Chapter 2
Sustainable Aquaculture: Socio-Economic and Environmental Assessment

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Abstract One of the goals of the sustainable development is to minimize or eliminate the environmental externalities and target social and economic development. Socio-Economic and Environmental Assessment (SEEA) deal with assessing the socio-economic and environmental issues that can potentially be a threat to the existing condition. SEEA also deals with developing a proper alternative or management techniques. As the world capture type of fishing is stagnant or declining, the growth of the aquaculture is inevitable as it fills the gap between declining natural production and increasing market demand. Aquaculture is the only viable way of raising the production of seafood and freshwater fish. Thus, the sustainable development of aquaculture industries has been the necessity. This chapter highlights the different socio-economic and environmental issues that aquaculture leads to and also presents the impact areas, mitigation and monitoring plans that can be adopted to ensure sustainability of the aquaculture.

Keywords Sustainable aquaculture · Environmental assessment
SEEA · Environmental impact

2.1 Introduction

Aquaculture also known as aquafarming, is the farming (breeding, rearing and harvesting) of both aquatic plants and animals in various water environments like ponds, rivers, lakes and the ocean under controlled condition. The conditions are designed to increase the production of the organisms beyond the natural capacity

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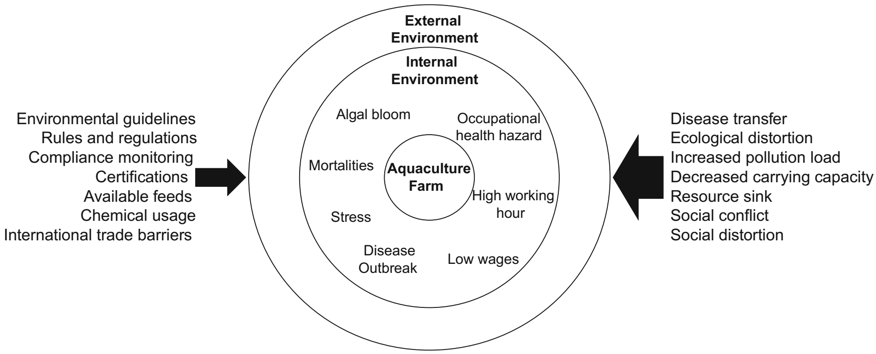

Fig. 2.1 Internal and external environment of the aquaculture farm

and involves cultivation of both marine and freshwater species and utilizes natural resources and interacts with the environment.

Aquaculture differs from the conventional approach of capture type of fishing and refers to more planned and technical approach of farming which is a more labor intensive process. Aquaculture helps to sustain many farmers and is one of the major sources of income to many households. It also indirectly affects the social and economic aspects of many stakeholders who are indirectly involved in it. Thus, a considerable socio-economic impact can be associated with it, in additional to the environmental aspect of aquaculture. As aquaculture industry utilizes resources to cultivate the stock beyond the natural carrying capacity, ecological and environmental impacts are the major concern in the aquaculture industry. As presented in Fig. 2.1 external environment which majorly includes market demand, governmental regulations and institutional capacity of the countries plays a significant role to control the internal environment of the aquaculture. However as presented in Fig. 2.1 these forces are smaller than the raising social and environmental issues. Uncontrolled external environment can worsen the internal environment leading to many social and environmental issues.

With the aim of achieving sustainable aquaculture production while exerting minimum environmental degradation, prior assessment of socio-economic and the environmental component is needed. Sustainable aquaculture implies socially and economically sound aquaculture industry where the environmental damages are minimized or avoided. Socio-Economic and Environmental Assessment (SEEA) is one of the methods to harmonize social, economic and environmental conditions for sustainable growth of the aquaculture industry.

The primary objective of the SEEA is to identify the activities that hamper the lives of people. SEEA performs detail study and analysis and helps to predict direct, indirect and cumulative impacts of the project. Another main objective of SEEA is to mitigate these impacts either by avoiding it, remedying it or by compensating the effects of the impacts. SEEA can act as an important mechanism to ensure the sustainability of the aquaculture. However, the success of the socially, environmentally and economically sound aquaculture practice depends on the attitude of the three key players: Proponent, Stakeholders, and Decision Makers.

Proponents include the entrepreneur's/companies/government departments, etc., who plans to carry out the project and are responsible for complying with the imposed rules, regulation, standards, etc. In additional to making a profit from the , the proponent is also responsible for harmonizing the social aspect of the project, which is important for long-term planning. Stakeholders are the one who either benefits or affected by the project and includes institutes, governmental agencies, businesses, labors, associated business, etc. who are to be benefitted or affected by the project. The proponent has a responsibility to harmonize the stakeholders to avoid any chaotic conflicts. The last key players are the decision makers who have the legislative power of licensing, regulating standards, etc. and pushes the proponent to adopt practices that are more socially and environmentally acceptable. These three key players play a major role in the sustainable aquaculture and it is important for any project to harmonize their concerns and interest. SEEA can also act as a tool to harmonize these key players.

Thus, SEEA aims to harmonize these three key players by providing them with the following information:

i. Information regarding the current socio-economic and environmental scenario within the virtual project influencing boundary, within which the project impacts can be predicted to be felt with high magnitude.
ii. Description of the key socio-economic and environmental parameters that will be potentially impacted due to the established project.
iii. Impact identification, prediction, and evaluation due to the implications of the project.
iv. Highlights of the major environmental impact and plans to mitigate the effects.
v. Monitoring plans to ensure the compliance of the outcomes of the SEEA study.

SEEA tends to focus on the avoidance of adverse impacts and optimization of the beneficial impacts. The beneficial impacts of the project generally include rise in living standard due to increased employment opportunity and economic activity; improved business opportunity; improved infrastructure as the project matures, while the adverse impact might include loss of endemic species due to the introduction of exotic species, loss of farmland, loss of traditional business, etc. SEEA also targets to study the interaction of various impacts, which could be synergistic and irreversible in nature. Moreover, it predicts indirect impacts. All the identified impacts are evaluated and only significant impacts with high magnitude are mitigated. It provides an important platform for the decision maker to rationalize their decision based on the findings of the SEEA.

2.2 Types of Aquaculture

Aquaculture can be categorized based on intensification level, species cultivated and technology used. The socio-economic and environmental issues related to it also differ according to the types of aquaculture. This chapter highlights the aquaculture based on the intensification level. Based on the intensification level of the aquaculture, it can be divided into extensive, semi-intensive and intensive aquaculture. The productivity and the type of food requirements vary according to the level.

2.2.1 Extensive Aquaculture

Extensive aquaculture utilizes natural productivity of the environment for the growth. Under the extensive aquaculture, no additional food is added for the growth and there is very little control over the stocks. It can be done in freshwater, brackish and marine environment using several techniques like multiple mesh, trapping nets, pond culture, etc. Since the growth conditions like temperature, pH, nutrients, etc. cannot be altered, an extensive form of aquaculture strongly relies on the surrounding conditions. This form of aquaculture also has detrimental impacts and proper management is essential. If not managed properly, it can lead to the damage in the surrounding natural habitat. The organic waste from the cultured area can potentially deplete dissolved oxygen level and reduce the benthic habitat population. In addition, it can also introduce (in the form of escapes) foreign species or less tolerant genetically modified species in the natural environment, which can reduce the adaptive capacity of the indigenous species as they interbreed with these less tolerant cultured species.

