The Study of the Shoreline Change of Bengkalis Cape, Indonesia

Rifardi[1*], Chairunisa Rachmani[1] and Elizal[1]

[1]*Department of Marine Sciences, Faculty of Fishery and Marine Sciences, Riau University, Kampus Bina Widya Sp.Panam Pekanbaru-Riau-Indonesia*

The main purpose of this study is to determine shoreline change in Bengkalis Cape, Riau Province, Indonesia using sediment samples analysis, satellite images, and oceanographic parameters. The samples were collected at five stations by using sediment grab and oceanographic observation was also carried out at each station in November 2015. The southern part of Bengkalis Cape is characterised by fine-grain sediments (mud) and high rate of accretion that reaches 29.77 metre/year, and is influenced by weak tidal currents with a velocity of less than 0.06 m/s and low wave energy. In contrast, the northern part is occupied by coarse-grain sediments (sand) which is characterised by high rate of abrasion as shown in the image data for 20 years; 1995-2015 reaches 38.02 metre/year, and is under the influence of strong tidal current (0.16 m/s) and high wave energy. The major contributing factor for the shoreline change is the current system which flowing from Malacca strait to the shore area and sediments deposition in the area.

Keywords: bottom sediments, shoreline change, abrasion, accretion, current system

I. INTRODUCTION

Bengkalis Island is located close to Malacca Strait in the eastern coast of Sumatera Island, Riau Province, Indonesia. In general, the island has been abraded due to hydrodynamics system of Malacca Strait and shore area of the island is composed by soft sediments (recent sediments). However, only a few areas of the island have been sedimented because the areas are located rather far from Malacca Strait and terrigenous sediments supplied from the hinterland deposited in the areas.

*corresponding author: rifardi@lecturer.unri.ac.id

Coastline is one of the most important linear features on the earth's surface, which displays a dynamic nature and is an indicator for coastal erosion and accretion (Ghosh *et al.*, 2015). Coastline movement happens when geomorphological process that occurs in coastal segment process exceeded the usual process. Geomorphological process changes effected from many oceanographic parameter that have a role like wave, current, and tidal (Opa, 2011). Tidal processes, sea-level fluctuations, sediment transport and deposition, and flooding also contribute in shift of shorelines resulting in to newer coastal land forms and also in their disappearance. So, in order to formulate development activities both in terms of infrastructure and ecology, it is necessary to substantiate rate of change in shoreline (Vaidya *et al.*, 2015)

Many studies in ecological and oceanographical aspects of Bengkalis Waters have been carried out by many authors. However, only one study had been conducted in Bengkalis Island to analyse abrasion and sedimentation rates. Results of the study indicate that the island has been changed since 26 years ago,abraded 59 hectare/year and accreted 16.5 hectare/year (Sutikno, 2014). Unfortunately, these results do not describe and determine changes in the shoreline of the island.

The western part of the island, where the present study area is located, is characterised by the highest abrasion and accretion visually. This study was conducted to determine the shoreline change, in term of velocities (metre/year) of abrasion and accretion at the shore area of Bengkalis Cape based on sediment samples analysis, satellite images, and oceanographic data.

II. MATERIALS AND METHODS

The samples of bottom surface sediment were collected from five stations along the shore of Bengkalis Cape in November 2015. A GPS was used to fix the positions of sampling sites (Figure 1). Bottom samples were collected by using sediment grab. The samples were used for analysis of mechanical grain size. The gravel and sand proportions were determined by sieving and were weighed oven dried (Oki, 1989; Rifardi *et al.*, 1998) which were also used by Rifardi *et al.* (2015). The settling tube method was utilised to determine the mud proportion. The graphical method of Folk and Ward (1957) was used to calculate the mean diameter (Mz ϕ), sorting coefficient (Ó$_i$) and skewness (Sk$_i$) of the sediments. The textural proportions of gravel, sand and mud were plotted on Shepard's triangle (Shepard, 1954). Current velocity, wave height and slope of the shore area were also measured at each station.

