Environment Monitoring of Offshore Sand Mining in Pearl River Estuary

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Abstract

Based on the analysis of the monitoring data of an offshore sand mining area in the Pear River estuary, the submarine geomorphy of the mining area can be classified into four types, namely shore, coarse sand mining pit, smooth sand mining pit and semi-deep terrain. From the sub-bottom profiles, it can be found that the four types represent four stage processes of sand mining, of which the most direct impact is the change of water depth, geomorphy and shallow sediment. Coarse granule sediments of autochthonous deposit cause strong reflection in the seabed surface and reduce the penetrating power of seismic wave. However, fine particles like clay and silt become suspended solids and gradually deposit, forming a smooth sediment surface of weak reflection and an illuvial horizon that can be penetrated by the seismic wave of shallow stratum section plotter, after being away from the sand mining center in a certain distance. Carry out research on four stratigraphic profiles representing the sand mining process that are selected from the testing zone and conduct analysis description on the sedimentation process of the sand mining area. By comparing topographic monitoring data of March in 2009 and that of September in 2010, the annually variation diagram of sedimentation can be acquired. There is more sedimentation in low-lying places. The thickest sedimentation is 3m. Yet the annually sedimentary thickness is less than 1m in the broad semi-deep water area that is more that 0.5km away from the depocenter. This data show the local typical sedimentation rate.

Keywords: Pearl River estuary, offshore sand mining, environmental monitoring, topography, geomorphology, sub-bottom profile.

1. Introduction

Economic development of China Pearl River Delta is increasing rapidly. The increasing infrastructure construction promotes the demands for construction sand. However, river sand and land sand suitable for exploitation are diminishing in the meantime, then more people begin mining the offshore sand in the Pearl River Estuary. Offshore sand is a kind of limited mineral resource formed through the long
geological time. With the increasing demands, sand resources of the Pearl River estuary is facing the threat of over-consumption [1,2]. Therefore, enhancing environmental monitoring of offshore sand mining is a very urgent task.

To make offshore sand mining reasonable and orderly, relevant government departments issued a number of rules and regulations to standardize the conduct and management of it. Choosing a mining region needs strict approval and detailed assessments, and environmental monitoring should also be carried out regularly during the exploitation. The main purpose of environmental monitoring is to obtain the status of seabed, to monitor mining area and mining amount, to provide the seabed reference for mining companies, and to provide fair and credible report for the government departments. This paper is based on the field monitoring results in a sand mining area of the Pearl River estuary in September 2010, and the emphasis is placed on the comprehensive analysis of the survey data such as topography, geomorphology and sub-bottom profile. Moreover, it carries out comparative analysis through combining part of terrain data in 2009.

2. Survey Area and Methods

Survey area shown in Figure 1, is located in the middle of LingDingYang Bay of Pearl River Estuary, and mostly in LingDing shoal between LingDing Channel and FanShi Channel. Data were collected during a regular survey in September 2010 by South China Sea Marine Engineering Surveying Center, and the total length of the survey lines is 150 km. Bathymetric, side-scan sonar, and sub-bottom profile data were collected with these equipment: SDH-13D single-frequency echo sounder, EDGETECH 2400DSS side scan sonar and sonar combo system and C-NAV 2050 DGPS.

![Figure 1. (a) Sketch of the location of Pearl River Estuary. (b) Survey area and the track lines map of the area within the red box shown in Figure 1a. Data were collected during a regular survey in September 2010. Red lines outline the boundary of the actual Survey area, and the total length of the survey lines is 150 km. Bathymetric, side-scan sonar, and subbottom profile data were collected.](image)