2.2.2 Semi-intensive Aquaculture

Semi-intensive techniques utilize different culture techniques like raceways, sea-cages and require to supplement the stock with additional food. However, semi-intensive system is partially dependent upon the natural productivity. Thus, it requires less space than the extensive system to have the same yield. Its environmental risk is similar to the extensive and intensive aquaculture.

2.2.3 Intensive Aquaculture

Intensive aquaculture is a highly dense farming and involves the total addition of the food. It is also a technology driven process which focuses on maximizing the yield by maintaining palatable growth condition for the target species. The stock is fully dependent on the artificial food provided and involves many activities that could lead to environmental issues.

As the environment variables (pH, temperature, oxygen level, feed, etc.,) are completely controlled and managed by the skilled workforce, higher yield can be obtained which is one of the advantages of the intensive aquaculture. However, it has a higher environmental impact and its magnitude and significance vary according to the technology used. One of the general issues related to the intensive system is effluent management. The effluent of the intensive system are rich in nutrients (Pullin 1989) (both organic and inorganic) and if not properly managed can lead to eutrophication in the natural environment causing a threat to the indigenous species.

Table 2.1 presents the impact associated with different intensification level and technology used. Moreover, it must also be noted that some impacts are location specific.

2.3 Socio-Economic Impacts of Aquaculture

As aquaculture business deals with the usage of environmental resources and human resources for the extraction and production of the consumable products, it will inevitably cause distortion in the social and economic conditions of the project area. This distortion often termed as ‘impacts’ can be both beneficial (positive) as well as adverse (negative) in nature as presented in Fig. 2.2. However, the ultimate goal of any project is to maximize the positive impact and minimize or eliminate the negative impact of proper technological and operational measures. Some of the beneficial and adverse socio-economic impacts are presented below in Sects. 3.1 and 3.2, however, it must also be noted that the intensity of these impact varies according to the species, location of the farm, farm yield and technology used.

2.3.1 Beneficial Impacts

Aquaculture has many socio-economic benefits. Some of the socio-economic benefits are as follow.

2.3.1.1 Food Security

Food security is the current global problem to be addressed as it is estimated that the world will need 70–100% more food by 2050 (The World Bank 2007; Baulcombe et al. 2009). Sustainable Development Goal (SDG) for 2030 has also targeted goals to achieve food security, improve nutrition and promote sustainable agriculture.

Table 2.1 Different levels of aquaculture and socio-economic and environmental impact associated with different technology adopted and level adopted

	Type of aquaculture*	Damage to reefs	Mangrove destruction	Saltwater intrusion	Eutrophication problem	Wastewater hazards	Social conflict	Social disruption	Public health risk	Creation of resource sink	Loss of traditional jobs	Increase in jobs	Export earnings
Extensive	Coastal bivalve culture (mussels, oysters)	✓					✓	✓	✓			✓	✓
	Coastal fishpond (shrimps, tilapias)	✓	✓				✓	✓	✓	✓	✓	✓	✓
	Cage culture in rich benthos (carps, catfish, tilapias, etc.)				✓		✓	✓				✓	✓
Semi-intensive	Fresh and brackish water pond (shrimps & prawns, tilapias, catfish, etc.)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Integrated agricultural aquaculture (rice-fish, poultry-fish, vegetable-fish, etc.)					✓			✓			✓	✓
	Cage culture in rich benthos (carps, catfish, tilapias, etc.)				✓		✓	✓				✓	✓

(continued)

Table 2.1 (continued)

	Type of aquaculture*	Damage to reefs	Mangrove destruction	Saltwater intrusion	Eutrophication problem	Wastewater hazards	Social conflict	Social disruption	Public health risk	Creation of resource sink	Loss of traditional jobs	Increase in jobs	Export earnings
Intensive	Freshwater, brackish water & marine pond (shrimps, finfish especially carnivorous, etc.)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Freshwater, brackish water & marine cage culture (finfish especially carnivorous, and some omnivorous)	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
	Re-circulating system					✓							✓
	others—raceways, silos, tanks, etc.				✓	✓	✓	✓	✓				✓

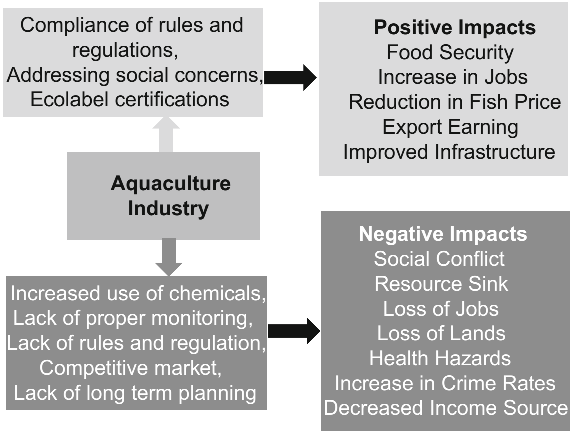

Fig. 2.2 Causes of socio-economic impacts

However, the key barrier to increasing the food is the availability of productive land due to rapid urbanization, increased competition of land, loss of productive land due to natural hazards, increased competition from biofuels. Thus, the prominent solution under these circumstances is to increase the agricultural productivity. Aquaculture, which has a higher yield than the conventional fishing is indeed one the method which can help to attain the SDG 2030 goals.

When analyzing the food security from the aspect of nutrients available, the health benefits from the finfish and shellfish are well known, as it is rich in vitamins and protein. In 2010, 16.7% of the global population's intake of the animal protein was covered by the consumption of fish. Fish protein has been the vital source (around 50%) of animal protein intake to many poorer island and coastal states (FAO 2014a, b). Moreover fish are cheaper than the other source of animal protein, which makes it affordable to low-income groups as well. Consumption of aquatic food is found to be higher in the developing and least developed countries and so aquaculture plays an important role to ensure both the quantity and quality of food.

2.3.1.2 Increase in Jobs

Aquaculture increases the job opportunity at several levels. Jobs are created in the whole supply chain from the production to the supply. Low-income group and rural communities are the ones who benefits significantly from the employment created. The ability of aquaculture to create jobs in the rural areas is one of the reasons for governments to promote aquaculture. The potential for job creation is not limited to the fishing industry itself but other associated industries (like net industry, boat building, food processing, etc.) are also benefited from the aquaculture. With all the jobs created, cumulating the job holders and their dependent, fisheries and aquaculture support estimated livelihood of around 10–12% of the world's population (FAO 2012). These indirect benefits can also be experienced by increased trade and inflow of the traders into the area, as more jobs are created to manage the basic needs of these traders.

2.3.1.3 Reduction in Fish Price

Fish price will continue to decrease in the future and will be more affordable to the low-income groups. Aquaculture is a promising method of growing stocks at cheaper operating cost due to the possibility of increasing its yield beyond the natural productivity. As aquaculture rises in the future, the production cost of these fish will get cheaper affecting the market cost. Considering the time frame from 1990–2010, the overall decline in the fish price was observed due to the sharp decline in price in some of the species which was able to radically change due to aquaculture development (The World Bank 2013). Thus in future, as technological advancement are achieved with technologies such as aquaponics, aquaculture production cost will lower down making it more accessible to all.

