Ocean & Coastal Management xxx (2014) 1–10

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Asset or liability? Aquaculture in a natural disaster prone area

Manjurul Karim [a,*], Sarah Castine [b], Alan Brooks [c], Douglas Beare [b], Malcolm Beveridge [d], Michael Phillips [b]

[a] WorldFish, House no-22B, Road no-7, Block no-F, Banani, Dhaka 1213, Bangladesh
[b] WorldFish, Jalan Batu Maung, 11960 Bayan Lepas, Penang, Malaysia
[c] WorldFish, #35, Street 71, Sangkat Beng Keng Kang 1, Phnom Penh, Cambodia
[d] WorldFish, 18 (B) El Marashely St., 4th Floor, Aprt # 17, Zamalek, Cairo 1121, Egypt

ARTICLE INFO

Article history:
Available online xxx

ABSTRACT

Cyclone *Sidr*, which hit in November 2007, caused widespread damage and death among communities in coastal Bangladesh. A range of actions or 'coping strategies' were employed by households to ensure that their families had sufficient food and income resources to survive in the months following the cyclone. Coping strategies adopted by the households were categorized into three groups (i) food related, ii) income generated through selling assets, and iii) income generated though borrowing money. We found that the range of coping strategies adopted did not depend statistically on access to aquaculture assets, indicating that neither group (those with aquaculture assets and those without aquaculture assets) was better equipped to cope with the disaster. Aquaculture ponds were, however, important for supplying food and income in the post-disaster period and 78% of households were willing to re-invest in aquaculture despite the risk of stock losses and damage to infrastructure during recurrent disasters. It is concluded that aquaculture ponds are likely to provide a mechanism for coping after a disaster, despite the costs involved in repairing them. We recommend that aquaculture development be promoted for income and food security for rural families but that development occurs in areas that does not compromise other ecosystem functions i.e., mangrove forests. Risk management strategies, such as raising fast growing fish, which shortens the production cycle and allows for early harvesting, be embedded into policy reforms. We also recommend that a diversified livelihood strategy including non-farm activities be included in the reforms.

1. Introduction

Globally, over 300 natural disasters occur every year, which in 2010 resulted in an estimated 106 891 fatalities and cost the global economy US$109 billion (Guha-Sapir et al., 2012). Bangladesh is especially vulnerable to natural disasters due to its geographical position, dense population, high levels of poverty and dependence on climate sensitive industries, namely agriculture and aquaculture, which support over 60% of livelihoods (Huq, 2001; Paul and Routray, 2010).

Collectively, fisheries and aquaculture are the second most important livelihood component in Bangladesh after rice production. Small-scale aquaculture occurs mainly in ponds and contributes to the welfare and nutrition security of poor households through increased consumption of fish and incomes (Kawarazuka and Béné, 2010). An estimated 4.27 million households in Bangladesh own ponds, covering an area of 0.3 million ha and providing full- and part-time employment for 1.4 and 11 million people, respectively (Mazid, 2002; Belton and Azad, 2012). Aquaculture accounted for 53% of total fish production between 2011 and 2012 (DoF, 2013), underpinning the supply of fish which is integral to the Bangla diet. Fish are the primary source of animal protein, and contribute a large proportion of the vitamin A, calcium, zinc and iron intake needed by rural households (Roos et al., 2003, 2007b). An average of 37 g of fish is consumed per person per day contributing up to 21% of the recommended vitamin A intake (Roos et al., 2003). Small-scale aquaculture is, however, vulnerable to natural disasters, particularly during the monsoon season when

* Corresponding author. House no-22B, Road no-7, Block no-F, Banani, Dhaka 1213, Bangladesh. Tel.: +880 2 8813250 GMT +6; fax: +880 2 8811151.
E-mail addresses: m.karim@cgiar.org, mkarim@mail.com (M. Karim), s.castine@cgiar.org (S. Castine), a.brooks@cgiar.org (A. Brooks), d.beare@cgiar.org (D. Beare), m.beveridge@cgiar.org (M. Beveridge), m.phillips@cgiar.org (M. Phillips).

http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021
0964-5691/

flooding and cyclones result in significant loss of fish and income for poor households. While beneficial for household nutrition and food security, owning aquaculture assets carries risks, and thus has the potential to increase the vulnerability of poor households to natural disasters.

Cyclone *Sidr* crossed the coast of Bangladesh on 15 November 2007 and moved inland, where it caused 3 406 deaths and destroyed crops, livestock and infrastructure disrupting livelihood activities (Government of Bangladesh, 2008). It reached a category 4 (Saffir Simpson Scale) with wind speeds up to 305 km per hour in the Bay of Bengal, and 190 km per hour over land (Gutro and Olsen, 2007). An estimated one million households were severely affected, while 2 million people suffered loss of income and employment in the more affected districts. The disaster was concentrated in the districts of Bagerhat, Barguna, Patuakhali, Pirojpur and Barisal where poverty levels are among the highest in the country (35–50% of population) (HIES, 2005).

Whilst the national and international community responded quickly, the disaster tested the ability of households to secure sufficient food, income and work to survive in the months following the cyclone. Over the last decade researchers have investigated the range of coping strategies (behaviors) employed by households to ensure survival after natural disasters (Skoufias, 2003; Paul and Routray, 2010; Helgeson et al., 2013). Coping strategies include reducing household consumption, consuming unfavorable cheap food, consuming seed stock, selling productive assets, mortgaging land, borrowing money or temporarily migrating to find employment (Paul and Routray, 2010). The type of coping strategy a household employs has implications for recovery, resilience, and whether or not a household remains in poverty (Skoufias, 2003). Formal credit services, for example, and other income sources are often inaccessible to poor households, preventing them from re-purchasing productive assets and re-building livelihoods (Skoufias, 2003). Of particular consequence for poverty traps are circumstances where households are forced to reduce investment in child nutrition, health care and education (Skoufias, 2003). Decisions to make these sacrifices in order to survive post disaster are driven by complex socio-economic factors such as educational attainment, age of the household head and a household's access to human, financial, natural, physical and social assets (Lal et al., 2009; Paul and Routray, 2011; Webster, 2013). Understanding differences in the way that a household copes, based on these socio-economic factors, contrasts groups of people who are particularly vulnerable, against those who are well positioned to cope with disaster (Vadacchino et al., 2011). This informs policy interventions which encourage the development of resilient farming systems that reduce the vulnerability of poor households.

The role of aquaculture ponds in reducing household vulnerability has rarely been studied and there is a paucity of literature regarding the role of ponds as multipurpose resources in post-disaster coping (Little et al., 2007). Ponds may cushion households from different types of shocks and vulnerability, improving their resilience to unforeseen events. The physical structure of ponds may provide protection against otherwise catastrophic flood, while water reserves in the pond may offer protection against drought (Little et al., 2007). Pond-raised fish may act as more easily liquefiable assets that can be sold to acquire income, similar to the demonstrated role of livestock within smallholder systems (Little and Edwards, 2003; Helgeson et al., 2013). Smoothing consumption of fish can, in principle, relieve hungry periods common in post-disaster situations and positive impacts on expenditure and income may emerge (Little et al., 2007).

