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Seafloor Characterization and Backscatter Variability of Coral Reef by Different Acoustic Techniques, El-Gouna, Red Sea, Egypt

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Abstract

Seabed sediment classification is an important research study for marine geology, marine environment and other research areas. The study area located at 25 km North of Hurghada. This study aims at identification of sea bed sediments and coral reef habitat of El-Gouna Area. Side scan sonar and QTC system used for surveying the area. Detection of the destroyed coral reef areas depends on the acoustic backscatter and diving survey along the study area. The sea floor sediment types, features and the biological habitats were the main causes that control the acoustic signature in the study area. The main seabed sediment types in the study area were hard bottom representing the coral reef patches, coarse and fine sand fractions. Overall, the acoustic approach showed consistent results for the assessment and mapping of the benthic habitats in this shallow-water area. Three different acoustic patterns were recognized: pattern of strong backscatter related to coarse sand, while Pattern of weak backscatter confined to silt and fine sand, patches of strong and weak backscatter are Patterns with isolated reflections belong to hard and soft coral reefs.

Keywords: Sediment characteristics; Coral reef; Side scan sonar; single beam echosounder; Bathymetry; Red Sea

Introduction

In regular under water habitat mapping studies side scan sonar and echosounder (single beam or multibeam) in accompanying with QTC system used as remote sensing techniques for surveying, pursued by sediment sampling and sea floor videography for ground-truthing [1-4]. For sea floor mapping acoustic techniques are widely applied and rapidly developed to serve this field of research [5-9].

QTC system is a technology for mapping surficial seabed properties and sediment distribution with echo sounders. The idea is that a change in sediment composition will result in a change in acoustic properties [10,11].

The side scan sonars are able to cover large areas and providing high resolution images of seabed characteristics, due to spreading of wide swaths of sound energy on the sea floor [12,13]. The side scan sonars backscattering are determined by: i) the angle between the incoming wave and the sea floor (incident angle); ii) the sea floor features and slop; iii) the nature of the sea floor its composition and density; iv) the configuration of the transducers towards the targets.

El Gouna started as a touristic resort dating from about 1990. Through time, El Gouna is evolving to be more like a city which holds permanent residents beside the tourists. The study area was located in the front of El-Gouna Bay which located in conveniently 25 kilometres north of the city of Hurghada, capital of the Red sea governorate. It extends from north to south between latitude 27° 44' N, 27° 39' N and longitude 33° 68' and 33° 72' E. It has rectangular shape opened toward the south. The shoreline of the bay extends for about 10 km as shown in the (Figure 1).

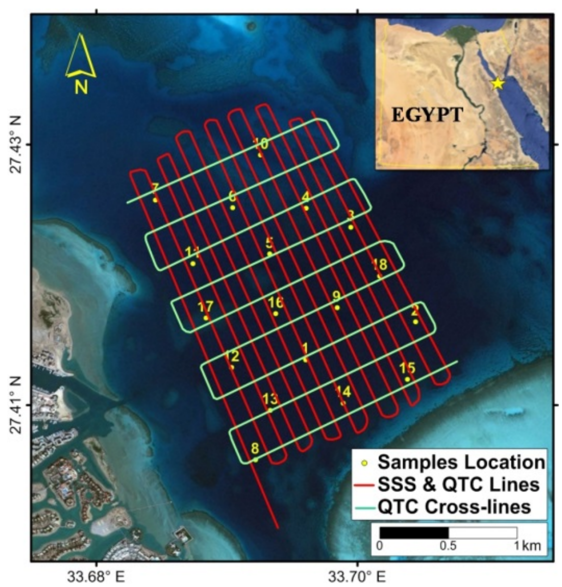

Figure 1: The area of study (El-Gouna Bay), collected sediment stations, sidescan and QTC survey lines.

Material and Methods

Side scan data acquisition and processing

The side scan sonar (SSS) has been defined as an acoustic imaging device used as a sound propagation tool for data acquisition. It considered as an active remote sensing system that emits a pulse of sound and then listens to echoes generating images of the sea floor.

