites.

Coral diversity may increase resistance, but this likely depends on the species composition and their species-specific sensitivities or tolerances to disturbance, (Nyström *et al*., 2008, McClanahan *et al*., 2011). On the other hand, there is limited evidence that coral diversity promotes recovery following disturbance (Cote and Darling, 2010). The coral diversity differs from site to another and tend to increase in the sheltered sites, but generally the rapid increase in the coastal developments tend to decrease the coral diversity (Riegl *et al*., 2012).

Algal assemblages are a very important part of many marine systems, providing food and shelter for higher trophic levels of marine ecosystems (Bruno and Bertness, 2001). The impact of algae on resistance is not clear though potential factors are generally negative. Factors can work to counteract one another. For example, algae can reduce growth rates, and disease transmission from algae can divert coral resources (West and Salm, 2003; Mumby, *et al*., 2007). Algae is a significant factor limiting the recovery of corals following disturbance by increasing competition for benthic substrate, by trapping sediment that smothers coral recruits (Mumby and Steneek, 2011; Hoey and Bellwood, 2011). Algae can withstand different wave intensities based on their form and structure, but are especially affected in the upper limits of areas that receive the most constant and intense wave exposure, toward the top of the water line and tend to be more abundance in sheltered and impacted areas, (Fields and Hubach, 2014). This is totally agree with our finding were the un-impacted and exposed sites had lower algal cover than other sites.

The total recruitment colonies in this study found to be higher in un-impacted and exposed sites than the sheltered and impacted ones, as results of successful settlements of coral larvae and also availability of settlement space in these sites compared to sheltered and impacted sites which are characterized by fast algal growth that blocking larval settlements (Tilot *et al*., 2008). Mixed evidence surrounds the thermal sensitivity of coral recruits and small size classes, compared to larger corals, with some evidence suggesting small corals bleach more severely, while a great number of studies suggest coral recruits and small size classes are more resistant to bleaching and mortality (Bena and van Woesik, 2004; Shenkar *et al*., 2005). In additional, high rates of successful coral recruitment and survival enhance coral recovery rates following disturbance (Mumby and Harborne, 2010).

Several studies have illustrated that there is a strong negative relationship between anthropogenic physical impacts to coral reefs and their ability to resist stressors. Physical destruction may not kill coral colonies entirely, but even partial mortality and weakening increases susceptibility to thermally induced coral bleaching, disease outbreak or and reduce the reproductive potential of individuals. However, the degree of resistance exhibited by coral reefs or colonies may be dependent on the scale and frequency of the disturbance (Chabanet *et al*., 2005; Fox *et al*., 2005). There is mixed evidence on the impact of physical anthropogenic disturbances on coral reef recovery. Most studies have linked anthropogenic physical impacts to coral lower growth rates, lower reproductive potential, fewer coral recruits, lower and survivorship and increased disease incidence (Ebersole, 2001; Rogers and Cox, 2003). The total damaged colonies due to physical human impacts in this study increase in impacted sites (Marsaes and House reefs) than the others sites. This is totally agreed with Attalla (2011) and Mohammed (2012), when they found higher damaged colonies in impacted sites than un-impacted ones.

Herbivores fish biomass varied between sites and it increased in sheltered sites than the others, because most of these species consider as commercial fishes and the fishing pressure in the sheltered sites (Marsaes and Houses reefs) are prohibited by divers and the resorts owner. On the other hands, exposed sites are used by the local people for fishing from the coast. Bruckner *et al*. (2011), stated that, in the last two decades, increased human settlement in coastal areas of the Red Sea and the resultant increase in artisanal and commercial fishing activities to support local consumption, and to supply a growing international trade in coral reef species and products, have led to depletion of many commercially valuable species. No clear evidence the herbivory increases resistance. It is possible that reduced algal competition might help corals withstand other stressors but thane is no clear evidence (Foster *et al*., 2008), but several studies have demonstrated a critical role of herbivores reef fishes in recovery as they influencing competitive interactions between corals and algae and therefore increase in coral recruitment despite higher corallivory (Hughes *et al*., 2011; Mumby and Steneek, 2011)

