

## Establishing a National Shellfish Sanitation Program in The Gambia, West Africa

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### Abstract

A successful national program to assure sanitary quality of molluscan shellfish requires a multi-disciplinary and multi-agency governmental training, data collection, policy development and management effort in collaboration with members of the shellfish industry. The Tanbi Wetlands and other estuaries of Gambia support shellfisheries for oysters, *Crassostrea tulipa*, and the senile ark, *Senilia senilis*, conducted by the TRY Oyster Women's Association. With low shellfish prices and a small local market, a Gambian National Shellfish Sanitation Program (GNSSP) was begun as a means to boost consumer confidence and allow market access to Gambia's robust seasonal international tourism trade. Gambian officials began training with a study tour to Rhode Island to work with counterpart officials engaged in administering the US-NSSP. Since August 2010, water was sampled bimonthly for total (TC) and fecal coliforms (FC) at stations near shellfish harvesting areas. Sanitary shoreline surveys began on 18 June 2011 to document sources of contamination and to establish priorities for remediation. Conclusions were 1) sanitary shoreline surveys identified numerous point contamination sources, 2) FC is a superior indicator of fecal contamination than TC, 3) FC values from most shellfish growing areas met or exceeded a FC standard of 14 MPN/100 ml most of the year, indicating clean growing waters, 4) highest average FC values corresponded to local rainfall maxima from July to October during the traditional off-season for shellfishing, 5) sanitary remediation (e.g. introduction of sanitary latrines at Old Jeshwang) resulted in localized water quality improvement and 6) there is enough data precision and repeatability to establish and map water quality classification zones. In areas without sanitation or near a dumpsite, FC values indicate a prohibited zone, but areas away from settlements could be certified year-around harvest sites. Postharvest shellfish sanitation and cold chain management from harvest to market remain as the key challenge of the GNSSP.

### Introduction

The Republic of The Gambia has a robust seasonal shellfishery for two species of estuarine mollusks, the West African mangrove oyster, *Crassostrea tulipa* (Lamarch, 1819) = *C. gasar* (Deshayes, 1830) and the West African blood cockle or

senile ark clam, *Senilia senilis* (Linnaeus, 1758). The shellfishery is primarily carried out by women fishers who have traditionally harvested these shellfish in the Tanbi Estuary system in the metropolitan area of the capital city of Banjul, near the mouth of the Gambia river, or in the Allahein river estuary near

the southern border of The Gambia with the Casamance Region of Senegal. Fishing for these species is also conducted by women in the North Bank Region of the country in wetland areas near the mouth of the Gambia river and in wetlands contiguous with the Sine-Saloum estuary in adjacent Senegal. For the most part, shellfish are harvested in the early part of the year prior to the seasonal rainy season that peaks in August. Depending upon the harvest area, a modest amount of shellfish harvesting occurs during the latter part of the year, but in the major fishing area of the Tanbi estuary the women fishers and Gambian fisheries managers have jointly agreed to restrict shellfishing as a resource management strategy through a special area shellfishery co-management plan consistent with maximum oyster spatfall occurring from September to November, as the seasonal rains subside (Ministry of Fisheries, Water Resources and National Assembly Matters, 2012).

Typically oyster and clam meats are steamed and shucked from their shells and sold as a semi-cooked product at roadside stands or in the public markets, and the shells are often burnt in wood fires to make lime for use in masonry mortar (Rice *et al.*, 2012b). The prices received by the oyster women for the shellfish meats are typically around GMD50 per kilo of meats (30 GMD = US\$1), so the overall value of the shellfish is quite low in comparison to market values of similar shellfish in many other, mostly highly industrialized, countries around the world (Rice *et al.*, 2012). Most often, water quality and post-harvest handling of shellfish in the market chains presents a formidable barrier to the entry into lucrative international shellfish markets as importing countries maintain strict control on the sanitary quality

of all whole, fresh and fresh-frozen shellfish sold within their own borders (Rice, 1992). To engage in international export trade in raw shellfish, exporting countries may frequently develop a specific program apart from their domestic shellfish sanitation protocols in order to meet requirements of importing countries. Australia, for example, is a country that has maintained a set of separate sanitation standards for shellfish destined for international trade with countries that use different sanitary certification standards from those used domestically (AQIS, 2004).

Given the challenges of developing a shellfish sanitation program suitable for meeting the standards of international markets, the Gambian Departments of Fisheries and Water Resources in cooperation with sister agencies within the Government of The Gambia have begun to develop a Gambian National Shellfish Sanitation Program (GNSSP) with the aim at boosting domestic consumer confidence in the sanitation of raw and fresh shucked shellfish originating from Gambian waters by developing shellfish growing water certifications, sanitary handling procedures, and a cold chain from harvest to the consumer. The overall goal of the GNSSP would be to develop a high value market segment for raw shucked shellfish among hotels and restaurants catering to the robust seasonal international tourism industry during the European winter months. The winter season also corresponds with periods of good water quality in most of the estuary, but prior to the peak harvest season for Gambian shellfish that runs from March to June (Rice *et al.*, 2014).

A market survey conducted by members of the TRY Oyster Women's Association showed that the majority of the businesses

that were visited do not currently feature oysters on their menus due to a variety of reasons including lack of reliable delivery, availability of oysters (oyster harvesting season is later than the high tourist period of December and January), sanitation concerns (especially in the higher class hotels), and previous experiences purchasing oysters from women's oyster stands along the Banjul-Serrekunda highway that lacked adequate quality by being too small or containing too much sand. However, many of the hotel and restaurant managers that they visited expressed great interest in purchasing and incorporating oysters into their menus, especially smoked product. They described how their customers greatly appreciate the experience of eating locally. A big selling point for these businesses is reliable delivery services. Due to the later harvesting season, oysters cannot be a permanent item on the menu, which is undesirable for some of the businesses. However, some expressed interest in featuring oysters during their special Gambian/African meal nights or seafood buffet nights (Ba Nafaa/USAID, 2012a). The market survey suggested that there are potential markets with tourism-related restaurants and hotels, as long as there is attention to product quality and sanitation.

The primary aim of this study is to investigate the feasibility of initiating a national shellfish sanitation program in a sub-Saharan African country using the methods of university extension education training and applied action research. There are a number of models on which to pattern a national shellfish sanitation program, including the approach used by the Codex Alimentarius Commission, primarily based upon common sanitation practices in the European Union (Codex Alimentarius Commission, 2009).

However, as a model for a proposed Gambian National Shellfish Sanitation Program (GNSSP) the National Shellfish Sanitation Program (US-NSSP) of the United States was chosen because, although there are protocols for assuring safe handling of shellfish from harvest to market as in the Codex, at its core it relies more heavily on rigid monitoring and maintaining sanitary quality of shellfish growing waters as the foundational basis for protecting public health (Murray & Lee, 2010).

