frontiers in Marine Science

BRIEF RESEARCH REPORT
published: 04 March 2021
doi: 10.3389/fmars.2021.635281

Innovative Aquaculture for the Poor to Adjust to Environmental Change in Coastal Bangladesh? Barriers and Options for Progress

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More so than wealthier, less nature-dependent social groups, the poor in tropical coastal regions suffer from adverse environmental change and need new income options. With high levels of saltwater intrusion into coastal lands, innovative brackish water aquaculture (BWA) including integrated multi-trophic aquaculture (IMTA) are crucial adaptation options to the expanding marine waters. This article examines how poor Bangladeshi coastal residents view BWA, and what is needed to make BWA a viable and sustainable livelihood for the coastal poor. In sites that are affected by major salinity intrusion, we used a semi-structured questionnaire to interview 120 households. We examine three questions: (1) What kind of aquaculture is currently being undertaken in brackish/saline/coastal waters? (2) Do poor coastal residents see BWA (and, by implication the hitherto fairly unknown IMTA) as a viable and sustainable livelihood? (3) What is needed to make BWA a feasible and promising livelihood in Bangladesh? Our results show both information and perception biases obstruct in particular coastal poor women and men from engaging with innovative BWA. Their knowledge on ecosystem-based aquaculture was scarce and their views of aquaculture were related mainly to previous experiences with shrimp monoculture and its polarizing socio-economic effects. We propose some strategic fields of action to develop innovative BWA that also benefits coastal Bangladesh's poorest people.

Keywords: pro-poor innovation, marine and coastal change, brackish water aquaculture, integrated multi-trophic aquaculture, climate adaptation

OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Ocean Solutions, a section of the journal Frontiers in Marine Science

Received: *30 November 2020*
Accepted: *11 February 2021*
Published: *04 March 2021*

Citation:
Selim SA, Glaser M, Tacke FI, Rahman M and Ahmed N (2021) Innovative Aquaculture for the Poor to Adjust to Environmental Change in Coastal Bangladesh? Barriers and Options for Progress. Front. Mar. Sci. 8:635281. doi: 10.3389/fmars.2021.635281

INTRODUCTION

Poorer residents of tropical coastal regions are more dependent on nature and more vulnerable to environmental change than more affluent groups. The poorest coastal women and men are therefore also most in need of new opportunities to adapt their livelihoods (Cinner et al., 2018). Particularly coastal regions that are densely populated and heavily impacted by the expanding sea and related environmental changes require a transformation toward new socially and ecologically sustainable nature-dependent forms of production that ensure the livelihoods of the poorest (Berkhout, 2002; Chapin et al., 2009; O'Brien, 2011; Glavovic, 2013).

Coastal Bangladesh is among the regions on earth that are most affected by salinity intrusion with oceanic and other sources. Former agricultural lands transform to brackish or marine states while the millions of terrestrial livelihoods for the poor are lost. This calls for innovative ideas. Despite early work on innovative agricultural services by the landless in Bangladesh (Wood and Palmer-Jones, 1991), the benefits from new ideas and technologies have largely bypassed those initially endowed with least resources, both in agriculture and more recently in aquaculture (Röling, 2009; Hornidge et al., 2011; Ul-Hasan et al., 2011; Diana et al., 2013; Krause et al., 2015). The innovative co-development of production technologies with and for the poor therefore remains an important and still underexplored arena with few long-term achievements. The expanding ocean boundary and its polarizing socio-economic effects makes relevant research more urgent.

This article identifies barriers to the participation of poor and marginal coastal populations in innovative ecosystem-based brackish water aquaculture (BWA). We use a set of indicative early field research results and outline first steps toward the co-development of an innovative, ecosystem-based approach (integrated multi-trophic aquaculture—IMTA) to aquaculture in the brackish and marine areas of Bangladesh. At the moment, marine aquaculture is only incipient in Bangladesh, but as salinity advances into coastal lands, millions of farmers and rural laborers who are losing agriculture as their main income source require new options.

MATERIALS AND METHODS

Background

Bangladesh is the sixth most climate change vulnerable country on earth (Kreft et al., 2016). The shallow, funnel-shaped Bay of Bengal is subject to particularly fast salinity intrusion while, at the same time, Bangladesh's densely populated coastal regions sustain about one third of the country's at least 160 million people (Alexandratos and Bruinsma, 2012).