Few studies have directly tested how disease affects bleaching sensitivity. Instead, research has focused on the effect of temperature on pathogen virulence, how disease outbreaks follow bleaching episodes (suggesting corals are more susceptible), and how disease might become more common as climate change continues (Lesser *et al*., 2007). While little evidence that high levels of disease impede recovery from bleaching. However, disease outbreaks often follow episodes of mass bleaching, which would imply slower recovery as corals expend resources to combat infection (Buuno, *et al*., 2007). The present results indicate a low coral disease prevalence of 1-36colonies/125m^2 on coral reefs in the area of study. This level of coral disease is much lower than those reported from other reefs both in the Indo- Pacific and GBR of Australia (Willis *et al*., 2004); Southeastern India (Thinesh *et al*., 2009) and in the Caribbean; St. Lucia (Nugues, 2002), and it agreed with the states of coral disease in Northern Red Sea (Mohamed *et al*., 2012). Field and experimental evidence suggests that nutrient pollution can reduce coral reef resistance to stress, but differences have been observed based on coral species, morphology, type of nutrient, level of nutrients and local context (Wooldridge and Done, 2009), and it is associated with decreased recovery following disturbance but studies recognize the challenge of separating the effects of multiple stressors, such sedimentation, overfishing from pure nutrients (Carilli *et al*., 2009). Nutrient pollution was very low within the study area due to the absence of the source of these pollutants. The effects of increased sediments on corals, widely studied in both classical recent literatures are linked to resistance properties of corals. In synergy with SST, increased sediment and nutrients have been shown to decrease the thermal tolerance of corals causing bleaching during marginal increase in SST, and sediments can limit the recovery of coral reefs. It has been shown that sediment can smother corals tissue, and limit coral larvae settlement impairing coral recovery (Gleason and Hofmann, 2011; Burke *et al*., 2014).Whiten the study area the sedimentation increased in the sheltered area due to the man activities such as resorts and diving activities.

The most important factors for recovery included high levels of coral recruitment to replenish denuded locations (Hughes *et al*., 2010); suitable substrate for coral settlement and survival (Victor, 2008); and low cover of algae, which in high abundance can directly kill corals, trap sediment, prevent coral settlement, and dominate benthic space (Smith *et al*., 2006; Mumby *et al*., 2007). Together, the top-ranked factors show that the most resilient reefs are expected to be those with high fish and coral diversity (Mora, *et al.*, 2011); and few human impacts (Sandin *et al*., 2008). This is totally agree with our finding where the sites with high recruitment colonies, coral resistance species, herbivores fishes biomass, and lower algal cover, human impacts had higher resilience rank than the others sites.

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REFERENCES

Attalla, T. M. (2011). Natural and Human Impacts on the coral Reef Of the Red Sea-Egypt. M. Sc. Thesis, Suez Canal University, Ismailia, Egypt; 268 pp.

Baker, A. C.; Glynn, P. W. and Riegl, B. (2008). Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuarine, Coastal and Shelf Science, 80: 435–71. doi: 10.1016/j. ecss.2008.09.003.

Barshis, D. J.; Ladner, J. T.; Oliver, T. A.; Seneca, F. O.; Traylor-Knowles, N. and Palumbi, S. R. (2013). Genomic basis for coral resilience to climate change. Proceedings of the National Academy of Sciences of the United States of America, 110: 387–1392.

Bena, C. and van Woesik R. (2004). The impact of two bleaching events on the survival of small coral colonies (Okinawa, Japan). Bulletin of Marine Science, 75: 115-125.

Bruno, J. F. and Bertness, M. D. (2001). Habitat modification and facilitation in benthic marine communities. In: Marine Community Ecology (ed. Bertness, M.D.). Sinauer Associates Inc., Sunderland, MA, pp. 201–218.

Burt, J.; Bartholomew, A. and Usseglio; P. (2008). Recovery of corals a decade after a bleaching event in Dubai, United Arab Emirates. Marine Biology, 154: 27-36.

Brown, B.E. and Cossins, A.R. (2011). The Potential for Temperature Acclimatisation of Reef Corals in the Face of Climate Change, Springer, Po Box 17, 3300 Aa Dordrecht, the Netherlands.

