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Mapping of Seafloor and Delineating Coral Reefs of Southern Iraq/Northwest Arabian Gulf by Side Scan Sonar Technique

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Abstract - High-resolution Side Scan Sonar data, under-water observation (video and photograph) and bottom samples (rocks and sediments) were integrated to map the seafloor of the Palinurus shoal which is one of the submerged shoal site in the Iraqi territorial marine, Northwest region of the Arabian Gulf. The Side Scan Sonar field survey was carried out along with eight parallel profile extending in SE-NW direction, at a length of 2.8 km for each line. Four backscatter patterns were mapped within the study area. The pattern reflects various seafloor lithology. The average depth of sea bottom was determined at 7 - 10 m. Coral Reefs were mainly found at two parts of the shoal site in the formed assemblages and sporadic in central and northern parts of the site respectively. These coral take different shapes, sizes and colors. Also, they are live in some places and dead in others.

Keywords: Arabian Gulf (AG), Side Scan Sonar (SSS), Seafloor Mapping (SFM), Coral Reefs (CR).

Introduction

Coral Reefs (CR) are found in the seas and oceans that are recognized by scientists as well as the world's most biologically diverse ecosystems. Many studies have documented the stresses on reefs worldwide with concomitant degradation (Lough, 2000; Wilkinson, 2000). The Arabian Gulf (AG) is characterized by its harsh environmental conditions such as high water temperature and salinity (Coles and Fadlallah, 1991), therefore, CR have been persisting probably the most difficult environment for reef-building corals (Kinsman, 1964 ; Downing, 1985 ; Sheppard *et al.*, 1992; Riegl, 2001; Sheppard and Loughland, 2002). In additional to annual temperature up to 20 °C, marine biota in the AG has been affected by several strong sea-surface temperature anomalies. The development of coral communities and reef growth in the AG are intricately linked to disturbance frequency (climate changes), and has been intensely studied in this respect and several ancillary studies documenting the biological and geological dynamics of reef building exist for the AG. Coral reefs are distributed widely throughout the AG, but not found in the narrow section of the Iraqi coast.

The AG has a shallow depth where there are many large and small islands extend near the coasts or toward the Gulf. There are many other islands under sea level that do not rise above the sea level. The islands in the AG region have several origins, The coastline of Iraq is about 58 km, although this distance is small relative to the others Gulf coasts, it is important because it is the only part of the Gulf coasts that has the permanent water inlets from Shatt Al-Arab and Khor Abdullah. The presence of the sedimentary structures that have a shallow features in local sites are important because they may represent suitable sites for Coral Reefs (CR) growth in case the other conditions are available.

The marine geophysical studies (e.g., Side Scan Sonar [SSS] and sub-bottom profilers [SBP]) are essential for design, map and construction the crustal, structure and morphology of the sea bottom. The goal of SSS is to map the seafloor features properties. The acoustic backscatter response recorded by SSS systems was well suited for the detection of sediment cover contrasts in the seafloor. Because, the large extent of the sediments are appeared as spatial trends in backscatter corresponds to changes in texture and microtopography of the sediments (Johnson and Helferty, 1990; LeBlanc *et al.*, 1992 and 1995). In the Iraqi regional marines, there are many shoals sites relative to surrounding areas are missing of any marine geophysical surveys. So, the aim of the present study have used SSS techniques to specify the geomorphologic features and structures of sea bottom, explore and delineate the existence of the CR in the study area which represents one of the submerged shoal site In the Iraqi territorial marine, it was named as Palinurus Shoal (PS) in Admiralty map.

Study area and geological setting:

The location map of the present study area was displayed in Figure (1). The study area lies in the extreme southern part of Iraq at the vicinity of Khor Al-Khafka within Iraqi marine border about 42 km southwest of Shatt Al-Arab estuary and 40.3 km south Khor Abdullah entrance. The study area represents the northern part of the AG.

