Original Research Article

Bathymetric Survey and Topography Changes Investigation of Part of Badagry Creek and Yewa River, Lagos state, Southwest Nigeria.

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ABSTRACT

Aims: Bathymetry survey of Part of Badagry Creek and Yewa River was conducted with the aim of investigating the topography changes in depth between two epoch dataset by calculating the volume of sediment and dredged material between the two periods.
Study Design: Depth sounding at 100m interval, data grid of 100m interval, constant vessel speed of 2.2m/secs (8Km/hr) for data capture, data storage at interval of 30 Secs was ensured at both the Creek and the river.
Place and Duration of Study: Seabed topography changes of Part of Badagry Creek and Yewa River was investigated. The two dataset investigated was the data acquired in September 2008 and November 2015.
Methodology: Data acquisition was done using digital echo sounder SDE28, Handheld Real time Kinematic (RTK) Global Positioning System (GPS) in acquiring the spatial coordinates (x, y) and water depth (z). Six (6) wrecks (Shipping Boat) were determined along both the creek and the river. The initial processing was carried out with the use of HYPACK 2008 software for data sorting. ArcGIS 10.2.1 was used for data analysis as well as graphics design. The processed depths were presented in form of tables, map/plan and charts.
Results: The result showed that In 2008, the depth observed ranges from (-0.5 to 10.4)m while in 2015, the depth observed ranges from (-0.324 to 10.852)m which implies that some area have been cut. Also, the results of the volume of deposited sediments and dredged material are computed as 10546238.125413m^3 and 7241588.323126m^3. It showed from the result that volume of accreted sediment is greater than volume of the material dredged.
Conclusion: Increase in volume of sediment deposited could be as a result of the adjoining river Yewa flowing into the larger river (tributaries) of the Badagry Creek. Therefore, further studies need to carry out in order to know the source of accreted mass through integrated coastal management plan.

Keywords: Bathymetric Survey, *Topographic changes, Depth Sounding, Wreck determination, Volume determinations*

1. INTRODUCTION

The countless benefits offered humanity by the global oceans makes the study of water bodies a vital field of research to man [1, 2]. Ranging from easing and ensuring safe navigation of vessels on waterways [1], simple reconnaissance (at project formulation) to payment for work carried out underwater, such as dredging or reclamation [3], mineral exploration [4] and other such benefits derivable from the water bodies, a concise study of the morphometric and/or physio-c properties of the water body is highly relevant. A common practice in such studies especially where water body morphometry is of major concern is bathymetric survey while morphometry represents the topographical expres land by way of area, slope, shape, length, etc. and these parameters affect catchment stream flow pattern throu influence on concentration time [5, 6].

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Bathymetric survey is required whenever a detailed survey of the bed level is to be carried out, which is defined as the measurement of water Depth e.g. lakes, oceans, dams, and seas, rivers [7]. Bathymetry according to [8] is the measurement of the depths of water bodies from the water surface. It's the marine equivalent of topography and a major component of the overall hydrographic survey operation.

In bathymetric survey, charts are produced to support safety of surface or sub-surface navigations which usually shows seafloor relief or terrain as contour lines (depth contours), and such chart provides surface navigational information [1]. Bathymetric survey is just like carrying out topographic survey on land. The chart produced from bathymetric survey of underwater depicts the nature of the underwater bed. A three Dimensional (picture) of the bottom would meet this requirement, and this is exactly what is meant by High Definition Gridded Bathymetric (HDGB). [9]. It must be said that since inception, the major task of hydrography had been the capability to efficiently tie measured sea bed depths to the correct planimetric positions [3]. There are many instruments that have been designed to achieve better standard of hydrographic surveying. Display quotations of over 40 words, or as needed. With such advance in class instruments, surveyors have the capability to perform better and straightforward data acquisition of observation in hydrographic surveying and at the same time achieve better accuracy in their observations [10]. For a bathymetric chart to be produced; tidal observation and reduction must be done in order to reduce sounding depth to chart datum [11].

Monitoring navigation channels for shipping, traffic safety, and mapping underwater sand bars, rocks, shoals, reefs, and other hazardous marine features relies on accurate and up-to-date seafloor topography (Bathymetry) information [12,13]. Bathymetry changes rapidly in response to storm surges, sea level rise, changes in river condition, and engineering activities such as dredging [14]. Bathymetry information is also important in navigation safety, water volume computation, pollution control, mineral and fish industries, underwater engineering construction, harbor and docks construction and maintenance [15]. Improvement are continually made to the types of data and analysis method used for estimating bathymetry across the global ocean as stated by [14].

The repeated emergence and submergence of coast have been instrumental in shaping the morphological expression of the continental shelves in general and shorelines in particular [16]. The coast is going on emerging by tectonic movement as proved by [17]. As dredging occurs a lot in the Creek and river, the equilibrium depth of the Creek and river will be less than the optimum depth required for navigation as stated by [18]. This is very crucial for the mariners and the shippers that need up-to-date information about the creek and river before embarking on any activities so as to avoid presence of wrecks and other dangerous marine features.