The purpose of this paper is to evaluate the role of aquaculture in improving a family's ability to cope with disasters like cyclones. Small-scale aquaculture is expanding in deltas globally. This work, therefore, seeks to better understand the role of such household assets in one particularly vulnerable region; coastal Bangladesh. Benefits and the potential contribution of aquaculture towards surviving after a catastrophe are explored. That is to say, the objective of this study is to assess whether aquaculture is an asset or a liability for people living in disaster-prone coastal areas. The multifaceted roles of aquaculture assets are elucidated, including their contribution towards food and income security. Recommendations for improved management and disaster preparedness are presented in a bid to enhance the ability of rural communities to cope with such disasters. We conclude by discussing the limitations for the expansion of aquaculture within a diversified livelihood strategy.

2. Methodology

2.1. Project area and study households

The Cyclone Affected Aquaculture Rehabilitation Project (CAARP) funded by USAID was implemented in the wake of Cyclone *Sidr* in five districts: Patuakhali, Barisal, Jalokathi, Pirojpur and Bagerhat from 2007 to 2009, where an estimated total population of 7.57 million people lives (Fig. 1) (Government of Bangladesh, 2008). According to the upper poverty line, many of the inhabitants in these districts live in poverty, according to the upper poverty line, particularly in the Barisal Division where the poverty rate was 52% in 2007 (Government of Bangladesh, 2008; HIES, 2005).

The coastal delta in the affected areas consists of low-lying land (<3 m above sea level) which is vulnerable to floods and storm surges. Soils are highly fertile and, in areas unaffected by saline intrusion, agricultural productivity is high. Land holdings are typically small, with 55% of the population owning <0.01 ha due to land shortages, and in some areas increasing demand for other land uses such as infrastructure, industry, and urban settlement (Government of Bangladesh, 2008).

The present study is based on data collected, during that project, from two groups of households; 1) households owning aquaculture ponds who were part of CAARP and 2) households who did not own aquaculture ponds and who were not part of CAARP but who received post disaster assistance from other aid agencies.

2.2. Cyclone affected aquaculture rehabilitation project (CAARP) and household characteristics

A detailed description of CAARP is given in WorldFish Center (2009). Briefly, the most vulnerable aquaculture households were identified and supported through the CAARP. Priority was given to include female headed/managed households and the worst affected households. Farmers who were not already receiving *Sidr* aquaculture relief from other NGOs were also considered during farmer selection. Essentially, the project selected the most vulnerable households who had no scope for continuing their aquaculture farming in 2008, and were deemed to be reliant on aquaculture as their main source of income. In addition, households owning aquaculture ponds, and who were defined as functionally landless (landholdings of <0.2 ha), inclusive of the homestead, pond, vegetable field, rice field and any other land, were also given high priority. A total of 37 523 farmers were assisted by CAARP, and 69% of these (25 890 farmers) were considered functionally landless, with landholdings <0.20 ha (HIES, 2005). A further 9 221 farmers had only moderate land holdings (0.21–0.40 ha) and 2 412 farmers, comprising 6% of the total CAARP participants, had landholdings between 0.41 and 0.60 ha (WorldFish Center, 2009).

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

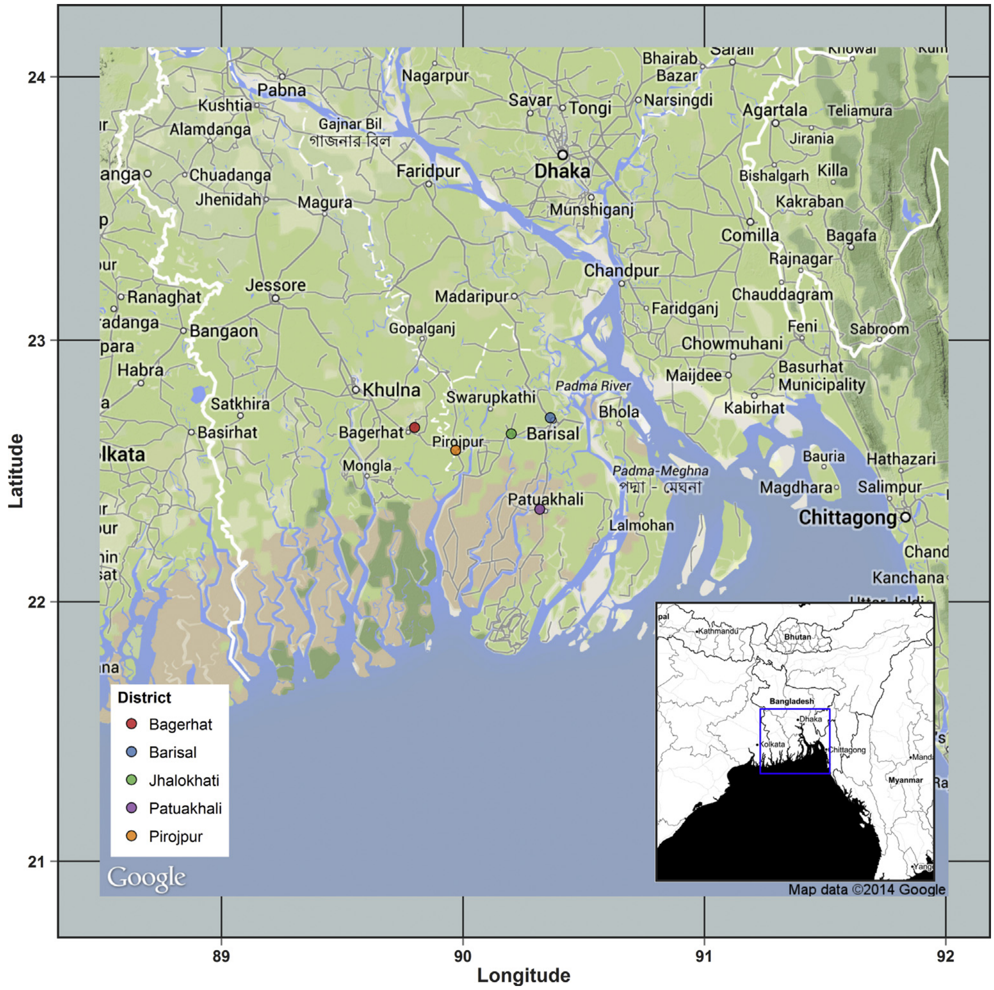

Fig. 1. The location of the five survey districts in the cyclone affected area of the Bangladesh coastal zone.

CAARP households were involved in aquaculture in various ways and were categorized according to aquaculture system type (fish, prawn or shrimp), and levels of cyclone damage (Table 1). The majority of farmers participating in the CAARP cultured primarily fish, while the remainder focused on growing prawns and shrimp (Table 1). Overall, 24% of farmers (9 094) suffered category 1 damage, and 76% category 2 damage (Table 1). Key CAARP activities included provision of aquaculture starter packs, consisting of either fish, shrimp or prawn (both 'seed' and fertilizer). Capacity building, in the form of infrastructure repair and training (improved management practices), was also conducted, so that farmers could re-establish their farms and possibly also increase productivity compared to pre-cyclone levels.

2.3. Sampling methodology

Data for the present paper were derived from two sources: (i) a questionnaire of post-disaster coping mechanisms (aquaculture and non-aquaculture households); and (ii) focus group discussions (aquaculture and non-aquaculture households). Data from the questionnaire were analyzed using the statistical software R (R Core Team, 2013) and information from the focus group discussions was used to support the statistical analysis.