Poverty is pervasive in Bangladesh, particularly on the coast. According to the World Bank (2018), 13.8% of the population live below the poverty line in Bangladesh. The population is predominantly rural (almost 80%). Dependence on nature is a mainstay for the poorest who cultivate coastal lands and/or work with freshwater pond aquaculture, as small owners, and in the majority, as landless laborers. Flooding and river erosion are major challenges, particularly for the coastal Bangladeshis who also face freshwater shortages due to increases in sea level and salinity (Selim et al., 2018). The coastal districts (19 of 64 districts), are home to one-third of the national population, almost 50 million people, and are the most vulnerable and poorest areas in the country, highly exposed to natural disasters. Between 1970 and 2015, over 45 devastating cyclones swept across mostly the coastal regions causing immense harm to lives, property and coastal livelihoods in fisheries, forestry, and agriculture (Haque et al., 2016).

Coastal natural resources are also exposed to rapid environmental change. Salinity has advanced up to 100 km inland (Disaster Management Bureau (DMB), 2010), causing losses of agricultural terrain to the sea and productivity losses for paddy fields and freshwater ponds. To support millions of coastal poor people who depend on agriculture and freshwater aquaculture, and also to mitigate out-migration from coastal Bangladesh (Kartiki, 2011), coastal and marine production systems in the Bay of Bengal need to transform to provide livelihoods to 20 million Bangladeshis in line with the increasingly saline and insecure conditions in the coastal lands they live and work in.

Salinity-tolerant paddy varieties and raised horticulture are part of the needed transformation of coastal production (Pouliotte et al., 2009; Islam et al., 2016). However, low and falling available land per capita, due to growing population density and land losses from saltwater intrusion, indicate that BWA will also need to increase. Shrimp monoculture, the currently predominant form of BWA, is a major export sector and foreign exchange earner for Bangladesh (Department of Fisheries (DoF), 2017). Shrimp aquaculture is, however, associated with social and economic polarization and ecological problems and conflict; its expansion is likely to exacerbate coastal inequality and poverty (Paul and Vogl, 2011; Hossain et al., 2017).

New uses of the coastal environment, which are supported by appropriate institutional frameworks, are needed, These should respond to the increasingly saline conditions in the densely populated coastal lands and the resulting displacements of livelihoods for large numbers of poor coastal inhabitants. BWA is a necessarily important part of the adaptation to the ongoing landward expansion of saline conditions, and it will need to be environmentally and economically sound as well as accessible to the coastal poor.

IMTA aims for the integrated waste-free production of diverse aquatic goods (including food, feed, fertilizers or bioactive compounds). IMTA uses the waste of (fed) species as fertilizer, food or energy for other (extractive) species (Zhang and Kitawaza, 2016). We suggest that, with a context-appropriate co-design of IMTA production systems for Bangladesh, within a favorable institutional context (Zwaag and Chao, 2006; Ahmed and Glaser, 2016), IMTA has "plausible promise" (Hornidge et al., 2011; Largo et al., 2016) of providing sustainable new livelihoods for the salinity-affected coastal poor of Bangladesh.

A pro-poor development of IMTA for brackish or marine areas will require appropriate choices. This includes the choice of species and construction inputs, of production technologies and processes, of management techniques, and of how the development of value chains is undertaken. It is now consensus that classical one-way "technology transfer" models (Rogers, 2003) are developmentally ineffective and that to increase their own opportunity space for beneficial engagement, poor women and men need to be involved in developing appropriate approaches "as experts and experimenters" (Röling, 2009; Hornidge et al., 2011).

We propose that, in the context of the unavoidably expanding ocean boundary, and as part of an ecologically and socially responsible aquaculture (Diana et al., 2013) that aims for "inclusive innovation and development" (Heeks et al., 2014; Joffre et al., 2017), IMTA needs to be developed with socially and

economically marginal women and men in coastal regions. These groups have been further harmed by environmental change and need to be enabled to pursue forms of production and marketing of marine products with equitable resource access rights that improve their food and livelihood security (Kittinger et al., 2017).

