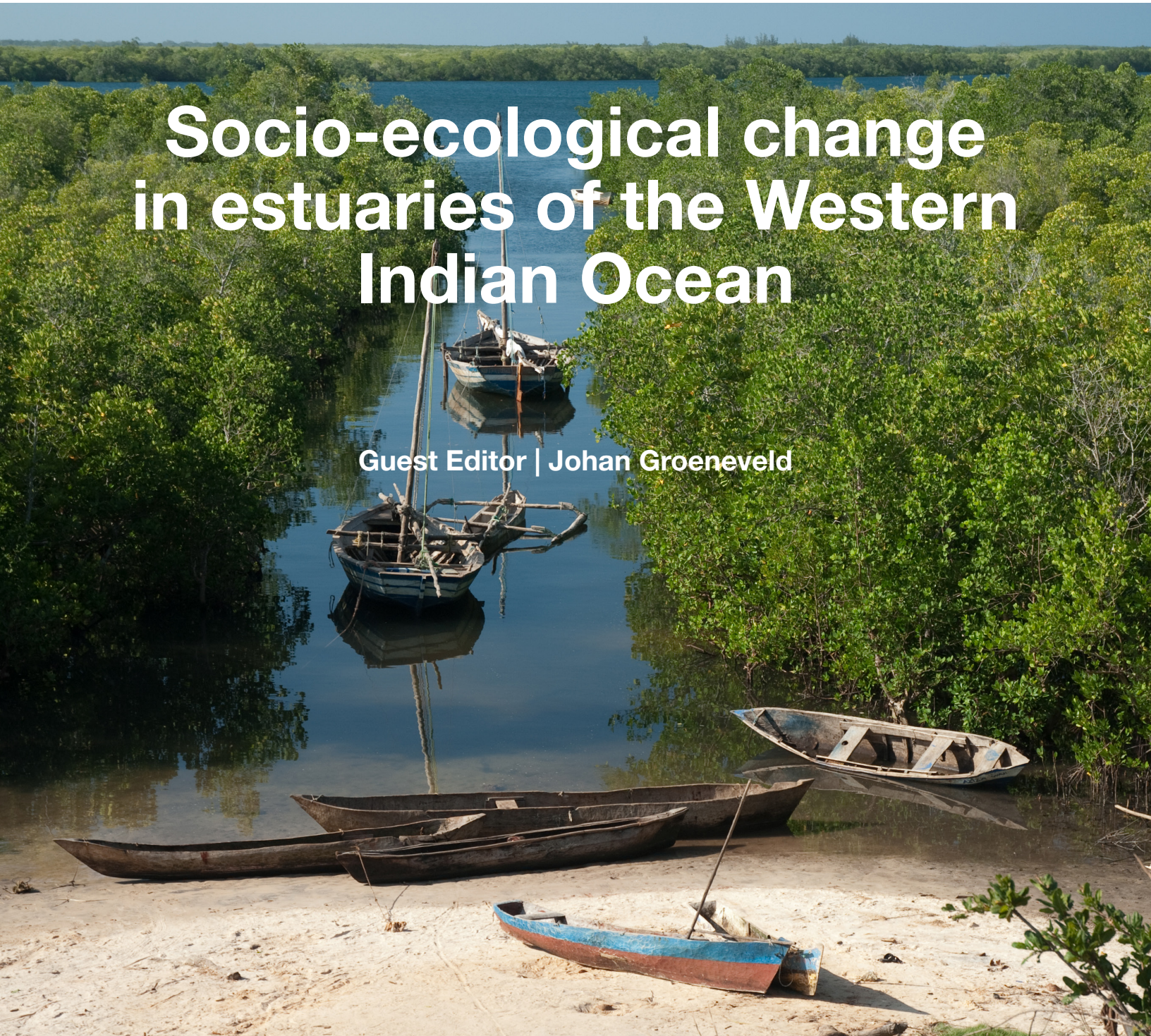
Western Indian Ocean
JOURNAL OF
Marine Science

Special Issue 1/2021 | ISSN: 0856-860X



Socio-ecological change in estuaries of the Western Indian Ocean

Guest Editor | Johan Groeneveld

Western Indian Ocean
JOURNAL OF
Marine Science

Published biannually

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ISSN 0856-860X

Cover image: The Rovuma Estuary creeks near Quionga in Mozambique. © José Paula, 2007

Household dependence on fish-based farming systems in the Bons Sinais Estuary in Mozambique

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Abstract

Households in estuarine deltas of the Western Indian Ocean depend on small-scale fishing, farming in flood-recession and adjacent areas, and mangrove forest products for food security, energy and an income in so-called deltaic fish-based farming (FBF) systems. It was hypothesized that the relative importance of household activities would depend on location along the Bons Sinais Estuary in Mozambique, diversifying in peri-urban settings. Semi-structured interviews were undertaken at five sites, including rural sites near the estuary mouth and upstream, and peri-urban settings near Quelimane city. Fishing contributed the most to FBF livelihoods (54 %) followed by farming (15 %), small business operators (14 %), collection and use of mangrove products (6 %) and other activities such as wage-earning or formal employment (10 %). The highest diversity of activities was at a peri-urban site, Chuabo Dembe, which differed from all other sites in Cluster and Principal Components Analyses. Fishing dominated activities at four of five sites, with the highest preponderance near the estuary mouth. Women played an important role in generating household income, mainly through farming and operating small businesses in peri-urban areas. The education level declined in rural settings. Overexploitation and degradation of natural ecosystems to provide for an increasing urban population around Quelimane threaten estuarine functioning, making deltaic FBF systems vulnerable. Rural development programmes should focus on improving education levels and the efficiency of food production, processing and distribution systems.

Keywords: rural-urban linkage, rural development, urban expansion, agriculture, fishing, mangrove, charcoal

Introduction

Hamerlynck *et al*. (2020) defined fish-based farming (FBF) systems along the edges of Africa's water bodies as "mixed fishing / farming households that derive from 30 to 50 % of their income from fisheries." The basic economic unit of FBF systems is the household (or even the extended family) with some individuals focussing more on fisheries, while others predominantly farm. It includes both genders – with women contributing to farming and sometimes to fishing in shallow waters from the shore. The inclusion of livestock keeping, hunting and gathering of forest products and occasionally wage-earning makes FBF systems flexible and increases resilience and adaptive capacity of households during periods of change (Blythe, 2014; Blythe *et al*., 2014; Hamerlynck *et al*., 2020).