Physical loss and damage to the seabed has widespread effects on biodiversity, ecosystems, food web dynamics and marine habitats [19]. Thus, understanding seafloor morphology and its evolution is critical to scientific investigations of boundary layer processes. Hydrographic survey supports a variety of marine functions: port and harbour maintenance (dredging), coastal engineering (subsidence assessments and restoration projects), coastal management and offshore resources development [20]

Accurate estimation of dredged volume is a very important aspect of dredging. This is because volume computation is the only way to monitor the dredging process, thereby comparing the amount of materials planned to be dredged and the amount that was actually dredged [21].

The accuracy of a resultant volume is dependent on many random variables, such as the horizontal positioning accuracy, elevation (or depth) measurement accuracy, data density or personified footprint size relative to the overall area, terrain uniformity, and the volume computational method employed [22]. Therefore, this study investigates topography changes in the sea bed between two adjoining rivers (Part of Badagry Creek and Yewa River) using two epoch data 2008 and 2015 bathymetric dataset, so as to reveal the spatial/morphological changes that has occurred between the period of the study.

2. THE STUDY AREA

The study location is Part of Badagry Creek and Yewa River (fig. 1). Badagry creeks is located in Badagry, Lagos State, Nigeria. It lies within geographic longitude 2° 42′ 00"mE and 3° 42′ 00"mE and geographic latitude 6° 22′ 00"mN and 6° 42′ 00"mN. It covers approximately a total distance of 177km [23] while part of the Creek study covers a total distance of 43.882km in length and 1.143km in segment. River Queme and Nakoue lagoon are the major sources of water into the Creek. Combination of these two water bodies form the Badagry creek which joins part of the continuous lagoon known as Osa lagoon that stretches from Port Novo to Lagos and finally opens into the Atlantic ocean via Lagos harbour in three channels [24]. Yewa River is an adjoining stream flowing into Badagry Creek in Lagos, Nigeria. It is located at an altitude of 36 meters above sea level with population amounting to 174,152. Yewa River is a trans-boundary river between Benin republic and Nigeria and it lies approximately within geographic longitude 2° 42′ 00"mE and 3° 00′ 00"mE of the

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Greenwich meridian and geographic latitude 6° 15′ 00"mN and 6° 45′ 00"mN of the equator. It covers a total distance of 16.898km in length and 0.094km in segment.

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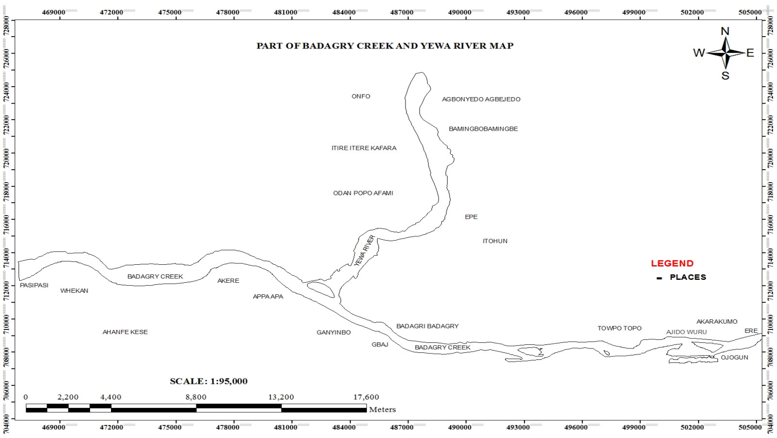

FIG. I. MAP OF THE STUDY AREA

Fig. 1: Map of the Study

3. MATERIAL AND METHODS

3.1 Bathymetric instruments used for the study

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The equipment used for this bathymetric operation is as follows:
i. SDE28 Digital Echo Sounder and its accessories
ii. Transducer (Component of Echo Sounder)
iii. Garmin 78s (Handheld) GPS
iv. Service Boat with 4hp engine
v. Life Jacket

3.2 Methods of data acquisition

The collection of data for this study cuts across various methods of surveying. In line with the aim and objectives of the study, the following methods were employed to acquire all the necessary data needed.
a) Sounding
b) Wreck determination across the Creek and River
c) Use of tidal prediction table for depth correction

3.2.1 Sounding operation (Depth sounding)

The data acquisition was done by setting up the Echo sounder on the vessel connected to the transducer and setting data storage interval at 30 Secs and the observations carried out in strips. The vessel speed was kept constant while vessel heading was also maintained throughout each observation strip and the instrument automatically stores the XYZ values of every point.

3.2.2 Setting data acquisition timing

Sounding interval of 100m was used; the vessel speed was kept constant at 2.2m/secs (8Km/hr) during the data capture. The Echo Sounder was then set to capture data every 31secs. As such the data grid of 100m interval was ensured.

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3.3.3 Setting the parameters in the Echo Map

The echo Map parameters were set as follows:
Coordinate System: WGS 1984 UTM Zone 31N
Units - Meters
Projection - Traverse Mercator

Ellipsoid - Clarke 1880 (Minna)

3.2.4 Sounding preview

In order not to miss any point during sounding, having left the site only to discover that one or two or several other points were not sounded, check was done on the raw data files in the main window of the echo sounder so as to see if there are any such point(s) or other problems. All this was ascertain before leaving the site.

3.2.5 Detailing / Wrecks positioning

Surface wrecks within the creek and Yewa River were mapped using a hand-held GPS. As such the positions of all surface wreckages were determined (see fig. 3). Three fishing boat were found each along the Creek and River (see fig. 3**)** which was not found in 2008 bathymetric survey. During the sounding, no underground wrecks were found. The coordinates (x, y, z) of wreck position were determined with handheld GPS (Table 1). The four (4) coordinates observed each for the submerged wrecks denotes the two bottoms and the two edge of the boat.