#### *National shellfish sanitation program of the United States as a model*

The US-NSSP is maintained and periodically revised by the multiple member agency Interstate Shellfish Sanitation Conference (ISSC) and overseen and enforced by the U.S. Food and Drug Administration (see FDA, 2011). However, in using this program as a model for The Gambia, it must be recognized that the US-NSSP has been in place as a program since 1925, and work to begin the program had begun a quarter century earlier (Clem, 1994). At the turn of the 20th century, detailed sanitary shoreline surveys were instituted in some U.S. shellfish-producing states to identify and inventory sources of water contamination as a first step in their shellfish sanitation programs, but it was only after the development of a simple and reliable method (McCrary, 1915) of quantifying coliform bacteria as an indicator of fecal contamination in water and shellfish meats that quantitative bacteriological standards were possible, thereby, making a nationwide standards-based shellfish sanitation program a feasible proposition.

Over the near nine decades of its existence, the US-NSSP has undergone

revision and improvements to take advantage of emergent technical advances and expand in scope to include emergent threats to public health and greater numbers of domestic and international participants (Clem, 1994). In recognition that the US-NSSP is a highly developed program that cannot be *fully* replicated by Gambia in its entirety, at least in the short-term, Gambian officials have chosen to develop their own multi-agency program focusing on the key shellfish producing areas in the Tanbi Wetlands, Kubuneh Wetlands and Allahein River Estuaries. They chose to begin the process by establishing protocols for periodically conducting sanitary shoreline surveys, maintaining a survey database and developing water quality classification zones in shellfish growing waters based upon fecal coliform bacterial standards of the US-NSSP.

#### *Gambia-Rhode island study tour on shellfish sanitation*

As a shellfish-producing state, Rhode Island is a member of the ISSC, and, thus, responsible for the local implementation of the US-NSSP provisions that are outlined in state law and the Standard Operating Procedures Manual (RIDEM, 2008). To familiarize Gambian officials from agencies likely to be collaborating parties in a potential GNSSP, a study tour was arranged in 2010 to allow Gambian fisheries, water quality and enforcement officials to interact with their counterparts implementing shellfish sanitation program in Rhode Island and the US-FDA laboratories and offices in Silver Spring, Maryland. Study tour participants were chosen based on the assumption that GNSSP-related water sampling and bacteriological analysis of water and shellfish meats would be carried out by the Department of Water

Resources; periodic sanitary shoreline surveys would be carried out jointly by officials from the Department of Fisheries and the Department of Water Resources; mapping of water quality classification zones would be carried out by the GIS Environmental Mapping Unit of the National Environment Agency; and the enforcement of the GNSSP pollution closures would be by the Park Rangers of the National Parks and Wildlife Management Department, particularly in the Tanbi Wetlands Estuary that is managed as a Gambian National Park.

Post-harvest shellfish handling and food safety issues would be the responsibility of the Gambian Food Safety and Quality Authority, and the overall lead agency coordinating the Memorandum of Agreement among all the agencies to form the basis of the GNSSP would be the Ministry of Fisheries, Water Resources and National Assembly Affairs. The representatives of these Gambian government agencies worked for 2 weeks with their counterpart officials in the Rhode Island Department of Environmental Management Divisions of Fish and Wildlife, Water Resources, and Enforcement, the Food Safety Division and Food Safety Laboratory of the Department of Health, and the Coastal Resources Management Council that share responsibilities for implementing the protocols of the US-NSSP in Rhode Island. Participants also visited the national laboratories of the U.S. Food and Drug Administration at Silver Spring, Maryland to observe and discuss the US-NSSP oversight by the responsible national agency. Output from the Rhode Island study tour consisted of a set of recommendations by the study tour participants for the development of a GNSSP. These recommendations were

delivered by study tour participants at a workshop for Gambian environmental and health agency heads, and legislators from the Gambian National Assembly about a week after the conclusion of the Rhode Island trip. These recommendations and discussions by agency and ministry officials formed the basis of a draft inter-agency memorandum of agreement that would later become the basis of developing a more formalized GNSSP that would be agreed to by the shellfish industry trade organization and receive legislative and presidential approval. Once in place, Gambia would join South Africa in being one of the few countries in sub-Saharan Africa with an active national shellfish sanitation program (e.g. Republic of South Africa, 2012).

#### *Establishment of sanitary shoreline survey and database*

The first action undertaken to establish GNSSP procedures was to initiate a system of sanitary shoreline surveys of shellfish producing areas around the Tanbi Wetlands Estuary in metropolitan Banjul, and the Allahein River Estuary near the village of Kartong. The first sanitary shoreline survey was conducted as part of a training effort on 18 June 2011 along the Bund Road levee that connects the Port of Banjul with the main Banjul-Serrekunda Road that is the only access highway to the capital city. The survey included officials from the departments of Fisheries and Water Resources, and the National Environment Agency as part of the survey team. Babanding & Rice (2011) provide a detailed account of the methods employed in the survey as well as an account of the survey results. The sanitary survey was preceded by examining Google Earth images of the planned survey area in an effort to locate potential contaminant sources that

would be examined more closely on the ground and photographed as part of the database record.

Along Bund Road are a number of fishing villages that lack sanitary facilities, and the country's primary fishing port and the sole deepwater container port for the country. As part of this survey, areas of special attention from a water quality standpoint were identified and the data collected formed the nucleus of the database of potential sources of contamination affecting shellfish growing waters. Of particular concern was a dumpsite immediately adjacent to the Tanbi Wetlands National Park that in part was in the tidal waters of the estuary. Additionally, the fishing port area on the Gambia river near the eastern end of Bund Road was identified as problematic by lacking sanitary toilet facilities despite being a heavily used area of public gathering of fishers and fish buyers. The GNSSP sanitary shoreline surveys, once fully developed, would have multiple uses beyond documenting threats to shellfisheries. The database could also be used by multiple agencies in the Gambian government, including the Department of Public Works and Highways in prioritization of pollution abatement and remediation projects, including water sanitation infrastructure, as funds become available.

#### **Materials and methods**

Following the initial sanitary shoreline survey in the Bund Road area of Banjul, sanitary shoreline surveys were undertaken in the months following at 10 important shellfishing areas along the perimeter of the Tanbi wetlands, four sites in the Kubuneh/Kembujeh estuary system, located about 15 km eastward of the Tanbi along the south bank of the Gambia river, and an additional

site in the Allahein River Estuary near the village of Kartong (Table 1).

At each site, data of potential contaminant sources of adjacent shellfish growing waters were collected and entered into a sanitary shoreline survey database maintained by the

were highest in areas with greater human habitation and in areas where livestock were being raised near or within the intertidal zone of the study sites, or in locations where there is direct discharge of sewage into the estuary by water seal flush toilets.

