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RESEARCH PAPER

Evaluating the impacts of dredging and saline water intrusion on rural livelihoods in the Volta Estuary

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ABSTRACT

Many communities around the world are directly dependent on rivers. In Ghana the damming of the Volta River for hydro-electric power led to the development of a sandbar at the estuary, which disrupted salt water intrusion. Inadequate salt water intrusion also led to the proliferation of snail vectors of schistosomiasis (bilharzia) and growth of aquatic weeds. In 1990, dredging began at the Volta Estuary to address the identified problems. After more than 20 years, information on the impacts of the dredging activities remain scanty. In this paper, the socio-economic impacts of dredging activities being carried out by the Volta River Authority was investigated using interviews, analysing salinity data, sampling schistosomiasis snail vectors and administering questionnaires. The results revealed that sea water intrusion has improved. However average salinity at some points exhibited downward trends. No snail vectors were sampled at the estuary due to saline water intrusion at high tides. While the number of tourists visiting the area has increased, livelihood activities such as fishing and farming have declined. Hence while dredging at the Volta Estuary has helped to reduce some of the physical problems posed by the construction of dams on the Volta River it has failed to improve the livelihoods of local residents. The authors recommend alternative livelihood programmes to address poverty and well-being issues in the surrounding communities. It also advocates for understanding of the value systems and priorities of residents to ensure projects are integrated within the traditional governance structures and community priorities to minimize conflicts.

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1. Introduction

Estuaries are among the most productive natural environments (Ronald and Kathleen 2006). Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and salt marshes, swamps, sandy beaches, mud and sand flats, rocky shores, oyster reefs, mangrove forests, river deltas, tidal pools and sea grasses (Good 1997). Unfortunately, most of the world's estuaries face a plethora of challenges, mainly from anthropogenic sources (Gerken and Paukert 2009, Falke *et al.* 2010). These include dam construction and conversion of vital habitats into farms, dwellings and tourist attractions.

Dam construction comes with numerous social and environmental impacts. These impacts, according to the World Commission of Dams (WCD), are the 'unnecessary prices paid to secure those benefits' (WCD 2000, Aird 2001). The adverse environmental and social impacts of dam creation are largely unanticipated or underestimated during the design of most reservoirs (WCD 2000). Social impacts such as displacement and resettlement of people before river damming may be considered the severest of these impacts, with about 40–80 million people displaced globally due to dam creation (WCD 2000). Hydropower dams have led to the erosion of livelihood opportunities of the downstream communities and the physical ecosystem processes on which they depend (Okuku *et al.* 2016). According to Okuku *et al.* (2016) river damming may continue in the developing countries despite their negative impacts on downstream ecosystems and community livelihoods. With many people without access to a reliable water supply or electricity, water and electricity will continue to be recognized as key resources for advancing industrialization and community development, and also for damming. What is more in many developing nations, hydro-electric power provides electricity generation where other forms are not possible due to limited infrastructure or the high cost of importing of fossil fuels (Evans *et al.* 2009). However, dams change the pattern of flow of rivers, reduce their overall volume and change their seasonal variations (WCD 2000). Such alterations in a river's flow regime can speed up the deposition of sediments on the river bed and at its mouth to speed up the formation of large permanent sandbars (Tanaka *et al.* 2005).

Ghana is one of the many countries that have undertaken dredging activities over the last few decades. The on-going dredging activity at the Volta Estuary is considered as the most methodical dredging activity in the history of Ghana. The purpose of the dredging by Volta River Authority (VRA) is to clear the almost permanent sandbar at the mouth of the Volta River to improve saline water intrusion (Mensah 2014). It has been over 20 years since dredging operations began but there is still inadequate data on the extent to which dredging activities have restored saline water intrusion in the estuary. Apart from the physical impacts, the possible impacts on the livelihoods of the people who live in the surrounding island communities have also not been adequately studied. Hence this paper seeks to answer three main questions:

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- What are the current trends in saline water intrusion at the Volta Estuary as a result of the dredging activities underway?
- How has dredging affected prevalence of the bilharzia snail vector at the estuary?
- How has dredging affected the livelihood activities of island communities?

Since dredging began in 1990 there have been very few studies assessing the impacts of the dredging activities. Generally, most of the studies on dredging have focused on the physical impacts of dredging (Rasheed and Balchand 2001, Schoellhamer 2002, Esslemont *et al.* 2004, Erftemeijer and Lewis 2006, Manap and Voulvoulis 2016). In this paper, we include insights from communities to assess the effectiveness of dredging activities in Volta Estuary, which were originally meant to restore salinity, remove bilharzia snails and revitalize livelihoods. Insights from communities affected by dredging activities can provide a more comprehensive understanding of the socio-economic and marine ecosystem services especially to policy-makers and district planners. Such insights play a key role in prioritizing strategies to effectively manage coastal ecosystems (Greene 2002, Lawson 2016). The paper this contributes to the global discussion on how to proactively manage coastal ecosystem amidst multiple, interactive drivers.

2. Theoretical framings

Sandbars are common features at the mouths of rivers. They are usually formed under the combined effects of waves, tidal movements, long-shore and cross-shore currents and river flow (Tanaka *et al.* 2005). Even though sandbars occur through natural processes, their formation can be enhanced by alterations in the flow regimes of rivers through human activities such as the construction of dams (Tanaka *et al.* 2005). River damming is increasing at unprecedented rates globally mainly for electricity generation, domestic or industrial use, food production, navigation, fisheries, recreational as well as for flood control purposes (Snoussi *et al.* 2007, Okuku *et al.* 2016).