2.3.1.4 Export Earning

Unlike to the traditional catch type of fishing, aquaculture provides more opportunities for the farmers to increase their production capacity following the increased demand for seafood worldwide. For Asian countries like Thailand, Bangladesh, Indonesia, Vietnam, etc. export earnings from the seafood industries is significant. As the production capacity of capture type fishing has remained stagnant, the only method to increase the production of finfish and shellfish has been the expansion of the aquaculture industry. These industries are generating a GDP both locally and in the form of exports. Shrimp industry is the third largest exporting industry in Bangladesh and it plays a crucial role in the GDP of the Bangladesh generating export earnings of 544 million USD in 2013 (Kabir 2013).

2.3.1.5 Improved Infrastructure in Rural Areas

Aquaculture can have the indirect benefit of improved roads, governmental facilities, harbor, etc., which increases the productivity of aquaculture. The rural communities are benefitted from the improvement in infrastructure.

2.3.2 Negative Impacts

Aquaculture has several negative impacts which need to be considered for the smooth operation of the business. As aquaculture has many negative environmental impacts, social issues ripple through its effects.

2.3.2.1 Conflict Over Resource Usage

Resource usage has always been an issue for the aquaculture industry. One of such conflicts that is normally seen is between the shrimp farmers and other farmers (crops, freshwater fish) who lose their yield due to the environmental impact created by the shrimp culture. The shrimp farm salinizes the freshwater bodies and crop lands which cause conflicts over the usage of the resources. In the sub-Saharan Africa where the water is scarce, conflicts have also arisen due to the conflict over the use of water between tobacco farmers and fish farmers (Subasinghe 2006). Also as the cage and pen culture of aquaculture is also dependent upon the natural food, conflicts are seen over the artisanal fishers and the aquaculture farmers.

Social Issues of Shrimp Farming in Khulna, Bangladesh
Khulna is the leading producer of the Bangladesh's vast shrimp industry. Shrimp farming has certainly employed a lot of people in Khulna but it has also increased the vulnerability group and reduced the coping capacity of the farmers. Some of the social issues observed in Khulna are:

i. **Loss of productivity of the land**: The shrimp farming has affected the fertility of the nearby lands due to the leaching of sediments. The lands are now barren and traditional rice farming is not possible. Cattle raising is also impossible as the lands are barren. There are hardly any environmental monitoring and big farmers hardly cares for the environmental impact to the community.
ii. **Illegal land acquisition**: Most of the shrimp farming in the area is being done by the immigrants. These immigrants/big farmers often with the help of the local regulatory bodies, illegally control or occupies the land of the locals. Shrimp farming has raised the corruption level in the area.
iii. **The increase of vulnerability group**: Although shrimp farming has provided jobs to many, a lot of farmers associated with it are paid very less for their effort. These vulnerable groups are associated in the catching of juvenile shrimp from the local rivers. Moreover, the market of the shrimp farming is so intense in the area that they can hardly engage in other areas for income. Malnourishment is commonly observed in these vulnerable groups.
iv. **Loss of jobs**: Fishman who traditionally caught fish in the river are severely affected as they can hardly find any fish in the rivers now. The juvenile shrimp are caught using a very fine net. These nets also trap juvenile fishes which are then discarded in the land. Loss of juvenile fish has affected the fish population to a great extent.

v. **Increased use of pesticides**: Driven by the market need, the use of the chemical is uncontrolled in the region. Farmers use chemicals, most of which have already been banned in many countries due to its health hazards. The effluent from the shrimp farm has risked the health of the local people.
vi. **Increased rate of crime**: As the workers in the shrimp farm are mostly immigrant, they have the least responsibility toward the community. The crime rate in the Khulna has also increased due to the Shrimp farming.
vii. **Conflicts**: There is a long battle between the local habitants who have lost their lands and occupations to the powerful shrimp industry.

Source: Link TV. (2005, Jan 5) & Environmental Justice Foundation. (2014, Aug 14).

2.3.2.2 Creation of a Resource Sink

The opportunity cost of aquaculture development must also be evaluated as a significant amount of capital and labor is required. The failure in the market can adversely impact the rural areas where the aquaculture is more concentrated and have the least adaptive capacity. Thus, a careful evaluation is needed under the existing economic and resource potential to evaluate aquaculture in terms of long-term profitability. Lack of planning and management can lead to a resource sink, which implies low resource and labor productivity. One of the examples is the aquaculture development in the Sub-Saharan Africa where nearly 100 million USD was invested, however, little benefit was generated from it (Neiland et al. 1991).

2.3.2.3 Loss of Traditional Occupation's

As aquaculture creates new job employment opportunities, traditional occupations are also lost in the process. It leads to loss of traditional skills that were sustainably utilized for income generation. Switching jobs to more income generating activity are economically sound but can be vulnerable to the 'Boom and Bust Cycle.[1] Any possible market failure of aquaculture will not only result in the loss of jobs in future but will also result in loss of capability to revert back to the traditional jobs. Thus, aquaculture can have an impact on the traditional values of the societies as well.

[1]Boom and bust cycle: It is a process of economic growth and contraction, which occurs frequently and is the key characteristic of capitalist economies. Boom phase of the growth creates numerous job opportunities while the bust phase of the cycle collapses these jobs.

2.3.2.4 Health Hazards

The aquaculture industry is associated with many occupational hazards which are found more prominently in developing nations due to lack of policies. Further to highlight 87% of the aquaculture production is done in developing nations (Waite et al. 2014), which imply only a small or negligible portion of the aquaculture can be regarded as complying with proper occupational safety measures. As aquaculture uses several chemicals (pesticides, inorganic fertilizers, antibiotics, etc.) for the growth of the stock, aquaculture practitioners are more prone to the potential detrimental effects of it. Labor are more vulnerable to the skin diseases, respiratory diseases (asthma, bronchitis, etc.) and allergies. Further, long-term and chronic diseases are being attributed to the aquaculture (Erondu and Anyanwu 2005). The wastewater generated from aquaculture if not properly treated can also potentially cause a threat to the local communities.

2.4 Environmental Impacts of Aquaculture

Previously aquaculture was considered too small an industry to have any significant impact on the environment. However, the remarkable growth of the aquaculture industry in many countries (China, Vietnam, Thailand, Indonesia, etc.,) over the past decades has also increased the adverse impact of it on the environment. Aquaculture focuses on growing stocks beyond the environmental carrying capacity by the use of inputs like fertilizers, antibiotics, pesticides, etc. which negatively impacts the ecology. In such systems resources are pumped in, used up, and pumped out in a linear fashion, rather than being recycled. This leads to accumulation of wastes in the recipient ecosystems, often causing severe and irreversible environmental problems. Aquaculture technology/practice requires high inputs of protein and phosphorus diets, and a high rate of water exchange. A large portion of nutrients becomes waste, which is then directly discharged to the surrounding waters causing rapid deterioration of water quality.

Some of the environmental impacts caused by the aquaculture are discussed below. However, the nature, magnitude, and significance of these impacts varies according to the species cultivated, intensity of the farm, carrying capacity, the geography of the farm, etc.

