Benthic Biotopes Remote Sensing Using Single Beam Acoustics on the South Coast of the Qeshm Island, the Persian Gulf

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Received: August 2011 Accepted: September 2011

Abstract

The study presents the result of a new attempt for benthic biotopes remote sensing in the southern coast of the Qeshm Island in the Persian Gulf. This survey site covers approximately 233 km\textsuperscript{2} in water depth between five and 25 m. Bathymetric data was derived from the single beam survey and grab stations, underwater video and photos were undertaken as ground-truthing. The acoustic results showed the survey occurred in shallow waters. Sediments were classified as muddy and into six types following Went-Worth scale. In total, 214 species belonging to 91 families, 48 orders and 20 classes were identified. Majority of species were Polychaete with Cirratulidae, Amphinomidae, Paraonidae and Capitellidae being dominant, respectively. Porifera, Nematoda, Malacostraca, Enopla, Bivalve, Osracoda, Ophiuroidea and other macrofauna comprised the remaining species, respectively. The results showed sediment type did not affect species distribution and richness. The acoustic mapping of southern coast of the Qeshm Island provided preliminary data and initial overview of the sediment biotopes and faunal communities. This was the first attempt to integrate geological, biological and dynamic data of the region.

Keywords: Remote sensing, Biotopes, Benthos, Single beam, Persian Gulf

1. Introduction

Benthic biotope is a spatially defined area where the physical, chemical and biological environment is distinctly different from the surrounding environment. The characterization of habitat requires definition of spatial boundaries and limits of physical factors pertaining to a particular organism or groups of organisms that share environmental preferences and occupy the same habitat type (Kostylev et al., 2001). According to a general theory, because organisms live in or on the sediment, have the specific preferences for particle size and have a reliance on the sediment for feeding and there should be a measurable relationship between the two (Etter and Grassle, 1992; Mair et al., 2009). Additionally, gradients of sediment properties can also vary with depth (Bergen et al., 2001).

Mapping seabed biotopes involves mapping both the sediment composition and morphology of the sea floor and the biological communities, pertaining to it. That is often, highly controlled by the hydrodynamic environment because of a close link between them (Overmeer et al., 2009). Geo-reference maps have been used for integrating new data and have
conveyed an essential knowledge to and about the area (Sartor et al., 2007). Mapping sea floor habitats has also been the fundamental first step necessary for scientific fisheries management, for monitoring environmental change and for assessing the impact of anthropogenic disturbance on benthic organisms. Benthic biotopes are primarily determined by substrate type, which reflects past and present physical processes in the near-bottom environment (Kostylev et al., 2001).

Seabed surveyors have traditionally used sampling device such as grabs, trawls and / or underwater video or photography to collect benthic data from which seabed characteristics could be determined, identified and enumerated (Eleftheriou and McIntyre, 2005). This approach yields detailed data regarding the composition of the seabed from a series of spot samples. However, understanding of the spatial distribution of benthic habitat from such surveys requires the interpolation of data between the sampling points and this can often lead to erroneous assumptions, especially if there is a high degree of geological and biological feature heterogeneity within a survey area (Brown et al., 2005). In recent years, marine scientists have turned to the use of remote sensing systems to help in understanding and mapping the spatial extent of seabed biotopes, which in turn improves our understanding of benthic ecosystems (Mayer, 2006).

Remote sensing methods are the most versatile remote sensors for sub-tidal marine studies. In fact, acoustic record from echo sounders is indicator of the nature of the sea floor (Freitas et al., 2003). This development offers the opportunity for researchers to move away from a process of inference around a matrix of spot samples in to the realm of spatially continual mapping using spot sampling for ground-truthing. Therefore, the geographical distribution of biotopes can be seen to have many potential advantages, including the prospect of full coverage of the seabed as resources allow or priorities dictate (Brown et al., 2002).

Prior investigations focused on animal identification and distribution, sediment type or seabed topography. This work, however, aims to identify and map the benthic biotopes from a shallow coastal shelf area in the southern coast of the Qeshm Island, based on the analysis and interpretation of a single beam seabed echo combined with sediment and benthic animal sampling. The biological objectives are to discriminate distinct assemblages of benthic species (organisms larger than 0.5 mm in linear dimensions), to understand and correlate the relationship between sea floor surficial sediments and biota, and to classify and map the defined benthic biotopes to subsequent management of this area for the first time.