Research Questions

This article assesses some contextual preconditions for poor residents in coastal Bangladesh who are exposed to an expanding sea and increasing salinity, to co-develop and to benefit innovative BWA, such as IMTA. We investigate the opportunity spaces in BWA with a focus on those who are typically least successful within conventional transfer of technology models, i.e., poor coastal women and men; we explore local knowledge on BWA and we discuss opportunities and challenges for (co)-developing aquaculture as a sustainable livelihood with and for the poor majority in coastal Bangladesh. This article addresses three interrelated questions:

1. What kind of aquaculture is being undertaken in brackish/saline/coastal waters?
2. Do poor coastal residents see BWA (and, by implication IMTA) as a viable and sustainable livelihood?
3. What are the opportunities and barriers for making BWA a possible and promising livelihood in particular for these groups?

Methods

Our field research was hosted by the Climate-Resilient Ecosystems and Livelihoods (CREL) project and done in four sites where CREL had operated since 2012 (**Figure 1**). In these sites, CREL focused on training women for three livelihood options (integrated aquaculture in freshwater ponds, homestead gardening and poultry raising) and carried out vulnerability assessment training for climate change and disaster risk reduction (Climate-Resilient Ecosystem and Livelihoods (CREL), 2016). CREL focused on salt-tolerant species and improved genetic varieties of such species (e.g., Tilapia) and provided training, mostly to women, on income generating skills (e.g., stitching/knitting for an international fair trade organization). Our field research team conducted 120 sampling interviews, notably with non-beneficiaries of the CREL project from eight villages in the four coastal CREL project sites (**Figure 1**). These interviewees had not received any intervention, e.g., poultry or aquaculture training from any NGO projects. In these study areas, around 2,000 non-beneficiaries were involved in aquaculture related activities. A sample of 120 respondents was considered to be representative based on expert judgment, though we acknowledge some limitations in their selection. We employed a semi-structured questionnaire to capture households' socio-economic status, level of education, access to land, means of employment and their knowledge and perception of climate change impacts and of opportunities and challenges with implementing BWA. Due to the extreme remoteness and lack of accommodation in the study sites, our fieldwork was part of a set of prearranged visits to CREL field sites. This reduced our options to randomize interviewee selection. Respondents were recruited opportunistically while walking through the villages and visiting tea stalls and shops. Data from questionnaire