Socio-Economic and Environmental Impact of Shrimp Farming

Most of the shrimp production (55%) is through the aquaculture (WWF 2016). As shrimp farming is profitable, intensive aquaculture methods have been adopted to increase the yield of the shrimp. Menasveta and Fast (1998) estimated the production level of the intensive shrimp farming to be greater than 6000 kg/ha/yr which was found to more than the semi-intensive (600–1800 kg/ha/yr) and extensive (100–300 kg/ha/yr). However, the use of intensive shrimp farming techniques has double the environmental impact when compared with the less intensive system (Cao et al. 2011). Some of the environmental impacts of the intensive shrimp farming are as follow:

i. **Loss of lands**: Marine shrimp aquaculture leads to the loss of lands. It has caused the loss of thousands of hectares of mangrove and wetlands. Moreover, it causes soil acidification as the waste of the shrimp is dumped to the land.
ii. **Destruction of other juvenile species**: During the harvesting of the shrimps, often juvenile shellfish, shrimps, finfish, macrozooplankton animals are caught which disrupts the ecosystem. It disturbs the entropy of the eco-system causing biodiversity loss and reduction of the food for other species in the food chain.
iii. **Impacts of excessive feeding**: Shrimp farming often excessively use the nutrients (fertilizers) to naturally grow the food for the shrimp or uses supplemental feeding. Utilized nutrients, feed, and excreta in the shrimp farm increases the nutrient loading, reduces oxygen in the pond water supplies and increases the sedimentation. This wastewater discharge from such pond can cause eutrophication and death of animal and plants in the receiving water bodies.
iv. **Impacts due to the chemical dosing**: Various chemicals are used during the shrimp farming to control the pathogens causing diseases. These chemicals contaminate the surrounding environment, as well as negatively affect human health. Excessively used antibiotics can also make the disease more resistance to the antibiotic causing more problem in its treatment in the future.
v. **Ground water depletion**: Shrimp farming uses a lot of fresh water to maintain appropriate salinity level for the shrimps. The aquifer used for this purpose becomes vulnerable to drying out causing the risk of salt-water intrusion in the ground water source.
vi. **Abusive land seizure**: Shrimp farms are often associated with human right issues like the seizure of land without any compensation. Land encroachment by powerful companies has jeopardized the traditional farming practices to the risk of extinction and has left many farmers landless. Shrimp farming is often done in coastal areas where no formal land rights exist.
vii. **Labor right violation**: Shrimp farms often pay very low wages to the laborers to maximize their profit and labor rights are always violated. In developing nations, the issue of human trafficking is commonly seen in shrimp farming due to weak governmental policy.

2.4.1 Loss of Mangroves Areas

Mangrove forest destruction is one issue at the forefront of environmental concerns in tropical areas. Lack of ownership supported by policy gaps leads to these lands being exploited for the aquaculture by small farmers, which majorly includes the shrimp farmers. Mangrove ecosystem is a reservoir, refuge, feeding ground and nursery for many useful plants and animals. Several tropical countries have lost extensive mangrove areas due to clearing and conversion to fish and shrimp ponds (Barg 1992). In Thailand, 16–32% of the total loss of mangrove between 1979 and 1993 was attributed to shrimp farming alone (Dierberg and Kiattisimkul 1996). The mangrove areas are important for the sediment and coastline stabilization, trapping of water, providing habitats and food for animals hence destruction or alteration of the mangroves leads to the adverse impacts to the benthic communities, microbial flora, phyto- and zooplanktons and other wild fish stock, and animals (Rosenthal 1992). Moreover, the reclaimed mangrove area is acidic in nature. Jayasinghe (1995) reported that oxidation of pyrite (FeS_2) occurs during pond-bottom drying which results in the release of sulfuric acid into the pond water and adjacent water bodies causing acidification and generation of highly toxic soluble aluminum phosphate.

2.4.2 Intensive Water Uses and Pollution

Aquaculture is water-intensive sector and uses a lot of water which is then polluted by the usage of chemicals. Waite et al. (2014) estimates that in 2010 the usage of freshwater in the aquaculture industry was 2% of the global agricultural water consumption.

2.4.3 Impacts of the Chemical Waste

The use of chemicals in aquaculture is obvious due to the high market demand for it. Chemicals are important for aquaculture industries to ensure the high yield of the stock. Some of the commonly used chemicals in the aquaculture are shown in (Table 2.2).

These chemicals increase the chemical waste causing various impacts in the ecosystem (Fig. 2.3). Commonly used chemicals in aquaculture are formalin, malachite green, potassium permanganate, copper sulfate, medicated feed, and local herbs. Aquaculture also causes water pollution as discharges consist of excess nutrients, fish waste, antibiotic drugs, pesticides, hormones and inorganic fertilizers. These pollutants affect the entropy of the natural aquatic habitat, leads to eutrophication in the nearby water bodies and cause diseases in the natural species. It increases mortality in the endemic species and also causes sub-lethal effects.

Table 2.2 Different type of chemicals used and its impacts

Types	Example	Environmental impact
Fertilizers	Chicken manure, animal manure, ammonium phosphate, urea, solophos	Eutrophication and damage to benthic population
Soil and water treatment	Alum, EDTA, lime, zeolite, gypsum	Sediment contamination
Disinfectant	Sodium or calcium hypochlorite and chloramine, benzalkonium chloride (BKC), formalin, iodophores, ozone	Localized biological effects
Pesticides and herbicides	Saponin, rotenone, ammonia, gusathion, Sevin, organophosphates, organotins, carbaryl, ivermectin	Affects the local ecosystem where the wastewater is discharged; Death of non-targeted species: occupational hazard
Antibacterial agents	Nitrofurans, phenicols, erythromycin, chloramphenicol, oxolinic acid, sulphonamides, tetracyclines, quinolones	Increased resistance in the pathogen; Sediments contamination; Transfer to the endemic species and benthic environment
Other therapeutants	Formalin, acriflavine, malachite green, methylene blue, potassium, copper compound, permanganate, Trifluralin	Long-term exposure to it is carcinogenic; Affects health of workers and consumers
Feed additives	Immunostimulants, preservatives and anti-oxidants, feeding attractants, vitamins, carotenoids, ethoxyquin	Not known
Anesthetics	Benzocaine, quinaldine, metomidate, carbondioxide	Used in limited amount hence least environmental impact
Hormones	Corticosteriods, anabolic steroids, growth hormones, serotonin	Consumer health risk

2.4.4 Saltwater Intrusion

Aquaculture farming can potentially lead to the saltwater intrusion in the nearby freshwater sources. The impact is generally caused by the pond type of aquaculture practice, which commonly occurs in the mangrove zones. These areas are affected by surface and subsurface salt-water intrusions generated by the aquaculture ponds. This may lead to changes in the salinity of the freshwater supplies used for irrigation and potable water sources. (Dierberg and Kiattisimkul 1996). Intensive Shrimp farming has been strongly related to the declining health of farmers due to the salt water intrusion in the drinking water source in Bangladesh (Joanna 2016)