Table 1: Coordinates x, y, z opf wreck position along the Creek and the River

Coordinates of Wrecks along Yewa River		
Wreck	Easting	Northing
1st Wreck	488474.621	719747.593
	488188.927	719747.593
	487952.372	719747.593
	488011.511	719925.009
	488602.899	715489.600
2nd Wreck	488307.205	715489.600
	488070.650	715489.600
	488129.789	715667.017
	483812.657	712710.077
3rd Wreck	483516.963	712710.077
	483280.408	712710.077
	483339.547	712946.633
Coordinates of Wrecks along Badagry Creek		
	500134.962	708392.946
1st Wreck	499839.268	708392.946
	499602.713	708452.946
	499661.852	708629.501
	504333.816	708511.224
2nd Wreck	503978.983	708511.224
	503801.567	708511.224
	503860.705	708688.640
	505161.759	708747.779
3rd Wreck	504866.065	708747.779
	504629.510	708747.779
	504688. 648	708925.195

3.3 Extracting Depth information for corresponding points in data 2008

The “griddata” command statement in matlab was used for extracting depth of corresponding points as taken during the 2015 bathymetry survey from the 2008 bathymetry data (see Table 3). Using the 2008 data as a base data frame, the “griddata” command interpolates for the value at same corresponding points as taken in the 2015 observation using the nearest neighbor search algorithm.

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3.4 Water channel erosion/Accretion rate assessment

Understanding the mechanisms and rates of bank erosion, accretion and lateral channel migration has fundamental significance, as well as results of these researches which are applicable in the field of water and soil resources management, hydro-technical works, and in different aspects of the environmental protection [25, 26]. Riverbank erosion has important implications for short and long term channel adjustment, development of meanders, sediment dynamics of the river catchment, riparian land loss and downstream sedimentation problems [27]. Detecting the rate of spatial change in sea bed topography at the part of Badagry creek and Yewa River was done after depths at corresponding points have been determined. The methodology involved in the change detection approach is as shown in Fig. 2. The rate of seabed change for Bathymetry data 2008 and 2015 were plotted using ArcGIS and Microsoft excel software. The resulting graphs showed variation in depth for both years. Algebraic addition of the stream path graph of both years thus resulted in the residual graph for the study area.

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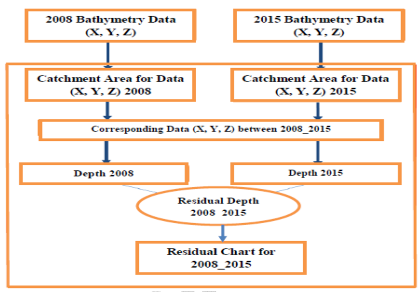

Fig. 2: Workflow diagram for assessment of river bed topographical changes

3.5 Data Processing

The data observed were copied out of the memory card inserted in the Echo Sounder. The data was saved directly on the memory card as Easting, Northing and Depth and as such there was no need for any further post processing. Sample of the results are as presented in Table 1. The observed sounding readings were then reduced to the sounding datum (sounding values) by applying formula below

Value $= S.R - (Sounding\ Value_{Sounding\ Datum} - Predicted\ tidal\ reading_{tide\ table})$ eq. (1)

Where S.R = Observed Sounding Reading

Thereafter, the sounding values are reduced to actual depth (chart datum) using the general formulae below;

Chart Datum (Mean Water Level) = $Reduced\ Level_{sounding\ Datum} + Sounding\ Value$ eq. (2)

Depth n = $Depth_n = Mean\ Water\ Level - Sounding\ Value$ eq. (3)

Where n = All other subsequent observations apart from the first reading.

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4. RESULTS AND DISCUSSION

The results presented in this section are in form of tables, maps and charts of relevance which represent processed dataset 2008 and 2015. Fig. 3 is a processed bathymetric dataset for 2008 and 2015 survey as observed with the echo sounder plotted with ArcGIS 10.2.1 software. In 2008, the depth observed ranges from (-0.5 to 10.4)m with area of low depth ranges from (-0.5 to 0.711)m and area of high depth of (9.189 to 10.4) m while in 2015, the depth observed ranges from (-0.324 to 10.852)m with area of low depth of (-0.324 to 0.918)m and area of high depth of (9.61 to 10.852)m (see profile graph in fig. 4). Fig. 4 showed the profile graph of depth variation along the seabed. Fig. 5 showed depth variation between 2008 and 2015 and their depth residuals overtime. Fig. 6 described the spatial changes that occurred between 2008 and 2015. To detect depth change over time on the creek and river topography. A graphical plot of change in sea bed topography has also been shown in Fig. 7. Fig. 8a is the volume of sediment deposited with its query while fig. 8b is the volume dredged volume with their query. Tables 2 show the processed bathymetric data for dataset 2008 and 2015. Table 3 shows depth residual data from 2008 and 2015 survey.