For conventional SSS two sets of transducers (one port and one starboard) are carried by the stream lined tow fish, towed behind the survey vessel. An electrical impulse from a transmitter is converted into sound by the transducer and sent into the water. When this wave strikes the sea bed and/or objects it rebounds. This echo strike the transducer, which convert it back into an electrical signal, which is amplified by the receiver and send to the display.

The SSS equipment used during the survey emits both 300 KHz and 900 KHz beams with operation range 75 m. Positioning was done using DGPS (max-CSI) at an accuracy of 1 m. The sonar was towed at a speed of 4 knots. The survey lines should be arranged according to the area of study; it can be parallel, radial or zigzag [14]. In the present study, 15 acoustic survey lines were parallel to the coast line (Figure 1).

The distance travelled from the transducer to the target of the sea floor is called the slant range. In order to determine the real distance, the slant range corrected to true ground distance.

Acoustic backscatter bronze levels range from 0 to 255 has been used during the survey and the processing.

The collected images by the SSS were subjected to analyses for identification of the observed habitat and sea bed characteristics with the Edgetech software package [15]. All the processed data files were mosaicked to build up a composite image using HYPACK [16] software and then the final product were exported as GeoTIFF to allow importation to other software programmes.

QTC data acquisition and processing

The Quester Tangent Corporation (QTC VIEW Series 5) system was connected to a single-beam echosounder (Model: Suzuki 2035) operating at 50 kHz and echo pulse length 0.3 ms. The transducer was side-pole mounted and located 1 m below the water's surface. Differential GPS (GBX-PRO) was used for sub meter accuracy recording position. The DGPS antenna was placed at the top of the pole for accurate positioning. The data acquired using Quester Tangent Real-Time (QTRT) Seabed Classification software and QTC IMPACT software was used for data processing and classification [17]. Twenty six acoustic survey lines, 15 lines oriented parallel to the coastline and 9 cross lines, with 3 km length and 110 m spacing between lines (Figure 1). Survey speed was kept between 4 to 5 knots.

Sediment analysis and ROV videos

Eighteen bottom sediment samples were collected using Van Veen Grab sampler (Figure 1). The stations that had coral reef were sampled by the help of divers; in order protect coral reefs from damage according to Egyptian Environmental Law (4/1994). The sediment grain size was analyzed according to [18]. The ROV (Video ray) was used for detailed study to specific areas by taking video surveys and photographs. Both collected sediment samples and ROV videos were used for ground truth and confirming the acoustic images and signals.

Results and Discussion

Bathymetric survey

The depth in the study area varies between 4 m to 22 m as represented in the bathymetric 2D map (Figure 2). The deepest area was observed at the southern part of eastern side of the study area (appeared in dark blue colour). The shallow areas were characterized by the presence of coral reef patches (4 m to 10 m depth) that mainly located in the Northern and Southern part of the study area. The steep slope was observed surrounding the areas of hard coral reef colonies, while the gentle slope was in the areas of fine sand sediment. Figure 3 shows the 3D bathymetric map.

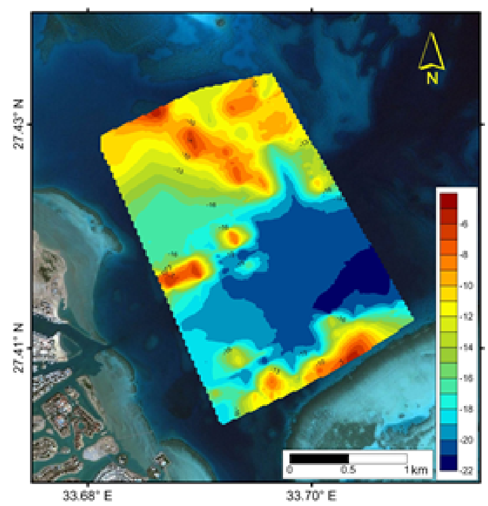

Figure 2: The bathymetric map (2D) of El-Gouna Bay.

