Darwin Initiative Main Project Annual Report

Important note: *To be completed with reference to the Reporting Guidance Notes for Project Leaders: it is expected that this report will be about 10 pages in length, excluding annexes*

Submission Deadline: 30 April

Darwin Project Information

Project Reference	21-013
Project Title	Alternative livelihood opportunities for marine protected areas fisherwomen
Host Country/ies	Sierra-Leone, UK
Contract Holder Institution	University of Stirling (UoS)
Partner institutions	Fourth Bay College, University of Sierra Leone Institute of Marine Biology and Oceanography (IMBO), Njala University (NJU), Macalister Elliot and Partners Ltd. (MEP).
Darwin Grant Value	£247,264
Funder (DFID/Defra)	DFID
Start/end dates of project	1 Apr 2014 to 31 Mar 18
Reporting period (e.g., Apr 2015 – Mar 2016) and number (e.g., Annual Report 1, 2, 3)	Annual Report 2: 1 Apr 2015 to 31 Mar 2016
Project Leader name	Francis Murray
Project website/blog/Twitter	http://www.stir.ac.uk/aquaculture-mangrove-oyster/
Report author(s) and date	Francis Murray, Salieu Sankoh, Richard Wadsworth, William Leschen, James Green, Richard Quilliam, R. Kapindi, Amara Kalone, Nick Shell

Glossary of Terms and Abbreviations

BFPC	Bonthe Fisheries Processing Centre
CBD	The Convention on Biological Diversity (1992)
CMA	Community Management Association
EJF	Environmental Justice Foundation (UK NGO)
FT	Freetown
GHI	Global Hunger Index (IFPRI)
HH	Household
HABS	Harmful Algal Blooms
IMBO	Institute of Marine Biology and Oceanography (Fourah Bay College, Freetown)
IRDP	Integrated Rural Development Program
LAR	Living Aquatic Resources
LMC	Local Management Committee (with oversight for CMAs)
Lumi	A weekly (usually Sunday) open-air food market
MFMR	Ministry of Fisheries and Marine Resources
MPA	Marine Protected Area
dd-RAD	Double Digest Restriction-site Associated DNA marker analysis
SSL	Sierra Leone Leones (Le: local currency)
TDS	Total Dissolved Solids
UoS	University of Stirling

Contents

1. Project Rationale

This 'Sherbro Oyster Project' was established to support the work of the recently established Sherbro Marine Protected Area (MPA) by providing alternative livelihoods based on carefully managed extensive culture and value-added marketing of native mangrove oysters, in order to make it a financially viable income earning activity for local women whilst also protecting its sustainability for the future. A localised native oyster depletion and mangrove degradation problem was first identified during 2006/7 by a previous Darwin Initiative project under which two reconnaissance surveys (Wadsworth 2009a & 2009b[1]) were undertaken to consider the possibility of including the mangrove forests as a "biodiversity offset" to a commercial Rutile-mineral mining concession (NACE 2009[1]).

Fig 1. Research locations in the Sherbro estuary; numbered red-flags indicate communities shortlisted for further in-depth assessment (see Table 1). Green flags indicate two weekly mainland retail and wholesale markets.

The primary research area and main target beneficiaries, i.e. female oyster gatherers and their households, are located in Bonthe District, Southern Province around the Sherbro River estuary. These women are responsible for most of the oyster harvesting, processing and marketing activity in the area. Most gathering and processing is undertaken by small satellite communities located around the oldest and largest settlements of Bonthe and York on Sherbro and York Islands (Fig 1). Oysters are steamed using mangrove wood for domestic consumption and local sales in Bonthe and York. Remoter communities must first steam then smoke-preserve their oyster (and fish) surpluses to retail or wholesale in one of two weekly mainland markets (*lumis*) with road connections; Yagoi on the Sherbro River to the south and Gbambatok to the north. In the absence of roads and motorised transport, most oyster-gathering, fishing and local transport

[1] Wadsworth, Richard. 2009a *Novel and practical conservation strategies following mining in Sierra Leone. Field Report 25th January to 18th February 2009.* NERC/Centre for Ecology and Hydrology, 8pp. (CEH Project Number: C03141) (Unpublished).
Wadsworth, Richard A.; Sundufu, Abu; Jalloh, Abdul. 2009b *Report on Inspection of Mangrove Forest Adjacent to Sierra Rutile Operational Areas 5th - 6th December 2007.* NERC/Centre for Ecology and Hydrology, 6pp. (CEH Project Number: C03141).
Sierra Leone at the Crossroads: Seizing the chance to benefit from mining. Published by National Advocacy Coalition On Extractives (NACE). March 2009. http://www.christianaid.org.uk/Images/sierra-leone-at-the-crossroads.pdf
http://www.darwininitiative.org.uk/documents/15031/20931/15-031%20FR%20revised%20-%20edited.pdf

is dependent on large numbers of small, 1-3man dug-out canoes. Market research on value-added fresh-live oyster sale options has also been conducted in and around the capital city Freetown, half a day's drive north of the MPA.

Further critical understanding of the development context has been gained following a first (post-Ebola) joint-mission to research areas in January 2016. A case for refinement of project objectives made in this report (Section 3.4) will be the subject of a separate logframe output and outcome change request with justifications presented in Sections 3.1, 3.4 and Annex 4:

2. Project Partnerships

The following project partners and affiliates collaborated on research activities during the projects first (post Ebola: Section 3) joint field-mission to Freetown and Bonthe District over 10 days in January 2016:

- Dr. Francis Murray and Mr William Leschen: aquaculture development specialists, UoS
- Dr Richard Quilliam: food borne pathogen analyses, UoS, UK
- Dr Salieu Sankoh: aquaculture and fisheries specialist, IMBO, SL
- Mr. Richard Kapindi: Community outreach & survey expert, IMBO, SL
- Dr Richard Wadsworth: environmental science specialist, Njala University, SL
- Mr James Green: Commercial oyster aquaculture specialist, Whitstable Oysters, UK
- Mr Edward (Amara) Kalone: IUU project officer, Environmental Justice Foundation, Bonthe, SL
- Fisheries support officer MFMR, Bonthe SL

Collaborators included local staff of the Ministry of Fisheries and the Environmental Justice Foundation (EJF) with an office in Bonthe. Building enduring working relations with these organisations is a key aspect of the projects exit-strategy. Plates 1a-f: show project partners collaborating on a range of research activities during the January mission.

Mr Kapindi (IMBO) and Mr Kalone (EFJ) are or will become permanently based in Bonthe to coordinate and support on-going project field-work. Dr Sankoh has also liased with Mr. Phil Gawne, Chairman of Isle of Man Govt. International Development Committee to provide additional financial support for the MPA co-management process through ISFMSL. This could potentially result in recruitment of a dedicated Fisheries Officer located Bonthe contingent on the World Bank continuing funding from August 2016. Dr Richard Quilliam (an environmental scientist from the University of Stirling), joined the mission to analyse the risk of oyster contamination with human pathogenic bacteria of faecal origin. Mr James Green, proprietor of Whitstable Oysters a UK commercial oyster producer and retailer also joined the January Mission and provided technical advice on production and marketing issues. Mr Green who also coordinates the annual Whitstable Oyster Festival is highly committed to long-term post-project collaboration with local partners. At this stage of the project UK partner Macalister Elliot (with a minor budget) is yet to engage in activities as laid out in the proposal.

Ministerial re-shuffles complicate relation-building with Ministry of Fisheries and Marine Resources (MFMR) at national level. However, we have excellent connections at operational level through project partner Dr. Salieu Sankoh and his liaison with the West African Regional Fisheries Project, Sherbro MPA local and devolved Community Management Associations (CMAs). Face-to-face engagement between the project and other stakeholders also filled 'inception-meeting' gaps partially fulfilled through earlier Skype conferencing.

The research team were observers at a MPA Local Management Committee meeting in Bonthe attended by 19 persons, including 6 female oyster gatherers/ vendors and 13 fishermen (one member represents approximately 10 villages). The key concern for the male membership was the continued use of illegal mono-filament gears (banned nationally in 2010) contributing to depletion of fish stocks. The females present indicated that women could manage production, harvesting and marketing of farmed oysters; men could assist with construction of racks.

However, no concerns were expressed regarding over-exploitation of oyster stocks. This became a key topic for exploration during satellite community visits that were also poorly represented on the LMC. Generally the membership seemed frustrated with the lack of actionable outcomes from meetings to date.

Plates 1a-f: Clockwise from top left a&b: Project team members conducting focus group interviews with communities in the Sherbo MPA (Mr Will Leschen (UoS) to R), c. Dr Richard Quilliam (UoS) conducting oyster bacterial contaminants analysis, EJF office Bonthe, d-e. Mr James Green (Whitstable Oysters), Mr Amara Kalone (EFJ), Mr Richard Kapindi (IMBO), Dr. Richard Wadsworth (NJU), Nick Shell (UoS) conducting water and sediments analysis near Bonthe. f. Dr Francis Murray (UoS) and Dr Saliue Sankoh (IMBO), Ministry of Fisheries & Marine Resources Freetown.

3. Project Progress

On 7 November 2015 the WHO finally declared an end to the Ebola outbreak in Sierra Leone which had severely disrupted our planned year 1 and 2 activities (resulting in Darwin granting the project a 12 months no-cost project extension to 31 mar 2018). A joint mission of local and UK partners was immediately arranged from 16-24 Jan 2016 to conduct joint-planning and situation/ needs analyses and to further develop relationships, awareness-raising and 'social license' with local stakeholders. Building on previous contacts, meetings were held with the following stakeholders during the January mission (See Appendix 4 for further details):

Secondary

- Deputy Minister of Fisheries and Marine Resources, Freetown
- Staff of the 'Institutional Support for Fisheries Management in Sierra Leone' project (ISFMSL) at IMBO.
- Mr Layemin Joe Sandi, Mayor of Bonthe (met with Mayor and staff before and after field work to brief/ de-brief on mission findings)

Primary

- Survey of live oyster vending on 4 beaches & steamed oyster vending in 1 daily retail market of Freetown
- Meeting of the local management committee (LMC) of the Sherbro MPA - representing community management associations (CMA)
- Individual and focus groups meetings with female oyster gatherers and fishermen in 9 communities within the Sherbro MPA
- 1 sub-chief of a traditional Paramount Chieftaincy.

Although no Ebola cases were recorded in Bonthe or surrounding islands the outbreak clearly further isolated these already remote communities from both national and international (development) support. Project progress, mainly linked to the January joint-mission is summarised against logframe outputs below (and Annex 1). More detailed accounts and images of activity outputs are presented in Annexes 4 to 9.

3.1 Progress in carrying out project activities

Output 1

Activity1.1 Multi-stage sample design for selection of 6-8 intervention communities according to social and environmental criteria (e.g. harvesting mangrove oysters along salinity and primary productivity gradients)

In the absence of reliable sample frame data[2], community selection was based on purposive sampling along a salinity gradient along the Sherbro River from Yagoi and the main delta sea channel to its southern mouth at Mania. A total of 9 of 15 communities previously short-listed using this approach in 2015 were selected for further in-depth assessment during the current mission (Fig 1a and Table 1). Exclusions included communities (i) in areas of lower seasonal salinity upstream and oyster abundance on the Sherbro River; delineated by the occurrence of flood-irrigated rice cultivation on river banks (ii) nearer the delta mouth requiring extended journey times by boat from the project base in Bonthe (Fig 1).

[2] The first national census since 2004 was enumerated in Dec 2015; at time of writing only preliminary results were available: see Annex 9.

Table 1: Community names and locations (see Fig 1.)

SN	Village	Code	Location	GPS N	GPS W
1	Gbembeehun	GHN	Islet coast, creek mouth	7°37'9.56"N	12°30'11.11"W
2	Bomblake	BBK	Shero Island coast	7°34'35.60"N	12°29'54.10"W
3	Bontibai	BTB	Shero Island coastal creek	7°32'38.35"N	12°30'51.74"W
4	Gbongboma	GBM	Shero Island inland creek	7°31'21.80"N	12°31'50.81"W
5	Yankain	YKN	Islet coast	7°30'10.86"N	12°29'28.76"W
6	Keigbe	KGB	Islet coast	7°31'5.56"N	12°28'33.80"W
7	York	YRK	York Island river mouth	7°32'34.98"N	12°27'47.73"W
8	Momaya	MMY	Sherbo River	7°32'1.64"N	12°23'9.88"W
9	Kingjimi	KJM	Bonthe Town	7°32'5.37"N	12°30'15.99"W

'Satellite' fishing communities can be differentiated by (i) their distance to and primary means of access (land-connection or canoe) to Bonthe Municipality (Fig 4.2), the main MPA population/ service centre and market for freshly steamed oysters (ii) age and size of settlement; communities on smaller islets with no *in-situ* access to well water or agriculture tend to be smaller, more transient and dependent on harvesting living aquatic resources (Annex 4). The largest fishing communities (50 households or more) are located along the landward side of Sherbro Island, with many smaller communities (4-20 households) distributed between and (especially) in the mangrove interior west of Bonthe. For reasons of safety, women harvest oysters in more sheltered mangrove areas out with the main sea-channel.

Results highlight limitations of the sampling approach, development of which was constrained by the Ebola crisis and lack of appropriate secondary frame-data. An *ex-post* sample frame (Fig 4.2) based on supervised satellite image classification and field-survey, will be further refined through (i) estimation of community-size based on hut counts, (ii) cross-referencing the origins of steamed and smoked oyster vendors at retail and wholesale markets (through longitudinal surveys) (iii) results of the Dec 2015 national population and housing census when/ if data becomes available as suitable resolution[3]**.**

Table 2 lists 22 communities recorded selling smoked oysters (and clams) at the Yagoi weekly market during a single visit. Only 2 project communities are represented; three of our satellite communities closest to Bonthe (GHN, BTB and KJM) preferentially retail steamed oysters to consumers in Bonthe on a daily basis. One other nearby community (YKN) indirectly sends smoked oysters to Yagoi through female gatherer-assemblers in nearby Bonthe as well as selling teamed oysters there. Thus, Table 2 is more representative of the majority of remoter communities who must undertake secondary smoking to preserve their oysters for sale in mainland markets i.e. Yagoi or secondary markets in Gbambatok and Matru (Fig 3). The most distant communities, Cheppu at the west end of Sherbro Island are 78km by boat to Yagoi. Survey outcomes from our sample communities will be validated against a random selection of communities identified as supplying these markets, both directly and indirectly in future work-phases. Fig 4 shows how these sites and our 9 sample communities are positioned within the wider settlement context of the MPA.

Analysis of preliminary census data (Annex 9) shows the population of Bonthe District (3,468 km^2) has risen by 55% since 2004, to 200,730 in 2015 (in 1,011 villages and towns) and is projected to rise to over 318,000 by 2050 (Fig 2). Most growth has been in villages (Annex 9: Plate 9.2a&b), presumably linked to fishing opportunities with the population of Bonthe town remaining relatively static; population density now stands at 58 persons/ km^2 compared to a

[3] Provisional results indicate Sierra Leone's population has grown by 2.1 million persons (from 4,976,871 during the last census in 2004 to 7,075,241 in 2015). Females account for 50.9% of the population and the southern region (Inc. Bonthe District) is the least populous with 1,438,572 people. http://www.sierra-leone.org/Census/ssl_final_results.pdf - See Annex9

national average of 99. A heavily skewed gender balance with 94 males per 100 females in 2004 i.e. shortly after the civil war, has begun to rebalance with the ratio now standing at 98.

Sampling-designs for future bio-physical assessments (water quality, primary productivity and bacterial food-safety: Annexes 6 & 7) will also be integrated in this design and analysis stratified on key ecosystem and community livelihood characteristics in order to enhance the generalizability of findings and specificity of intervention recommendations.

Table 2: Locations of female vendors in the Sherbro MPA selling smoked oysters at Yagoi weekly market (Note: names in bold are project sample communities)

SN	Community	SN	Community
1	Barki	12	Mosembo
2	Bendu	13	Mossally
3	**Bomblake**	14	Msemea
4	Chako	15	Mutty
5	Cheppu	16	Porbatoke
6	Delkin	17	Sale
7	Gbanema	18	Seway
8	Gbangsie	19	Sulay
9	Mbokie	20	Suway
10	Molebeh	21	Tome
11	**Momaya**	22	Yele

(Note: Communities near the sea mouths harvest and smoke other more stenohaline shellfish species including clams to retail, often together with oysters. Data: Nick Schell)

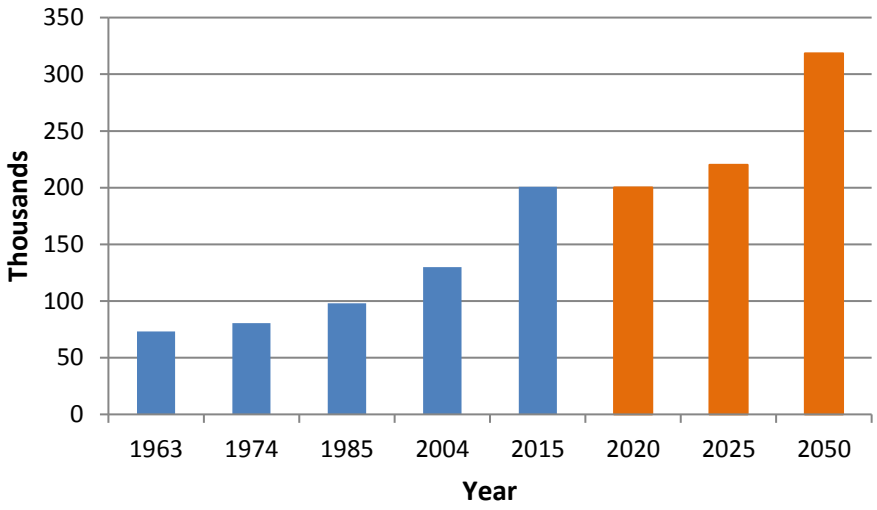


Fig 2: Bonthe District population trends 1963-2015 (in blue: Source: 2015 Housing & Population Census (preliminary) & extrapolated to 2050 (in orange: Source: extrapolated from a national UN -WPP 2015 Revision - See Annex 9)

Fig 3. Origins of vendors (green flags) marketing smoked oyster & clams at Yagoi weekly market (red flags also show secondary markets at Gbambatok & Matru: Map Nick Shell)

Fig 4. Sample frame of communities within the main mangrove areas of the Sherbro MPA based on supervised classification of Google Earth satellite images and field survey (red flags = project sample communities, yellow pins = other mangrove communities, ? = supervised classification only).

Future work required:

- Further supervised classification and ground-truthing of time-series satellite (Google Earth) images for improved understanding of oyster gathering effort and dependency in the wider Sherbro MPA and generalizability of in-depth research outcomes in project communities. Further integrated with marketing results (Activity 3.1) and census results when published).