TABLE I  
*Sanitary shoreline survey village sites*

<i>Code</i>	<i>Site</i>	<i>Date of survey</i>	<i>Time of survey</i>	<i>Presence of toilets</i>	<i>Latitude (N)</i>	<i>Longitude (W)</i>	<i>Surface salinity (ppt)</i>
1	Wencho	2-Feb-12	9:34	No	13.460384	-16.598669	41
2	Kamalo	2-Feb-12	10:20	No	13.468951	-16.637085	41
3A	Old Jeshwang A	11-Jan-12	10:30	No	13.459784	-16.656287	38
3B	Old Jeshwang B	11-Jan-12	10:45	No	13.459209	-16.655181	38
3C	Old Jeshwang C	11-Jan-12	11:15	No	13.458447	-16.655574	37
4	Ebo Town	2-Feb-12	10:50	No	13.434974	-16.658933	35
5	Fagi Kunda	2-Feb-12	11:53	No	13.414761	-16.653974	39
6	Abuko	2-Feb-12	12:10	No	13.409475	-16.648363	41
7	Lamin Lodge	2-Feb-12	12:40	Yes*	13.392885	-16.625331	37
8	Daraka	2-Feb-12	13:20	No	13.385721	-16.621598	14
9	Kerewan	2-Feb-12	13:40	No	13.380102	-16.615082	14
10	Mandinaring	2-Feb-12	14:03	No	13.383571	-16.602937	35
11	Kubuneh	3-Feb-12	10:05	No	13.315334	-16.597537	38
12	Bufulofo	3-Feb-12	10:40	No	13.319733	-16.613995	35
13	Kembujeh	3-Feb-12	11:20	No	13.300287	-16.612611	28
14	Mandinabe	3-Feb-12	12:00	No	13.289652	-16.592201	24
15	Kartong	3-Feb-12	12:55	Yes*	13.073127	-16.743724	40

Sites with water seal flush toilets have discharge pipes emptying untreated sewage directly into the estuary.

Gambian Department of Water Resources. A summary of the sanitary shoreline survey data with some of the supporting photographs that are archived along with the data was previously published (USAID/Ba Nafaa Project, 2012b). Details of the sanitary shoreline survey sites were given along with preliminary data on water quality based upon total coliform (TC) and fecal coliform (FC) microbiological criteria using data collected in 2010 and 2011 from each of the 15 study sites. It was reported that coliform counts

#### *Microbiological indicators of sanitary water quality*

Beginning 25 August, 2010, the Gambian Department of Water Resources has been collecting regular monthly water samples from the 15 identified shellfishing locations (Table 1). Another sampling site was added at Bund Road near the floodgates where runoff from urban Banjul streets is discharged into waterways of the Tanbi (Table 2). Sampling at Bund Road occurred monthly beginning in March 2012 until December 2013 with

samples taken at the lowest and highest daily tides. Beginning in January 2013, additional water sampling sites were added to aid in establishing water quality in the interior of the extensive Tanbi Wetlands Estuary, where a considerable amount of shellfishing by the TRY Oyster Women's Association is conducted further away from land based sources of contamination and, therefore, areas presumed likely to have better *in situ* water quality and more likely to meet water sanitation standards and be an "open" harvest area.

TABLE 2  
Additional water sampling sites 2012 and 2013

Code	Site	Latitude (N)	Longitude (W)
MT1	Middle Tanbi 1	13.459102	-16.607889
MT2	Middle Tanbi 2	13.421526	-16.620569
MT3	Middle Tanbi 3	13.435972	-16.644234
MT4	Middle Tanbi 4	13.457103	-16.630876
BR1	Bund Road 1	13.452068	-16.589585
BR1	Bund Road 2	13.452431	-16.589211

Collection of water samples at each of the sample sites followed protocols outlined in *Standard Methods for the Examination of Water and Wastewater* (APHS, 2012) and returned to the Water Quality Laboratory in Abuko in cooled ice chests for analysis by filtration methods on the same day of collection or refrigerated for analysis the next day. The m-Endo LES medium was used for enumeration of TC bacteria on filters by counting colonies with a greenish sheen in the filters soaked with the magenta-colored medium following protocols of Graybow & DuPreez (1979). Likewise, FC bacteria were enumerated by colony counts on filters soaked with Modified M-FC media

(Graybow *et al.*, 1981). TC and FC values at each of the sample sites were compared to coliform standards for shellfish growing waters used by the US-NSSP: 70MPN/100 ml for TC and 14MPN/100 ml for FC (FDA, 2011).

### Results and discussion

Sample data compilation sheets for coliform counts at sampling sites in example months are provided in Tables 3 and 4. Data from these Tables suggest that point sources of fecal contamination are a major source of dry season coliform counts. Highest FC values during the dry season were at site 3 (Old Jeshwang), where villagers were raising pigs in pens partially in the intertidal zone; at sites 4 (Ebo Town), 5 (Fagi Kunda) and 6 (Abuko) all with dense suburban human habitation close to the estuary, and 13 (Kembujeh) a rural village close to the estuary. These data also provide some evidence that the FC levels in shellfish harvesting sites are affected by freshwater runoff from land during the rainy season. These non-point source FC values are higher in all but one sample site during the rainy season, with all but one sample site failing to meet the proposed GNSSP FC water quality standard of 14/100 ml during the rainy season. TC counts were higher during the rainy season sampling as well, but only in two instances did TC counts fail to meet the 70/100 ml standard, suggesting that under Gambian conditions, FC counts provide a much more sensitive indicator of sanitary water quality.

Climatological data from the Gambian National Environment Agency indicate that there is a distinct rainy season in Banjul and its environs from June to October, with average peak rainfall in July (230 mm),

TABLE 3  
Dry season example data sheet

		Weather Conditions: 30th March 2011 = sunny					Weather Conditions: 31st March 2011 = sunny	
Location: Tanbi National Park and West Coast Region		Type of sample: River/Surface Water						
Site number	Date	Test results		Salinity ppt	F C No./100 ml	T C No./100 ml	Remarks	
		Time	Temp. °C					
1	30/03/2011	14:20	31.0	43.0	24*	36	Fairly clean not far from city settlements, low tide	
2	30/03/2011	15:11	30.2	44.5	12	24	Clean surrounding, low tide	
3	30/03/2011	15:20	29.2	40.5	28*	44	Fairly clean pigs living near the harvesting sites low tide	
4	30/03/2011	15:49	29.5	38.9	28*	64	Fairly clean recreational activities on, low tide	
5	30/03/2011	16:37	29.4	43.6	24*	48	Fairly clean recreational activities on, low tide	
6	30/03/2011	16:58	29.3	45	28*	44	Fairly clean surrounding, low tide	
7	30/03/2011	17:05	26.9	39.1	8	20	Fairly clean surrounding, high tide	
8	31/03/2011	9:50	27.1	39.4	12	28	Clean surrounding, high tide	
9	31/03/2011	10:01	27.1	39.8	4	16	Fairly clean surrounding, high tide	
10	31/03/2011	10:15	27.0	39.7	8	12	Fairly clean surrounding, high tide	
11	31/03/2011	10:34	27.7	36.7	8	20	Clean surrounding, high tide	
12	31/03/2011	11:15	27.7	37	4	12	Clean surrounding, high tide	
13	31/03/2011	11:57	30.5	37.1	16*	28	Fairly clean surrounding, high tide	
14	31/03/2011	12:24	30.9	33.7	8	16	Fairly clean surrounding, high tide	
15	31/03/2011	13:20	29.0	39	4	16	Fairly clean surrounding, high tide	
Mean			29.7	38.0	16	33		