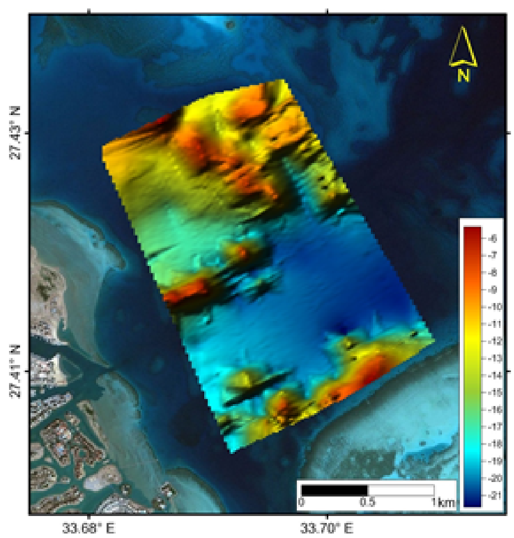

Figure 3: The 3 D bathymetric map of El-Gouna Bay.

Spot dives

Spot dives were used to examine areas, in which a number of habitat types were identified in close proximity to each other, following the initial analysis of the SSS imagery, QTC mapping and video footage.

The spot dives yielded more detailed habitat information, including; sediment type, species assemblages, species abundance and small-scale variability within each habitat. This allowed the more detailed description of habitat types and distributions within the areas covered by spot dives.

El-Gouna study area was characterized by fine sand sediments texture as 44% of the area was covered by very fine sand and 28% was covered by coarse sand; while coral reef patches covered about 28% of the total area. Percentages of sand, silt and clay were shown in Table 1. The main sediment textures observed in El-Gouna study area were sandy silt and sand according to folk classification [18].

Sample No.	Sand %	Silt %	Clay %	Nomenclature
1	22	72	6	Sandy silt
2	21	70	9	Sandy silt
3	98	2	0	Sand
4	ND	ND	ND	Coral reef
5	97	3	0	Sand
6	91	9	0	Sand
7	94	6	0	Sand
8	95	5	0	Sand
9	19	75	6	Sandy silt
10	22	71	7	Sandy silt
11	21	69	10	Sandy silt
12	18	68	14	Sandy silt
13	ND	ND	ND	Coral reef
14	22	72	6	Sandy silt
15	ND	ND	ND	Coral reef
16	ND	ND	ND	Coral reef
17	ND	ND	ND	Coral reef
18	21	69	10	Sandy silt

Table 1: Sediment grain size of surface sediments of El-Gouna area.

The percentages of different species that cover the study area such as live reef-building corals as well as other categories of organisms and substrata are indicated in Table 2. Line transect surveyed indicates that 16 branching, 8 massive, 5 encrusting and 2 solitary species were recorded, while the non scleractanian corals are represented by 1 species only (Tubipora musica).

Name of species and other categories	Percentage (%)
A) Branching	
Acropora variabilis	2.8
A. formosa	2.6
A. lamarcki	2.2
A. maryae	1.9
A. humilis	1.6
A. valenciennesi	1.3
A. tenuis	1.2
A. squarrosa	1.2
Stylophora pistillata	1
S. wellsi	0.9
Ceriatopra hestrix	0.7
Pocillopora verrucosa	0.7
P. damicornis	0.8
Pavona divaricate	0.7
Merulina ampliata	0.6
Montipora grisea	0.5
Total	20.7
B) Massive	
Goniastrea retiformis	1.5
Leptastrea transversa	1.3
Montipora monatsteriata	1.2
Porites lutea	0.8
Favia stelligera	0.6
Favites persi	0.5
Platygyra daedalea	0.4
Galaxea fasciculris	0.2
Total	6.5
C) Hydrocorals	
Millipora dichotoma	2.1
M. platyphylla	1
Total	3.1
D) Non Scleractanian corals	
Tubipora musica	1.9
Total	1.9
E) Encrusting	
Porites echinulata	1.9