Sandbars at river mouths have several impacts on the features of a river. For example they hinder navigation, increase flooding as well as obstruct the intrusion of saline water from the sea into rivers (Tanaka *et al.* 2005). Dredging through sandbars to restore the intrusion of saline water and consequently reduce the negative effects on the people is often undertaken in these circumstances (Cohen 2005, Padmalal *et al.* 2008, Liu *et al.* 2009). Dredging involves the excavation, removal and transport of sediments from the bottom of the river (Rasheed and Balchand 2001, Vlasblom 2003, Cohen 2005, Junqua et al. 2006, Bray and Cohen 2010). Although dredging has some negative effects on aquatic environments (Ohimain *et al.* 2005, Bray and Cohen 2010, Hoover *et al.* 2011, Fischer *et al.* 2012), it has been used all over the world to restore estuaries and improve on the well-being of local residents (Cohen 2005, Padmalal *et al.* 2008, Liu *et al.* 2009).

2.1. Salinity and estuaries

Salinity is an important property of estuaries. Unlike fresh water from riverine sources which has a salinity of 0.5 ppt or less, estuaries usually exhibit a gradual change in salinity throughout their length (Ronald and Kathleen 2006). Salinity levels in estuaries may be oligohaline (0.5–5.0 ppt), mesohaline (5.0–18.0 ppt) or polyhaline (18.0–30.0 ppt) (Lowe-McConnell 1987, Ronald and Kathleen 2006). It may also be more than 30 ppt near the connection with the open sea, which is known as euhaline (Lowe-McConnell 1987). Salinity plays several roles in ensuring that estuaries perform their functions. It determines to a large extent the types of plants and animals that can survive in an estuary (Ronald and Kathleen 2006). It may however be influenced by the level and intensity of the tides, the seasons and obstructions to saline water intrusion such as permanent sandbars (Lowe-McConnell 1987). Obstructions to the intrusion of saline water such as permanent sandbars can lead to reduced estuarine salinity (Lowe-McConnell 1987).

According to the World Health Organization (WHO)[1] schistosomiasis (bilharzia) is the second most prevalent and socio-economically devastating parasitic disease in tropical countries, after malaria. It is endemic to 74 countries in Africa, South America, and Asia, where approximately 200 million people are infected and up to 800 million people are at risk to become infected (Zhou *et al.* 2008). The disease is perceived to be most common among children of school going age in poor rural communities with poor sanitary conditions and unsafe water supply (Gryseels *et al.* 2006 cited in Zhou *et al.* 2008, Yirenya-Tawiah *et al.* 2011b). There are two forms of schistosomiasis, urinary and intestinal schistosomiasis (Gordon and Amatekpor 1999, Yirenya-Tawiah *et al.* 2011a). Urinary schistosomiasis caused by *Schistosoma haematobium* damages the bladder and kidneys, causing painful urination, blood in the urine, and abdominal pain. The other type, intestinal schistosomiasis is caused by *Schistosoma mansoni* and damages the intestines and liver, resulting in abdominal pain, fever and rectal bleeding. Schistosomiasis is caused by a parasite called a schistosome, which is a trematode worm with a complex life cycle (Zhou et al. 2008). The prevalence of schistosomiasis in the Volta Estuary was largely been attributed to the construction of the Akosombo and Kpong dams (Onori *et al.* 1963, McCullough and Ali *1965*, Gordon 2006, Aboagye and Edoh 2009, Nkegbe 2010, Yirenya-Tawiah *et al.* 2011b).

Salinity influences the abundance and distribution of planorbid snails which intermediately host the parasites which cause schistosomiasis (Yirenya-Tawiah *et al.* 2011a). The snails survive in water with little or no salinity record. As a result, they are not found in oceans and salty water bodies but in freshwater bodies such as ponds, dams and many others (WHO 1993, Yirenya-Tawiah *et al.* 2011a). There are two forms of schistosomiasis, urinary and intestinal schistosomiasis (Gordon and Amatekpor 1999, Zhou *et al.* 2008, Yirenya-Tawiah *et al.* 2011b). Urinary schistosomiasis caused by *S. haematobium* damages the bladder and kidneys, causing painful urination, blood in the urine, and abdominal pain (Zhou *et al.* 2008). The other type, intestinal schistosomiasis is caused by *S. mansoni* and damages the intestines and liver, resulting in abdominal pain, fever and rectal bleeding (Zhou *et al.* 2008).

2.2. Dredging in the Volta Estuary

The Akosombo and Kpong Dams were built on the Volta River in 1964 (Pople and Rogoyska 1969) and 1981 respectively, mainly for the generation of hydro-electricity (Gordon and Amatekpor 1999). The dams led to low river discharge coupled with high coastal sediment transport and consequently, the formation of a sandbar across the estuary which virtually closed it (Gordon and Amatekpor 1999). This prevented the intrusion of seawater upstream during high tides. As of 1969, it was estimated that the dry season position of the salt/fresh water boundary had moved 20–25 km towards the sea (Pople and Rogoyska 1969). As outlined in Gordon and Amatekpor (1999), this situation led to a number of unfavourable conditions at the estuary and surrounding communities, including:

- Flooding of inhabited areas along the river especially during the times when the VRA spills water from the dams.
- Disturbance of the ecological system by aquatic weeds leading to a decrease in fishing activities especially shrimp and clam industries.
- The growth of vector snails of bilharzia which increased the incidence of bilharzia infections in surrounding communities.
- Hindrance to river transport.
- Reduced tourism.