2.3.1. Questionnaire

In February 2009 a questionnaire based survey of 401 households was carried out to assess the role of aquaculture in coping with the after-effects of Cyclone *Sidr*. The questionnaire was completed by 266 CAARP households with aquaculture ponds, and 135 non-CAARP participants (without aquaculture assets). All 401 households (aquaculture and non-aquaculture) were selected from the five districts identified during the CAARP (Patuakhali, Barisal, Jalokathi, Pirojpur and Bagerhat). There were 18 partners working with WorldFish on CAARP and these partners compiled a list of all households in each of these five districts. The list was used to identify aquaculture and non-aquaculture households and to assign each household an identification number. A random number generator was subsequently used to select households to participate in the questionnaire and all households had to be deemed as vulnerable according to their asset base and income. If they did not meet these criteria different households were again selected at random. Preliminary analysis demonstrated no significant difference in land holding size (a proxy for wellbeing) between aquaculture households and non-aquaculture households (*t-test*; $P > 0.005$).

2.3.2. Examining the probability of having a pond for aquaculture given the age and education level of the head of the household

In general the survey data were complex and challenging to analyze statistically. We first explored the data to assess the degree of confounding using 'lattice' graphics available for the R statistical software package (Sarkar, 2008). As a result data subsets that could not support statistical analysis were discarded. The numbers of respondents who had any tertiary education, for example, were too

Table 1
Number and characteristics of CAARP project participants at the time of the present study (2008).

Culture animal	Damage category 1		Damage category 2	
	No. households	Pond area (ha)[a]	No. households	Pond area (ha)[a]
Fish	7 093	280	22 164	882
Prawn	1 621	104	3 934	268
Shrimp	380	66	2 331	389
Total	9 094	451	28 429	1 539

Category-1: 25% dike damaged due to storm surge and fallen trees, moderate siltation, no desiltation required, large trees fallen in the ponds, water polluted and 100% stock lost. Category-2: Not flooded, minor or no dike damage, no siltation, water polluted due to fallen leaves and run off, 80% stock lost due to water pollution.
[a] Total area of all ponds.

small to be analyzed and were therefore removed from modeling; only participants who had no education (code = 0), those who had primary education attending classes 1 to 5 (code = 1), and those who had secondary education attending classes 6 to 10 (code = 2) were included in the final analyses.

Initially, we examined whether ownership of an aquaculture pond was dependent on age and/or level of education of the heads of each household surveyed, as these factors are known to be contributing determinants of how a family copes with a natural disaster (Paul and Routray, 2011), and may confound our analysis and interpretation of models. We did this by modeling the probability of owning a pond given the age and education of each household head using binary generalized linear models which are part of the standard or "base" R installation (Venables and Ripley, 2002; R Development Core Team, 2006). By fitting the series of nested models (1–4) below we were able to assay, statistically, whether age and educational attainment of households were significant predictors of aquaculture pond ownership:

1. Pr(Pond) = 1
2. Pr(Pond) = Age
3. Pr(Pond) = Age + Education
4. Pr(Pond) = Age * Education

where Pr(Pond) is the probability of owning a pond for aquaculture, Age is the age of the household head in years, fitted as a numeric term, and Education is the educational level fitted as a factor variable.

The response variable (household) category was thus coded 0 for non-pond and 1 for possessing a pond. We are, therefore, modeling the probability of owning a pond given the specific demographics of each household. Analysis of deviance tests between the nested models above then allowed determination of the 'best' model. Model 1 is the NULL model; 2 assumes that household category (i.e. aquaculture or non-aquaculture livelihood strategy) depends linearly on the age of the household head; model 3 assumes that household category depends linearly on both the age and the education level of the household head; while model 4 assumes that household category depends on both the age, and the level of education of the household head; and that there is an interaction effect between these two 'independent' variables.

2.3.3. Modeling how households coped in the wake of Cyclone Sidr

Differences in the manner that households with and without access to aquaculture assets coped in the aftermath of the *Sidr* disaster were also similarly examined; i.e. by using exploratory data analyses, followed by confirmatory statistical testing using binary generalized linear models (McCullagh and Nelder, 1989). Prior to analyses the survey data were split into the following three overall 'coping strategies': (i) food security; (ii) generating income by selling household assets; and (iii) generating income via borrowing. For example, in the food security category each respondent was asked whether he or she 'limited portions at mealtimes', and how frequently this was done (e.g. never, seldom, sometimes, often, and daily).

For each of the three coping strategy datasets we calculated the proportion (percentage) of household heads that had selected each combination of 'coping strategy' (e.g. limiting portion size) and 'frequency' (e.g. seldom). A certain percentage, therefore, would opt for 'Reducing the number of meals' 'Often'. By then linking the characteristics of each household head (e.g. age or educational level) to these responses we could test whether factors such as owning or pond or the age of the household head were statistically important, given other factors such as educational attainment that were already included in the model.

The probability of making each choice was then explored using generalized linear models from the quasibinomial family which are also part of the standard or "base" R installation (R Core Team, 2013). Quasibinomial models were used to correct for 'underdispersion' (Smith, 1983). To simplify the analytical process the ages of household heads were first grouped into three age categories (old >55, mid 40–55, young < 40). Close examination of the data revealed that most respondents were in the 'mid' age category and there was considerable confounding between age category and the educational attainment variable, i.e. there was not a big enough range of educational levels within each of the age categories to separate the effects statistically.

Hence the decision was made to limit modeling and statistical testing to the 'mid' age category. Similarly, the distribution of educational attainment within the 'mid' age category was so patchy that we focused the confirmatory statistical analyses on education levels 0, 1 and 2 only. The differences in the coping strategies that respondents said they adopted were analyzed using the following series of regression models which were, again, compared and contrasted using analysis of deviance tests. The proportions or percentages calculated can also be considered as 'probabilities of having used a particular coping strategy' (or probability of saying each respondent used a particular coping strategy). We think this eases comprehension, and is the best way to interpret the models and their output.

1. Pr(choice) = 1
2. Pr(choice) = coping strategy * frequency
3. Pr(choice) = coping strategy * frequency + Education
4. Pr(choice) = coping strategy * frequency + Education + pond

where Pr(choice) is the probability of selecting a particular combination of coping strategy (e.g. 'consuming rice seed stock') and frequency (e.g. 'often' or 'never').

'Coping strategy' is the action the household (head) took to ensure food or income in the 60 days following the cyclone. As mentioned above 'frequency' refers to the number of times that a household head said he or she employed a particular coping strategy. Households were only able to select one 'frequency' for each coping strategy. 'Education' in the models refers to education levels 0, 1 or 2 and 'pond' refers to whether a household had access to aquaculture ponds or not. Responses were only analyzed for households who said that they were not forced to employ coping strategies before Cyclone *Sidr*, but did employ coping strategies after Cyclone *Sidr*.

Analysis of deviance tests allowed us to find the 'best' model. Model 1 is the NULL model; model 2 assumes that the probability (or percentage) of respondents making each choice depends on the combination of coping strategy and frequency; model 3 assumes

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

that the probability (or percentage) of respondents making each choice depends on the combination of coping strategy and frequency, plus the level of education obtained by each the household head; while model 4 assumes that the probability (or percentage) of respondents making each choice perforce depends on the combination of coping strategy and frequency, the level of education of the household head, and whether that particular household head had an aquaculture livelihood strategy.

The analysis of deviance test between models 3 and 4, for example, allows us to ascertain statistically whether or not it pays a mid-age (40–55) household head to engage in aquaculture, given that educational effect has been taken into consideration (NB. we were only able to 'test' the mid-age range statistically due to confounding effects with the educational variable). To plot the model output a data set of all permutations among the 'predictor' or 'independent' variables (e.g. education) was constructed, and parameters from the model used to 'predict' values over each combination.