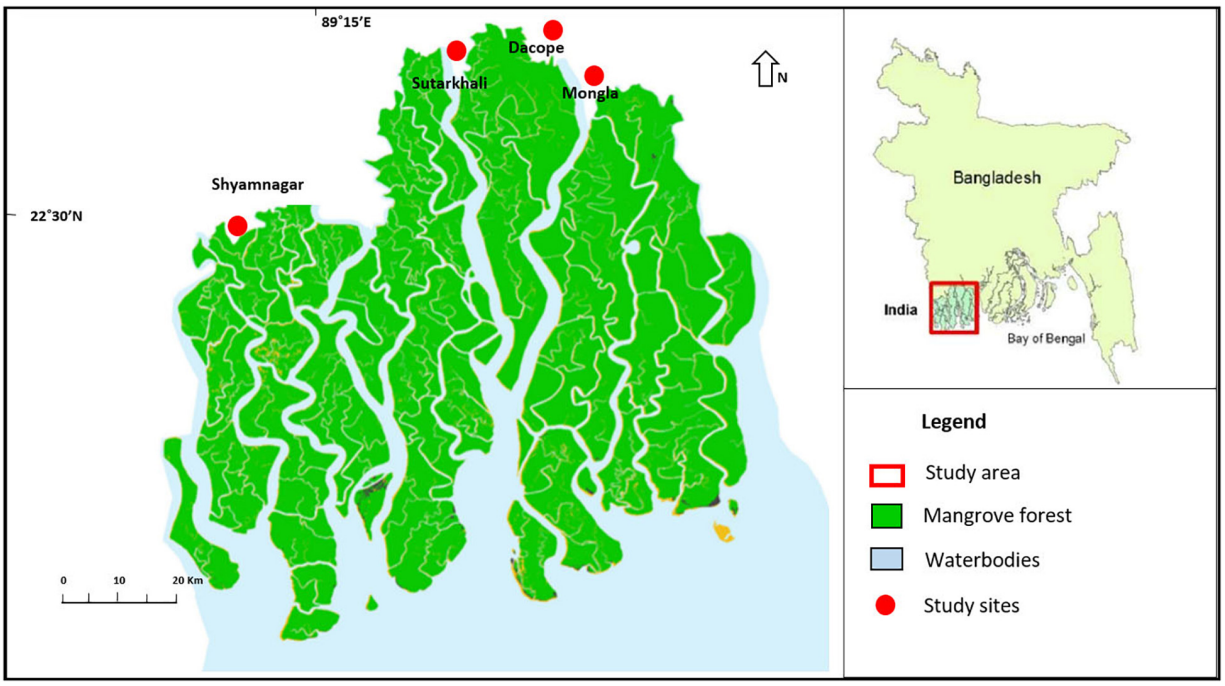

FIGURE 1 | Bay of Bengal and CREL research sites (red dots).

TABLE 1 | Distribution of positive attitudes toward BWA among socio-economic groups (no and % of respondents within category).

Is current BWA an option for sustainable livelihoods?	**No**	**Not sure/no reply**	**Yes**
Number of respondents	8% (*n* = 10)	60% (*n* = 72)	32% (*n* = 38)
Reasons for response	"it is increasing salinity in the water" "it reduces sources of pure drinking water" "salinity is not a problem there"		"shrimp and tilapia can be cultivated, less cost & time and good profit " "salinity increasing so it is needed now" "yes due to salinity, it is a way for us to still earn money" "Decrease in agriculture and fresh water fish cultivation" "creates jobs" "salinity is increasing, cannot have fresh water fish anymore"
Gender			
Female	9% (*n* = 4)	55% (*n* = 26)	36% (*n* = 17)
Male	5.5% (*n* = 4)	42.5% (*n* = 31)	52% (*n* = 38)
Land ownership			
Landowner	12% (*n* = 9)	54% (*n* = 42)	35% (*n* = 27)
Landless	2% (n = 1)	71% (*n* = 30)	26% (*n* = 11)
Income group			
Annual income BDT 0–20 k (poor)	7.4% (*n* = 2)	48% (*n* = 13)	44% (*n* = 12)
Annual income BDT 20–45 k (middle)	8.5% (*n* = 5)	49% (*n* = 29)	42% (*n* = 25)
Annual income BDT >45 k (high)	4% (*n* = 1)	39% (*n* = 11)	57% (n = 16)
Did not declare income	0% (n = 0)	67% n = 4	33% n = 2
Occupation			
Farmer/fishing	2% (*n* = 1)	67% (*n* = 29)	30% (*n* = 13)
Labor	29% (*n* = 7)	58% (*n* = 14)	13% (*n* = 3)
Rickshaw/van/bike puller	0 (*n* = 0)	40% (*n* = 4)	60% (*n* = 6)
Small business owner	0 (*n* = 0)	60% (*n* = 9)	40% (*n* = 6)
Other occupation	6% (*n* = 2)	44% (*n* = 16)	28% (*n* = 10)