Recommendations by the company contracted to suggest effective measures to solve the problems (AVECO Infrastructure Consultants bv. of the Netherlands) included dredging a new opening through the sandbar to restore salt water intrusion. Thus in 1990 the VRA acquired a dredger at great cost and began dredging through the sandbar and deepening silted channels to reduce the negative impacts of the Akosombo and Kpong Dams. According to Gordon and Amatekpor (1999) it was envisaged that the dredging operations would:

- Interconnect deeper ponds which will allow salt water to penetrate the whole tidal area.
- Serve as a protection for communities inhabiting the lower banks from flooding in case of a future emergency spilling of the lakes.
- Cover aquatic weeds growing on the banks of the communities for the elimination of the bilharzia intermediate host snails.
- Enhance the restoration of fishing and shipping activities in the area.
- Improve the tourism industry in the area.

The current Dredge Master of the VRA revealed in an interview with the authors that cutting through the sandbar was done in 1990, 1996, 2003 and 2009. After dredging, the materials removed were deposited at the river banks to nourish the beaches and for possible sale to construction companies. The Dredge Master further said that, dredging has helped the VRA to maintain a flood free environment and sustain a salinity level of 4–6 ppt for neutralizing the bilharzia colonies within a distance of 9 km from the estuary. This according to him has led to a drastic reduction in the prevalence of bilharzia to below 4% within the dredged areas in the past years. The major challenge is the unavailability of adequate equipment for the operations. Arrangements are however being made to bring in additional dredgers to support the process.

3. Methodology

3.1. Salinity monitoring

Data used to answer study question one (1) concerning current trends in saline water intrusion in the Volta Estuary was obtained from salinity records of the VRA. The data represented monthly records for the surface, middle and bottom layers of the estuary taken at positions that were 1 km apart from the river mouth to the 14th km position at high tides. The annual average for the bottom and surface values of each position was computed by summing up values from January to December for each year and dividing it by 12. Further, the average salinity values for each position were computed by summing up all the annual average values for each position and dividing it by the total number of years. The average values for the various positions were then used to draw line graphs to show the variations in salinity levels as one moved away from the river mouth.

The XLSTAT, which is an excel add-in, was used to perform the Mann–Kendall test for trend analysis. The Mann–Kendall test (which is non-parametric) was used because; the data did not conform to strict parametric assumptions. The test was performed by computing the Kendall's statistics (Kendall's tau) from the time and salinity data pairs. The null hypothesis (H_0) for the test was 'there is no trend in saline water intrusion at the Volta Estuary over time'. The alternate hypothesis (H_1) was 'there is a significant trend in saline water intrusion at the Volta Estuary over time'. The Kendall's tau values show whether there is a negative or positive trend (tau < 0 means there exists a negative trend; tau > 0 means there is a positive trend). The p-values indicate whether the trend is significant or not ($p < .05$ meant there was a significant trend; $p > .05$ meant there is not enough evidence to conclude that there is a trend).

3.2. Snail vector monitoring

Data used to answer study question two (2) concerning the effects of dredging on the prevalence of bilharzia snail vectors at the estuary was obtained by sampling snails at the estuary. A sweep net technique was used. At each sampling site, a GPS was used to identify the exact location of the place and a quadrant with an area of 100 m^2 was demarcated within which samples were randomly taken. On each day of sampling, a sweep net with a long handle, mesh size of 200 µm and diameter of 19.5 cm was used to sweep through the fringe vegetation in a figure of 10 motions within 3 minutes. The contents of the net were emptied into labelled buckets after the 10th sweep. This was done in five replicates at each site. The contents of the bucket were later emptied into a sorting tray along with some clean water from the river to wash out soil particles. A plastic spoon was then used to sort through the debris for snails of the genus *Biomphalaria and Bulinus*, which host *S. haematobium* and *S. mansoni* (Bosompem *et al.* 2004, Yirenya-Tawiah *et al.* 2011b).

The samples were taken at four island communities; Kpetsupanya, Tuanikope, Afrive and Alorkpem which were selected after interactions with stakeholders and personal observations. Kpetsupanya is located on the largest island in the study area. Its geographical co-ordinates are N 05.81444°, E 0. 62557°. It is about 9 km away from the estuary and is located along the western channel which has been dredged. It is one of the largest island communities with a population of 920 people according to the 2010 population census. Sampling area is about 1.4 m deep with a flow rate of about 21 cm/s. Tuanikope is more than 10 km away from the estuary and is located on a smaller island found along a channel which has not been dredged. Its geographical co-ordinates are N 05.82576°, E 0.65921°. It is a smaller community as compared to Kpetsupanya with a population of 290 people according to the 2010 population census. The area where samples were taken is about 1.9 m deep with a flow rate of about 15 cm/s. Afrive is about 5 km from the sea and is located at the eastern side of the biggest island in the study area and the river channel closest to it has not been dredged. It is a small community with a population of 300 people according to the 2010 population census. The major point of human contact at this site is about 1.2 m deep. It has a flow rate of about 11 cm/s. Alorkpem is a community located on a smaller island between the central and eastern channels. It is about 4 km from the sea and the channels around it have not been dredged. Its geographical co-ordinates are N 05.79691°, E 0.65225°. According to the 2010 population census it has 710 people occupying it. The average depth of the river at this site is 0.8 m with a flow rate of about 18 cm/s. Aquatic plants such as *Ceratophyllumdemersium, Eichhorniacrassipes*, *Mimosa pigra* and *Typhadomingensis* were present at all the sites. Sampling was done at the fringes of the river where human contact was most common. Data were collected at two weeks' intervals in the months of May and June 2014.