FBF systems occur in a wide range of climatic zones and ecosystems in sub-Saharan Africa, including marine (sandy coasts, coral reefs), fresh water (lakes and floodplains) and brackish water (estuarine) subsystems (Hamerlynck *et al*., 2020). They support an estimated 22 million fisher-farmers, of which about half live in extreme poverty (Hamerlynck *et al*., 2020). In the Western Indian Ocean (WIO), FBF systems in estuarine deltas (termed deltaic fish-based farming systems) are characterised by brackish water habitats, use of mangroves forest products and a high diversity of fish and crustacean species in catches (often juvenile or small individuals). Deltaic FBF systems occur, *inter alia*, in the Bons Sinais Estuary in Mozambique (Furaca *et al*., 2021; Mugabe *et al*., 2021), Tana Estuary in Kenya (Manyenze *et al*., 2021; Mwamlavya *et al*., 2021) and Ruvu Estuary in Tanzania (Groeneveld *et al*., 2021a; 2021b). System-associated farming activities include tree crops (coconut, banana, mangos, various fruits and palms), maize and root crops such as cassava (Hamerlynck *et al*., 2010; 2020) and tidal or mangrove

http://dx.doi.org/10.4314/wiojms.si2021.1.3

rice cultivation, which relies on river floods and tidal bore to passively irrigate rice paddies (Hamerlynck *et al.*, 2020; Mwamlavya *et al.*, 2021). Harvesting of mangroves (forest products) for use as poles for building and charcoal for energy production form an integral part of deltaic FBF systems and is ubiquitous in WIO estuaries (Okello *et al.*, 2019).

Studies in the WIO region have highlighted several threats to ecosystem health and associated livelihoods around estuaries (papers in Diop *et al.*, 2016). Key among these are reduced freshwater input from upstream catchments (Duvail *et al.*, 2017) and change in land use and land cover (both upstream and in the estuarine zone) to accommodate the needs of growing human populations (Mwaguni *et al.*, 2016; Furaca *et al.*, 2021). These threats are exacerbated by overexploitation of estuarine habitats (mangrove cutting and clearing) and fish resources (Bosire *et al.*, 2016; Diop *et al.*, 2016) and increased climatic variability. At the estuary level, interventions are often hampered by low education levels of fisher-farmers, a lack of exchange between traditional and technical knowledge, and a limited understanding of ecological baselines and socio-cultural context (Hamerlynck *et al.*, 2020; Mwamlavya *et al.*, 2021). Full household livelihood spectra have rarely been assessed for deltaic FBF systems in WIO estuaries.

It was hypothesized that the relative importance of livelihood activities of deltaic FBF systems along the Bons Sinais Estuary in Mozambique would change along its length (i.e., linearly); and that activities would diversify in peri-urban areas around Quelimane city. Household surveys were used to investigate the demography and relative contributions of key livelihood activities of communities in rural and peri-urban settings along the estuary. We provide benchmark information for co-management approaches to maintain ecosystem health and flexible livelihood portfolios, within an existing socio-cultural context.

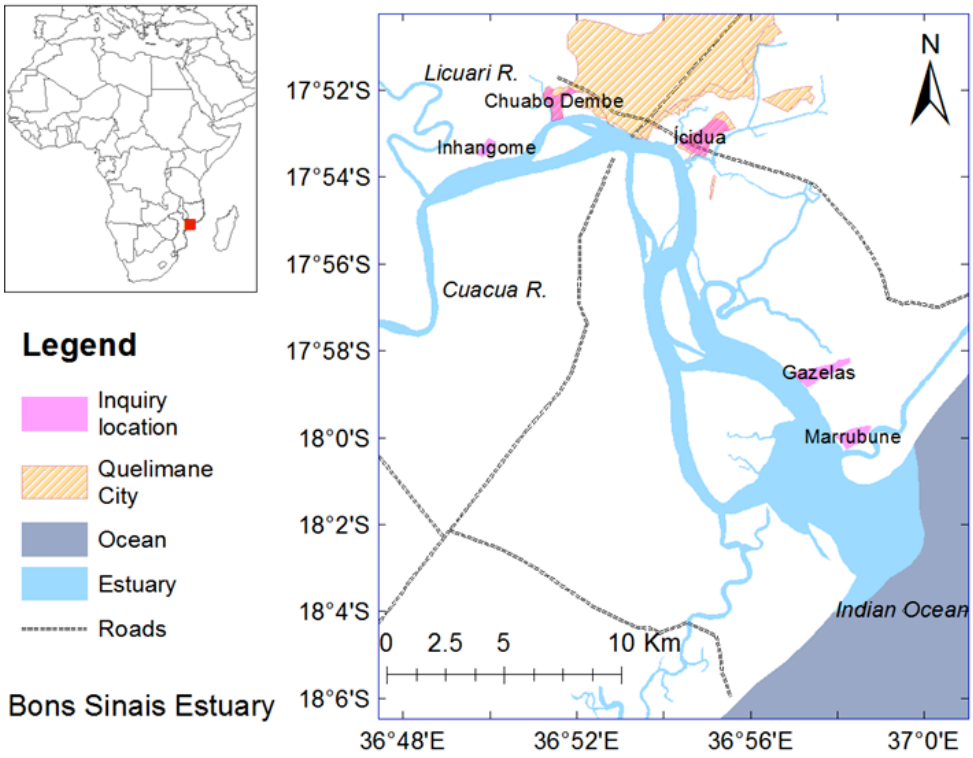

Figure 1. Location of sampling sites at Bons Sinais Estuary, showing Marrubune and Gazelas (rural areas near the coast), Icidua and Chuabo Dembe (peri-urban areas around Quelimane city) and Inhangome (rural area at the estuary head).