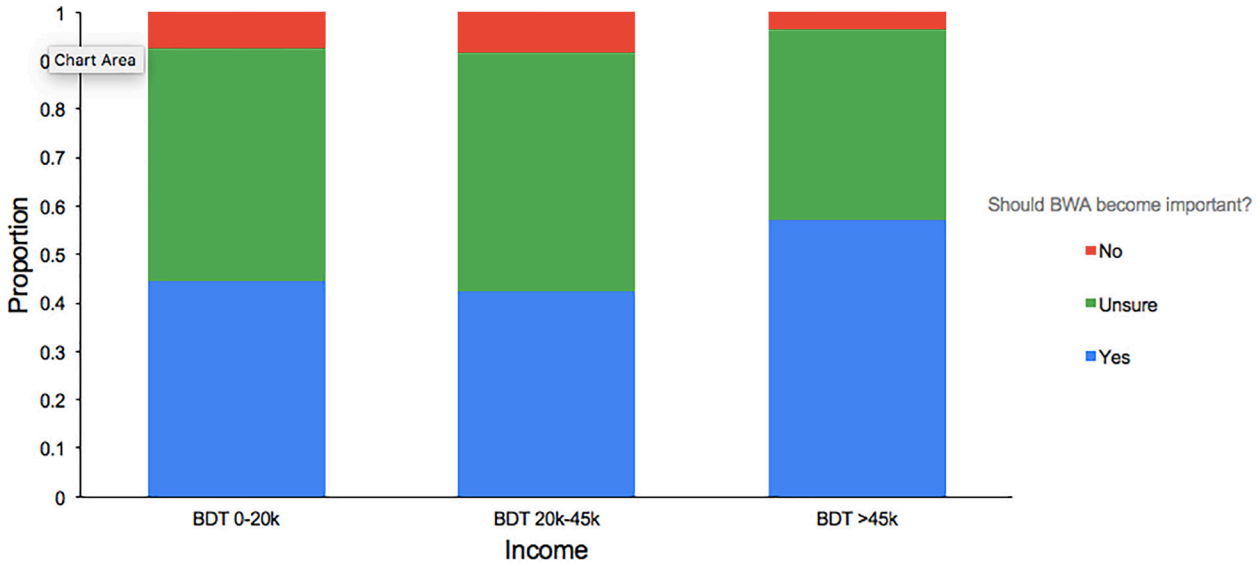

FIGURE 2 | Interest in brackish water aquaculture (BWA) among case study site respondents by self-reported annual household income [in Bangladesh Taka (~100 Taka/Euro)].

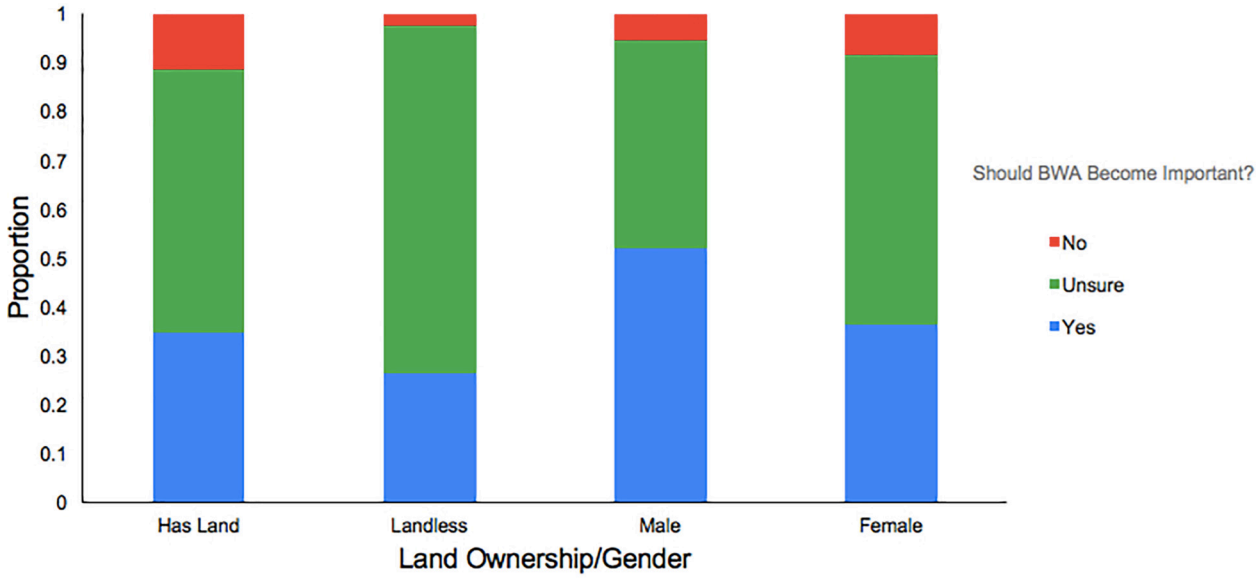

FIGURE 3 | Interest in brackish water aquaculture (BWA) by land ownership category and gender.

interviews were analyzed by using Microsoft Excel to produce descriptive statistics.