\* Samples failing US-NSSP coliform water quality standard of 14/100 ml (FC) or 70 ml (TC)

August (380 mm), and September (276 mm), with negligible rainfall during the November–May dry season. Salinity measurements of surface waters taken at each of the coliform sampling sites suggest that northern and western areas of the Tanbi Estuary that are closer to the Atlantic Ocean tend to reestablish higher oceanic salinities of 38–40 ppt within a month of the onset of the dry season in November, while sites toward the east are more heavily influenced by the

Gambia river, taking several months to reestablish the higher oceanic salinity regime (Fig. 1).

In addition to predicting likelihood of non-point source runoff-derived coliforms, the salinity of the estuaries has a pronounced effect on initiating the spawning of oysters in the estuary. Data presented earlier (Rice *et al.*, 2012a; Babanding *et al.*, 2014) showed that spatfall of oysters, *Crassostrea tulipa* in Gambian estuaries occurs primarily during



TABLE 4  
Wet season example data sheet

		Weather Conditions: 6th September 2010 = drizzle Weather Conditions: 7th September 2010 = drizzle					
Location: Tanbi National Park and West Coast Region		Type of sample: River/Surface					
Site number	Date	Test results		Water		Remarks	
		Time	Temp. °C	Salinity ppt	FC No./100 ml		TC No./100 ml
1	6/9/2010	12:35	27.0	17.7	64*	72*	Fairly clean not far from city settlements, low tide
2	6/9/2010	13:01	25.8	11.9	12	24	Clean surrounding, low tide
3	6/9/2010	13:20	26.8	14.8	72*	88*	Fairly clean pigs living near the harvesting sites low tide
4	6/9/2010	13:40	26.8	12.4	20*	24	Fairly clean surrounding, low tide
5	6/9/2010	13:50	26.7	10.8	28*	32	Fairly clean surrounding, low tide
6	6/9/2010	14:00	26.9	11.4	52*	68	Fairly clean surrounding, low tide
7	6/9/2010	14:30	28.9	16.5	68*	76*	Fairly clean surrounding, low tide
8	6/9/2010	14:50	29.1	16.6	32*	68	Clean surrounding, low tide
9	6/9/2010	15:15	28.9	16.4	28*	64	Fairly clean surrounding, low tide
10	6/9/2010	15:25	28.9	16.8	32*	56	Fairly clean surrounding, low tide
11	7/6/2010	12:45	27.5	16.6	16*	24	Clean surrounding, low tide
12	7/6/2010	12:13	26.9	14.5	32*	52	Clean surrounding, low tide
13	7/6/2010	12:50	28.3	15.5	24*	44	Clean surrounding, low tide
14	7/6/2010	13:20	28.4	14.2	20*	32	Clean surrounding, low tide
15	7/6/2010	14:25	27.1	18.2	40*	60	Clean surrounding, low tide
Mean			28.0	16.1	35*	54	

\* Samples failing US-NSSP coliform water quality standard of 14/100 ml (FC) or 70 ml (TC)

the period of increasing salinities in the Tanbi and, Kubuneh estuaries, and maximum spatfall occurs at different times after the onset of the dry season depending on location which affects timing of the reestablishment of the high oceanic salinity conditions. Maximum spatfall from oysters occurring in West African estuaries take about 18 months to 2 years in the wild, but placing oysters subtidally in aquaculture gear can shorten the time to reach market size (Kamara, 1982). Oysters spawning in the Tanbi or Kubuneh estuaries from September to November

would be reaching market size between March and May during the dry season, with TRY oyster fishers targeting oysters primarily from the year class of the spatfall occurring the year before last. Fortuitously, the period of greatest oyster harvest in the Tanbi and Kubuneh estuaries occurs during the dry season in the early part of the year, in which water quality is better based on coliform criteria.

Both TC and FC indicator counts fluctuated considerably through the course of a year. Mean FC counts ranged from <10/