Activity 1.2 Baseline livelihood surveys & selection of target-households:

Semi-structured focus group and individual key informant interviews: were conducted in each of the nine communities described above in order to assess:

- Community characteristics (demography, settlement pattern wealth profiles & indicators).
- Levels of dependency and effort (by gender, age, wealth, household and community) on oyster gathering activity (seasonally and historically) and linkage with other household livelihood activities (inc. fishing, mangrove harvesting, agriculture)
- Gender roles in seasonal production, processing and marketing
- *De jure* and *de facto* access rights (the former linked to over-lapping legal and traditional tribal property rights systems; the latter most closely linked to gender mobility differences and access to canoes)
- Linked resource dependency; especially re. impacts on mangroves linked to oyster harvesting practices and use for post-harvest processing (steaming and smoking)
- Market geography linked to processing options & demand-supply driven price trends
- Sanitation facilities and practices linked to human pathogen contaminant risk in oyster harvesting areas – linked to live-whole value-added marketing options
- Stakeholder attitudes towards enhanced oyster culture options

Main Findings: Survey results are described in Annex 4 and key points summarised below

- A typology of gathering communities was developed based on well-being indicators (roofing materials, canoe-ownership, secondary education levels), oyster resource access and market geography indicators.
- Households on smaller satellite communities on resource limited islets appear poorer and most dependent on oyster gathering, though they are also likely to be more transient.
- Oysters are currently managed as open access resources, predominantly by female gathers within a limited radius, typically within 2-3km of their homes.
- Most gathering is of single year-class inter-tidal oysters exposed on mangrove roots with most gathering occurring from Jan-Aug and peak months May-Jul linked to salinity conditions.
- Canoe access is the main *de-facto* access determinant of gathering effort. Though few women own their own canoes, tidal optima for gathering is highly complementary with alternating canoe use for male fishing activity. Women will share, borrow or lease boats from extended family members and neighbours.
- In more exposed locations females (gathering) are more likely to partner with male family members (paddling) also potentially extending their range.
- Although considered a female activity, some unemployed male youth in Bonthe were found to be exploiting remoter longer range gathering sites. *Further research is required to determine the significance of this trend.*
- Harvesting is either by selective removal of larger oysters (less damaging to mangrove roots) or indiscriminate cutting of entire roots. Indiscriminate cutting may be more common during the peak season.
- Women are almost entirely responsible for steaming, shucking and smoking oysters at their homes.
- Bulk commercial steam and smoke processing of oysters using mangrove wood as fuel typically follows 2-3 days of continuous harvesting, with one harvest around low tide per day and most activity around neap tides.
- Participation in a local management committee (LMC) with CMA oversight responsibility revealed some progress on canoe licencing and registration but frustration over lack of enforcement of a ban on mono-filament gill-nets. Oyster gathering communities within our sample were poorly represented. CMA focus is primarily on regulation of unsustainable fishing practices. *Further exploration is*

required of how CMAs can support mutually reinforcing co-management of oyster resources with effective participation of the primary female dependents.

Outputs:

- Validation and further refinement of conclusions from initial reconnaissance surveys.
- Transcripts of 14 semi-structured individual, key informant and focus group interviews.

Future work required:

- Longitudinal survey work in sample sites to assess seasonal oyster gathering and processing patterns, female and household dependency on the activity and the adverse contribution of oyster gathering and processing activity on mangrove health.
- Understanding whether oyster distribution patterns are predominantly driven by harvesting or abiotic and biotic factors is highly challenging under field conditions. One approach will be to classify and map harvesting effort and associated mangrove impacts against a community typology based on household and canoe numbers (and estimates of active gatherers), gendered mobility conditions and market geography (other research needs highlighted in italics above).

Activity 1.3 Development of oyster artificial-substrate culture & depuration options.

A trial oyster culture rack has been established to the east of Bonthe Town according to the specification of Mr James Green an experienced UK commercial oyster cultivator (Annex 8). An 'appropriate technology' ethos underpinned the design, one early raft-option (see last annual report) being over-reliant on what are by local standards costly imported materials likely to be scavenged for alternative uses. The rack option was designed around locally available materials; mangrove wood, rope/ string from the local market and waste oyster shells spaced at intervals on suspended strings as spat collectors (cultch). Spat collectors were hung in September and October 2015. The design is also simple to construct and repair. Cultch was also laid on a nearby inter-tidal mud bank in a second trial. Yield outcomes to be assessed in June 2016 will contribute to a cost-benefit analysis.

As conditions on the rack approximate inter-tidal conditions on mangrove roots, the trial will also allow us to assess oyster recruitment and growth performance in conjunction with water quality assessments at an adjacent sample site, discussed below:

Water Quality: Five parameters salinity (Secchi depth, total dissolved solids (TDS), temperature and pH) were measured by local partner Amara Kalone (EJF) from Bonthe Town pier at high and low tide on a daily basis from Nov 2015 (Annex 7).

Trends are highly correlated with seasonal rainfall patterns and to a lesser extent tidal states. Salinity ranged from a brackish 5ppt in Nov to a full oceanic 35ppt in April. Water temperature ranged from 25 to 34 ^{o}C over the same period and pH from 7.4 to 8.4. Secchi readings, which give a crude indicator of primary productivity, rose during the rainy season (readings were temporarily interrupted thereafter). How these factors interact to influence oyster growth, reproduction and survival requires further research. For example although survival is clearly correlated with salinity conditions in time and space, this may also influence availability and quality of the oysters main phytoplankton food source[4]. Although mangrove (rock) oysters also appear to thrive in full oceanic salinity, reproduction and spat-fall, triggered by the onset of rains may be more restricted to lower salinity conditions within the delta.

Depuration options and microbial contaminants analysis: Public health risks associated with consumption of filter-feeding shellfish are widely recognised (for which reason globally,

[4] Bainbridge (1963) describes phytoplankton species composition in gut contents of the phytophagous clupeid *E. dorsalis* with a similar seasonal diet and occurrence as mangrove oysters. Bainbridge, V. 1963 The food, feeding habits and distribution of the Bonga *Ethmalosa Dorsalis* Oceanic Lab. Edinburgh. http://icesjms.oxfordjournals.org/content/28/2/270.full.pdf

currently only 13 countries are licenced to import fresh shellfish into the EU). Risks include contamination with human bacterial and viral pathogens, algal toxins and heavy metals. Harmful algal blooms (HABs) are often linked to availability of nitrates and (especially) phosphates from anthropogenic sources e.g. agricultural run-off, or naturally occurring e.g. in coastal upwelling's. Although HABs have been recorded in S. Africa no examples of their occurrence were found in tropical W. Africa (further research still required). Risk of inorganic pollution also appears low (the Sierra Rutile mining concession has a barge trans-shipment dock at Nitti on the 'Northern Channel': Fig 1) whilst there is little or no industry on the Sherbro River). The greatest risk therefore appears associated with organic faecal pollutants from the micro-dispersed nature of settlement in the Sherbro MPA (Fig 3.). Using portable culture equipment, tissue samples from juvenile oysters collected from the mud and rack trials (see above) and 3 other Sherbro estuary sites were analysed for *E. coli* as an indicator of faecal contamination (Dr Richard Quilliam, UoS, Annex 6). Preliminary results indicate that some (mangrove) oyster harvesting areas are contaminated by extremely high levels of faecal pollution; oysters could therefore be contaminated by human pathogens such as rotavirus, *Vibrio* spp., norovirus, *Cryptosporidium* & *Giardia.* Some concentrations were so high that shellfish harvesting for human consumption would be prohibited as 'beyond-depuration' under an EU risk classification system. This clearly presents a significant challenge for value-added live oyster sales on Freetown Beaches, though it is important to stress that depuration efficiency may also be very different compared to temperate conditions.

Outputs

- Oyster culture trials and longitudinal water quality recording established for improved understand of reproduction, growth and survival and culture/ wild harvest cost-benefit.
- Preliminary assessment of human pathogen risk in live oyster tissue from faecal contamination.

Future work required:

- Preliminary bacteriology findings will be validated in a more systematic, replicated survey during the peak harvest season (June 2016). This will also compare Sherbro samples with locally harvested oysters currently supplying tourist beaches to the south of Freetown.
- Proximate analysis will be conducted on samples of steamed and smoked oysters to assess potential impacts of primary and secondary processing on nutritional quality.
- Depuration options (including simple solar methods) will be evaluated on oysters across a spatial range of faecal contamination risk (determined in the above survey).
- Residual currents will be measured at strategic locations within the estuary using GPS mapping of boat launched drogues around high and low tides. The resulting tidal ellipse plots will contribute to our understanding of dispersal patterns for (i) faecal contaminants, (ii) oyster-spat and (iii) nutrients underpinning primary productivity and oyster carrying capacity. Linked to this, we will also attempt to measure oyster phytoplankton clearance rates (this is likely to be challenging under field conditions).

Output 2

Activity 2.1 Procurement and adaptation of solar powered freezers

Survey findings highlight the challenges for reliable cold-chain operation in this setting. Annex 4 documents a number of failed or struggling cold chain interventions at different scales in the research area. The examples highlight the need for adequate maintenance training and support and spares-inventories as integral parts of any sustainable initiative. Drs Sankoh (IMBO) and Wadsworth (NJU) had previously reviewed solar powered freezer technological options appropriate to field conditions in Sierra Leone and obtained quotes for a series of different product options in country.

Fixed installation of freezers in Bonthe could also increase the range and capacity of outlying communities around to sell value-added steamed oysters (see Activity 3.1) to the retail market

in Bonthe[5]. This would bring benefits both for local food security and reduction of pressure on mangroves through reduction of secondary smoke-processing requirements.

Future work required:

- Next steps will be contingent on positioning cold-chain needs within the evolving value-addition strategies described above and in Section 3.4. Evaluation of options will incorporate cost-benefit analysis, a 'do-no-harm' ethos linked to primary food security and complementarities with alternative 'non cold-chain' dependent preservation strategies e.g. brine pasteurisation, solar drying, vacuum-packing, use of preservative ingredients in ready-meals.

Output 3

Activity 3.1 Analysis of markets for oyster-based products and their substitutes

In January 2016 the research team jointly conducted further marketing interviews with female vendors of locally harvested steamed oysters in Freetown (Pamuronkoh market in Calaba Town and a vendor of fresh oysters on a tourist beach in Freetown. Female oyster harvesters in each of the nine communities in Bonthe were questioned about their marketing and associated processing practices (Annex 4).

- The choice between primary processing (steaming) and secondary (smoking) processing is mainly contingent on market geography. Given ability to process and access retail markets on the same day the clear preference is to steam only.
- Remoter communities must stockpile smoke-preserved oysters to sell at static weekly mainland markets with good river/sea road connections. Preserved (smoked) oysters are sold at weekly markets. Preliminary findings indicate negligible wholesale discounting indicative of strong local demand relative to supply (further monitoring over the peak harvesting season (May-Jul) is required).
- The short 'shelf-life' and high demand for fresh oysters (and other fresh sea foods) means that most product is retailed ('hawked') by mobile vendors along roadsides and door to-door within 24hrs of processing.
- These observations and a margin analysis of smoking and steaming losses (Annex 5) confirm that in local markets (i.e. Bonthe District), and in the absence of a functioning cold-chain smoking is primarily a preservation rather than a value-addition strategy.
- Both steamed and smoked oysters are sold volumetrically, by the heaped 'cup' or tin (around 400mls/cup); steamed oysters retailed for Le 1,000/cup in Bonthe and Le 3,000 in Freetown (all locally sourced in each case) and smoked oysters for Le 2,000-2,500 in Yagoi and up to Le 6,000 in Freetown.
- Little evidence of any supply chain specialisation was observed in Bonthe District; most females are responsible for their own gathering, processing and marketing. Further mapping of regional wholesale supply chain components for smoked oysters is required i.e. beyond the two primary mainland weekly markets.

Future Work Required:

- Longitudinal survey of smoked oyster sales in weekly mainland markets (especially Yagoi which appears to be the most accessible primary outlet). To include collection of volumes, prices, vendor origins and numbers, product mix, retail-wholesale patterns and discounting, value-added marketing (e.g. fried oysters and bread), consumer characteristics and origins.
- This will also permit an assessment of micro-dispersed seasonal harvesting effort over much of the MPA. Though more challenging due to the mobile nature of vending, further attempts will also be made to quantify steamed oyster marketing in Bonthe.

[5] Imported frozen marine clupeids are sold by female 'hawkers' in Freetown, defrosting as they go.

Output 4

Activity 4.1 Establishment of project web-site

The project website (http://www.stir.ac.uk/aquaculture-mangrove-oyster/) continues to be developed and populated with content as the project proceeds. The in-depth progress summary embodied in this report will be posted here and a link circulated on the 'SARNISSA' African Aquaculture network website (www.**sarnissa**.org/) coordinated by Mr William Leschen (also responsible for our project website). Social media (Facebook and Twitter) sites will also be developed now that interim results are available and monitored using Google analytics etc.

3.2 Progress towards project outputs

A review of our initial problem-framing following exploratory field research indicates that there is likely to be little economic incentive for oyster aquaculture (Output 1a) under current resource conditions in the Sherbro MPA (Section 3.4). This may change if resource extraction pressure on oysters and (especially) mangroves increases due to increasing population growth (extraction methods appear less likely to intensify) and (if) more males move to oyster gathering as fish stocks decline.

Whilst further effort will be directed at evaluating these trends, we propose to adopt a more explicit supply-chain development focus looking for opportunities to redeploy resources earmarked for this output around our existing post-harvest intervention strategies i.e. depuration, cold-chain logistics and value-added sales of fresh oysters to tourists and ready meals. Options in these areas are elaborated in Sections 3.1, 3.4 and Annex 4, and will be the subject of on-going stakeholder consultations. Projects around the most promising interventions will be offered to two UoS MSc students partnered with local counterparts in 2017.

3.3 Progress towards the project Outcome

No project interventions are underway as yet. We propose to revise the existing project outcome as follows consistent with the arguments presented in Section 3.4:

From: *'Incomes of oyster-fisherwomen in at least 40 households of the Sherbro MPA increased by 45% pa and abundance/ mean-size of adjacent wild-oyster populations increased by at-least 18% over base-line levels'*

To: '*Incomes of oyster-fisherwomen in at least 40 households of the Sherbro MPA increased by 20% pa and consumption of mangrove wood for primary and secondary oyster processing decreased by at-least 10% over base-line levels'.*

3.4 Monitoring of assumptions

In ecological 'r/K' selection theory (MacArthur and Wilson, 1967, Ito 1980, Parry 1981[6]) 'r' selected species mature quickly, have short generation and gestation times, are highly fecund and have the ability to disperse offspring widely with little parental investment. This is a common strategy in unstable or unpredictable environments where ability to reproduce quickly is more critical than investment in the quality of off-spring. Thus 'r-selected' species are natural opportunists, contrasting with k-selected 'equilibrium' species more evolved to compete with other species. Such adaptations are or of less value in environments such as estuaries with their highly variable spatial and temporal salinity profiles. Consistent with this view oysters and other bivalves including cockles and clams can adjust spat production and generation times in response to environmental pressure. Known as 'mangrove', 'rock' or 'mud' oysters the euryhaline *Crasostrea tulipa* is plastic enough to phenotypically adapt to such estuarine variability. In the

[6] Ito, Y. 1980 Comparative Ecology, Cambridge University Press. NY. Pp 38-46
MacArthur, R.H., Wilson E.O. 1967 The theory of island biogeography. Princeton University Press.
Parry, G.D. 1981 The meanings of r- and K-selection. Oecologia 48, 2, 260-264

Sherbro estuary, oysters are mainly harvested from mangrove roots where their inter-tidal position also results in high periodic natural mortality linked to low surface water salinity during the rainy season. Thus most harvesting pressure is on single year-class cohorts capable of rapid growth under nutrient rich, warm-water conditions. Sub-tidal mud (and rock) oysters appear more resistant to the dominant method of hand gathering oysters exposed during low tides. Furthermore due to gendered mobility restrictions (Annex 4), most oyster gathering effort is concentrated within a short radius of fishing settlements. Thus, despite increasing artisanal gathering effort, oyster populations on available substrates still appear to be rebound on an annual basis due to this combination of residual breeding pools, high fecundity and rapid growth. Mangrove oysters reach a minimum harvestable size in as little as 4-5 months post spat-fall. These findings have the following implications for planned project interventions:

- The fundamental precondition of natural resource scarcity for investment in aquaculture is not currently met. Thus even if the bio-technical potential of oyster culture can be demonstrated there is likely to be little economic incentive for its adoption under the prevailing resource, market and regulatory conditions described below and in Annex 4 i.e. unless culture conditions can confer unique value-added attributes. On-going pilot trials of suspended and mud-bank culture options will provide a more conclusive economic assessment: Annex 8[7]).
- Rather, the most serious imminent threat to future well-being of the oyster fishery is pressure on mangrove tree populations, directly through imprudent & unsustainable oyster harvesting methods (especially root cutting) and extraction of mangrove wood as a fuel for domestic cooking, steaming and/ or smoking oysters (and fish) and other secondary uses e.g. construction. Levels of indiscriminate root cutting appear much higher where gathering territories overlap and competition is more intense e.g. closer to Bonthe or York Towns.
- Thus protecting mangroves will ensure sustainability of the more resilient oyster fishery and other aquatic biodiversity. Improved understanding is needed of the relative importance of the aforementioned pressures, seasonal interactions and underlying behavioural motivations of resource dependents. Mitigation strategies should be one element of a more integrated value-chain approach.
- Undisturbed 'mud oyster' beds refractory to hand-gathering in deep water sediments indicate mud oysters may contribute a resilient multi-year class *C. tulipa* breeding pool (Annex 4, Section VIII). Consistent with CBD objectives; before recommending any conservation strategy based on such dependence or enhancement strategies based on live-oyster movements further genotypic characterisation of the three different *C. tulipa* 'morphotypes' is required (i.e. growing on mangrove, mud and rock substrates). This can be achieved using double-digest restriction site associated DNA (dd-RAD) marker analysis. Populations may, or may not also be geographically restricted contingent on the natural ability of spat to migrate on oceanic currents. Therefore flesh samples of the three morphotypes should also be collected from Sierra Leone's other major mangrove estuaries; the Sierra Leone River and an intermediate coastal site near putative tourist beach-markets, respectively to the north and south of Freetown.
- Oysters are currently exploited as an open-access resource by micro-dispersed communities with little or no effective external regulation. They are also an important primary source of seasonal food security for these communities, many of whom lack alternative agricultural food-production options.
- Thus under free-market conditions, interventions that support up-scaling of commoditised steamed and smoked oyster transfers to regional and national markets, risk escalating unsustainable mangrove extraction and damage and potentially negative food-security impacts on a growing population of vulnerable local resource dependents[8].

[7] A grey-literature report by Kamara and McNeil describes results of trials using a range of oyster culture methods in estuaries around Freetown in 1976. Although the research was successful in elucidating bio-technical constraints, there was no consideration of socio-economic development and marketing contexts and no record of adoption. The report has been scanned and uploaded on the project website.

[8] Sierra Leone ranked 4th in the world on IFPRI's Global Hunger Index (GHI) in 2015; 4 indicators are: calorific intake, child wasting, stunting & mortality https://www.ifpri.org/topic/global-hunger-index

- Primary project interventions should therefore be on post-harvest supply-chain up-grading with emphasis on niche value-addition. The project is evaluating two such options; sale of (i) live fresh oysters, to tourists and expatriates visiting beaches around Freetown (Fig 4.4) (iii) steamed and or smoked oysters as ingredients of ready-meals through beach-bars, cold chain retail outlets in Freetown and other regional centres.
- Future research is needed to improve understanding of and promotion of market potential for such value-added goods. Any deployment of solar cold-chain infrastructure must also be compatible with these objectives.
- At the production level, mangrove damage mitigation steps will include awareness-raising around poor oyster harvesting practice, more fuel efficient processing.
- Given the economic limitations described above low-cost fishery enhancement options may represent a more realistic low input-output transitional aquaculture step. Oyster-shell waste-middens are an especially common sight in remoter satellite villages where transport costs make re-use as a permanent construction material economically prohibitive. A trial is underway to assess their effectiveness as spawning 'cultch' on inter-tidal mud-flats (Annex 8 and Plate 4.4f).
- Strategically located and timed no-take zones might augment spat-fall in depleted areas, though enforcement would be a challenge. Knowledge of residual currents is first required to understand natural planktonic dispersal patterns.
- Efforts will be made to engage and involve MPA-CMAs in these activities.

3.5 Impact: achievement of positive impact on biodiversity and poverty alleviation

The project is nearing the end of its exploratory phase, thus it is still too early to demonstrate biodiversity and poverty impacts. However, the improved understanding of critical risks and assumptions (Section 3.4) gained during this early effort provides the basis for refinement of project objectives and activities consistent with more achievable and sustainable development outcomes.

