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Sediment Characteristics Study at Sharm Obhur, the Red Sea Using Multibeam Backscatter

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Abstract. Sharm Obhur, situated approximately 35 km north of Jeddah City along the Red Sea coast, is a prominent recreational area with diverse benthic habitats. Accurate mapping of seabed sediments is critical for characterizing marine ecosystems and elucidating benthic habitat distribution in this region. This study underscores the importance of assessing sediment distribution patterns in Sharm Obhur, particularly due to the prevalence of recreational activities and navigational traffic. Investigates sediment dynamics in Sharm Obhur, a coastal creek near Jeddah, utilizing Multibeam Echo Sounder (MBES) backscatter data and grab sample analyses. The study focuses on understanding sediment distribution patterns and their implications for coastal management. MBES technology provides high-resolution data on seafloor composition and roughness, essential for assessing sediment types and bedforms. Through spatial alignment of MBES data with ground truth sediment samples, we analyze sediment characteristics and validate findings. The results indicate the predominant presence of sand, with detectable mud in deeper channels and northern anthropogenically impacted areas. Gravel deposits correlate with the coral formations near the creek edges. Tidal influence is evident, as indicated by the increased presence of sand at the creek entrance. The study demonstrates MBES backscatter's efficacy in mapping sediment distributions and seabed characteristics, benefiting marine science and coastal management. This research enhances knowledge of sediment transport processes, facilitating informed decision-making for sustainable coastal development and conservation efforts.

Keywords: Hydrographic survey, MBES, Backscatter mosaic, Sediment analysis.

1. Introduction

The world food shortage and the shakable Coastal areas, such as Sharm Obhur, a creek located along the Red Sea coast near Jeddah, represent dynamic environments shaped by intricate sediment transport processes driven by hydrodynamic forces and human activities. The movement of organic and inorganic particles by water, known as sediment transport, is fundamental in shaping marine ecosystems through processes like erosion, transportation, and deposition. These processes are influenced by various factors including river flow, water level fluctuations, meteorological events, and human impacts, making the study of sediment distribution patterns essential for effective coastal ecosystem management and sustainable development. Advancements in technology, particularly Multibeam Echo Sounder (MBES) systems, have transformed our ability to study seafloor morphology and sediment characteristics (Jackson *et al.*, 1986; Jackson and Briggs 1992; APL, 1994; APL, 2000; Fonseca and Mayer, 2007; Lamarche *et al.*, 2011; Huang *et al.*, 2013). MBES backscatter data provides high-resolution information about seafloor composition, offering critical insights into sediment types, roughness, and bedforms (Le Bas, and Huvenne, 2009, Hughes Clarke *et al.*, 1997). This data is invaluable for investigating sediment transport dynamics and understanding the nature of seabed environments.

Sharm Obhur, with its diverse benthic habitats and recreational significance, presents an ideal setting for investigating sediment distribution using MBES backscatter data. Previous studies have emphasized the hydrodynamics and sediment characteristics of this region; however, specific research focusing on MBES backscatter data for sediment characterization remains limited. This study aims to bridge this gap by leveraging MBES backscatter data to analyse sediment characteristics and validate findings through spatially aligned grab sample sediment analyses at Sharm Obhur. The integration of MBES technology with ground truth sediment sampling enables a comprehensive assessment of sediment distribution patterns in Sharm Obhur. By utilizing advanced remote sensing techniques, this research contributes valuable insights into sediment dynamics, supporting informed decision-making for coastal management and development initiatives. The findings not only enhance our understanding of sediment transport processes in Sharm Obhur but also provide a foundational basis for future research and conservation efforts in coastal environments.

