Assessment of economic loss due to fish diseases in Assam, India and implications of farming practices

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Abstract Extensive surveys were conducted in 60 fish farms in Cachar and Nagaon districts of Assam, India to assess economic loss due to aquatic animal diseases and the contribution of fish farming practices therein. Epizootic Ulcerative Syndrome (EUS), also known as mycotic granulomatosis or red spot disease, was the most common disease that affected most fish species during winter months. Other disease conditions reported were dropsy, fin/tail rot and Argulus infestation. Overall disease prevalence was less in Cachar district compared to that in Nagaon district. Estimated loss of fish production (as percentage of total production) and total economic loss (in INR) were estimated to be 10.8% & 67,500.0 per farm (30,770.0 per ha) in Cachar and 5% & 55,300.0 per farm (14,900.0 per ha) in Nagaon district.The average farm area, water area and the number of ponds (per farmer) were less in Cachar compared to that in Nagaon district. Average fish production was also lower (1870 kg ha^{-1}) in Cachar compared to Nagaon (2470 kg ha^{-1}). The majority of fish farms in Cachar (60%) operated as a nursery (N) and grow-out (G) systems whereas those in Nagaon operated as nursery-fingerling-growout (N-F-G) system (63.33%). An overwhelming majority of farmers (93.33%) in Cachar practiced polyculture, but 30% of farmers practiced integrated farming in Nagaon district. N-F-G farming system and integrated culture practice adopted by the majority of Nagaon farmers led to higher fish productivity and lesser economic loss. Poor pre-stocking management of fish ponds was found to be the main contributory factor for higher disease prevalence in Nagaon compared to that in Cachar district. However, the farmers in Nagaon district were more aware of disease control measures that resulted in moderate economic loss.

Key words Aquaculture practices, Fish diseases, Economic loss, Assam

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Introduction

The world fish production has been growing steadily over the last five decades; food fish supply is increasing at an average annual rate of 3.2%, double that of world population growth rate (FAO, 2016). Global aquaculture production reached an all-time high of 73.8 million tonnes in 2014 (FAO, 2016). Keeping in pace with global fish production, the fisheries sector of India has witnessed a 13-fold increase from 0.75 million tonnes in 1950-51 to 10.07 million tonnes during 2015-16. Assam, one of the important fish producing states of India in the inland sector, has witnessed a production increase from 0.19 million tonnes in 2005-06 to 0.29 million tonnes in 2015-16 (Das *et al.*, 2017). The state has vast and varied fisheries resources in the form of rivers (4820 km), floodplain wetlands (1,00,817 ha), derelict water bodies (1,16,444 ha), forest fisheries (5,017 ha), reservoir fisheries (2,553 ha), individual ponds

(55,430 ha) and community ponds (5,141 ha) and produced 306.6 thousand tonnes of fish during 2016-17 (Das *et al.*, 2017). Assam is also one of the major fish consuming states of India and has put much emphasis on harnessing its fish production from ponds and wetlands in recent years.

Disease in cultured aquatic organisms is one of the major factors that contribute to poor production in aquaculture worldwide. It was estimated in 1997 that the world is losing approximately US$ 3 billion per annum due to diseases in aquaculture (Subasinghe *et al.*, 2001a); the huge economic loss must have remained so if not increased in last two decades with the intensification of aquaculture practices. According to Wei (2002), China lost around 15% of its fish production annually due to fish diseases. The extent of mortality loss due to epizootic ulcerative syndrome (EUS) was severe in rivers, reservoirs, oxbow lakes, tanks, estuaries, and backwaters in the Indian subcontinent during the late 80's. EUS in Bangladesh caused an estimated loss of about US$ 3.38 million in 1988 (Barua, 1994). The socio-economic impact of EUS was also estimated in Indian states. For example, in Bihar the loss was estimated at US$ 150,000 during 1990; in Orissa, it was US$ 95,000 in 1989-91; and in Kerala at US$ 625,000 during 1991-92 (Das, 1994). Data on the impact of EUS on carp culture in ponds are highly variable and inconsistent (Mohan and Bhatta, 2002). According to Bhaumik *et al.* (1991), 73% of the culture ponds in West Bengal were affected and most of the farmers lost 30-40% of their stock due to EUS in the 90's. Economic loss due to disease is likely to increase as aquaculture expands and intensifies. However, assessment of economic loss from diseases - barring a few intensively cultivated species like shrimp, catfish, etc. has not gained sufficient focus. According to Idowu *et al.* (2017), the economic impacts of aquatic animal diseases are almost a grey area in literature.