Echinopora lamellose	1.6
Montipora spumosa	1.1
Turbinaria mesentrina	0.6
Leptoseris myceloseroldes	0.3
Total	5.5
F) Solitary	
Fungia fungites	0.3
Ctenoctis echinata	0.2
Total	0.5
G) Other categories	
Soft corals	9.5
Dead corals and rocks	25.5
Sand	10.5
Algae	1.5
Rubbles	8.8
Sponges	0.5
Sea urchins	0.3
Shells (bivalves and gastropods)	0.2
Total	56.8

Table 2: Percentage covers of different species of reef-building as well as other categories of organisms and substrata.

Branching corals had the higher coverage percentage 20.7%, followed by massive corals with 6.5%, then encrusting of about 5.5% and finally solitary that had the lowest percent cover 0.5% (Figure 4). Also, the non scleractanian corals covered about 1.9% and hydrocorals covered about 3.1%, while the soft corals covered about 9.5% (Figure 5).

Dead hard corals, rocks and sand have the considerable values 25.5%, while rubbles have lower values 8.8%. Other fauna such as algae, sea urchins, sea shells and sponges have lower percentage cover 2.5% (Figure 6).

The dominance of branching corals on other coral species in the shallow areas may be attributed to the light capturing abilities in shallow water is favoured by branching corals; this consistent with the result of Preston et al., [19]. The scarcity of solitary corals may be because they do not find the suitable substrata to fix on. Algae, sponges and sea urchin were recorded with few numbers. Sediment type control the overall amount of suitable substrata [20] leading to limited abundance.

The field survey shows that the area containing spots of algae, in addition to few individual of sponges, followed by sea urchins and sea shells.

The main phenomenon in this site is the sedimentation rate that appears to be the main factor affecting coral surviving and distribution. The high sedimentation rate kills the coral reefs. These dead corals act as substrata for the new growing colonies.

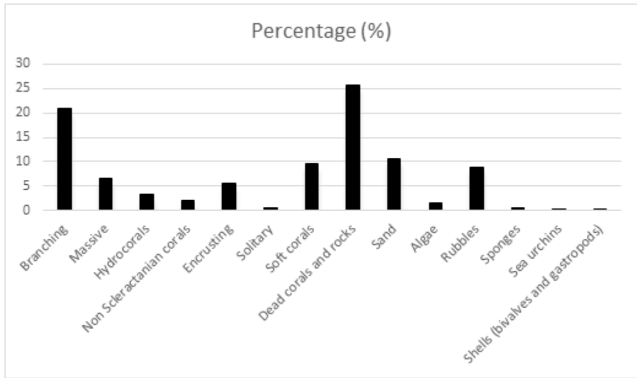

Figure 4: Coverage percentage of coral reef species and other categories of organisms and substrata.

Side scan sonar habitat mapping

The side scan sonar mosaic map (Figure 7) shows high variable acoustic backscatter of the seafloor. The reanalysis of the backscatter mosaic map by using the 'Extract Beam Pattern' of the Hypack software (2014) shows three different acoustic patterns (Figure 8). These patterns represent isolated reflections (b1), weak backscatter (b2) and strong backscatter (b3), respectively.

The isolated reflection backscatter pattern (b1) appears widespread mainly located at the north and southern part of the study area. This area characterized by assemblies of coral reefs. According to the ground truth survey by using ROV images; this pattern is composed mainly of hard coral reef (Figure 5). It characterized by relatively elevated area confirmed from the surrounding seafloor that observed from the wide extension shadow.

The weak backscatter pattern (b2), appear as uniform dark tones of very fine sand to silt sediments, according to the ROV images and bottom samples. This pattern (b2) is mainly found in the central deep part of the study area. That is related to the sedimentation process that is affected by the depth gradient.