The Gulf is an elongated basin located in the south of the Zagros fold belt between the Tigris-Euphrates Delta and the Straits of Hormuz. It is the second smallest marine body, and it lies in the Arabian plate (Waris, 1989). Its evolution agreed to be commenced at Late Tertiary and has been directly influenced by the continental collision along the Zagros fold belt. The first continental collision of Arabian and Central Iran took place during the Late Cretaceous, and by early Miocene a Proto-AG was evolved from the closure of the Neo-Tethys (Koop and Stoneley, 1982). The basin of the Gulf is asymmetrical where the slope of the Arabian flank is much gentler than that of the Iranian side and the deepest water lies close to the Iranian shore (Kassler, 1973). A north-trending bathymetric high, centered around 52 ^{o}E longitude, divides the Gulf into two major parts. The relief is small, but this sub-division may be tectonically controlled. The basement beneath the Gulf dips towards the northeast and extends to the main Zagros thrust (Warsi, 1989).

The coastal region in the Arabian side of the Gulf was tectonically stable with only small movements (Kassler, 1973). The main morphologic features have been formed by tectonic activity. Climate and rock type play secondary roles. A flat deltaic surface was formed by the flood plains of the Tigris, Euphrates and Karun rivers. According to Seibold and Vollbrecht (1969) and Seibold *et al.* (1973), the submarine topography of the Gulf was divided into seven bathymetric provinces namely: (1) The Mesopotamian Shallow Shelf; (2) The Arabian Shallow Shelf; (3) The Western Basins; (4) The Central Swell; (5) The Eastern Basin; (6) The Eastern Swell and (7) Hormuz Straits. The study area was located in the Mesopotamian shallow shelf province. The sea bottom depth in the study area was from 6 to 12 m, while the depth was about 14 to 20 m in the surround area (UKHO, Admiralty map, 2004).

Side-Scan Sonar (SSS) Technique:

The SSS is an active system consist of a long acoustic array provide a beam which was wide perpendicular to the array and narrow parallel to the array's long

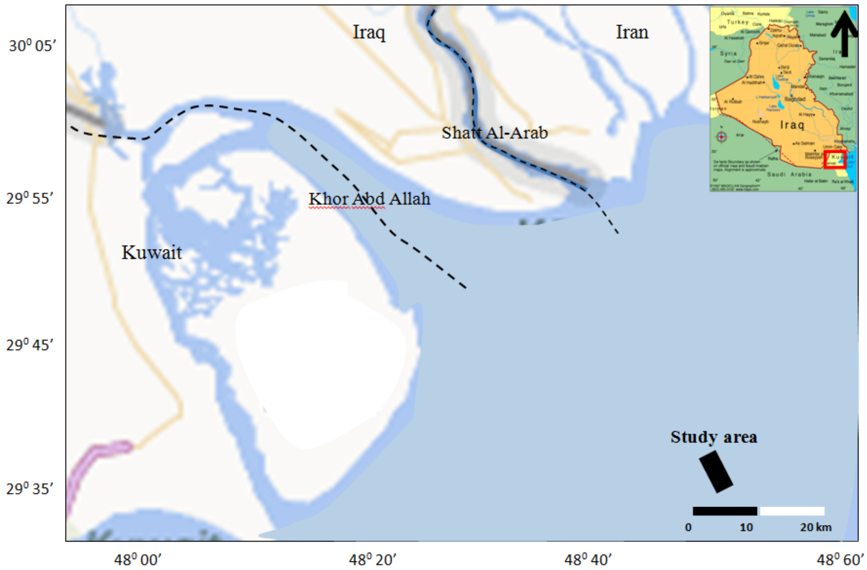

Figure 1. Location map of the study area.

axis (Urick, 1983; Mazel, 1985). SSS is a category of sonar system that was used efficiently to create an image of large areas of the sea floor. It may be used to conduct surveys for maritime archeology, in conjunction with seafloor samples it was able to provide an understanding of the differences in material and texture type of the seabed (Fig. 2). The SSS imagery was also a commonly used tool to map the distribution of sea bottom sediments, as well as detect the occurrence of CR (Hooge *et al.*, 2004; Wheeler *et al.*, 2005; Collier and Humber, 2007; Guilloux *et al.*, 2009).