In recent years, studies such as those by Galloway *et al.* (2005) and Dufek (2012) have explored the comparability of suspended-sediment concentration (SSC) and total suspended solids (TSS) data and also study the backscatter analysis of MBES backscatter data for of marine Classification of sediments. Additionally, efforts by the Lurton *et al.,* 2015 and Lamarche & Lurton (2018) have provided valuable recommendations for acquiring and processing backscatter data, emphasizing the need for standardization to enhance accuracy and reliability. Studies on sediment characteristics at Sharm Obhur, particularly using MBES backscatter data, are limited. Notably, research by El-Diasty (2020) has demonstrated the capability of MBES backscatter data to map seabed sediments and differentiate sediment types in a small area of Sharm Obhur. The utilization of MBES backscatter data in this context not only enriches our understanding of sediment dynamics but also lays the groundwork for advancing marine science and supporting sustainable coastal management practices.

This comprehensive literature review aims to synthesize existing knowledge and identify gaps in sediment dynamics study, particularly concerning the unique challenges and opportunities presented by Sharm Obhur. By analyzing the collective insights from previous studies and integrating MBES backscatter data with ground truth sediment sampling, this research contributes to a deeper understanding of sediment distribution patterns and dynamics in coastal environments, ultimately informing strategies for effective coastal management and conservation.

2. Material and Methods

2.1 Study Area

Situated in the Red Sea region of Jeddah city, Saudi Arabia, Sharm Obhur is a site of significant scientific interest due to its unique hydrodynamic and sedimentary features (see Fig. 1). Close proximity to tide-dominated coastal currents, tides, and wind patterns contributes to the complex dynamics shaping the area's hydrodynamics and sediment distribution (Basaham *et al.*, 2006). The sediment composition varies widely, with sheltered areas accumulating fine-grained sediments like silt and clay, while exposed regions impacted by wave energy contain coarser sediments such as sand and gravel. Research at Sharm Obhur aims to advance understanding of coastal processes, inform environmental management strategies, and support sustainable development in the region by investigating hydrodynamic and sedimentary characteristics to unravel coastal dynamics and sediment transport pathways.

2.2 Data Collection

This study aimed to comprehensively investigate sediment distributions in the Sharm Obhur region of the Red Sea using advanced multibeam echo sounding (MBES) technology and systematic sediment sampling techniques. The data were collected through various surveys conducted using survey vessels KAU-Hydrography 2 (Fig. 2).

The MBES systems, the SeaBat T50-P from Teledyne Technologies, were utilized to gather high-resolution acoustic data covering a wide range of frequencies (40 to 420 kHz). These systems allowed for precise mapping of underwater topography and detailed characterization of sediment composition, capturing fine-scale features of the seafloor. Data processing was conducted using Caris HIPS & SIPS software (CARIS, 2017), with a specific focus on the SIPS backscatter (WMA) module for backscatter data analysis. This software enabled the generation of detailed bathymetry maps and backscatter mosaics, providing insights into seafloor roughness. By integrating field-collected sediment data with MBES outputs, spatially aligned analyses of sediment characteristics were performed, enhancing the reliability and accuracy of the study's findings.

The sediment analysis methodology conducted at the Sharm Obhur in the Red Sea involved collecting 15 samples using a Van Veen Grab (Fig.3). In this region, prior to our study, only one investigation had been conducted involving grab sampling of seabed sediments, as documented by Gheith and Hariri (2010), encompassing six sampling stations. For present study each sample underwent careful preparation and analysis to determine grain size distribution. After collection, samples were mixed to homogeneity, weighed, and subjected to sieving using a stack of standard sieves with varying mesh sizes, following the Folk (1954) classification scheme. Sediment classes were designated based on particle size, including gravel (>2 mm), coarse sand (0.5–2 mm), medium sand (0.25–0.5 mm), fine sand (0.125–0.063 mm), silt (0.04–0.063 mm), and clay (<0.04 mm). The silt and clay fractions were determined by pipette analysis. Wet sieving was employed due to the small size and bioclastic nature of the samples, preventing solidification upon drying. Samples were passed through sieve openings, and the retained fractions were dried and weighed to ascertain gravel, sand, and mud percentages. The median (D_{50}) value was computed for each sample, and sediment types were classified according to the Wentworth scale (Wentworth, 1922). Statistical analysis, including mean, median, and standard deviation calculations, was applied to the dataset to derive insights into sediment characteristics and depositional environments.