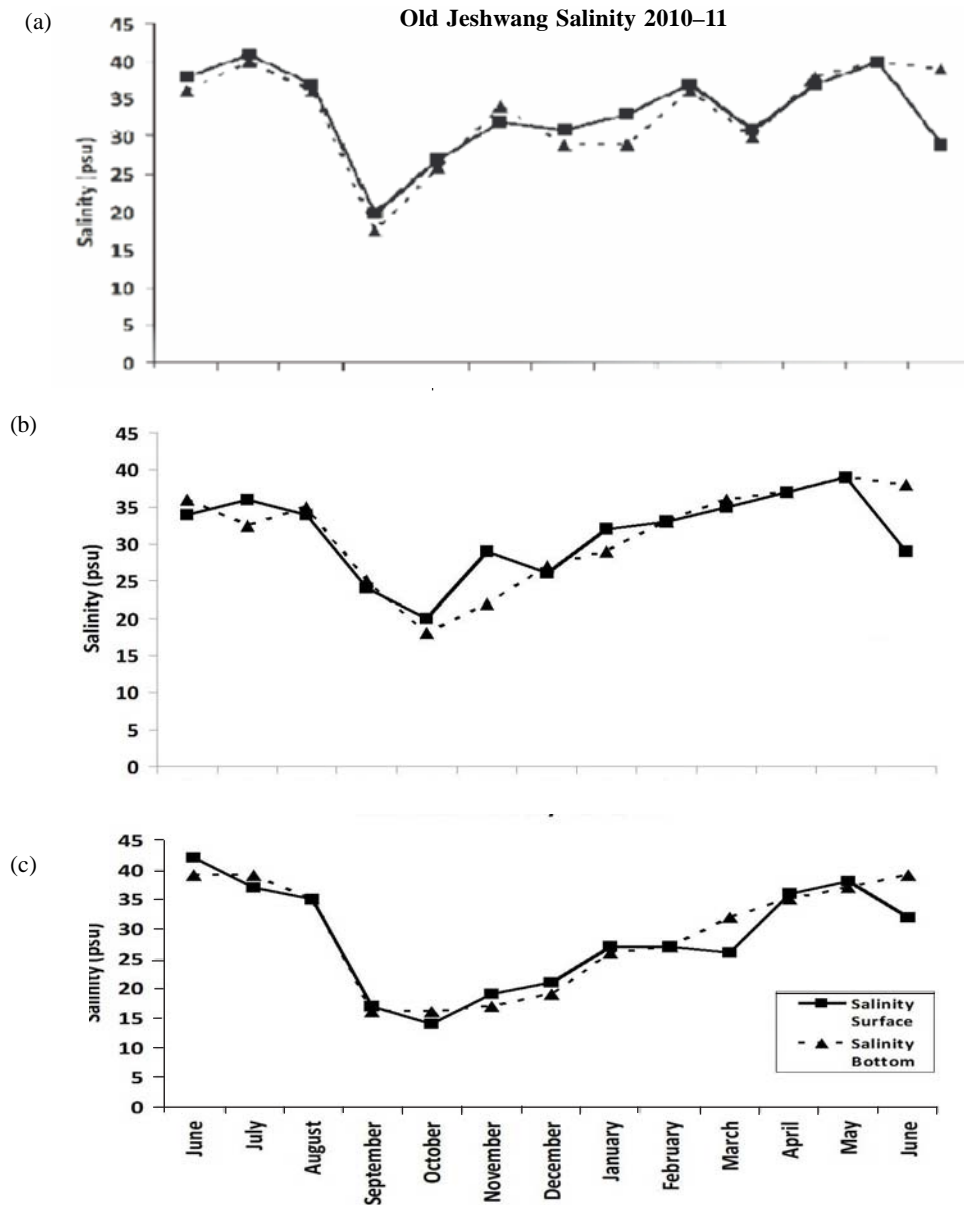


Fig. 1a, 1b and 1c. Salinity profiles taken in 2010-11 at oyster growing areas at Old Jeshwang (1A) located in the northwestern Tanbi Estuary with close tidal exchange with the Atlantic Ocean at nearby Denton Bridge; Lamin (1B), in the southwestern region of the Tanbi Estuary with greater water exchange with the Gambia River; and Kubuneh (1C) in a wetland complex separate from the Tanbi that is 12 km up the Gambia river. Data suggest a greater reestablishment of oceanic salinity at Old Jeshwang, followed by Lamin that has greater riverine influence, and then by Kubuneh that has prolonged freshwater mixing months after the rainy season is over.

100 ml during the dry season in early 2013 to >80/100 ml during the 2012 rainy season (Fig. 2). Maximum FC counts fluctuated to a greater degree than mean or minimum values, possibly due to uncontrolled transient events. Highest mean counts occurred in August 2010 and August 2012 corresponding to two heavy rainy seasons, while the August counts in 2011 and 2013 were relatively low due to lesser rain in those years. With the exception of September 2010, minimum FC counts remained below the GNSSP standard throughout the study period. Likewise, mean TC counts range from < 30/100 ml in the 2013 early dry season to > 60/100 ml during the 2012 rainy season (Fig. 2). Maximum TC counts fluctuated to a greater extent than the mean or minimum counts possibly due to uncontrolled transient events. Maximum mean coliform counts occurred during the 2010 and 2012 rainy seasons, but mean TC counts remained below the 70MPN/100 ml US-NSSP standard throughout the entire study period (Fig. 3). Taken collectively these data suggest that the FC indicator and corresponding standard are a more sensitive measure of fecal contamination and risk than the TC indicator and standard. Thus, the FC indicator and standard, at least in the Gambian context, is of greater utility in establishing sanitary water quality classification zones in the country's shellfishing regions.

Bund Road was built atop a levee constructed in 1954 by the British Colonial Government in response to the 1947 flooding event in the capital city of Banjul (then known as Bathurst). The levee acted to protect the city from subsequent flooding, but the levee enclosed part of the wetland area adjacent to the city that served to retain and partially treat some sewage and rainwater

runoff from the streets. Discharge of the collected urban runoff from Banjul in this levee-enclosed wetland area is discharged into the Tanbi Wetlands at a single point along the Bund Road levee that has a series of floodgates that were designed to be manually closed in case of a Gambia river flood. Normally, the flood gates are maintained in an open position allowing a semi-free flow of tide waters into the inner levee-enclosed area. Thus, water sampling at the Bund Road floodgates can provide a measure of the water quality impacts in Banjul on much of the upper Tanbi Wetlands. Samples were taken near the floodgates monthly from March 2012 and spanning the 2012 and 2013 rainy seasons, with high tide and low tide water sampling on the same day. Coliform counts are generally higher during the August–September rainy season, with the relatively drier 2013 rainy season showing lower values (Fig. 4). TC was significantly higher ( $P < 0.05$ ) at low tide than at high tide, suggesting the source of fecal contamination is from the city and that incoming tidal waters from the Tanbi estuary serve to dilute and flush away these contaminants into the estuary.

With a goal of establishing water quality zones in the Tanbi and other major shellfishing grounds in Western Gambia, additional water sampling was carried out at key locations within the interior of the Tanbi estuary that are accessible only by boat (Table 2). Water sampling for FC during the wet and dry seasons showed that the interior areas of the Tanbi wetlands are largely free of fecal contamination, but even in these areas fairly distant from human habitation there are a few instances of individual samples showing elevated counts (Fig. 5). The addition of these data allowed for some preliminary mapping of water quality zones

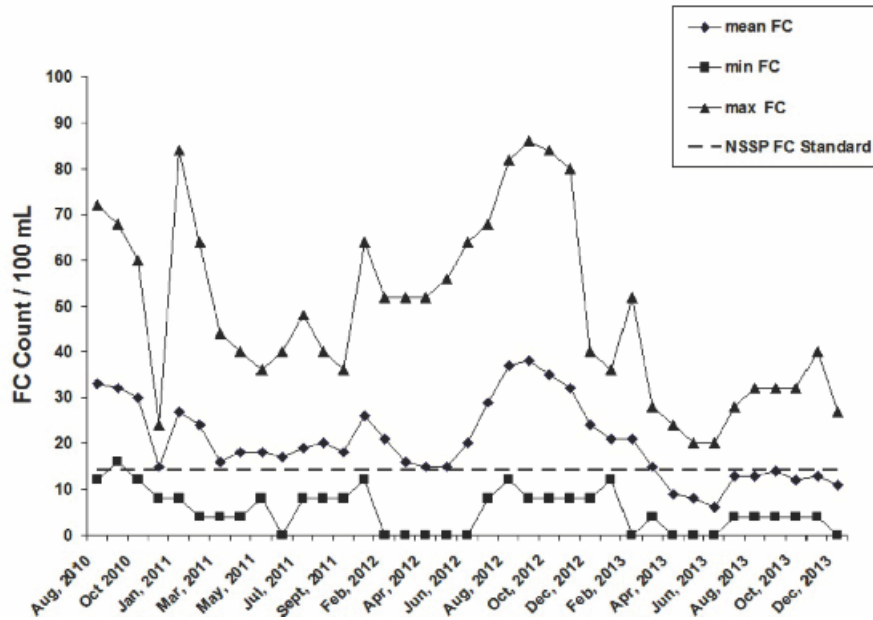


Fig. 2. Mean, minimum and maximum fecal coliform (FC) values at 15 oyster shellfishery sites in the Tanbi, Kubuneh and Allahein estuaries of Western Gambia from August 2010 to December 2013 in comparison to the 14 MPN/100 ml FC standard from the US-NSSP, and serving as the proposed standard for the GNSSP.

