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Ecological study on Seaweeds of Earthquake Crack in Ras Muhammad National Park, South Sinai, Egypt.

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ABSTRACT

Temporal variability and describe the abundance and distribution of marine benthic seaweeds that inhabit walls of Ras Muhammad earthquake crack and their relationship to the diagenetic nature of the substratum reef using the field investigation. The study period extended seasonally from spring to winter 2015. The assessment of seaweeds abundance and distribution were performed using the Dominant, Abundant, Frequent, Occasional and Rare (DAFOR) scale, which is a method of defining species abundance and community richness, especially during intertidal rapid surveys, such in our case when the precise numbers or coverage of a species in the field is difficult to measure. A total of 19 seaweeds taxa were collected from Ras Muhammad Earthquake crack belonging to four different algal phyla and had been identified to the level of the species level following the standard taxonomically guides which dealing with the seaweeds of the Indo-pacific region and the general references of the tropical and subtropical areas. The *Chlorophyta* is the most diverse division and prevailed with 9 taxa followed by *Rhodophyta* (5 taxa), then *Ochrophyta* (3 taxa), and the last division is Cyanophyceae (2 taxa).This study emphasizes the significant impact of seasonal variations, especially temperature, and Salinity on the temporal distribution and Biomass of seaweeds taxa in Ras Muhammad Earthquake crack.

INTRODUCTION

Ras Muhammad National Park (RMNP) is a small uplifted and faulted Neogene blocks that partially covered by Pleistocene coralline algal limestone. RMNP is situated in the southernmost tip of the Sinai Peninsula at the northern end of the Red Sea 27° 43.150' N and 34° 15.590′ E **(Hegazi, 1992)**. It is bordered to the west by a relatively shallow elongated depression of the Gulf of Suez, (average bathymetry of 70 m), and to the east by the deep tectonic trough of the Gulf of Aqaba (depths of up to 1850 m), as shown by **Garfunkel *et al*. (1981)**. Its location at the junction of the Gulf of Aqaba, the Gulf of Suez, and the Red Sea expose it to a variety of environmental conditions. RMNP was established in 1983 as the first Egyptian national park. It is classified into two parts: marine (part of the Gulf of Suez and part of the Gulf of Aqaba) which represents 70%, and terrestrial, representing 30% **(Paleczny, *et al.*, 2007)**. Ras Muhammad National Park is a rich and vulnerable marine environment where the surface morphology structure has shown open crack cutting through the uplifted fossilized reefs. Ras Mohamed National Park is a rich and fragile marine environment where the surface morphology structure has revealed an open crack through raised fossil reefs.

It discovered in October 1971 **(Por & Tsurnamal, 1973)**. The crack is the site of inland caves with linear development that flood with seawater. They are known in Ras Muhammad area as earthquake pool showing tidal fluctuations but have no surface connections to the sea, they fit the definition of anchialine pools (from the Greek anchialos, near the sea), and classified as Polyhaline-Euhaline Anchialine Pools to indicate this type of habitat, rather than to have to define it each time as "pools with no surface connection with the sea, containing salt or brackish water, which fluctuates with the tides" **(Holthuis, 1973)**. Anchialine pools or ponds are land-locked, saline bodies of water with permanent connections with the oceans. Ras Muhammad Earthquake has an intensive environment of marine organisms, especially seaweeds.

There is a severe lack of environmental studies on seaweeds of the land-locked pools Ecosystems (Earthquake Pools) in the world especially South Sinai, but there are some few studies on the biodiversity of those Ecosystems including seaweeds community **(Holthuis, 1973)**. Only two marine algal collections have been reported previously from Ras Muhammad Earthquake pool **(Por & Tsurnamal, 1973; Hegazi, *et al.* 2006)**.

Seaweeds are one of the most important biological resources in shallow marine ecosystems in the Red Sea. Seaweeds make a substantial contribution to marine primary production and provide habitat for benthic communities especially earthquake communities **(Mann, 1973; Williams & Smith, 2007)**. They can support some of the most diverse and productive communities in the marine environment by performing the important role of primary producers.

So, the aim of this work is evaluating the temporal variability and describe the abundance and distribution of marine benthic seaweeds that inhabit walls of the developed earthquake pools and their relationship to the diagenetic nature of the substratum reef.