2.3 Backscatter Data Analysis

The data analysis methodology employed for the Multibeam SeaBat T50 dataset collected at Sharm Obhur utilized CARIS HIPS & SIPS software for processes and analysis. This included procedures like noise elimination, erroneous value removal, and sounding correction using tide and sound velocity variations to mitigate systematic errors. The objective was to enhance the precision of the derived bathymetry surface and overall data quality. Following noise filtering, a high-resolution patch-based surface bathymetric grid model with a spatial resolution of 1 meter was generated, offering intricate details of the survey. The resulting bathymetric grid model is depicted in (Fig. 3)

showcased enhanced surface representation post-processing. Furthermore, the SIPS backscatter (WMA) tool within CARIS HIPS & SIPS was utilized to create a backscatter mosaic, to evaluate seafloor acoustic reflectivity and texture. A SIPS Beam Pattern was generated to rectify irregularities in the backscatter data caused by acoustic energy variations, ensuring accurate interpretation. Figuer 4 displays the corrected backscatter map, enabling the identification of different seafloor deposits based on acoustic reflectivity and facilitating comprehensive interpretation of seafloor properties.

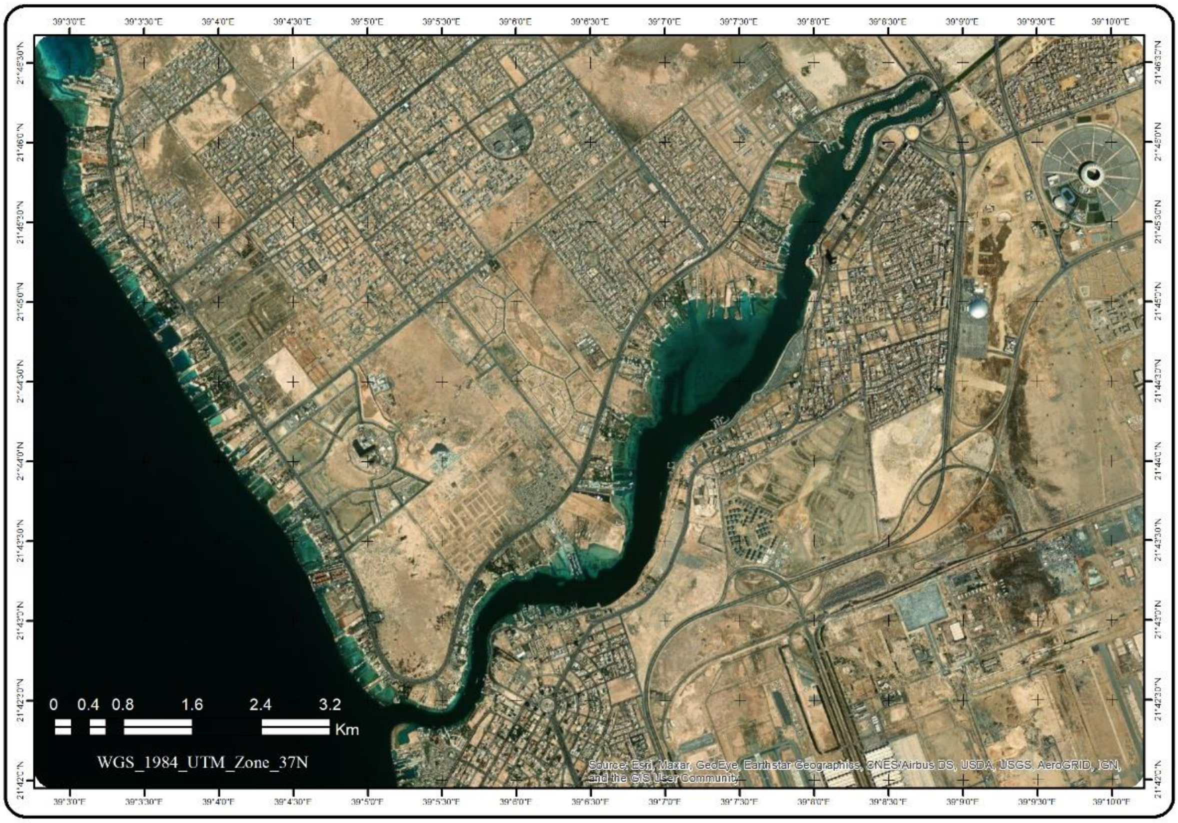

Fig. 1. The study Area.