The basic data analytical protocol described above in detail for the 'food security' group of questions was repeated for the two other coping strategy groupings, generating income by either selling assets or borrowing money.

2.3.4. Focus group discussions

Focus group discussions, (FGDs) with 108 (58 CAARP households and 50 non-CAARP households) households, were used to generate qualitative data to complement that generated through the questionnaire. Each of the FGDs involved groups of 10–12 people from nine villages in the five districts. Each group was asked semi-structured questions relating to their experiences during and after Cyclone *Sidr* and relating to their losses and coping strategies. Participants spoke openly and discussed issues with one another as well as with the FGD facilitators, who were staff members of the 18 partner organizations of CAARP. Due to the small sample size of nine groups and the poor recall abilities of FGD participants, the results were primarily used to contextualize the role of aquaculture with respect to other post-disaster coping options and were not analyzed statistically.

3. Results

3.1. Household demographics and agriculture assets prior to Cyclone Sidr

Sixty nine percent of all households participating in the questionnaire were functionally landless (<0.2 ha land), having access to an average of 0.07 ± 0.06 ha, and the remaining households had much larger land holdings, with an average 0.50 ± 0.40 ha. Though aquaculture households had slightly larger landholdings than non-aquaculture households, this difference was not significant (*t*-test; $P > 0.05$). Both aquaculture and non-aquaculture households had diverse livelihoods including poultry production (89% of all households), vegetable gardens, livestock rearing, capture fisheries, rice cultivation and aquaculture (Table 2). The prevailing aquaculture systems in Patuakhali, Barisal, Jalokathi, Pirojpur and Bagerhat were household ponds.

The demographic characteristics of the heads of aquaculture households were significantly different from the heads of non-aquaculture households (see Table S1 in supporting information), with the probability of practicing aquaculture increasing linearly with age ($df = 1$, $P = 0.001$) and combined age and education level ($df = 5$, $P = 0.000$) (see Figure S1 in supporting information). The mean age of the heads of aquaculture households was 47 ± 1 y while the mean age of the heads of non-aquaculture households was 42 ± 1 y. Similarly, the mean education level of heads of aquaculture households was 1.4 ± 0.1 (0 representing no education, 1 representing primary education and 2 representing secondary education) compared to 0.9 ± 0.1 for heads of non-aquaculture owning households. There was no significant interaction effect between age and education level ($df = 5$, $P = 0.616$).

Table 2
Agricultural assets owned by aquaculture farmers and non-aquaculture farmers.

Agricultural assets	Aquaculture			Non-aquaculture		
	Mean	SD	N	Mean	SD	N
Land total (ha)	0.25	0.30	266	0.14	0.33	135
Pond area (ha)	0.06	0.10	266	NA	NA	NA
Rice field (ha)	0.26	0.25	163	0.31	0.45	53
Vegetable field (ha)	0.05	0.06	170	0.04	0.04	66
Poultry (no.)	24	43	242	19	31	106
Fishing net (no.)	2	1	134	1	1	49
Cattle (no.)	3	3	133	2	1	39
Goats (no.)	3	3	74	3	2	46
Plough (no.)	1	0	51	1	1	16
Boat (no.)	1	0	32	1	0	16
Buffalo (no.)	2	2	11	2	1	2

3.2. Impacts of Cyclone Sidr

Jhalokathi and Priojpur districts were the most impacted regions, with 34% of houses being severely damaged. Barisal also suffered 32% severe damage followed by Bagerhat and Patuakhali with 24% and 18% severe housing damage, respectively. Cyclone *Sidr* also created widespread damage to aquaculture infrastructure (Table 3). Eighty eight percent of aquaculture households reported water pollution, while 86% of households reported damage from debris and accumulation of fallen trees and tree branches in ponds. In addition, 80% of households reported widespread flooding and a further 76% of households suffered damage to pond embankments. Thus, cyclone *Sidr* also caused fish, prawn and shrimp mortality. Forty six percent of aquaculture households reported complete loss of aquaculture stock (Table 4). Of the households which had stock remaining, a total of 34% of initial stock survived. During focus group discussions, farmer's perceptions of the vulnerability of different commodities to cyclone damage and the impact of such losses on household income and food security were elucidated. Rice and fish were perceived as being at high risk of damage or destruction, being rated 2.9 on a scale of 0–3. The loss of rice and fish was also rated as highly detrimental to household income and food security. Livestock was perceived to be the least vulnerable, being rated 1, and suffering only low mortality.

3.3. Coping strategies

Four hundred and one households participated in a questionnaire and were asked about the strategies they used to cope in the 60 days post Cyclone *Sidr*. Participants were asked how they coped with two limiting factors including, limited food and income. Questionnaire participants were also asked if they employed these

Table 3
The proportion of aquaculture households suffering impact to aquaculture assets from Cyclone *Sidr*.

Impact type	% Households
Water pollution	88
Tree damage	86
Water inundation	80
Embankment damage	76
Heavy silting	32
Saline water intrusion	13

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

Table 4
The level of aquaculture stock loss incurred during Cyclone *Sidr*.

Proportion pond stock loss	No. HH affected (%)
Few lost[a]	10 (4)
Half lost	29 (11)
Most lost[b]	104 (39)
All lost	123 (46)
% of HH with stock remaining	54
% of stock remaining per HH	34

HH = household.
[a] Assume that “few lost” is equivalent to 25%.
[b] Assume that “most lost” is equivalent to 75%.

coping strategies before Cyclone *Sidr* and only those households which did not employ coping strategies before Cyclone *Sidr* but did employ a coping strategy after Cyclone *Sidr* were used in further analysis.

3.3.1. Food security

Participants were asked what strategies they employed to acquire sufficient food for their families in the months following Cyclone *Sidr*. Participants were also asked how frequently (daily, often: 3–6 days a week, sometimes: 1–2 days a week, seldom: <1 day a week, or never) the post-Cyclone *Sidr* conditions forced them into employing these coping strategies to feed themselves and their families. Households with and without aquaculture ponds employed similar coping strategies ($P = 0.968$; Table S2 in supporting information). Conversely, educational attainment of the household head was a significant determinant of how families coped in the months following Cyclone *Sidr* ($P = 0.042$; Table S2 in supporting information). A higher percentage of households in which the household head had no education said that they were forced to employ a coping strategy between 3 and 7 days a week, compared households whose head received primary or secondary education (see ‘daily and ‘often’ panels in Fig. 2a, compared to ‘daily’ and ‘often’ in Fig. 2b and c).

A common coping strategy (action) to ensure food security by both aquaculture and non-aquaculture households was to consume cheap food, with a high proportion of households, across educational levels, applying this strategy between 3 and 6 days per week (Fig. 2). Many households also reduced the number of meals they ate in a 24 h period, and families were often forced to apply this strategy >3 days per week (Fig. 2). Nearly every household reported that they limited food portion sizes at least once per week. Given that this was such a common coping strategy we looked deeper into ‘limiting portion sizes’ as a means to ensure food security. This revealed that a higher percentage of aquaculture households limited portion sizes ‘never’, ‘seldom’, ‘sometimes’ than non-aquaculture households, while a higher percentage of non-aquaculture households limited portion sizes ‘often’ and ‘daily’ (Table 5).