MATERIALS AND METHODS

1. Study site

Ras Muhammad Earthquake crack is situated at the southern tip of the Sinai Peninsula at point (27°44'0.91"N, 34°14'40.91"E) **(Fig. 1)**. It is a narrow open crack in an elevated fossil reef. This crack, which formed by an earthquake (seismic activity) in 1968, is about 42 m long 0.2 m to 2 m wide. It is about 150 meters distant from the nearest sea inlet and has no external connection with the sea. The surface of the water is about 1 m below that of the land. The water depth at places is over 14 m. The rocky wall is caved in and have overhanging ledges hereby extensive areas of shade and semi-obscurity are formed in the crack, especially along the walls, which covered with algae among them *Valonia* sp, *Codium* sp, *Botryocladia* sp, and calcareous red algae **(Hegazi *et al*., 2006)**.

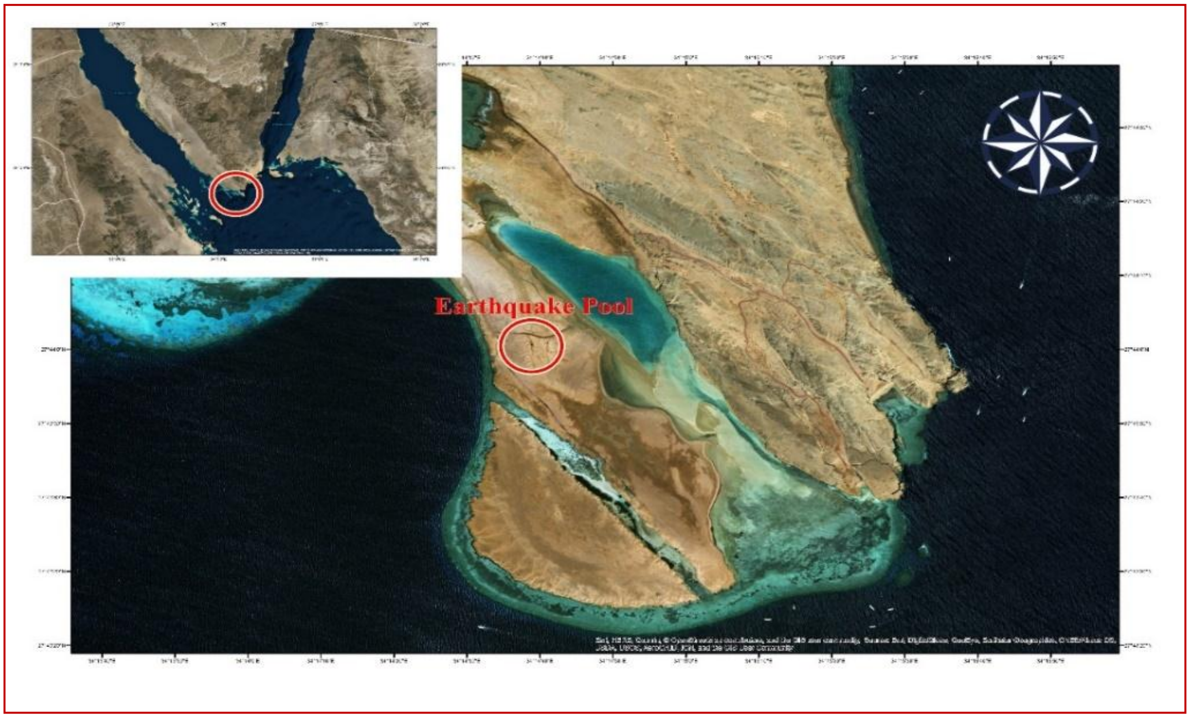

Fig (1): A map of Ras Muhammad National Park showing the Earthquake location

2. Sampling Collection Procedure and Field Survey

Seaweeds Monitoring Program carried out seasonally through four seasons in 2015 by using scuba diving and snorkeling. Generally, the best time for collection of seaweeds samples in the field is around the time of very low tide especially, one or two hours before the time of low tide to avoid rubbing against the steep walls of the crack, or very high tide level by diving into the Crack; This will give more time for seaweed collection and for observing seaweeds in the natural habitat **(Al-Yamani *et al*., 2014**). The abundance was visually determined based on photographs (made perpendicularly to the surface of the substrate occupied by algal community) of analyzed by estimating the mean substrate surface area occupied by algae **(Eduard, 2019**). All notes on the description of the site location, topography, associated flora and fauna, and other related variables are recorded carefully. Seaweeds samples were collected in polyethylene bags with proper labelling for further preservation and identification at the later stage in the laboratory, then estimate the algal biomass. Seaweeds were identified using the taxonomic keys provided by **Aleem (1993**).