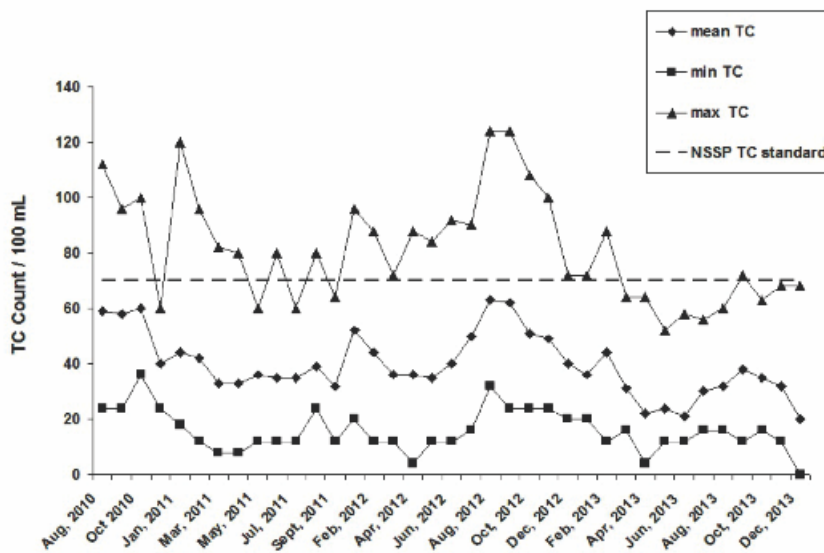


Fig. 3. Mean, minimum and maximum total coliform (TC) values at 15 oyster shellfishery sites in the Tanbi, Kubuneh and Allahein estuaries of Western Gambia from August 2010 to December 2013 in comparison to the 70 MPN/100 ml TC standard from the US-NSSP.

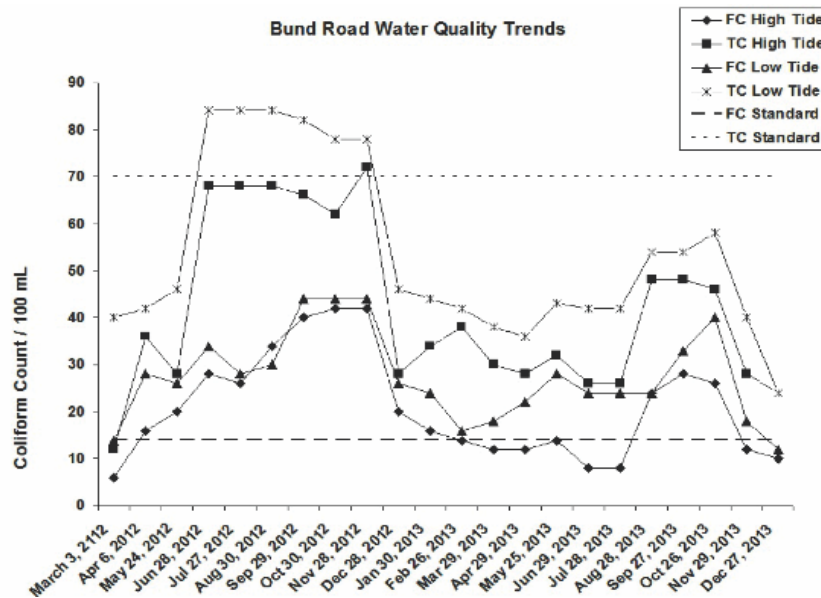


Fig. 4. Total coliform (TC) and fecal coliform (FC) counts were taken at two sites inside and outside the flood-gates on Bund Road that forms the discharge of a constructed wetland receiving runoff water from sewers and streets of Banjul, Gambia and discharging into the Tanbi Estuary. TC counts were significantly higher ( $P < 0.05$ ) at low tide than at high tide as determined by non-parametric Wilcoxon rank-sum analysis, while the higher FC counts at low tide were significant only at the  $P < 0.10$  level.

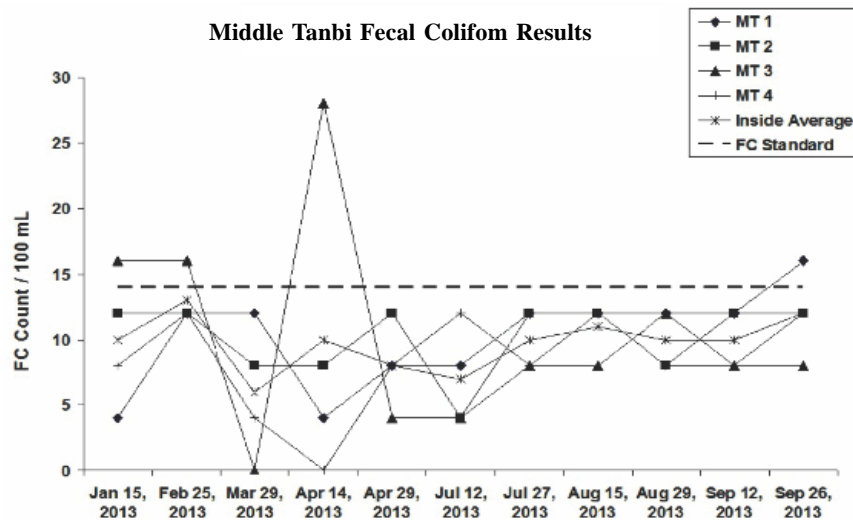


Fig. 5. Four water quality sites inside the Tanbi Estuary System that are accessible only by boat, but are used periodically as oyster harvest sites were tested for dry season and wet season fecal coliform (FC) counts. During these 2013 periodic samplings over nine months, mean FC counts remained below the 14 MPN/100 ml proposed GNSSP standard. At site MT3 there were three instances of counts exceeding the standard on three of the 11 sampling days, indicating some transient contamination events occur.

and the recommended classification zones are more complex (Fig. 6). Areas recommended for prohibited status include the village of Wencho near Banjul, the Bund Road Area, the upper Tanbi Estuary near Banjul. The area around Denton Bridge on the Banjul-Serrekunda Highway is recommended as a prohibited area as it is a fishing port and tourism boat marina without adequate toilet facilities. Another prohibited area includes Lamin Lodge, an eco-tourism hotel site with toilet pipe discharge directly into the estuary. Most areas on the outer edges of the estuary are considered part of the Banjul periurban area and are recommended for conditional/seasonal closing to shellfishing during the rainy season and the following months.