Despite there being no difference in the actions that aquaculture and non-aquaculture households took to cope with the limited food availability, there is some evidence that having access to aquaculture ponds helped families cope after a natural disaster. Just over half of the aquaculture households had fish remaining in their ponds after the cyclone (Table 6). Focus group discussions (FGD) revealed that the most important source of food in the 60 days following Cyclone *Sidr*, was rice, followed by aquaculture products. Families with ponds relied on them for food post-cyclone, consuming more than half the usual amount than in the previous two years, despite large losses. Aquaculture systems were the only food producing asset that provided households with access to both food and income. A total of 4 009 kg of fish were utilized from these households with a mean of 10 ± 9 kg from each pond being used for consumption (Table 6). Eighty seven percent of households with fish remaining in their ponds used the fish as a food source and 59% used the fish as a source of income (Table 6). The fish remaining in ponds provided a supply of food for several months. It was especially important during the first month when 24% of households with ponds and fish remaining relied on the ponds for food.

3.3.2. Income security

Participants were asked about coping strategies (actions) they employed to ensure that they had sufficient income after Cyclone *Sidr*. Income was generated through two broad mechanisms; 1) utilizing assets or 2) borrowing. Examples of coping strategies grouped under ‘utilizing assets’ include selling or mortgaging assets, utilizing savings and reducing money spent on medical treatment. Examples of coping strategies grouped under ‘borrowing’ include borrowing money or grain from neighbors, NGOs or banks. Analysis of the ‘borrowing’ strategies also gives an indication of access to social capital, because borrowing is often achieved through informal insurance structures accessible through social networks (Helgeson et al., 2013).

The results for income strategies were similar to those for food security and we have therefore not presented these data. There was no significant difference in the actions that aquaculture and non-aquaculture households took to ensure they had some income for household expenditure through either selling assets ($P = 0.989$) or through borrowing money from a lender ($P = 0.989$). However, the educational attainment of the household head had a significant effect on determining the actions that a family took to ensure they had sufficient income to cope in the months post Cyclone *Sidr* (selling assets, $P = 0.000$; borrowing money from a lender, $P = 0.005$).

Across household types, the most common coping strategies were to use savings, reduce expenditure on medical treatment, sell livestock and trees and to secure a loan from an NGO or neighbors. Across the two household types (aquaculture and non-aquaculture) 38% of households used savings to cope and 34% of households reduced expenditure on medical care. Eighteen and 19% of households sold livestock and poultry, respectively. Advanced sales of standing crops, fruit and fish were also among the strategies adopted. During focus group discussions participants explained that the volumes of shrimp, fish and prawn sold by households fell by more than half during 2007, but still contributed to post-cyclone sales for cash. Reportedly, aquaculture was also among the most important sources of income along with livestock and for some social groups, betel leaves.

Approximately 77% of both aquaculture and non-aquaculture households had access to social capital and were provided with items such as ploughs, fertilizers, seed and household items from family members, neighbors or friends to cope with limited expendable income.

3.4. Investment and rehabilitation priorities: perceptions of aquaculture households

During focus group discussions nine groups of aquaculture households were asked to rank aquaculture and other agricultural income options, such as rice, livestock, poultry and vegetables, with respect to their investment priority. Seven of the nine groups ranked investment in aquaculture as second only to rice and this was reflected during cyclone cleanup efforts, with 78% of aquaculture households re-investing in rehabilitation measures despite high stock losses during the cyclone. Mean investment in rehabilitation of aquaculture assets was US$ 23 ± 2 per household. Households also placed a high priority on physical rehabilitation of

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

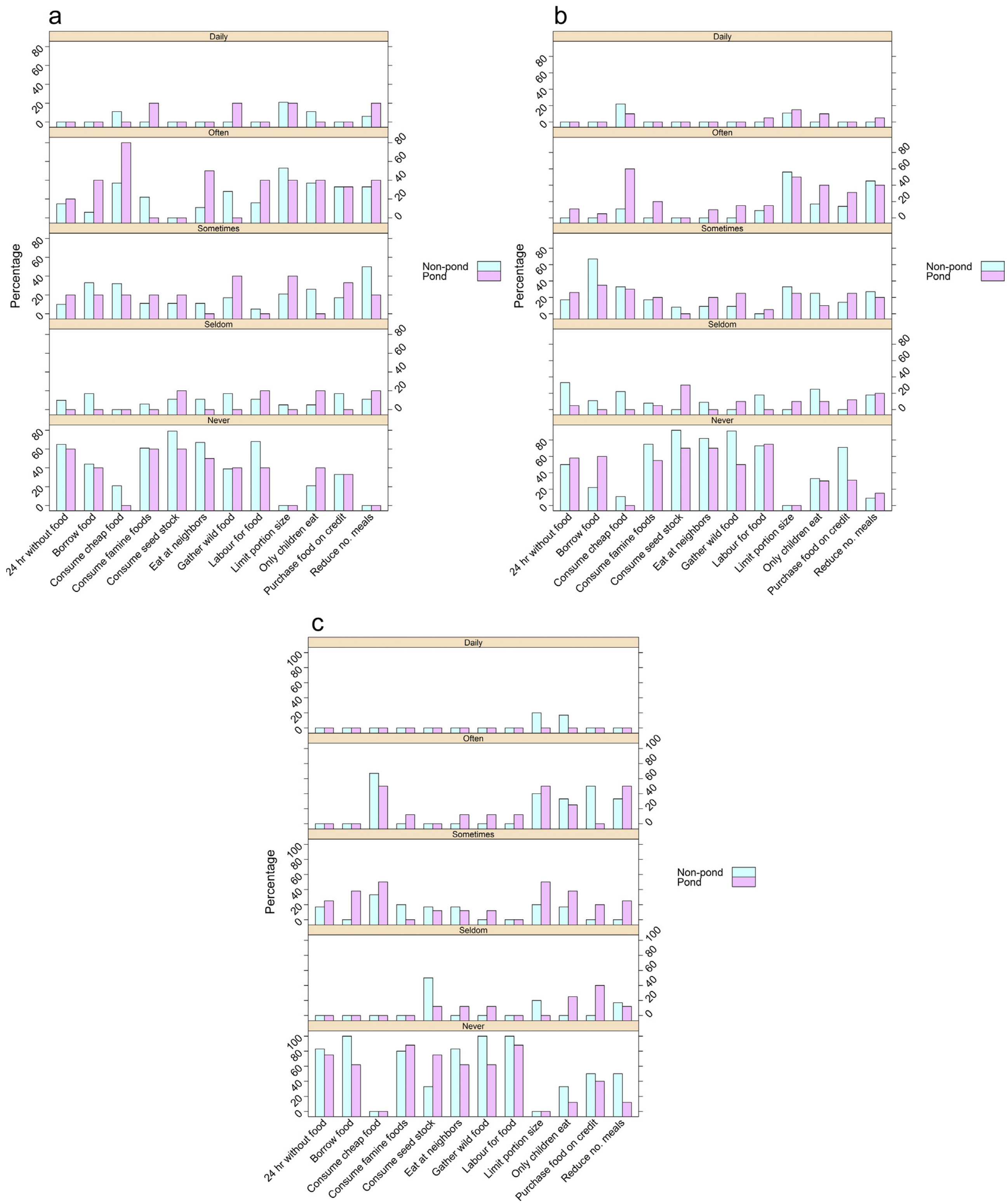

Fig. 2. The percentage of households, whose head had a) no education, b) primary education and c) secondary education, that employed coping strategies to ensure household food security. Note 'often' = ≥3 days a week, 'sometimes' = 1–2 days a week and 'seldom' =<1 day a week.

aquaculture ponds. Within a week, most farmers had cleaned ponds by removing the silt and other farmers simply repaired dikes and removed trees. Over 70% of the ponds that were not de-silted returned to a state that was deemed suitable for restocking within 4 weeks.