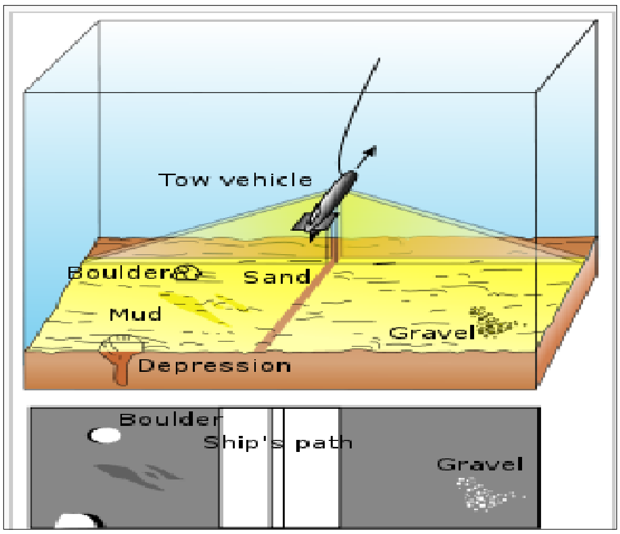

Figure 2. Diagram of side scan sonar.

Side scan uses a sonar device that emits conical or fan-shaped pulses down toward the seafloor across a wide angle perpendicular to the path of the sensor through the water which may be towed from a surface vessel or submarine, or mounted on the ship's hull. The intensity of the acoustic reflections from the seafloor of this fan-shaped beam was recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an image of the sea bottom within the swath (coverage width) of the beam. The sound frequencies were used in side-scan sonar usually ranged from 100 to 800 kHz; higher frequencies yield better resolution but less range. A frequency of 500 kHz gives a shorter range, up to 80 m per beam but provides greater resolution and was recommended for the detailed inspection of coastal structures under most circumstances (Urick, 1983; Mazel, 1985).

Field work:

The SSS survey was carried out using the Imagenex Model 872 "YellowFin" marine geophysical Instrument (produced by Imagenex Technology Corp., USA). Acoustic energy was projected laterally from a pair of transducers mounted a towed cylindrical body. The horizontal beam of energy was from 0.2 to 2 deg wide. Marine survey has been conducted during three marine cruises on board of the investigation ship (Al-Bahith) belongs to the Marine Sciences Centre. The survey was conducted during three time periods, the first was from 6-16/11/2013, the second was from 25/5-4/6-2014 and the third was from 25/9-30/9-2014 by using fiberglass vessel that appropriate for the marine measurement (Fig. 3) to obtain the optimum results.

Figure 3. Pictures of the Yellowfin equipment that has been used for the SSS survey before and during the measurements are taking.

The SSS surveys consisted of eight parallels survey profile that have been run over the study area oriented SE-NW from southeast to northwest, lengths of each profile averaged about 2.8 km. Total survey length was 22.4 km of track line. The collected data in the study areas are covered approximately 2.24 km^2 of the sea floor, the spacing between each profile is about 100 m and the recovery area of the device (50 - 50 m to each sides) was about 100 m (Fig. 4).

In addition to SSS surveys, rock and sediments samples from sea-bottom, direct observations to the bottom by divers, bottom camera and video were performed to determine the best characterization of sea bottom.

Results and Discussion

The accuracy and ability of the system to provide an imagery of the sea bed depends on number of factors including the material type, size, shape of material and structures, refraction, noise, biological interference, boat speed, surface reflections and sonar stability. On a homogeneous bottom type, shadow zones or lighter areas (or darker areas for digital reverse image display) on the sonar record are typically a function of the amount of personification an area receives. A shadow zone in front (towards the sonar) of a strong reflector indicates a depression in the sea floor. A shadow zone behind (away from the sonar) of a strong reflector, indicates a rise in the sea floor.