Fish diseases not only incur a direct loss in terms of mortality of fish but also as loss from morbidity, poor growth, poor quality and market price of the produce, cost of treatment, preventive measures, etc. (Francis Floyd, 2005). Besides, livelihood and living standards are affected due to reduced product availability, loss of income and employment (Subasinghe *et al.*, 2001b). Therefore, assessment of social and economic impacts of disease on rural aquaculture is needed so that farmer-oriented, environmentally friendly, and integrated primary health management packages could be emphasized for adoption (Mohan and Bhatta, 2002; Bagum *et al.*, 2013). Fish disease outbreaks and mortality are caused by pathogenic organisms, however, environment quality and aquaculture practices might predispose fish to such infections and are important in fish health management. Thus, it is important to document the farm management practices being followed by farmers. Fisheries development including pond aquaculture is growing at a fast pace in the Indian state of Assam. Against this background, we conducted the present surveys to assess economic loss due to the prevalence of aquatic animal diseases in Assam and the contribution of fish farming practices thereon.

Materials and methods

The present study was conducted in Cachar and Nagaon districts of Assam, India (Fig. 1) since these two districts (among 26 districts) of the state have the maximum aquaculture resources and contribute significantly to the fish basket of the state (www.fisheries.assam.gov.in). Cachar district, located in Barak Valley, has a total of 20,352 ponds covering 6,278 ha, and Nagaon (Brahmaputra Valley) has 44,126 ponds covering 4,482 ha. The random sampling method was adopted for the selection of thirty (30) fish farms from each district to cover all parts of the districts. Data were collected on culture practices followed, production, mass mortality, economic loss, etc. through farm surveys and personal interviewing of the fish farmers and farm managers using pre-tested questionnaire developed under the All India Network Project on Fish Health. While the primary data collected through personal interviews were being analysed, cross-check visits and telephonic calls were made, whenever required, to verify previously collected data. Mass mortality of fish was mostly considered for estimation of economic loss; less severe diseases/infestations that do not lead to mass mortality were recorded but not accounted in disease loss estimate. Field visits were intensified during winter months (December-February) since disease outbreaks were common in the study area during this period. Fish diseases were personally observed, diseases identified, and loss of fish production and economic loss due to fish diseases assessed in consultation with the fish farmers. Data obtained through the questionnaire was statistically analyzed to work out loss in fish production and revenue due to fish diseases, characteristics of fish farms, expenditure incurred on various inputs including aquaculture drugs/ medicines, and so on. Correlation between feed cost and productivity of the pond was worked out using MS Excel.

Results and discussion

The average fish production from selected pond aquaculture systems of Nagaon district was estimated at 2470 kg $ha^{-1}year^{-1}$, whereas it was 1870 kg $ha^{-1}year^{-1}$ in the Cachar district. On average, farmers of Cachar district lost more fish (246.5 kg ha^{-1}) due to mortality as compared to their peers in Nagaon (112 kg ha^{-1}) (Table 1). Economic loss (as percentage of total production) and total economic loss were estimated to be 10.8% and ₹ 67,500.0 per farm (₹30,770.0 per ha) in Cachar as compared to 5% and ₹55,300.0 per farm (₹14,900.0 per ha) in Nagaon.