3. Survey Results
3.1. Methodology.

By adding some survey lines in the field survey, the survey results reveal whole sand mining pits, but in the northern and the northeastern part of the survey area, the semi-deep water terrain zone extends too far to be fully revealed. According to the nautical charts, the region is a part of the LingDing shoal with originally water depth from 2 to 6 m and minimum water depth is at the southern end. Figure 2 (a) shows that, from the regional point of view, the actual depth now is between 2 and 23 m. In central and the southern part of the survey area, there is the shoal with NNW direction and water depth from 2 to 6 m, in which there is a mining pit with a depth of around 13 m in southern middle, and in southeast another mining pit with a NW-SE direction and a depth of around 20 m. While in the north and northeast there is a relatively wide zone with the water depth of 12-16 m, and it is defined as the semi-deep terrain. As mining operation is not so concentrated, three underwater islands with water depth of around 6 m were formed at the boundary of the shoal and the semi-deep terrain. And near the underwater islands and the shoal, there are two mining pits with NW-SE direction and the center maximum depth of 22 m.

Figure 2. (a) Bathymetry map. The depth of LingDing shoal of the Survey area is between 2m and 6m, and among them there are 4 main sand mining pits and a semi-deep terrain on north-east of the Survey area. (b) Submarine geomorphology map of Survey area. Based on data analysis results, there are four types of geomorphology, which are remaining shoal, semi-deep terrain, smooth mining pit and rough mining pit.

3.2. Morphology.
Seabed geomorphology in the region is divided into three classes: remaining shoal, sand mining pits and semi-deep terrain, as shown in Figure 2 (b) and Figure 3. Large area of shoal is located in the central and southern part of the survey area, and the seabed surface is smooth with uniform acoustic reflection. There are also other seabed features like small ripples, anchor trenches and trawling, which illustrates the original seabed, indicating that these areas have not yet been carried out sand mining operations. Therefore, on the northeast boundary of the survey area, some shoal is divided into several isolated underwater islands. There are two different characteristics of sand mining pits, smooth mining pit and rough mining pit. The former pit bottom has a weak acoustic reflection and a kind of relatively smooth seabed; however, the latter has a strong acoustic reflection and a broken, rough seabed. One rough mining pit was found near the northern underwater islands, representing the recent sand mining activities. Semi-deep terrain locates in the northeast of the surveyed area, being characterized by the water depths from 12 to 16 m, wide area, smooth seabed and weak acoustic reflection.

3.3. bottom Profile.

Corresponding with the Seabed geomorphology, there are four typical seismic profiles shown in Figure 3 in the surveyed area. Remaining shoal profile shows several sets of clear and continuous strata reflecting interfaces, which are seabed reflecting interface $R_0$ and two underlying strata reflecting interfaces $R_1$ and $R_2$. Rough mining pit profile shows a strong surface reflecting interface $R_d$, without other stratum displaying. While smooth mining pit profile shows weaker but clear and continuous surface reflecting interface with a blurred underlying reflection interface $R_d$. Semi-deep terrain is similar to the smooth mining pit, but it has a wide open area and a more curved seabed.

Figure 3. There are four typical seabed geomorphologies and and their corresponding sub-bottom profiles in study site. (a) Remaining shoal shows smooth seabed, shallow water depth, and several sets of clear and continuous stratum reflecting interfaces. (b) Rough sand mining pit shows rough seabed, and strong surface reflecting interface, without other stratum displaying. (c) Smooth sand mining pit shows smooth seabed in the pit, and weaker but clear and continuous surface reflecting interface with a blurred underlying reflection interface. (d) Semi-deep terrain, similar to the smooth mining pit, but it has a wide open area and more curved seabed.