The assessment of seaweeds abundance and distribution were performed using the Dominant, Abundant, Frequent, Occasional and Rare **(**DAFOR**)** scale, which is a method of defining species abundance and community richness, especially during intertidal rapid surveys, such in our case when the precise numbers or coverage of a species in the field is difficult to measure **(James, 2007)**. A detailed description of the DAFOR scale is summarized below.

'D' for Dominant, used for the most common macroalgae. **'A' for Abundant**, if the plant is very common in many parts of the square. **'F' for Frequent** or Common**,** designates the occurrence of algae in several places in the square and there are usually more than just a few individuals in each of these places. **'O' for Occasional** or Uncommon, use for species that occur in several places in the square, but whose populations are usually not very big. **'R' for Rare,** use for any species that occur as a small number of individuals in the square.

3. Sample preservation

Seaweeds samples were collected from the Earthquake Crack washed carefully to remove all adhering materials such as sand particles and other debris as well as epiphytes before preservation. A solution of 5% formaldehyde in seawater prepared to preserve the seaweed sample. Before adding the preservative, water from the polyethylene bags drained and then added sufficient preservative. Fumes of the formaldehyde would help to fix and preserve the seaweed material. Polyethylene bags tied with rubber bands properly to prevent leakage until reached to the laboratory.

4. Hydrographic factors

Through four seasons, salinity, temperature, and PH measured regularly at the same time of collection. Salinity measured by using hand-held Refractometer (ATAGO S/Mill), with scale range from 0 to 100 ‰, and has specific gravity 1.000 to 1.070. The temperature measured by using thermometer set JENWAY, model 2052 (-50 / +199.9 º C)., and by using the PH paper test to measure the level of crack water PH.

5. Biomass Assessment

The biomass assessment process is determined the ash-free dry weight (AFDW). Ash-Free Dry Weight is a measurement of the weight of organic material in the seaweed's specimen. To measure AFDW, one takes 100 grams of seaweeds species (wet weight) and removes all the water. The water is removed by baking the seaweeds specimen at a low temperature (around 50 degrees Celsius, which is a low enough temperature that combustion does not occur) for 24 hours to get the "dry weight". The resulting dry weight is the weight of both the organic and inorganic contents of the seaweed's specimen. Next, the dried seaweeds specimen is combusted by placing in an oven (Carbolite Furnaces) at 450 degrees Celsius for 4 hours, in the presence of oxygen. In the oven, all of the organic content (carbon) is burned off- all of the carbon in the seaweed's specimen reacts with oxygen to produce carbon dioxide. Carbon dioxide is a gas, so it leaves the specimen. The ash that is left over is thus the inorganic contents of the specimen. The AFDW is then the dry weight (inorganic + organic contents) minus the weight of the ash (inorganic contents only). AFDW is, therefore, the weight of the organic content of the seaweed's specimen.

6. Dry preservation (Herbarium)

Fresh seaweeds specimen carefully cleaned of sand particles, rocks, shells, mud and other adhering materials and epiphytes. Seaweeds species put into a tray containing freshwater (half-filled). An herbarium sheet, a size smaller than the tray to be inserted from below the specimen and then spread the specimen on the herbarium sheet with the help of brush in such a way that overlapping of the specimen is minimized. To blot dry, herbarium sheets are placed on the newspaper sheets to remove the remaining water from the herbarium. A cheesecloth is placed on the top of the specimen in such a way that it covers an entire specimen. Another sheet of the blotting paper was placed over the herbarium sheet. All herbaria piled one above the other and then placed between the two sheets of the wooden press. The press is tied tightly with appropriate pressure by a rope. The press is kept at room temperature for 24 hrs. After 24 hours, blotting papers are required to be replaced. The process of replacing blotting papers is repeated until the time specimen is free of moisture. On drying of the specimen, the specimen gets attached to the paper due to the phycocolloid present in the seaweed. The cheesecloth is carefully removed and the herbarium sheet is properly labelled containing the name of the specimen, and locality. Sheets placed in the polyethylene bags and sealed and stored.