The majority of the farmers in Nagaon were found to over-stock their ponds and no proper feeding practice was followed. Supplementary feeding was neither a common practice nor scientifically followed. To support fishes stocked in higher densities, farmers usually over-fertilized (to support plankton production) their ponds leading to the occurrence of obnoxious gases from the pond bottom. To deal with this problem, most of the farmers reportedly applied sanitizing agents/medicines to remove such gases. Higher stocking densities, a higher rate of fertilization, improper feeding, little or no prophylactic treatment of fish seed, and improper pond preparation were reported, which might predispose fish to disease problems in fish ponds.

The prevalence of different disease conditions in the study area is shown in Fig. 2. EUS was the most commonly reported disease condition in Cachar (53.33%) and Nagaon (60%) farms. EUS was a seasonal disease mostly occurring during winter months (Nov-Feb) in the studied region, affecting almost all cultured species including *Labeo rohita*, *L. gonius*, *Cirrhinus mrigala*, *Barbonymus gonionotus*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, *Heteropneustes fossilis,* and *Clarias magur*. *Cyprinus carpio* and *Chitala chitala* were also reported to get affected by EUS in the Cachar district. Other disease conditions such as dropsy (caused by *Aeromonas hydrophila* and *A. veronii*), tail and fin rot (caused by *Flavobacterium* spp.) and *Argulus* (lice) were also observed in both the districts with higher prevalence in Nagaon than in Cachar.

The systematic study of aquaculture resources in the two districts revealed that average farm area, water area and a number of ponds belonging to the farmers of Cachar district (4.8 ha, 2.5 ha & 4 no., respectively) were smaller as compared to those in Nagaon district (14.5 ha, 8 ha & 8 no., respectively) (Table 2). Based on the water area (Viswanatha *et al.*, 2014), ponds in Cachar could be classified as medium and those in Nagaon as large ponds. On an average, the selected farmers of Cachar had 15 years of fish farming experience while Nagaon farmers had 19 years of experience. Thus,

Fig. 1 Map showing location of selected districts (i.e., Nagaon and Cachar) of Assam, India where the survey of fish farms was conducted

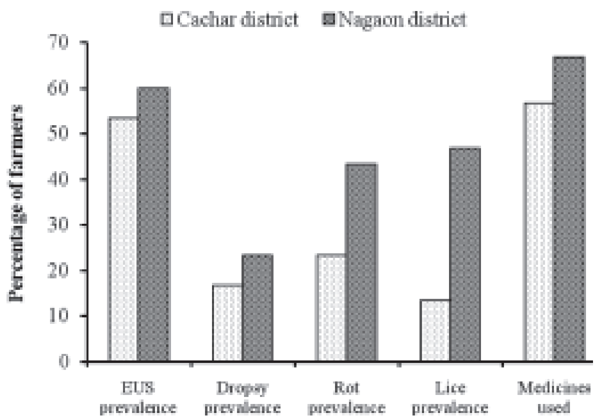

Fig. 2 Prevalence of different disease conditions in fish farms of selected districts of Assam, India. Data presented as percentage of farmers who reported the disease condition or medicine use

Table 1 Fish production and estimated economic loss caused to the farmers due to fish diseases in selected districts of Assam, India

	Production (kg/ha)	Estimated production loss (Kg/ha)	Estimated economic loss (₹/ha)	Estimated economic loss (% of production)	Estimated economic loss (₹ /farm)
Cachar district	1870	246.5	30,770	10.80	67,500
Nagaon district	2470	112	14,900	5.0	55,300

Data is expressed as percentage of total farms; number of fish farms in each district (i.e., n) = 30.

