Impact of water quality changes on livelihood options among aquaculture farmers along Vembanad lake

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Abstract

Water quality is an important variable in food production . Protection of water quality is an important management mesure for improving productivity of food production systems such as agriculture , horticulture and aquaculture . In aquaculture a variation in water quality may leads to complete lose of production . Hence aquaculture farmers are always conscious about managing same toteh benefit of productivity and livelihood security . How ever their livelihood negotiations are less captured academic discourse . The objectives of the study is to understand the effect of water quality changes on livelihood resources and to understand conflict and livelihood negotiations by the farmers . The study site is Vembanad Lake a ramsar site and method of study is case study method .The study points out that only through public –private partnership we could have livelihood security for farmers

Keywords: Farmers , Aquaculture , water quality , Disease, Livelihood

Introduction

Water and food are basic necessities for all living organisms. Although 75 percent of the surface of the earth is covered with water, hardly 1 percent of water in terms of volume is available for living organisms to meet basic necessities including management of food production systems. The availability or lack of water has often led to rise and fall of civilizations. Therefore, ancient communities resorted to managing water with stringent rules for access and withdrawal, creating boundaries, monitoring of water resources and enforcing sanctions against misuse. With the advent of industrialization; the competition for resources increased which led to the belief that external intervention in the form of government or private ownership could only manage or regulate resources like water, fisheries, forestry and pasture lands. Although the move was effective in certain cases, most of the resources diminished despite this intervention because of reasons that are well known. The case of water was not different; along with decreasing quantity, the quality of water also deteriorated. Compared to other resources, in the case of of water, this deterioration is treated as an emerging issue that was highlighted only recently, although the issue is being discussed for the last 200 years .The tension between water security and food production is going to increase in future. Pollution, climate change, and market mechanisms all have contributed to this state of the resource and this will impact the livelihood of marginalised communities the most.

Aquaculture is considered as one of the fastest growing food production systems in the world. Since 1970, aquaculture production has grown at 8.9 annual rate while fishery catch has grown at 1.2percent and terrestrial stock at 2.8 percent (FAO, 2003). It is believed that the aquaculture will grow at the same growth rate as agriculture shortly (Bandyopadhyay, 2008). Major issues faced by the sector include inadequate seed quality, water management and quality issues,,as well as government support and policy issues. In aquaculture, water quality can be considered as an input factor which determines yield. In Kerala, aquaculture is concentrated mainly in Kuttanad and Kole lands and Pokkali farm lands along Vemband lake. IThe data shows that the shrimp production in Pokkali fields varies year to year

Table 1. Sustainable shrimp aquaculture development in Pokkali fields (2005-06 to 2011-12)

Year	Area covered(ha)	No of Beneficiaries	Production	Revenue achieved by farmers (in 1000ks)
2005-06	1488.95	458	444.66	911.45
2006-07	1631.46	425	836.93	1756.07
2007-08	2000	125	198.4	489.66
2008-09	357.17	94	210.9	446
2009-10	152.43	51	149.94	418
2010-11	341	103	336	769
2011-12	443.31	567	280.3	700.75

Data Source: ECONOMIC REVIEW 2012; STATE PLANNING BOARD, TVM, MAR, 2013

In this scenario, the main objective of this study is first to understand the extent of water quality changes and its impacts on the livelihood of aquaculture farmers in Vembanad lake, and, second,

,to evaluate the livelihood negotiations by the affected communities along Vemband lake. This study uses the sustainable livelihood frame work proposed by Ian Scoones (Scoones, 1998). Vembanad lake is a Ramzar located in the west coast of south India, in the state of Kerala. The Vembanad wetland system and its associated drainage basins lie in the humid tropical region between 09°00' -10°40'N and 76°00'-77°30'E. The Vembanad wetland ecosystem is a massive coastal wetland ecosystem, covering an area of 24,000 ha and contributes over 50 percent of the total area of backwaters in the state. Nearly 1.6 million people live on the banks of the lake. Vembanad lake is considered as a moderately polluted Lake.