The presence and growth of CR depends primarily on the availability of shallow depths, hard bottom of the sea and low turbidity, as well as the suitable water temperature.

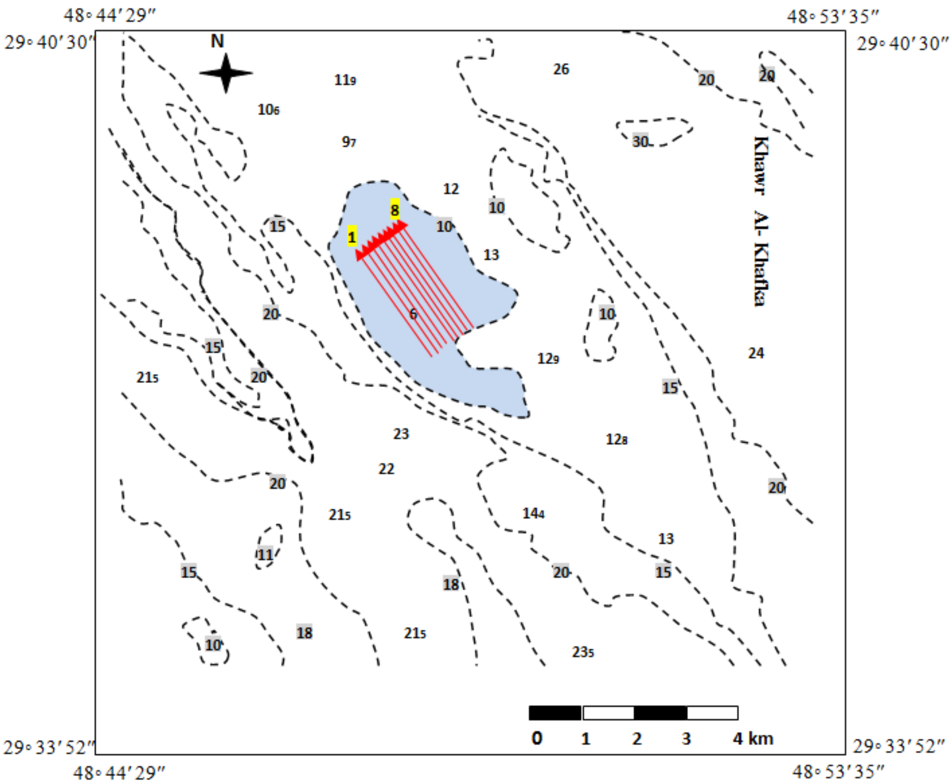

Figure 4. The SSS track lines (bathymetric of the study area and surrounding modified from Admiralty map of Khawr Abdullah and Shatt Al-Arab, UKHO, 2004).

To obtain a comprehensive depiction of CR and sediments distribution in the study area, all SSS sonographs were laid out side by side to show all the survey area at once and a complete map of seafloor (Fig. 5). Color density changes on the SSS sonograph represent well-defined facies. In general, the backscatter intensity was highest in the north and in the center of the site. Then, the color was reduced in the region between the north and the center part and in the southward, although, there are high-backscatter patches in the south.