Table 2 Farm characteristics and ownership of fish farms in selected districts of Assam, India

	Av. farm area	Av. water area	Av. no. of ponds	Av. experience in fish farming	Farm ownership type (% of farmers)			
					Own	Leased	Own + Leased	Community pond
Cachar district	4.8 (0.33-66)	2.5 (0.26-20)	4 (1-17)	15 (3-40)	73.33	6.66	6.66	13.33
Nagaon district	14.5 (2-250)	8.0 (1.6-75)	8 (1-38)	19 (2-80)	80.0	13.33	3.33	3.33

Data is expressed as average (range); farm ownership is shown as percentage of total farms; number of total farms in each district (i.e., n) = 30.

Table 3 Farming systems and culture practice in fish farms of selected districts of Assam, India

	Only Nursery	Nursery + Grow-out	Nursery + Fingerling+ Grow-out	Hatchery+ Nursery +	Fingerling+ Grow-out	Growout	Fingerling	Polyculture	Integrated farming
Cachar district	0	60	10	3.33	13.33	13.33	0	93.33	6.66
Nagaon district	0	6.66	63.33	3.33	3.33	20	3.33	70	30

Data is expressed as percentage of total farms; number of fish farms in each district (i.e., n) = 30.

Table 4 Nature of farming and source of water in fish farms of selected districts of Assam, India

	Perennial crop	Seasonal crop	Source of water in aquaculture ponds				
			River	Rain	Rain + River water	Rain + Ground water	Ground water
Cachar district	100	0	13.33	40	36.66	10	0
Nagaon district	80	20	0	10	0	66.66	23.33

Data is expressed as percentage of total farms; number of fish farms in each district (i.e., n) = 30.

Table 5 Sources of fish seed, quality testing of seed and stocking density (SD; no./ha) in nursery, rearing and grow-out stages practiced by fish farmers of selected districts of Assam, India

	Commercial hatchery	Own hatchery	Other farms	Send quality testing	SD in nursery	SD in rearing	SD in growout
Cachar district	86.66	3.33	10	0	2,95,800	38,000	9,300
Nagaon district	66.66	33.33	0	0	33,84,800	63,000	15,000

Data is expressed as percentage of total farms; number of fish farms in each district (i.e., n) = 30

technical knowledge gathered and shared by the farmers on pond aquaculture was reasonably good as verified during personal interviews. Most of the farmers of Cachar (73.33%) and Nagaon (80%) districts had their own ponds; well-to-do farmers also took ponds on lease from others for aquaculture.

The farming system and culture practices followed in these two relatively advanced districts of Assam so far as pond aquaculture is concerned are shown in Table 3. No farmers in the two districts were observed to have 'only nursery' system of farming indicating less profitability of nursery rearing in these districts. It might be less profitable for the selected farmers to bring in fertilized eggs or hatchlings from other areas for nursing up to 15-20 days and dispose off, because this early development stage is highly susceptible to

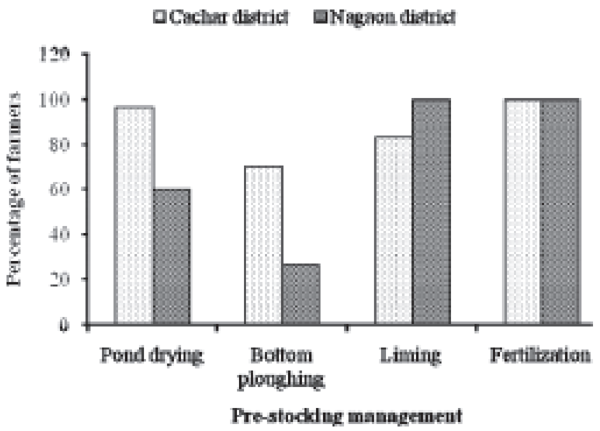

Fig. 3 Pre-stocking pond preparation procedure for fish farming in selected districts of Assam, India. Data is expressed as percentage of total farms; number of fish farms in each district n = 30