Bruckner, A.W.; Alnazry, H.H. and Faisal, M. (2011). A parading shift for fisheries management to enhance recovery, resilience, and sustainability of coral reef ecosystems in the Red Sea. Sustainable Fisheries: Multi-Level Approaches to a Global Problem, pp. 85–111.

Bruno, J. F.; Selig, E. R.; Casey, K. S.; Page, C. A. and Willis, B. L. *et al*., (2007). Thermal stress and coral cover as drivers of coral disease outbreaks. Plos Biology, 5: 1220-1227.

Burke, L.M.; Reytar, K.; Spalding, M. and Perry, A. (2014). Reefs at Risk Revisited. In. World Resources Institute, Washington, DC.

Carilli, J.; Norris, R.; Black, B.; Walsh, S., McField, M. (2009). Local Stressors Reduce Coral Resilience to Bleaching. PLoS ONE, 4: e6324.

Chabanet, P.; Adjeroud, M.; Andrefouet; S.; Bozec, Y.M. and Ferraris, J. *et al*. (2005). Human-induced physical disturbances and their indicators on coral reef habitats: a multi-scale approach. Aquatic Living Resources, 18: 215–230.

Cote, I. and Darling, E. (2010). Rethinking ecosystem resilience in the face of climate change. PLoS Biology, 8: e1000438.

Dar, M A.; Mohamad, T.A. and Mahmoud, I. E. (2012). Geomorphic and geographic distributions of reef-building and soft coral communities in the inshore zone of the Red Sea. Egypt. J. Aquatic Rese., 38:105–117.

De'ath, G.; Fabricius, K.E.; Sweatman, H. and Puotinen, M. (2012). The 27–year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the

National Academy of Sciences of the United States of America, 109:17995–17999.

Donner, S. D. (2009). Coping with commitment: projected thermal stress on coral reefs under different future scenarios. PLoS ONE, 4: 5712.

Ebersole, J. P. (2001). Recovery of fish assemblages from ship groundings on coral reefs in the Florida keys National Marine Sanctuary. Bulletin of Marine Sciences, 69: 655-671.

Edwards, F. J. (1987). Climate and oceanography. In: Edwards AJ, Head S (eds) Key environments: Red Sea. Pergamon Press, Oxford, pp. 45–68.

English, S., Wilkinson, C. and Baker, V. (1997). Survey manual for tropical marine resources. Australian Institute of Marine Science, Townsville. Australia., pp.34-49.

Fields, S. and Hubach, E. (2014). The relationship between wave action and algae communities. http://pbsci.ucsc.edu/

Foster, N. L.; Box, S. J. and Mumby, P. J. (2008). Competitive effects of macroalgae on the fecundity of the reef-building coral Montastraea annularis. Marine Ecology Progress Series, 367: 143-152.

Foster, K. A.; Foster, G.; Tourenq, C. and Shuriqi, M. K. (2011). Shifts in coral community structures following cyclone and red tide disturbances within the Gulf of Oman (United Arab Emirates). Marine Biology, pp. 1-14.

Fox, H. E.; Mous, P.; Pet, J.; Muljadi, A. and Caldwell, R. L. (2005). Experimental assessment of coral reef rehabilitation following blast fishing. Conserv Biol., 98-107.

Friedlander, AM. and DeMartini, EE. (2002). Contrasts in density, size, and biomass of reef Wshes between the northwestern and the main Hawaiian islands: the eVects of Wshing down apex predators. Mar Ecol Prog Ser, 230:253–264.

Froese R. and Pauly, D. (eds) (2003). FishBase. World Wide Web electronic publication, www.fishbase.org.

Granados-Cifuentes, C.; Bellantuono, A.J.; Ridgway, T.; Hoegh-Guldberg, O. and Rodriguez- Lanetty, M. (2013). High natural gene expression variation in the reef-building coral *Acropora millepora*: potential for acclimative and adaptive plasticity. BMCGenomics, 14:228–240.

Gleason, D. F. and Hofmann, D. (2011). Coral Larvae: from gametes to recruits. Journal of Experimental Marine Biology and Ecology, 408(1–2): 42-57.