2. Material and methods

2.1. Study Area

The study area lies between 26° 40’ 52” N, 55° 42’ 01” W and 26° 36’ 45” N, 55° 34’ 38” W in the south coasts of the Qeshm Island at the west of the Hormoz strait within the Persian Gulf. This survey site covers approximately 233 km² in water depths between five and 25 m (Fig. 1).

2.2. Geophysical Data

Geophysical data was acquired by the National Geographical Organization aboard Persian Gulf vessel; bathymetric data was derived from the single beam survey using a hull-mounted Deso Atlas 30 system operating at 210 kHz. Vessel position was provided by the Differential Global Positioning system (DGPS). The remote sensing survey was conducted in every 50 m of the bottom with some check line laid in the southern coast of the Qeshm Island (Fig 2).

Data processing was performed in CARIS v4.3.3 software (Hydrographic Information Processing System).
Fig. 1: Location map of the coastal shallow waters in the south of the Qeshm Island, Persian Gulf.

Fig. 2: The remote sensing data derived from single beam echo-sounder system in each 50 m of the bottom with some check line in the south of the Qeshm Island, Persian Gulf.
2.3. Ground –Truth data

Ground truthing was undertaken; using Van Veen grab samples were attempt over 76 stations with positional information derived from the ship DGPS. Stations were located equidistantly and on a systematic grid throughout the whole study area and were separated by each two kilometer (Fig. 3).

At each station, triplicate benthic grab samples were taken, one for sediment analysis and the content of the other two processed for benthic fauna. Benthic sample was washed over 0.5 mm square mesh sieves to remove excess sediment. The retained macrofauna were fixed in 4-6% formaldehyde solution and diluted with seawater for laboratory identification and enumeration.

In the laboratory, benthic fauna were identified to the lowest possible taxonomic level using standard taxonomic keys. Then, abundance of each species was recorded.

The sediment data, including grain size classes was analyzed to identify spatial patterns in the surficial sediment type according to Went-Worth scale (Table 1).

<table>
<thead>
<tr>
<th>Medium (Φ)</th>
<th>Grain size (mm)</th>
<th>Sediment Classification</th>
<th>Fines content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.0</td>
<td>2.5</td>
<td>Sand</td>
<td>Very coarse</td>
</tr>
<tr>
<td>0-1</td>
<td>1.0-0.5</td>
<td></td>
<td>Coarse</td>
</tr>
<tr>
<td>1-2</td>
<td>0.5-0.25</td>
<td>Medium</td>
<td>Clean</td>
</tr>
<tr>
<td>2-3</td>
<td>0.25-0.125</td>
<td>Fine</td>
<td>Silty</td>
</tr>
<tr>
<td>3-4</td>
<td>0.125-0.0625</td>
<td></td>
<td>Very fine</td>
</tr>
<tr>
<td>4-5</td>
<td>0.0625-0.0313</td>
<td>Mud</td>
<td>Coarse silt</td>
</tr>
<tr>
<td>6-7</td>
<td>0.0313-0.0156</td>
<td>Silt</td>
<td>Above 50%</td>
</tr>
<tr>
<td>7-8</td>
<td>0.0156-0.0078</td>
<td>Fine silt</td>
<td></td>
</tr>
<tr>
<td>8-9</td>
<td>0.0078-0.0039</td>
<td>Fine silt</td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>0.0039-0.002</td>
<td>Clay</td>
<td></td>
</tr>
</tbody>
</table>

Sediment particle size analysis was conducted on each sample following standard protocols described by Collier and Brown (2005). Fine material content including mud, silt and sand were determined with a laser particle sizer. The remaining material from each sample was dried, weighed and sieved through a series of sieve from four to 0.063 mm. The results from the fine and coarse analysis were then combined, averaged and binned to give percentage weight per Went-Worth grain size class for each grab sample.

An underwater video survey was conducted at 12 randomly positioned stations using underwater video camera towed close to the sea floor to check and cover the sounding data. Some still photographs were taken during sampling course using a drop-frame fitted with an underwater Canon camera.

3. Results

The remote sensing results showed that the survey occurred in the shallow waters. Almost 90% of the area sampled with the remote sensing system is located in depths up to five meters. Spatial distribution of acoustic data showed some fluctuation in depth, remarked with colors in Figure 4.
The sediment characteristics of 76 stations were analyzed. Sediments were muddy (89.2%) and on the basis of the percent content of the fines (particles with diameter below 0.063 mm), sediments were classified into six types by Went-Worth scale (Table 2).