4. Project support to the Conventions (CBD, CMS and/or CITES)

Project objectives are also highly consistent with national CBD objectives underpinning establishment of the Sherbro MPA. No contact has been made with the local CBD focal point as yet; this is being prioritised by local PI Dr. Sankoh and will be an agenda item on future joint-missions. The project aims and progress to date and summarised above are consistent with the 3 main Conventions on Biological Diversity goals as follows:

1. **Conservation of biological diversity**: In the short to medium term and under prevailing environmental, market and artisanal gathering practices; oyster populations appear relatively resilient to over-exploitation. The project will focus greater attention on the negative impacts of gathering and processing practices on the health of mangrove assemblages which underpins wider ecosystem health (Section 3.4).
2. **Sustainable use of its components:** The economic rationale for investment in aquaculture appears questionable under prevailing resource conditions (further assessment is underway). The proposed shift of emphasis toward post-harvest supply chain interventions (Section 3.4, Annex 4) especially value-added product options, will also be designed to limit extraction pressure and secondary impacts on mangroves.
3. **Fair and equitable sharing of benefits arising from genetic resources**: exploratory analysis (Annex 4) has identified the most resource-poor dependents on the oyster fishery in remoter satellite communities lacking land-connections to Bonthe. These same reasons and their greater population transience make such communities a challenging intervention target. Risks of centralising post-harvest options (in Bonthe for

example) are well recognised and attempts will be made to mitigate them learning from other local development projects. Nevertheless poverty levels are universally high and interventions may be merited even if the poorest of the poor are difficult to reach. Any interventions must still consider food-security implications for these most vulnerable and a 'do-no harm' ethos has also been described above.

5. Project support to poverty alleviation

Although too early to demonstrate impact, the project aims to achieve direct impacts on livelihoods through value-added production and supply chain interventions (described above). Female oyster gatherers in and around Bonthe Town and their households are the direct target beneficiaries. Interventions will also be designed to limit extraction pressure on mangrove populations bringing indirect benefits to a wider range of resource dependents.

6. Project support to Gender equity issues

The project is highly gender focussed with female oysters gatherers (and their households) being the primary target beneficiaries. Preliminary research has increased understanding of female access rights, both formal and informal to oyster resources and markets for steamed and smoked product forms. As oysters in the Sherbro MPA essentially remain an open-access resource, female access is highly dependent on mobility characteristics linked to canoe ownership and sharing arrangements with males, geographic safety factors and competition for oyster beds in more populous areas. Although females are responsible for most gathering and almost all processing and marketing (with little evidence of supply-chain specialisation) early findings suggest male participation and competition may increase as fishing yields decline.

7. Monitoring and evaluation

M&E planning will be further developed consistent with the refined intervention-foci elaborated in Section 3.4. Following several exploratory missions we are now commissioning longitudinal surveys to understand seasonal variability in the dependency of gathering communities/ households on oyster (& mangrove) harvesting and marketing. Findings will also constitute a baseline for monitoring project interventions.

8. Lessons learnt

Even by developing country standards, the research area is a particularly poor and remote area. Even in Bonthe Town access to electricity and all but basic supplies is highly limited. Thus extremely careful contingency planning is required for any 'kit-intensive' activities. For example oyster bacteriology work (Annex 6) was delayed for two days due to contamination of a vessel used to transport distilled water from Freetown (IMBO).

Learning around development failures and best-practice was gained from other established development organisations active in and around Bonthe. These lessons are contributing to refinement of our own intervention strategy (Annexe 4) e.g. challenges around cold-chain maintenance and repair and centralisation of cooperative production interventions.

9. Actions taken in response to previous reviews

Steps taken to address actions recommended by the reviewer of last year's annual report are as follows:

1 Review M&E plan to ensure indicators are achievable and ensure that all indicators and targets are achievable given the likely change in focus of beneficiaries and stakeholders on the ground post Ebola.
    - See Section 3.4 regarding proposed steps to deal with variances in risks and assumptions.

2 Demonstrate how the project will effectively communicate with beneficiaries, given low literacy levels in some project sites.
    - The aims and progress of the 'Sherbro Oyster Project' will be presented in a weekly local radio (Radio Bontico) public service hour. Radio and 3G SMS appear to be the most reliable means of reaching outlying stakeholders (Annex 4). With support of James Green (Whitstable Oysters), local government & radio.
    - We have started consultation and planning for a 'Bonthe (or Sherbro) Oyster Festival' in June 2017. In addition to culture events, activities will include judging of value-added oyster recipes, branding and promotion and show-casing of value-addition options (e.g. vacuum packing, solar cold-chain etc.).

3 Ensure the trade aspect of the project is considered in the M&E review. Given that the market is likely to change as a result of the Ebola outbreak, the project should not become over ambitious.
    - The project is highly value-chain orientated. Further analysis was a key focus of the January joint mission based on which intervention refinements are proposed in Section 3.4. On-going analysis has been constrained by lack of relevant local capacity (tragically our local marketing specialist, Ms Zainab Sankoh who led our initial surveys, summarised in the first annual report passed-away during the Ebola crisis). A UoS MSc student will collaborate of longitudinal market analysis in Bonthe District during field work planned for May to June 2016.

4 Define 'low-income' women and explain targeting criteria
    - Considerable effort has been directed toward sample-frame refinement (see Activity 1.1 above) and further livelihoods analysis and validation during the current mission. Communities and households have been differentiated according to fisheries and female oyster gathering dependence based on market geography, resource endowments and access, in turn heavily contingent on canoe ownership and sharing arrangements. Household level well-being indicators have also been defined in Annex 4. Further resolution of intra-household poverty characteristics is needed e.g. linked to polygamous marital arrangements i.e. appearing to necessitate greater levels of individual income autonomy (polygamy is also predisposed by a still significant gender imbalance a legacy of the civil war (Annex 9).

10. Other comments on progress not covered elsewhere

Project design is being refined consistent with the revised assumption and risk assessment in Section 3.4. Sample-design/ frame improvements (Section 3.1; Activity 1.1) will also improve specificity and generalizability of project recommendation outcomes.

One well-established locally embedded Development NGO 'Green Scenery' (www.**greenscenery**.org/) was found to be particularly active in the research area (Annex 4). Further engagement will be sought as part of our exit-strategy; with a view to understanding how project findings might be incorporated within the NGO's integrated rural development programming (IRDP).

11. Sustainability and legacy

Regrettably a planned stakeholder inception meeting was not possible due to the Ebola crisis. Activities during the January mission have started to fill this gap (including meetings with

national and local governance bodies), but further promotional effort is required. Summary findings synthesised from this and following reports will be one means of increased outreach locally (via short project news briefs) and internationally (via the project website). Planning for a Bonthe Oyster Festival 2017 is also underway with participation of local government and radio (Section 3.1).

12. Darwin Identity

The project will be branded as the 'Bonthe Oyster Project' (or Sherbro tbc, & associated logo to be developed) as part of our marketing promotion strategy (Sections 3.1 & 11). The Darwin logo will be embedded in this branding and our social media outreach strategy (Section 3.1; Output 4).

13. Project Expenditure

Table 1 Project expenditure during the reporting period (1 April 2015 – 31 March 2016)

Project spend (indicative) since last annual report	2015/16 Grant (£)	2015/16 Total Darwin Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)	0	-231.81	-	Carried 2014/15
Consultancy costs	12,449.46	12,449.46	0	
Overhead Costs				
Travel and subsistence	2,200	2,062.66	6.24	
Operating Costs	1,800	1,584.49	12	See below
Capital items (see below)	5,927.54	0	100	See below
Others (see below)				
TOTAL	**£22,422**	**£15,864.80**	**29.3%**	

The variance of 24.1% with the budgeted figure (a 19.3% underspend above the 10% threshold) is due to extended implementation delays caused by the Ebola Crisis. This pushed most field activity during this year into the last quarter of the reporting period, and planned capital expenditure (100% variance) on interventions into 2015/16 (to be discussed with Darwin).

14. Outstanding achievements of your project during the reporting period

I agree for the Darwin Secretariat to publish the content of this section:

Although planned development interventions are still to be initiated, the project's exploratory phase provides useful lessons around inter-disciplinary problem-framing for sustainable development in a data-deficient context. A short article will be drafted for the Darwin Newsletter summarising these findings.

Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2014-2015

Project summary	Measurable Indicators	Progress and Achievements April 2014 - March 2015	Actions required/planned for next period
Impact: *Environmentally sustainable and pro-poor livelihood opportunities created in Sierra Leone through enablement of community-managed, mangrove-based oyster culture systems with value-added marketing attributes**.*** Proposed change (see Sections 3.3 and 3.4) *Environmentally sustainable and pro-poor livelihood opportunities created in Sierra Leone through enhanced processing and value-added marketing of mangrove oysters.*		Results of a scoping visit (Jan 16) indicate that oysters populations in the Sherbro delta appear more resilient to artisanal gathering than earlier thought. Rather the main biodiversity concern appears linked to impacts of imprudent harvesting and processing practices (steaming and smoking of oysters & fish catches) on the health of mangrove populations. Naturally high recruitment and growth of single-year class cohorts on mangrove roots means even aquaculture interventions are unlikely to be economically viable under current circumstances.	Longitudinal community and market surveys are being developed to better characterise oyster gathering & effort, livelihood dependency and environmental impacts. Project focus on post-harvest value-addition strategies, depuration, cold-chain logistics etc. will be expanded consistent with the reduced focus on aquaculture.
Outcome: Incomes of oyster-fisherwomen in at least 40 households of the Sherbro MPA increased by 45% pa and abundance/ mean-size of adjacent wild-oyster populations increased by at-least 18% over base-line levels. Proposed change (see Sections 3.3 and 3.4) *Incomes of oyster-fisherwomen in at least 40 households of the Sherbro MPA increased by 20% pa and consumption of mangroves for primary and secondary oyster*	Indicator 1. Annual income of oyster-fisherwomen increased by at least 45% above baseline levels through oyster culture Indicator 2. Contribution of wild-oyster culture to annual income of target-beneficiaries decreased by 50% during first culture cycle and 100% by the second cycle Indicator 3. Adjacent abundance and mean shell-size of wild-oyster populations increased by 18% (along with stable or increased cover of associated mangrove assemblages)	Indicators to be reframed consistent with the proposed impact and outcome level revisions. The new, more supply chain orientated project outcome will also see greater focus on linkage/ design of interventions to reduce mangrove extraction pressure. This to be the subject of a formal project change request.	9 of 16 shortlisted communities selected for in-depth focus representative of a range of oyster production, marketing and dependency conditions across the Sherbro MPA.

processing decreased by at-least 10% over base-line levels.			
Output 1. Sustainable production and collective management systems (WP2)	Indicator 1. Technical and economic efficiency of alternative culture systems for at least two mangrove-oyster species (annual yield > 20kg/m2 substrate area) Indicator 2. Spatial mapping and field surveys of wild oyster and mangrove assemblage abundance/ diversity indicating specified improvement above baseline levels Indicator 3. LMC and/ or community area-management and collective production activity agreements formalised and documented)	Indicators to be reframed consistent with the proposed impact and outcome level revisions (see above).	
Activity 1.1. Multi-stage sample-design for selection of 6-8 intervention-communities according to social & environmental criteria (e.g. harvesting mangrove oysters along salinity and primary-productivity gradients).		*Ex-post* sample frame developed based on supervised classification of satellite images (Google Earth) and marketing surveys. This has improved understanding of the representativeness of selected communities to the wider MPA.	
Activity 1.2. Environmental, rapid rural appraisal (RRA) and household livelihood surveys for selection of target-households and establishment of intervention baselines.		Exploratory survey work has characterised key interacting resource use threats to mangrove help. Further understanding to gained through systematic longitudinal survey of households in project communities.	
Activity 1.3. Development of initial oyster artificial-substrate based culture-technology and depuration options.		Pilot suspended rack and bottom culture systems installed in Bonthe for cost-benefit and growth/ survival assessments.	
Activity 1.4. LMC and/or community agreements brokered on collective-production activities and extractive-restrictions in adjacent mangrove oyster-nursery areas.		Meetings held with the Bonthe Muncipal Council and the Local Management Committee of the Sherbro MPA in Bonthe. Next substantive collaboration steps contingent on refinement of interventions and effective representation of target beneficiaries in satellite fishing communities.	
Activity 1.5. Initial training of 40 wild-oyster harvesters on oyster-spat collection and culture techniques		To be reframed consistent with the proposed impact and outcome level revisions (see above).	
Activity 1.6. Adaptation of artificial-substrate based oyster culture techniques (e.g. post, tray, raft, long-line) through two full iterative phases of action research.		To be reframed consistent with the proposed impact and outcome level revisions (see above).	

Output 2. Supply chain enhancement (WP3)	Indicator 1: Solar-freezer systems procured, adapted, maintained and operated by target-community-groups Indicator 2: Supply-chain systems operate effectively under seasonal conditions most associated with demand for value-added oyster products	Technologies (and costs) appropriate to ground conditions in Sierra Leone reviewed in year 1. Key operation and maintenance challenges learned from other development projects in Bonthe will help shape our intervention design.
Activity 2.1. Procurement and adaptation of solar powered freezers for transport of oysters from the Sherbro MPA to free town under variable seasonal conditions		Notes produced on prices and operation of solar freezers in Sierra Leone (Annual Report No1). Procurement pending further market and needs analysis. Fixed installations in Bonthe could provide an opportunity for local value-added marketing of steamed (v smoked oysters) with further food security and mangrove extraction off-setting benefits. Focus to be expanded to other 'appropriate technology' means of extending product life e.g. brine pasteurisation, solar drying, preservative ingredients in ready meals, vacuum packing.
Activity 2.2. Training staff/ beneficiaries in operation and maintenance of freezer plant		No progress to date
Activity 2.3. Seasonal testing of freezer systems & cold-chain implementation		No progress to date
Output 3. Market promotion and value-addition (WP 4)	Indicator 1: Sales inventories of producer-groups and buyers increased Freetown compared to baseline levels Indicator 2: Project and media reports of outcomes of the oyster recipe competitions documented	No progress to date
Activity 3.1. Analysis of markets for premium oyster-based products (and their substitutes) in Freetown and other regional markets		Further market survey work in Freetown and Bonthe District and a processing loss margin analysis confirms steamed oysters to be more profitable than smoked oysters in local retail markets but 24hr' shelf-life' constrains market access (further seasonal survey work required).
Activity 3.2. Staging of regional and national oyster recipe competitions		Planning underway to host a Bonthe/ Sherbro Oyster Festival in June 2017 – to stage the regional competition and promote locally branded value-added products.
Activity 3.3. Development and testing of value-added oyster ready meals with super-markets, restaurants and beach-bars in Freetown		Potential local filler ingredients with low primary food-security opportunity cost and preservative qualities identified during January survey (further assessment required).

Activity 3.4. Evaluation of wider international demand & market-based certification potentials & statutory recommendations for MPA policy-makers		No progress to date
Output 4. Training and dissemination	Indicator 1: Documentation of curricula and attendance at 2 Farmer Field Schools (FFS) and final project workshop Indicator 2: Relevant decision-makers as identified by stakeholder analysis rate usefulness of policy briefs on a five point scale. Indicator 3: At least 2 peer-reviewed primary research papers made available in open access format.	Findings summarised in this report will contribute to a peer-reviewed co-authored paper around mixed-methods problem-framing for sustainable development.
Activity 4.1. Establishment of project web-site (with links to partner web-sites and the regional SARNISSA research network		Website operational and being updated http://www.stir.ac.uk/aquaculture-mangrove-oyster/
Activity 4.2. Extension to neighbouring communities through 2 'Farmer Field-Schools' (in each case for separate female and male groups).		No progress to date
Activity 4.3. Regional best-practice/ policy workshop (inviting participants from comparable initiatives in Benin, The Gambia, local EJF project, MPA representatives)		No progress to date
Activity 4.4. Project reports & publications (x2) on environmental social and economic sustainability outcomes in international peer-reviewed journals		See output level comment above

Annex 2: Project's full current logframe

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Goal. Effective contribution in support of the implementation of the objectives of the Convention on Biological Diversity (CBD), the Convention on Trade in Endangered Species (CITES), and the Convention on the Conservation of Migratory Species (CMS), as well as related targets set by countries rich in biodiversity but constrained in resources.			
Outcome. Incomes of oyster-fisherwomen in at least 40 households of the Sherbro MPA increased by 45% pa and abundance/ mean-size of adjacent wild-oyster populations increased by at-least 18% over base-line levels.	Indicator 1. Annual income of oyster-fisherwomen increased by at least 45% above baseline levels through oyster culture Indicator 2. Contribution of wild-oyster culture to annual income of target-beneficiaries decreased by 50% during first culture cycle and 100% by the second cycle Indicator 3. Adjacent abundance and mean shell-size of wild-oyster populations increased by 18% (along with stable or increased cover of associated mangrove assemblages)	Project reports & peer reviewed publications (at least 2) Local media coverage of project initiatives	Containment of the Ebola outbreak will allow local and international project partners full access to project field sites. Sustained & sufficient demand will be exist for value-added ready-meals by consumers in Freetown
Outputs: **1. Sustainable production and collective management systems (WP2)**	1a. Technical and economic efficiency of alternative culture systems for at least two mangrove-oyster species (annual yield > 20kg/m2 substrate area) 1b. Spatial mapping and field surveys of wild oyster and mangrove assemblage abundance/ diversity indicating specified improvement above baseline levels 1.c LMC and/ or community area-management and collective	1a.Technical efficiency report 1b. Biodiversity report (inc. site maps) 1c. Livelihoods report and documentation of management agreements	Enhanced oyster culture and negotiated formal/ informal access rights can reduce fishing effort on wild oysters around culture areas.

	production activity agreements formalised and documented		
2. Supply chain enhancement (WP3)	2a Solar-freezer systems procured, adapted, maintained and operated by target-community-groups 2b Supply-chain systems operate effectively under seasonal conditions most associated with demand for value-added oyster products	2a. Procurement inventory and training/ operation reports 2b. Supply-chain enhancement 'action-research' report(s)	
3. Market promotion and value-addition (WP 4)	3a Sales inventories of producer-groups and buyers increased in Freetown compared to baseline levels 3b Project and media reports of outcomes of the oyster recipe competitions documented	3a. Market report inc. testimonials of producer groups, supermarket and food service-sector stakeholders 3b. Coverage by local media and project website	Market demand for value-added oyster products is not significantly depressed by the Ebola outbreak over the project duration.
4. Training and dissemination (WP1)	4a. Documentation of curricula and attendance at 2 Farmer Field Schools (FFS) and final project workshop 4b. Relevant decision-makers as identified by stakeholder analysis rate usefulness of policy briefs on a five point scale. 4c. At least 2 peer-reviewed primary research papers made available in open access format.	4a. Training manual, FFS and workshop reports. 4b. Policy brief evaluation report 4c. Papers submitted to appropriate peer-reviewed scientific journals	
Activities (each activity is numbered according to the output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1) Activity 1.1 Multi-stage sample-design for selection of 6-8 intervention-communities according to social & environmental criteria (e.g. harvesting mangrove oysters along salinity and primary-productivity gradients)			

Activity 1.2 Environmental, rapid rural appraisal (RRA) and household livelihood surveys for selection of target-households and establishment of intervention baselines.
Activity 1.3 Development of initial oyster artificial-substrate based culture-technology and depuration options
Activity 1.4 LMC and/or community agreements brokered on collective-production activities and extractive-restrictions in adjacent mangrove oyster-nursery areas
Activity 1.5 Initial training of 40 wild-oyster harvesters on oyster-spat collection and culture techniques
Activity 1.6 Adaptation of artificial-substrate based oyster culture techniques (e.g. post, tray, raft, long-line) through two full iterative phases of action research
Activity 2.1. Procurement and adaptation of solar powered freezers for transport of oysters from the Sherbro MPA to free town under variable seasonal conditions
Activity 2.2. Training staff/ beneficiaries in operation and maintenance of freezer plant
Activity 2.3. Seasonal testing of freezer systems & cold-chain implementation
Activity 3.1. Analysis of markets for premium oyster-based products (and their substitutes) in Freetown and other regional markets
Activity 3.2. Staging of regional and national oyster recipe competitions
Activity 3.3. Development and testing of value-added oyster ready meals with super-markets, restaurants and beach-bars in Freetown
Activity 3.4. Evaluation of wider international demand & market-based certification potentials & statutory recommendations for MPA policy-makers
Activity 4.1. Establishment of project web-site (with links to partner web-sites and the regional Sarnissa research network
Activity 4.2. Extension to neighbouring communities through 2 ‘Farmer Field-Schools’ (in each case for separate female and male groups).
Activity 4.3. Regional best-practice/ policy workshop (inviting participants from comparable initiatives in Benin, The Gambia, local EJF project, MPA representatives)
Activity 4.4. Project reports & publications (x2) on environmental social and economic sustainability outcomes in international peer-reviewed journals