The strong backscatter pattern (b3), that appear as lighter tones. It covers different parts on the seabed of the study area as shown in Figure 7. The ground truth data; collected bottom samples and ROV images show that this pattern corresponds to coarse to medium sand overlay dead hard coral (Figure 6). The pattern (b3) is characterized by the presence of coarse sand sediments. This pattern is accompanied by the high relief of hard coral reef colonies (Pattern b1). This observation is related to the depositional mode in the area surrounding the hard reef. The coarse sand aims to deposit around the high relief outcrop of the hard coral reef.

The reanalysis of the backscatter mosaic map by using the 'Extract Beam Pattern' of the Hypack software (2014) clarified the boundaries between different types of sediments and coral reefs. Three different acoustic patterns were recognized along the study area: red colour indicated to hard corals and coarse sediment, blue colour indicated to soft corals and yellow colour indicated to very fine sediments which have benthic area, Figure 8.

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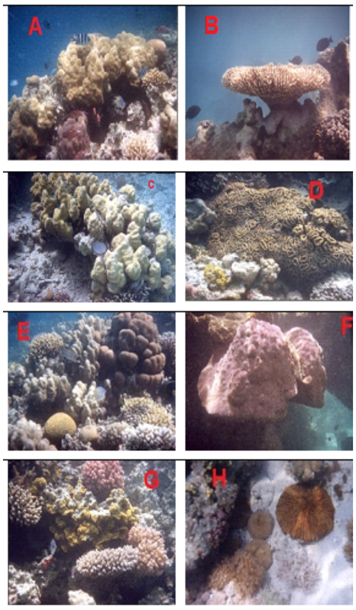

Figure 5: Some coral species recorded in the study area; (A, C, D, E and F show massive corals; B and G are branching corals and H is solitary coral).

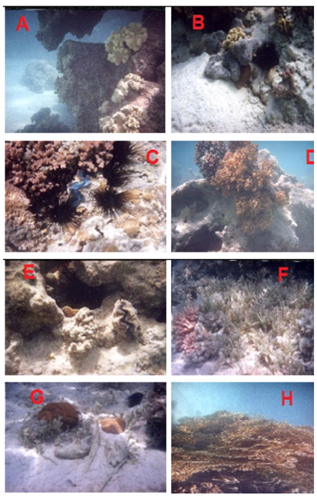

Figure 6: Other categories of organisms and substrata in the study area; (A: Soft corals; B: Black sponges; C: Sea urchins; D: Dead corals; E: Sea shell (bivalves) and Sediments; F: Algae; G: Sea shells (gastropods) and H: Hydrocorals (*Millipora dichotoma*)).

QTC habitat mapping

The acoustic sediment classification data in QTC IMPACT™ revealed the presence of three significant classes (Figure 9). Acoustic class (C1) clearly dominates the vast majority of the survey area, comprising about 60% of the acoustic data set, represented by green colour on map (Figure 9). This class is corresponding to the Sandy silt (very fine sediment) according to collected ROV images and collected sediment analysis.

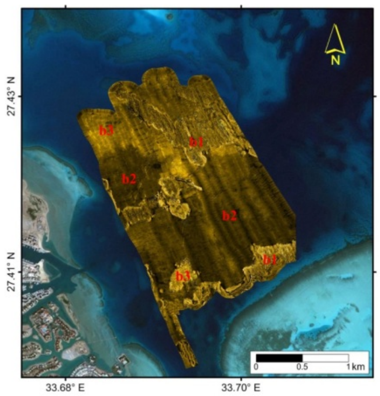

Figure 7: The side scan sonar mosaic map of El-Gouna Bay; (pattern with isolated reflections (b1), pattern of weak backscatter (b2) and pattern of strong backscatter (b3)).