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Table 2. Sample of the processed dataset for 2008 and 2015

2008 Bathymetric Data for Badagry Creek			**2015 Bathymetric Data for Badagry Creek**			**Depth Diff. (2008/15)**
EASTING	NORTHING	DEPTH	EASTING	NORTHING	DEPTH	
483252.770	711334.730	2.01000	501410.260	708870.860	0.017217	1.992783
483302.430	711340.520	2.27000	501515.370	501515.370	0.083933	2.186067
483352.090	711346.310	2.46000	501565.040	708838.570	-0.324056	2.784056
483401.760	711352.100	2.61000	503962.920	708564.410	0.013286	2.596714
483197.310	711378.600	1.63000	503957.130	708614.070	0.705576	0.924424
483246.980	711384.390	1.91000	501769.480	708812.060	-0.076793	1.986793
483296.640	711390.180	2.17000	501819.140	708817.850	0.315078	1.854922
483346.300	711395.970	2.35000	501868.810	708823.650	0.351946	1.998054
483395.970	711401.760	2.51000	501076.640	708278.240	0.296690	2.21331
483191.520	711428.260	1.53000	501719.820	708806.270	0.192472	1.337528
483241.190	711434.050	1.81000	504231.950	708847.470	0.409570	1.40043
483290.850	711439.850	2.07000	504281.610	708853.260	0.856854	1.213146
483340.510	711445.640	2.26000	504331.280	708859.050	0.598653	1.661347
483390.180	711451.430	2.44000	504380.940	708864.840	0.814213	1.625787
483185.730	711477.930	1.43000	501360.590	708865.070	0.853764	0.576236
483235.400	711483.720	1.71000	504424.810	708920.290	0.698465	1.011535
483285.060	711489.510	1.97000	504474.480	708926.080	0.844947	1.125053
483334.720	711495.300	2.16000	504524.140	708931.870	0.865855	1.294145
483384.390	711501.090	2.34000	504573.800	708937.660	0.006122	2.333878
483130.280	711521.800	1.15000	504623.470	708943.450	0.520193	0.629807
483179.940	711527.590	1.35000	504717.000	709004.700	0.680052	0.669948
483229.610	711533.380	1.61000	504766.670	709010.490	0.158338	1.451662
483279.270	711539.170	1.87000	504816.330	709016.280	0.765350	1.10465
483328.930	711544.960	2.06000	504865.990	709022.070	0.017235	2.042765
483378.600	711550.750	2.24000	504915.660	709027.860	0.659379	1.580621

From the table 2 above, negative depth difference denotes sounded depth increase which implies that mining/dredging (material added/area filled) operation has occurred in those areas whereas; positive depth difference denotes presence of sediments (material removed/area cut).

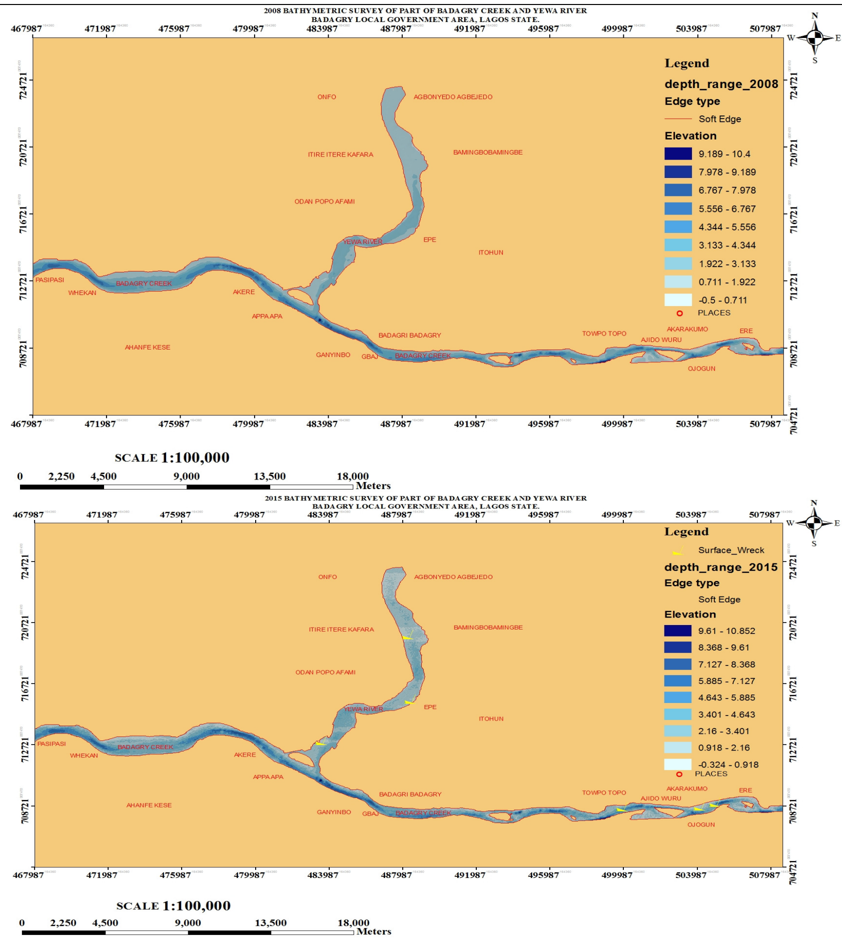
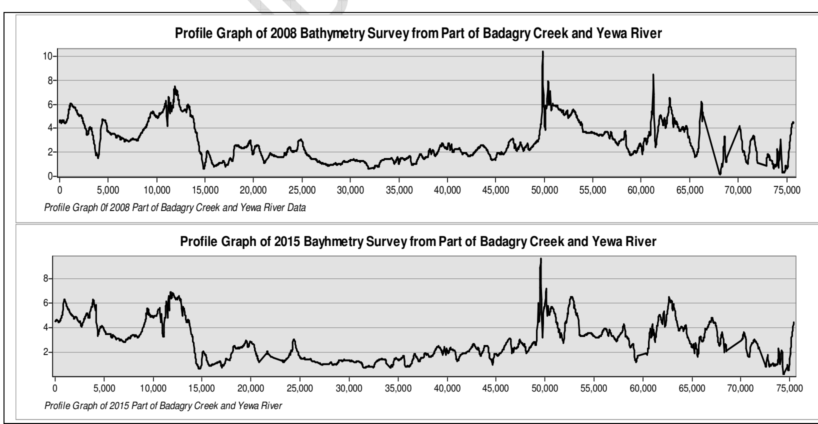