Literature review

A livelihood comprises people, their capabilities and their means of living, including food, income and asset (Conway & Chambers, 1991). A person's livelihood refers to their "means of securing the basic necessaries – food, water, shelter and clothing – of life". Livelihood is defined as a set of activities, involving securing water, food, fodder, medicine, shelter, clothing and the capacity to acquire those necessaries working either individually or as a group by using endowments (both human and material) for meeting the requirements of the self and his or her household on a sustainable basis with dignity. The activities are usually carried out repeatedly (Oxford, 2011). According to a study (Scoones, 1998) livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from the stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base. Water being an important natural capital is vital for human existence and growth. As a property, mainatining water quality means the maintenance of physical, chemical and biological characteristics of water. Water quality is a complex issue as the natural composition of water in many ecosystems is altered due to development pressures and environmental changes. The need to manage natural resources is critical today as the complexity of human impact on the environment is increasing day by day.

A study (Rudolf, 2000) found that farmers will be interested in managing their natural resources only if their rural livelihoods system as a whole becomes attractive and sustainable and it does not depend on economic and technological issues alone. Water quantity as a property, is well explored from a socio-economic, technical and livelihood perspective, but water quality as a property and its livelihood linkages are assessed peripherally. As water quality deteriorates, it affects people health and livelihoods. Such issues can cause local instability and in turn can destabilize nations and regions. During the 30 years that Israel occupied the Gaza Strip, for example, water quality deteriorated steadily, saltwater intruded into local wells, and water-related diseases took a toll on the residents. In 1987, the second *intifada* began in the Gaza Strip, and the uprising quickly spread throughout the West Bank. While it would be simplistic to claim that deteriorating water quality caused the violence, it undoubtedly exacerbated an already tenuous situation by damaging health and livelihoods (Wolf, Kramer, Carius, & Dabelko, 2005). Studies on the impact of the gold mining sector in Peru on local livelihood have identified that often communities end up in conflicts with mining companies due to the decrease in water quality. The decrease in water quality often escalates medical and health costs, financial incomes decline and it results in no increases in cattle and sheep holdings which are the primary source of rural house hold income. The livelihood strategies adopted by farmers in Peru were to mostly intensify agriculture and to migrate to nearby cities (Bury & Bebbingtona, 2009). Another study by (Bury J. , 2004) also discusses the livelihood impact of transnational gold mining in Peru. The authors argue in the paper that while access to produced and human capital resources has increased, access to natural and social capital resources has declined in that region. Studies on the impact of mining, agricultural runoff and industrial effluents on the Kafue river in Zambia have identified conflicts and livelihood issues among inland fishermen and the communities complain of loss of taste and the decrease in both the fish catch and size in these areas. The communities complained about the objectionable taste of the river water (Kambole, 2003). Another paper (Keraita, Drechsel , & Amoah, 2003) examined the impact of waste water usage in agriculture in Ghana and identified health risks among farmers and consumers.

With capture fishery declining, culture fishery is considered as the resolution for increasing demand for nutritional security, food security and livelihood security of marginalised fishing and agricultural communities. Aquaculture is one of the prime catalysts for the socio-economic development of Indian economy contributing to the nation’s food and nutritional security, export earnings, income and employment generation.. According to the FAO, aquaculture is understood to mean the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators among other aspects. Many chemical and physical variables of water can impact fish and shrimp growth and survival. Salinity increase beyond 40ppt retards the growth of shrimp; dissolved oxygen (DO), a low concentration of oxygen, lowers shrimp resistance to disease and inhibits their growth. A pH concentration between 7.5 to 9.0 is generally regarded as suitable, while a pH concentration less than five retards growth and a concentration more than 9.5 is harmful to shrimp growth. The nitrogen component, especially exposure to an ammonia concentration of 0.45 mg can reduce shrimp growth by 50 percent. With temperature fluctuation, the rate of chemical and biological reactions is said to double with every 10°C increase in temperature. With Hydrogen sulphide (H_2S) at the levels of 0.1–0.2 ppm in the water, the shrimps appear to lose their equilibrium and they die instantly at a concentration of 4 ppm**.**