RESULTS

Respondents (73 men and 47 women aged between 18 and 65) were interviewed at eight villages (administrative subunits): Koyra, Dacope, Halna, Kaligonj, Mongla, Morelganj, Shatkhira, and **Figure 1** shows Shyamnagar. About 35% of interviewees owned no land at all (i.e., not even their homestead land). Among the 65% of respondents that owned land, the size of landholding ranged between 1 *Katha*[1] (0.03 acres) and 937.5 *Kathas* (28.13 acres), an average of 89 *Kathas* (2.67 acres).

Confirming relevant available literature (Disaster Management Bureau (DMB), 2010), salinity intrusion was mentioned by almost all interviewees (86%), and ranked as by

[1]*Katha* is a unit of area used in Bangladesh. The units are mainly standardized, e.g., 1 *Bigha* = 20 *Kathas* (Ministry of Land (MoL), 2016), however, they can vary significantly between district to district. Therefore, this study uses the local conversion of the coastal district Khulna with 1 *Katha* = 0.03 acre.

far the most deleterious coastal environmental change. We now turn to our three main research questions:

1. *What kind of integrated or other aquaculture is currently being undertaken in brackish/saline/coastal waters?*

BWA in our study sites features ponds with various combinations of aquatic species but focuses on *bagda* shrimp (*Penaeus monodon*) farming and mud crab fattening. The poorest people, mostly women and children, survive on shrimp fry collection from the wild, an illegal, low-income, and ecologically potentially unsustainable occupation (Selim et al., 2018).

2. *Do poor coastal individuals and households see current BWA as a viable and sustainable livelihood?*

Respondents' perceptions and knowledge on BWA related to shrimp farming in *ghers*[2] and saltwater tolerant tilapia. Only a third of respondents (34%, n = 38) thought that BWA was a sustainable livelihood option. About 65% (n = 72) were unsure and knew little about BWA (**Table 1**), and 8% (n = 10) thought that BWA was not a viable livelihood.

Disaggregated by our indicators of poverty (landownership, income level, and occupation—**Table 1**), we find indications of a gender bias:

- A higher percentage of female than male respondents were unsure or critical of BWA,
- 52% of men but only 36% of women saw chances for sustainable livelihoods based on BWA.

Figures 2, **3** distinguish perceptions of BWA as a means for sustainable adaptation to increasing salinity by income level, access to land and gender of respondents.

While there is no strong connection between income level and outlook on BWA, **Figure 2** shows that the lowest income group had the least positive and the highest income group the most positive views on BWA. Also, a higher percentage of men than women, and more landowners than landless respondents perceived BWA as of future importance (**Figure 3**).

3. *What is needed to make BWA a feasible and promising livelihood and what are the barriers?*

Our results (**Table 1**) indicate that:

- The outright rejection of BWA is a minority opinion: 12% of landowning but only 2% of landless respondents reported negative attitudes toward BWA.
- A majority of all three income groups report little knowledge on BWA but this was most pronounced among the landless, the two lower income groups, and among female respondents.
- The percentage of respondents that considered current BWA a sustainable income source is strikingly higher among respondents with the highest income level (57% of respondents with higher income, but only 44 and 42% with poor and middle income, respectively).
- Although farming and fishing are potential competitors to BWA, farmer and fisher respondents rarely dismissed the potentials of BWA (2% of respondents) but largely professed lack of knowledge on BWA (67%).
- Poor respondents from the service sector (rickshaw/van/bike pullers) have more positive views on the prospects of BWA (60%) than higher income service sector respondents of business/shopkeepers (40%).

Barriers to BWA and needed conditions for developing it which were most frequently mentioned all concerned assets and access: training in aquaculture (23% of respondents, n = 28), funds (20% of respondents, n = 24) and land/assets (19% of respondents, n = 23). Further mentioned needs were technology, NGO support, and business ideas.

DISCUSSION AND CONCLUSION

Where absolute poverty is high among large sections of the population and further impoverishment is under way, as in coastal Bangladesh, new production approaches such as IMTA for newly wet and saline environments, need to be environmentally sound, economically profitable, well governed, and produce healthy products for which there is demand (Barrington et al., 2010). However, beyond this, they also have a clear development task. Production and marketing need to be explicitly tailored for the economic, social, and cultural context and needs of the poorest victims of environmental change so as to enable these groups to realize significant benefits. In coastal Bangladesh, the poor, among them a majority of women, own little or no land but are as sharecropper/tenants or laborers nonetheless most dependent on the rapidly changing natural resource base while having little access to other promising income sources and services.