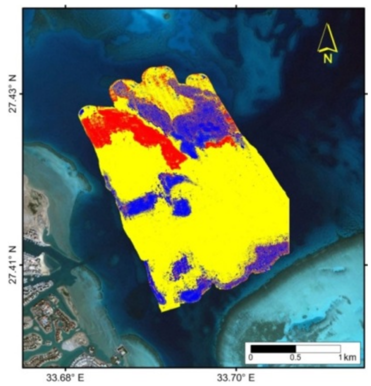

Figure 8: Post-processing for backscatter mosaic map by using the 'Extract Beam Pattern' along the study area: red colour indicates hard corals with coarse sand, blue color indicates soft corals and yellow colour indicates very fine sediments.

Acoustic class (C2) has about 35% of the total acoustic data set, represented by blue colour on map (Figure 9). It corresponds to coral reef patches according to ROV images. Class (C2) covers different parts of the sea floor of the study area and with larger extent; it dominates at the northern part of the study area.

Acoustic class (C3) is the least significant class identified and represents only about 5% of the data set, represented by yellow colour on map (Figure 9). It is corresponding to soft corals, Algae and sponge according to ROV images. Class (C3) was found as small patches in the center of the study area.

It is obvious that the QTC habitat map is less accurate than the SSS habitat map. This is attributed to the low coverage of single beam QTC system used verses to the SSS that depend on swath beam of higher coverage area.

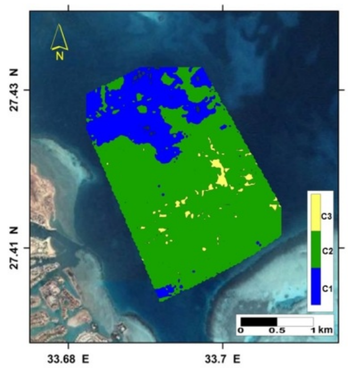

Figure 9: QTC three acoustic classes covering El-Gouna Bay; (C1) corresponds to hard coral reef colonies and coarse sand, (C2) corresponds to fine sand sediment, (C3) is small patch areas mainly soft corals, algae and sponge.

Pattern C1 from QTC is corresponding to both b1 and b3 from SSS. The single beam QTC system was unable to differentiate between the two patterns. While, the pattern C2 is corresponding to b2 that represent the fine sand sediments. On the other hand, QTC was able to detect a different signal corresponding to the soft bodies as soft corals, algae and sponges but in low resolution due to the single beam used.

Conclusions

Three sets of patterns show good classification performance using sonar data from side scan and QTC that cover and illustrate a habitat mapping for El-Gouna bay. These patterns clarify and differentiate between the areas of hard corals, coarse sand, fine sand and soft bodies (soft corals, algae and sponges).

Acoustic method for mapping coral reef substrate is independent of water depth, visibility, light penetration and time. Hence, the acoustic method shows itself to be a better alternative to the conventional transect line method and satellite images in terms of time, cost spent and the results gained especially for large-scale surveys. It is possible to identify the acoustic signatures of different types of materials, such as soft sediment deposits and hard coral.

The use of two different acoustic techniques to survey the same area support the idea that improved reproducibility among repeated surveys of the same area is a reliable indication that the quality and accuracy of acoustic habitat mapping has also been improved. The resolution of the mapping was dependent upon the survey coverage achieved. For the QTC survey, mapping resolution was low, as the single beam echo sounder was used. While, for the side scan sonar, the extents of the habitats were much more accurately defined and more detailed classification of habitat types was; as the swath data collection provide better coverage. So it is recommended to use SSS in shallow areas as for bays and lagoons survey.

The acoustic mapping and ground truth data allowed the habitat types to be described in more detail than ever before, with a far broader range of coral reef and benthic habitats being identified. Areas covered by SSS and ROV video were mapped at a higher resolution, with habitat boundaries and habitat types more accurately mapped. Those areas covered by SSS and spot dives were mapped at an even higher resolution, with the production of highly detailed habitat maps possible.

Finally, the most important advantages of both SSS and remote sensing acoustic technique for coral reef habitat mapping are: i) they are environmentally safe methods; ii) without direct contact with the coral reefs.

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