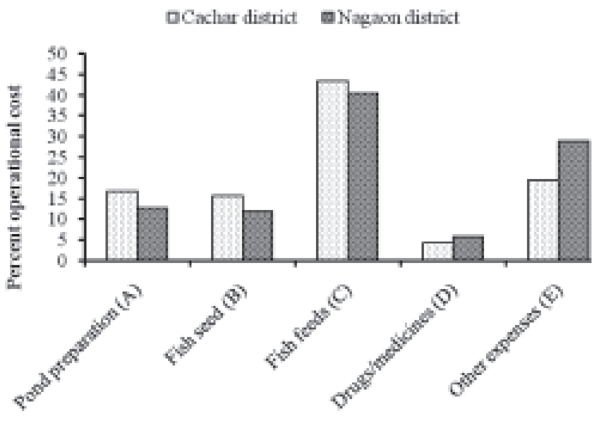

Fig. 4 Expenditure incurred on various inputs including aquaculture drugs/ medicines in fish farms of selected districts of Assam, India. Data is expressed as percentage of total farms; number of fish farms in each district (i.e., n) = 30

deterioration in water quality with associated very high mortality rates. The majority of farmers in Cachar (60%) operated as nursery and grow-out farming systems whereas the majority of farmers in Nagaon operated as the nursery-fingerling-grow-out system (63.33%). One of the reasons for low productivity (1870 kg $ha^{-1}year^{-1}$) in aquaculture farms of Cachar could be the absence of 'fingerling production' facility and hence the farmers mostly stocked their ponds with the smaller seed (i.e., fry or early fingerling) which is prone to higher mortality in grow-out ponds. Further, the small-sized seed did not grow to a good marketable size (~ 1 kg) in 10-12 months of the culture period (including winter months). Thus, the farming system followed had considerable economic implications on the aquaculture enterprises, which was evident from higher economic loss in Cachar district as compared to Nagaon district. Culture practices were also considerably different in these two districts. Whereas 93.33% of the farmers practiced polyculture (culturing more than one species in one water body) in Cachar district, a lower proportion of farmers (70%) practised polyculture in Nagaon district; the other 30% farmers practised integrated farming (fish-cum-livestock systems including piggery, poultry, and duckery), which reduced input costs on fish feed and fertilizers, improved the overall productivity and return from the system. In polyculture practice, species combinations most commonly used were three Indian major carps (*Labeo catla*, *L. rohita* and *C. mrigala*), three exotic carps (*H. molitrix*, *C. idella* and *C. carpio*), minor carps (*L. gonius* and *L. bata*). In addition, exotic silver barb (*B. gonionotus*), catfishes (*H. fossilis*, *C. magur*), *C. chitala* and *Channa* spp.were also stocked in lower numbers. This was in contrast to the culture practice prevalent in Andhra Pradesh wherein advanced fingerlings of *L. rohita* and *C. mrigala* are mostly cultured in polyculture (Viswanatha *et al.*, 2014). The monoculture practice was non-existent in these districts of Assam, which is in contrast to a monoculture of *Litopenaeus vannamei* and *Penaeus monodon* in Andhra Pradesh, India (Viswanatha *et al.*, 2014) and of late *Pangasianodon hypophthalmus* in cages and ponds.

The feed is a major cost in aquaculture. In the Northeastern states of India, culture practices are mostly organic. The integrated farming of fish with animals was very popular in Nagaon. Integrated farming enhances the efficiency of the culture system. The rationale behind integrating fish with livestock is the large amount of nutrients (N-P-K) present in the animal feed being recovered in the manure, with high proportions of nitrogen (72–79%), phosphorus (61–87%) and potassium (82–92%) which act as fertilizers in fish ponds (Sahoo and Singh, 2015). Integrated farming systems usually reduce the input costs such as costs on fish feed and pond fertilizers, thereby improving the overall productivity of the system (Bhattacharjya *et al.*, 2017), which was accrued by 30% farmers of Nagaon district and only 6.66% farmers of Cachar district. A good benefit-cost ratio (2.38) observed in fish culture using recycled piggery wastes in the region (Bhattacharjya *et al.*, 2017) apparently contributed to off-setting the economic loss due to fish diseases in integrated fish farming systems in the Nagaon district.