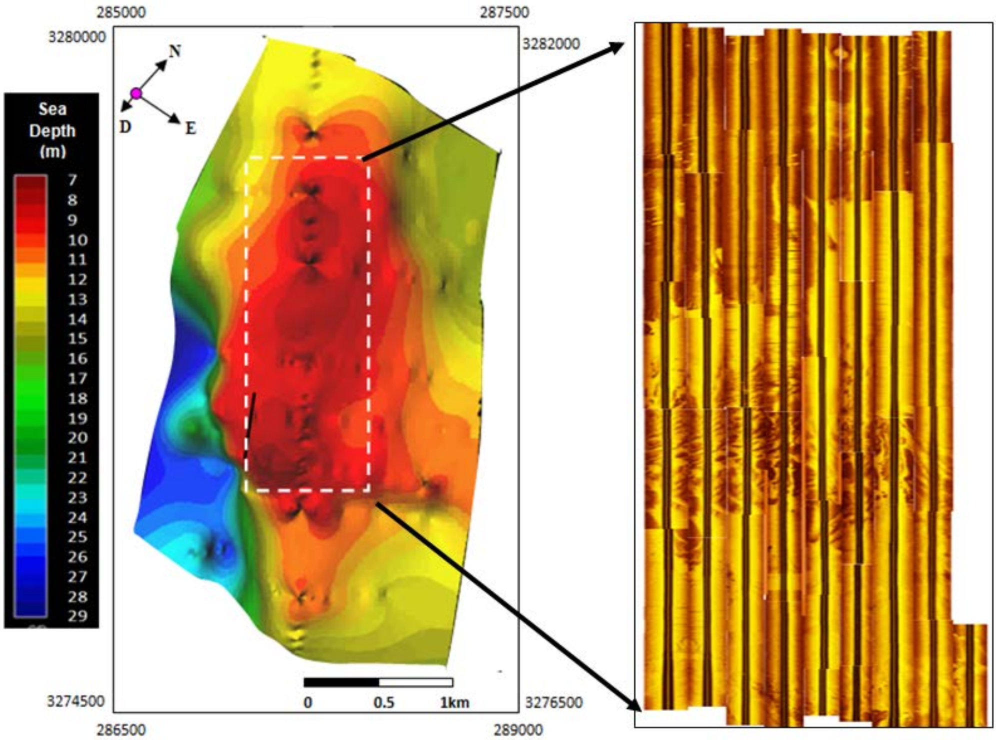

Figure 5. 3D bathymetry map with the area that had been covered by SSS (left), Sea-floor mapping based on SSS image (all sonographes) (right). (3D bathymetry map presented by Al-Musawi *et al.* (2015).

Four distinct sea bottom types were identified qualitatively on the basis of the acoustic characteristics (backscatter) of the SSS sonographs. SSS results were integrated with the underwater video and photograph was taken by divers and bottom samples inspection (sediments and rocks). These sets of data represented a multi-line of evidences to: (1) Pattern with strong backscatter and hard-bottom, indicate a strong surface return, rubble blocks and fractures resulting in areas (Fig. 6) with acoustic shadows (Fig. 7); (2) Pattern of relative strong backscatter focused in the north of the SSS map. This pattern corresponds to coarse and medium sand with shells fragments more than carbonate rocks, the sand sediments covered the rock with the thickness of about 10 cm (Fig. 7); (3) Pattern of relatively low backscatter noticed in the south of the SSS map. This pattern corresponds to the medium sand with shells fragments and extraneous carbonate rocks, also the sand sediments cover the rock with thickness of about 10 cm (Fig. 8); (4) Pattern of weak backscatter, its generally featureless, that appear in the areas between P1-P2 and P1-P3. This pattern are composed of medium and fine sand with shells fragments, also, the presence of sediment waves was noticeable and it was associated to this pattern (Fig. 8).

Extensive sea level fluctuations have occurred globally and mostly caused contemporary changes in sea level. When the AG region was flooded, reef growth has occurred at shallow regions. The under-water shoal sites are important today to provide the conditions of CR occurrence which achieves two important things: first the hard substrate was detected by sonographs elevated nearer to proper sun light, and secondary slopes are created which are less vulnerable than other parts of the AG floor to sediment accumulation.