#### *GNSSP data for prioritizing pollution abatement projects*

The maintenance of a database of sanitary shoreline survey and coliform count data has allowed recommendations by the Department of Water Resources to officials of the Kanifing Municipal Council to take actions to improve sanitary water quality in their jurisdiction. At one oyster harvesting site in that jurisdiction, Old Jeshwang, some local residents were engaged in the raising of pigs in enclosures within the intertidal zone (Fig. 7). The pig farmers designed their piggery to be self-cleaning relying on the tides to carry away the feces buildup in the pens. Using the water quality data, municipal officials were able to legally designate the piggery as a public nuisance and order the removal of the pens for reestablishment at a more upland site where the manures can be properly managed.

The removal of the pig pens from the Old Jeshwang oyster site was carried out in

September 2012 and there are indications that the removal of pens may have resulted in a measurable improvement in water quality at the site (Fig. 8). Dry season FC counts in 2013 were lower in 2013 than in the previous three years. However, this trend should be treated with some caution and confirmed by water sampling, subsequent years because, overall, the 2013 wet season was rather dry in comparison to previous years with wet season counts low at all sampling sites (Fig. 2).

The initial sanitary shoreline survey of Old Jeshwang also showed that the settlement and work area had absolutely no toilet facilities for any of the local village inhabitants who would frequently defecate into the water or in an upland location away from the shoreline huts, but allowing fecal contamination to runoff into the estuary during the rainy season. A Water, Sanitation and Hygiene Needs Assessment conducted in late 2011/early 2013, together with information from water quality data and the sanitary shoreline survey, were key factors considered by stakeholders in the prioritization of both the oyster harvesting and fish landing sites at Old Jeshwang (which are adjacent) to receive water, sanitation and hygiene (WASH) support from the USAID/BaNafaa project (Banja, 2012).

WASH Support included: 1) Participatory Hygiene and Sanitation Transformation (PHAST) training of 40 people at Old Jeshwang, 2) Training of Trainers (TOT) for 20 people in Community Outreach and Hygiene Promotion, 3) Fish Handling and Hygiene Training for 20 people, 4) Establishment of a site-based WASH Management Committee and Development of a WASH Management Plan managed by the Committee, including fines for open

in the Tanbi, which were presented in a preliminary report early in 2014 (Rice *et al.*, 2014).

#### *Translating sanitary water quality data into GNSSP policy*

Using all of the available data of sanitary shoreline surveys, FC counts by season and the proposed GNSSP standard of 14 MPN/100/mL, we constructed a map of sanitary water quality using the GIS mapping capabilities of the Gambian National Environment Agency using ArcMap 10.2,

following zoning criteria in the US-NSSP (FDA, 2011). In general the Allahein River Estuary on the southwestern border of Gambia with the Casamance Region of Senegal is recommended to be classified as being uncertified for shellfishing during the wet season and several following months, as is the Kubuneh/Kembujeh Estuary located south of metropolitan Banjul and the Tanbi Wetlands is also recommended for seasonal closure (Fig. 6).

The Tanbi Wetlands is the Gambia's largest and most important shellfishing area

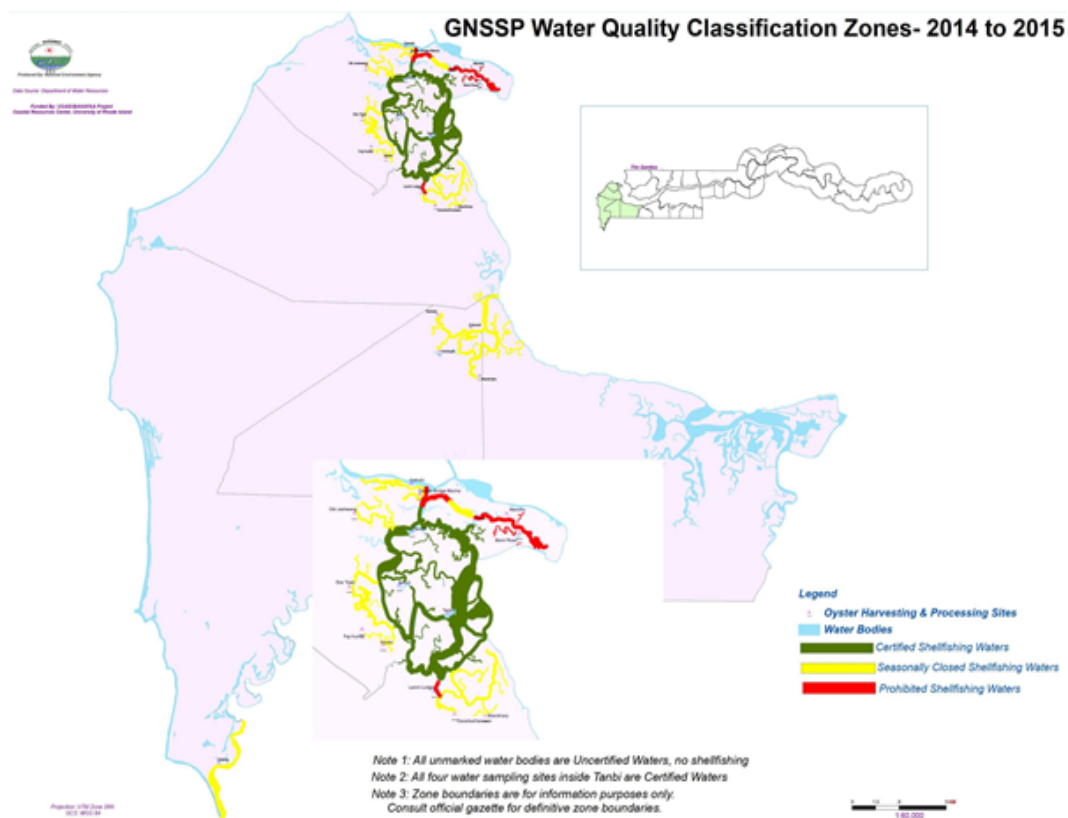


Fig. 6. The 2014–15 Gambian shellfishing water classification zones based on sanitary shoreline surveys and fecal coliform microbiological criteria from the Gambian Department of Water Resources and mapped by the National Environment Agency.



Fig. 7. Photograph taken in January 2011 of one of several pig pens constructed in the intertidal zone in the neighbourhood of old Jeshwang in Kanifing Municipality. Oyster harvesting occurs in the mangrove swamps in the background of the photo by women shellfishers and oyster shucking processing occurs at the site as evidenced to the shell midden on which the piggery was constructed. Photo by M. A. Rice.