Materials and methods

The Bons Sinais Estuary discharges into the WIO at 18°01' S; 36°58' E and extends ~30 km inland to the city of Quelimane where a seaport is located (Fig. 1). The geographical setting, history of settlement, ecosystems and socio-ecological importance of the estuary have been summarized by Groeneveld *et al.* (2021a). Quelimane is the administrative capital of

Zambézia Province, with average population growth rate of 2.6 % per year (INE, 2007; 2017) and a population of ~400,000 in 2020 (www.populationstat.com). The estuary is surrounded by a mosaic of cultivated croplands and tree plantations, wetlands, mangroves and intertidal mudflats and built-up areas (Furaca *et al*., 2021). Five villages between the mouth and upper estuary were sampled (Fig. 1): Marrubune and Gazelas in a rural area near the estuary mouth; Icidua and Chuabo Dembe in peri-urban locations near Quelimane city; and Inhangome in a rural area at the head of the estuary.

Semi-structured interview questionnaires at household level were conducted, applying a purposive-random sampling method to select households (Deng *et al*., 2017). Interviews were conducted face-to-face with household heads or another household member, to collect qualitative and quantitative information on household demographics and livelihood activities. A standard questionnaire form is shown in Appendix 1.

Data were aggregated by site and activity and normalized to express activities as a proportion of households per site that participated in each activity. Household members frequently participated in more than one activity, and therefore proportional participation across activities often summed to >1.0 per site. The prevalence of each activity per site was first explored visually using a shadeplot of the data matrix (rows as activities, columns as sites). Data were further analysed using PRIMER 7 (Plymouth Routines in Marine Ecological Research) and selected procedures (see Anderson *et al*., 2008). A hierarchical agglomerative clustering using a Euclidean Distance similarity resemblance matrix with group-average linking of clusters was used to construct a dendrogram. Permutation based on similarity profiles (using the procedure SIMPROF) was

Table 1. Number of households and sample size per site for this study. The demographic profile of households is presented as percentages, based on interviews of household heads. For the Religion (%) category, Other includes local beliefs and non-responses. For the Education (%) category, "<" indicates that the specified education level was not completed.

Category and Level	Combined	Marrubune	Gazelas	Icidua	C. Dembe	Inhangome
All households (number)	4834	1118	750	1816	850	300
Sample size (numbers)	182	28	36	37	39	42
Sample size (%)	3.8	2.5	4.8	2.1	4.6	14.0
Gender (% male)	76	89	61	78	51	88
Marital status (% married)	79	96	74	62	69	95
Age group (% per category)						
16-25	31	25	17	41	40	21
26-35	30	21	47	22	20	29
36-45	18	25	17	11	13	19
46-55	10	4	6	11	20	5
>55	7		14		8	10
No response	4	25		16		17
Religion (%)						
Christian	62	11	74	49	79	86
Muslim	24	86	4	24	10	7
Other	9		22	8	10	7
Education (%)						
< Primary school	45	61	70	38	33	38
Primary school	25		26	24	36	31
< Secondary school	12	11		8	8	26
Secondary school	8	7		22	3	5
<Tertiary certificate	2			3	8	
No response	8	21	4	5	13	

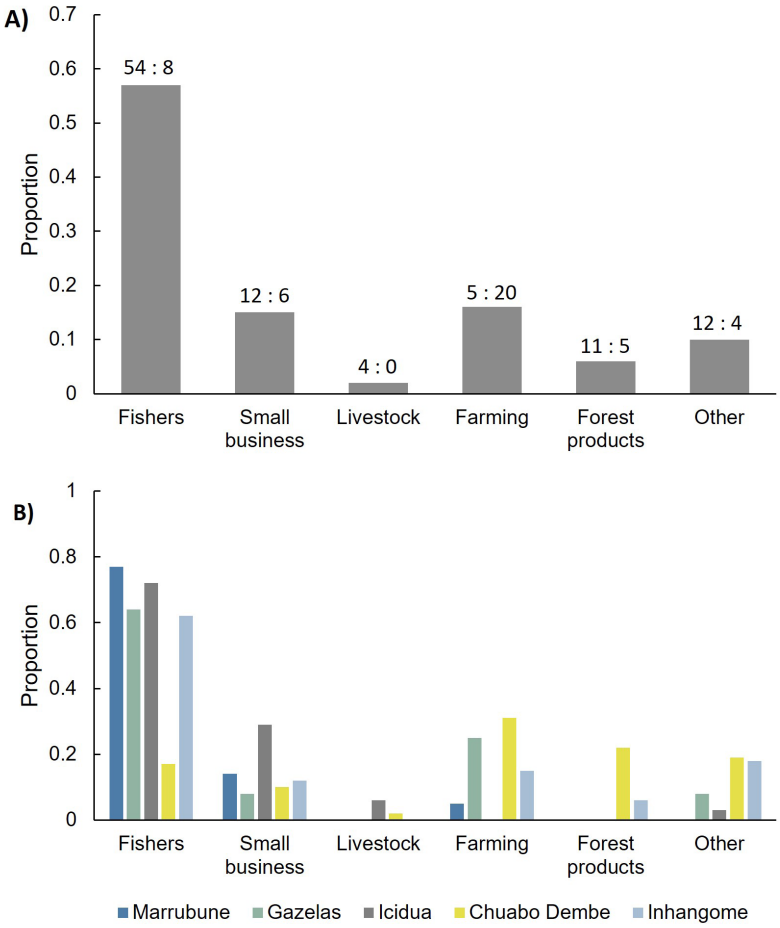

Figure 2. (a) Proportion of all interviewed household heads that answered affirmative per livelihood activity at Bons Sinais Estuary for all data combined. The percentages of men and women, respectively, that answered affirmative per activity are shown above the bars (% Men : % Women). (b) Proportion of all interviewed household heads that answered affirmative per livelihood activity at Marrubune, Gazelas, Icidua, Chuabo Dembe and Inhangome.

used to test for multivariate structure in the data at dendrogram nodes and significance levels were taken as <5 %. Principal Components Analysis (PCA) was used on the original normalised data using Euclidean distance as the underlying dissimilarity to ordinate sites according to the range of activities noted per site along two PCA axes. Activities were presented along vectors, vector lengths denoting the proportional importance of individual activities within and among sites.