People from various disciplines have studied the impact of water quality on aquaculture such as biologists, taxonomists, hydrologists, aquaculturists, economists, anthropologists, and sociologists. Economists have studied it from the production or from the valuation angle. One study (Rohitha, 2008) has valued to what extend water quality improvement can contribute to shrimp fishery in Dutch canal, Sri Lanka. A 2001 study(Paez-Osuna, 2001) assessed the impact of aquaculture on water quality. Another study (Kautsky , Tedengren, & Troell, 2000) has assessed the need for an ecosystem perspective against a technology perspective and its advantages of ecosystem-based management in reducing disease occurrence. A paper (Hein, 2002) highlights the importance of bringing better environmental policies, sharpening the licensing system and improving the monitoring along shrimp farms as fast development of shrimp farming is causing a number of environmental problems and social conflicts, including conversion of mangroves, water pollution, and salinisation of drinking water wells. Although it is claimed that aquaculture can badly degrade environmental conditions; it is also apparent that degrading environmental conditions can also impact the farming practises and livelihoods of small and medium farmers. This study is a modest attempt to highlight the livelihood issues of aquaculture farmers impacted by waste water disposal from industry, domestic sewage and agricultural runoff

Method

The Methodology of the study is case study method and we have selected the case of Ezhikkara panchayat (local governing body). The method of study is participatory rural appraisal method and data was collected using key informant interviews, focus groups and unstructured questionnaire administered to aquaculture farmer households. The sampling method used is the stratified random sampling method in which the strata are based on entitlements --- sluice gate owners and non-owners --- because water is managed through sluice gates and strata's based on water can give a better understanding of the water management aspect of water quality

Context of the study

Aquaculture is believed to have started in the Vemband lake in Kerala about 600 years ago. The Kudumbis, a migrant Konkani peasant community from the Goa-Karnataka border introduced this culture system in Kerala. Further, Hindu Ezhava, Christian and Muslim community members started aquaculture with the advent of the pink gold rush, targeting the lucrative export market for shrimp. Ezhikkara panchayat is located along the Vembanad Lake in Paravur Taluk of Ernakulam District. The boundaries of the panchayath are Vypin Island in the west, Kottuvally in the east, Kadamakkudy panchayat in the south and North Paravur municipality in the north. In Ezhikkara, shrimp farming is relatively nascent compared to the adjacent panchayats as this fragile ecosystem was for long considered not viable for aquaculture. Ezhikkara, compared to other panchayats, has weaker dykes that are smaller in width and shorter in height. Shrimp farming was started here only about 120 years back. Interestingly Kudmbis were not the frontrunners in aquaculture in Ezhikkara. It was the native Hindu and Christian fishermen who started the culture here.

The Initially used system was a modified version of "Changalapachil" fishery. Changalapachil fishery is a system in which fishermen tie two canons in face-to-face position with two bamboos on both sides and an iron rode hanging in middle. The sound of the iron rode dragging on low lying wetlands terrifies the shrimps and they are led to the harvest In the modified version of Changalapachil system, dykes are created in low lying wetlands to trap shrimp fry and the same changalappachil system is used to catch the fish. In this system, dykes are constructed in low lying wetlands for a period of 120 days. Water exchange naturally happens over the dykes during tides..Dykes are opened in specific locations after 120days. A special gear is be placed while the dykes are open to harvest the shrimp. Sluice gates were used for water exchange around 90 years back. It was called box sluice as it was in the shape of a box . To operate this box sluice four labourers were needed for each sluice. Further improvement came in the next 10 years in the shape of four piece sluice gates. In this format, there were wooden planks that could be removed on the sides and this could be operated by one or two labourers. All farming practises were traditional and there were enough wild stock of shrimp in the estuaries.

The scenario changed after 1960s. The increasing pollution from the Eloor industrial belt reduced the wild stock of shrimp available in the inland waterways. This made shrimp farmers to carry the shrimp fry from remote locations less impacted by pollution and deposit them in the aquaculture farms in Ezhikkara. During this period, the auctioning system also started in Ezhikkara which also led to a more industrial farming practices. By the 1980s, they started buying hatchery-reared fry for farms. This development made them move from traditional to extensive shrimp farming which is currently practised in Ezhikkara.