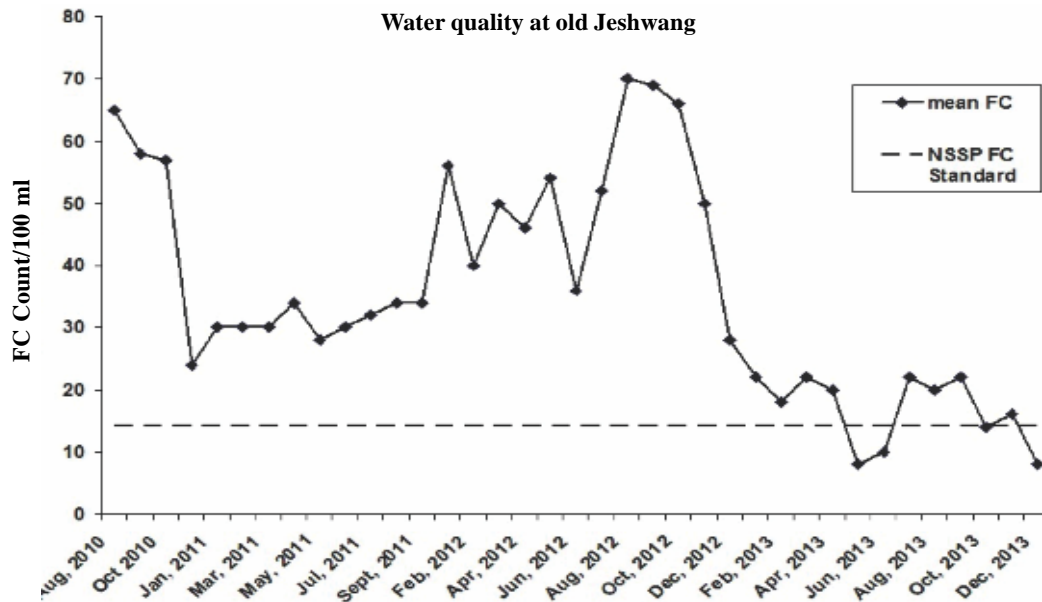


Fig. 8. Mean monthly faecal coliform (FC) counts in at the estuarine sampling site at Old Jeshwang from August 2010 to December 2013. Peak counts were in the rainy season in 2010 and 2012 with much lesser peaks in the drier 2011 and 2013 seasons. Pig pens in the intertidal zone of the site were carried out September 2012 and a water seal toilet facility for villagers was installed in December 2013.



defecation, and 5) WASH infrastructure, including a municipal water point and a water seal flush, sealed tank toilet at both the oyster harvesting and fish landing sites at Old Jeshwang (Fig. 9). With the toilet and water facilities at Old Jeshwang dedicated and initially used on 16 December 2013, it remains to be seen if they will result in further additional measurable reductions in FC counts at the site. A similar sanitary water supply source and toilet facility was also established at the oyster village at Kartong.

#### **Conclusion and recommendation**

Shellfisheries in Western Gambia are an important income source for families of women shellfishers who are often single heads of households. Market prices received

by the shellfishers are quite low as the local population cannot afford high priced oysters. It is surmised that a high end market could be established for hotels catering primarily to Europeans willing to pay higher prices. The establishment of a the GNSSP with data collection, development and enforcement of shellfish sanitation regulations is seen as a means to build consumer confidence in The Gambia and boost higher value market segments for shellfish. Primary conclusions from the initial GNSSP studies include 1) sanitary shoreline surveys have identified numerous point sources of fecal contamination of estuarine waters; 2) FC is a more sensitive indicator of fecal contamination than TC in the Gambian context, and recommended as the primary



Fig. 9. Women of the TRY Oyster Women's Association celebrating at the formal dedication of the water sealed toilet and municipal water supply facilities at the Old Jeshwang fish landing and oyster harvest and processing site in the Municipality of Kanifing on 16 December 2011. Photo by Karen Kent.

water quality certification standard for the GNSSP; 3) FC values from most shellfish growing areas are at or below a FC standard of 14 MPN/100 ml most of the year; 4) highest average FC values correspond to local rainfall maxima from July to October that also corresponds to the traditional off-season for shellfishing; 5) there is enough precision and repeatability in the data to establish water quality classification zones at shellfishing sites in the Tanbi Wetlands, Kubeneh/Kembujeh, and Allahein River Estuaries; 6) GNSSP data can be used to prioritize water sanitation improvement projects to improve oyster harvests and marketing and promote public health in general.

The fact that in The Gambia, there is no widespread use of sewers to collect and discharge sanitary wastes into coastal waters has resulted in remarkably good water quality in many of the shellfish harvesting waters in Western Gambia. This is in stark contrast to highly populated urban estuaries in other parts of the world, where sewage is not managed and fecal coliform counts in oyster growing waters are frequently >10,000 MPN/100 ml on regular basis. (Palpal-latoc *et al.*, 1986). A major implication of the relatively oyster growing waters is that as a matter of national water quality management policy, it may be more cost-effective to *not* design and install expensive centralized sewerage and septic systems that have been the norm in cities of Europe and North America, since the late 19th century. An alternative and more innovative system of waste disposal/recycling may be the use of composting dry toilets or water sealed toilet systems that collect into upland septic systems that can be maintained and cleaned out periodically, with nightsoil composted for use as agricultural fertilizers. Thus, wastes would be recycled while

maintaining sanitary cleanliness of the Gambia river and coastal waterways. The program to establish water-sealed toilets emptying into a sealed tank at oyster harvesting and processing sites at Old Jeshwang and Kartong may be a model for improving and maintaining sanitary water quality throughout the coastal zone.

An interagency memorandum of understanding of the Government of The Gambia for developing the GNSSP can provide the basis for interagency cooperation and shared funding and is the basis for a sustainable shellfish sanitation program in the country, especially since donor funds have expired. Additionally, there must be a system of maintaining a cadre of trained GNSSP staff as the program expands and participants move on in their professional careers. As the GNSSP moves forward, particular attention must be paid to the sanitary quality of the harvested shellfish from estuary waters to the consumer's plate. Good water quality alone does not assure a successful shellfish sanitation program. The next steps in developing the GNSSP into a truly effective program to boost consumer confidence in Gambian shellfish will be in the cold chain of harvest, processing, shipping and marketing of Gambian shellfish.

The ability to establish NSSPs in developing countries like The Gambia is feasible but requires significant up-front investment. Access to international export markets such as the European Union or US may be extremely difficult at first, but if there are potential local high end markets as a first step, this could lead to the possibility of exports in the future. However, given the interdisciplinary nature of shellfish sanitation, no single agency within government would likely be charged with sole responsibility of

administering the program. Thus, interagency cooperation within the government is extremely critical for success as is working closely with the harvesters themselves, while keeping in mind market considerations.

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