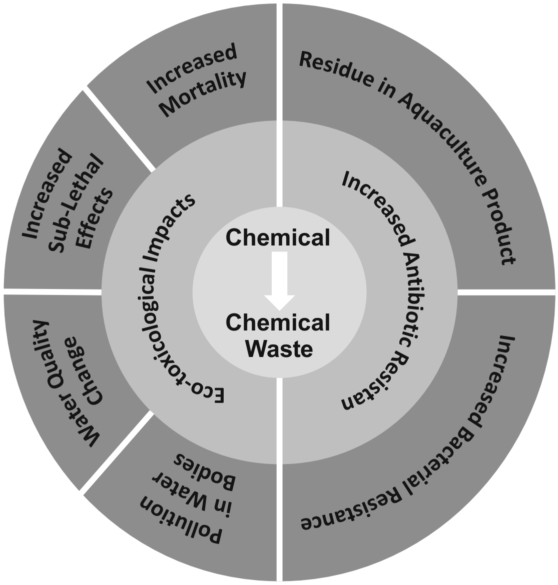

Fig. 2.3 Impacts of chemical waste from aquaculture

2.4.5 *Effluent and Sediment Management*

Sediment management in the pond culture is an environmental issue as improper management can lead to deterioration of ecosystem. The bottom of the pond is usually constructed with fine subsoil, which is impervious in nature. As the water is added for the cultivation, sediment formation is inevitable due to sedimentation of uneaten food, excess nutrients, excreta from stock, dead phytoplankton and zooplanktons, dead stocks, inorganics added etc. The accumulation of the sediments in the bottom of the ponds causes trapping of feeds and creation of anaerobic zones which results in the death of benthic organisms, increased pollution load in the discharged effluents, etc. Thus, the sediments are removed periodically from the pond and the frequency of cleaning varies with the type of the species cultivated. Accumulation of the sediments in the shrimp farming is substantial and was reported to be 157–290 tons/ha in Thailand (Boyd 1992) and Senarath and Visvanathan (2001) reported 5–10 cm of sediments disposal for Sri Lanka.

Disposal of accumulated sediments leads to increased nutrient loads to the discharged water bodies as these pond wastes are often drained in the process of sediment cleaning. The sedimentation unit, which functions to collect sediments might not be present as it requires land and money to operate. These effluents affect the local ecosystem. The treatment and disposal of the sediment is a costly process thus avoided by farmers as environmental laws and regulations of pond culture is more often least monitored in developing countries. Recirculation system (Fig. 2.4) that can treat the effluent with biological and physical treatment process and reuse the treated effluent back to the system has also gained popularity over past decade.

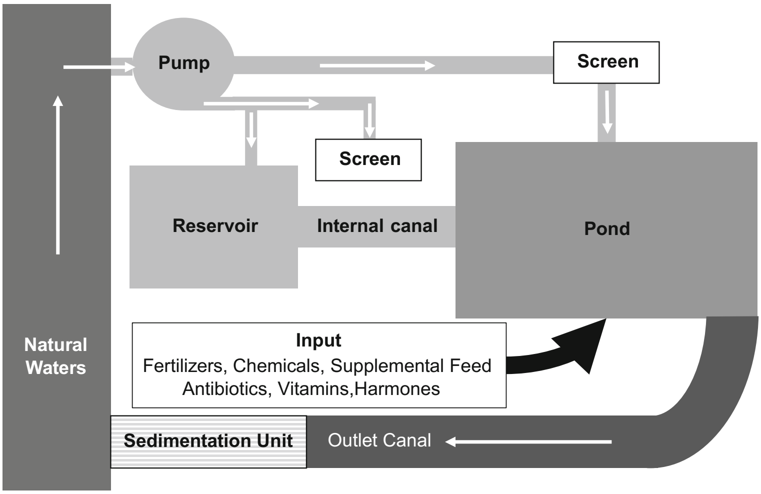

Fig. 2.4 Water management approach using recirculation of water

2.4.6 *Consumer Health*

The chemical fertilizers, lime, flocculants, algaecide, disinfectants, and chemotherapeutics are widely used in aquaculture and are persistent in nature. They are considered to be hazardous from the perspective of food safety as some of these compounds are biomagnified (Erondu and Anyanwu 2005). These compounds might have a detrimental effect on the consumer's health.

2.4.7 *Introduction of Non-endemic Species Causing Ecological Imbalance*

Non-endemic/exotic fish from the farm can escape from the aquaculture facilities and cause a threat to the endemic species. In Norway from 2001 to 2009, 3.93 million Atlantic salmon, 0.98 million rainbow trout and 1.05 million Atlantic cod was estimated to have escaped from the farm (Jensen et al. 2010). These juvenile, as well as adult fishes, are lost from the aquaculture through holes in the nets and operational errors. These fish can breed causing genetic impact in the adaptive capacity of the endemic/wild species (Thorstad et al. 2008). The offspring from such breeding has been found to be less adaptive to the environmental changes. Interbreeding between the farm and wild stock may lead to the reduction of the population of fish or lead to the extinction of the vulnerable groups (Naylor et al. 2005). It can also outcompete the endemic species. Thus, a huge ecological imbalance can also be associated with the escaped fish from the farm as it leads to competitive interactions for food and affects the levels of food availability.

Environmental advantages of Finfish over other meat sources

Finfishes are capable of converting more of the product they eat into edible products. Thus, the efficiency of the fishes is high when compared to other animals like beef, pork and chicken as illustrated in Figs. 2.5 and 2.6. Finfish can convert the feed with 30% efficiency while the beef, pork, and chicken with 5, 13 and 25% efficiency. Beef requires 31.7 kg of grain to produce 1 kg of the edible product while the finfish on average requires only 2.3 kg to convert into 1 kg of edible product. Moreover, the edible portion of the finfish is higher than the other livestock which makes it easier from the perspective of waste management. Fish being cold blooded animal spends very less energy to maintain its body temperature compared to the warm-blooded livestock, hence, the feed can be utilized more efficiently.

Livestock also causes higher environmental emission than finfish with the exception of poultry. As illustrated in the Fig. 2.7 beef has the highest nitrogen and phosphorus emission followed by pork. Finfish and chicken have the lowest nitrogen (360 and 300 kg/ton protein produced respectively) and phosphorous emission (48 and 40 kg/ton protein produced respectively).

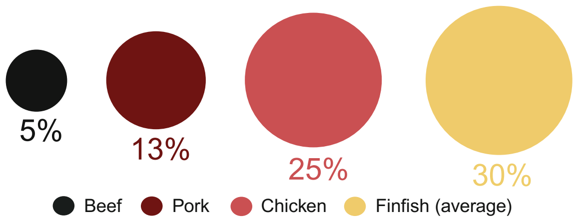

Fig. 2.5 Protein efficiency (%) of various meat sources. *Data source* Hall et al. (2011)

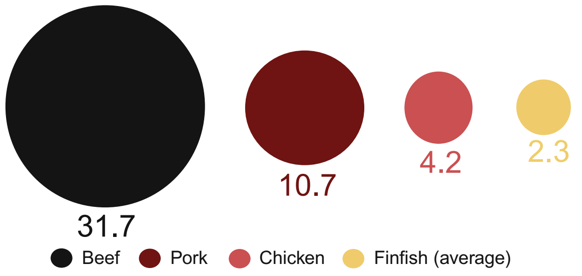

Fig. 2.6 Food conversion in kg feed/kg edible weight of various meat sources. *Data source* Hall et al. (2011)