Need for Informed Knowledge Exchange

Despite its potentials for responding to salinity intrusion (Ahmed and Glaser, 2016), IMTA is, so far, neither known nor practiced in coastal Bangladesh. Therefore, we adopted the wider term BWA for this study. Between 20 and 60% of respondents reported interest in BWA (**Figures 2**, **3**). Higher income respondents had higher BWA acceptance levels and fewer reported information deficits than low-income (**Figure 2**) landless, and female respondents (**Figure 3**). Interviews also indicated that both the positive and the negative perceptions of BWA expressed by our wealthier study respondents were mostly associated with shrimp monoculture while there was little or no knowledge on ecosystem-based production. There is thus a clear need for information on modern IMTA and related options. The differences found across responses given by women vs. men should be investigated further. Although they are active in and are a target group for aquaculture development, female respondents reported lower levels of information and less positive attitudes

[2]The Bengali term *gher* combines aquaculture with a remnant of crop cultivation in the transitional land-ocean zone: A high protective dike is built around a rice field and a canal of several feet in depth excavated along the inner periphery of the rice field. The outer canals retains water during the dry season. During the rainy season, the entire water body is used to cultivate prawn and fish, while only the canal is used for fish during the dry season, with rice planted in the central plot.

about the potentials of BWA for providing sustainable livelihoods than male respondents (**Figure 3**).

Globally, considerable research has been conducted on the development of BWA, including IMTA (Gunning et al., 2016). In China, IMTA has been practiced for decades, and understanding of the dynamics between IMTA and the environment in Sanggou Bay can provide guidance to adaptively manage IMTA systems to ensure sustainability (Fang et al., 2016). The adoption of IMTA into tropical settings using local species of high market value can help sustainable farming in southern Cebu, Central Philippines (Largo et al., 2016). A successful trial of IMTA in the Sundarban region, India has been conducted (Biswas et al., 2019). These findings suggest that the development of IMTA in coastal Bangladesh is feasible if identified challenges are addressed.

Inequality and Pro-poor Development in Rural Coastal Regions

Negative perceptions can turn into self-fulfilling prophecies and undermine potential opportunities in aquaculture development as in other fields. Investigations of stakeholder perceptions of IMTA are rare in the literature and have so far focused on consumers in regions of the globe with high consumer power (Barrington et al., 2010). Our study looks at the producer side, in a context of pervasive and extreme poverty and finds that a higher proportion of wealthier respondents perceived opportunities associated with BWA[3] while lower income, landless and female respondents, although they displayed a good level of interest in BWA (**Figures 2**, **3**) clearly viewed the cards as stacked against them. The constraints and barriers to BWA that our respondents might be mostly asset-related, and associated with poverty.

Absolute landlessness was widespread with 35% of our respondents affected, while many of the landowning respondents in this study only had just enough land for homestead gardening and, at times, a small pond. In contrast, those with the largest landholdings in our study reported to own 28 acres, 900 times the amount of land that the smallest landowner reported. These and other stark inequalities within rural coastal communities in Southwestern Bangladesh need to be taken into account if the scope for benefiting from innovative aquaculture co-development is to be extended to the poorest women and men. Success in expanding the productive or marketing potentials of the poor has been documented in a few cases across the globe (Asian Development Bank (ADB), 2005; Pant et al., 2014).

Social and Governance Biases

Inequality and poverty embedded in asymmetrical relations of power and influence (Escobar, 2008; Peluso and Lund, 2012), set the scene for pervasive patron-client relations in Bangladesh, and also for gender relations. These limit the scope for the poor to engage in self-organized, and self-serving efforts at transformative innovation (Aminuzzaman and Sharmin, 2006). In the context of a project to enable the landless poor to become "sellers of irrigation water" Wood and Palmer-Jones (1991) speak of the "political weakness and status inferiority" of the rural poor. This is framed by a wickedly resilient governance context (Glaser et al., 2018), in which power dynamics and associated institutions consistently operate against the poor (Gereffi et al., 2005; Aminuzzaman, 2006; Lewis, 2011) and particularly against poor women. Efforts such as the co-development of pro-poor IMTA will need to take such persistent social and governance biases into account, for instance, by promoting institutions that support equal access for the poor to credit, inputs, and markets.