Results

Demographic analysis

Interviews covered 182 households in five villages, representing an average of 3.8 % of households per village (Table 1). Men made up 76 % of all interviewees and the bulk of interviewees at Marrubune, Gazelas, Icidua and Inhangome, but equal numbers of men and women were interviewed at Chuabo Dembe (Table 1). Overall, 79 % of interviewees were married, and the rest were either single, widowed or divorced. Some 63 % of interviewees were younger than 36 y old and only 6 % were older than 55 y. The age structure of interviewees approximated the proportional demography of Quelimane in 2017 (INE, 2017): 44 % between 20-30 y, 19 % between 30-50 y and 7 % older than 50 y. Dominant religions were Christianity and Islam, with a large Muslim community at Marrubune (86 %) but mainly Christians at Inhangome, Chuabo Dembe and Gazelas. Literacy was low; of all interviewees, 45 % had not complete primary school education, 8% had completed a secondary school education, and only 2 % attended college. Literacy was lowest at rural sites, with 61 % (Marrubune) and 70 % (Gazelas) of interviewees not completing primary school (Table 1). There was no significant difference in the level of education of men and women.

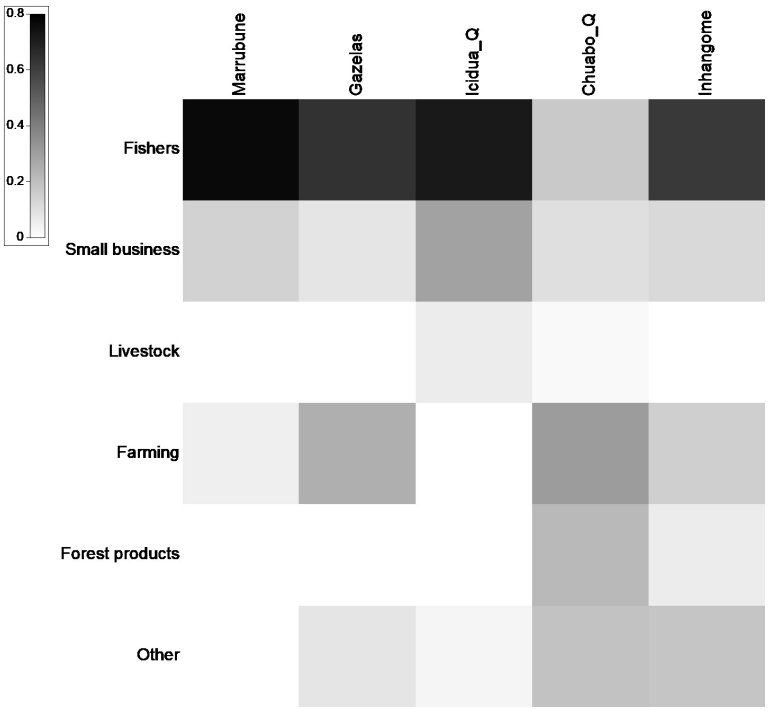

Figure 3. The prevalence of activities per site as the proportion of affirmative answers by interviewed household heads. Grey shading to black depict a high scale of activity and grey to white depict fewer or no instances of a particular activity at a sampling site.

Livelihood analysis

For all interviews combined, fishing contributed the most to livelihoods (54 %) followed by agriculture (15 %), small business operators (14 %), forest product collectors / dealers (6 %) and 'other' activities (10 %) (Fig. 2a). By gender, men focussed on fishing (54 %) whereas women participated mainly in agricultural activities (20 % overall). Few women participated in fishing (8 %). Both genders contributed to diverse livelihood activities at a lesser scale, with 6 % of women interviewees contributing as small business operators, 5 % as forest product dealers and 4 % undertaking other activities. Men contributed to small business (12 %), forest products (11 %), other activities (12 %) and livestock keeping (4 %) – the latter was only done by men.

Fishing dominated at Marrubune (77 %) and Icidua (72 %), Gazelas (64 %) and Inhangome (62 %) (Fig. 2b). Farming was important at Chuabo Dembe (31 %), Gazelas (25 %) and Inhangome (15 %). A broader spectrum of activities occurred at Chuabo Dembe; apart from farming (31 %), forest product dealers (22 %; mainly mangrove products), fishing (17 %) and small business enterprises (10 %) were important. A large proportion of 'other' activities (19 %) such as civil servants and college or shop employees was consistent with the location of a university college at this peri-urban site. Small business operators consistently made up 10 to 14 % of livelihood activities across sites (no sample at Gazelas).

The shadeplot showed the high importance of fishing at all sites, except Chuabo Dembe (Fig. 3). The plot further showed a greater diversity of activities at Chuabo Dembe than at any of the other sites. In the cluster analysis, Chuabo Dembe differed significantly ($p < 0.05$ at the node) from the other four sites (Fig. 4). Although not significant, the dendrogram clustered Gazelas and Inhangome (two rural sites relying on fishing and farming) as opposed to Icidua and Marrubune (two sites dominated by fishing). In the PCA, the first two principal components represented 96.1 % of cumulative variation. The ordination showed the overriding importance of fishing at Marrubune, and of farming and fishing combined at Gazelas and Inhangome (Fig. 5). Based on the range of activities, Chuabo Dembe was highly dissimilar to the other four sites, which grouped closer together. The grouping indicated a suite of fish-based farming systems, in which the relative importance of activities differed between sites.

Relative contributions of livelihood activities to household income

Fishing contributed most to household income at Marrubune (71 %), Gazelas (49 %) and Icidua (Fig. 6). Icidua is a peri-urban site, and where most fish

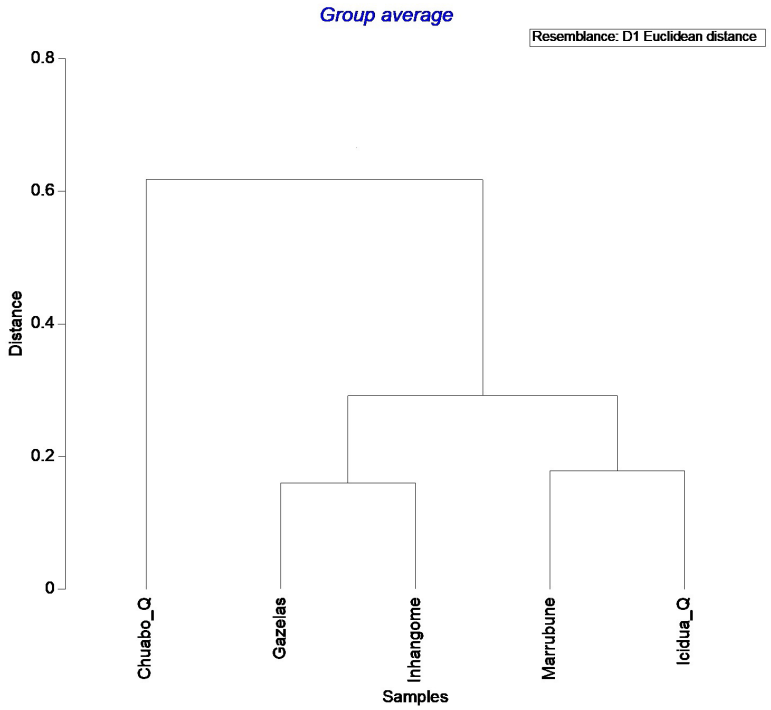

Figure 4. Dendrogram based on similarity profiles (using the procedure SIMPROF and Euclidean Distance) to test for multivariate structure in the data. Chuabo Dembe differed significantly ($p < 0.05$ at the node) from the other four sites.