Fig. 2. Survey vessel KAU-HYDROGRAPHY 2.

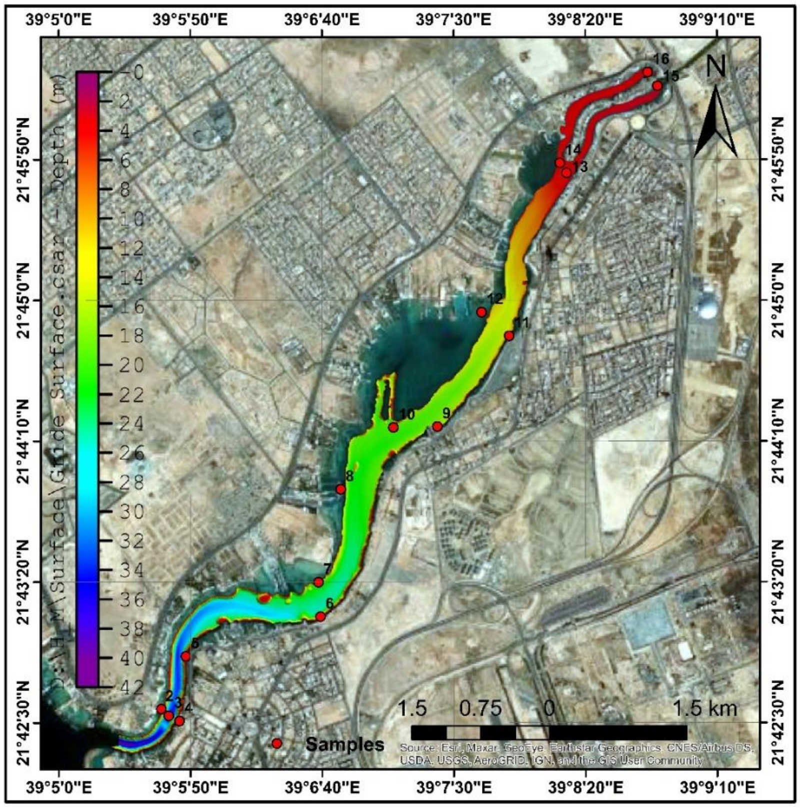

Fig. 3. Bathymetric grid model.

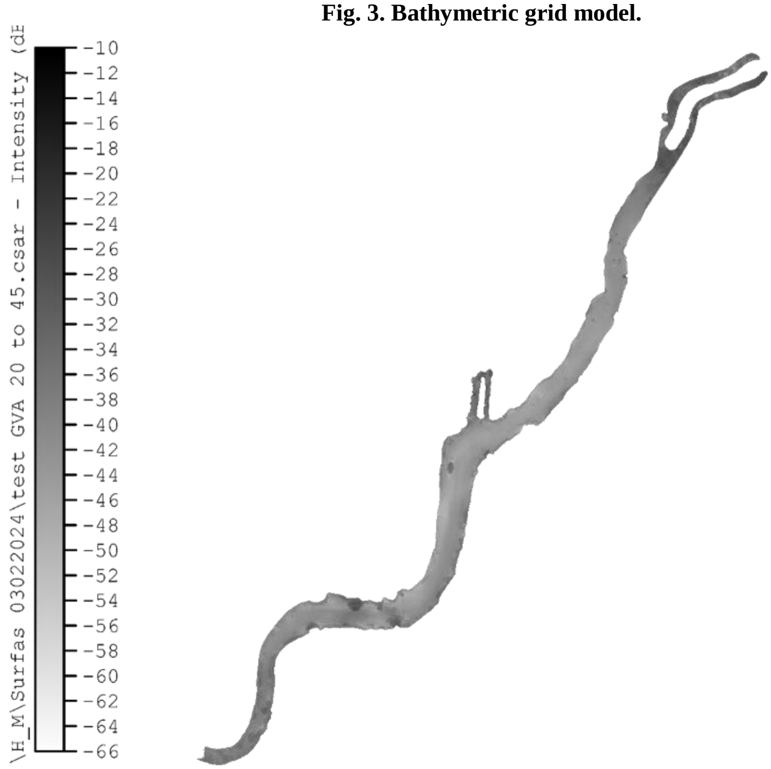

Fig. 4. Final backscatter mosaic.