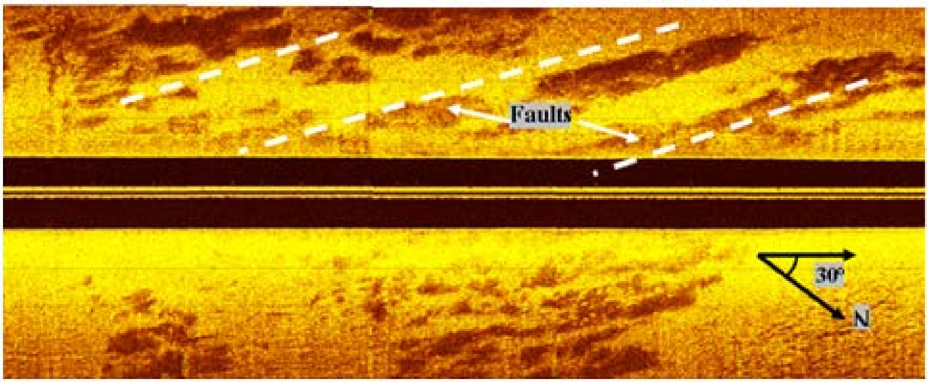

Figure 6. SSS image showing the possible faults in P-1.

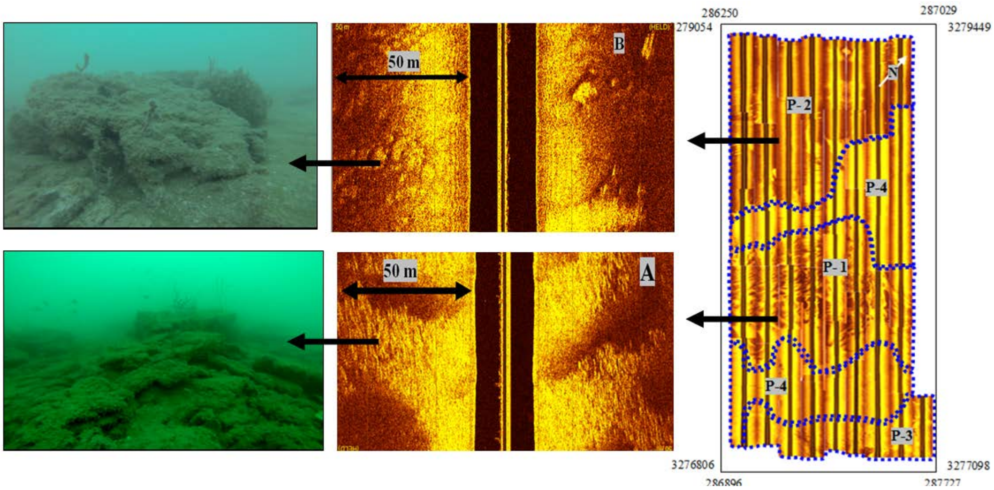

Figure 7. Sea-floor mapping of backscatter patterns based on SSS image. A and B represents the sonographs showing the characteristic feature of P-1 and P-2 respectively with under-water images (left).