The shrimp and fish farming is practised from November 15 to April 15 after the Pokkali rice farming. A majority of the population in Ezhikkara works in fishery, fish farming or fish processing and allied activities. About 50 percent of the population lives below poverty line .The export of shrimp and crab from the panchayat bring Rs four crore worth of foreign exchange annually. Currently shrimp farming in Ezhikkara is practised in three padashekharams (paddy field collectives) after the Pokkali rice farming. The farms of 70 percent of the farmers are below five hectares while the biggest farmer holds 100 hectares of land. .These farms have their own governing bodies with a president, secretary and treasurer. This governing body manages the auctioning of shrimp, and the finances of auctioning, oversees the plastering of main dykes and the building of canals inside the farms, distributes the auction money among property owners, resolves conflicts among the farm owners within the padashekaram and between padashekrams owners. The auctioning of farms are organised one month before the farming season and any farmer or non-farmer inside or outside the community can give a sealed bid along with the prescribed fees (called Kuzhi Panam) to take farm land in auction for shrimp farming. Once the bid is won, three times the Kuzhi Panam must be paid to seal the deal, — they must give one third of the bid money within a week and rest of the money within a month.

Results

Effect of water quality changes on livelihood resources

From the livelihood resource perspective, in Ezhikkara, the major challenge addressed by aquaculture farmers in terms of capital is natural capital. This ecosystem has turned into a pollution sink mainly due to human interventions. The untreated waste water discharge from the ice plants and peeling sheds has made the water unfit for aquaculture farming. The effluents end up being circulated within this ecosystem without being flushed out. The data shows mainly the ammonia content in water has risen to 17 ppm although the water must not have more than 1 ppm of ammonia for aquatic life to survive.

Table 2. Water quality in farms effected by waste water discharge in Ezhikkara

Parameters	Unit	Value
pH		6.81
Salinity	ppt	27
Alkalinity	Mg/l	750
Total hardness	Mg/l	310
Calcium hardness	Mg/l	110
Magnesium hardness	Mg/l	200
Ammonia	Mg/l	17.427
Iron	Mg/l	0.0968

Source : Primary collection

In terms of economic and financial capital, the changes in natural capital – the changes in the property of water quality have invariably led to an increase in investment in terms of more probiotics such as Super PS and Detrodigest and chemicals such as lime and chlorine. On many occasions, farmers might not know the changes that happen in the water chemistry, and are thus prevented from taking appropriate remedial actions immediately. This situation leads to fish diseases – over the last eight years in Ezhikkara some pockets face fish diseases even at an early stage of farming which results in 100 percent loss from farming and some farmers have stopped fish farming in those farms . Fish death has resulted in returns of 10 percent of production although the expected production is 65 percent in the case of *Peneous Mondom.* The production of most species shows a decline or there is no growth in production.

Table 3. Fish Production in Ezhikkara- kg/hectare

Major species cultured	2000-2001	2005-2006	2010-2011	2012-2013
Peneaus Indicus	200	250	300	300
Phetapeneaus monocerus	100	250	200	200
Peneous Monodon	250	200	100	50
Scylla Serata	100	150	100	100
Oreochromeus Mosambicus	300	300	200	150

Primary Data

Another economic and financial constrain faced by aquaculture farmers is that the auction value of farm land correlates with the water quality status. From our analysis we find that there is positive correlation between water quality in an ecosystem and auction value of aquaculture farm lands .The auction value of polluted farms are decreasing while those of non-polluted farms are improving .While those farms without water quality issues fetch Rs 20000 per hectare in 2012-13 compared to Rs15000 per hectare in 2000-2001; the farms with water quality issues fetch just Rs 9000 to Rs15000 per hectare. The livelihood resources in terms of human capital, and the increasing labor charges are forcing many farm owners to employ themselves in their farms. It is also a risk aversion method as daily monitoring alone can only help identify changes in water quality from water colour, taste, smell,to skin and eye reactions .In a system were water is managed through tidal functions, the water exchange happens every six hours , flowing in two times and flowing out two times . Labour charges amount to Rs 10000 per month per head for a season. In the extensive farming method, a minimum of two labourers are required. If any fish disease or death is identified, farmers resort to harvest before the maturity period which invites extra labour charges. Gill net fishermen will be employed and they charged on weight basis., usually 30 percent of the total catch harvested. In case of fish death, again the fish is harvested and destroyed to avoid the spread of diseases. This additional effort also adds to the costs for the farmers. Health costs also increase in these areas as more workdays are lost and health expenses increase for farmers. With regard to the social capital, -- the social networks,association and membership – most of the fish farmers are formally associated with fisheries department, the Marine Products Export Development Authority (MPEDA) and Agency for Development of Aquaculture Kerala (ADAK) for seed and feed subsidies. They are informally organized through Kerala Aquaculture Farmers' Federation (KAFF) which has its presence at the local, regional and state level. About 80 percent of the farmers in Ezhikkara are members of KAFF. At panchayat level there are fish farmers' clubs that mainly give suggestions on programmes and projects related to fish farmers.