intended for sale in Quelimane city is landed. Farming contributed most to household incomes at Chuabo Dembe (27 %) and Inhangome (32 %). The lower contribution of fishing to income at Inhangome (32 % relative to 62 % of household effort spent on fishing; Fig. 2b) is potentially due to captured fish being used for household consumption, rather than sold at markets. Operating small businesses contributed 18 % to household income at Marrubune, 17 % at Incidua and 12 % at Chuabo Dembe (Fig. 6). Contributions from 'other' sources were much larger at Chuabo Dembe (22 %) than at other sites, supporting a hypothesis of higher diversity of livelihood activities.

Discussion

The study aimed to determine the relative importance of livelihood activities in households that rely on FBF systems in rural and peri-urban settings around the Bons Sinais Estuary, based on a small dataset of 182 questionnaires directed at household heads, most of whom were men. The small and gender-biased dataset restricted the analyses that could be performed, but even so, clear trends emerged. Livelihood activities were dominated by fishing at most sites, but were diversified to include farming, collection and trade of mangrove poles and charcoal and small business enterprises. Unaite (2017) also found that 64 % of

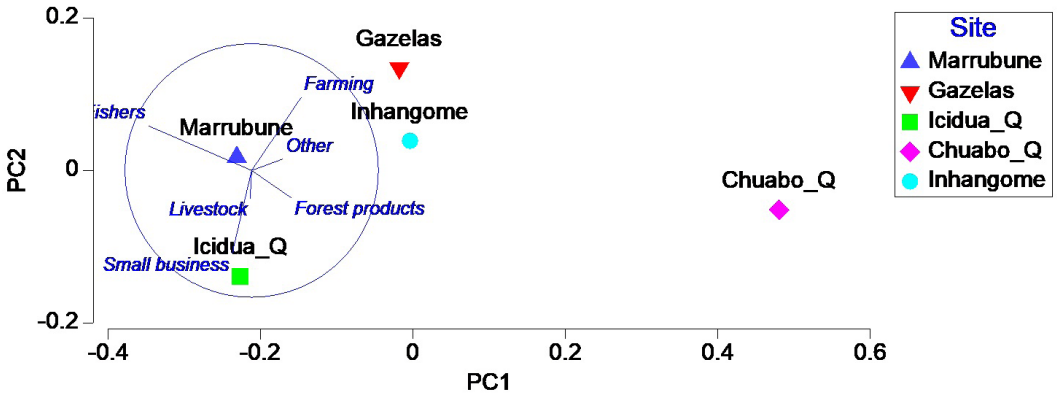

Figure 5. Principal Components Analysis (PCA) based on original normalised data using Euclidean distance to ordinate sites according to the range of activities along two PCA axes. Activities were presented along vectors, with vector lengths denoting the proportional importance of individual activities within and among sites.

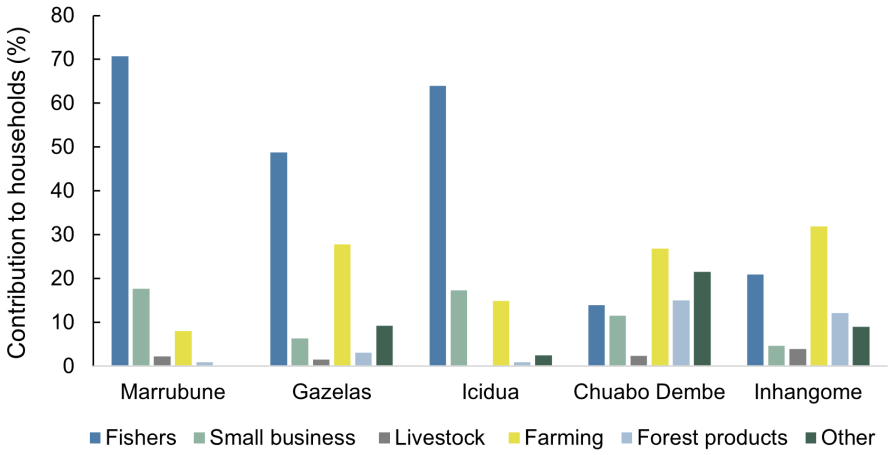

Figure 6. Relative contributions of livelihood activities to household incomes at the Bons Sinais Estuary at Marrubune, Gazelas, Icidua, Chuabo Dembe and Inhangome sampling sites.

households around the Bons Sinais Estuary included fishermen. The relative importance of household activities was further influenced by location along the estuary, reflecting the availability of specific resources and peri-urban concentration of markets. An emerging small business sector and higher percentage of paid employment (other activities) were evident at the peri-urban Chuabo Dembe site. Both initial hypotheses of this study (variability of the deltaic FBF system along the length of estuary; and rural/urban influence) were therefore accepted.

The mixed rural-urban form of living observed around Quelimane is common to many African towns and cities (Agergaard and Ortenbjerg, 2017; Agergaard *et al*., 2019) and elsewhere in the developing world (Sati *et al*., 2017; Shan *et al*., 2017). The inhabitants of newly urbanized areas are sometimes drawn back to rural livelihoods when unemployed, to supplement their income (Chibvongodze, 2013). Even so, the diversification of livelihoods at rural/urban edges can contribute to poverty eradication, better education and increased resilience of households (Drakakis-Smith *et al*., 1995; Cunguara *et al*., 2011; Potts, 2013; Thuo, 2013). Diversification forms an essential part of rural transformation and small-town development (Agergaard and Ortenbjerg, 2017; Agergaard *et al*., 2019).