All the farmers in Cachar district cultivated fish throughout the year, with more than 76% farmers harvesting rainwater and river water for their ponds (Table 4). Farmers of Nagaon appeared slightly water-deficient as 20% of farmers did fish farming seasonally; 90% of the farmers were dependent on rain and groundwater. Since a large number of Nagaon farmers used bore wells as a source of water, they could maintain sufficient water levels in their ponds even under drought or during insufficient rainfall leading to improved productivity. However, it seemed that one out of five farmers of Nagaon switched to occupations other than aquaculture during dry months (winter) of the year.

Pre-stocking pond preparation is one of the most important factors that influence the subsequent stages of the production cycle. Growth and health of fish in a pond are determined by productivity and quality of water and sediments in terms of biotic (such as plankton, periphyton, benthos availability) parameters which in turn are dependent on abiotic parameters such as pH, dissolved oxygen, presence of obnoxious gases, alkalinity, etc. Periodic draining and drying of ponds followed by removal of excess muck/ mud from the pond bottom, ploughing to loosen bottom sediment followed by application of lime (for pH correction, disinfection, etc.) and fertilization (with organic and/or inorganic fertilizers) are four most important pre-stocking management steps in aquaculture (Jena and Das, 2006) that determine the level of success of the enterprise. The majority of the farmers in Cachar district were reported to practice pond drying (96.66%) and ploughing (70%) (Fig. 3). In Nagaon, 60% of the farmers dried their ponds and but only 26.66% of farmers practised bottom ploughing, mostly because most of the ponds were not fully drainable. However, cent percent of farmers in Nagaon district applied lime not only during pond preparation but also during the culture cycle. Drying of pond bottom helps in reducing organic matter build up and removing unwanted organisms including pathogens. Bottom ploughing or raking releases obnoxious gases that are harmful to fish, and liming wards off the ill-effects of organic matter decomposition and restores hygienic conditions in the pond (Sinha, 1985). This simple step effective for preventing environmental diseases was not practiced by the farmers in the study area except for a few farmers in the Cachar district.