3.5. Perceptions of non-aquaculture households

The perceptions of non-aquaculture farmers were generally positive towards rehabilitation and recovery of aquaculture systems. One hundred and twenty seven non-aquaculture households

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

Table 5
Percentage of households who were forced to limited their portion sizes which did not limit portion sizes before Cyclone *Sidr* but did limit portion sizes after Cyclone *Sidr*.

HH category	Never	Seldom	Sometimes	Often	Daily
AQ HH	7	17	30	37	10
Non-AQ HH	4	16	18	44	19

AQ HH = households who own aquaculture ponds.
Non-AQ HH = households who do not own aquaculture ponds.

Table 6
Utilization of fish from homestead ponds in the 60 days following Cyclone *Sidr*.

Use of fish	No. of HH[a]	% of total	Total amount of fish used (kg)	Mean amount of fish used from each pond (±SE)
Eat	123	87	1 267	10 (9)
Sale	84	59	1 230	16 (19)
Gift	37	26	151	5 (4)
Keep	37	26	1 361	37 (15)
Eat and sale	76	54		
Total			4 009	

[a] Note only 142 out of 266 households had fish remaining in their ponds but households with fish remaining could chose more than one option for utilization.

(94%) regarded aquaculture as a good asset in a disaster prone area, stating that aquaculture provided additional food and income after a natural disaster. The majority (86% and 58%, respectively) of non-aquaculture households also stated that aquaculture systems provided a source of income and water for household consumption. Also, 69% of respondents considered aquaculture a good asset because dike cropping provides a further increase in income. Despite the positive responses non-aquaculture households stated that they could not engage in aquaculture because they did not have sufficient land or capital.

3.6. Management of risk in aquaculture

Household risk management strategies were explored using questionnaire data from focus group discussions. These included physical interventions such as constructing net fences around the perimeter of the ponds and elevating dikes to avoid overspill and loss of stock. Clearing debris and trees from the outside of the ponds in order to reduce organic deposition during storms and pond shading throughout the year was also suggested. Other strategies, including frequent partial harvesting, restocking of less vulnerable species and modification of production systems, for example, from ponds to improved gher systems (the term *gher* refers to a paddy field that has been modified for shrimp or prawn production) or to nursery systems, were also suggested by 48%, 39% and 21% of survey respondents, respectively. Culturing bottom dwelling species may reduce stock losses, and species with short production cycles such as tilapia (*Oreochromis niloticus*), sarputi (*Puntius gonionotus*) and silver carp (*Hypophthalmichthys molitrix*) were recommended to ensure early harvesting before cyclone season. In addition, adaptation of production cycles, through timed stocking, to align harvesting before the beginning of the cyclone season would help to reduce major stock losses (Fig. 3). For example, full harvest in August or September, or selective harvesting of larger fish prior to the October–November cyclone season is recommended (Fig. 3).

4. Discussion

4.1. Is aquaculture an asset or a liability?

A variety of coping strategies (actions) were employed by families in the southern coastal zone of Bangladesh in response to Cyclone *Sidr*. We classified households into two groups – aquaculture and non-aquaculture – and investigated differences in the ways households coped to determine the role of aquaculture in supplying food and income after the natural disaster. A Generalized Linear Regression model (GLM) demonstrated that households with access to aquaculture assets responded in similar ways i.e. applied similar coping strategies at a similar frequency to households without aquaculture assets. This implies that non-aquaculture households had access to additional or different assets which also provided food and income for families to cope post cyclone. This finding could also imply that aquaculture ponds are neither an asset nor a liability in comparison to other agricultural assets, though additional qualitative evidence gathered through focus group discussions suggests that aquaculture ponds make a valuable contribution to supporting households in the wake of a natural disaster. Over half of aquaculture households had fish remaining in their ponds after Cyclone *Sidr*, and from each of these ponds approximately 10 kg of fish was used for consumption. The food production sector in Bangladesh was severely impacted by Cyclone *Sidr*, resulting in a reliance on dry processed food which offered limited nutrition in the weeks following the cyclone (Government of Bangladesh, 2008; Islam et al., 2011). For half of the households, owning a pond meant that a nutritious animal source food was accessible for months following the cyclone, despite the nationwide food crises. Fish, rich in calcium (when eaten whole), vitamin A, zinc and protein (Roos et al., 2007a), were also shared

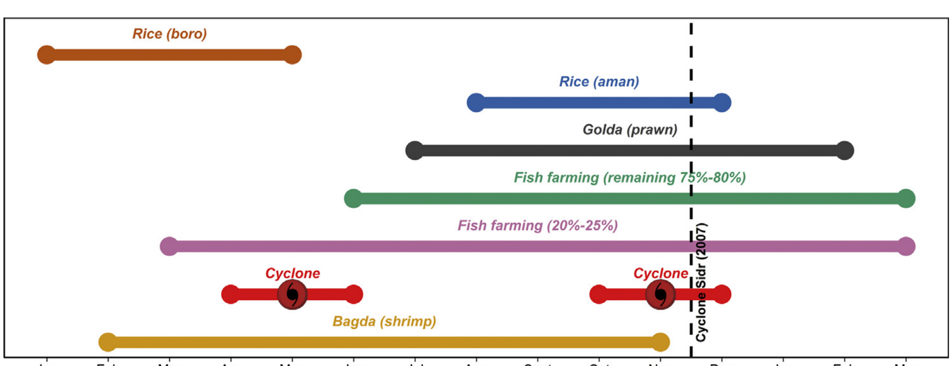

Fig. 3. Current cropping cyclone calendar constructed through focus group discussion findings. 'Bagda' refers to *Penaeus mondon*, 'golda' to *Macrobrachium rosenberghei*, 'boro' to dry season rice and 'amon' to wet season rice. Stars denote the disaster prone periods.

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

among relatives and neighbors during social gatherings. This acted to strengthen the social networks of aquaculture households, an invaluable contribution given the fundamental role of social networks in coping, rehabilitating and adapting after a disaster event (Pomeroy et al., 2006; Paul and Routray, 2010, 2011). In addition, ponds also served as a source of income and a supply of water for both household use and livestock.

Aquaculture, however, carries risks which, if not managed, can result in an aquaculture pond putting extra financial pressure on a household following a natural disaster. Damage to dikes, flooding and stock loss occurred in many of the ponds and, in response, the majority of aquaculture households spent over US$20 per household to restore their ponds. The gross national income per capita in 2007 was US$510 (calculated using the Atlas method), so US$20 represents a significant proportion of the income for poor rural households (The World Bank, 2012). The additional financial pressure of rehabilitation after a natural disaster or extreme weather events can force households to sell other productive assets, remove children from school and reduce household consumption (Ahmed and Garnett, 2010; The World Bank, 2010). Individual or cluster insurance is recommended to abate aquaculture risks (Vadacchino et al., 2011). However, there are limited insurance programs for shrimp and virtually no insurance for fish farming in Bangladesh (van Anrooy et al., 2006; The World Bank, 2010). Building on and strengthening existing insurance and microfinance institutions is essential for kick-starting small businesses after a disaster (Pomeroy et al., 2006). In addition, system adaptation will help reduce the risk and enhance the role of aquaculture ponds for poor communities coping with natural disasters.