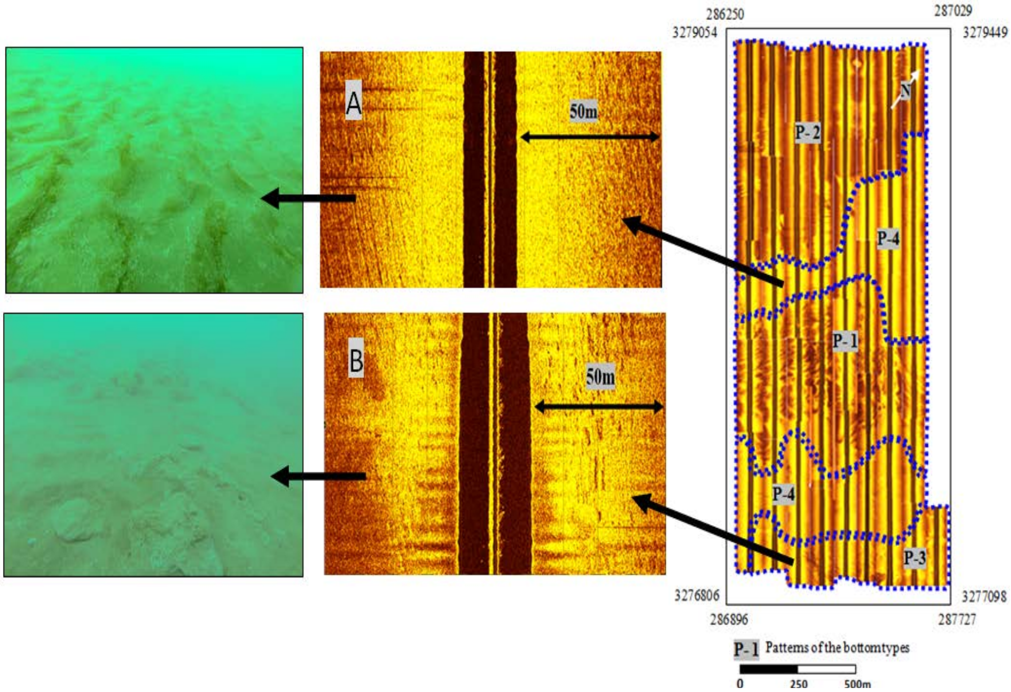

Figure 8. Sea-floor mapping of backscatter patterns based on SSS image. A and B represents the sonographs showing the characteristic feature of P-3 and P-4 respectively with under-water images (left).

The results of the gathered information revealed that the CR in the study area occurred in two sites, between the water depths from 7 to 10 m at the central and northern parts of the study area as indicated in locations P1 and P2, respectively. The center (P1) was characterized by the presence of coral reefs in assemblages, while the northern part (P2) was found as sporadically.

The current study indicated the presence of many coral species with different shapes, sizes and colors (Fig. 9). In addition to other locations, it contains live and dead corals (according to the under-water observations). Some corals rise above the seabed, whereas the others are buried or half buried within the sediments. As well as, the study revealed that the locations are containing coral communities are characterized by biodiversity and the reef rocks are consisting of sandy limestone and sandstone mixed with shells and bones of marine organisms.

The present study attempted to explain if the presence of CR are recent or ancient in origin and their age. The answer was not possible in the present time due to the lack of the technique and the necessary tests for the materials which require the collection of samples from the sea bottom for several meters. The equipment cannot penetrate the bottom because of the hardness of rocks, as well as lack of dating test. But, an experiment has been made which include sinking a concrete debris during one of the cruise and left it for months (because a hard bottom was one important conditions for coral growth founding to adhere to it, after this it was observed that the corals began to grow on the body well.

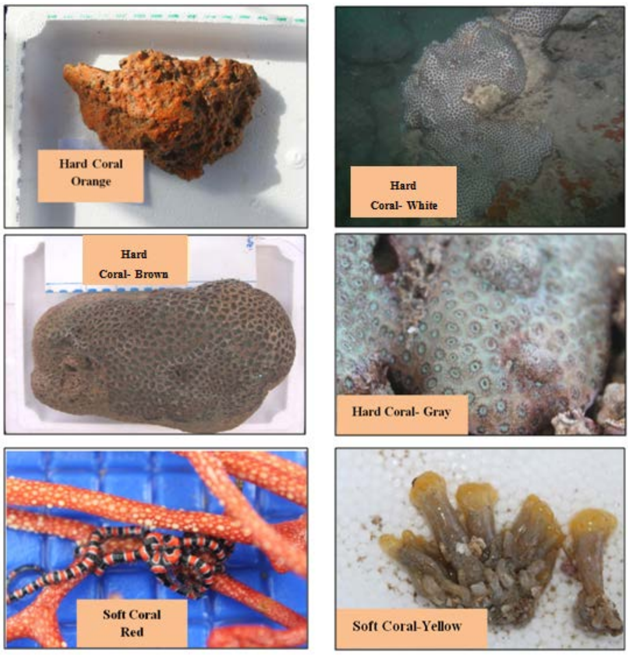

Figure 9. Types of corals that have been seen in the study area as observed and collected by divers.