Institutions, conflicts and negotiations for livelihood

Institutions are the rules of the game for a society, or more formally, institutions are the humanly devised constraints that shape human interaction. They can be formal (rules) or informal (conventions, code of behaviour).They can be created or evolved. They differ from organisations in such a way that institutions are rules of the game while organisations are the players. Organisations are group of individuals bound by some common purpose to achieve objectives (North, 1990). India, being a participant of the United Nations conference on human environment held at Stockholm in 1972, took various measures to protect its environment. The Environment (Protection) Act, 1986, an act to provide for the protection and improvement of the environment and for matters concerned therewith has provisions to ensure that water, air and soil quality are adequately manitained. Any person or company causing environmental pollution by means of emission of environmental pollutants in solid, liquid or gaseous form in a concentration which tends to be harmful to environment can be punished with imprisonment up to 5 years and can be fined up to Rs 1,00,000..In case of failure to protect the environment or continuous contravention of the act, an additional fine of Rs 5000 can be levied for each day of the period the offence is observed. In terms of formal rules on water, the water quality in a water bodies is managed through the Water (Prevention and control of pollution) Act, 1974.The act specifies that "pollution" means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms (Water Act, 1974). The act authorises the pollution control board to prevent, control or abate discharge of waste into streams, to decide on the tolerance limits of pollution permissible in the water of the streams and to decide on mass education of the impact of pollution on human and aquatic health. The board is also authorised to advise the state government with respect to the location of any industry the carrying on of which is likely to pollute a stream or well. The institutional arrangement for execution of this act which is the “ The water (prevention and control of pollution) Cess Act,1977” focuses on the quantity of water used and levies a maximum of 30 paise per kilolitre from a processing industry through which the water gets polluted (Water Cess Act, 2003) .It is defined as an act to provide for the levy and collection of a cess on water consumed by persons who carry on certain industries by local authorities, with a view to augment the resources of the central board and the state boards constituted under the Water (Prevention and Control of Pollution) Act, 1974 for the prevention and control of water pollution. An aquaculture farm invariably is managed though Kerala Inland Fisheries and Aquaculture Act, 2010. The rule notes that to start new industrial firms in an aquaculture area, industrialists require approvals from the fisheries department. Although distance-based parameters on the location of industries from a water body come under the jurisdiction of Central Pollution Control Board and the distance of an industry from an aquaculture field come under the fisheries department, there is no clear process in place which links the pollution control board and fisheries department to decide on the distance parameters. Therefore, the fisheries and aquaculture rules do not mention distance limits. This anomaly invariably takes the process out of legal jurisdiction which helps industries behave according to their self interest on the water quality aspect of resource use.

The other formal quality-based standard for aquaculture is the implementation of *Hazard Analysis Critical Control Point (*HACCP*).* While the implementation of HACCP-based food safety assurance programmes is at an advanced level in the fish-processing sector, the application of such programmes at the fish farm level is in its infancy. Although HACCP application is not extended to the aquaculture farmers unless they do some of the processing activities or intensive farming, the farmer should be aware of the water quality and the aspects of the environment in which their products are grown as the information will be useful while selling their products. This is a pure consumer-based, market-oriented approach which is of no use to the farmer in protecting his property and investment.