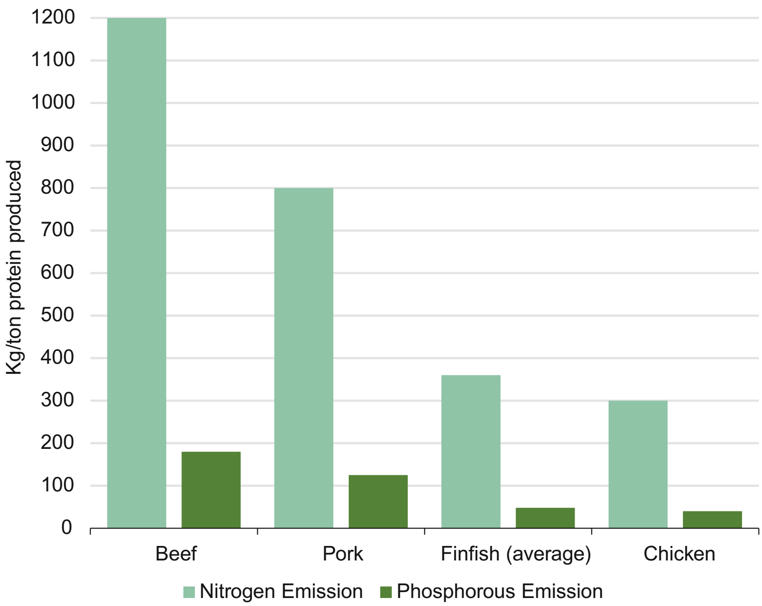

Fig. 2.7 Nitrogen and Phosphorous emission of various meat source. *Data source* Hall et al. (2011)

2.4.8 Spread of Diseases from the Aquaculture

Aquaculture is also one of the potential threats to the transfer of diseases to the surrounding environment. Uncontrolled aquaculture, intentional or unintentional management errors, lack of knowledge about the disease, etc., might be the factor contributing to the outbreak of disease. The additional absence of buffer zone around the open aquaculture system like sea-cage attracts much wild fish due to the availability of the food which can lead to the transfer of diseases like sea lice to the native species. Escaped fish from the farm cages can also act as a vector for diseases and parasites. Moreover, the risk of transmission of the disease is high for the intensive type of aquaculture due to high stock density (FAO 2014a) and since the world aquaculture is trending toward the intensive aquaculture system, driven by the market demand, more disease can be predicted to be transferred under normal circumstances. As the aquaculture products are traded from one country to another, the disease can also be transferred from one country to the other like *Haplosporidium nelsoni* in the Pacific oysters was unintentionally transferred from Japan to eastern oysters in the United States (Burreson et al. 2000) and the Sabellid worm was transferred from South African Abalone to the Californian Abalone (Kuris and Culver 1999).

2.4.9 Greenhouse Gas Emission

Greenhouse Gas Emission Activity such as energy use to maintain water level and quality, production of feed, transportation, processing of the aquaculture, packaging of the products, disposal of the waste, etc., cause greenhouse gas emission in aquaculture (Waite et al. 2014). Although a small fraction of the GHG emission is attributed to aquaculture, but with the raising aquaculture production and increasing concerns about the climate change, the significance of the impact can be considered to be high. Aquaculture production in 2010 emitted nearly 332 million tons of carbon dioxide equivalent (CO_2e) which is about 5% of emissions from agricultural production and less than 1% of total global anthropogenic emissions (FAO 2014a, b). Another potential source of GHG is related to the land use change associated with the mangrove forest. The degradation of the mangrove forest ultimately leads to the loss of carbon sink. The evolution of aquaculture toward intensive system will also add the GHG emissions as the intensive systems need more energy to operate than the semi-intensive and extensive system.

2.4.10 Fishmeal Trap: Added Pressure to the Fisheries

Sustainable aquaculture demands sustainable feeds but the raising concern for the aquaculture industry is the culture of carnivorous species like Salmon, which further add pressure to the wild fisheries for fishmeal[2] and fish oil. As the aquaculture industry expand the fishmeal and fish oil will be scarcer because as discussed earlier, capture type of fishing has already reached its saturation point and can no longer expand and a significant portion of the wild fish captured are the ones (small bony fish) utilized for the fishmeal. The sustainability of such farming is also questionable as about 6 kg of wild fish are required to produce 1 kg of the farm fish (Schipp 2008). Thus either a sustainable feed (alternative to the current fishmeal and fish oil) or the aquaculture of the herbivorous breed is required for sustainable aquaculture. The opportunity cost of these captured fish could be high for the wild fish productivity.

2.5 Assessment of Impacts

Impact assessment is one of the key processes of the SEEA. It requires the involvement of experts and stakeholders. The hired experts/consultant/practitioner also needs to be unbiased in impact identification. Different methods can be used to

[2]Fishmeal, which is derived from wild capture is the processed meal for the aquaculture carnivorous fish. It is majorly processed from fresh wild captured small, bony/oily fish and a small fraction is processed from the other fish trimmings (or fish waste). These kind of captured fish and by-products are not suitable for direct human consumption.

identify the impacts. Methods used depend on the experience of the consultant hired and also depend on the size, location and nature of the project. However, the method used must be simple and easy to interpret as a different level of decision makers will be later involved in the decision-making process. Some of the commonly used methods are the matrix, checklist, network, mathematical modeling, stakeholder consultation, expert judgment, etc. Some of the specific methods involved in the impact identification of the aquaculture project are as follow.

2.5.1 Stakeholder Analysis

Stakeholder analysis emphasizes on the individual interest of the stakeholders. Stakeholders that might be involved in an aquaculture project are governmental agencies, business associations, non-governmental agencies, community bodies, community leaders, religious bodies and local residents. This analysis helps to understand and anticipate the role and impacts of stakeholder with the introduction of the project. Figure 2.8 is a form of stakeholder analysis, which includes different stakeholders who has better understanding of the local environment. This kind of analysis not only helps to explore the impacts and its causes, but it also helps understand stakeholder interest to some extent. Since, aquaculture involves activities and actions that need to use the natural resources of the community, key stakeholders and their role (positive or negative) need to be understood. Stakeholder analysis identifies both the beneficiaries and affected groups and focuses on the active group (who have an economic interest in the project) of stakeholders as they can affect the project. Stakeholder analysis identifies their interests, examines the conflicts and explores trade-offs (Cordell et al. 2009).

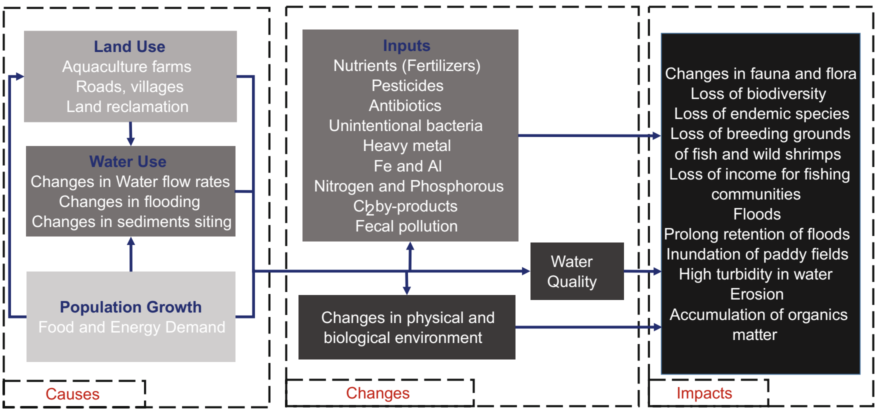

Fig. 2.8 Pollution aspects of the mangroves and the salt marshes generated from stakeholder analysis in Puttalam Lagoon and Dutch Bay, Sri Lanka due to shrimp farming. Reproduced from Senarath and Visvanathan (2001)

2.5.2 Rapid Rural Appraisal and Participatory Rural Appraisal

Rapid rural appraisal (RRA), and participatory rural appraisal (PRA) is a tool to promote sustainable development and is widely used in sustainable aquaculture and fisheries. This technique facilitates the interaction between stakeholders, researchers, and planners to exchange information and opinions. With the use of maps, matrices, details of past events, etc., brainstorming exercises are carried out to draw project impact and appropriate solutions to it. RRA and PRA technique ensures the incorporation of impact identified or predicted by the public. In addition, it also acts as a tool to generate mitigation measures from the public and provide them the opportunity to be involved in the decision-making. This planning process also helps to gain public acceptance and additionally RRA and PRA is an effective tool to utilize the local knowledge in the decision-making process.