Finally, after these results, it can be said that the current environmental conditions are suitable for the growth of CR. On the other hand, the existence of dead coral can be explained by two reasons, first, fluctuations in sea level was taking place during the previous times which have been followed by variation in environmental conditions associated with temperature of water, water depth, speed of the marine waves and tides (which cause erosion of coral rocks as well as increased turbidity currents then decrease coral growth). The second reason is the exhausted fishing which was usually used (trawl), a large fishing net that was used by dragging from the fishing boat for a large distances and this has been seen frequently in the study area due to the abundance of fishing.

Conclusion

The interpretation of SSS records together with under-water observation and the bottom samples analysis has provided a much more accurate map of the present seafloor of the study area.

- Four distinct patterns from sea bottom types includes, P1: This pattern has been interpreted and characterized by a strong surface return, hard-bottom, rubble blocks and fractures resulting in areas with acoustic shadows that appear in the south of the study area. P2: Pattern of relative strong backscatter that appear in the north of the study area, this pattern corresponds of coarse and medium sand with shells fragments more than carbonate rocks. P3: Pattern of relatively low backscatter that appear in the south of the study area, this pattern corresponds to medium sand with shells fragments with extraneous carbonate rocks and P4: Pattern of weak backscatter, its generally featureless, that appear in the area between P1-P2 and P1-P3, this pattern are composed of medium and fine sand with shells fragments.

- The CR in the study area have been occurred in two sites, between water depths 7 to 10 m, precisely in the central and northern regions of the study area presented by the sites P1 and P2 respectively. The center (P1) was characterized by the presence of coral reefs in assemblages, while the northern region (P2) it was found as sporadically.
- The results of the study suggested that the current environmental conditions are suitable for the growth of CR. There are others sites that may be resembled and could indicate the possible existence of CR outside the study area, specifically, in the region east of the study area. There are another under-water shoal sites, but these may be less obvious than that in the study area and these will be depending on the environmental conditions.

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رسم ظواهر قاع البحر وتحديد الشعب المرجانية في أقصى الجزء الجنوبي من العراق/ شمال غرب الخليج العربي باستخدام تقنية السونار البحري

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المستخلص - تتضمن الدراسة الحالية استخدام تقنية رسم المقاطع الصورية للقيعان البحرية باستخدام السونار (Side Scan Sonar) ذات التحليل

الدقيق وبالتكامل مع المعلومات المستحصلة من الغوص العلمي (تصوير وفيديو تحت الماء) فضلاً عن نماذج القاع لرسم وتحديد ظواهر ومعالم قاع البحر وتحديد تواجد الشعاب المرجانية لأحد المواقع الضحلة الغاطسة في المياه الإقليمية العراقية، شمال غرب الخليج العربي، والذي يسمى بموقع البالينورس الضحل. تضمن المسح البحري لتقنية SSS انجاز 8 مسارات متوازية باتجاه شمال شرق-جنوب غرب، طول كل مسار 2.8 كم. تمت عملية معالجة البيانات وجمع مقاطع SSS مع البعض لإعطاء صورة متكاملة للقاع. أظهر تفسير النتائج أن هنالك أربعة أنماط للقاع تتضمن سحنات رسوبية اعتمادا على دقة تمييز الظواهر والتراكيب التي تظهر في مقاطع السونار، والتي تعتمد بالدرجة الأساس على نوعية رواسب القاع. بينت النتائج أيضاً أن أعماق البحر في موقع الدراسة تراوحت ما بين 7م في الجزء المركزي من الموقع إلى 10م في الجزء الشمالي. تم تحديد مواقع تواجد الشعب المرجانية، وبينت النتائج أن تجمعات المرجان تتركز في المناطق الصخرية، وبالتحديد في مركز منطقة الدراسة (بشكل تجمعات) فضلاً عن الجهة الشمالية منها (بشكل متفرق). كما أظهرت النتائج أن هنالك أنواع عديدة من المرجان الحي (الذي يرتفع عن القاع) والميت (المغطى بالرواسب القاعية) والمتغير في النوع والحجم والشكل.