RESULTS AND DISCUSSION

The seasonal variations of seaweeds were evident in the Earthquake crack during the study in terms of abundance and distribution within the crack. Quantitatively, the contribution of seaweeds varies significantly between seasons. Earthquake Crack Habitat has an intensive form of seaweeds. Seaweeds affected by several hydrographic factors, were measured seasonally and the results were as follows:

There is a difference between the open sea and the crack in the water temperatures **(Fig. 3)**. Sea surface temperature is the most significant seasonal parameter controlling seaweed abundance and distribution. At the Crack, the water surface temperature was ranged between 22,6 C° – 26 C° **(Fig. 3)**. The minimum water surface temperature recorded in winter (22,6 C°) and the maximum in the summer (26 C°). Both growth and photosynthetic rates of seaweeds increase with temperature, plateau at a maximal level, and then rapidly decline near the upper critical temperature **(Eggert *et al*., 2003)**. As for salinity, it ranged from 40 ‰ – 41 ‰. The minimum salinity recorded in winter and the maximum in the summer. The Crack is found in a dry region (South Sinai) where the evaporation rate is high compare to the rainfall. Because of the high evaporation rate and the complete lack of fresh water input, the Red Sea is one of the most saline water bodies in direct connection with the world oceans. The most abundant species in the crack are the ones that are most adapted to the special conditions of crack in terms of variations in temperature, salinity, and shade resulting from the presence of barrier walls for lighting during daylight hours.

Physico-chemical characteristics of water affect growth responses of algal flora in aquatic ecosystems (**Abdulwahab & Rabee, 2015; Sharma *et al*., 2016**) and the growth performance of algal flora depend on many biotic and abiotic factors of the aquatic environment (**El-Shafai *et al*., 2007; Ansari & Khan, 2009; Lu *et al*., 2010**). Light and temperature determines the total photosynthesis in aquatic ecosystems (**Ansari & Khan, 2008; Olive *et al*., 2009**). Light is an important limiting factor for marine algae because of their habitat submersed in water (**Dennison *et al*., 1993**).

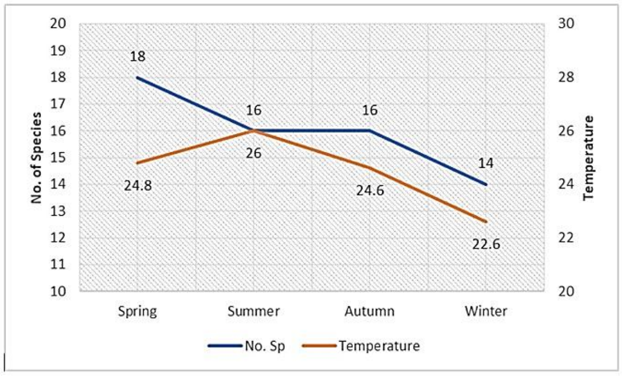

Fig. 3. The relation between Number of Species and crack water surface temperature.

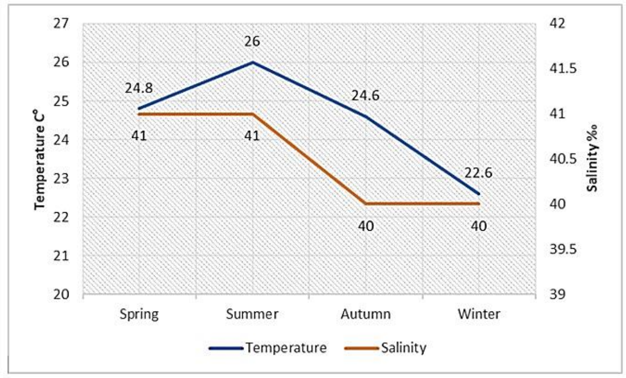

Fig. 2 . The Seasonal Variation in Temperature and Salinity in Ras Muhammad Earthquake Crack

- **Identification of taxa**

There are 19 taxa had been identified to the level of the species level following the standard taxonomically guides which dealing with the seaweeds of the Indo-pacific region and the general references of the tropical and subtropical areas and the History catalogue of **Papenfuss, G.F. 1968** and **(Guiry, M.D. 2020)**. The *Chlorophyta* is the most diverse division and prevailed with (9 taxa) followed by *Rhodophyta* (5 taxa), then *Ochrophyta* (3 taxa), and the last division is *Cyanophyceae* (2 taxa) (**Error! Reference source not found.**). **Hegazi, et al. (2006)**. Made an overview of the algal communities in Ras Muhammad Earthquake Pool. He found that twenty species of fauna and flora were observed on the steep and shaded walls of the cracks. They are favorable to life in condition of high manganese and iron oxides of the substratum.