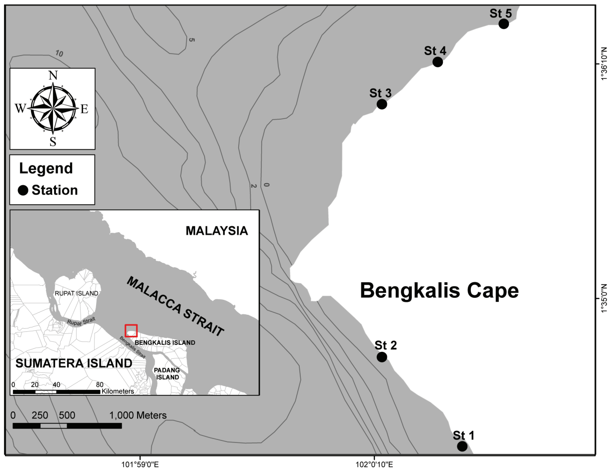

Figure 1. Index map of the study area showing sampling stations

Coastal slope was measured to determine the value of slope using a reference purposed by Mardianto (2004):

$$K = \frac{C}{L} x 100\% \qquad (1)$$

Notes:

K = Coastal Slope (%)

C = Depth (m)

L = distance from coastal toward the sea (30-50 m) at period of high tide

Notes:

K:

→0–2% = Flat

→2–8% = Sloping

→8–30%= Oblique

→30–50%= Steep

→50 %= Very steep

Velocity of currents was measured during the high tide using following formula:

$$v = \frac{s}{t} \tag{2}$$

Notes:

v = velocity of current (m/s)

s = distance (m)

t = time (s)

Wave energy is also calculated at high tide using following formula:

$$E = \frac{1}{8}\rho g h \tag{3}$$

Notes:

E - Total energy (Nm/m^2)

ρ - Sea water density (kg/m^3)

g - Gravity acceleration (9,8 m/s^2)

h - Wave height (m)

Image data of Landsat 5 TM level 1T periods of 1995, 2005, and Landsat 8 LDCM level 1T periods 2015 were used for further analysis. The data was obtained from U.S Geological Survey (USGS) and can be downloaded at www.earthexplorerer.gov. The data was analysed using Semi-Automatic Classification Plugin (SCP) from Quantum GIS (QGIS).

Landsat data consist of data classification, radiometric correction, band stacking, image enhancement, digitisation, and overlay were analysed and interpreted to determine shoreline change. Flow chart of the image data processing is shown in Figure 2.

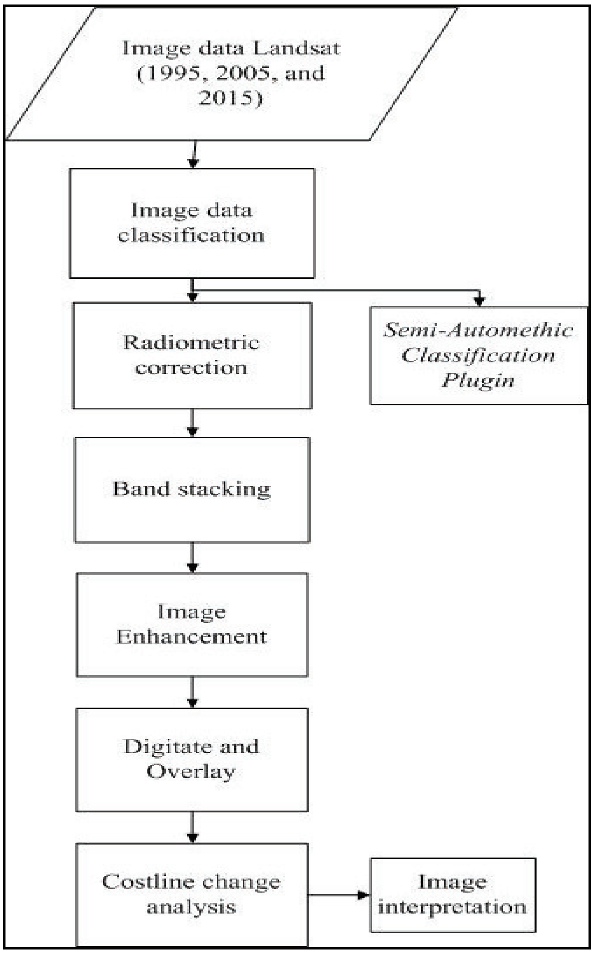

Figure 2. Flow chart of image data processing

III. RESULTS

A. Oceanographical and Slope of the Coastal Area

Results of the oceanographical observation indicate that the shore area of Bengkalis Cape can be divided into 2 (two) parts, namely, the southern and northern parts. The southern part is occupied by weak current velocity (0.06 m/s) and wave energy (0.19 Nm/m^2). This part has rather flat bottom topography as shown by 4.3 – 5.8% of the coastal slope (sloping category). In contrast, strong current velocity (0.16 m/s) and wave energy (0.90 Nm/m^2) can be recognised in the northern part, which is located face to Malacca strait, and this part is characterised by rather steep bottom topography as shown by 10% of the coastal slope (oblique category).