4. Analysis and Discussion
Based on the surveyed results, the most direct impact of the sand mining is to change the bottom bathymetry, geomorphology and sub-bottom sediments [3, 4]. Water jet mining ships are mostly used in sand mining operations in Pearl River Estuary. Insert the long tube into the seabed until the sand stratum. Then high pressure water is ejected into the sediment, and then the sand-water mixture is sucked on the deck. As sand for building is largely medium to coarse sand, the gravel, shells and other coarse sediments are filtered and deposited in situ. And meanwhile, silt and fine sand are removed by the rinse water [5]. Sand stratum is mined a lot, then the seabed is subsidence, and the mining pit is formed. Coarse sediments deposited in situ results in a strong seabed surface reflection and reduces the penetration of seismic waves. The typical profile is as shown in Figure 3b. The silt and fine sand in the water suspension, leaving mining area and travelling a certain distance, is deposited in low-lying place, especially the old sand pit that forms a weak reflecting interface on the smooth seabed surface, therefore the seismic waves can penetrate the sediments, and the typical profile is as shown in Figure 3c and Figure 3d.

Figure 4. (a) Bathymetry map of reference area within the diagonal box shown in Figure 1b. The water depths data was collected in March 2009. Comparison to the map of September 2010, area of shoals then was much bigger. By calculating the water depth changes in the two surveys, we get the annual change of deposition. (b) Bathymetry map of annual change of deposition shows that low-lying areas more likely to accept the deposits and maximum sediment thickness change is about 3 meters per year.

Four profiles shown in Figure 3 represent the seabed change as the process of the sand mining. Original shoal is shown in Figure 3a, and then sand mining begins from the left side of the profile. During the sand mining’s active period, coarse sediments are deposited on the bottom, with seabed subsiding and water depth increasing, and then the typical profile is formed as shown in Figure 3b. With the reduction of the sand resources in the region, the activity of sand mining stops, and as the sedimentary center, the mining pit begins to accept the suspension deposition from the near mining activities, forming a thick sedimentary layer shown as the left side in Figure 3c. At this time most activities of sand mining are on the left of the profile, and even the thicker sediment layer is formed. As shown in Figure 3c, when sand mining activities come to the right of the profile, suspended sediment deposition begins to form a thick sediment layer at the right side of the profile. After the end of sand mining on the right side, its seabed subsides to the depths corresponding with the left side. However, due to the end of the mining activities is relatively late; the seabed only accepts a small amount of suspension deposition, the profile of which is as shown in Figure 3d.

In the profile shown in Figure 3d, the sediment thickness from suspension on the left side is about 8m and thinner than 2m on the right side; sediment thickness is uneven, indicating their different deposition
time. The bathymetry data surveyed in March 2009 contain the region of the rough mining pit in north of the surveyed area. Its location is shown in the diagonal box area of Figure 1b and its bathymetry map is shown in Figure 4a. Compared to the map of September 2010, the area of shoal then was much bigger. There are two low-lying areas at the edge of the shoal, and their maximum depths respectively are 18 m and 15 m. By calculating the water depth changes in the two surveys, we get the annual change of deposition as shown in Figure 4b. Blue represents deposition and red erosion. The bathymetry map of annual change of deposition shows that low-lying areas are more likely to accept the deposits and maximum sediment thickness change is about 3 meters per year. And with 500m distance from the depocenter, the thickness has been reduced to 1m or less. Then assuming that their intensity of mining activities is similar, deposition process of Figure 3d can be inferred from these data: the left as a deposit center received deposition for 2 or 3 years, while the right as semi-deep terrain received deposition for nearly 1 year. However, if there are more mining activities, causing superimposed effects, the deposition process may be accelerated.

5. Summary

Based on the analysis of the monitoring data from the offshore sand mining area in Pearl River Estuary, seabed of the mining area can be classified as four typical geomorphologies: remaining shoal, semi-deep terrain, smooth mining pit and rough mining pit. Their corresponding sub-bottom profiles represent the four stage processes during sand mining. Through the digital terrain analysis on the survey data of March 2009 and September 2010, a conclusion can be drawn: the sediment thickness of the depocenter is about 3m, and with 500m distance from the depocenter, the thickness has been reduced to 1m or less. Based on this valuable reference data, we can use the deposition thickness in the sand pit to approximately estimate the mining time, however, if we want to calculate more accurate numbers, more accumulation of information and data are needed.

References