The present survey revealed that commercial hatcheries were the sources of fish seed for most of the fish farmers in Cachar (86.66%) and Nagaon (66.66%) districts (Table 5), which is also the case elsewhere in the country (Nair and Salin, 2007). However, a considerable number of farmers (33.33%) in Nagaon were having their own hatcheries that would be convenient for farmers for stocking as per need and at less cost. Quality of fish seed is critically dependent on the size and nutritional status of the broodfish, which also determines the growth and health of offspring. Other seed quality attributes of importance are uniformity in size, absence of disease and external parasites, healthy nourished appearance, and swift movement. It was surprising that none of the farmers in both the districts bothered about seed quality, and hence they did not enquire about or observe any seed quality attributes before procuring and stocking in their farms. Stocking density, i.e., the number of fish seed stocked per hectare of waterbody determines the production and productivity of the aquaculture enterprise. It is one of the most important variables in aquaculture because it directly influences survival, growth, production, behaviour, health, and water quality (Smith *et al.*, 1978; Haque *et al.*, 1994; El-Sayed, 2002; Kolhi *et al.*, 2002). Density-dependent growth is a common phenomenon in aquaculture: as population density increases, competition for food and space increases as well and animals stocked in higher densities grow less (Biswas *et al.*, 2014). An inverse correlation between growth rate and stocking density was observed in *Oreochromis niloticus* (El-Sayed, 2002). Density-dependent growth in the Cyprinidae is generally associated with food availability, although Pfuderer *et al.* (1973) have shown that goldfish (*Carassius auratus*) and common carp (*Cyprinus carpio*) released a hormone that inhibited growth and production at higher stocking density. Smith *et al.* (1978) studied the growth of fathead minnows (*Pimephales promelas*) fed *ad libitum* in tanks at different densities and reported that growth ceased at high densities regardless of food abundance. Our study revealed that farmers of Nagaon followed a considerably higher stocking density (no./ ha) in nursery (33,84,800), rearing (63,000) and grow-out (15,000) phases compared to their peer groups in Cachar (2,95,800; 38,000 and 9,300, respectively). Surprisingly, it was observed in both the districts that farmers were not following any standard practice of stocking especially concerning the number of species to be stocked, species composition of fish seed, stocking ratio and density – all these led to sub-optimal fish production and disease susceptibility. This is in sharp contrast to farmers of Andhra Pradesh who either use stunted fingerlings of three-species at 5,000 no. of *L. rohita*, 500 no. of *C. catla*, and 250 no. of *C. mrigala* per ha leading to an overall yield of 9,000-11,000 kg $ha^{-1}year^{-1}$, or they stock 10,000 no. of *L. rohita* and 500 no. of *L. catla* with average production of 13,000-15,000 kg $ha^{-1}year^{-1}$ (Nair and Salin, 2007). In West Bengal and other states of India, a six-species stocking ratio comprising of 30-40% surface feeders (silver carp and catla); 30-35% column feeders (rohu and grass carp) and 30-40% bottom feeders (common carp and mrigal) is also used for more efficient use of different niches in the pond ecosystem. Inferior pre-stocking management coupled with higher stocking densities followed by most farmers of Nagaon district could be associated with a higher prevalence of tail rot/gill rot and ectoparasite infestations observed in this study. Stocking density was recognized as one of the important factors related to the occurrence of streptococcosis in tilapia *Oreochromis niloticus* (Amal and Zamri-Saad, 2011). However, single stocking-multiple harvesting or multiple stocking-multiple harvesting, in which larger or grown-up fishes are periodically harvested and marketed, could potentially be practiced by farmers adopting higher stocking densities.

Farm management in terms of pre-stocking pond preparation/sanitation and stocking management has a strong bearing on disease outbreaks in aquaculture systems. It is reported that water and sediment pH, temperature, dissolved oxygen, and other water quality parameters influence occurrences and severity of fish diseases (Bromage and Owens, 2009; Amal and Zamri-Saad, 2011). In the present study, it was observed that most of the farmers stocked their grow-out ponds with smaller size fingerlings (3-5 g) comprising of multiple species (>6 species). When this is compared with the usual practice in Andhra Pradesh, a leading aquaculture state in India, it can be understood that the majority of farmers in Andhra Pradesh follow a two-species system comprising of 23% *L. catla* and 77% *L. rohita* (Veerina *et al.*, 1993). *C. mrigala* (a bottom dweller) is not cultured in Andhra Pradesh at present, because it was suggested that total harvesting of the species (which is difficult) might help in preventing the occurrence of EUS outbreaks in culture ponds (Mohan and Bhatta, 2002). It was observed in the study that the prevalence of EUS and other bacterial ulcers mostly occurred in winter months indicating a significant role of temperature in disease outbreaks. It was reported that seasonal variation in air temperature in Cachar and Nagaon districts was wide, ranging between 10-35 ^{o}C. Perhaps, low water temperature during winter months would reduce fish immunity which probably makes the fish susceptible to *Aphanomyces invadans*, the primary causative agent of EUS. Once this fungus makes deep wounds on the skin of fish through its invading hyphae, opportunistic bacteria start infecting and causing the wound more severe (Das, 1994). Similar to our findings, in Bangladesh also about 76.7% of the disease outbreaks were reported in the winter season (Bagum *et al.*, 2013).