Table 2. Sediment classification and coverage percent in survey site

<table>
<thead>
<tr>
<th>Sediment classification</th>
<th>Area (km²)</th>
<th>Percentage in survey site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay- Fine Silt</td>
<td>102.54</td>
<td>44.0</td>
</tr>
<tr>
<td>Clay- Medium silt</td>
<td>24.68</td>
<td>10.6</td>
</tr>
<tr>
<td>Clay- Very Fine Sand</td>
<td>1.99</td>
<td>0.9</td>
</tr>
<tr>
<td>Clay- Very Fine silt</td>
<td>73.06</td>
<td>31.3</td>
</tr>
<tr>
<td>Fine Silt-Clay</td>
<td>5.69</td>
<td>2.4</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>25.13</td>
<td>10.8</td>
</tr>
</tbody>
</table>

The most frequent sediment type was clay-fine silt (44.0%) and the least one was clay-very fine sand with 0.9% coverage. In the near coastline stations, sediments were mostly composed of larger grain sizes including very fine sand and clay-medium silt, but in farther stations, the grain size became smaller with mostly clay. The two-tailed Pearson correlation demonstrated no significant relation between remote sensing data and sediment.

In total, 214 species belonging to 91 families, 48 orders and 20 classes were identified. A list of taxa identified in ground-trusthing samples is provided in Table 3. Majority of individuals identified were Polychaete (59.6%), followed by Porifera (8.9%), Nematoda (7.6%), Malacostraca (5.2%), Enopla (4.26%), Bivalve (3.4%), Osracoda (3.26%), Ophiuroidea (2.11%) and other macrofauna with 5.67%, respectively. Principal Polychaete families were Cirratulidae with 17.25% in all 76 stations, Amphipoda (16.75% in 70 stations), Paraonidae (14.75% in 73 stations) and Capitellidae with 11.9% in 69 stations (Table 3).

The Pearson correlation showed no significant relationship between depth, sediment and benthic macrofauna, except a positive significant relation between Polychaetes and Porifera abundance with depth fluctuation (P < 0.010) respectively.
The general trend of the distribution of benthic macrofauna in the south of the Qeshm Island showed a predominance of Polychaetes in all stations. Polychaete abundance increased with depth. Their abundance in stations with smaller grain size such as clay-very fine silt and clay-fine silt was more than stations with larger grain size including very fine sand and clay-medium silt. Additionally, very high abundances of this bristle worm correlated with lower abundance of other macrofauna. Porifera occurred commonly in stations with more depth far from coastline. Nematoda were present in most of stations and their abundance increased from coastline to the sea and from eastern to the western stations. Correlation test showed the negative significant relationship between Nematoda and Polychaetes abundances (P<0.01) and the positive significant relationship with Porifera (P<0.01). Despite Porifera and Nematoda, the Ostracoda and Ophiurida were more abundant in near coastline stations with larger grain size sediment.

Analysis of variance showed sediment type did not affect species richness. The cluster analysis of the occurrence of the major taxa as identified from ground-trusting grab samples was performed (Fig. 5) and the affinity of taxa for seabed sediment type was determined. The result confirmed that stations depth and sediment grain size had no effect on macrofauna frequencies of occurrence.

Fig. 5: The cluster analysis of the occurrence of major taxa and the affinity of taxa for seabed sediment type in the south of the Qeshm Island, Persian Gulf.
The data collected from underwater video and photographs revealed a fine grain size in much of the study site which exhibited a lot of very small and small burrows in the sea bed. It appeared burrows pertained to deposit feeder Polychaetes and crabs. Based on the sea floor fine sediment and statistical analysis of benthos, the biotopes and corresponding associations of benthic fauna were mapped. Each of the habitats was distinguished based on substrate, macrofauna composition and water depth. The 3D geospatial distribution of dominant macrofauna in fine sediment classes and depth were defined as final biotope maps (Fig. 6).

Fig. 6: Interpreted habitat map in coastal shallow waters in the south of the Qeshm Island located in Persian Gulf. Five colour coded benthic habitats are defined, distinguished on the basis of substrate type, benthic assemblage and depth.