B. Bottom Sediments

The results of mechanical analysis of the five bottom sediment samples are shown in Table 1. The bottom sediments in the shore area are characterised into mud and sand (Mz ϕ: 3.60-6.40 ϕ). Gravels are not found at all stations, which are occupied dominantly by sand fractions (more than 50%), indicating that the bottom character in the estuary must be sandy mud sand except for stations 1 and 2, which are composed of mud.

Table 1. Results of mechanical analysis of the bottom surface sediments

Station	Gravel (%)	Sand (%)	Mud (%)	*Mz* (ø)	*Ó_i* (ø)	Sk_i	Bottom Character
1	0	20.89	79.11	6.00	1.99	-0.88	Mud
2	0	15.37	84.63	6.40	2.12	-0.91	Mud
3	0	79.07	20.93	3.60	2.51	0.21	Sand
4	0	77.12	22.88	4.40	1.86	0.28	Sand
5	0	54.66	45.34	4.07	2.16	0.72	muddy sand

The areas with low mean diamater (Mz ϕ : $\leq 5\phi$) can be seen in the northern parts (St. 3, 4 and 5). The peculiar features of these sediments are assumed to result from the derivation of coarser materials from Malacca Strait and from the neighbouring coastal areas accessible to abrasion landward. Strong main currents are seen in the area composed of coarser grained-sediments, indicating that strong tidal currents as rapid as more than 0.16 m/s influence the bottom sediments. The southern part is occupied by finer grained-sediments, (high mean diamater: Mz ϕ : $\geq 5\phi$) which are influenced by weak tidal currents less than 0.06 m/s.

A general trend of sorting coefficient in the studied area is that sediments are poorly sorted (1.86-2.51 ϕ). Very poorly sorted sediments ($\acute{O}_i$: $\geq 2\ \phi$) are recognised in areas influenced by strong tidal currents as seen in the station 2, 3 and 5. The distributions of skewness (Sk_i) indicate that the study area is characterised by very fine to coarse-skewed sediments (Sk_i : -0.88 to 0.72). High skewed sediments are recognised in the northern part of study area. Geographical distribution of the skewness sediments show the same tendency as of the sorting coefficient ($\acute{O}_i$), indicating the study is strongly under the influence of tidal currents system as mentioned above. Contrastingly, low skewed sediments are recognised in the southern part of study area.

C. Shoreline change

The results of shoreline change of Bengkalis Cape based on the interpretation of image data of Landsat 5 and 8 during 1995 to 2005 and 2005 to 2015 are shown in Table 2.

Table 2. Shoreline change of Bengkalis Cape during 1995 to 2015

Station	1995 to 2005 (m)	2005 to 2015 (m)	1995 to 2015 (m)	Avarage (m/year)
1*	4579	113.31	159. 11	7.95
2*	193.69	401.78	595.48	29.77
3**	345.39	404.55	749.94	37.49
4**	342.44	418.00	760.44	38.02
5**	193.38	453.90	647.29	32.36

Notes *: accretion; **: abrasion

In general, shoreline change of Bengkalis Cape ranges from 7.95 to 37.49 m/year and the lowest movement can be recognised in the southern part of the cape, while the highest occur in the northern part. The shoreline of Bengkalis Cape is moved toward two different directions namely landward and seaward which are called abrasion and accretion respectively.

The accretion of the shore area occurs in the southern part (St. 1 and 2) which reach 7.95 to 29.77 m/year in average. In contrast, the northern part is occupied by coarse-grain sediments (sand) which characterised by high rate of abrasion as shown by the image data interpretation for 20 years (1995-2015) reaches 760.44 metre equal to 38.02 metre/year in average. The shoreline change of Bengkalis Cape can be seen in Figure 3.