3. Results and Discussions

3.1 Backscatter Mosaic

The primary dataset collected using the SEABAT T50-P MBES system comprehensively covered the entire Sharm Obhur study area, contributing to an extensive and representative dataset for subsequent analysis and backscatter mosaic generation. Geometric and radiometric error corrections were meticulously applied using CARIS HIPS and SIPS software to enhance data accuracy (Cobra, 1992), although beam pattern error correction was notably excluded from these procedures. The pivotal role of the bathymetric grid model in geometric and incidence angle corrections during backscatter mosaic creation within the SIPS Backscatter (WMA) engine module is emphasized. The resulting backscatter mosaic, without beam pattern correction, exhibited backscatter intensity variations ranging from -78 dB to -20 dB across the study area. Subsequently, a beam pattern model was established for the backscatter mosaic, and its integration into the backscatter mosaic correction process effectively refined backscatter intensity, as illustrated in Fig. 4. with variations ranging from -55 dB to -26 dB. The mosaic highlights varying backscatter intensity patterns indicative of heterogeneous seabed compositions, corroborated by spatial sediment analyses and on-site observations. The distinct features observed contribute significantly to understanding the complex sediment characteristics of the Sharm Obhur, study area.

3.2 Grain Size Analysis

The sediment analysis results, detailed in Table 1, reveal significant variations in grain size distribution across multiple sampling locations within the study area. Samples characterized by predominant sand content (>50%) with minimal mud (<25%), such as P2, P4, P5, P6, P7, and P8, suggest hydraulic sorting likely influenced by strong tidal currents. This sorting effect indicates a pattern where coarser grains are deposited closer to the source, while finer particles are transported further away. In contrast, samples like P3, P14, and P15 exhibit mud-dominated compositions (>50% mud and <25% sand), indicative of tranquil water conditions with limited current energy for particle transport. Samples P9, P10, P11, P12, and P13, characterized by a balanced combination of sand (25-50%) and mud, represent transitional environments like estuaries or shelves. Lastly, sample P16, with gravelly sand (>45% gravel), reflects high-energy environments conducive to sorting and deposition of coarser particles. These findings, alongside Table 1 summarizing the grain size analysis, provide essential insights into sediment dynamics and depositional processes, offering valuable information about prevailing hydrodynamic conditions and sediment transport patterns within the study area. The interpretations align closely with the Wentworth scale classification scheme for grain size characterization and contribute to a comprehensive understanding of the sedimentary environment.

3.3 Backscatter Sediment Analysis

The backscatter mosaic utilized in this study area for sediment analysis was ground-truthed using grab samples collected spatially in Sharm Obhur. To convert backscatter intensity to sediment texture classifications, the present study applied the classification method outlined by Pratomo *et al.,* 2018, which is detailed in Table 2. The analysis revealed that backscatter tends to be more pronounced in rigid substrates like rock and weaker in softer sediments such as mud (Lurton, 2010). Utilizing this classification scheme, we categorized the backscatter intensity map into a sediment map based on broad sediment texture classifications including boulder, gravel, sand, and mud.