Wordwide it is evident that when the formal systems fail, it may lead to the evolution of informal code of conduct and conventions among resource users or refinement of formal systems informally by the community to cope up with their livelihood stresses. The informal institutions are mainly built through the farmer groups and political organisations .The KAAF (Kerala Aquaculture Farmers' Federation) has a strong presence in the panchayat. A panchayat-level secretary reports to district-level presidents and in turn the districts are linked to state-level general secretary and president. The local secretary conducts the function of securing seeds from the government hatchery, distributing it among farmers, and oversees conflict resolution and management among farmers in the locality. When shrimp farming becomes a livelihood activity at an industrial phase the presence of allied activities such as shrimp processing firms and ice plants also increases. A major company that has launched operations in Ezhikkara in 2005 is the marine exporter Unni and Co . The company first penetrated into the locality by winning the auction of a 100 hectare farm land, the biggest farm in Ezhikkara. Soon they purchased the nearby land and established a shrimp processing firm. In a year‘s time they diversified into an ice plant. The outlet for waste water discharge from the plant flushes into the Puttiyathode canal which is a inland source of water for "Central Pokkali padshekaram" farms. The waste water discharge from the ice plant changes the water composition in surrounding ecosystem. This discharge changes the physical, chemical and biological composition of the water that invariably becomes the input for shrimp farming. This situation led to increased incidents of fish diseases, fish growth retardation and fish death. The shrimp farmers incurred heavy losses year after year. The farmers organised under the name "Puttiyathode Samrakshana Samadhi" and conducted scientific water quality analysis to prove their claims with the help of the National Centre for Aquatic Animal Health, Cochin University of Science and Technology. The analysis report produced by the centre states that " the water is highly polluted with organic matter, because of which the ammonia level has gone up to 17.4ppm. For aquaculture, the maximum level of total ammonia permitted is 1ppm within a pH range of 6.5 to 7.5. In addition, alkalinity is also very high (750ppm) – it should normally be around 70ppm. This situation is sufficient to kill all aquatic animals in the area and therefore urgent remedial measures must be taken to rectify the problem and to save the aquaculture and agriculture in the region." *(Ref: Table 2 for details*)

The fish farmers organised against the firm and petitioned the panchayat, the fisheries department and the district collector. They organised protest marches to the local village panchayat office, to ensure that the company take necessary steps to treat waste, on 28-6-2011 because the licence for the operation of the ice plant and water usage was issued by the panchayat. The company responded to this by organising labourers in the ice plant to launch a march to protect their employment. Further, the farmers appealed to district collector on 27-7-2011 and an enquiry was made in to the matter. Further to this appeal, the company was forced to create a waste water treatment system. After positive results in the initial days of the installation of the water treatment facility, farmers claim that the company later started draining waste water without treatment. This action again aggravated the tension between the farmers and the company. Farmers are now requesting for effective monitoring and sanctioning to minimise the untreated waste water disposal.

Livelihood strategies and outcome

The interaction between the formal and informal institutions mediate the ability of the community to make different choices for livelihood strategies and resultant outcomes. The three broad clusters of livelihood strategies are aquaculture intensification or extensification, diversification, and migration(Scoones, 1998). Themajor strategies adopted in Ezhikkara are the following:

Change in technology. Like many panchayat's, Ezhikkara was also following a traditional shrimp farming method. In Traditional shrimp farming, farmers depend on wild stock for seed, and use natural feeds. Ponds are tidal fed and there is no artificial aeration using any new technology. They exchange water four times in 24 hours. Two high tides and two low tides happen in 24 hours one each during day and night, and the approximate time gap between tides is six hours. Water exchange depends on the precipitation and temperature .During the day time more water is exchanged normally, amounting to 25 to 30 percent of the water, while during night time only 15 to 20 percent of the water is exchanged .If the temperature is higher or if there are sudden variations, the exchange of water also varies accordingly. With decreasing water quality in general in the Vembanad lake, the availability of wild stock has decreased and the destruction of mangroves has increased, while paddy cultivation has reduced, increasing the demand for artificial and imported feeds. If paddy is cultivated, the young shrimp stick to paddy roots and feed off them. For the initial 45 days they do not require any additional feed in their 120-day growth cycle. This change in water quality has forced the farmers to move from traditional system to improved traditional, extensive or semi-intensive culture systems .These systems use tidal waters for water exchange but use hatchery grown seeds and artificial feeds .In the semi-intensive method, artificial aeration is done and water may be stocked and pumped to the fields after it is treated with pathogens and chemicals. This strategy is more technical and, therefore, involves more investments making it unviable for small scale farmers who have less than five hectares of land .This method is less eco-friendly as additional feeds increase the nutrient load in the water and require technically superior waste water management in the ponds to avoid diseases and nitrification of lakes .In effect, the changes have made shrimp farming less profitable and ecologically unsustainable.