Fig. 3. Spot values of part of Badagry Creek and Yewa River sea-floor obtained for 2008 and 2015 dataset



a

b

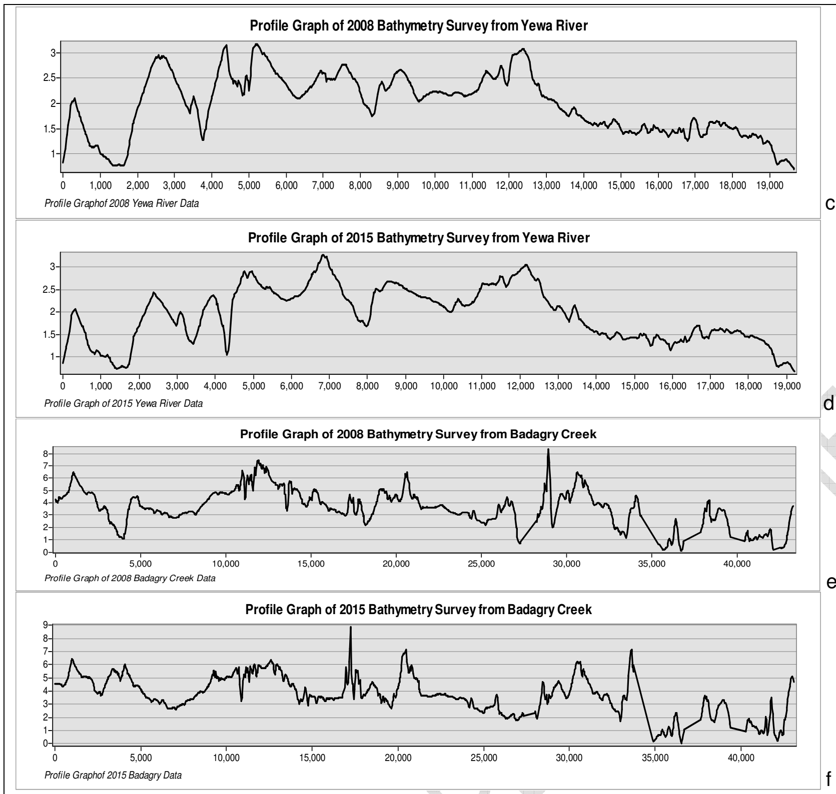


Fig. 4. Sea-bed profile graph from 2008 and 2015 Bathymetry data from Badagry Creek and Yewa River.

Fig. 4 above showed that from the profile graph (a & b), at 20,000m (20km) in 2008, the depth was 2.0m while in 2015, the depth was 2.5m which implies that dredging has taking place after 2008 observation leading to increase in depth in 2015. At 40,000m (40km) in 2008, the depth was 2.15m while in 2015, the depth was 1.90m which denotes sediment deposit in 2008. From profile graph (c & d), it showed that at 2500m (2.5km) in 2008, the depth was 2.4m while in 2015, the depth was 2.2.8m which means that dredging has taking place after 2008 observation. At 15500m (15.5km), the depth was 1.40m while in 2015, the depth was 1.26m which denotes sediment deposit in the area (area fill). Profile graph (e & f) showed that at 4000m (4km) in 2008, the depth was 1.01m while in 2015, the depth was 4.90m which indicates that dredging has taking place after 2008 observation. At 15000m (15km) in 2008, the depth was 3.80m while in 2015 the depth was 2.90m which indicates sediment deposit has taking place after 2008 observation.