Table 1: List of the recorded species at the Earthquake Crack.

Chlorophyta		***Ochrophyta***	
1	*Bryopsis corymbosa* J.Agardh 1842.	**10**	*Dictyota dichotoma* (Hudson) J.V.Lamouroux 1809.
2	*Bryopsis plumosa* (Hudson) C.Agardh 1823.	**11**	*Ectocarpus siliculosus* (Dillwyn) Lyngbye, 1819
3	*Cladophoropsis membranacea* (Hofman Bang ex C.Agardh) Børgesen 1905.	**12**	*Lobophora variegata* (J.V.Lamouroux) Womersley ex E.C.Oliveira 1977.
4	*Codium dwarkense* Børgesen 1947.	***Rhodophyta***	
5	*Valonia aegagropila* C.Agardh 1823.	**13**	*Botryocladia leptopoda* (J.Agardh) Kylin 1931.
6	*Valonia ventricosa* J.Agardh 1887.	**14**	*Ceramium diaphanum* (Lightfoot) Roth 1806. *Ceramium gracillimum* (Kützing) Zanardini 1847
7	*Ulva intestinalis* Linnaeus 1753.	**15**	*Gelidium pusillum* (Stackhouse) Le Jolis 1863: 139
8	*Ulva flexuosa* Wulfen 1803.	**16**	*Peyssonnelia involvens* Zanardini 1858: 269,
9	*Rhizoclonium grande* Børgesen 1935.	**17**	*Sporolithon erythraeum* (Rothpletz) Kylin 1956: 205
	Cyanophyceae		
18	*Lyngbya aestuarii* Liebman ex Gomont 1892.	**19**	*Oscillatoria nigroviridis* Thwaites ex Gomont 1892.

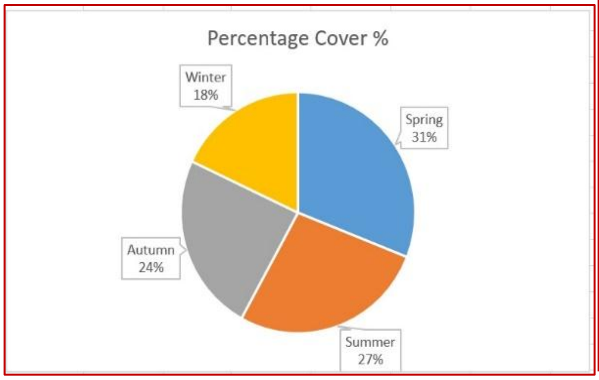

Fig. 5. Percentage Cover of Seaweeds.

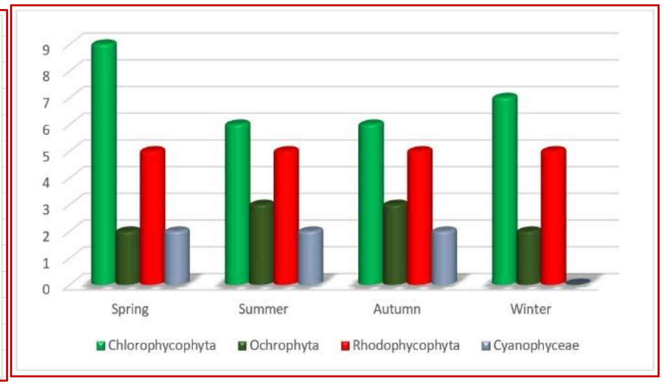

Fig. 4. No. of seaweeds phyla in each Vegetation in seasons in Crack.

The study showed that, *Codium dwarkense*, *Valonia aegagropila* and *Lobophora variegata*, were the most dominant species over the studied seasons. *Codium dwarkense* is light greenish spongy algae, attached by flat discs with many erect cylindrical axes; erect axes 16 cm or more tall, terete, 2 – 4 mm broad, many times regularly dichotomously divided at a distance of 2 – 3 cm or a little more between the divisions; angles between branches narrow, straight and upwardly directed. *Valonia aegagropila* is the second dominant species in the cracks, it is densely packed, single-cell bladders with a tendency towards a long, distorted, curved-sausage shape. The dark green vesicles, grow up to ½ inch in length. The vesicles are not singular, branching off into successive tiers of bladders, up to five sprouting from the top of each. This branching can be difficult to detect visually, given the often very tight clustering of the vesicles (**Hegazi *et al*., 2006**). *Lobophora variegata* is generally greenish-brown or pale brown, which grows in overlapping flat blades which may cover large areas of the crack-bed with a roof-tile like pattern.