2.5.3 Remote Sensing and Geographic Information System

Remote Sensing (RS) and Geographic Information System (GIS) have been widely used in the environmental and socio-economic analysis of the baseline information in sustainable aquaculture planning. However, there are plenty of limitations associated with the use of RS and GIS as it is a more costly process. In this scenario, PRA and RRA can be a more effective mechanism for planning aquaculture projects.

2.5.4 Environmental Capacity and Limit to Change

Environmental capacity also referred to as absorptive capacity or assimilative capacity is the ability of the environment to accommodate a particular activity without any unacceptable impact (GESAMP 1996). In relation to the aquaculture, environmental capacity can play a crucial role in defining the rate of nutrition addition and organic flux. Nutrition addition causes eutrophication while the organic flux can be associated as the limiting factor to the benthic process. Excess feed and organic waste affects the benthic organisms and must be considered. Evaluation of environmental capacity helps in the assessment of the cumulative impacts. This analysis is also useful to calculate the sustainable aquaculture production rate. In addition to being an important tool for the technical parameters like farm size, population size, and carrying capacity can also be applied to more regional issues like an ecosystem and watershed management (Byron and Costa-Pierce 2013).

Estimation of environmental capacity is expensive and to be cost-effective preliminary scoping about the impacts relevant to the type of aquaculture and technology must be performed. For example, shellfish breeding causes reduction of phytoplankton while the finfish cultivation will cause nitrogen, phosphorous and organic matter pollution. Environmental capacity can be calculated using various models. It has been used to evaluate: impacts caused by phytoplankton's by bivalve cultivation, the impact of nitrogen inputs from salmon cultivation, impact of organic matter input to seabed's, impact of organic matter input to benthic population, etc.

2.6 Identifying Mitigation Measures

One of the main purposes of the SEEA is to propose mitigation measures based on the social and environmental condition of the project area. Hence, it is not necessary that the mitigation measures appropriate for an area be appropriate for another area. The identified impacts can vary in nature as some impacts are beneficial (e.g.: the creation of jobs to local people) while some are adverse (e.g.: loss of biodiversity due to eutrophication). The mitigation measures focus on either enhancing the beneficial impacts or mitigating the adverse impact with the principle of avoiding first, then reduce, then propose remedy measures and if nothing is possible to mitigate by compensation.

The identified mitigation measures should be an integral part of the project approval and must be implemented during different phases of the project to mitigate the project impacts. Usually, the mitigation measures are incorporated in the contract/terms of condition documents so that it is implemented during the planning, construction and operational stages of the aquaculture. Some of the mitigation measures that can be taken at different stages of the aquaculture are presented in Table 2.3.

2.7 Monitoring

Monitoring is an important step involved in the socio-economic and environment assessment. As the sustainable or environmentally friendly practices are adopted it becomes necessary to monitor the adopted measures and the effectiveness of it. Monitoring is done with the following aim:

- To ensure that the mitigation measures adopted are incorporated in the project design and in the tender document
- To keep the record of the changes, that follows after the execution of the projects
- To ensure the achievement of the targeted standards

Table 2.3 Presents the impacts that commonly occurs in different stages of aquaculture and the potential mitigation measures that could be taken

Project activity	Impacts	Mitigation measures
Site selection		
Conflicts with existing site users	Competition for the use of resources	Adoption of relevant land uses planning
		Consultation and mutual agreement with the beneficiaries
Change in livelihood of the local inhabitants	Rise in social conflicts	Participation of local people in aquaculture projects
Ecologically sensitive site in the project area demarcation	The potential loss of biodiversity	Consideration of sensitive zones during the site selection with integration of aquaculture into integrated coastal zone management (ICZM)[a]
		Physical demarcation of ecological sensitive zone and inclusion of it in the management plan
Natural hazards like typhoons, flooding, hurricanes	Destruction or damage to the aquaculture's physical facilities and loss of harvest	Consideration of catastrophic events during site selection
		Designing of climate-resilient structures
Effluent generation from aquaculture	Deterioration of water quality causing reduction/loss of production	Consideration of carrying capacity as a key parameter during evaluation of appropriate site (Alternative analysis can be done to select the appropriate site)
		Adoption of ICZM to keep the water pollution within the carrying capacity
Disease in the fish	Loss of harvest, loss of production and possible infection to the nearby indigenous wild fish	Expert consultation
		Nearby farm survey for the detail information regarding types, frequency and occurrence of the disease to develop preventive measures for the risk avoidance
		Planning of risk management strategies to reduce risk before the operation of the project

(continued)

Table 2.3 (continued)

Project activity	Impacts	Mitigation measures
Design of the farm		
Project design of the farm	Lack of experience and poor understanding of the project components can result in negative environmental impacts	Proper design of the farm with proper consultation (public and expert)
		Designing with the principles of sustainability
Construction		
Change in socio-economic condition	Raise in social conflict	Public involvement in all the stages (planning, design, operational) of the project
		Priority to local employment. Enhancing the opportunity of locals by capacity building and training
Use of natural resources in the project area	Hampers traditional occupation	Locate the site away from the traditional users
		Create and monitor buffer areas between farm and other users
Construction and operation of physical facilities in the project area	Deterioration of aesthetic beauty in project area	Siting the farm away from the local inhabitant
		Adoption of designs and technology like low profile cages which minimize the uses of unsightly structures
		Considering local architecture while constructing physical facilities
Construction of aquaculture farm	Various environmental impacts due to poor construction practice	Built it with standard engineering and construction practice
	Disturbance to the wildlife and benthos ecosystem during construction	Maintenance of buffer zone and minimizing the construction disruption to the construction area only
Farm operation and management		Adoption of 'Best Management Practice' and ecolabel schemes
Solid waste disposal	Impacts on benthos wildlife due to decreased oxygen level	Collection and safe disposal of the non-organic solid waste materials
Wastewater/effluent discharge	Deterioration in water quality level of the streams where effluent is discharged causing impact to the population of other species	Adopting best management practices available
		Efficient feeding practices (optimizing the quantity of fish food)
		Locating farm in the area with adequate tidal flow

(continued)

Table 2.3 (continued)