Increase in the number of man days of work. Farmers now realise that a higher density of stock is one reason for shrimp disease and loss. 0Therefore, in one season, farmers opt to have three cycles of shrimp seed deposits with decreasing stock density in the ratio 5:3:2. With experience, the farmers have realised the shrimps are showing symptoms of diseases between 70 to 75 days of culture. Though it is at a stage just half way through the culture, farmers are vigilant during these days and harvest the shrimps if they shows some symptoms any day after 70 days. Decreasing stock density helps shrimps to be less stressed of decreasing oxygen which primarily lead to diseases. Invariably the impact increases the time spent by farm owners and workers on the field As they have to cater to the needs of shrimps in different life cycles, it reduced scale of operations and increased the number of man days of work which increased labour costs.

Bifurcated investments and dependence on middlemen. As farming is done in three cycles, investment is also required in three cycles. This situation also increases the farmers' dependency on money lenders and middle men as they lack bargaining power for better borrowing rates on scale and in case there is disease occurrence in first cycle of farming it increases such dependency and investment rates and most farmers resort to move out of farming.

Focus on subsidiary income for risk aversion. Farmers have moved from monoculture to polyculture as a risk aversion measure. Monoculture is aquaculture practice of producing or growing a single species over a wide area and for many consecutive years. It is widely used in modern industrial aquaculture and it helps for large harvests from minimal labour. Polyculture is aquaculture using multiple species in the same space, in imitation of the diversity of natural ecosystems, and avoiding single species, or monoculture. From 2002, the farmers became interested in farming *Peneous Monodom* (tiger prawn) as monoculture .Though initially they produced good results, in consecutive years farmers faced huge losses due to disease outbreak. Today farmers in turn do polyculture, majorly with *Peneous* shrimp variety, crab and fish. With decrease in capture fisheries, there is increasing demand for cultured fish like Tilapia. Green and red mud crab also have a significant export market .This strategy has also helped farmers reduce poverty and improve livelihood security.

Changes in land use patterns. Another important strategy adopted by farmers is changing the land use patterns. The ponds are divided into smaller ponds: 50 percent of the area is demarcated for polyculture, 25 percent for crab or monoculture of shrimp and 25 percent of the area is allocated as free space and this may include the nursery space. Nursery may take up to 10 percent of the space. The farmers use the rest of the space to move shrimps when there is some disease outbreak or for integrated farming by adding ducks, for example. This strategy helps them control diseases in a better way as well as earn better income through high-value products .Though this strategy can considerably reduce risk, the initial investment is high and the strategy is used by farmers with more than three hectares of land.

Rejection of eradication norms

In Ezhikkara, the farmers in the panchayat have decided not to sanitise the land using pesticides. This strategy allows them to have wild stock of shrimp, crab and fish growing along with hatchery grown shrimp fry’s .This strategy gives them additional income as well as minimises the stress on the ecosystem by reducing pollution load of wetlands

Conclusion

The awareness of water quality for the aquaculture industry is as important as the understanding of precipitation and temperature for agriculture. With water security decreasing and demand for aquaculture production increasing, the outlook for aquaculture production to contribute to food security and there by livelihood security looks bleak. Additional investment and labor will be required to maintain production. If production is to be maintained, urgent measures and policy interventions are required to reduce water security issues. It's evident from the study that the environment quality is an important parameter in the production process of aquaculture and its variability effects livelihood options of the community dependent on it. The changes in livelihood options will lead to job migrations, insecurity in food supply and nutritional supply, health issues, and ecosystem degradation while increasing poverty and affecting the wellbeing of the community. For the progress of this sector, a process is required where aquaculture farmers get real time updates on water quality and waste water disposal is monitored effectively. Inevitably, the necessary steps to manage and communicate on the quality variability of the environment must be made and policies to bring sustainability to the aquaculture industry must be streamlined. The pollution control board along with the fisheries department must take steps to initiate studies to have the process in place.

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