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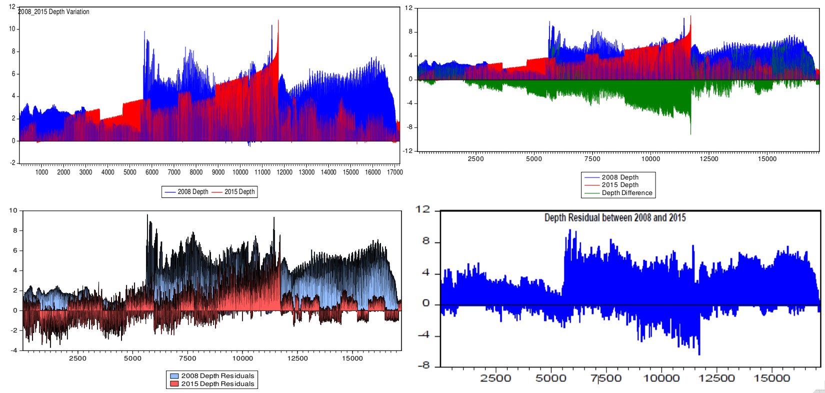

Fig. 5. Variation in 2008 and 2015 Depth, Depth Difference and their Depth Residuals

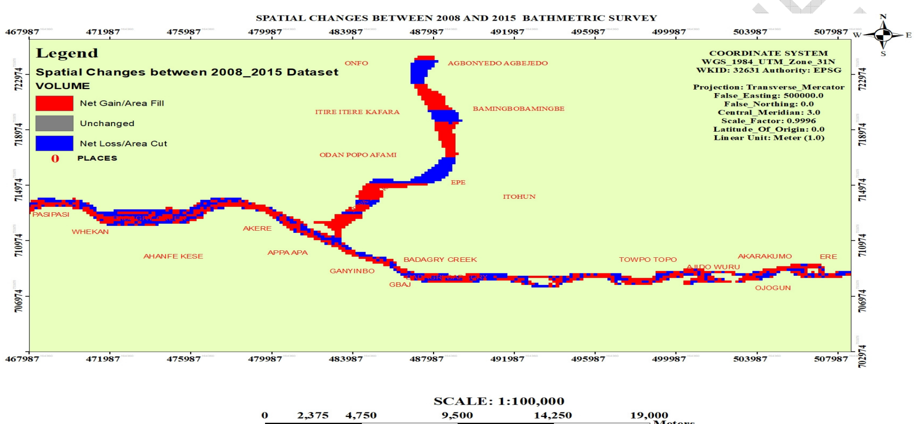

Fig. 6. Spatial Changes between 2008 and 2015

Table 3: Residual values between 2008 and 2015 depth across Badagry Creek and Yewa River

Easting (m)	Northing (m)	Depth 2008	Depth 2015	Res. (2008/15)	Easting (m)	Northing (m)	Depth 2008	Depth 2015	Res (2008/15)
483892.7	710265	-2.61	-3.36	0.75	487968.6	716135.1	-2.11	-1.95	-0.16
483477.7	710543.9	-2.61	-3.36	0.75	488334.6	716475.9	-2.54	-1.864	-0.68
483062.8	710822.8	-2.01	-2.85	0.84	488700.5	716816.6	-2.51	-2.096	-0.41
482647.8	711101.7	-1.63	-1.94	0.31	488879.3	716983	-2.65	-1.811	-0.84
482232.8	711380.7	-0.93	-1.13	0.2	488810	717086.9	-2.77	-3.658	0.89
481817.9	711659.6	-1.61	-1.68	0.07	488675.7	717568.5	-3.03	-3.48	0.45
481402.9	711938.5	-0.77	-1.52	0.75	488545.4	718051.2	-1.78	-2.097	0.32
480987.9	712217.5	-0.77	-1.52	0.75	488410.6	718532.7	-1.40	-2.07	0.67
480573	712496.4	-0.77	-1.52	0.75	488275.8	719014.2	-1.45	-2.436	0.99
482992.4	711996.4	-0.75	-1.17	0.42	488141	719495.7	-1.16	-0.697	-0.46
483296.8	712393.1	-1.26	-1.35	0.09	488006.2	719977.2	-1.01	-0.727	-0.28

483601.2	712789.7	-0.73	-0.79	0.06	487871.4	720458.7	-0.98	-1.289	0.31
483905.6	713186.4	-1.34	-1.65	0.31	487736.6	720940.1	-1.13	-1.669	0.54
484210	713583	-1.78	-1.114	-0.67	487601.8	721421.6	-1.20	-2.147	0.95
484514.4	713979.7	-2.32	-3.065	0.75	487390.2	722177.3	-1.47	-2.267	0.80
484818.8	714376.3	-2.34	-2.982	0.64	487182.5	722696.8	-1.56	-1.5	-0.06
485123.2	714773	-2.59	-3.179	0.59	487332.1	723173.8	-1.42	-0.70	-0.72
485277.9	714974.5	-3.22	-3.426	0.21	487481.8	723650.9	-1.30	-0.59	-0.71
486870.8	715113	-2.61	-2.852	0.24	487631.5	724128	-0.86	-1.49	0.63
487236.8	715453.7	-2.57	-1.616	-0.95	487736.5	724462.9	-0.68	-1.28	0.60
487602.7	715794.4	-1.9	-1.837	-0.06					

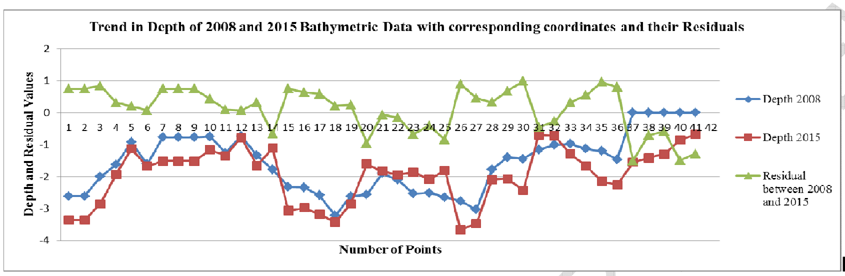

Fig. 7: Profile lines along which sea-bed topographical analysis was carried out.