The resulting sediment map indicates a predominance of sand across the region, with the presence of mud detected in the deeper channel areas throughout the study area. Mud was also observed in the northern end of Sharm Obhur, coinciding with areas of heightened anthropogenic activity. Gravel deposits were identified near the edges of Sharm Obhur, likely due to the presence of coral formations, which are notably abundant in this area. Given that Sharm Obhur is a tide-dominated creek, tidal action is more pronounced at the entrance, resulting in an increased presence of sand in this region. This observation aligns with both the sediment distribution map and the results of grab sample analyses. Grab samples (P03, P10, and P16) were collected evenly throughout the study area and compared with sediment characteristics derived from the backscatter mosaic (Fig. 5). The comparison confirmed a strong correlation between the texture characteristics of grab samples and the sediment classified map using backscatter intensity data. The backscatter image analysis proves invaluable for characterizing sediment distributions and seabed characteristics within this study area. This remote sensing approach provides researchers and other stakeholders with spatial data using modern techniques, significantly saving time and resources.

Table 1. The grain size analysis of the sediment along the observed locations.

Sample Id	Initial Weight (g)	% of Gravel	% of sand	% of mud	D50 (mm)
P2	103.13	7.77	91.65	0.58	2.40
P3	77.33	0.00	23.47	76.53	0.08
P4	89.40	17.85	81.59	0.56	2.45
P5	103.23	11.73	87.88	0.39	2.42
P6	44.71	52.96	43.46	3.58	8.15
P7	97.00	19.07	80.21	0.72	2.46
P8	96.49	12.80	83.47	3.73	2.41
P9	80.85	9.60	73.10	17.30	2.32
P10	86.07	13.33	42.06	44.61	2.09
P11	74.12	13.22	73.53	13.25	2.37
P12	79.93	19.77	72.69	7.54	2.43
P13	88.57	0.45	55.78	43.77	2.08
P14	75.94	0.00	15.80	84.20	0.08
P15	64.01	0.78	22.65	76.57	0.08
P16	69.09	49.93	22.43	27.63	2.80

Table 2. Backscatter Intensity Ranges for Various Sediment Types (Pratomo *et al*., 2018).

Sediment type	Backscatter intensity (dB)	
	From	To
Boulder	-9	-23
Gravel	-23	-34
Sand	-34	-49
Mud	-49	-67
Clay	-60	-67