3.3. Socio-economic impact monitoring

To answer study question three (3) concerning the effects of dredging on the socio-economic lives of island residents, 100 questionnaires were administered to randomly selected residents on 5 island communities at the Volta Estuary (Appendix). The aim was to identify the ways in which dredging activities have affected the people socio-economically. These communities were Kpetsupanya, Afrive, Alorkpem, Azizakpe and Tuanikope. The questionnaire which had open- and close-ended questions was administered in the local languages. It had seven sections with questions on respondents' demographic information, economic activities, length of stay in communities, effects of dredging on their livelihoods, health, incidents of flooding as well as policy recommendations. The number of respondents per community was determined based on the population sizes of the various communities. Thus, the community with the largest population had the highest number of respondents and the community with the least population had the lowest number of respondents. In each community, the required number of respondents was selected using the simple random sampling technique with each member of the population having an equal chance of being included in the sample. The questionnaires were administered on Sunday afternoons which according to the respondents was the day most people were available in the communities.

The responses were coded using value labels and were entered into the Statistical Package for Social Sciences (SPSS). SPSS was used to perform frequency distribution, descriptive statistics and the Wilcoxon Signed-Rank Test. The Wilcoxon Signed-Rank Test is a non-parametric test which performs the same function as the Paired-Sample *T*-Test. When the assumption of normality is violated, the Paired-Sample *T*-test becomes inappropriate hence non-parametric tests such as the Wilcoxon Signed-Rank Test becomes more appropriate since such tests do not require data to be normally distributed. The Wilcoxon Signed-Rank Test is used to compare two sets of scores that come from the same participants. The Wilcoxon Signed-Rank Test is useful when a researcher wants to analyse difference in scores from one time point to another, or when individuals are subjected to more than one condition.

This study used the Wilcoxon Signed-Rank Test to compare changes in number of days spent on fishing and farming before and after dredging. This test enabled the researcher to determine whether there was a significant reduction/increase in the number of days spent on fishing and farming before and after dredging. In other words, the Wilcoxon Signed-Rank Test was used to determine the effect of dredging on economic activities (fishing and farming).

The *p*-value in the Statistics table of Wilcoxon Signed-Rank Test was used to determine significant change in the number of days spent on fishing or farming attributable to dredging. The null hypothesis of 'no significant change' is rejected if the *p*-value is less than .05 and the alternative hypothesis of 'significant change' is accepted.

4. Results and discussion

4.1. Saline water intrusion at the Volta Estuary

Table 1 presents the average salinity levels for each position at the upper water layer and bottom water layer of the estuary. The results indicate that from 2001 to 2013, the average level of salinity both at the surface and bottom of the estuary decreased consistently with increasing distance. The farthest distance to which saline water moves up the river during high tides is about 14 km from the sea.

4.1.1. Salinity levels for surface and bottom waters of the Volta Estuary

Figure 1 is a line chart showing the salinity levels in surface waters of the estuary, from 2001 to 2013. The figure shows a clear decrease in salinity as one moved away from the sea and reaches its lowest at the 14 km mark. The highest average salinity of 25.25 ppt was recorded at the mouth of the river and this decreases sharply to 14.35 ppt 3 km away. It then decreases gradually until 0.22 ppt was recorded 14 km away.

Table 1. Average salinity at specific distances from the sea in parts per thousand (ppt).

	Surface waters		Bottom waters	
Distance (km)	Mean	Standard deviation	Mean	Standard deviation
0	25.25	6.42	31.52	1.30
3	14.35	11.75	30.68	1.73
4	11.99	11.58	29.18	2.63
5	9.92	11.24	27.29	4.29
6	7.49	9.08	24.84	5.79
7	5.84	7.71	22.69	5.80
8	4.95	6.86	18.43	6.57
9	3.68	5.60	12.27	5.51
10	2.32	3.85	7.39	5.61
11	1.39	2.59	3.8	4.44
12	0.81	1.82	2.4	3.73
14	0.22	0.67	1.07	2.41

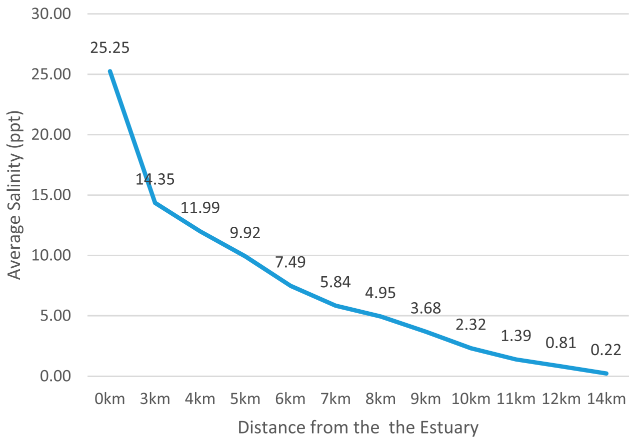

Figure 1. Average salinity at the surface of the Volta Estuary measured in ppt from 2001 to 2013.

The average salinity levels for bottom waters of the estuary from 2001 to 2013 is depicted in Figure 2. Just like the surface waters, the average level of salinity for the bottom waters of the estuary decreases as one moves away from the sea. Salinity levels for bottom waters are however higher than those in surface waters for the same positions. For instance, the highest average salinity for bottom waters was 31.52 ppt as against the 25.25 ppt recorded for surface waters.

4.1.2. Trends in salinity values for bottom waters of the Volta Estuary

The results of the Mann–Kendall test for trends (Table 2) indicate that there is generally a downward trend in salinity values 0 km from the sea in bottom waters of the estuary ($p \leq .05$). This suggests that salinity values recorded 0 km from the sea in bottom waters of the estuary generally decreases over time. The Kendall's tau of −0.643 suggests that salinity values for bottom waters at the river mouth, is strongly negatively correlated with time. Thus, generally salinity values for bottom waters taken at places that are 0 km from the estuary are expected to decrease annually. The Sens's slope of −0.378 is an indication that salinity for bottom waters of the estuary generally decreases by an average of 0.378 ppt annually.