Annex 3: Standard Measures

Table 1 Project Standard Output Measures

Code No.	Description	Gender of people (if relevant)	Nationality of people (if relevant)	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the
2	Aquaculture MSc student dissertations	M &/or F	TBC	0	1	1-2	0	2-3
6A	Initial training of 40 wild-oyster harvesters on oyster-spat collection and culture techniques	Mainly F	Sierra Leone	3	0	0	0	3
6B	Weeks training on spat collection (above)	Mainly F	Sierra Leone	2	0	0	0	2
6A	Training staff/ beneficiaries in operation and maintenance of freezer plant	M &/or F	Sierra Leone	0	10	10	0	20 (tbc)
6B	Weeks training on freezer plant (above)	M &/or F	Sierra Leone	0	1-2	1-2	0	2-4
6A	Extension to neighbouring communities through 2 'Farmer Field-Schools' (in each case for separate female and male groups)	M & F	Sierra Leone	0	0	40-50	0	40-50 tbc
7	Freezer plant operation training manual FFS training manual	M & F	Sierra Leone, UK	0	1	1	0	2
9	Policy brief on intervention recommendations based on action research outcomes	M &/or F	Sierra Leone UK	0	0	1	0	1
11B	Number of papers to be submitted to peer reviewed journals	M & F	Sierra Leone, UK	0	0	1-2	0	1-2
12A	Excel database of abiotic, biotic and social mapping survey results - for research areas in Sherbro MPA	M &/or F	Sierra Leone, UK	0	0	1	0	1

14A	Regional best-practice/ policy workshop (inviting participants from comparable initiatives in e.g. Benin, The Gambia, local EJF project, MPA representatives)	M &/or F	Sierra Leone	0	0	1	0	1
14B	Number of conferences/seminars/ workshops attended at which findings from Darwin project work will be presented/ disseminated.	M &/or F	International – TBC	0	1	1-2	0	2-3
20	Estimated value (£'s) of physical assets (freezer & culture system equipment, to be handed over to host country(ies)	NA	Sierra Leone	0	22,200	25,000	0	47,200
23	In-kind funding (£'s) through UoS MSc student participation	M &/or F	UK (UoS)	0	1000-2000	1000-2000	0	2000-4000
23	West African Regional Fisheries Project (Contribution in kind)	NA	Sierra Leone	5000	5000	5000	5000	5000

Table 2 Publications

Title	**Type** (e.g. journals, manual, CDs)	**Detail** (authors, year)	**Gender of Lead Author**	**Nationality of Lead Author**	**Publishers** (name, city)	**Available from** (e.g.website link or publisher)

- There have been no project publications as yet

Annex 4: Summary findings of stakeholder interviews Jan 2016

Over the course field mission semi-structured interviews were conducted with key informants (Fisheries Dept. and local administration), tourism business representatives (Freetown beaches) and oyster gathering/ fishing communities in the Sherbro MPA, as focus group or individual interviews (Table 4.1). Interviews with fisher communities were conducted in Mende and other interviews in English. Qualitative interview data was transcribed in Word and systematic elements in Excel documents. Key findings, building on preliminary exploratory assessments are summarised below.

Table 4.1 Semi-structured & focus group interviews, Freetown & Sherbro MPA Jan 2016

Respondent Type	Interview Type	Location	Gender (& No)
Deputy Dir. Fisheries	Individual	Min. Fisheries & Marine Resources, HQ, Freetown	F (1)
Steamed oyster vendors	Individual	Pamuronkoh Mkt, Calaba Town Freetown	F (2)
Live oyster vendor	Individual	No 2 River Beach Freetown	M (2)
Beach bar owners	Individual	Lumley & Hamilton beaches (FT)	F/M (2)
Municipality Admin Staff (Inc. Mayor)	Group	Bonthe Town Hall, Sherbro Island	M (9)
Fisheries Community Mgt Association (CMA)	Group	Bonthe Govt. Fisheries Office, Sherbro Island	M (13) F (6)
Satellite Sherbro fishing communities	Individual & Group	Sherbro Island (3), surrounding islets (3), Sherbro River (1), Bonthe Town (1),	F/M (9)

(i) Community Characteristics and Demography

- With the exception of Bonthe (9,975 persons) and Yorktown (400-500persons); communities in the oyster-zone delineated by seasonal salinity gradients, consist mostly of small extended family groups of 3-30 HH and populations of 18 to 125 persons (*more accurate demographic information for the research area should become available following publication of the Nov 2015 population and housing census results; the first since 2004 – see page 8*).
- Most of these smaller, remoter communities are of the indigenous Sherbro tribal ethnicity and Muslim religion, whilst Bonthe and Yorktown include a growing Mende population with mainland origins and a substantial Christian population linked to colonial era settlement. Mende is the *lingua franca* of the larger towns & commerce in the area.
- Marriage (Muslim or Christian) is 'virilocal', brides moving to their husbands own or extended family households. Extended-family household had up to 11 members (with as many as 20 in a single instance) with occupancy rates likely to be higher in polygamous Sherbro Muslim households (Table 4.2).
- Nearby communities with overland track access to Bonthe tended to be longer established; settled 40 to >100yrs ago. Conversely communities on smaller islets were settled from as little as 8 to 35yrs ago. One such was resettled after its desertion during the 1990's civil war (Table 4.3).
- Settlement of these islets is constrained by access to fresh-water; three such communities in our sample had to canoe drinking water from neighbouring communities during the dry season (Table 4.3).
- Results indicate rapid population growth in most established communities, with the exception of York which has seen significant outmigration following decline of its traditional agriculture-base, earlier over-population and ground-water salinization.
- Smaller, recently settled communities exhibited the highest population growth rates, albeit from a low base; as a combined result of exogenous settlement of extended

family members establishing new households and endogenous growth resulting in increasing household occupancy.

- Smaller, remoter settlements also appear to be more transient, populations swelling periodically with seasonal migrations of fisher households following different fish stocks. This may also lead to secondary pressure on oysters i.e. with migration of whole households, though oysters do not appear to be a primary cause of such migration.
- Other than some solar installations and small generators (mainly linked to short-term development projects), none of the research communities have a permanent electricity supply. Bonthe and York Towns and one nearby village within Bonthe Municipality have recently had solar street lights installed (Table 4.3).
- Although, several ('non-islet') villages also had communal sealed latrines installed (Table 4.3), defecation in the bush or shore adjacent to settlement still appeared common practice. *Further investigation of sanitary practice and links to oyster contamination risk is required (see Annex 6)*.

Table 4.2: Community Geography & Demography

SN	Village	Type	Location[1]	Salinity	[2]Bonthe / Yagoi Km	NoHH	Pop	Mean HH No	Ethnicity Sherbo: Mende	Religion [3]
1	GHN	Sat	**Islet**	Higher	10/25	30-52	125	4.2	80:20	M
2	BBK	Sat	SIC	Int.	6/21	25	85	3.4	100	M
3	BTB	Sat	SIC	Int.	3/21	7	65	9.3	100	M
4	GBM	Sat	SII	Int.	4/23	11	80	7.3	100	M
5	YKN	Sat	**Islet**	Int.	3/19	3	18	6.0	100	M
6	KGB	Sat	**Islet**	Int.	3/17	10	53	5.3	60:40	M
7	YRK	Town	YIC:York	Lower	5/15	150	400-500	6.7	100	C/M
8	MMY	ML	River	Lowest	13/7	50	>500	10.0	90:10	-
9	KJM	Town	SIC:Bonthe	Int.	0/19	>1000	9,975[4]	-	-	C/M

[1] SIC = Sherbro Island Coast, SII = Sherbro Island Inland, YIC = York Island Coast

[2] Distance by canoe (note BBK = 6km by seas and 12km overland) [3] M= Muslim, C = Christian

[4] 2015 Population & household census data

Table 4.3 Livelihood Assets & Activities (in addition to fishing & oyster gathering)

SN	Village	AgeYrs	FW[1]	Electricity [2]	Sanitation [3]	Canoes	Farming[4]	Livestock [5]	Other[6]
1	GHN	35	RF/NC	No	None	56	None	Ck	FWS,CF
2	BBK	>100	Well	No	SLC	15	Cv,OP	Ck	SL (x1)
3	BTB	40	Well	No	SLC	9	Cv	Ck	
4	GBM	'old'	Well	SLM	SLC	>5	OP,Rc,GN	Ck,Sh,Gt	SL (x2)
5	YKN	8	RF/NC	No	None	8	None	Ck	FWS
6	KGB	-	RF/NC	No	None	11	None	Ck	
7	YRK	>100	Well	SLM, GnP	SLC	>300	Limited	Ck	FWS*,CF
8	MMY	>100	Well	No	SLC	50	Rc	-	
9	KJM	>100	Well	SLM,GnP	SLC/ SLD	56	Cv,GN,	Ck, Sh, Gt	FWS,CSL

							Vg, Pv		

[1] Fresh Water source of: RF/NC = Rainfall and neighbouring community (by canoe)

[2] SLM = Solar Lighting Municipal, SLP = Solar Lighting Private, GnP =Generator Private

[3] SLC = Sealed Latrine Communal, SLP = Sealed Latrine Domestic

[4] Cv= Cassava, Rc = Rice, GN = Ground Nut, OP = Oil Palm, Vg = veg, Pv Piassava (cash crop)

[5] Ck = Chicken, Sh = Sheep, Gt = Goats

[6] FWS = Mangrove Firewood Sales (note: all such sales banned in KGB & external sales in York*), SL = Salaried Labour, CSL = Commerce & salaried labour, CF = contract fishing for high value species esp. *Pseudotilletheus elongatus* for a Korean company providing fishermen with ice & cold-boxes (Plate 4.4c).

(ii) Governance of the Sherbro MPA

- In rural areas governance is devolved to local communities at 4 tiered levels within tribal 'Paramount Chiefdoms' (Fig 4.1: Green Boxes). The research area is divided into four such Chiefdoms; Bendu Dha and Imperi on the mainland whilst Sherbro Island is divided into Dema to the West and Sittia centre-west (Fig 4.2 and Annex 9). The more populous settlements of Bonthe, York and surrounding villages (with a combined population estimated at around 10,000-11,000 are governed as a single municipality by Bonthe Local Council.

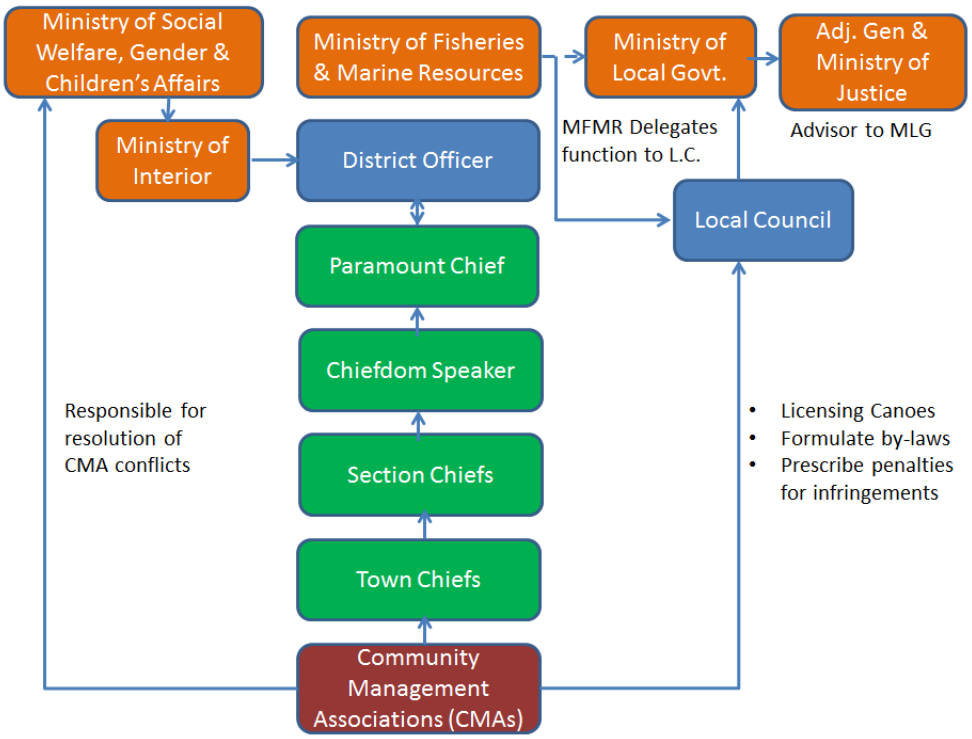


Fig 4.1 Governance accountabilities (upward) and roles in the Sherbro MPA through newly established Community Management Associations (CMAs: Orange = National Ministries, Blue = Regional Government, Green = Traditional Community Level Governance. Data Source: MFMR).

Fig 4.2 Boundaries of 4 Paramount Chieftaincies in the Sherbro MPA: orange triangles = Chieftaincy base, green triangles = Section Chiefs (Note: Bonthe District is divided into 11 Paramount Chiefdoms: see Annex 9)

- 8 of our 9 project communities (Table 1) are within the Sitia Chiefdom; 5 also falling within the overlapping Bonthe Municipality. The 9th community (GHN) is within the Imperi Chiefdom.
- It is intended that grass-roots governance of living aquatic natural resources (i.e. fish and shellfish) in the MPA will be the responsibility of Community Management Associations (CMA's with representation down to Section Chief level) with coordinating support by the local Municipal Council in Bonthe (Fig 4.1).
- The challenges facing implementation of this governance structure were clearly apparent at a joint CMA committee meeting conducted at the Bonthe Fisheries Centre in January 2016 (Plate 4.1b). Whilst some steps had been taken toward canoe licensing and registration, frustrations were evident regarding enforcement of the associated on ban on mono-filament fishing gears (Plate 4.1a) whilst fish catches 'generally continue to decline'. Representation was also partial; of 32 signed-attendees only 18 (inc. 6 women) attended the whole meeting. Seven of the 32 travelled from Bendu Town (Fig 4.2: home to a Section Chief of the mainland Benducha Paramount Chiefdom) and the balance from Bonthe Town including one local council member i.e. there was no direct representation of any of our satellite communities which include one Section Chief Village (BTB).

Plates 4.1a & b: a. Registered dug-out artisanal fishing canoe bearing MPA fishing licence number, but still deploying mono-filament nets b. Community Management Assoc. committee meeting Bonthe Fisheries Centre Jan 2016.

- Attendees were briefed on the aims and progress of the 'Sherbro Oyster Project' and their opinions solicited (all were already familiar with the nearby pilot culture racks). There was general agreement that the CMA should be consulted on any intervention planning, but greater clarity on the nature of any future cooperation was limited by three factors (i) ability to define precise interventions at this exploratory project stage, compounded by frustration over wider problem of CMA in-action (ii) Deprecatory male attitudes toward oyster production; one respondent challenged the wisdom of any female production participation on safety grounds ('canoeing is dangerous'); a female delegate responded 'men can help build and maintain culture racks and we can harvest, process and market the oysters' (Note: of 13 male attendees 5 reported some involvement in oyster harvesting over the last 12 months) (iii) the current narrow focus of CMA on fishing related activities; there is no explicit mechanism for integrated management of other living aquatic resources including oysters and mangroves.
- Opportunities for further constructive engagement will be sought as the project progressives. Acknowledging the above challenges, (particularly in regard of representation), during this trip further effort was directed at understanding the interplay of formal and informal governance mechanisms shaping female access to living aquatic resources in the project communities.
- During community visits it became apparent that the larger, longer established, less transient, generally better resourced and easier accessed satellite communities around

Bonthe with easier access are more likely to be beneficiaries of more substantial integrated rural development projects (IRDP) i.e. including agriculture/ livestock, water & sanitation support. Green Scenery an active locally staffed development NGO is currently implementing an IRDP in 6 such communities (including 3 project communities: Plates 4.1 a-d); all within or immediately adjacent and having overland access to Bonthe Municipality (Plates 4.2b-f).

Plates 4.2a-f: Clockwise from top left: b-f Green Scenery NGO integrated rural development Signage and water and sanitation interventions in 3 project communities with land access to Bonthe Municipality.

(iii) Education, Literacy, Information and Communications Technology (ICT)

- Children in Bonthe have good access to primary education, though attendance is a greater challenge for children in remoter satellite communities where labour obligations for adolescents may also be more pressing. Bonthe also has a state and other development funded secondary schools (including an all-girl school), and a recently established technical college offering vocational training in electronics, catering and joinery and a public library.

Plates 4.3a-f: Clockwise from top left: a. Radio Bontico station Bonthe, b. Solar/ wind-up radio in use in satellite community c-d small-enterprise mobile charging shops in Bonthe (petrol generator) and York Town (solar power).

- Further understanding of functional literacy levels is required, particularly with respect to data gathering and dissemination options. A local radio station ('Radio Bontico'; Plate 4.3a) transmits a weekly Monday public service 'Council Hour' on Development related activity in collaboration with the Bonthe Municipality communications officer. This appears a primary local news channel and essential listening even in satellite

communities (many were recently donated robust solar/ wind-up flash memory radios). *This show will be used to further disseminate project aims, progress and to solicit participation in envisaged interventions to a wider audience during the next joint-mission.*

- Bonthe and Yorktown have high 3G mobile phone penetration[9] linked to the presence of small-scale solar charging businesses (Plates 4.3b-f). This also limits mobile phone-use in remoter satellite communities. Mobile internet connectivity is also available, though service and smart-phone ownership (i.e. due to higher cost and charging requirements) are more limited i.*e. SMS messaging could provide a more accessible dissemination tool*.

(iv) Land and Water Transport and Communications

- Vehicular transport on Sherbro Island is very limited (i.e. restricted to bicycles, some private motorbikes and a small number of mainly service vehicles) and almost entirely restricted to Bonthe Town. Passage along narrow sandy tracks to interior and coastal communities is constrained by tidal inundation where they cross mangrove areas compounded by lack-of and poor maintenance of the few existing bridges. Thus, regular commerce along these tracks is limited to short-range carriage of head loads mainly by girls and women, between satellite communities within a few hrs walking distance and the markets in Bonthe.
- Conversely, penetration of tidal creeks on the inland facing sides of Sherbro Island[10] gives many apparently landlocked communities access to transport-routes, fishery and oyster grounds by canoe. Dug-out ('Kru') canoes remain the most important means of local transport and haulage and central determinant of access to aquatic resources including fish, oysters and mangroves (Plates 4.4c-g; Section vi). These copious craft are used to fish within the more sheltered mangrove areas, usually with one man operating gill-nets, cast-nets or hand-lines.
- Larger outboard-motorised 'standard' and larger 'Ghana-type' planked canoes (Plates 4.4b,c,h) and a scheduled (though erratic) ferry (Plate 4.4a) periodically link Sherbro and York Islands with local mainland road heads. The ferry connects Bonthe with a larger weekly mainland retail/ wholesale market in Yagoi on the Sherbro River; a 19km journey (Section x). Other uplift points include Bendu and York Island (Fig. 1).
- There is no direct scheduled service from Bonthe to a second, larger though more distant mainland weekly market at Gbambatok (55km by boat). Gbambatok lies near to the head of a second and wider navigable channel ('Freedom Pampa') to the north of the MPA (Fig 1); though separate service(s) connecting with the Sierre Rutile concession landing point at Nitti may also extend to the lower part of the channel - and potentially Delkin with a Section Chief and one of the larger settlements on the north coast of Sherbro Island (Fig. 1). There is also a smaller secondary market at Matru upstream of Yagoi on the Sherbro River.
- A 12hr service ferry service which ran from Bonthe to Freetown was discontinued in 2015. A recent private sector attempt to introduce regular passenger flights to the Bonthe airstrip (to service recreational sport-fishermen) has also been suspended for reasons of economy.