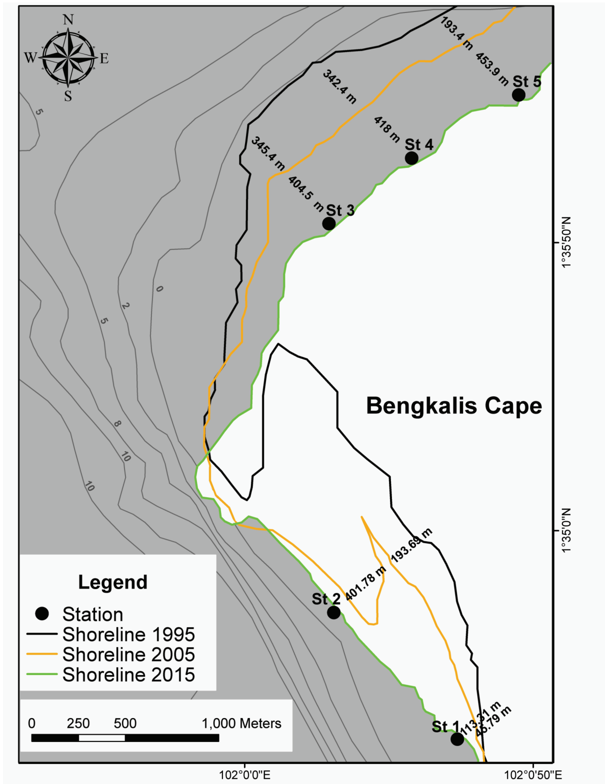

Figure 3. The shoreline change of Bengkalis Cape

IV. DISCUSSION

The Bengkalis Cape can be divided into the following two parts according to movement direction of the shoreline: 1) the southern part is moved toward sea and is characterised by the fine-grained sediments, and 2) the northern part moved toward land and is characterised by coarse-grained sediments. Geographical distribution of the parts is shown in Figure 3. The relationship between the shoreline change and characters of bottom sediments and oceanographic parameters in these two parts is discussed below.

1. The southern part in which the movement direction of the shoreline toward sea recognised as accretion process, is characterised by the fine-grained sediments.

The stations included in the southern part (St. 1 and 2) show the bottom sediment characters of mud sediments (mud content $> 80\%$; Mz ϕ : $\geq 5\phi$) which are influenced by weak tidal currents less than 0.06 m/s and low wave energy (0.19 Nm/m^2). Strong relationship between grain size of sediment and current velocity is also found in Angso Duo Island Pariaman City West Sumatera by Azizul *et al.* (2017) and in the Rokan River Estuary Bagansiapiapi Riau Province Indonesia by Galib *et al.* (2017). The relationship indicates that areas characterised by fine grain sediments are under influence of weak currents, and reversed at areas with coarser grain sediments.

There is a tendency that high accretion rates indicate high sedimentation rates have occurred in the southern part. The same tendency of this features is also found by Rifardi and Badrun (2017) in estuary, which shows that high relative sedimentation rate occurs at the station located very close to the coastal area that is eroded by the current. This part is under influence dominated by terrigenous sediments, as recognised by Rifardi and Ujiee (1993) in coastal area of Okinawa Island and by Rifardi *et al.* (1998) in Yatsushiro Sea, Japan. Transport directions of sediments are mostly controlled by current circulation (Delhez, 1996; Wei *et al.*, 2004; Zhao et al., 1995). The seasonal variation of suspended sediment transport and its seasonal dispersal patterns from the Bohai Sea to the Yellow Sea was discussed by Wang *et al.* (2016) and the results indicate that the dispersal patterns of sediment were strongly influenced by current system. This peculiar feature was also seen in the continental shelf adjacent to Japan as reported by Sakamoto (1982). The weak tidal currents and the low wave energy of the southern part caused by materials (sediments) derived from other areas is accumulated in the bottom of the part. Strong relationship between accumulated materials and sedimentation rates is also clarified by Rifardi (2008a) in Yatsushiro Sea, Japan and by Rifardi (2008b) in Paya Sea, Kondur-Riau, Indonesia. High sedimentation rate of the southern part harmonises well with its morphology shown by rather flat bottom topography 4.3 – 5.8% of the coastal slope (sloping category). For the situation above, the southern part has been in accretion process and consequently, the shoreline has been moving toward sea at least since 1995 with velocity of the accretion reaches 595.48 metre/20 years (29.77 metre/year).

2. The northern part in which the movement direction of the shoreline toward land recognised as abrasion process, is characterised by coarse-grained sediments.