4.1.3. Trends in salinity values for surface waters of the Volta Estuary

The results for Mann–Kendall's test for trends suggest that there is a downward trend in salinity values from 4 km to 11 km in the surface waters of the estuary ($p \leq .05$) (Table 3). The salinity values for surface waters decreases annually by an average of 3.397 ppt at 4 km, 3.313 ppt at 5 km, 2.535 ppt at 6 km, 1.646 ppt at 7 km, 1.559 ppt at 8 km, 0.77 ppt at 9 km, 0.537 ppt at 10 km and 0.261 ppt at 11 km.

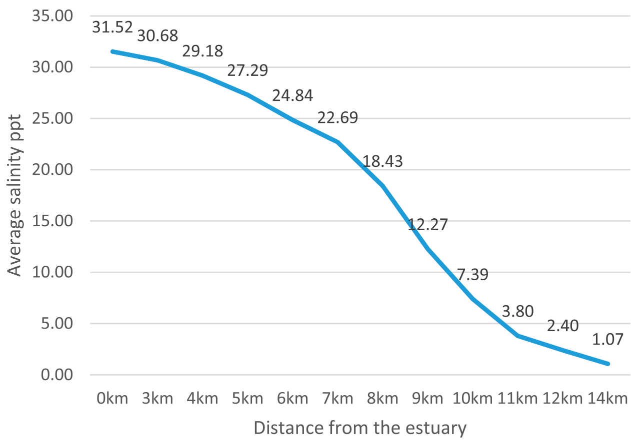

Figure 2. Average salinity at the bottom of the Volta Estuary measured in ppt. from 2001 to 2013.

4.2. Prevalence of snail vectors at the Volta Estuary

The *Biomphalaria and Bulinus* genus of snails were sampled to examine their prevalence at the estuary. However there were no snail collected throughout the study period. All the sampling sites recorded zero snail density during the four different occasions of sampling. The elimination of the snail vectors was one of the key objective for dredging activities by the VRA.

4.3. Impacts of dredging on socio-economic activities

4.3.1. Demographic details

Five out of the 100 questionnaires could not be used as they were not well filled. Table 4 presents the background information of the respondents. About 38.3% of the respondents were traders, whilst 33% were employed by the fishing industry (Table 4).

4.3.2. Fishing

Several questions were asked to determine the effects of dredging on fishing activities. The purpose was to compare fishing before and after dredging. About 67% of respondents were engaged in fishing before dredging began. After dredging began however this number dropped to 60.2%, because of declining fish availability. The Wilcoxon Signed-Rank test was employed to compare the number of days respondents went for fishing before and after dredging. The results indicate that the minimum number of days in a week that the respondents went fishing before and after dredging was two days while the maximum number of days that the respondents went fishing before and after dredging is seven days. However, the median number of days that the respondents went for fishing before dredging was seven days while that of after dredging was six days. The result also suggests that 75% of the respondents went fishing for a minimum of six days in a week before dredging while 75% of the respondents went fishing for a minimum of three days after dredging began (Table 5).

The Wilcoxon Signed-Rank test further reveals that 17 respondents went fishing more days in a week before dredging began than after dredging. No respondent spent more days fishing after dredging than before dredging. Twenty-two respondents spent the same number of days fishing before dredging and after dredging (Table 6).

Further, the Wilcoxon Signed-Rank test indicates that there is a significant difference in the number of days that the respondents spent on fishing before and after dredging ($Z = -3.689$, $p = .000$). Thus, the number of days spent on fishing had significantly decreased after dredging.

88.5% of the respondents indicated that there were some fish varieties caught in the estuary before dredging that could no longer be found. 93.2% of the respondents indicated that there was a decrease in the quantity of fish caught after dredging began.

Table 2. Trends in salinity values for bottom waters of the Volta Estuary.

	0 km	3 km	4 km	5 km	6 km	7 km	8 km	9 km	10 km	11 km	12 km	14 km
Kendall's tau	−0.643	−0.400	−0.357	−0.286	−0.071	−0.214	−0.214	−0.214	−0.357	−0.357	−0.340	−0.403
p-Value	.035	.212	.266	.386	.902	.536	.536	.536	.266	.266	.308	.232
Alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sen's slope	−0.378	−0.317	−0.686	−0.55	−0.164	−0.499	−1.16	−0.804	−0.943	−0.545	−0.347	−0.078

Table 3. Trends in salinity values for surface waters of the Volta Estuary.

	0 km	3 km	4 km	5 km	6 km	7 km	8 km	9 km	10 km	11 km	12 km	14 km
Kendall's tau	−0.222	−0.444	−0.611	−0.648	−0.667	−0.667	−0.667	−0.609	−0.609	−0.609	−0.458	−0.236
p-Value (two-tailed)	.466	.118	.029	.021	.019	.019	.019	.033	.037	.037	.134	.561
Alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sen's slope (*B*)	−0.906	−2.31	−3.397	−3.313	−2.535	−1.646	−1.559	−0.77	−0.537	−0.261	−0.082	0

Table 4. Respondents' demographic information.