Project activity	Impacts	Mitigation measures
Use of chemicals	Possibility of negative effects on worker's health	No use of chemicals or avoid the use of chemicals
		Use of safety measures by workers
	Decrease in quality of the product due to deteriorated water quality	Avoid or minimize the use of chemicals
		Adoption of preventive management system
Rearing of exotic or farmed stocks	Escape of farmed or exotic species can have negative impact on the ecosystem as well in the gene of wild stocks	Development of hatcheries
		Designing the farm to avoid any escapes
		Designing the farm to be resilient to natural damage (e.g. strom)
		Introduction of exotic species following the Code of Practice of ICES/FAO (Turner 1988)
Outbreak of disease	Impact to the endemic species due to the dispersion of disease	Preventive management system
		Regular monitoring of the water and harvest
		Sanitary disposal of the dead or infected harvest
Occurrence of natural events like storm	Loss of harvest	Preventive approach against the storm
		Developing strategy to deal with the occurrence of unlikely events
		Routine monitoring and maintenance of nets, mooring, etc.
		Climate resilient design, technology, and practice
Interference of predators and wildlife	Decline in productivity of the aquaculture	Consideration of predators and wildlife during site selection
		The introduction of relevant management plans to cope with it. Eg. double net

[a]The European Commission defines ICZM as "a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space"

- To measure the accuracy of the predicted impact
- To monitor the effectiveness of the mitigation measures adopted and to provide scope of adopting better adaptive measure through the feedback mechanism
- To provide data for environmental audit
- To maintain the threshold set by the project which is often guided by governmental standards and policies
- To identify, measure and mitigate unanticipated impacts.

In addition to targeting minimum environmental impact monitoring also provides scope to increase public acceptance. Through regular and systematic monitoring activities, the project will have minimum impact on the social and environment component of the project area which will reduce the chances of social conflict.

Some of the methodologies used in monitoring are shown in Table 2.4.

Selection of monitoring parameters needs to be chosen considering various factors like legal standards, nature of the impacts identified initially, the technology used for the culture, species grown, etc. Monitoring parameters should also consider quantifying the positive impact in addition to the negative impacts.

2.8 Environmental Certification to Sustainable Aquaculture

Over the past decades, the use of market-based management approaches like codes of conduct, best management practices, eco-labelling and certification which targets both the aquaculture and capture type of fishing has grown. These voluntary approaches target both the socio-economic and environmental aspects of the fishery industry. As the regulatory approaches have a high implementation, monitoring, and enforcement cost (USAID 2013) voluntary approaches can be considered a cost-effective means to achieve sustainable targets.

Codes of conduct refer to the guideline that incorporates the socio-economic and environmental aspects and is designed to minimize negative impacts, ensure safety, increase benefits and optimize production. Adoption of these best management practices are voluntary in nature, however, efforts are given at national level to advocate the benefits of it.

Certification and Ecolabelling are another widely used voluntary method, which targets to disseminate information for the consumers to make the appropriate decision. The certifications and ecolabel required a set of criteria to be fulfilled and these criteria focus on making the product environmentally and socially sound. These ecolabels on the product help consumers to make purchasing of the environmentally friendly products and allows the consumers to create demand for sustainable goods. In developed regions such as North America and Europe where green consumerism has flourished, greater demand for the certified aquaculture products is observed at the supermarkets and restaurant chains (Waite et al. 2014).

Table 2.4 Monitoring methods

SN	Methodology	Monitoring components
1	Walkthrough survey	General overview of the changes compared to the baseline scenario
2	Questionnaire survey, key informant interview, secondary data collection, etc.	Social conflicts, economic status, environmental problems, etc.
3	Video survey	Approximate sediment thickness; sediment color; sediment consistency; surface consolidation; gas bubbles; presence of feed and feces; macro-fauna/flora; presence of detritus and fouling organisms
4	Sediment sampling	Solids deposited in the core due to the aquaculture
5	Water quality sampling	Water quality parameters (often according to the governmental standards) Eg: Redox, pH, DO, TVS, TDS, TOC, Zn, Cu, etc.
6	Sampling of various components	Biophysical characteristics, microfauna abundance
7	Modeling (Models like DEPOMOD can be used)	Area of maximum impact from culturing operation
8	Echo sounder monitoring	Bathymetric profile
9	Visual inspection	Disease, vectors, fungus and others that can cause disease leading to loss of productivity of the harvest

Thus, aquaculture also gains an advantage by increasing the marketability of the product by adding value to the quality of the product. Some of certifications and ecolabel for the aquaculture are:

I. Aquaculture Stewardship Council (ASC): ASC ecolabel certifies the farmed seafood that has taken measures to reduce the environmental damage. In addition to demonstrating environmental responsibility, the aquaculture also needs to demonstrate social responsibility toward the workers to be certified by ASC.
II. Marine Stewardship Council (MSC): MSC certification was initiated by WWF and Unilever in 1997 and is an independent body that certifies the sustainability of the industry. The industry has to undergo the MSC auditing process and comply with all its standards to obtain the certification to use its ecolabel. The use of MSC ecolabel certifies that the aquaculture industry linked to the product has adopted sustainable and responsible practices.
III. The EU Eco-label: was launched in 1992 by the European Commission with the motive of developing a Europe-wide trustworthy labeling scheme that consumer could believe to have minimum environmental stress. As of September 2015, it had 44,771 products and 2031 services licensed under it (European Commission 2016). The licenses give companies the right to use

the EU Ecolabel logo on their product group. Aquaculture products with EU eco-label in the European market have more demand than the other.

IV. Best Aquaculture Practices (BAP): BAP ecolabel is commonly used for the shrimp farm and hatcheries and seafood processing plants. The use of BAP ecolabel reflects the standards that are specifically directed toward the protection of biodiversity and workers right.

The use of ecolabelling can reflect the sustainability of the industry, the market for sustainable goods is also an important component for its success. As the majority of the aquaculture production and consumption occurs in developing countries (Eg. China, Thailand, Vietnam, Indonesia, etc.,) the demand for the sustainable aquaculture product is low. Currently, the private ecolabelling schemes only certify 5% of the global production (Bush et al. 2013).

2.9 Concluding Remarks

With the increasing demand, aquaculture has provided new means to increase the aquatic products, which have reached its saturation limit in nature. Over the past decade, the aquaculture industry has kept expanding and has over-exploited at socio-economic and environmental cost. Aquaculture production is now focused on increasing the yield at the lowest possible cost to be competitive in the market. This has driven the aquaculture industry to a more intensive system with more impacts related with it. This trend tends to neglect the environmental and socio-economic aspect, which forms the pillar of sustainable development.

The competitive market, market demand for low price products and overly ambitious aim of the producers to maximize the profit are the constraints to the sustainability of this industry. Apart from the benefits such as increased jobs, food security, increased trade, etc. aquaculture leads to several adverse socio-economic impacts like loss of traditional occupation, social conflicts, food safety, etc. It also has environmental cost as it pollutes the nearby environment, hampers wild fishes, spreads diseases, and causes genetic variation in the ecosystem. These impacts vary geographically and according to species cultivated and technology used. It further depends on the intensity of the farm. Thus, it is necessary to identify these impacts and take necessary mitigation measure with strong management practice.

SEEA can act as an important mechanism to achieve the sustainability of aquacultures. Moreover, as the intensive aquacultures are predicted to grow in the future, SEEA will play a more vital role. Sustainable aquaculture might need a little more effort and spending but it could be a viable option to ensure long-term profitability of the industry.

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