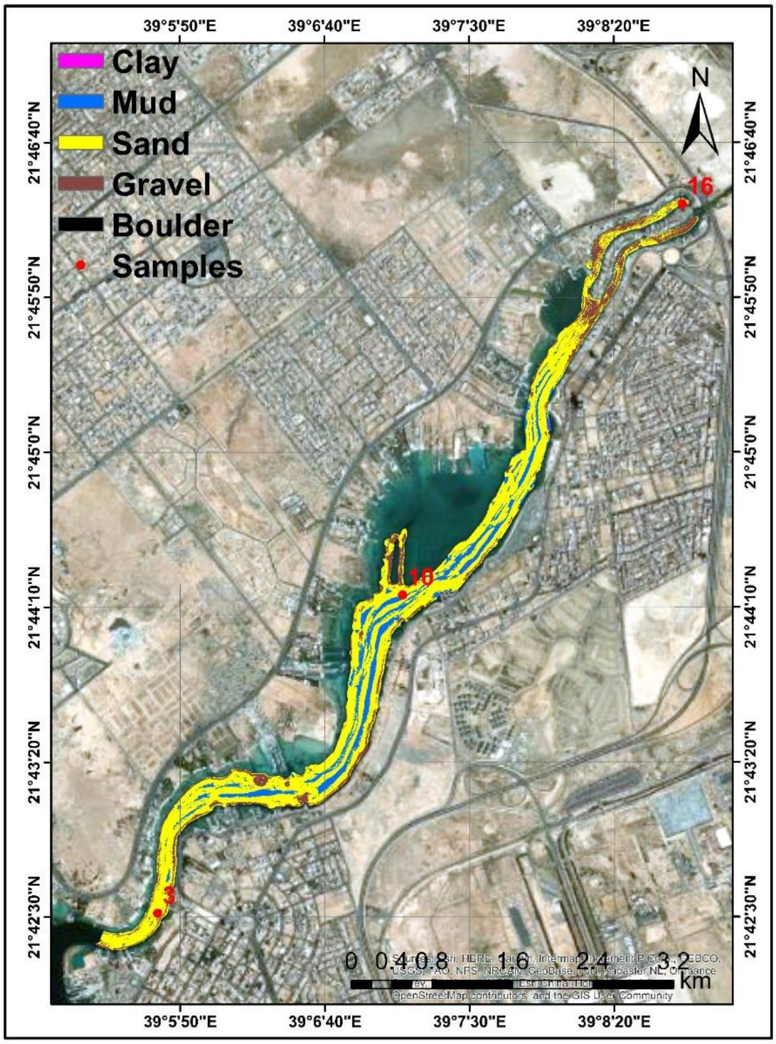

Fig. 5. Sediment distribution map at Sharm Obhur using multibeam backscatter classification.

4. Conclusion

In conclusion, this study underscores the critical importance of accurately mapping sediment characteristics in Sharm Obhur, Red Sea, using advanced Multibeam Echo Sounder (MBES) technology. The research findings highlight the prevalence of sandy sediments with variations in mud content across different areas of Sharm Obhur. The presence of gravel deposits near coral formations indicates unique benthic habitats that are crucial for marine biodiversity. The study demonstrates the effectiveness of MBES backscatter data in providing high-resolution insights into seabed composition and sediment distribution patterns. These findings are essential for advancing marine science and informing sustainable coastal management practices. Moving forward, future research can leverage these outcomes to deepen our understanding of sediment dynamics and their ecological impacts in coastal environments, supporting conservation efforts and responsible coastal development initiatives.

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دراسة خصائص الرواسب في شرم أبحر، البحر الأحمر باستخدام تقنية التشتت الخلفي متعدد الحزم

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المستخلص. تقع شرم أبحر على بعد حوالي ٣٥ كم شمال مدينة جدة على طول ساحل البحر الأحمر، وهي منطقة ترفيهية بارزة ذات موائل قاعية متنوعة. يعد رسم خرائط دقيقة لرواسب قاع البحر أمرًا بالغ الأهمية لتوصيف النظم البيئية البحرية وتوضيح توزيع الموائل القاعية في هذه المنطقة. تؤكد هذه الدراسة على أهمية تقييم أنماط توزيع الرواسب في شرم أبحر، وخاصة بسبب انتشار الأنشطة الترفيهية وحركة الملاحة. يتناول هذا البحث ديناميكيات الرواسب في شرم أبحر، وهو خور ساحلي بالقرب من جدة، باستخدام بيانات التشتت الخلفي لجهاز قياس الصدى متعدد الحزم (MBES) وتحليلات العينات المأخوذة. وتركز الدراسة على فهم أنماط توزيع الرواسب وتأثيراتها على الإدارة الساحلية. توفر تقنية جهاز قياس الصدى متعدد الحزم بيانات عالية الدقة عن تركيب قاع البحر وخشونته، وهو أمر ضروري لتقييم أنواع الرواسب وأشكال القاع. ومن خلال المحاذاة المكانية لبيانات جهاز قياس الصدى متعدد الحزم مع عينات الرواسب الحقيقية على الأرض، نقوم بتحليل خصائص الرواسب والتحقق من صحة النتائج. تشير النتائج إلى الوجود السائد للرمال، مع وجود طين يمكن اكتشافه في القنوات العميقة والمناطق الشمالية المتأثرة بالأنشطة البشرية. ترتبط رواسب الحصى بتكوينات المرجان بالقرب من حواف الخور. كما أن تأثير المد والجزر واضح، كما يتضح من زيادة وجود الرمال عند مدخل الخور. وتوضح الدراسة فعالية التشتت الخلفي لجهاز قياس الصدى متعدد الحزم في رسم خرائط توزيع الرواسب وخصائص قاع البحر، مما يعود بالنفع على العلوم البحرية وإدارة السواحل. يعمل هذا البحث على تعزيز المعرفة بعمليات نقل الرواسب، مما يسهل اتخاذ القرارات المستنيرة من أجل التنمية الساحلية المستدامة وجهود الحفاظ عليها.

الكلمات المفتاحية: المسح الهيدروغرافي، MBES، فسيفساء التشتت الخلفي، تحليل الرواسب.