Literacy declined at sites further from Quelimane (i.e., Marrubune and Gazelas), explained by the increasing distance to schools and a tertiary education college located at Chuabo Dembe. Fishing dominated livelihoods at Marrubune, leaving little time for further education at Quelimane, some 25 km away. Interestingly, literacy of farmers was similar to those engaged in small business and civil servants, though low, and the literacy of men and women did not differ. The Mozambique government has adopted education policies which includes adult literacy, the ability of people to make best use of the diversified income opportunities in a competitive market, and to improve their livelihood (INE, 2017; UNESCO, 2021).

At Chuabo Dembe, women were engaged with production and sale of charcoal and poles from mangroves. Women in rural Mozambique make a significant contribution to all stages of charcoal production which contrasts with much of the existing literature on charcoal in sub-Saharan Africa (Jones *et al*., 2016). Charcoal had different uses in livelihood strategies, including as an energy source and providing some financial autonomy for women, enabled by the informal nature of local regulations (Jones *et al*., 2016). The demands for agricultural products and charcoal are likely to increase as Quelimane city grows, thus continuing the important role of women in the local economies. Porsani *et al*. (2020) suggested that a gendered livelihood approach may give better insights to local culture in Mozambique, and hence increasing the number of women interviewed is likely to enhance inferences on livelihood strategies.

At present, rural and peri-urban forms of livelihood coexist around the Bons Sinais Estuary and are inter-dependent, strengthened by the demand for fresh food and energy from charcoal, and by marketing opportunities offered to farmers and fishers (see Allen, 2003; Allen *et al*., 2014; Kuusaana and Eledi, 2015). Whereas the mutually dependent system can prevail in theory, human population growth coupled with an ever-increasing demand for natural resources makes it ecologically unsustainable over a longer term.

Changing land use and land cover around the estuary over the past 27 years have indicated the degradation of wetland habitats (Furaca *et al.*, 2021) and estuarine fish and crustacean resources are heavily exploited for human consumption (Mugabe *et al.*, 2021). An additional concern is that rural livelihoods will remain a poverty trap, with few opportunities for education or alternative livelihoods, thus aggravating inequalities between rural and urban households (McMichael, 2000; Kuddus *et al.*, 2020).

Several authors (de la Masselière *et al.*, 2020; Gebre and Gebremedhin, 2019) have argued for sustainable urban-livelihood linkages that convey mutual benefits to rural and urban households. This would require support for rural development, such as improving food production systems to attain efficiency on land and water usage; introduction of innovative agriculture practices and energy production; and improvement of transportation infrastructure. In addition, there is a need for urban development planning (Deng *et al.*, 2017) – to prevent encroaching into low-lying areas prone to flooding. A key presumption of the above is that the capacity of rural households to contribute to innovation and the operation of more complex production systems will be enhanced by raising the level of education.

In conclusion, the Bons Sinais Estuary provides a good example of a deltaic FBF subsystem, with the relative importance of livelihood activities depending on location in the estuary, and diversification occurring in peri-urban areas near Quelimane. Women played an important role in generating household income, particularly through farming and dealing in forest products. The level of education declined further from urban areas, reducing opportunities of rural households. Degradation of natural ecosystems and overexploitation of living resources – to support growing human populations – threaten estuarine functioning, and hence dependent livelihoods. A programme for improved peri-urban planning, innovation of farming systems to increase efficient food production, and renewal of food production, processing and transport infrastructure is recommended. Improved education of rural communities is crucial, to enable them to participate effectively and harness benefits from the rural-urban linkage.

Acknowledgements

The research was integrated in the Estuarize-WIO project and funded by WIOMSA under a MASMA Grant. The authors wish to thank Johan Groeneveld (Oceanographic Research Institute) for guidance during the implementation of research, constructive suggestions and editing which significantly improved the quality of the manuscript. We thank Fiona MacKay (also from the Oceanographic Research Institute) for assistance with the statistical analyses undertaken. Two anonymous reviewers are thanked for helpful comments.

References

Agergaard J, Ortenbjerg SB (2017) Urban transformations and rural-city connections in Africa. Geografisk Tidsskrift-Danish Journal of Geography 117 (2): 63-67 [doi: 10.1080/00167223.2017.1367698]

Agergaard J, Tacoli C, Steel G, Ørtenblad SB (2019) Revisiting rural–urban transformations and small town development in Sub-Saharan Africa. European Journal of Development Research 31: 2-11 [https://doi.org/10.1057/s41287-018-0182-z]

Allen A (2003) Environmental planning and management of the peri-urban interface: Perspectives on an emerging field. Environment and Urbanization 15 (1): 135–148 [doi:10.1177/095624780301500103]

Allen A, Frediani, AA, Hill, MW (2014) Land and planning for urban agriculture in Accra: Sustained urban agriculture or sustainable urbanisation? Irrigated urban vegetable production in Ghana: Characteristics, benefits and risk mitigation. pp 161–179 [http://www.iwmi.cgiar.org/Publications/Books/PDF/irrigated_urban_vegetable_production_in_ghana-chapter-13.pdf]

Anderson MJ, Gorley RN, Clarke KR (2008) PERMANOVA+ for PRIMER: Guide to software and statistical ethods. PRIMER-E: Plymouth, UK. 214 pp

Blythe JL (2014) Resilience and social thresholds in small-scale fishing communities. Sustainability Science 10 (1): 157-165

Blythe JL, Murray G, Flaherty M (2014) Strengthening threatened communities through adaptation: insights from coastal Mozambique. Ecology & Society 19 (2): 6 [doi:10.5751/ES-06408-190206]

Bosire J, Mangora M, Bandeira S, Rajkaran A, Ratsimbazafy R, Apadoo C, Kairo, JG (eds) (2016) Mangroves of the Western Indian Ocean: status and management. WIOMSA, Zanzibar Town. 161 pp

Chibvongodze DT (2013) The ruralization of urban spaces in the context of subsistence farming: The case study of Gwabalanda Township, Bulawayo, Zimbabwe. Master of Development Studies in the School of Built Environment and Development Studies, University of KwaZulu-Natal. 115 pp [https://pdfs.semanticscholar.org/c078/5bfc7f18171a5766f926343ce3814a0faf6d.pdf]