[9] Nationally *Africell* and *Airtel* control 90% of subscriptions; at around 79% (4.6mill subscriptions in 2015) mobile penetration remains low by regional standards http://store.bmiresearch.com/sierra-leone-telecoms-report.html

[10] Note: Much of the central and southern seaward facing side of the islands consists of fossil raised beaches with relatively little forest or mangrove cover and consequently lower settlement levels. Although as yet unexploited, much of this area is included in the Sierra Rutile mining concession. Most settlements here run along the seaward side of a narrow strip of mangrove and forest running parallel to the coast, culminating in a sizeable (3.3x1km wide) inland lake at Gbie on the SE of the island (Fig 4.2a).

- Though few in number compared to the Kru's, the larger planked canoes enable access to the '*Dengar*' continental shelf trawling grounds on the ocean-facing side of Sherbro Island. An FAO report[11] documented 2,517 1-3 man dug-out canoes operating in and around Bonthe in 1981; 50.1% of the total recorded in Sierra Leone, whilst nationally the total number of fishing canoe rose by 15% between 1974 and 1981 (Tables 4.3 & 4.4).

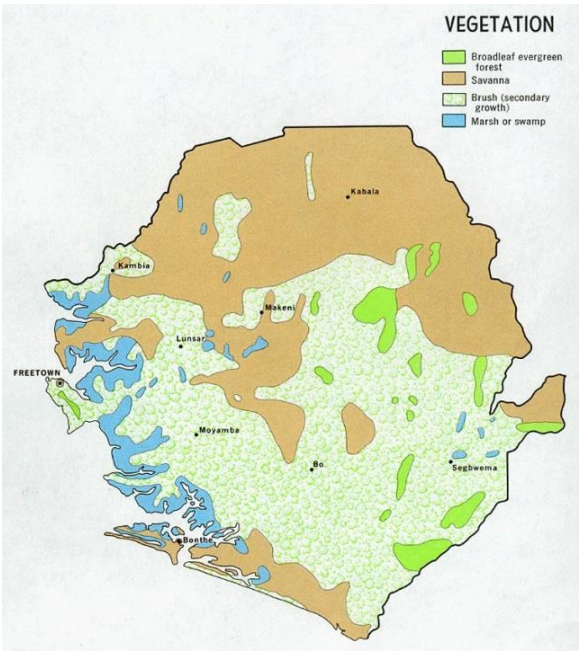
Table 4.3 Fishing canoes numbers in Bonthe & Sierra Leone, 1981 (FAO 1986)

Year 1981		Bonthe	Sierra Leone	Bonthe % SL Total
Canoe Type	1-3 men	2,517	5,026	**50.1**
	3-5 men	237	1,326	17.9
	Ghana-Type	12	284	4.2
	Other	0	100	0
Total Sierra Leone		**2,766**	**7,074**	**39.1**
No Outboard Engines		9	677	-
Motorization %		0.3	9.6	1.3

Table 4.4 National trends in fishing canoe numbers 1974-1981 (FAO 1986)

Year	Total	Change YoY %
1974	6,150	-
1975	6,382	3.8
1976	6,334	-0.8
1977	6,730	6.3
1978	6,818	1.3
1979	6,896	1.1
1980	6,998	1.5
1981	7,074	1.1

Fig 4.2a Sierra Leone vegetation map with mangrove zones along north & central coasts



Source: http://www.lib.utexas.edu/maps/africa/sierra_leone_veg_1969.jpg

[11] Ssentongo, G.W., Ansa-Emmim. M. 1986 Marine Fishery Resources of Sierra Leone: A review of exploited fish stocks. FAO Rome. CECAF/ECAF Series 86/34 (En).

Plates 4.4a-h: Clockwise from top left: a. Passenger ferry, Bonthe, b. Supply boat, Yagoi, c. ocean-going planked wooden canoe contracted to Korean fishing company, York Island. d. new 2-man dug-out canoe newly constructed from a cotton-wood tree (C*eiba pentandra*), e. Dug-out transporting mangrove fuel wood, f. Dug-out transporting waste oyster shells for construction use in Bonthe. g. Dug-out carrying drinking water under sail, h. Ocean going fishing/ supply Ghana-type canoe using outboard motors, Bonthe.

(v) Livelihood and Wealth Indicators

- Three aspirational well-being (wealth) indicators permitting comparisons between households across communities were identified:
    - Housing with or without tin roofs (houses in satellite communities outside Bonthe are almost universally of temporary construction, better-off households being able to afford tin-roofs)
    - Access to canoes (number and size)
    - Proportion of children participating in secondary education
- The first and to some extent the second indicators can be assessed by supervised classification of satellite images (Google Earth). Time series images can also be used to assess changes in demography and well-being.
- Fishing and (less consistently) oyster gathering ranked first and second respectively for annual income provision for most households in satellite communities; followed by mangrove timber extraction (*seasonal contributions require further assessment*). Most regular mangrove timber extraction is for sale as a fuel wood for cooking, or fish and shellfish processing. Mangrove timber is also extracted for house-frame construction; all houses satellite villages and much of Bonthe being of temporary construction.
- Households in the larger Bonthe and York Island communities and some satellite communities on Sherbro Island and the Sherbro River were more likely to have access to agricultural plots for cultivation of cassava, groundnut and rice along with some oil palm cultivation. No cultivation was practiced on any of the islet sites.
- Cultivation is mostly subsistence orientated with plot size and production intensity more limited by lack of access to inputs (i.e. mechanisation and agrichemicals) and labour requirements for weeding and crop-protection.
- Beyond small amounts of backyard poultry, and occasional goats and sheep (Table 4.2), livestock holdings are very low due to resource and religio-cultural reasons. One local development organisation ('Green-Scenery'[12]) is providing improved agricultural seed inputs and sponsoring broiler production as a collective women's activity and Bonthe.
- Remittance returns from out-migrated family members i.e. in Freetown or abroad, appears very limited further increasing dependence on the local resource base.

(vi) Spatial and Seasonal Patterns in Oyster Harvesting Effort

- Although significant numbers of women (and some male youths) in Bonthe and Yorktown regularly harvest oysters, gathering appears more central to the livelihoods of the smaller, remoter and poorest satellite communities; due both to lower competition for local resources and lack of alternative livelihood options.
- *Inter alia* seasonal effort is longest and most sustained (Table 4.5) when such communities also have access to more sheltered grounds outside the main E-W sea channel. Under these conditions girls also appear more likely to start regular harvesting at an earlier age; starting as young as 7, 10 &11years in three such villages (Table 4.6).
- Seasonal effort across communities also appears to be correlated with location across salinity gradients and associated oyster abundance. Almost year round harvesting was reported to be possible in the most northerly community (GHN) at the mouth of a tidal creek, and lowest in YRK and MMY (6-7 months) both subject to greater seasonal freshwater inundation from the Sherbro River.

[12] www.greenscenery.org/index.php/home01

- Harvest volumes and yield per unit effort increase progressively from Feb/ March, peaking in June/ July linked to the single year class characteristics of the main oyster resource harvested from mangrove roots (Section viii).
- Mud oyster harvesting appears most prevalent around York town linked to proximity to extensive mud-flats at the mouth of the Sherbro River (*further investigation required*).
- Harvesting frequency and effort is also closely linked to semi-diurnal lunar month tidal patterns. Early morning low water on water on neap tides, which despite their lower amplitude provides the most favourable extended and safest conditions for harvesting mangrove oysters.

Table 4.5 Seasonal Harvesting Effort by Community

SN	Village	StartMonth	EndMonths	PeakMonths	MonthsEffort	MainType
1	GHN	All year	All year	Mar - Jun	12	Mangrove
2	BBK	Mar	Aug	Mar	6	Mangrove
3	BTB	Feb	Aug	Mar - Apr	7	Mangrove
4	GBM	Oct	Aug	??	9	Mangrove
5	YKN	Oct	Aug	Mar-Apr	9	Mangrove
6	KGB	Feb	Aug	July	7	Mangrove
7	YRK	-	-	Aug - Sep	-	Mangrove/ Mud
8	MMY	Feb	Jul - Sept	Jun - Aug	7	Mangrove
9	KJM	Feb	Jul	May-Jul	7	Mangrove

(vii) Oyster and Living Aquatic Resource Access Rights and Gender

- Re-settlement of vacated or new village sites is contingent on permissions granted by traditional Paramount Chiefs (these territories also over-lap Bonthe Municipality). Such permissions extend to land-use and terrestrial resource extraction only. *De-facto* exploitation of living aquatic resources (LAR) remains almost entirely under open-access rights. Surprisingly little evidence was found of (even) informal common-property rights systems operating at individual community levels. Some informal restrictions operate with respect to mangrove harvesting for external sales; particularly on smaller islets (Table 4.2). For example females in one remoter satellite community (YKN) avoided harvesting oysters immediately adjacent to their settlement for subsistence use toward the end of the harvest season. Here too there was still no formal or informal outsider exclusion prohibition, or expectation of the same.
- Mono-filament nets (MFN) and fishing in boats with outboard motors are formally banned under MPA rules with community support (Section ii). Out-board motors remain unaffordable for the vast majority of small artisanal fishers to purchase, maintain and run, being effectively restricted for use on a relatively small number of larger ocean-capable wooden vessels. However, in the absence of effective government or communal enforcement free-riding remains common in respect of MFN use.
- In the absence of such formal or informally coded entitlements, access to LAR is determined by two principle endowments:
    i. Access to canoes, the sole means for bulk transport of LAR (including fish, shell-on oysters and mangrove wood) from harvest sites to satellite communities for processing; steaming and or smoking for preservation prior to marketing
    ii. Physical ability to harvest in the absence of motorised transport.
- Women's oyster gathering range is highly restricted by their mobility linked to these endowments along with tidal gathering windows and safety perceptions (see below); typically within a daily return range of 1.5km (max 2km) around their homes males regularly canoe substantially longer return-distances to catch fish, using tides and

occasionally make-shift sails, multi-night trips or longer migrations, with or without their households to extend their range (Plate 4.4h).

- Fishing within the mangrove area is conducted from wooden dug-out canoes, manufactured in the main from increasingly scarce cotton-trees (*Ceiba pentandra*). In the absence of more durable woods, such boats typically have a working life of only 2-3 years[13]. Depending on the size of tree, canoes mostly range in size from '1-3 man' (and more rarely 4-man) canoes.
- Small numbers of larger & longer distance ocean-capable canoes are produced in Bonthe using a simple strip-planking method. There are very few fibre-glass craft, and no local means of production.
- Access to canoes within communities and households is determined by a range of socio-cultural, economic and resource factors:
    - Only in one islet community did some women have exclusive use of smaller 1-man canoes for local oyster gathering.
    - Otherwise women must negotiate access with male family or other community members around their priority use for fishing in one of the following ways:
        i. Women borrow or rent canoes; paying a daily usage fee usually to a male owner.
        ii. Gathering is conducted in partnership with a spouse or other male canoe owning household member; males and females typically taking responsibility for paddling and harvesting respectively.
        iii. More occasionally men take full responsibility for harvesting; often selling catches on to women for processing and marketing
    - Practices (ii) and (iii) are common in instances of heightened safety concern i.e. following local accidents and/or during rougher weather conditions i.e. during Feb-Mar. Thus these practices are more prevalent in more exposed sites along the main sea-channel (Fig 4.2 &Table 4.6).
    - Subject to tidal limitations, practices (ii) and (iii) may also increase oyster yields as paddling range is extended and larger capacity 2-3man fishing canoes are likely to be employed.
    - Only one instance of an all-female crew was observed; x3 in a larger 3-man boat working a more sheltered creek (BTB: Table 4.6). Whilst this may extend range it will also reduce the boats carrying capacity; for the same reason safety may be enhanced during outbound legs but reduced on loaded return legs (when most accidents occur).
- Prior to the civil war (1991-2002) oysters were predominantly harvested by women at subsistence levels (Kamara and McNeil 1976[14]); the (still) local retail and wholesale market chains (see below) for bulk-steamed and smoked product described here, appear to have grown following the cessation of the civil war in 2002.
- Male attitudes towards oyster gathering as a 'less serious female' occupation appear to be playing a part in preserving gender roles. However some male youth in Bonthe also appear to be taking a more active role; in oyster gathering (which has lower entry costs than fishing re nets & gears) and much over wider ranges than females. In GHN males

[13] At the time of writing the Ghanaian Government (Min Fisheries & Aquaculture Dev) & the National Fuel Premix Committee had jointly outlined plans to phase out and replace wooden fishing canoes with subsidised fibreglass canoes as an anti-deforestation/ climate change and fishing safety measure (www.graphic.com.gh 18Jan16, http://www.outdoorrevival.com/news/ghanas-fiberglass-boats-and-other-changes.html)

[14] Kamara, A.B., McNeill, K.B.. 1976 Oyster Culture Project, Occasional Paper No1. Ministry of Agriculture and Natural Resources, Fisheries Division & International Development Resources Research Centre (IDRC). Freetown, Sierra Leone. 50pp.

were also reported to start harvesting oysters at certain times in the season when they can become more profitable than fishing. *Further understanding of these attitudes and potentials for further gender role transition is required*.

- Canoe sharing arrangements also correlate serendipitously well with men's dominant seasonal fishing patterns. During the main oyster harvesting season men often fish at night using passive gears (i.e. gillnets) and lamps. Men also favour high tides for fishing, rather than the neap tides favoured by female oyster gatherers.

Table 4.6 Female Effort in Oyster Gathering

SN	Village	Full-time Females	Age Range	Total Canoes	Female Canoes	Canoe Size(man)	Daily Lease (Le)[1]	Max Hrs 1-way	Exposure[2]
1	GHN	??	10-60	56	No	2-3	20k	2	H
2	BBK	15	25-40	15	No	2-4	-		H
3	BTB	20	-	9	Yes	1-3	-	1.5	I
4	GBM	>5	7->40	>5	No	-	-		L
5	YKN	5	15-30	8	Yes	1-2	-		L
6	KGB	10	11-50	11	No	2-3	-		I
7	YRK	<40*	-	>300	Yes	1-4	10k-20k	1.5	I
8	MMY	??	10-50	50	No	-	-	1.5	L
9	KJM	??	13-55	56	Yes	1-4	5-10k	2	I

[1] 8,000 Leones = £1 & 6,000 Leones = $1

[2] H = Higher, I = Intermediate, L = Lower

*Increases to 150 female participants during the peak mud oyster season in September

(viii) Oyster Substrate Type and Harvesting Pressure

- Oysters are locally described as mangrove, mud or rock oyster (Plates 4.6a-d) depending on the substrate they grow on. Formally classed as *Ostrea tulipa* (Lamarck, 1819) mud and mangrove oysters were re-assigned to the genus *Crassostrea* as *C. tulipa*, also recognised under the synonym *C. gasar*. Sub-tidal rock oysters have been designated as a separate species *C. denticulata* (Kamara and McNeil 1976) but phenotypic variation is continuous across estuaries and this taxonomic differentiation remains unaccepted (WoRMS 2016[15]). Mangrove and mud substrates predominate in the Sherbro MPA, whilst rock oysters are also harvested from exposed shores for live sales along with local mangrove oysters to tourists on beaches to the south of Freetown (Fig 4.2).
- Due to their greater accessibility and substrate availability, single year class oysters growing on submerged mangrove roots constitute the major share of harvests by the Sherbro research communities.
- Kamara and McNeil (1976) observed fouling, predation, siltation and low-salinity mortalities during the rainy seasons as the major biological constraints for oyster culture.
- Compared to mud and rock oysters, inter-tidal adult mangrove oysters located above the halocline are likely to suffer disproportionately higher mortalities following onset of rains (July – Aug), evidenced by a black to white shell colour transition.
- Mud oysters are accessible to hand collectors only in more limited inter-tidal mud flats (the razor sharp nature of the oysters also makes hand-dredging on foot far more challenging than canoe extraction from mangrove roots). Their submergence in sub-halocline sediments also appears to extend their seasonal availability during the rainy season (& potentially further upstream in the river mouth). There is also evidence to

[15] World Register of Marine Species: http://www.marinespecies.org/aphia.php?p=taxdetails&id=819170

suggest higher flushing rates following onset of the main rains (Jun/Jul) can expose mud oysters & enhance fishing effort.

- Larger sized mud oysters (Plate 4.5) are also indicative of greater survival potential for establishment of multi-year class cohorts. Mud oysters are harvested with shell-lengths up to 14cm reported whilst mangrove oysters rarely exceed 7-8cm.

Plate 4.5: Large mud oyster shells Gbembeehun (GHN) Village

- These factors and the likely persistence of undisturbed mud oyster beds refractory to hand-gathering in deep water sediments indicate mud oysters may contribute a resilient multi-year class *C. tulipa* breeding pool.
- Mud, mangrove and rock oysters may have broadly differing bacterial contamination risks associated with their environmental location (see Appendix 6).
- Gathering takes one of two forms (i) selective harvesting of larger individual oysters by 'chipping' them from mangrove roots with a knife (ii) more indiscriminate cutting off entire roots above the high-water line with their entire oyster load.
- Whilst both types of gathering may cause root damage, clearly the latter form is far more destructive (Plates 4.7a-d).
- Levels of indiscriminate root cutting appear to be much higher where gathering territories overlap and competition is more intense e.g. closer to Bonthe or York.
- There may also be a seasonal dimension with greater incentive for selective and indiscriminate harvesting respectively earlier and later in the season i.e. with more root cutting as larger individuals become more abundant from May to July.
- Root cutting will also extend gathering time on each tide i.e. as oysters become submerged.

Plates 4.6a-d: Clockwise from top left: a & b. Live whole and shucked mangrove oysters, c & d Live whole and shucked rock oysters (note higher yield of sub-tidal rock compared to intertidal mangrove oysters)

Plates 4.7a-d: Clockwise from top left: a & b. Selective knife removal of larger oysters, c & d stunting & erosion caused by indiscriminate harvesting of whole mangrove roots.

- Women also gather small shrimp with scoop nets and hand-gather a type of winkle for their household consumption (Plates 4.8a&b). Whilst this was earlier interpreted as evidence of oyster over-exploitation, further investigation revealed these species are traditionally harvested as an alternative food-source, particularly during the oyster low-season. Some communities also steam and smoke surplus winkles to market in Yagoi.

Plates 4.8 a&b: Female oyster gatherers also harvest and process (a) small-shrimp & (b) (shucked) winkles, particularly during the oyster-low season for household consumption

(ix) Processing

- During the main season commercial harvesting typically occurs over 2-3 consecutive days, always limited to one harvest per day with greatest effort on neap-low water tides (Section vii). The air-exposure tolerance of mangrove oyster is exploited as they are stockpiled alive under shade prior to bulk-primary processing i.e. steaming and shucking on the 3rd or 4th day post-harvest. Fresh steamed produce must then be sold (or consumed) on the same day. In remoter sites steamed oysters are subject to secondary smoke processing. In the absence a cold-chain this can extend shelf-life (and market range) for up to 4 weeks if 'well-smoked', though most smoked product is stockpiled and sold within 2 weeks of harvest in weekly mainland markets (Section x). The harvest and processing cycle is then repeated.
- At commercial scale, oysters are typically steamed in crude folded shallow 1-2m^2 open vessels of salvaged ¼" plate steel (operational life 3-4yrs: Plates 4.9a-d). The heaped oysters are covered in cloth during steaming and preparation typically takes place on the evening prior to steaming so processing can occur early in the morning where concurrent marketing is required. Some harvesters in Bonthe with immediate market access may harvest, process and market batches of oysters on the same day.
- Steaming is also likely to eliminate any primary risk of bacterial contamination (tbc). *There are no published records or stakeholder reports of health problems linked to algal toxin or other contaminants, though this merits further investigation*.
- Smoking of oysters, other shellfish or fish is conducted over open fires using simple wooden or perforated metal racks and covers with intermittent turning (Plates 4.10a-d). Excess water is hand-wrung from the steamed oysters, which then typically require 40mins to 1 hour, whilst depending on size smoking fish can take several hours.
- A small clupeid fish known as 'Bonga' (*Ethmalosa dorsalis;* with a similar salinity related seasonal abundance profile to oysters (i.e. Jan-Jul: Plate 4.10d) and like them also phytoplankton feeders (Bainbridge 1963[16]) caught using drift and gill nets is a particularly important food fish and frequently smoked alongside oysters.