Variable	Frequency	Percent
Sex		
Male	50	52.6
Female	45	47.4
Total	95	100.0
Age		
Less than 40 years	4	4.2
40–49 years	34	35.8
50–59 years	23	24.2
60 and above	34	35.8
Total	95	100.0
Location		
Azizakpe	20	21.1
Alorkpem	20	21.1
Afrive	10	10.5
Tuanikope	15	15.8
Kpetsupanya	30	31.6
Total	95	100.0
Occupation		
Farming	20	21.3
Fishing	31	33.0
Trading	36	38.3
Teacher	6	6.4
Artisan	1	1.1
Total	94	100.0
Number of years in the area		
Less than 20 years	2	2.1
More than 20 years	92	97.9
Total	94	100.0

4.3.3. Farming

There has also been a general decrease in farming activities with the onset of dredging. The number of respondents engaged in farming decreased from 40.2% to 29.6%. The Wilcoxon Signed-Rank Test was employed to compare the number of farming days before and after dredging. The results indicate that the minimum and maximum number of days respondents spent on farming before dredging, that is three and seven days respectively had not changed. However the median number of days the respondents spent farming before dredging has reduced from seven to six (Table 7).

The test also revealed that currently 2 respondents spent fewer days on farming than before dredging, 19 spent the same number of days, but no respondent spent more days on currently farming (Table 8). Thus there was no significant change in the number of farming days in a week ($Z = -1.342$, $p = .18$).

4.3.4. Flooding and health

Before dredging started in 1990, communities close to the estuary were flooded when the VRA opened the dams to spill water. This was due to the reduced discharge capacity of the estuary at that time. The study sought to assess incidents of flooding in the communities after dredging began. About 54.3% of the respondents had experienced flooding in their communities in the past. Currently, over 62% said they do not experience dredging. However residents at Azizakpe and Alorkpem, which are very close to the sea complained of an increase in flooding, which is attributable to erosion and tidal effects.

One unarguably positive impact of dredging in the Volta Estuary is the decrease of the reported cases of schistosomiasis (bilharzia) in the communities (Figure 3). The rapid increase in schistosomiasis after the construction of the Akosombo and Kpong dams led to an intensification of measures by the VRA to mitigate this problem. A combination of measures including aquatic weed clearing, dredging, vector snail survey and sampling, new treatment strategies as well as health education. However the increase in the cases of malaria as stated by the respondents needs to be addressed as well.

4.3.5. Tourism

About 60% of the respondents said tourism activities existed before dredging. Comparing tourism before and after dredging, 95.8% of the respondents stated that dredging had contributed to an increase in tourism in the area. Increased salinity through sea water intrusion has reduced the incidence of bilharzia and other water-borne diseases at human water contact sites in the communities attracting more visitors to the areas.

Table 5. Descriptive statistics of number of days spent on fishing before and after dredging.

Questions	*N*	Mean	Std. deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
How many days in a week did you spend fishing before dredging?	48	6.125	1.34678	2	7	6	7	7
How many days of the week do you spend fishing after dredging?	39	5.1026	1.74409	2	7	3	6	7

Table 6. Ranking the number of days spent on fishing before and after dredging.

Ranks	*N*	Mean Rank	Sum of Ranks
Negative Ranks	17	9	153
Positive Ranks	0	0	0
Ties	22		
Total	39		

5. Discussion and conclusion

This paper set out to assess the effectiveness of dredging activities in the Volta Estuary. The main objective of commencing dredging activities was to restore salinity, eliminate bilharzia snail vectors and revitalize livelihoods, especially the tourism industry. The paper uses results from empirical data and includes the perspectives of local communities, a component which is often overlooked. It sought to examine the current trends in saline water intrusion, determine the density of snail vectors of the bilharzia disease as well as assess the impacts of the dredging exercise on the socio-economic lives of people resident on islands at the estuary.

The salinity of the Volta Estuary was adversely impacted by the development of a sandbar at the estuary after the construction of dams on the river (Gordon and Amatekpor 1999). Dredging through the sandbar is one of the efforts being made to restore salt water intrusion. The analysis of the salinity records from 2001 to 2013 showed that, salinity of the estuary was greatly influenced by distance from the sea and depth. Salinity decreased consistently with increasing distance from the sea up to the 14 km mark. Even though maximum saline water intrusion of 14 km falls short of previous records of over 30 km (Pople and Rogoyska 1969), it meets the target of the VRA to sustain a lethal salinity level of 4–6 ppt within 9 km distance from the estuary.

The results suggest that there is a downward trend in saline water intrusion from 4 to 11 km in surface waters of the estuary ($p \leq .05$) from the end of a dredging activity to the start of the next dredging activity with annual average decrease of 3.397 ppt at 4 km, 3.313 ppt at 5 km, 2.535 ppt at 6 km, 1.646 ppt at 7 km, 1.559 ppt at 8 km, 0.77 ppt at 9 km, 0.537 ppt at 10 km and 0.261 ppt at 11 km. With regards to 0, 3, 12 and 14 km, the results showed that there is little evidence to conclude that there are trends. In relation to the bottom waters of the estuary salinity records at the estuary (0 km) generally decrease over time ($p \leq .05$). The Kendall's tau of −0.643 suggests that saline water intrusion 0 km (at the bottom), is strongly negatively correlated with time. Sens's slope of −0.378 is an indication that, there is an average decrease of 0.378 ppt in the salinity records at the bottom of the estuary itself (0 km) annually. There is however not enough evidence to conclude that there is a trend in saline water intrusion from 3 km to 14 km at the bottom of the estuary ($p > .05$). These results suggest a gradual reduction in the effectiveness of dredging in maintaining salt water intrusion. This could be due to the fast build-up of the sandbar as a result of the increased long-shore drift of sand, reduced flow rate of the lower Volta attributable to hydro-electric power generation and the length of the sandbar which makes the distance travelled by the salt water longer. To counter this problem, it is suggested that, the period between successive dredging activities should not always be six or more years as the case is presently. It should be based on actual salinity data collected through continuous monitoring. Dredging should be undertaken as soon as salinity values begin to show a reduction.