Cunguara B, Langyintuo A, Darnhofer I (2011) The role of nonfarm income in coping with the effects of drought in southern Mozambique. Agricultural Economics 42 (6): 701-713

de la Masselière BC, Bart F, Thibaud **B**, Benos R (2020) Revisiting the rural-urban linkages in East Africa: Continuity or breakdown in the spatial model of rural development? The case of the Kilimanjaro region in Tanzania. Belgian Journal of Geography 1. 26 pp [https://doi.org/10.4000/belgeo.38669]

Deng W, Lu Y, Zhang S, Wan J, Song X (2017) Urbanization and its impact on rural livelihoods: A study of Xichang City administration, Sichuan Province, China. Chinese Journal of Urban and Environmental Studies *5* (4): 1750028 [https://doi.org/10.1142/S2345748117500282]

Diop S, Scheren P, Machiwa JF (eds) (2016) Estuaries: A lifeline of ecosystem services in the Western Indian Ocean. Part of the estuaries of the world book series (EOTW). Springer International Publishing. 322 pp [https://link.springer.com/book/10.1007%2F978-3-319-25370-1]

Drakakis-Smith D, Bowyer-Bower T, Tevera D (1995) Urban poverty and urban agriculture: an overview of the linkages in Harare. Habitat International 19 (2): 183-193 [https://doi.org/10.1016/0197-3975(94)00065-A]

Duvail S, Hamerlynck O, Paron P, Hervé D, Nyingi WD, Leone M (2017) The changing hydro-ecological dynamics of rivers and deltas of the Western Indian Ocean: Anthropogenic and environmental drivers, local adaptation and policy response. Comptes Rendus Geoscience 349 (6): 269-279

Furaca NB, Hoguane AM, MacKay F, Willemse M, Langa AAA (2021) Exploring urbanization and critical habitat loss through land cover change in the Bons Sinais Estuary, Mozambique. Western Indian Ocean Journal of Marine Sciences, Special Issue 1/2021: 43-58

Gebre T, Gebremedhin B (2019) The mutual benefits of promoting rural-urban interdependence through linked ecosystem services. Global Ecology and Conservation 20: e00707 [https://doi.org/10.1016/j.gecco.2019.e00707]

Groeneveld JC, Hoguane A, Kuguru B, MacKay CF, Munga C, Santos J (2021a) Estuarize-WIO: A socio-ecological assessment of small-scale fisheries in estuaries of the Western Indian Ocean. Western Indian Ocean Journal of Marine Science, Special Issue 1/2021: 1-15

Groeneveld JC, MacKay CF, Kuguru B, Mchomvu B (2021b) A simple socio-ecological change assessment of the Ruvu Estuary using remote sensing and fisheries information (Western Indian Ocean Journal of Marine Science, Special Issue 1/2021: 75-91

Hamerlynck O, Nyunja J, Luke Q, Nyingi D, Lebrun D, Duvail S (2010) The communal forest, wetland, rangeland and agricultural landscape mosaics of the Lower Tana, Kenya: A socio-ecological entity in peril. In: Bélair C, Ichikawa K, Wong BYL, Mulongoy KJ (eds) Sustainable use of biological diversity in socio-ecological production landscapes. Background to the 'Satoyama Initiative for the benefit of biodiversity and human well-being.' Secretariat of the Convention on Biological Diversity, Montreal. Technical Series (52). pp 54-59 [https://www.researchgate.net/publication/256191645]

Hamerlynck O, Nyingi DW, Paul J-L, Duvail S (2020) Fish-based farming systems: maintaining ecosystem health and flexible livelihood portfolios (Chapter11). In: Dixon J, Garrity DP, Boffa J-M, Williams TO, Amede T, Auricht C, Lott R, Mburathi G (eds) Farming systems and food security in Africa: Priorities for science and policy under global change Routledge. pp 354-392 [https://hal.archives-ouvertes.fr/hal-02615282]

INE (2017) Recenseamento Geral da População e Habitação. Instituto Nacional de Estatísticas [http://www.ine.gov.mz/iv-censo-2017]

Jones D, Ryan CM, Fisher J (2016) Charcoal as a diversification strategy: the flexible role of charcoal production in the livelihoods of smallholders in central Mozambique. Energy for Sustainable Development 32: 14-21

Kuddus MA, Tynan E, McBryde, E (2020) Urbanization: a problem for the rich and the poor? Public Health Reviews 41: 1 [https://doi.org/10.1186/s40985-019-0116-0]

Kuusaana ED, Eledi JA (2015) As the city grows, where do the farmers go? Understanding peri-urbanization and food systems in Ghana - Evidence from the Tamale Metropolis. Urban Forum 26 (4): 443–465 [doi:10.1007/s12132-015-9260-x] [Crossref], [Google Scholar]

Manyenze F, Munga C, Mwatete C, Mwamlavya H, Groenebveld JC (2021) Small-scale fisheries of the Tana Estuary in Kenya. Western Indian Ocean Journal of Marine Science, Special Issue 1/2021: 93-114

Mugabe ED, Madeira AN, Mabota HS, Nataniel AN, Santos J, Groeneveld JC (2021) Small-scale fisheries of the Bons Sinais Estuary in Mozambique with emphasis on utilization of unselective fishing gear. Western Indian Ocean Journal of Marine Science, Special Issue 1/2021: 59-74

Mwaguni S, Ruwa RK, Odhiambo-Ochiewo J, Osore M (2016) Integrated water resources management in a changing climate: The implication of anthropogenic activities on the Tana and Athi/Sabaki Rivers water

system for sustainable development. In: Estuaries: A lifeline of ecosystem services in the Western Indian Ocean. Springer, Cham. pp 111-129

Mwamlavya H, Munga C, Fulanda B, Omukoto J, Thoya P, MacKay F, Manyenze F, Groeneveld JC (2021) Natural resource-use in the Lower Tana River Delta based on household surveys and remote sensing of land cover and land use patterns. Western Indian Ocean Journal of Marine Science, Special Issue 1/2021: 115-129

McMichael AJ (2000) The urban environment and health in a world of increasing globalization: issues for developing countries. Bulletin of the World Health Organization 78 (9): 1117-1126

Okello JA, Alati VM, Kodikara S, Kairo J, Dahdouh-Guebas F, Koedam N (2019) The status of Mtwapa Creek mangroves as perceived by the local communities. Western Indian Ocean Journal of Marine Science 18 (1): 67-81