The maximum percentage cover of algal species in Ras Muhammad earthquake crack during the spring **(Fig 4)**, where the highest percentage cover and healthy status of *Codium dwarkense*, *Valonia aegagropila*, *Lobophora variegata* and *Valonia ventricosa* were observed during the Spring, due to the temperature level is suitable for healthy growth and also the shadow of the crack walls, which always helps the algal abundances. and other species of algae slightly decrease in its cover. These algae also became traps for sediment that contribute to the continuity of this cover and no place is left for the settlement and development of new other species.

In this study, we find that the diversity of seaweeds on the earthquakes crack was lower than on the Ras Muhammad reef flat. The algal percentage cover is higher than of this on the reef flat. This observed during the seasonal survey and may be a result of the high temperature, low tidal fluctuations, low salinity and high supply of minerals (iron and manganese) due to their proximately landmass and from the substratum which appeared to be the main environmental factor governing the abundance and distribution of the flora in the crack.

Table 2: Species Diversity Indices during the study seasons.

	Spring	Summer	Autumn	Winter
Taxa_S	18	16	16	14
Dominance_D	0.0556	0.0625	0.0625	0.07143
Simpson_1-D	0.9444	0.9375	0.9375	0.9286
Shannon_H	2.89	2.773	2.773	2.639

As for the similarity between the study seasons, there is a rapprochement between the spring and the summer in the abundance of species, and their density **(Fig. 7)**. This follows the winter season and the farthest is the Autumn season. **(Fig. 6)** There is a strong similarity between phyla brown and blue-green algae (*Cyanophyta* and *Ochrophyta*), this is the most tolerant phyla to the Environmental conditions of the Earthquake crack. *Chlorophyta* and *Rhodophyta* are more sensitive to the Environmental changes in crack but have high seasonality species richness.

The great similarity between the spring and summer seasons is due to the favourable environmental conditions for better growth of marine algae in terms of abundance in numbers of individuals as well as the number of species present in the crevice during different seasons. Spring and summer are characterized by warm water in the crevice, which stimulates better growth for most families with seaweed.

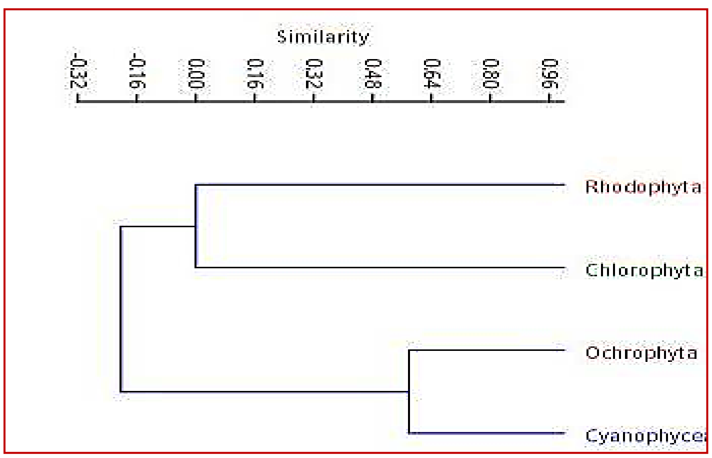

Fig. 6. The Similarity Between the Seaweeds Phyla according to the species abundances.