This part (St. 3, 4 and 5) is located close to Malacca Strait which is occupied by strong tidal currents and the current flows through the strait from the south to the north during ebb tide and reversed during high tide. As a result, the bottom sediments of the northern part is dominated by coarse-grained sediments and is under the influence of strong tidal currents greater than 0.16 m/s and high wave energy (0.90 Nm/m^2). Bramawanto et al. (2000) and Rifardi (2001)also found that strong tidal currents derived from Malacca Strait flowing into Rupat Strait play important role to form the bottom sediment characters of Rupat Strait. Strong currents tend to transport coarse sediments to Yatsushiro Sea Japan (Rifardi *et al.*, 1998). The feature is also found in Parangtritis beach, Indonesia as mentioned by Retnowati *et al.* (2012) where shoreline morphology are considered as signatures of rip currents occurrence along Parangtritis beach.

The bottom sediment of the northern part is occupied by sand sediments and by low mud content less than 23%, except for station 5 which shows 45% mud content. Mean diameter of the bottom sediment ranges from 3.6 to 4.4 ϕ which is categorised as fine sand sediments is assumed as the result of strong tidal currents and high wave energy as explained above. Very poorly sorted and fine skewed sediments of this part support this assumption.

The shore area of the northern part is abraded by the strong tidal currents andthe high wave energy. High abrasion rates of this part are shown by steep bottom topography as much as 10% of the coastal slope (oblique category). The shoreline of the northern part has been moving toward land which is showing high velocity of the abrasion 760.44 metre for 20 years (1995-2015) which equal to 38.02 metre/year in average.

V. CONCLUSION

General feature of the bottom sediments in the shore areas of Bengkalis Cape is characterised by fine to coarse grained sediments, which imply the areas are under the influence of weak and of strong tidal currents as shown by poorly sorted sediments. The tidal current system and waves play important role on the shoreline change of Bengkalis Cape. The cape can be divided into the following two parts according to movement direction of the shoreline:

1) The southern part of the shoreline has been moving toward sea with velocity of the accretion reaches 595.48 metre/20 years (29.77 metre/year) which is characterized by the fine-grained sediments and by rather flat bottom topography, indicating the part is under the influence of weak of tidal currents and low wave energy.

2) The northern part of the shoreline has

been moving toward land with high velocity of the abrasion 760.44 metre for 20 years (1995-2015), which equal to 38.02 metre/year. It is characterised by coarse-grained sediments and by steep bottom topography, indicating the part is under the influence of strong tidal currents and high wave energy.

VI. ACKNOWLEDGEMENTS

We express our deep gratitude to undergraduate students for their technical assistance in the field and laboratory works. Particular thanks are due to Ms. Hafiza Tartila Isty, my former student at the Department of Marine Sciences, Riau University, for her technical assistance with the computer work and in mapping, and to all our colleagues at the Department of Marine Sciences, Riau University for their kind help. This article was presented at The International Conference on Science and Technology in Pekanbaru, Indonesia in 2016.

[1] Azizul, R, Rifardi & Ghalib, M 2017, 'Study on abrasion and sediment in Angso Duo Island Pariaman City West Sumatera, Indonesia', International Journal of Science and Research (IJSR), vol.6, no. 6, pp. 1945-1948.

[2] Bramawanto, R, Rifardi & Ghalib, M 2000, 'The characteristics of waves and sediment in the port of Marine Center, Riau University, on the Rupat Strait of the east coast Sumatera Island', Jurnal Perikanan dan Kelautan Universitas Riau, vol. 5, no. 13, pp. 25-38.

[3] Delhez, E. J 1996, 'On the residual advection of passive constituents,' Journal of Marine Systems', vol. 8, no. 3, pp.147-169.

[4] Folk, RL & Ward, WC 1957, 'Brazos River Bar: a study significance of grain size parameter', Journal of Sedimentology and Petrology, vol. 27, pp. 3-26.

[5] Galib, M, Rifardi, Syafriadiman & Syafruddin, N 2017, 'Sedimentation at the Rokan River Estuary Bagansiapiapi Riau Province Indonesia', International Journal of Science and Research (IJSR), vol.6, no. 8, pp. 2254-2259.

[6] Ghosh, M.K., L. & Kumar, C. Roy 2015, 'Monitoring the coastline change of Hatiya Island in Bangladesh using remote sensing techniques', ISPRS Journal of Photogrammetry and Remote Sensing, vol. 101, pp. 137–144.