4.2. Improved coping: reducing aquaculture vulnerability through adaptation

Aquaculture development has been recommended as a strategy to reduce food insecurity and poverty of poor communities (Ahmed and Lorica, 2002), and during focus group discussions both aquaculture and non-aquaculture farmers in the present study reported ponds to be an asset in a disaster prone area. There is opportunity to adapt aquaculture systems by improving infrastructure and management practices. Recommended adaptations in the broader literature and the present study include increasing dike height to reduce stock escape in the interest of both the receiving environment and the farmer (Vadacchino et al., 2011). Choosing species which are fast growing, bottom dwelling or endemic will also reduce the duration between harvest cycles, reduce the risk of escape and reduce biodiversity impacts in the event that stock does escape (Vadacchino et al., 2011). Choice of the most suitable livelihood options will also reduce risks (Pomeroy et al., 2006). Participants in the present study suggested that aquaculture households in disaster prone areas could consider fingerling production, which is relatively quick, while regions in the north, which are lower risk areas, could consider fish grow-out, which is considerably longer and thereby more risky. While these measures provide practical solutions for adapting systems to a changing climate, the cornerstone of sustainability and coping is developing the capacity of farmers to assess risks, innovate and continually adapt systems and transfer knowledge among one another (Smit and Wandel, 2006; Anik and Khan, 2011; Vadacchino et al., 2011). These measures potentially enhance the sustainability of productive assets in high risk areas and help to break poverty cycles in which marginalized communities are often embedded (Chowdhury, 2008).

4.3. Improved coping: aquaculture as part of a diversified livelihood

Although aquaculture is well suited to the aquatic-agricultural landscapes of Bangladesh, income diversification, particularly away from a reliance on natural resources, has long been recognized as an effective way to enhance a household's capacity to cope with a natural disaster (Pomeroy et al., 2006; Paul and Routray, 2011). Households in the study area practiced diversified livelihood activities including production of vegetables, livestock, poultry, fish and trees, which helped them to cope with Cyclone *Sidr* through sale or consumption of productive assets. Diversification provides opportunities for a “food bank” and an “income bank”, through ownership of varied and disposable assets which spread the risk of income failure associated with reliance on a single livelihood activity (Allison and Ellis, 2001).

4.4. Improved coping: other factors driving coping

Making the decision to apply a coping strategy is driven by a complex array of factors, such as age, education level, land holding area, access to productive assets, geographic vulnerability, cultural or religious norms and social networks (Paul and Routray, 2011). Variability in these factors is likely to partly explain the lack of difference in the way that aquaculture and non-aquaculture households coped with the cyclone. Some of these factors (e.g. land holding area) varied significantly within each group, often more so than between aquaculture and non-aquaculture households.

In the present study, adding education as a factor to the GLM demonstrated that education was indeed a significant determinant of deciding to apply a coping strategy, which has been demonstrated previously (Paul and Routray, 2010, 2011; Helgeson et al., 2013). . Across aquaculture and non-aquaculture households, a higher proportion of household heads with secondary education never applied a coping strategy to ensure food security than those with no education. This is likely because household heads with a higher education level store food and ensure they have savings to cope with food insecurity during natural disasters (Paul and Routray, 2011). Coping capabilities can be increased through investment in education and training, in particular addressing natural disaster awareness and risk management (Pomeroy et al., 2006). In addition, households with a more educated head are better able to predict (through traditional methods) and understand weather forecasts regarding the approach and severity of a weather event which enables efficient preparation and improves coping (Paul and Routray, 2011; Webster, 2013).

Disaster forecasting and efficient communication networks reduce vulnerability of the poor and foster preparedness, allowing communities to implement mitigation measures before a natural disaster (Westlund et al., 2007; Lal et al., 2009; Webster, 2013). Bangladesh has a reasonably advanced disaster forecast and communication network system; the Regional Integrated and Multi-Hazard Early Warning System (RIMES) (Webster, 2013). As a result of this system some communities were recommended to harvest crops early, move livestock to higher ground and stockpile water and food supplies in preparation for the floods in mid-2007 (Webster, 2013). This resulted in savings of US$400-500 per household (Webster, 2013). However, limited funding for the system limits the capacity to stay up-to-date with global forecast systems (Webster, 2013). Given the substantial savings attributed to RIMES policy reforms, investment in RIMES are called for. Aquaculture extension and communication networks should be aligned with RIMES and aquaculture participatory action research programs should incorporate disaster risk reduction and management training.

Please cite this article in press as: Karim, M., et al., Asset or liability? Aquaculture in a natural disaster prone area, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021

4.5. Limitations

Although the present study has limitations i.e. problems associated with memory recall for survey data collection and interpretation and analysis of survey data (Alemayehu et al., 2011), the benefits of aquaculture in coping with a disaster were evident. Both aquaculture and non-aquaculture households demonstrated willingness to invest or re-invest or in aquaculture ponds but private sector investment in aquaculture must be managed to ensure systems are designed to reduce environmental impacts and pressure on natural resources (Hall et al., 2011). Fierce competition for input resources such as water, nutrients, seed and energy can lead to unsustainable use of these resources and can exclude poor households from accessing or maintaining aquaculture assets. Moreover, aquaculture systems are often optimized to produce only large fish cultured specifically as income earners, and these fish are typically sold at the markets, forgoing any potential nutritional benefits for poor household (Beveridge et al., 2013). There are emerging technologies which are centered on polycultures of mixed carp species and small fish species to provide both income (carp) and a rich source of protein and micronutrients (small fish) (Wahab et al., 2011). These systems have potential to reduce the vulnerability of poor households through provision of both income and nutritious small fish and such design considerations are paramount to ensuring aquaculture becomes an asset and not a liability in a disaster risk area.

Acknowledgments

The authors are grateful to the USAID (388-G-00-08-00054-00) for the financial support provided to the CAARP Project (CAARP). The authors wish to thank Susana Hervas Avila for survey design and for helping to conduct the focus group discussions. The field staff of the CAARP were also instrumental in conducting the questionnaire. We would also like to thank Jason Benedict from WorldFish for support in constructing Figs. 1 and 3. The preparation of this paper was supported by funding from the CGIAR Research Programs on Aquatic Agricultural Systems (AAS) and Climate Change, Agriculture and Food Security (CCAFS).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2014.04.021.