[16] Bainbridge, V. 1963 The food, feeding habits and distribution of the Bonga *Ethmalosa Dorsalis* (Cuvier & Valcenciennes). Oceanic Lab. Edinburgh. http://icesjms.oxfordjournals.org/content/28/2/270.full.pdf

- Mangrove wood is used for both processing steps. Whilst fish require more fuel than oysters to smoke due to their higher water content, oysters may consume more per unit weight when subject to both primary and secondary processing. Processors differentiate between white and red mangrove fuel wood, the latter said to import a good colour to the product. *Further assessment is required on the contribution of oyster gathering and processing practices to mangrove health and interaction with wider exploitation patterns i.e. for fish smoking, cooking, construction etc.*
- Both primary and secondary oyster processing is undertaken by female gatherers at their homes. Women are typically solely responsible for shucking, the most laborious and injurious element of the whole process, but may receive assistance from male household members with steaming and smoking, particularly when there is requirement for simultaneous smoking of oyster and fisheries harvests.
- Processing of fish is limited to smoking and may be undertaken by men and/ or women.

Plates 4.9a-d: Clockwise from top left: a & b. Steaming oysters at commercial scale and for household consumption, c & d women shucking oysters and steamed product

Plates 4.10a-d: Clockwise from top left: a & b. smoking fish and oysters, c. smoking of a mixed seafood harvest including mud crabs, d. smoking 'bonga' (*E. dorsalis*).

(x) Marketing

- Most gatherers steam and retain enough oysters for their own immediate daily household consumption (i.e. 1-2 cups for an average sized household of 5-8). Contingent on market access, surplus steamed product is either retailed on the same day to local consumers, or preserved by smoking and stockpiled in rice-sacs (stored off-ground in living quarters) for more periodic sales in one of two mainland weekly markets; Yagoi and Gbambatok (Fig 1).
- These fixed markets serve as foci for retail of a range of local artisanal agricultural and smoked/ dried fisheries products; the latter mainly sold in covered sections of the market, smoked oysters from the ground in open areas. Smoked (and steamed) oysters are universally retailed volumetrically by the 'cup' for home consumption (Table 4.7 and Annex 5). Some vendors also specialise in selling fried smoked oysters with bread as a value-added ready-snack. An unquantified volume of smoked oysters is wholesaled by the sack for retail in towns further inland (*further verification required*).
- Most female oyster gatherers based in or immediately around Bonthe (KJM and GBM: Table 4.4) only undertake primary processing. The resulting 'fresh' steamed product is then sold in Bonthe on the day of processing. Most spoilable seafood produce (i.e. including steamed oysters, other shellfish and fresh fish) is sold ('hawked') directly to consumers door-to-door or at other informal sales points i.e. tracks entering the town where consumers wait to get first choice advantage. No oysters and only small amounts of fresh fish were observed for sale in the Bonthe central street market (Plates 4.11a-c).
- Level of secondary smoking in satellite communities increases with distance from consumer concentrations i.e. here mainly Bonthe, York and Yagoi Towns. Thus the remotest communities (GHN and BBK) smoke 100% of their surplus.

- Gatherers in satellite communities at an intermediate distance from Bonthe (YKN, BTB) have mixed strategies; hawking steamed oysters up to 2-3 times per week (esp. BTB with 1hr access by track). In YKN, 3km from Bonthe by canoe, 80-95% of volume is smoked and sold to female 'assemblers' from Bonthe for sale in Yagoi on a weekly or fortnightly basis.
- Whereas most women also individually, or occasionally collectively market their own smoked oysters in Yagoi (or Gbambatok), gatherers in one village (YKN) wholesale their product to female gather/ assemblers based in Bonthe at marginally discounted rates. These assemblers, who visit the village to purchase the product, then sell this and their own produce on in Yagoi. *These trends may be subject to seasonal demand and availability factors for which further longitudinal market assessment is required*.
- Interim market and margin analysis results indicate of a general preference for locally supplied 'fresh' steamed oysters above smoked oysters as a staple dietary ingredient i.e. where market opportunity exists. Thus rather than adding value, smoking is primarily concerned with extending product shelf-life and market range in the absence of a functioning cold-chain. Margin analysis outcomes (Annex 6) support this observation; indicating little or no additional financial gain for smoked produce once additional processing (and transport) costs are accounted for.
- There is no price-differential for different sized oysters (smoked or steamed). Logically therefore selectivity in harvesting of different sized (or types of) oysters should be more directly linked to the relative effort required for their harvesting, transport and processing. *Seasonal condition indices (of dried meat to shell weight or volume) are being collected to address this question.*
- Risk of spoilage-losses appears very low based on current demand a supply characteristics. High demand means stocks of steamed and smoked oysters are sold very rapidly, typically in no more than a few hours of arrival at marketing points.
- Results also indicate greater consumer preference for steamed oysters for regular consumption, whereas as smoked oysters are more likely to be a less regular treat. *Further research is required on consumption patterns in conjunction with attitudes towards value-added ready meals (Section xi).*
- Prior to consumption smoked oysters are usually soaked in water to, (i) settle sand and shell fragments and rinse wood-smoke chemicals, and (ii) to soften the meat, particularly if they are to be fried for sandwiches. Elsewhere so called 'soaking' and 'pushing' is a commonly use means of cheating on weights and measures; also with potentially adverse public health outcomes. Further research is required to determine whether this is a problem in the current research context.
- Women are almost entirely responsible for all marketing as well as most processing effort. This includes marketing steamed or smoked shellfish and fish and most fresh product. Males may assist with transport i.e. paddling smoked stock to ferry/ launch pick-up points.
- This description of the Sherbro oyster value-chain is summarised in Fig 4.3. *Further longitudinal assessment of oyster sales in Yagoi and Gbambatok weekly markets are required (and extended supply chains). As these two sites are marketing bottlenecks for the northern and southern parts of the Sherbro MPA, regular assessments of vendor numbers and bags sold could also provide a simple indicator of micro-dispersed seasonal production effort.*

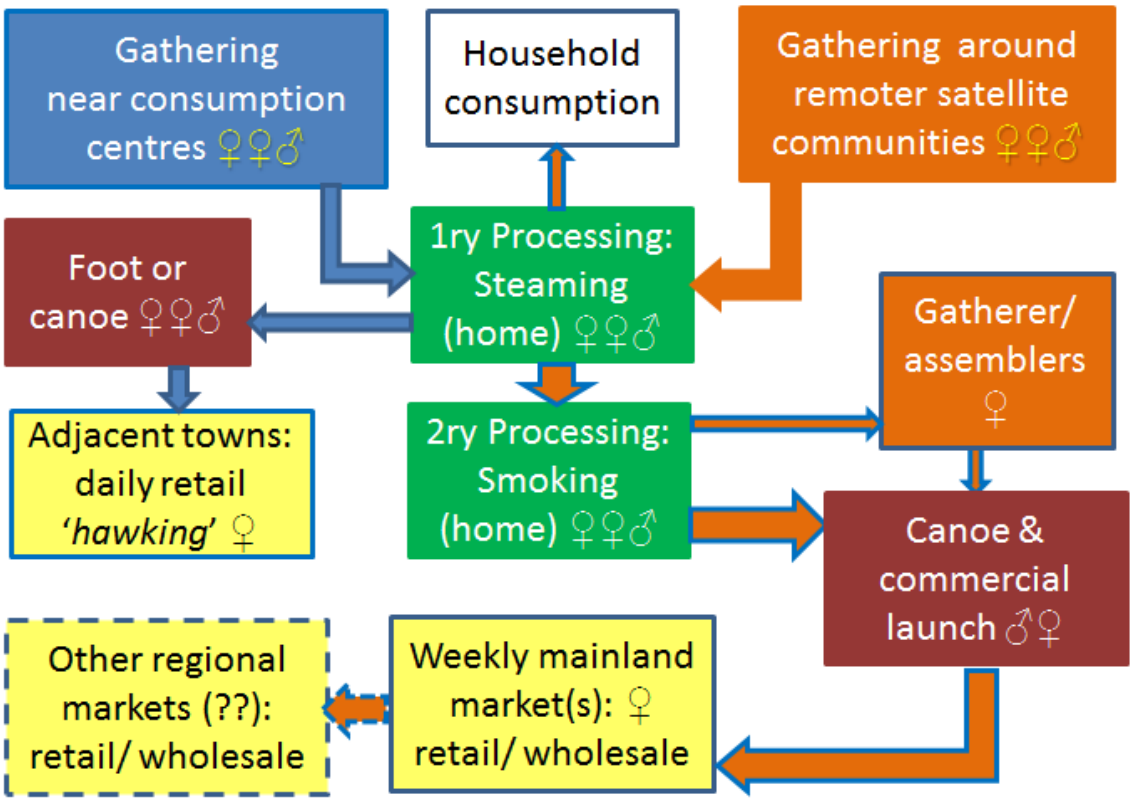


Fig 4.3 The Sherbro MPA Oyster Value-Chain (Note: (i) arrow thickness indicative of relative product volumes as live-weight equivalent (LWE) (ii) mix of ♀♂ symbols indicative of gender role dominance (iii) blue & orange background = production, green = processing, maroon = logistics, yellow = end-markets, dashed = further investigation required).

Table 4.7 Summary of Female Oyster Gathering and Marketing Effort Jan 2016

SN	Vill	Sale Form (%)[1]	Main Market(s)[2]	Yagoi Mkt trips/mnth	Le/cup[3] Steamed	Le/cup[3] Smoked	Bags/ Trip	Cups/ Bag[4]	Cups/ Day	Peak C/D[5]
1	GHN	Smk (100%)	Gb(1) Yg(2)	-	-	2,500	0.5-2	175-200	50	60-70
2	BBK	Smk (100%)	Y	-	-	-	-	-	-	60
3	BTB	Smk (80%), Stm (20%)	Yg(1) Bo(2)	2	-	2,500 1,000	3Max	100	10	70
4	GBM	Stm (100%	Bo	0	700-800	-	-	-	10-20	40
5	YKN	Smk (95%) Stm (5%)	Bo Bo	0	1,000	2,000	-	-	25-30	100
6	KGB	Smk (95%) Stm (5%)	Yg(1) Bo(2)	2	-	-	1-1.5	300-400	6	-
7	YRK	Smk (80%), Stm (20%)	Yg(1) Yk(2)	4	1,500 1,000	2,000 2,000	-	-	-	-
8	MMY	Smk (100%)	Yg	-	1,500	-	1	200	-	-
9	KJM	Stm (100%)	Bo	0	1,000	-	-	-	-	60
10	***FTW****	***Stm (100%)***	***Calaba***	***NA***	***3,000***	***-***	***-***	***-***	***-***	***-***

[1] Smk = Smoked, Stm = Steamed (note: %'s refer to fate of surplus production after home consumption)
[2] Y = Yankain, G= Gbambatok, Bo = Bonthe, Yk = York
[3] Prevailing exchange rate approx. SLL 8,000: £1and SLL 6,000 = $1
[4] Mean 400ml cup weight equiv. = 392g steamed (162 count), 367g smoked (215 count). See Annex 5
[5] Estimated yield range (cups per day) during peak season (Apr-July see Table 4.3)

* Two female vendors daily selling steamed oysters at Pamuronkoh market Calaba Town in Freetown (FTW).
Note: Smoked oysters were reported to have doubled in price from 1,000 per cup at Yagoi 4-5 years ago, whilst steamed oyster in Bonthe doubled from Le 500 just 2 years ago.

Plates 4.11a-d: Clockwise from top left: a. King St Market Bonthe; seafood sales limited to small amounts of smoked-fish and fresh fish landed by the market, b. female head-carriers 'hawking' fish landed at nearby villages at Bonthe Airstrip, c. steamed oysters hawked by the cup in Bonthe by local female processor on day of processing, d & e Stockpiled smoked oysters sold by the cup at Yagoi weekly mkt (Note: market adjacent to Sherbro river landing, covered & open sections visible).

(xi) Post-Harvest Value Added Marketing

- During a visit to a daily open-air retail market in Freetown (Pamuronkoh Mkt, Cabala Town, Jan 2016: Fig 4.4) only two female vendors were observed selling shellfish; steamed oysters and a type of winkle ('*okoto*': Plates 4.12a&b). The vendors who sell steamed produce only, on a daily basis buy processed product directly from harvesters every morning at the adjacent Pamuronkoh wharf serving the Sierra Leone River i.e. indicative of greater specialisation in production/ processing and marketing than in the Sherbro area.
- One vendor estimated current steamed oyster sales at 36 cups per day (approx. 14kg) and the other at 60 cups per day (approx. 23.5kg). As in Bonthe, transactions are entirely volumetric 'by the cup' with a heaped 400ml condensed milk tin retailing for Le 3,000 (and a half-third cup for Le 2,5000). This compares with concurrent prices ranging from Le 500-1,000 per cup of steamed-oyster in York town and Bonthe and Le 2,000–2,500 for smoked oysters in Gbambatok and Yagoi (Table 4.7).
- One male respondent near Bonthe (BTB) sent smoked oysters to his brother in Freetown, for his children to 'hawk' advising they could retail for up to Le 6,000.

- Should a reliable cost-effective cold chain be established, this price differential could conceivably be sufficient to allow profitable bulk extraction of still relatively low-value steamed oysters from the Sherbro MPA with implications for primary food security.

Plates 4.12a&b: Female oyster vendor Pamuronkoh market, CalabaTown, Freetown; local steamed oysters & okoto (winkles) sold by the 'cup'.

- Previous market research (Annual Report No. 1) indicated only limited export of smoked oysters; only 3 of 18 respondents interviewed across nine markets in Freetown sourced such oysters from Gbambatok or Yagoi. Whilst even inter-regional trade in smoked oysters may present quality assurance challenges given the current state of transport logistics, interpretation is complicated by (i) seasonal differences in the timing of interviews (i.e. low oyster season now and mid-high season for the earlier interviews) linked to seasonal availability and pricing effects (ii) the level to which chain-actors have imperfect knowledge of differences between regional markets (iii) disruption of commerce due to travel restrictions imposed during the Ebola crisis i.e. inter-regional flows may have been greater prior to the crisis. With development support, efforts are underway to rehabilitate and normalise 13 weekly markets in Bo, Kenema, Kailahun and Pujehun Districts adjacent to Bonthe DIstrict[17] (Annex 9).
- Project post-harvest supply chain interventions based on more commoditised product-forms (i.e. smoked and steamed oysters) should not increase the risk of unsustainable resource extraction. Under the prevailing poorly regulated, free-market conditions negative impacts on oyster and mangrove populations are a real risk to the detriment of primary food security. Particularly careful consideration must be given to deployment of solar cold-chain infrastructure in this respect.
- Primary project emphasis should therefore be on development of more niche and higher value-added strategies (i.e. commensurate with lower extraction pressure) together with improved understanding of and promotion of market potential for such goods. The project is pursing 2 options; sale of: (i) live fresh oysters, to foreign tourists and expatriates visiting beaches around Freetown[18] (Fig 4.4) (iii) steamed and or smoked[19] oysters as ready-meal ingredients through beach-bars, cold chain retail outlets in Freetown and other regional centres.

[17] http://awoko.org/2015/09/08/sierra-leone-news-weekly-market-rehabilitation-and-reactivation-for-boajibu-and-ngegbema-community/

[18] Preliminary analysis indicates such markets have adequate local supply of rock and mangrove oysters with potentially lower microbiological contamination risk. The socio-economic relevance of this strategy is therefore contingent on future up-scaling of this market and potentially more local transfer of live-oysters.

[19] Value-added interventions based on smoked-oysters should as far as possible be integrated with more fuel-efficient smoking techniques.

- Preliminary visits were made to four Freetown beaches (Fig 4.4) on a Sunday in January 2016. Regular live oyster sales were restricted to one of the southern-most beaches River No 2. Its relative remoteness, unspoilt nature and good road access appear to attract a more exclusive clientele (i.e. judged by parked luxury vehicles) than some of the more northerly beaches. Health risks of consuming oysters linked to higher population pressure and poor water quality may also be lower here. Another respondent suggested rock oysters were generally safer than mangrove oysters, being more likely to harvest in waters with full oceanic dilution. There are more erratic sales of live oysters on another similarly pristine but less easily accessible beach around 10km south of River No2 Beach.
- Only one vendor regularly supplies River No 2 beach with oysters he harvests himself from a nearby lagoon 'throughout the year', carrying on a business his uncle started before the civil war (Plates 4.13a&b). Is selling more rock-oysters than in the past, as mangrove oysters have become less available. He sells at Le 30,000 per dozen shucked oysters with lime, occasionally grilling oysters in shell on request for the same price. His oysters are particularly popular with Russian and Chinese tourists who typically eat 15-20 in a sitting, with business best on week days i.e. Mon-Fri. He described an optimal shell-size consistent with a mature single year class mangrove oyster; 'too big and wide and they are difficult to tip in the mouth'. During the rainy season he is careful to open oysters in seawater to enhance the flavour (thereby also increasing risk of microbial contamination). He is a member of the River No 2 Development Association (NDA) which organises business stalls and tourist seating, tables and umbrellas on the beach.
- Potential exists to develop this nascent market, particularly in the more northerly beaches where sales are limited by lack of quality assured local supply. Key challenges include (i) competition with local substitutes at low niche consumption levels i.e. from the Sierra Leone River (pointing to a need to consider a more localised interim-intervention strategy linked to conservation of residual mangrove stands adjacent to these beaches or the closer Sierra Leone River estuary) (ii) minimising risk of bacterial contamination in live mangrove oysters (Annex 6) (ii) introduction of a robust supply chain. Note due their inter-tidal location mangrove oysters have evolved to be particularly resistant to extended removal from water which may simplify or exclude cold-chain requirements.

Plates 4.13a&b: Live oysters sales River No. 2 Tourist Beach Freetown.