[7] Mardianto, D 2004, 'Coastal and coastal zone profiles as basic information on potential and constraints to sectoral development activities: Cases in Yogyakarta', Jurnal Kedeputian Ilmu Pengetahuan Kebumian LIPI, Jakarta, p. 89-99.

[8] Oki, K 1989, 'Ecological analysis of benthonic foraminifera in Kagoshima Bay, South Kyushu, Japan', South Pacific Study, vol. 10, no. 1, pp. 1-191.

[9] Opa, E. T 2011, 'Perubahan garis pantai Desa Bentenan Kecamatan Pusomaen, Minahasa Tenggara', Jurnal Perikanan dan Kelautan Tropis, vol. 3.

[10] Retnowati, A., M. A. Marfai & J. T. S. Sumantyo 2012, 'Rip currents signatures zone detection on Alos Palsar Image at Parangtritis beach, In-

donesia', Indonesian Journal of Geography, vol. 43, no. 2, pp. 12-27.

[11] Rifardi & Ujiie, H 1993, 'Sedimentological aspects of the Oura River Estuary and its Environs on the East Coast of Northern Okinawa Island', Bulletin College of Science University of Ryukyus, vol. 56, pp. 145-163.

[12] Rifardi, Oki, K & Tomiyasu, T 1998, 'Sedimentary environments based on textures surface sediments and sedimentation rates in the South Yatsushiro Kai (Sea), Southwest Kyushu, Japan', Journal of Sedimentology Sociaty Japan, vol. 48, pp. 67-84.

[13] Rifardi 2001, 'Study on sedimentology from the Mesjid River Estuary and its Environs in the Rupat Strait, the East Coast of Sumatera Island', Journal of Coastal Development, vol. 4, no. 2, pp. 87-97.

[14] Rifardi 2008a, 'Distribution of sediment, benthic foraminifera and mercury in the South Yatsushiro Sea, Kyushu, Japan', Journal of Coastal Development, vol. 11, no. 3, pp. 104-112.

[15] Rifardi 2008b, 'Deposition of sediment in shallow waters', Indonesia Journal Of Marine Sciences, vol. 13, no. 3, pp. 147-152.

[16] Rifardi, Syahminan, Suwarni, R. B. Butar & N. Fidiatur 2015, 'Sedimentary environments of the Dumai Coastal Waters on the East Coast of Central Sumatera Island, Indonesia', ASM Science Journal, vol. 9, no. 2, pp. 9-16.

[17] Rifardi & Badrun, Y 2017, ' Sandbar formation in the Mesjid River Estuary, Rupat Strait, Riau Province, Indonesia', Indonesian Journal of Geography, vol. 49, no. 1, pp. 65-72.

[18] Shepard, FP 1954, 'Nomenclature based on sand-silt-clay ratio', Journal of Sedimentology and Petrology, vol. 24, pp. 151-158.

[19] Sakamoto, W 1982, 'Detritus-roles of suspended and bottom sediment on coastal marine ecosystem', Marine Sci. Monhtly, vol. 14, no. 8, pp. 482-489.

[20] Sutikno, S 2014, Analysis of coastal abrasion rates of Bengkalis Island using satellite data, Jurusan Ilmu Kelautan, Fakultas Perikanan dan Ilmu Kelautan, Universitas Riau, Pekanbaru, Indonesia.

[21] Vaidya, A. M., Kori, S. K., & Kudale, M. D 2015, 'Shoreline response to coastal structures', Aquatic Procedia, vol. 4, pp. 333–340.

[22] Wang, A., H. Wang, N.Bi & Wu, X 2016, 'Sediment transport and dispersal pattern from the Bohai Sea to the Yellow Sea', Journal of Coastal Reaseach, vol. 74, pp. 104-116.

[23] Wei, H., D. Hainbucher, T. Pohlmann, S. Feng & Suendermann, J 2004, 'Tidal induced lagrangian and eulerian mean circulation in the Bohai Sea', Journal of Marine Systems, 2004, vol. 44, no. 34, pp. 141-151.

[24] Zhao, B., G. Zhuang, D. Cao & Lei, F 1995, 'Circulation, tidal residual currents and their effects on the sedimentations in the Bohai Sea', Oceanologia et Limnologia Sinic, vol. 26, pp. 473-478.