Hughes, T.P.; Baird, A. H.; Bellwood, D. R.; Card, M.; Connolly, S. R;, Folke, C.; Grosberg, R.; Hoegh-Guldberg, O.; Jackson, J.B.C.; Kleypas, J.; Lough, J.M.; Marshall, P.; Nyström, M.; Palumbi, S.R.; Pandolfi, J.M.; Rosen, B. and Roughgarden, J. (2003). Climate change, human impacts, and the resilience of coral reefs. Science, 301: 929- 933.

Hughes, T.P.; Graham, N.A.J; Jackson, J.B.C; Mumby, P. J. and Steneck, R.S. (2011). Rising to the challenge of sustaining coral reef resilience. Trends in Ecology and Evolution, 25: 633–642.

Hoey, A.S. and Bellwood, D. R. (2011). Suppression of herbivory by macroalgal density: a critical feedback on coral reefs? Ecol Lett, 14:267-273.

Jackson, J.B.C.; Donova, M.K.; Cramer, K.L. and Lam, V.V. (2014). Status and Trends of Caribbean Coral Reefs: 1970-2012. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland.

Lesser, M.P.; Bythell, J.C.; Gates, R.D.; Johnstone, R.W. and Hoegh-Guldberg, O. (2007). Are infectious diseases really killing corals? Alternative interpretations of the experimental and ecological data. Journal of Experimental Marine Biology and Ecology, 346: 36-44.

McClanahan, T. R.; Maina, J. M. and Muthiga, N. A. (2011). Associations between climate stress and coral reef diversity in the western Indian Ocean. Global Change Biology, 17: 2023-2032.

McClanahan, T.R.; Donner, S.D.; Maynard, J.A.; MacNeil, M.A. and Graham, N.A.J. *et al*., (2012). Prioritizing Key Resilience Indicators to Support Coral Reef Management in a Changing Climate. PLoS ONE, 7(8): e42884.

Mohamed, A.R.; Abdel-Hamid A. M. and Abdel-Salam, H.A. (2012). Status of coral reef health in the northern Red Sea, Egypt. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, pp. 9-13.

Mohammed, T. A. (2012). Rapid Assessment of Coral Reefs along the Egyptian Red Sea Coast IJEP, 2 (4): 25-33.

Mora, C.; Aburto-Oropeza, O.; Ayala Bocos, A. Ayotte, P.M. and Banks, S.*et al*. (2011). Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. PLoS Biology, 9: e1000606.

Mumby, P. J.; Harborne, A. R., Williams, J.; Kappel, C.V. and Brumbaugh, D.R.*et al*. (2007). Trophic cascade facilitates coral recruitment in a marine reserve. Proceedings of the National Academy of Sciences of the United States of America, 104: 8362-8367.

Mumby, P.J. and Harborne, A. R. (2010). Marine reserves enhance the recovery of corals on Caribbean reefs. PLoS One, 5: e8657.

Mumby, P.J. and Steneck, R. S. (2011). The resilience of coral reefs and its implications for reef management. In: Dubinsky Z, Stambler N (eds) Coral Reefs: An ecosystem in transition. Springer, Amsterdam, pp. 509-519.

Mumby, P. T.; Flower, J.; Chollett, I. and Stephen J.B. *et al*. (2014). Towards Reef Resilience and Sustainable Livelihoods: A handbook for Caribbean coral reef managers. University of Exeter, Exeter., pp.172.

Nugues, M. M. (2002). Impact of a coral disease outbreak on coral communities in St. Lucia: What and how much has been lost? Mar Ecol. Prog Ser., 229: 61-71

Nyström, M.; Graham, N.A.J.; Lokrantz, J. and Norström, A.V. (2008). Capturing the cornerstones of coral reef resilience: linking theory to practice. Coral Reefs, 27: 795-809.

Obura, D.O. and Grimsdith, G. (2009). Resilience Assessment of coral reefs – Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. pp.70.

Riegl, B., Purkis, S. (2009). Model of coral population response to accelerated bleaching and mass mortality in a changing climate. Ecological Modelling, 220: 192-208.

Riegl, B.; Brunkner, A.; Rowlands, G.; Purkis, S. and Renaud, P. (2012). Red Sea Coral Reef Trajectories over 2 Decades Suggest Increasing Community Homogenization and Decline in Coral Size. PLOS DOI, pp.10:1371.