It showed from Table 3 that equal depth exists in forty-one (41) points between Badagry Creek and Yewa River

4.1 Mass Volumes Determination

Volume can be determined from a triangular irregular network (TIN) model using spatially referenced depth-point measurements obtained from hydroacoustic surveys [28], [29]. Spatially referenced hydroacoustic instruments have become common means to collect depth data for waterbody volume estimates [30], 31], [29]. In the determination of mass volume for this study, the data was first stored in grid raster format in an arrays structure in square cells. Since the depth difference has been determined between the two epoch dataset 2008 and 2015 (Table 2), then the volumes for dredged mass (area cut) and volume of mass accretion (area fill) on the topography are determined. It was calculated from the table of content of the raster map dataset in ArcGIS 10.2.1 by selecting open the attribute table from the raster and select the attribute table and choose volume >0 for dredged volume which is positive and volume <0 for accreted volume which is negative (see fig. 8a and b).

Comment [h40]: This section should be moved into the methods section.

From the attribute table, the volume row was right click (yellow colour as a query for the volume determination (fig. 8a and b), then select the statistic of the raster cut fill to show the volume of accreted portion and was calculated as 10546238.125413m^3 (negative) which showed area that have been filled (material added/area fill) and that of dredged materials was calculated as 7241588.323126m^3 (positive) which also showed area that been cut (material removed/area cut). The total volume computed from this study for the accretion and as well as dredged material was 17787826. 448539m^3. From the volumes computed from the image raster, it showed that sediment of the deposited volume is higher than the mass of the material dredged from the creek and the River.

4.1.1 Volumes Conversion to Metric Ton

Comment [h41]: Just report the results under the result section and move the methods of analysis to the methods section.

Volumes were respectively converted into metric tons after the volume of accreted area was determined as 10546238.125413m^3 and that of dredged materials as 7241588.323126m^3 (fig. 8a and b). The volume determined are now converted to weight and computed as thus;
Density of the wet sand (D) = Sediment Mass/ Volume of accreted material.
Given the density for wet sand as 1922 kg/cu.m
For the accretion
Sediment Mass in (Kg) = density of wet sand × Volume accreted

Therefore, Net Gain/Sediment Mass (kg) = 1922kg/cu.m × 10546238.125413cu.m = 20269869677kg

Comment [h42]: 20.27 x 10^9 kg

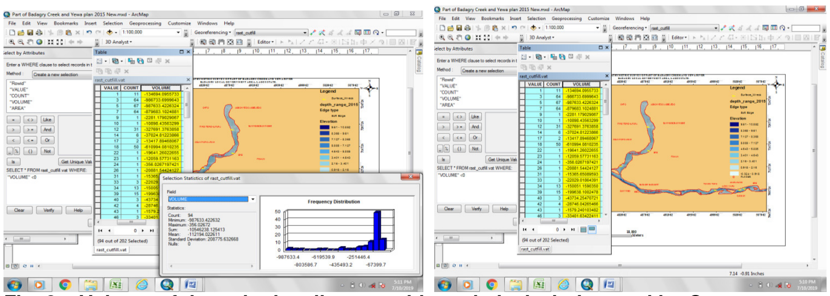

Fig. 8a. Volume of deposited sediments with statistical window and its Query

For the dredged materials

Given the density for wet sand is 1922 kg/cu.m, then

Density of wet sand = sediment Mass/Volume of dredged material

Therefore, dredged mass (kg) = Density of wet sand × Volume dredged**=** 7241588.323126m^3 × 1922 kg/cu.m = 13918332757kg

The number of tons was also determined for both sediment material and Dredged material. Since 1 metric ton is 1000kg. Mass (tons) for both dredged material and sediment materials are computed as;

Sediment Mass (Metric tons) = (1922kg × 7241588.323126) / 1000 = 13918332.7569 Metric tons

For Dredged mass (kg), since 1 metric ton is 1000kg

Then for the dredged mass (Metric Ton) = Dredged mass (kg)/1000kg = (139183327575/1000) kg = 139183327.5 metric tons.

Comment [h43]: 139.18 x 10^6

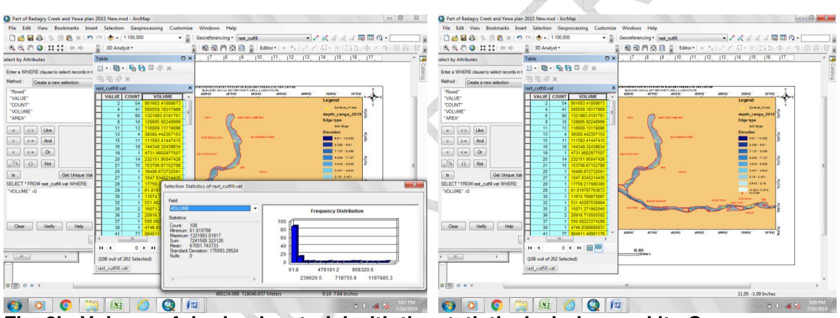

Fig. 8b. Volume of dredged material with the statistical window and its Query

In order to show the areas where spatial changes occurred, then this is done using the Arc Toolbox menu by selecting from the 3D Analyst, the raster surface and select the before raster (i.e. 2008 raster) and after raster (i.e. 2015 raster). Then the clip volumes from the raster image showed the net gain/dredged portion, unchanged portion and accretion area created. From fig. 6, areas in red colour are net gain/sediment portion (area filled) while deep blue colour shows net loss (area cut) and grey colour showed area where no changes exists which is similar to the study by [32].