As expected, due to higher disease prevalence, more number of farmers in Nagaon (66.66%), than in Cachar (56.66%) were using aquaculture drugs and medicines for prevention and control of fish diseases. All the farmers of Nagaon district were using lime but at suboptimal quantities. The survey revealed that the majority of the farmers did not follow best management practices during pre- and post-stocking phases, which might act as predisposing factors for the incidence of disease conditions, morbidity, and mortality of cultured fish.

Despite facing higher disease prevalence by farmers of Nagaon district, they could achieve higher fish production and lower estimated economic loss per ha of a pond. Larger ponds, greater farming experience, and higher stocking density could be directly or indirectly related to higher fish production in Nagaon compared to Cachar. In addition, integrated farming practiced by more number of farmers in Nagaon also reduced input cost on fish feeds. Assured source of water (i.e., groundwater) for the majority of the farmers of Nagaon also would have supported higher fish production in the district. Moreover, most of the farmers of Nagaon were aware of aquaculture drugs and medicines available in the market to deal with problems related to water quality, plankton production, and fish growth, which would have supported them to achieve higher production despite higher disease prevalence.

Expenditure incurred by the farmer on different aspects of aquaculture operation demonstrates the relative importance of those pre- and post-stocking management steps. In the present study, major input costs considered were expenditure on pond preparation, liming & fertilization (A), fish seed (B), fish feed (C), and drugs and medicines including water sanitizers and probiotics (D) (Fig. 4). It was observed that in Nagaon district, the percentage expenditure on A, B, C, and D were 12.8, 11.9, 40.5, and 5.8% respectively, whereas these were 16.80, 15.7, 43.4, and 4.5% respectively in Cachar district. Interestingly, feed cost consisted of more than 40% of total expenses in both the districts, but there was no significant correlation between feed cost and productivity (kg ha^{-1}). In fact, expenditure on feed in Nagaon district was negatively correlated ($r = -0.24$) with productivity, whereas it was positively correlated ($r = 0.21$) in the Cachar district. Mustard oil cake (MOC) was used as a supplementary feed by the majority of the farmers in both the districts; the use of compact or pellet feeds was negligible. Lack of awareness among the farmers and non-availability of formulated compact feeds were reported to be major constraints faced by the fish farmers of the study region. The feeding method generally followed by the farmers was similar to bag feeding wherein MOC were put in gunny bags, soaked in water for 2-3 days, and then released into the pond. Rice bran (RB) was also used as feed by the majority of the farmers by the broadcasting method. The study showed that high expenditure on fish feed did not lead to high productivity, which must be due to use of improper feeds (use of MOC or RB only instead of nutritionally balanced compact pellets), irregular feeding (random dumping instead of a calculated ration based on existing biomass of stocked fish) and wasteful feeding methods (use of jute-made gunny bags in corners of the pond instead of perforated HDPE or PP fabric bags hung across the length and breadth of the pond). It was evident that farmers of Nagaon spent less on pond preparation and hence more on drugs and medicines to control or prevent a higher prevalence of disease conditions in their farms. Expenditure on fish seed was less in Nagaon because many farmers had their hatcheries that reduced seed cost.

Conclusion

The study showed that excessive stocking density, high dose of fertilization, improper feeding, inferior fish seed quality, little or no prophylactic treatment of fish seed, and improper pond preparation were some of the factors that predispose fish to disease problems in fish ponds in the study area. N-F-G farming system and integrated culture practice (adopted by Nagaon farmers) led to higher fish production and lesser economic loss. The estimated economic loss in the region can be reduced by following better management practices like (i) periodic dewatering and desilting of fish ponds, (ii) applying optimum doses of lime and fertilizers in the ponds at regular intervals, (iii) stocking fish ponds with the good quality fish seed of proper size and density after prophylactic dips, (iv) feeding the stocked fishes with nutritionally balanced compound diet in appropriate quantity, frequency, time and method and (v) applying drugs and medicines in fish ponds at the first appearance of disease conditions.

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