Outlook

The desirable long-term scenario for coastal Bangladesh is an eventually self-organizing transformation toward sustainable and equitable coastal resource use and livelihoods under the emerging wetter and more saline environmental conditions. So as not to exacerbate poverty and socio-economic inequalities, those sections of the population that are most affected by environmental change and least well-endowed to engage with innovations, need to be actively included in, and capacitated for innovation co-development. This study shows that lower income groups and women perceive fewer opportunities in BWA and (consider themselves to) have less knowledge on it. Options such as an innovative ecosystem-based IMTA may turn into promising drivers of sustainability-enhancing transformation, if carefully embedded in inclusive and empowering knowledge generation and exchange. A range of factors including governance, transparency and bureaucracy, inequality, gender bias, power and access to resources need to be explored to assess upcoming challenges and options. This study indicates socio-economic and gender biases in perceived prospects and capabilities. Further questions to be explored concern forms and dynamics of local (collective) self-organization, formal and informal institutional dynamics and, for different aquaculture products, the potentials of knowledge networking and coalition-building along local to global value chains. Attention also needs to be paid to why, despite its plausible promise (Ridler et al., 2007), IMTA has not yet become a transformative force anywhere on earth (Klinger and Naylor, 2012), except possibly in China (Fang et al., 2016).

Aquaculture development across the globe has been dominated by economic growth objectives rather than by the livelihood priorities of the coastal poor (High Level Panel of Experts (HLPE), 2014). The Intergovernmental High Level Panel of Experts on Food Security and the SDGs call for policies that support zero hunger/food security. Inclusive pro-poor innovation to support ecosystem-based aquaculture development that includes ownership by small-scale or collective producers, labor-intensive techniques, gender equality and a role for low-skilled labor to deliver here.

Emerging Fields of Action/Next Steps

Aquaculture is culturally appropriate in Bangladesh where environmental change is generating growing potential for BWA and IMTA. We propose three strategic fields of action to start

[3]IMTA being a locally unknown concept, BWA was employed as the wider known category in this study.

addressing the emerging options and challenges of inclusive, pro-poor BWA and IMTA development:

1. Diagnostic and scoping workshops in local coastal communities that deliver knowledge on IMTA options and identify important stakeholder or gender-specific opportunities, priorities, concerns and challenges. Inclusive approaches such as future visioning could facilitate the process of adapting co-development approaches to the needs of (poorer) coastal women and men.
2. A first pioneering set of facilitated IMTA experimentation groups to serve as temporary "safe spaces" in which interested poor coastal women and men can be supported in collaborating in the development of ecosystem based aquaculture innovation. The outcome of such an "experimental co-design phase" with IMTA field trials, in which groups of local poor people contribute their contextual and grounded knowledge but also need to be supported by natural and social scientists and local technical expertise, would aim to explicitly include group members' own priorities, for instance in the selection of species, of aquaculture sites, of construction materials, and in the development of input and credit access and marketing.
3. Finally, we propose a networked and institutionalized knowledge exchange between key stakeholders along the value chain from producer to consumer. This might include an regionally active but internationally networked "knowledge-building and contextualization platform" to promote and include the creative agency of poor women and men displaced by coastal environmental change.

Social innovations beyond technology will be needed to enable developmentally effective (i.e., pro-poor) and ecologically sustainable innovation. Low-external-input modes have been found to best benefit poor rural people. This stands in contrast to increasingly capital intensive aquaculture development modes so that options and trade-offs have to be identified and negotiated. In this, the poor need capacities and rights to actively participate in decisions to ensure their benefits. Vested income and/or gender-based power differentials are likely to require the establishment of countervailing power among marginal coastal residents if innovative ideas are to be co-developed equitably. With our field results and the ensuing suggested strategic fields of action, we have sketched out some first steps.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Liberal Arts Bangladesh. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

SS: conceptualization, field investigation, methodology, project administration, and writing. MG: conceptualization, methodology, data analysis, writing, editing, and review. FT: data analysis, visualization, editing and review. MR: data analysis and visualization. NA: writing, review, and editing. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2021.635281/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.