There are several islands at the Volta Estuary inhabited by residents who depend on the estuary for many activities such as transport, fishing, farming and other domestic uses. Majority of the people living on the islands are fisher folk. They believed that the number of people currently engaged in fishing as well as the number of fishing days have reduced, and most of the people have resorted to other socio-economic activities in addition to fishing. The quantities and the variety of fish caught in the estuary have reduced, possibly due to the fluctuating salinity levels after dredging which causes most fish types to move further up the river. The composition of the local catch has therefore changed to a more marine mix; mainly anadromous fish, which use the river for breeding (Gordon and Amatekpor 1999). This explains why the minimum number of days for fishing has reduced from six days before dredging to three days after dredging as revealed by the study.

Respondents also reported a decrease in farming activities after dredging activities. Improper farming and cultural practices such as bush burning and deforestation, have contributed to a decline in crop yield, the cessation of natural irrigation and supply of alluvial soil that used to be brought in during the annual floods of the pre-impoundment era has also contributed (Gordon and Amatekpor 1999). Thus from their point of view, the dredging exercise has not had positive effect on fishing and farming activities and has rather led to a loss in livelihoods and an increase in poverty levels. This is corroborated by Ofori *et al.* (2016). The construction of the Akosombo Dam resulted in the loss of several lagoons and creeks in the estuary which served as important fishing and breeding grounds of the clam and prawn fisheries

Table 7. Descriptive statistics on the number of days spent on farming before and after dredging.

Questions	*N*	Mean	Std. deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
How many days of the week did you spend farming before dredging?	27	6.3704	1.24493	3	7	6	7	7
How many days of the week do you spend farming after dredging?	22	6	1.19523	3	7	5	6	7

Table 8. Ranking the number of days spent on farming before and after dredging.

	Ranks	*N*	Mean Rank	Sum of Ranks
Number of days spent on farming before dredging-number of days spent on farming after dredging	Negative Ranks	2[a]	1.5	3
	Positive Ranks	0[b]	0	0
	Ties	19[c]		
	Total	21		

[a]Number of days spent on farming before dredging < number of days spent on farming after dredging.
[b]Number of days spent on farming after dredging > number of days spent on farming before dredging.
[c]Number of days spent on farming before dredging = number of days spent on farming after dredging.

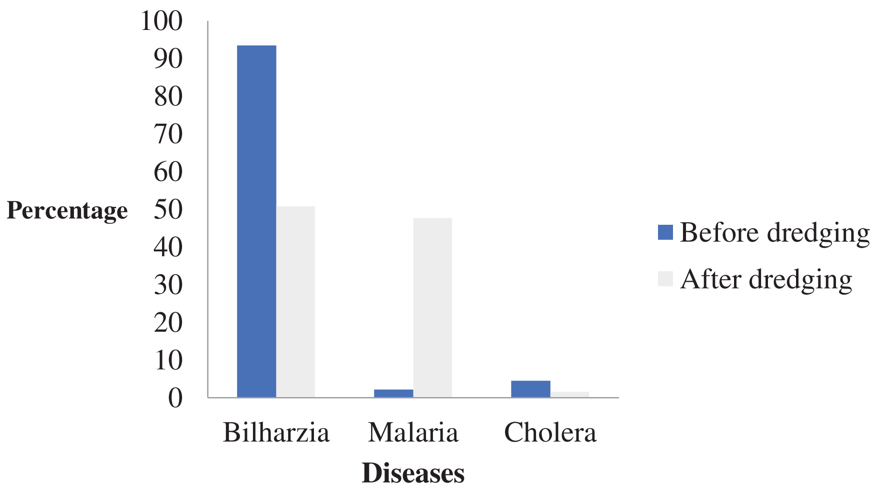

Figure 3. Respondents' perception of common diseases in the Volta Estuary before and after dredging.

which were major source of livelihoods. These losses are however more directly linked with the shift in the estuarine salt wedge than with dredging activities.

The areas where dredging seems to have made an impact were health and tourism. It is generally agreed that, tourism has become very vibrant since dredging began. This is because, the use of dredged sediments to nourish the banks have made the area more beautiful, the reduction in aquatic plants has made cruising on the river more interesting, and the reduction in the risk of bilharzia infections has made the area very attractive to both domestic and international tourists.

Although bilharzia infections have reduced drastically it has not been completely eradicated in the area and some people are still living with very old infections. Malaria is also on the rise.

Based on the findings of the research, it is concluded that, dredging has succeeded in reducing some of the physical impacts of dam construction on the Volta River but has been unable to improve on the socio-economic lives of local residents. This is a fact that was constantly highlighted by many of the respondents. Hence including the voices of local people in discussing the successes of the dredging activities helps to highlight the concerns of the local people and makes the results much more relevant. It is therefore recommended that public health education is intensified in the area. Continuous effort is needed to ensure that previous snail abundance levels do not re-occur. The VRA must also ensure that saline water intrudes further up the river by continuously dredging silted parts of the estuary. Some island communities have the river around them very silted to the extent that, salt water never gets there even at high tides. Such people are at a risk of being infected by schistosomiasis again. As mentioned by Ofori *et al.* (2016), alternative livelihood programmes could be introduced in the island communities. Residents must be introduced to other ways of getting income apart from the traditional fishing and farming. It is also important to understand the value systems of the residents when taking such decisions and ensure that dredging activities are integrated within the traditional governance structures and community priorities to minimize conflicts.

Note

1. See http://www.afro.who.int/en/schistosomiasis.

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Appendix

EVALUATING THE IMPACTS OF DREDGING AND SALINE WATER INTRUSION ON RURAL LIVELIHOODS IN THE VOLTA ESTUARY

QUESTIONNAIRE FOR COMMUNITY MEMBERS

The purpose of this questionnaire is to assess the effects of the ongoing dredging on the intrusion of sea water into the Volta estuary, as well as its consequences on the environment and the livelihood and health of surrounding island communities.