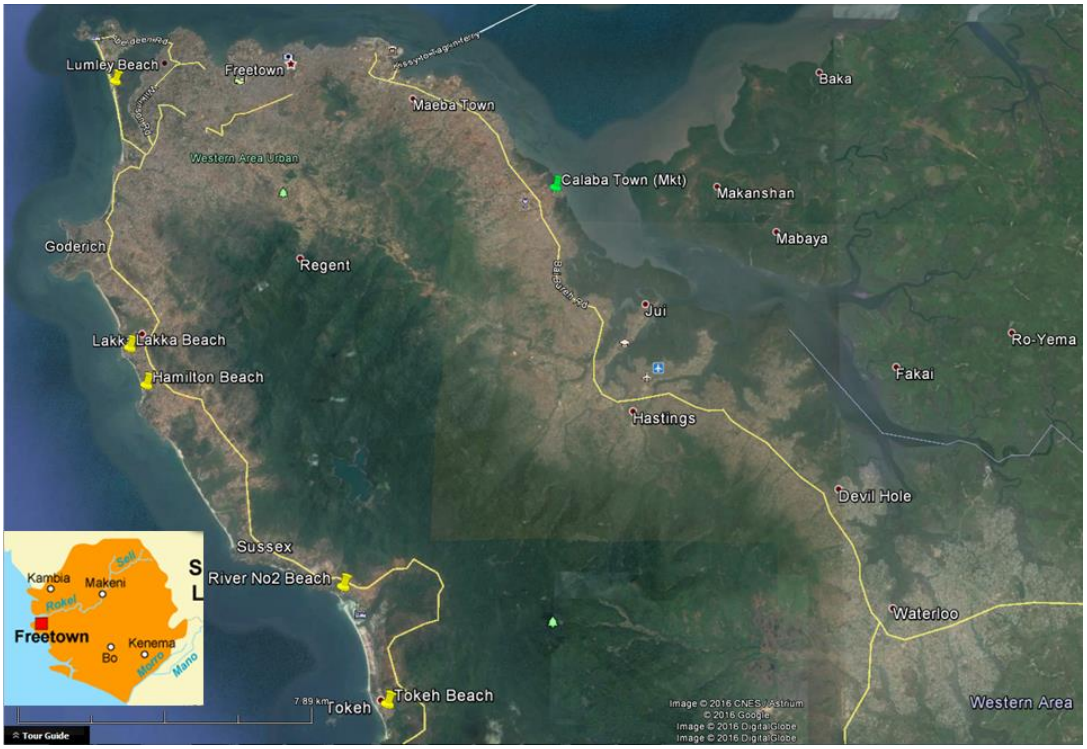


Fig 4.4 Freetown tourist beaches with live oyster sales potential (yellow flags) & local market with female vendors retailing locally sourced steamed oysters (green-flag)

- Whilst less value-added than live oysters, 'ready-meals' offer wider market options across market segments in intra and inter-regional population centres. For example fried-smoked oysters and bread are already sold snacks at regional markets (Section x). As with oysters, local food security requirements should be considered in choice of fillers. For example ground-nut and palm grown as cash crops in the Sherbro MPA offer a satay sauce option, chilies could be used in hot/ curried dishes Plates 14a&b).
- Key challenges include product development, promotion, quality assurance and distribution constraints. Consumer demand in key segments will be evaluated through focus groups and tasting alongside product placement with potential outlets.
- Locally appropriate low-tech opportunities for product shelf-life extension will also be explored, covering use of preservative ingredients (i.e. chili, smoked v steamed oysters etc.), vacuum packing technology as well as cold chain options. If properly branded and promoted vacuum packed 'Sherbro Smoked Oysters' could have potential for value-added sales in Freetown or other towns.
- Simple pasteurisation techniques could extend shelf-life of steamed product; even an extra-day could expand the spatial range of gatherers with access to this market.
- Processing plant for some of these options may need to be centralised (i.e. in Bonthe or York) for reasons of efficiency. Any such strategy will consider gender constraints, seasonal livelihood needs and complementarities. Lessons will also be drawn from other centralised collective interventions and specifically the challenges of enrolling involvement of women in satellite communities e.g. (i) facilities at Bonthe fisheries processing centre including cold-facilities and fuel efficient smoking units[20] (Plate4.15d) have seen negligible use since construction was completed over 5years ago (ii) In poultry-layer intervention targeting 20 vulnerable women in Bonthe, Local NGO Green Scenery shifted their initial development strategy of encouraging production in individual

[20] The Bonthe processing centre is one of four such 'state-of-the-art' coastal centres constructed in the last 10yrs with the intention of improving processing efficiency and product quality. The government was reported to be considering a public-private partnership with a foreign seafood company due to lack of commercial uptake to date. http://www.fis.com/fis/worldnews/search_brief.asp?l=e&id=81897&ndb=1

units within two purpose built buildings in Bonthe to smaller household based units (pers. comm.).

- Project affiliate Mr James Green, proprietor of Whitstable oysters and sponsor or the Whitstable Oyster Festival will bring commercial skills in post-harvest production and marketing to the project. Discussion and planning are underway for Bonthe Oyster Festival event in June 2017 with involvement of local institutions (e.g. Local Council, Radio Bontico, Fisheries Centre, CMAs). Recipe and product branding competitions will also be incorporated in the event.

Plates 4.14a&b: a. Milling ground-nut paste, King St. Market, Bonthe as an example of ready meal ingredient.

- Interim findings also highlight the challenge of ensuring reliable operation of cold-chain systems in this remote area. A freezer donated to the Yorktown community (for tandem operation in a solar powered mobile phone charging small enterprise) broke down after only 13months of operation (Plates 4.15a&b); the operators citing ‘a faulty compressor’ which they had removed. Similarly a flake-ice production facility and two chill rooms in the state-owned Bonthe fisheries processing centre (a model facility) had been inactive almost since their inception due to technical problems and delays in procurement and delivery of spare-parts. Similarly one of two solar powered freezers owned by one of the project staff was also inoperable due to unavailability of spare-parts. These examples highlight the need for adequate maintenance training and support and spare-parts access to be considered as integral parts of any sustainable cold-chain initiative.

Plates 4.15a-f: Clockwise from top left a&b: Failed Sundanzer 'solar' (12-24v DC) refrigerator York, Island due to 'faulty compressor', c&f: Non-operational cold-rooms Bonthe fisheries centre, e. Faulty solar freezer belonging to project member, awaiting shipment of spare-parts d. Fuel efficient fish smoking systems Bonthe fisheries centre with no community uptake as yet

Annex 5 Mangrove Oyster Processing Loss margin analysis (Francis Murray, James Green, Amara Kalone)

In order to understand potential value-addition strategies that might underpin adoption of oyster culture and or cold-chain logistics, a margin analysis was conducted around prevailing oyster processing practices, sales methods and prices.

Oyster marketing practices: Currently oysters and other seafoods including fish are marketed on a crude volumetric basis; in the case of oysters as steamed or steamed-smoked meats by the 'cup'; condensed milk tins (400ml) or other similarly sized plastic cups being commonly used (Plates: 5.1c-e). No use of weighing-scales was observed in either Sherbro of Freetown region markets for any commodity transactions.

The only observed exceptions to this pattern were niche sales of individual whole fresh live oysters to foreign tourists on beaches to the south of Freetown. Currently such sales are largely restricted to remoter 'unspoiled' beaches, favoured by foreign tourists and having nearby access to wild mangrove and rock oysters. Two beaches 'River No 2' and 'Tokeh' (Fig 4.4, Plates 4.13a&b) each had one male vendor specialised in self-harvesting and selling fresh oysters on a regular basis during the main (dry) tourist-season season. In each case oysters were sold by the dozen; shucked and served in the shell (with lime juice). Oysters were reported to be available on expression of demand (i.e. next day) on beaches nearer Freetown (Lumley and Hamilton) though no sales were observed. Higher contamination risk in these progressively more built up areas may also inhibit marketing of locally harvested oysters. Rock as well as mangrove oysters were available in Tokeh; where the vendor opined that foreigners stomachs 'were not hard enough' for mangrove oysters, suggestive of greater contamination risk in the more sheltered waters where the mangroves were growing.

Otherwise oysters are sold after primary processing as steamed, shucked meats for local sale whilst in the absence of any cold-chain, oysters needing to travel more than a few miles or to be stockpiled for sale at weekly markets in rural areas invariably undergo secondary smoking (Plate 5.1f). Demand in Freetown appears to be predominantly for locally sourced steamed oysters.

Processing loss and margin analysis scenarios: Three loss scenarios were assessed: (i) unit-weight yield, based on putative use of weighing scales (Fig 5.1), (ii) unit-price yield, comparing whole-fresh value-added versus smoked/ steamed oysters (Fig 5.2) (iii) volumetric yield, comparing steamed and smoked oyster value-addition (Fig 5.3).

Oyster sampling: Samples of fresh-whole and steamed (un-shucked) mangrove oysters were purchased from one of the communities near Bonthe (YKN). The steamed oysters were then

smoked according to local practice using 'white mangrove' wood purchased from the same community - sold in approx. 15kg bundles each costing Le 1,000 (Plates 5.1a&b). Separate oysters were used to assess the different processing phases i.e. whole to fresh meat weight (n=7), whole to steamed meat weight (n = 30), steamed to smoked weight (n = 75). The latter analysis was also repeated with 306 (21kg) of steamed whole oysters which were shucked and divided into 3 size classes: small 1.16g (STD +/-0.24g, = 1.6 cups) 1.79g (STD +/-0.1g, = 3.5 cups), large 2.8g (STD +/-0.24g, = 5.6 cups). This produced sufficient material to assess volumetric loss per cup.

Results: Results confirmed the magnitude of the potential margin to be had selling fresh whole oysters at Le 2500/piece compared to just Le 6.2/ piece and Le 9.3/ piece for fresh-steamed and smoked oysters respectively (Table 5.2), i.e. making whole oysters 406% and 269% times the value of the latter.

Value-added from steamed to smoking is contingent on the method used. Smoked oysters yielded 35% to 46% of the weight of steamed oysters (based respectively on bulk and individual weights: Table 5.1) whilst smoking added only 50% more value than steamed oysters adjusting for weight loss (Table 5.2). Smoking would therefore be likely to be a loss-making exercise if oysters were sold by weight, whilst realising 4-15% less than steamed oysters with no accounting for the additional costs of smoking. However, losses on the prevailing volumetric method (i.e. directly affecting behaviour patterns) were much lower, the number of steamed cups being reduced by only 27% following smoking commensurate with a 33% increase in the numbers of meats per smoked cup (Table 5.3). This represents a 23% gross value-added on steaming alone based on the prevailing doubling in market price for smoked oysters. However, net-profitability is also contingent on covering the additional costs of smoking. In this case Le 1,000 for 15kg of mangrove wood fuel would deduct an additional 6% of profit per cup of smoked oysters (costs declining for larger production volumes). Profit is further reduced if the additional cost of labour involved in smoking is included. Conversely profits could be increased through soaking of smoked oysters in water prior to sale, nominally done to (i) rinse of any shell, grit or smoking residues from the final product (ii) soften the meat prior to frying (popularly sold in sandwiches). *Further investigation of this practice is required – which may also have public health implications contingent on the source of water used.*

Underlying reasons for marketing preferences were generally poorly articulated by most respondents; time requirements for secondary processing and more distant marketing of smoked oysters being particularly under-valued. However a comparative analysis of marketing patterns described above (Annex 4, Section IX) further substantiates a preference for local retail of fresh steamed oysters above marketing of smoked oysters when the opportunity is available.

Table 5.1: Unit weight yield: whole to steamed to smoked

	N	Mean Weight (g)	SEM (g)	% Whole Live Wt	% Steamed
Whole fresh oyster (cleaned)	30	29.7	2.6	100	
Steamed whole oyster	30	23.1	2.3	77.8	
Fresh meat (liquids decanted)	7	3.1	1.2	18.3	
Steamed meat (individual) [1]	30	2.4	0.6	8.5	100
Steamed meat (individual) [2]	75	1.7	2.3		
Steamed meat (bulk)	[306] 3	1.9	2.2		
Steamed meat mean		1.8			
Smoked (individual)	75	0.8	1.7		46.4
Smoked (bulk)	[306] 3	0.7	0.2		34.5
Smoked meat mean		0.7		3.6	42.9

Table 5.2 Unit price yield: whole to steamed to smoked

	Price Basis (Le)	Unit Price (Le)	Whole Premium (x) [4]	Smoked Premium (x) [5]
Whole fresh oyster (cleaned)	30,000/doz	2500[1]		
Steamed meat mean	1,000/cup	6.2[2]	405.6	
Smoked meat mean	2,000/cup	9.3[3]	268.8	1.51

[1] Fresh whole oysters selling for 30,000 per dozen on 'River No. 2' tourist beach, south of Freetown
[2] Based on a mean price of 1,000 le per cup averaging 162 steamed meats (Bonthe Town)
[3] Based on a mean price of 2,000 le per cup averaging 215 smoked meats (Bonthe & Yagoi)
[4] Multiple of value of whole to steamed or smoked oysters; or [5] smoked to steamed oysters
Note: Prevailing exchange rate = 8,000 Le: £ and 6,000 Le: $

Table 5.3 Volumetric (& meat count) yield: steamed to smoked

	Meats Per Cup	Total Cups	Smoking Loss Meat No's %	Smoking Loss Volume%
Steamed	162	11.1		
Smoked	215	8.1	32.5	27.0
Smoking Loss corrected price (Le)			1,349	1,459
Loss corrected price inc. wood fuel (Le)			1,259	1,369
Fuel as % retail cost			7	6

Plates 5.1a-f: Clockwise from top left: a. mangrove fuel wood being sold, King St. Market Bonthe, 30kg of white mangrove retails for Le 4,000 - or 2,000 for 'farm-gate' uplift from satellite villages, b. 15kg of mangrove (4 logs) used to smoke the yield of 306 oysters shown front, c-e. Demonstrating marketing of smoked and steam oysters 'by the cup, f. Rice-bag of smoked oysters in roof space, stockpiled for sale in Yagoi weekly market.

Annex 6 Preliminary assessment of human pathogen contamination risk through assay of faecal indicator organisms (FIO) in mangrove oyster flesh (Dr R. Quilliam).

Background to shellfish regulatory monitoring in the EU

In Europe, shellfish beds are assigned a classification grade under EC/854/2004 based upon *E. coli* concentrations within shellfish flesh (Table 6.1). Subsequently, the classification grade assigned to an individual shellfish bed impacts not only consumers, but also the shellfish industry, as it dictates the level of post-harvest treatment required for shellfish products at each classification grading, and could promote either a change in management practice or a temporary closure of the harvesting area. Previous research has shown that environmental factors such as seasonality, tidal state & rainfall events, and position on the bed may alter concentrations of *E. coli* detected within shellfish tissues and hence affect the classification assigned to a harvesting area (Clements et al., 2014). Subsequently, the classification assigned to each shellfish harvesting area has substantial economic implications for both the local and wider shellfish industry.

Table 6.1: Current regulatory classification according to EC 854/2004

Shellfish bed classification	*E. coli* concentration (100 g^{-1} flesh)	Management requirements
A	< 230	Can be harvested for direct human consumption
B	230 - 4,600	Can be sold for human consumption: (i) after purification in an approved plant, or (ii) after re-laying in an approved Class A re-laying area, or (iii) after an EC-approved heat treatment process.
C	4,600 – 46, 000	Can be sold for human consumption only after re-laying for at least two months in an approved re-laying area followed, where necessary, by treatment in a purification centre, or after an EC-approved heat treatment process.

Sampling and processing mangrove oysters (Bonthe)[21]

Clusters of oysters were collected from a boat by carefully cutting them from mangrove tree roots or the strings of an artificial oyster rack (part of growth evaluation exercise). Oyster samples were stored in sterile plastic zip-lock bags and kept out of the sun whilst being transferred back to the lab for further processing. Individual oysters were opened aseptically and the flesh and extra-cellular fluid combined in a sterile container (each sample of ca. 5 g was obtained from approximately ten individual animals); an additional 20 ml of sterile phosphate buffered saline (PBS) was added to each sample to allow homogenisation. Samples were homogenised for 60 seconds at 10,000 rev min^{-1} using a Bamix® blender (Seal Rock Enterprises Ltd., Bishop's Stortford, UK), and 100 µl of homogenate streaked out onto MLGA media to quantify *E. coli* concentrations (diagnostically blue or blue-green colonies). All plates

[21] Reference: Clements K, Quilliam RS, Jones DL, Wilson J, Malham SK. (2015). Spatial and temporal heterogeneity of bacteria across an intertidal shellfish bed: implications for regulatory monitoring of faecal indicator organisms. Science of the Total Environment 506–507, 1-9.

were inverted and incubated at 37 °C and Colony Forming Units (CFU) were enumerated after a 24 h incubation period.

Table 6.2: First sampling (20 January 2016) of the oyster rack near Bonthe Town Pier

Location on wrack[1]	Fresh weight (g)	*E. coli* (CFU 100 g^{-1})
September inside	4.78	2,092
September outside	3.50	57, 142
October inside	4.45	nd
October outside	3.36	nd

nd, not detected

[1] Month indicates spat collector placement time

Table 6.3: Sampling oysters in the Sherbro estuary (20 Jan 2016)

Site	Coordinates	Fresh weight (g)	*E. coli* (CFU 100 g^{-1})
2 (mud oysters)		2.95	nd
3		8.50	nd
4		3.58	419,000
5		7.15	28, 000
7		10.35	4,831
8		4.60	13,043

nd = not detected

Results from the first day's harvesting were variable (Tables 6.2 and 6.3). Only one replicate was taken from each sampling site or location on the rack and so it is unclear whether these data are an accurate representation of the true levels of *E. coli* contaminations. However, *E. coli* was used as a faecal indicator organism (FIO), and this data suggests that some of these oyster harvesting areas are contaminated by extremely high levels of faecal pollution.
Although FIOs are not necessarily directly pathogenic, the presence of faecal pollution strongly suggests that these oysters could be contaminated by human pathogens such as rotavirus, *Vibrio* spp., norovirus, *Cryptosporidium* & *Giardia*.
Based on these indicative results, use of the EU regulatory classifications for this sub-tropical shellfish harvesting site would not be practically useful as faecal pollution levels are so high that shellfish harvesting for human consumption wouldn't be allowed under the EU Directive, and the harvesting areas wouldn't even receive a classification.

On the second day samples were taken to understand spatial heterogeneity of *E. coli* contamination in oysters growing in the rack: strings laid in both September and in October were sampled by harvesting oysters growing at the top and the bottom of the external and internal strings. In addition, oyster samples were collected from three other sites in the estuary. Samples were processed as above, however, a variable temperature profile, due to a loss of power, throughout the incubation period meant that *E.* coli on these plates could not be quantified with any certainty the next day. There was however, blue *E. coli* colonies on all of the plates although as they were not growing as discrete colonies they could not be accurately enumerated.

Plates 6.1a-d clockwise L-R: a. Communal sealed latrine Bonthe, B. 'Drop-latrine' over tidal lagoon behind King St. Central Mkt Bonthe, c & d Richard Quilliam (UoS) and James Green (Whitstable Oysters) inspect oyster bacterial colonies established on culture plates.

Annex 7 Water quality analyses, Bonthe Town pier, Oct 2015 to Apr 2016.

Measurements on five key oyster growth and reproductive parameters; salinity (Fig 7.1), Secchi Depth and Total Dissolved Solids (TDS: Fig 7.2), temperature (Fig 7.3) and pH (Fig 7.4) were measured daily by a local partner (EJF) from Bonthe Town pier at high and low tide (all in-situ measurements). Located on the inland side of Sherbro Island, the relatively sheltered sample site is exposed to semi-diurnal (i.e. 2x daily) tidal flows from the northern and southern mouths of the estuary mixing with freshwater from the Sherbro River to the East i.e. the site is effectively located in a sea-channel (rather than semi-enclosed lagoon) at the mouth of an estuary.

Salinity was measured using a refractometer, pH and TDS using conductivity meters. Secchi values can be used to estimate phytoplankton concentration; the primary oyster food sources. Unfortunately, Secchi depth measurements were discontinued following provision of a Milwaukee T75 TDS meter, but will be resumed as a simple robust and scalable method under local field conditions. All low-tide measurements were also discontinued in February.

Trends are highly correlated with seasonal rainfall patterns (no data); salinity, temperature and pH reaching seasonal lows early in the rainy season (Jul/Aug to Dec/Jan), climbing steadily thereafter before finally plateauing during the dry season (Jan/Feb to Jun/Jul).

Although a euryhaline species, oyster reproduction and inter-annual survival of year classes is highly correlated with salinity levels, spat-fall being triggered with onset of rains. Salinity ranged from a brackish 5ppt in Nov to a full oceanic 35ppt in April. Temperature ranged from 25 to 34 ^{o}C over the same period and pH from 7.4 to 8.4. Tidal differences were small for all parameters with the exception of Secchi values which were much lower at low-tide. Low tide levels rose from a low of 20cm (i.e. indicating high turbidity) in October to a peak of 60cm in November i.e. when measurements were discontinued. The low level and wide difference between high and low tide is indicative of high flushing rates, nutrient replenishment and carrying capacity for oysters. The marked ‘spikes’ punctuating the longer term trend-line appear correlated with spring and neap tide conditions. TDS, more indirectly indicative of nutrient conditions for phytoplankton growth, rose from 220ppm in Nov to fluctuate around 350ppm from Jan April (max 450 ppm in Feb-Mar). The level and timing of the maxima i.e. out with the periods of highest inorganic turbidity associated with rains, may also reflect seasonal salinity fluctuation interference.

From May 2016 onwards, the sample regime will be extended to include sites representative of higher and lower salinity conditions in less and more sheltered areas i.e. with lower flushing rates across the inner estuary. Crude oyster carrying capacity assessments will also be made based on experimental assessment of mangrove oyster phytoplankton clearance rates, tidal flows (using drogues), Secchi and total suspended solids (TSS) estimates.