Porsani J, Börjeson L, Lalander R, Lehtilä K, Martins A (2020) Enriching perspectives–experienced ecosystem services in rural Mozambique and the importance of a gendered livelihood approach to resist reductionist analyses of local culture. Ecology & Society 25 (4): 20 [https://doi.org/10.5751/ES-11781-250420]

Potts D (2013) Urban livelihoods and urbanization trends in Africa: winners and losers? Environment, Politics and Development Working Paper Series *57*, Geography Department, King's College London, London [http://urban-africa-china.angonet.org/sites/default/files/resource_files/african_migration_urban_development_-_potts_-_kings_college_2013_0.pdf]

Sati VP, Deng W, Lu Y, Zhang S, Wan J, Song X (2017) Urbanization and its impact on rural livelihoods: A study of Xichang City Administration, Sichuan Province, China. Chinese Journal of Urban and Environmental Studies *5* (4): 1750028 [doi: 10.1142/S2345748117500282]

Shan L, Yu A, Wu Y (2017) Strategies for risk management in urban-rural conflict: Two case studies of land acquisition in urbanising China. Habitat International *59*: 90-100 [https://doi.org/10.1016/j.habitatint.2016.11.009]

Thuo ADM (2013) Impacts of urbanization on land use planning, livelihood and environment in the Nairobi rural-urban fringe, Kenya. International Journal of Scientific & Technology Research 2 (7): 70-79 [https://www.researchgate.net/publication/251236795_Impacts_of_urbanization_on_land_use_planning_livelihood_and_environment_in_the_Nairobi_rural-urban_fringe_Kenya]

Unaite MCP (2017) Analysis of causes and possible methods of dealing with mangrove deforestation in Mozambican coastal areas: a case study of Quelimane District in Zambézia Province. MSc Dissertation, World Maritime University Dissertations *576*. 92 pp [http://commons.wmu.se/all_dissertations/*576*]

UNESCO (2021) Mozambique: Education and literacy. UNESCO Institute for statistics. [http://uis.unesco.org/en/country/mz]

Appendix

Questionnaire ID

The questionnaire form.

ESTUARIZE-WIO - Work Package 2

QUESTIONNAIRE – Bons Sinais estuary

Date	Time started interview	Time completed interview	Interviewer's name

Section A: Basic identification of estuary

Qi. What's the name of the village? _____

Qii. What's the name of the ward? _____

Section A: Respondent Socio-economic characteristics

Demographic information (Provide information on Household heads or representative ONLY)

Q1. What is your name? _____

Q2. Sex of respondent
a) Male b) Female ☐

Q3. Marital status of respondent
a) Married b) Divorced c) Widowed d) Not married ☐

Q4. How old are you? (Years) _____

Q5. Gender of household head
a) Male b) Females

Q6. What is the household head tribe? _____

Q7. What is the highest level of education of household head? ☐
a) Not complete Primary
b) Complete Primary High School
c) Complete College certificate
d) Not complete College Certificate
e) Bachelor's Degree
f) Master's Degree
g) Doctoral Degree (PhD)
h) Professional Course (JD, MD)
i) Prefer not to answer

Q7a. Does the household head have a household elsewhere besides the one in this village? ☐
a) Yes b) No

Q8. If yes where is this other household located? _____

Q9. Where was the household head born? ☐

a) This village
b) Another village in the ward/Location
c) Another ward in this district/county
d) Another district/county Specify _____
e) Another region

Q10. If not born in this village, when did the household head move to this village? _____

Q11. What is your monthly household income level? _____

Q12. What is the size of the household head? _____

Q13. What is your religion? ☐

a) Christian
b) Muslim
c) Others: _____

Q14. How many years have you been living in the Bons Sinais estuary? _____

Q15. What is your main occupation? (only one answer)

a) Fisher
b) Small business trader
c) Livestock keeper
d) Agricultural farmer
e) Forest product dealer
f) Other Specify _____

Q16. What other economic activity are you involved in? (only one answer) ☐

a) Fisher
b) Small business trader
c) Livestock keeper
d) Agricultural farmer
e) Forest product dealer
f) Other Specify _____

Q17. What are the economic activities that are carried out in this village?

S/N	Economic activities	Tick activities in your village
a)	Fishing	
b)	Small business trading	
c)	Livestock keeping	
d)	Agricultural farming	
e)	Forest product harvesting and trading	
f)	_____	

Section B: Socio-economic activities and cultural practices

Q18. Please rank the main cultural economic/productive activities that sustain your household

S/N	Income generating activity	Percentage of income from activity	Rank
a)	Agriculture		
b)	Fishing		
c)	Forest (Timber, poles, firewood etc)		
d)	Non-timber		
e)	Salt making		
f)	Livestock		
g)	Business		
h)	Other Specify		

Q19. Provide the proportion of income (cash-sell by your households from the following

Source of income per month	Percent
Fishing	
Crops (including associated products, e.g., beer)	
Livestock (including all products eg meat, milk, skin, eggs etc)	
Non timber forests products (poles, firewood, charcoal, palms, wild meat, live animals birds, wild food plants, medicinal plants, honey, mushrooms, reeds, grasses)	
Timber product (income from sale of logs, timber or working in timber related activities)	
Business income (not related to own-production of arable produce or livestock or harvested resources)	
Pensions & remittances (all incomes from friends, relatives)	
Salt making	
Salary or wage (from formal employment)	
Other casual (cash or in kind earning)	

Q20. How much do you generate from each or any of the following economic activities per season (specify the season i.e. month, two months etc)

S/N	Activity	Output/ Production (Unit measure)	Amount consumed (Unit measure)	Amount sold	Unit price	Cost per season
a)	Agriculture					
b)	Fishing					
c)	Wood and Wood procuts (Mbao, Mkaa, Kuni, Fito					
d)	Salt making					
e)	Livestock					
f)	Other Businesses					

Unit measure: (1) Kg (2) Bags (3) Baskets (4) Number of fish pieces

Q21. Please give details on your livestock keeping.

Type of livestock	How many now	If you have to sell now, what is the average price
Chickens		
Goats		
Cattle (local)		
Cattle (dairy)		
Milk (litre) per day		
Duck		
Pigs		
Sheep		