Rogers, K.S. and Cox, E.F. (2003). The effects of trampling on Hawaiian corals along a gradient of human use. Biological Conservation, 112: 383-389.

Sandin, S.A.; Smith, J.E.; DeMartini, E.E.; Dinsdale, E.A. and Donner, S.D. *et al*. (2008). Baselines and degradation of coral reefs in the Northern Line Islands. PLoS ONE, 3: e1548.

Scheffer, M.; Carpenter, S.; Foley, J.A.; Folke, C. and Walker, B. (2001). Catastrophic shifts in ecosystems. Nature, 413: 591–596.

Shenkar, N.; Fine, M. and Loya, Y. (2005). Size matters: bleaching dynamics of the coral Oculina patagonica. Marine Ecology-Progress Series, 294: 181-188.

Smith, J.E.; Shaw,M.; Edwards, R.A., Obura, D. and Pantos, O. *et al*. (2006). Indirect effects of algae on coral: algae-mediated, microbe-induced coral mortality. Ecology Letters, 9: 835–845

Thinesh, T.; Mathews, G. and Patterson Edward, J.K. (2009). Coral disease prevalence in Mandapam group of islands, Gulf of Mannar, Southeastern India. Indian J Mar Sci., 38(4): 444-450

Tilot, V.; Leujak, W.; Ormond, R.F.; Ashworth, J.A. and Mabrouk, A., (2008). Monitoring of South Sinai Coral Reefs: Influence of Natural and Anthropogenic Factors. Aquatic Conservation: Marine and Fresh Water Ecosystem. John Wiley Sons, Ltd.

Victor, S. (2008). Stability of reef framework and post settlement mortality as the structuring factor for recovery of Malakal Bay Reef, Palau, Micronesia: 25 years after a severe COTS outbreak. Estuarine, Coastal and Shelf Science,77: 175-180.

West, J.M. and Salm, R.V. (2003). Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management. Conserv Biol., 17: 956-967.

Willis, B.; Page, C. and Dinsdale, E. (2004). Coral disease on the Great Barrier Reef. In: Rosenberg E, Loya Y (eds) Coral Health and Disease. Springer-Verlag, Germany, pp. 69-104.

Wooldridge, S. A. and Done, T.J. (2009). Improved water quality can ameliorate effects of climate change on corals. Ecological Applications, 19: 1492-1499.

ARABIC SUMMARY

دراسة مرونة الشعاب المرجانية في الساحل الجنوبي المصري للبحر الأحمر

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أجريت هذه الدراسة في المنطقة ما بين هوس ريف قرية فانتزيا وهوس ريف قرية شمس علم جنوب مدينة مرسي علم. تم تقسيم هذه المنطقة إلي ٢٩ موقع. خلال هذه الدراسة تم استخدام ١١ عامل لقياس مرونة الشعاب المرجانية والذي قد تم أعدادهم من قبل (McClanahan *et al*. 2012) لتقيم المواقع التي تم دراستها استنادا علي البيانات التي تم تجميعها خلال هذه الدراسة والبيانات المتاحة مسابقا. ومرونة أي موقع تم دراسته تساوي حاصل جمع قيمة مقاومة الموقع وقيمة استرجاع الموقع. وخلال هذه الدراسة كان أعلي قيمة للمقاومة ٢.٦٦ وأقل قيمة ٢.٠٦ تم تسجيلهم في المواقع ٢٧-٢٨ علي الترتيب، بينما تراوحت قيمة الاسترجاع بين ١.٦٩ و ٢.٧٥ في المواقع ٢٩-٢٦ علي الترتيب. واستنادا علي ذلك فأن قيمة المرونة لمواقع الدراسة تراوحت ما بين ٣.٨٦ و ٥.١٥ في المواقع ٢٩ و ١٩ علي الترتب. وعموما فـأن المواقع التي احتوت علي أعلي عدد للمستعمرات الجديدة- أنواع الشعاب المقاومة- كتلة للأسماك العشبية وأقل نسبة للطحالب و التأثيرات البشرية كانت لديها قيم مرونة عالية أكثر من المواقع الأخرى.