Please be assured that the information received will be treated confidentially and used strictly for academic purposes.

A sincere response will be appreciated since it is very important for the success of the exercise. Thank you in advance.
Please Tick (√) and write down answers where appropriate.

SECTION A: SOCIO-DEMOGRAPHIC INFORMATION

1. **Sex** [1] Male ☐ [2] Female ☐
2. **Age** [1] Less than 40 ☐ [2] 40 to 49 ☐
   [3] 50 to 59 ☐ [4] 60 or more ☐
3. **Location** [1] Azizakpe ☐ [2] Alorkpem ☐
   [3] Afrive ☐ [4] Tuanikope ☐
   [5] Kpetsupanya ☐
4. **Occupation** [1] Farming ☐ [2] Fishing ☐
   [3] Trading ☐ [4] other (specify) ……
5. **How long have you lived in this area?** [1] less than 20years ☐
   [2] More than 20 years ☐

SECTION B: IMPORTANCE OF THE ESTUARY TO COMMUNITY MEMBERS

6. **Is the estuary of any use to you?** [1] Yes ☐ [2] No ☐

   If yes, why ……………………………………………………………….
7. **What do you use the estuary for?**
   Please Tick (√) all applicable ones.
   [1] Fishing ☐
   [2] Transport ☐
   [3] Source of domestic water ☐
   [4] Irrigation ☐
   [5] Recreation ☐
   [5] Other (specify) ……………………………………………..

SECTION C: EFFECTS OF DREDGING ON LIVELIHOOD

8. **Were you engaged in fishing activities before the dredging began?**

   [1] Yes ☐ [2] No ☐

9. **How many days in a week did you spend fishing?**

1	2	3	4	5	6	7

10. **Do you currently engage in fishing activities?**

   [1] Yes ☐ [2] No ☐

11. How many days of the week do you spend fishing?

1	2	3	4	5	6	7

12. Are there some varieties of fish caught in the estuary before dredging that are currently not there?

[1] Yes ☐ [2] No ☐

If yes, give examples …………………………………………………………………………

13. Are there some fish varieties caught in the estuary currently that were previously not there?

[1] Yes ☐ [2] No ☐

If yes, give examples …………………………………………………

14. Compare the quantity of fish caught currently to the quantity caught before dredging?

[1] More ☐ [2] Less ☐ [3] Equal ☐

15. Were you engaged in farming activities before dredging?

[1] Yes ☐ [2] No ☐

If yes, give examples …………………………………………………

16. How many days of the week did you spend farming?

1	2	3	4	5	6	7

17. Are you currently engaged in farming?

[1] Yes ☐ [2] No ☐

18. How many days of the week do you spend farming?

1	2	3	4	5	6	7

19. Were there tourism activities in the area before dredging?
[1] Yes ☐ [2] No ☐

20. How vibrant was it?

[1] Very vibrant ☐ [2] vibrant ☐ [3] not vibrant ☐

21. Compare tourism before dredging to tourism after dredging.

[1] Better ☐ [2] Same ☐ [3] Worse ☐

SECTION D: EFFECTS OF DREDGING ON HEALTH

22. Which disease was the most prevalent before dredging?

[1] Bilharzia ☐ [2] Mala☐ [3] Guinea W☐
[4] Other (specify) ……………………………………….

23. Which disease is the most prevalent in the area currently?

[1] Bilharzia ☐ [2] Malaria☐ [3] Guinea W☐

[4] Other (specify) ……………………………………….

24. Compare the current prevalence of the bilharzia disease to how it was before dredging

[1] Higher ☐ [2] Lower☐ [3] San☐

SECTION E: EFFECTS OF DREDGING ON TRANSPORT

25. How was river transport before dredging?

[1] Very easy☐ [2] easy ☐ [3] a little difficult ☐ [4] very difficult ☐

Why do you so answer?
…………………………………………………………………………………………
…………………………………………………………………………………………

26. How would you compare the current state of river transport to how it was before dredging?

[1] Worse☐ [2] same ☐ [3] a little better ☐ [4] much better ☐

Why do you so answer?
…………………………………………………………………………………………
…………………………………………………………………………………………

SECTION F: EFFECTS OF DREDGING

27. Did your community get flooded at certain times of the year before dredging?

[1] Yes ☐ [2] No☐

28. Does your community get flooded currently?

[1] Yes ☐ [2] No☐

29. Compare the current level of flooding to how it was before dredging.

[1] More ☐ [2] Less☐ [3] Same ☐

SECTION G: GENERAL ASSESSMENT OF THE IMPACTS OF DREDGING ON THE LIVES OF LOCAL PEOPLE.

30. Do you think the ongoing dredge operations have had any negative effect on you?

[1] Yes ☐ [2] No ☐

If yes, in which ways?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

31. Do you think the ongoing dredging operations have had any positive effects on you

[1] Yes ☐ [2] No ☐

If yes, in which ways?
……………………………………………………………………………………………….
……………………………………………………………………………………………
……………………………………………………………………………………………..

32. What would be your general assessment of the dredge operations?

[1] Very helpful ☐ [2] helpful ☐ [3] not helpful ☐

33. Has dredging made your life in this community better?

[1] Yes ☐ [2] No ☐

If yes, please explain …………………………………………………………….

SECTION H: RECCOMMENDATIONS

34. What are your recommendations for improving dredging activities by the VRA?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you very much for contributing to the success of this research. Your efforts are well appreciated.