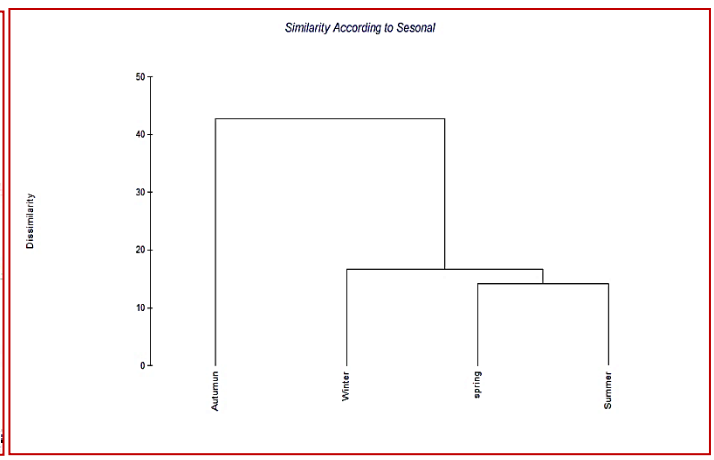

Fig. 7. The Similarity according to Seasonal Diversity

There is a difference in AFDW of each algae Species, where the winter season showed the highest weight in all species. The *Rhodophyta* (Red Algae), have the highest AFDW, then the *Ochrophyta* (Brown Algae), and the *Chlorophyta* (Green Algae) have the lowest AFDW (Figure 8). Red algae are the most algae resistant to seasonal variation of environmental conditions such as temperature change, salinity, lack of currents and high nutrients, so it has higher biomass Throughout the year. Marine chlorophytic algae are very sensitive to aquatic environment and are considered as strong indicators for the ecological health of aquatic ecosystems (**Harley *et al*., 2006; Faveri *et al*., 2010**).

This study is considered to be a basic pillar for intensive environmental surveying in the near future for such unique environments.

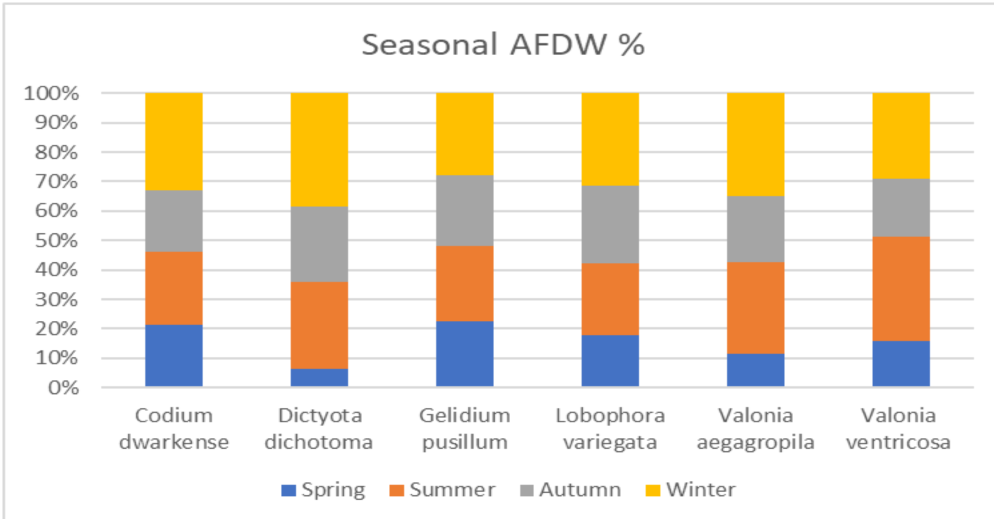

Fig. 6. Seasonal Variations in AFDW of Dominance Species.

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الملخص العربي

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دراسة التغيرات الزمنية للغطاء الخضري للطحالب البحرية بالشق الزلزالي بمحمية رأس محمد (الحديقة الوطنية). حيث تم تقييم وفرة الأعشاب البحرية وتوزيعها باستخدام مقياس السائد، والوفير، والمتكرر، والعرضي والنادر (DAFOR)، وهي طريقة لتحديد وفرة الأنواع وثراء المجتمع، خاصة خلال عمليات المسح السريع بين المد والجزر، كما هو الحال في حالتنا عندما يصعب قياس الأعداد الدقيقة أو تغطية الأنواع في الحقل. تم حصر عدد ١٩ نوعًا من الأعشاب البحرية في الشق الزلزالي برأس محمد، تنتمي الي أربع عائلات مختلفة وتم تحديده إلى مستوى النوع باتباع الأدلة التصنيفية القياسية التي تتعامل مع الأعشاب البحرية في منطقة المحيط الهادئ الهندي والمراجع العامة المناطق الاستوائية وشبه الاستوائية. تعتبر الطحالب الخضراء هي القسم الأكثر تنوعًا ونسود بـ ٩ أنواع تليها الطحالب الحمراء (٥ أنواع)، ثم الطحالب البنية (٣ أنواع)، والقسم الأخير هو الطحالب الخضراء المزرقة (نوعين)، وتؤكد هذه الدراسة التأثير الكبير للتغيرات الموسمية، وخاصة درجة الحرارة والملوحة في التوزيع الزمني والكتلة الحيوية لتصنيف الأعشاب البحرية في صدع زلزال رأس محمد.