Comment [h44]: Move to methods section

4.2 DISCUSSION OF RESULTS

From fig. 3, the deepest points within the Badagry creek and Yewa River occur in the southern area (base) of the water body contrary to expectations of a deeper inner seaward region. This pattern is suspected to have taking place as a result of dredging activities going on around the southern shoreline of the Badagry creek and the river. This is further proved by the seabed variation pattern drawn in fig. 4, 5 and 7. The inadequate nature of the profile graph shows an uneven sea bed topography which likely could have resulted from erosion and aggravated by dredging activities (see fig. 4, 5 and 7). From fig. 6, it showed that spatial changes exist in both the Creek and the River. The results also showed that area fill is greater than the area fill in Yewa River while in Badagry Creek, it showed almost equal area fill and area cut.

Fig. 7, profile line shows the significant amount of erosion and soil loss in the sea bed. This shows the deeper values of depth in the 2015 bathymetry data as compared to the 2008 bathymetry data (Table 3) and therefore negative residuals. However, traces of sedimentation are also noticed in some areas of the creek and the river (Tables 3). The mixed dynamics (erosion and accretion) observed in the creek and the river is not unexpected as the pattern of sea-bed topography variation complies with the natural behaviour of water bodies in their lower course. As the water travels from the high sea towards the Badagry creek and the river, it reaches a low lying plain (as evidenced by the bathymetry results in figure 4 in its final course and begins to a winding course (meander). Meanders are systems that are constantly changing, following a sinusoidal pattern, and playing an important role in the modelling and shaping of the landscape around them. These beautiful patterns have been the object of study of many researchers in diverse areas in the last 50 years [33–37]. Two main processes in meander migration are bank erosion and bank accretion [33, 34], [38]. On one hand, bank erosion is unpredictable, fast, and has very well-known negative effects on the environment and society [33]. On the other hand, bank accretion is a slow process and is commonly related with vegetation and sediments deposited at the bank-toe [33].

This meandering therefore has led to the erosion noticed around the curved surface i.e., the concave bank and as a result deposition at the convex bank of the meander. This thus requires that the officials of Nigerian Inland waterways Authority (NIWA) in conjunction with the Navy make conscious efforts to properly monitor the activities within the Badagry creek before this presently on-going concurrent erosion and deposition degenerates into the formation of an oxbow lake in the area. It can be deduced from this study that 3304649.802287m^3 of sand are dredged (Area cut) from the Creek and the River between 2008 and 2015 which is similar to result obtained by [39]. From the mass volume estimated; it showed that more than average of the above metric tons of sand has been dredged or deposited to some part of Creek and the River; and this showed that some portion of the accreted area have been dredged and there is no means of determining the quantity in mass sediments that has been dredged and later on leading to accretion. However, the source of this sediment deposits along the Creek and River topography requires investigation on the entire part of the land adjoining or near the seabed, and this estimated accretion volume is in confirmation with the study conducted by [40]. From the results of the study, mass sediment in the study area may likely caused by waste disposal into the Creek and the river by the resident in the neighboring communities, submerged wreckages such as shipping boats as determined in the course of the study, tidal current and erosion moving upstream and downstream into the Creek and the adjoining river Yewa, jetty construction along the waterways etc.

Comment [h45]: 3.30 x 10^6 m^3

5. CONCLUSIONS

This study has investigated the topography changes of part of Badagry Creek and Yewa River and the cause of such changes. Geographic Information System (GIS) has proved to be the best tool available in monitoring any spatial-related changes on any part of the world. Moreover, spatial changes were detected to have taken place in the study area within the two epoch time (2008 and 2015). The result from the findings of this study showed that sudden change occurred between 2008 and 2015 bathymetric observation which was in two forms; that is the areas of sediment deposits/accreted portion/area fill and areas of material dredged/ area cut. The volume of accretion as well as the dredged volume of sand within the area was computed, and they are respectively 10546238.125413m^3 and 7241588.323126m^3 similar to the result of [32; 39]. The result from the findings also showed that mass sediment (20269869677kg) is greater than mass dredged (13918332757kg) similar to the result of [29; 36]. Moreover, it showed that in Yewa River, area fill is more than the area cut and in part of Badagry Creek; almost equal portion has been cut and fill (fig. 7). Further study is required on the other part of Badagry Creek in order to determine the source of mass deposit into the Creek. The need for a wholesome embrace of an integrated Coastal Management, where the activities of the dredgers are to be monitored especially along Badagry creek. So also, the needs to carry out research into the source of accreted mass through integrated coastal management plan along the creek and the river. Lastly, wreck along the navigation route should be removed for easy navigation on water.

Comment [h46]: Said by who? GIS is not a montoring tool. It is among the useful tools for spatial data analyses.

Comment [h47]: The change observed is not sudden because the series data is not daily or weekly rather there is a difference of 7 years. It must have been gradual.

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COMPETING INTERESTS

None