References

Ahmed, M., Lorica, M.H., 2002. Improving developing country food security through aquaculture development – lessons from Asia. Food Policy 27, 125–141.
Ahmed, N., Garnett, S.T., 2010. Sustainability of freshwater prawn farming in rice fields in Southwest Bangladesh. J. Sustain. Agric. 34, 659–679.
Alemayehu, A.A., Abebe, Y., Gibson, R.S., 2011. A 24-h recall does not provide a valid estimate of absolute nutrient intakes for rural women in southern Ethiopia. Nutrition 27, 919–924.
Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Mar. Policy 25, 377–388.
Anik, S.I., Khan, M.A.S.A., 2011. Climate change adaptation through local knowledge in the north eastern region of Bangladesh. Mitig. Adapt. Strategies Global Change 17, 879–896.
Belton, B., Azad, A., 2012. The characteristics and status of pond aquaculture in Bangladesh. Aquaculture 358–359, 196–204.
Beveridge, M.C.M., Thilsted, S.H., Phillips, M.J., Metian, M., Troell, M., Hall, S.J., 2013. Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture. J. Fish Biology 83, 1067–1084.
Chowdhury, N.I., 2008. Bangladesh. Risk reduction boost livelihood security in disaster-prone district. In: UN/ISDR (Ed.), Linking Disaster Risk Reduction and Poverty Reduction. Good Practices and Lessons Learned, International Strategy for Disaster Reduction and UNDP.
DoF, 2013. National fish week 2013. In: fisheries, D.o.f.a.m.o.l.a. (Ed.), Compendium (in Bengali). Bangladesh. 144 p.
Government of Bangladesh, 2008. Damage, Loss and Needs Assessment for Recovery and Reconstruction after Cyclone *Sidr*. Report Prepared by the Government of Bangladesh, assisted by the International Development Community with financial support from the European Commission.
Guha-Sapir, D., Vos, F., Below, R., Ponserre, S., 2012. Annual Disaster Statistical Review 2011. The Numbers and Trends. CRED, Brussels.
Gutro, R. and Olsen, E., 2007. Hurricane Season 2007: sidr (Indian). Power Tropical Cyclone *sidr* Makes Landfall in Bangladesh. http://www.nasa.gov/mission_pages/hurricanes/archives/2007/h2007_sidr.html (accessed 09.07.13.).P
Hall, S.J., Delaporte, A., Phillips, M.J., Beveridge, M., O'Keefe, M., 2011. Blue frontiers: managing the environmental costs of aquaculture. The worldFish Center, Penang, Malaysia.
Helgeson, J.F., Dietz, S., Hochrainer-Stigler, S., 2013. Vulnerability to weather disasters: the choice of coping strategies in rural Uganda. Ecol. Soc. 18. http://dx.doi.org/10.5751/ES-05390-180202.
HIES, 2005. Bangladesh Bureau of Statistics. Household income and expenditure survey. http://www.bbs.gov.bd/PageReportLists.aspx?PARENTKEY=66.
Huq, S., 2001. Climate change and Bangladesh. Science 294, 1617.
Islam, A.S., Bala, S.K., Hussain, M.A., Hossain, M.A., Rahaman, M.M., 2011. Performance of coastal structures during Cyclone *Sidr*. Nat. Hazards Rev. 12, 111–116.
Kawarazuka, N., Béné, C., 2010. Linking small-scale fisheries and aquaculture to household nutritional security: an overview. Food Sec 2, 343–357.
Lal, P.N., Singh, R., Holland, P., 2009. Relationship Between Natural Disasters and Poverty: a Fiji Case Study, 678. SOPAC Miscellaneous Report.
Little, D.C., Edwards, P., 2003. Integrated Livestock-fish Farming Systems. Food and agriculture organizaiton of the United Nations Rome, Italy.
Little, D.C., Karim, M., Turongruang, D., Morales, E.J., Murray, F.J., Barman, B.K., Haque, M.M., Nitai, K., Belton, B., Golam, F., Azim, M.E., Islam, F.U., Pollock, L., Verdegem, M.C.J., Young, J.A., Leschen, W., Wahab, M.A., 2007. Livelihood impacts of ponds in Asia – opportunities and constraints. In: van der Zijpp, A.J., Verreth, J.A.V., Le Quang, T., van Mensvoort, M.E.F., Bosma, R.H., Beveridge, M.C.M. (Eds.), Fish Ponds in Farming Systems. Wageningen Academic Publishers, The Netherlands, pp. 117–202.
Mazid, M.A., 2002. Development of Fisheries in Bangladesh, Plan and Strategies for Income Generation and Poverty Alleviation. Nasima Mazid, Dhaka, Bangladesh.
McCullagh, P., Nelder, J.A., 1989. Generalized Linear Model. Chapman and Hall, London.
Paul, S.K., Routray, J.K., 2010. Flood proneness and coping strategies: the experiences of two villages in Bangladesh. Disasters 34, 489–508.
Paul, S.K., Routray, J.K., 2011. Household response to cyclone and induced surge in coastal Bangladesh: coping strategies and explanatory variables. Nat. Hazards 57, 477–499.
Pomeroy, R.S., Ratner, B.D., Hall, S.J., Pimoljinda, J., 2006. Coping with disaster: rehabilitating coastal livelihoods and communities. Mar. Policy 30, 786–793.
R Core Team, 2013. R: a Language and Environment for Statistical Computing. R foundation for statistical computing, Vienna, Austria. ISBN 3-900051-07-0. URL. http://www.R-project.org/.
R Development Core Team, 2006. R: a Language and Environment or Statistical Computing. R foundation for statistical computing, Vienna, Austria. http://www.R-project.org.
Roos, N., Islam, M., Thilsted, S.H., 2003. Small fish is an important dietary source of vitamin A and calcium in rural Bangladesh. Int. J. Food Sci. Nutr. 54, 329–339.
Roos, N., Wahab, M.A., Chamnan, C., Thilsted, S.H., 2007a. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. J. Nutr. 137, 1106–1109.
Roos, N., Wahab, M.A., Hossain, M.A.R., Thilsted, S.H., 2007b. Linking human nutrition and fisheries: incorporating micronutrient-dense, small indigenous fish species in carp polyculture production in Bangladesh. Food Nutr. Bull. 28, S280–S293.
Sarkar, D., 2008. Lattice: Multivariate data Visualization with R. Springer, New York.
Skoufias, E., 2003. Economic crises and natural disasters: coping strategies and policy implications. World Dev. 31, 1087–1102.
Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob. Environ. Change 16, 282–292.
Smith, P.G., 1983. Quantitative Plant Ecology. University of California Press, California, USA.
The World Bank, 2010. Agricultural Insurance in Bangladesh. Promoting access to small and marginal farmers. Report No. 53081-BD.
The World Bank, 2012. Bangladesh. http://data.worldbank.org/country/bangladesh Accessed online 22nd May 2013.
Vadacchino, L., De Young, C., Brown, D., 2011. The Fisheries and Aquaculture Sector in National Adaptation Programmes of Action: Importance, Vulnerabilities and Priorities. FAO fisheries and aquaculture circular No. 1064 FIPF/C1064(En).
van Anrooy, R., Secretan, P.A.D., Lou, Y., Roberts, R., Upare, M., 2006. Review of the Current State of World Aquaculture Insurance. FAO Fisheries Techniqual paper 493 Rome, FAO. 92p.
Venables, W.N., Ripley, B.D., 2002. Chapter 7. Generalized Linear Models Modern Applied Statistics with S. Springer, Germany, pp. 183–208.
Wahab, M.A., Kadir, A., Milstein, A., Kunda, M., 2011. Manipulation of species combination for enhancing fish production in polyculture systems involving major carps and small indigenous fish species. Aquaculture 321, 289–297.
Webster, P.J., 2013. Improve weather forecasts for the developing world. Nature 493, 17–19.
Westlund, L., Poulain, F., Båge, H., van Anrooy, R., 2007. Disaster Response and Risk Management in the Fisheries Sector. FAO fisheries techniqual paper 479 Rome, Italy.
WorldFish Center, 2009. Cyclone Affected Aquaculture Rehabilitation Project. Completion report (Phase 1). March 2008 to April 2009. Funded by USAID. Grant no. 388-G-00-08-00054-00.