4. Discussion

In this study, we defined benthic biotopes on the basis of sediment characteristics, water depth and dominant benthic associations. This information was interpreted from single beam, geographical, geological and grabs sample data. The benthic fauna information and their association with sediment stratigraphy were assessed and 214 taxa of macrofauna were identified. The seafloor in the south coast of the Qeshm Island was muddy (82% total sediment area). The sediment texture approximately was homogenous with some changes in fines particles including silt and clay. This supports Gray (2002) who noted that in the tropics, most continental shelves were dominated by mud (over 50%). Although, grain size was the most commonly found correlative factor with benthic animal occurrence (Rhoads, 1976), here the sediment type had no significant effect on species distribution and richness. Therefore, similar groups of species commonly occurred in most of stations, covered with similar sediment grain size. While the relationship between sediments and biota was self-explanatory for many scientists, recent reviews showed little evidence that sedimentary grain size alone was a primary determinant of species distribution (Kostylev et al., 2001).

The polychaetes were the most abundant group (59.6%) with 36 families in the southern coast of the Qeshm Island. The most dominant families, Cirratulidae, Paraonidae and Capitellidae were surface deposit feeder and the Amphinomidae were sluggish carnivores. Probably, the high organic matter in the water column provided a large food source for benthic surface deposit feeder organisms.

The regional geomorphology and sediment texture was described based on interpretation of single beam and ground-truthing data, respectively. High-resolution representation of seabed morphology allowed the interpretation of dynamic characteristics of water and furthermore, an interpretation of benthic habitats (Kostylev et al., 2001). In the southern coasts of the Qeshm Island, the approximate isomorphic sediment description proved to be useful for describing properties of benthic biotopes. According to the single beam and sediment fine texture analysis, most of the habitat was covered by a layer of clay and using the mere interpretation for distinguishing habitat was so difficult. In such instances, the benthic community would provide more information about seabed biotopes than sediment data. Therefore, the remote sensing biotope map was conducted by combining the sounding, sediment grain size and benthic macrofauna distribution data. The spatial allocation of samples, abundance and commonness of species were used as additional guide for biotopes zonation. Species associations typical for each biotope were considered as well.

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1- Surface water biotope - The shallowest area with less than ten meter depths and clay-medium silt substrate was characterized by a relative high abundance of young settled Porifera, Nematoda and Amphinomidae.

2- Shallow water biotope - Shallow water habitat comprised the largest zone, with depths ranging between 10 to 23 m but mostly depths less than 15 m (72.73%). Different substrates occurred and most of sediment was fine textured, clay-fine silt followed by clay-verey fine silt, clay-medium silt, very fine sand and fine - silt clay, respectively. This area was distinguished by high diversity and abundance of macrofauna with domination of Cirratulidae and Nephtyidae families. The member of other families such as Capitellidae, Amphinomidae, Tellinidae (Bivalve), Amphiuridae (Ophiuroidea), Nematoda and Ostracoda were present as well. The occurrence of these surface deposit and suspension feeders suggested that this biotope was rich in plankton and suspended organic matter.

3- Polychaete biotopes with more depth - In most part of this area, the depth was between 15 and 24 meters. The sea floor sediment was more homogenous, clay-fine and very fine silt covers this zone, except a very small part with clay-verey fine sand. Amphinomidae was the most dominant macrofauna family in this habitat. The other abundant families were Paraonidae, Capitellidae, Cirratulidae and Nematoda.

4- Porifera and Nematoda biotope. The habitat occurred on clay- fine and very fine silt substrate with an average depth of 15 meters. A relatively high percentage of young porifera settled in the small substrates such as shells. Probably, transports by the Persian Gulf currents were settled here, but because of the lack of hard substrate, the adult colony could not relocate after establishment. Nematods were the second abundant group in this biotope and showed relationship with porifera.

5- Ostracoda biotopes- Ostracoda habitat was found in 15 m depth and very fine sand substrate on the north of study area and closer to the coastline. The highly abundant Ostracoda followed by Harpacticoida and Nephtyidae family were dominant in this biotope. The map of the south coast of the Qeshm Island biotopes provided preliminary data and an initial overview of the sediment biotopes and their faunal communities. It represented a first attempt at integration of geological, biological and dynamic data over this region. But, there is the potential for further work on the Persian Gulf. The work presented here was apparently the first attempt for Iran’s southern coasts and perhaps in the Persian Gulf, where no work of this nature has been previously done at this scale and level of detail.

Acknowledgements

The authors wish to thank the Iranian National Geographical Organization for providing necessary facilities and technical support throughout the course of this research. Special thanks are due to Valdimir E. Kostylev for his valuable counseling on project progress and P. Kaedi and V. Hosseini-nejad for their contribution to data processing and interpreting. Additional thanks are due to M. Rahnavard for her assistance in the ground-truth sampling.

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