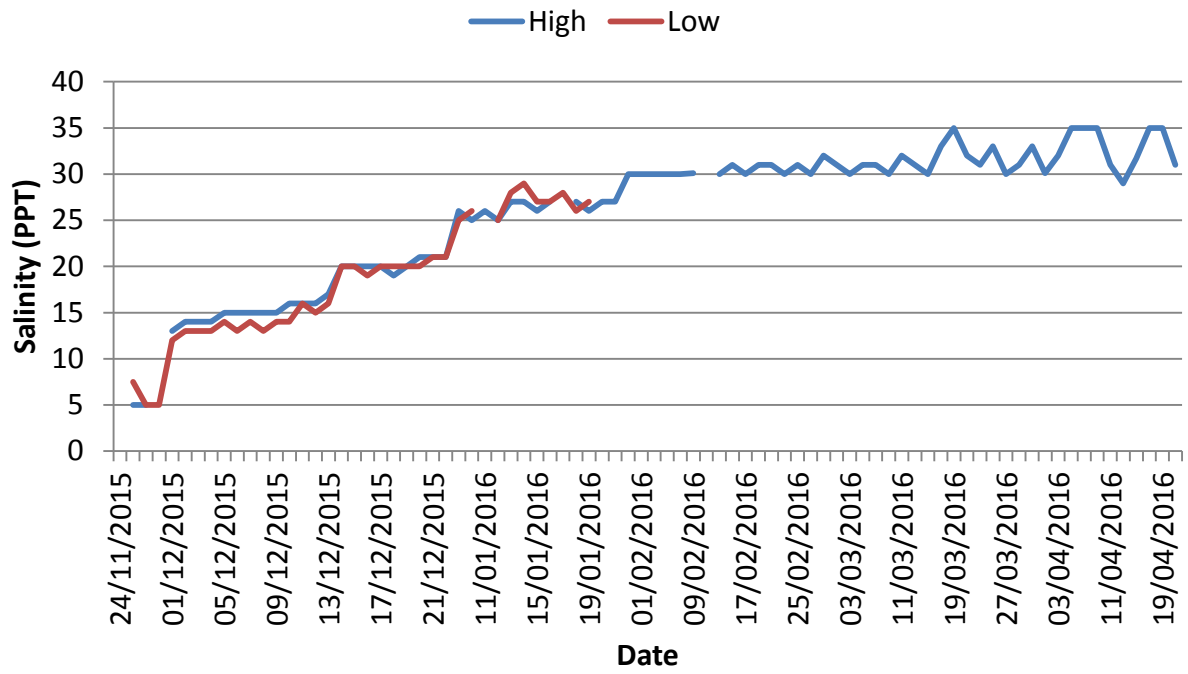


Fig 4.1. Salinity, Bonthe Pier Nov15 – Apr 16

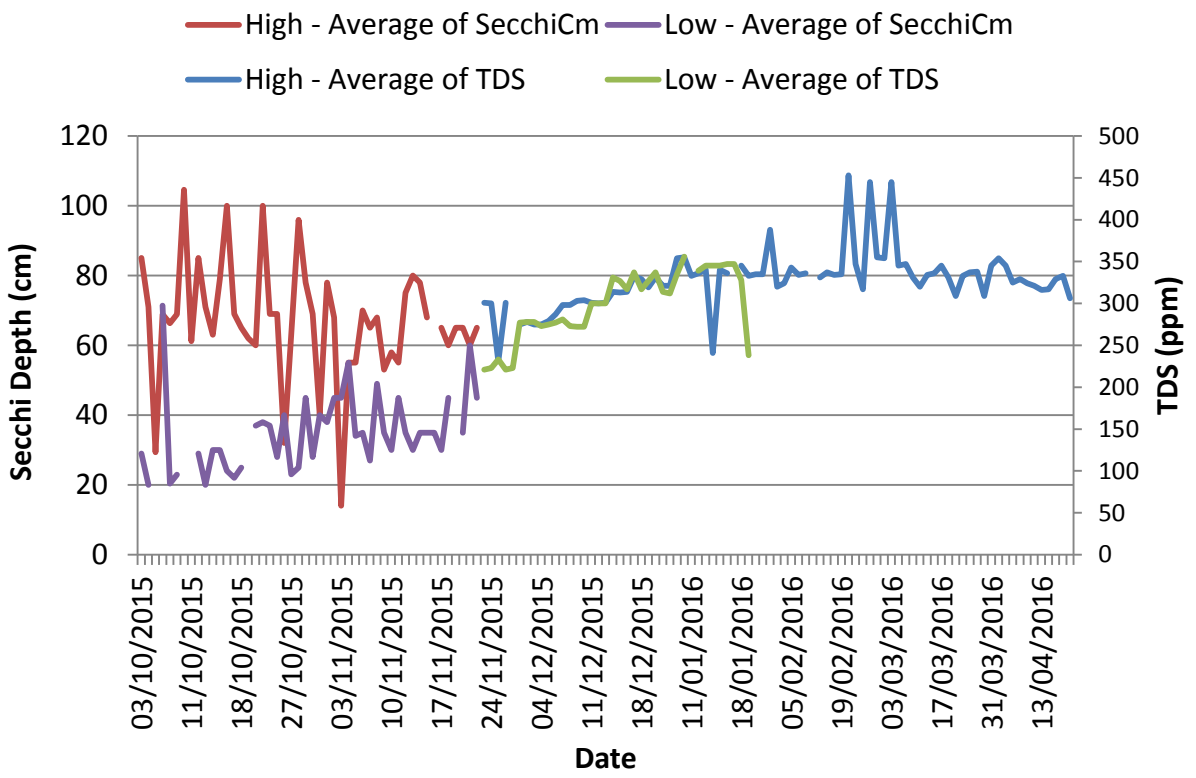


Fig 4.2. Secchi Depth and Total Dissolved Solids (TDS), Bonthe Pier Oct 15 – Apr 16

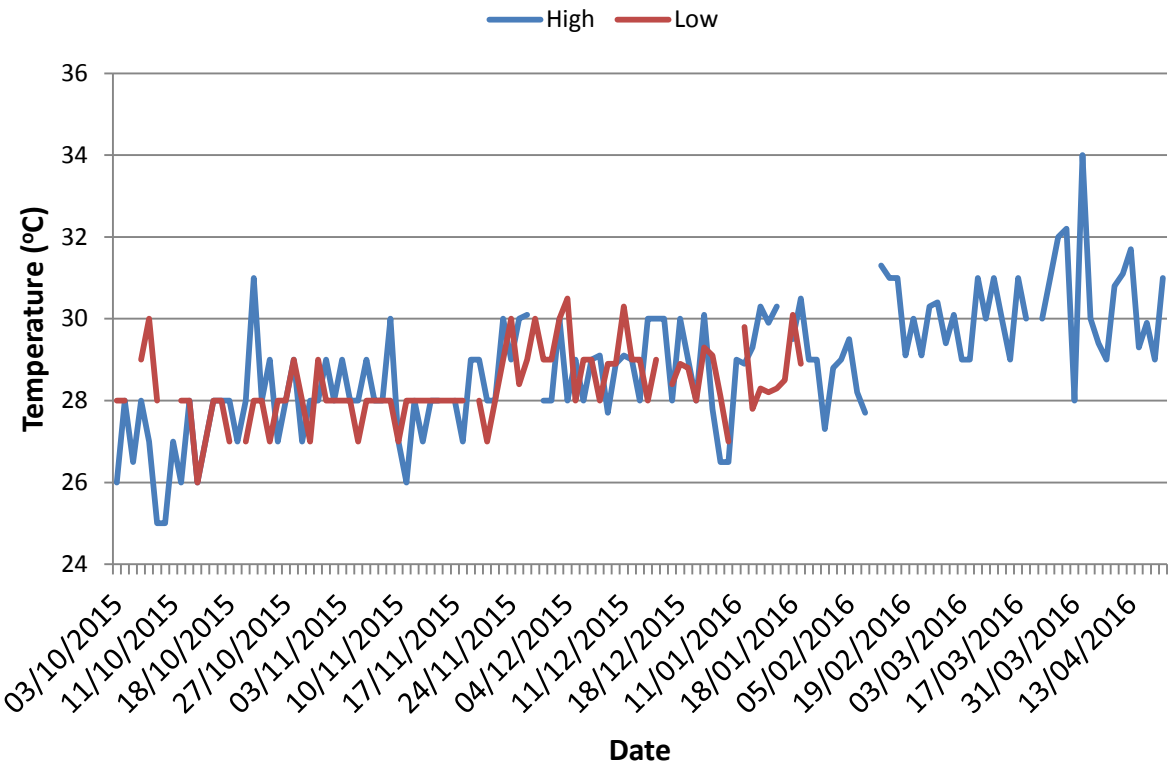


Fig 4.3. Temperature, Bonthe Pier Oct 15 – Apr 16

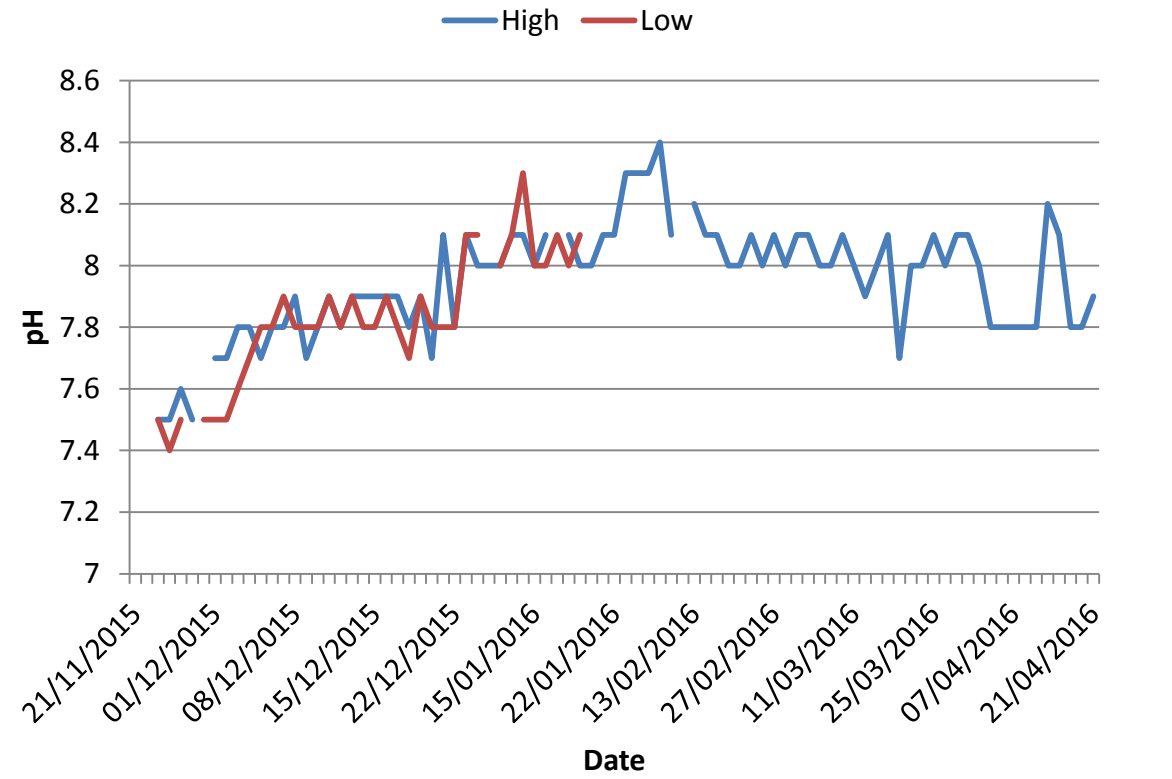


Fig 4.4. pH, Bonthe Pier Nov 15 – Apr 16

Annex 8 Oyster culture options based on local resource availability (James Green; Development Manager, Whitstable Oyster Fishery Company)

Bonthe is very isolated making getting materials for any sort of aquaculture and shipping any final product very difficult and expensive. Also if you do import materials of value the likelihood is that they may end up being used for some other purpose. An initial proposal of using rafts was soon realised to be impractical and overly expensive as the main materials needed - flotation, mooring rope and sinkers were not available in Bonthe. It was therefore decided trial a rack system with the emphasis on using locally available materials and a design that would be simple and cheap to build and repair. This also means they are less likely to be scavenged for materials. It can be used for both the spat collection phase of the oyster production and the grow-out phase (Plates 8.1a,b,c,e,h).

The sewage management in Bonthe relies on cess pits that do not enter the river so proximity to the community was not considered a problem for the cultivation of oysters. The rack location was also not far from the water sampling site (Annex 7: results also came back clear from any heavy metal contamination).

The trial rack was built over three days using wooden poles and rope bought at the local market. It was placed in close proximity to Bonthe and the mangroves as this was considered to be of the utmost importance so as to be within easy canoe distance (the mangroves near the communities in the Bonthe area had also been heavily harvested for oysters by chopping the mangrove with the oysters still attached).

The rack measured approx 3.5m by 12m and has two levels to hang the spat collectors from to compare collection and growth of the oysters at two depths one of which is below the mean low water mark and the other in the intertidal zone were the oysters are usually found on the mangroves (The tidal range was measured at approx 1.5m). There is room for 40 strings of spat collectors on each level each with 15 oyster shells on. The cost of the trial facility was 60,000 leones for the wood, 55,000 leones for the rope bringing the total cost to date of 115,000 leones[22].

Staff at EJF in Bonthe were shown carefully how to make the collectors and asked to inspect the rack on a regular basis. Local fisherman and communities were informed and told the purpose of the rack. Proximity of the racks to the communities who would manage them was a key issue arising in discussions with the communities. As they only had a small tidal window to harvest wild oysters and as the season progressed they had to go further and further to get to the best oysters. Any cultivation would have to be close and easily accessible at all states of

[22] Prevailing exchange rate approx. SLL 8,000 : £1

tide-this is a big benefit and one that can be used to encourage people to put the effort in to starting oyster cultivation.

As well as having spat collectors suspended to cover sub-tidal and intertidal-positions on the rack; oyster shells were also laid on an adjacent and easily accessible sandbanks to encourage spat settlement for the growth of the more prized "mud oysters". This is standard procedure for many oyster farms. Water quality (Annex 7) synchronised with rack growth-trial will provide explanatory power for observed results.

If the trail is successful (and I don't see why ultimately it should not be given the large recruitment that obviously occurs each year) the main problem is going to be demonstrating incentive for communities to put effort into the cultivation of oysters given the relative abundance of the wild stock. They also need to do this whilst still trying to earn a regular daily income to survive.

There is a definite benefit in engaging the local communities so that they can grow oysters sustainably by minimising impact on the ecologically important mangroves. Thus incentives likely to underlie choice of rack construction materials must also be considered i.e. the relative accessibility, cost and operational life of mangrove v non-mangrove wood, bamboo etc.

Plates 8.1a-h: Clockwise from top left: a & b. Wooden racks for suspended oyster culture trial, Bonthe, c&h. juvenile oysters growing on suspended spat collectors, d&g. Mud oyster pilot culture site on inter-tidal mud bank facing Bonthe, e&f Oyster cultch spat collectors for pilot bottom and rack culture trials

Annex 9: Population and Demographic Trends

Table 9.1: Population, actual & predicted, Sierra Leone & Bonthe District 1963-2050 (Source: SL Statistic Office, Population & Housing Census 2004 & 2015).

Year	Sierra Leone	Bonthe District	Bonthe %	Bonthe Sex Ratio[1]	Sierra Leone Sex Ratio[1]
1963	2,180,355	73,245	3.4	94	98
1974	2,735,199	80,606	2.9	95	99
1985	3,515,812	97,975	2.8	97	99
2004	4,976,871	129,947	2.6	93	94
2015	7,075,632	200,730	2.8	-	98
2020	*7,160,373*	*200,161*	*2.8*	-	-
2025	*7,874,195*	*220,116*	*2.8*	-	-
2050	*11,391,787*	*318,447*	*2.8*	-	-

Data sources:
2014 census: http://www.sierra-leone.org/Census/ssl_final_results.pdf
2015 census, preliminary results: http://www.geohive.com/cntry/sierraleone.aspx
2020-2050 projections: UN - WPP 2015 Revision (medium) & extrapolated for Bonthe District

[1] Sex Ratio = Number of Males Per 100 Females

Table 9.2: Household occupancy & sex ratios, Bonthe District & Town 2004

Admin Unit	Population	No HH	Avg No/ HH	Males	Females	Sex Ratio [1]
Bonthe District	129,947	24,211	5.4	62,517	67,361	92.8
Bonthe Township	9,740	1,274	7.6	4,540	5,187	87.5
Total/ Weighted Avg	**139,687**	**25,485**	**6**	**67,057**	**72,548**	**92**

[1] Sex Ratio = Number of Males Per 100 Females. **Source:** 2014 census data

Table 9.3: Population & sex ratios, Bonthe District Chiefdoms 2004 & 2015 (SL Statistics)

SN	Chiefdom	Population 2004	Population 2015	Pop % Change	Male 2004	Female 2004	Sex Ratio 2014 [1]
1	Bendu Cha	4,680	7,009	49.8	2,293	2,387	96.1
2	Bum	18,827	24,031	27.6	9,060	9,767	92.8
3	Dema	5,301	7,512	41.7	2,555	2,746	93.0
4	Imperi	17,576	33,772	92.1	8,723	8,853	98.5
5	Jong	28,495	33,524	17.6	13,610	14,885	91.4
6	Kpanga Kemo	7,661	10,442	36.3	3,688	3,973	92.8
7	Kwamebai Krim	7,715	14,436	87.1	3,685	4,030	91.4
8	Nongoba Bullom	13,617	19,747	45.0	6,559	7,058	92.9
9	Sittia	13,449	21,815	62.2	6,295	7,154	88.0
10	Sogbini	7,853	10,949	39.4	3,734	4,119	90.7
11	Yawbeko	4,773	7,518	57.5	2,354	2,419	97.3
-	*Bonthe Town*	9,740	9,975	2.4	4,546	5,194	87.5
	Total	**139,687**	**200,730**	**43.7**	**67,102**	**72,585**	**92.4**

[1] Sex Ratio = Number of Males Per 100 Females **Source:** 2014 & 2015 census data

Table 9.4: 2004 & 2015 Population characteristics for districts adjacent to Bonthe with market potential for processed oysters (SL Statistics)

SN	District	Province	Chiefdom Wards	Sections	Enumeration Areas	Localities (villages)	Population 2004	Population 2015	% Change	Area (Km2)	Density 2015 Persons/km
1	Kailahun	Eastern	14	81	704	1,147	358,190	525,372	46.7	3,859	136
2	Kenema	Eastern	16	87	792	1,311	497,948	609,873	22.5	6,053	101
10	Port Loko	Northern	11	162	890	2,370	453,746	614,063	35.3	5,719	107
11	Tonkolili	Northern	11	80	825	1,398	347,197	530,776	52.9	7,003	76
12	Bo District	Southern	15	91	629	1,237	463,668	574,201	23.8	5,219	110
13	Bo Town	Southern	1	22	209	1					
14	***Bonthe***	***Northern***	***11***	***77***	***346***	***1,011***	***129,947***	***200,730***	***54.5***	***3,468***	***58***
16	Moyamba	Southern	14	142	616	1,831	260,910	318,064	21.9	6,902	46
17	Pujehun	Southern	12	94	477	847	228,392	345,577	51.3	4,105	84
18	Western Rural	Western	4	22	176	217	174,249	442,942	154.2	544	814
19	Western Urban	Western	8	65	1,349	2	772,873	1,050,301	35.9	13	80,792
	SubTotal		**117**	**923**	**7,013**	**11,372**	**3,687,120**	**5,211,899**	**41.4**	**42,885**	**122**
	Sierra Leone		**166**	**1,321**	**9,673**	**16,734**	**4,976,871**	**7,075,632**	**42.2**	**71,710**	**99**

Fig 9.1a&b: Districts (a) and major towns and roads (b) of Sierra Leone (MoD UK 1998)

Table 9.5: Populations of major Cities 1985-2015 (SL Statistics)

City/ Year	1985	2004	2015
Freetown	469,776	772,873	1,050,301
Kenema	52,473	128,402	200,354
Bo	59,768	149,957	173,905
Koidu	82,474	80,025	128,074
Makeni	40,038	82,840	126,059

Fig 9.2a&b: Yankain 'Islet' village 3km from Bonthe Town (a) empty site in Dec 2005 (b) settled village with 3 thatched huts and a smoke-house, Aug 2015 (Source Google Earth)

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