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The Impact of Aquaculture on the Environment: A Ghanaian Perspective

Michael Dabi
Lecturer, Evangelical Presbyterian University College, Ghana
Sheena Edem Anita Dzorvakpor
Student, Evangelical Presbyterian University College, Ghana

Abstract:
Aquaculture has over the years been able to offset the deficits in national fish production all over the world. There have been substantial socio-economic benefits arising from the expansion of aquaculture. Previously seen as a solution to capture fisheries which has over the years caused significant ecological changes to the environment, aquaculture has now been identified to pose equally the same problems, or even worse in some cases. The study reviews some deleterious effects of aquaculture and assesses the impact of the increasing practice of aquaculture on the world's environments and the possibility of its occurrence in the Ghanaian environment. Recommendations are made in line with good aquaculture practices seen elsewhere around the world.

1. Introduction

Aquaculture, the art of intentional farming of species, has the potential to play a key role in feeding human populations in the years to come (Duarte *et al.,* 2009). Holmer (2010) has predicted aquaculture to be the solution to world food security since catches from the wild (capture fisheries) are unlikely to increase; with food production on land being limited by the availability of arable land. Mariculture, a form of aquaculture, for instance, has no demand for freshwater and land, as an estimated 70 % of the earth's surface is covered by water.

The fisheries sector in Ghana has played a major role in sustaining the national economy since independence. Seini *et al.* (2004) reports that it contributes 5 % to the gross domestic product (GDP), serving as a source of income to about 10% of the population. The sector comprises the marine and the inland fisheries. The marine fisheries is mainly capture-based with no reported records of marine culture in Ghana to date. The inland fisheries sector is made up of the inland capture fisheries (freshwater) and the inland culture fisheries (culture based fisheries and aquaculture). Braimah (2003), in an overview of the fisheries sector in Ghana observed the Volta Lake (created from the Volta River) to be the central source of inland capture fishery supporting about 300,000 livelihoods; estimated to have contributed about 16 % of total domestic production and 85 % of inland fisheries output in 2002, these figures needing verification in recent years with the high proliferation of cage fishery on the Volta River. Together with capture based fisheries, the cage culture aquaculture being practiced on the lake is currently attracting individuals and fishing companies all over the country. Apart from cages, aquaculture (fish farming) in Ghana is also practiced in ponds, raceways, and tanks among others.

Common among the cultured species in Ghana (in all forms of culture systems) are various species of tilapia, Chrysichthys sp., Synodontis, Mormyrids, Heterotis, Clarias sp., Bagrus sp. and Citharinus.

Once considered an environmentally benign practice, fish farming has been reported as a potential polluter of mainly aquatic environments across the globe (e.g. Findlay *et al*., 1995). Much of this pollution has been centered on water pollution mainly associated with intensive systems such as cage culture with high nutrient loads and organic enrichment of the recipient waters resulting in anoxic sediments, changes in water bed community, and the eutrophication of lakes (FAO, 2005). Untreated waste products of all forms from the systems are normally released into the recipient waters where they contribute to the contamination of the water supply.

Land degradation associated with aquaculture can be observed via the conversion of mangroves and wetlands into land aquaculture (shrimp) farms and the clearing of arable land for the construction of large aquaculture farms leading to salinization of agricultural and drinking water supplies among others. These farms are normally commercial and associated with high intensification (increased inputs) and astute entrepreneurial management to meet market demands. Such intensification may increase the risk of environmental pollution.

There are copious studies reporting the adverse effects of aquaculture on the environment throughout the world (e.g. Costello *et al*., 2001; Dean *et al*., 2007; Rodgers and Furones, 2009; Al Mahmud *et al.,* 2012). However, the availability of research relating to the impacts in the Ghanaian environments is scanty. Therefore, any attempt at delving into the research on possible impacts of culture fisheries on the Ghanaian ecosystem should be justifiable.

This study seeks to investigate the possible impacts that aquaculture practices will have not the Ghanaian environment.

2. Literature Review

2.1. Definition of Aquaculture

Different authors have come up with different definitions of aquaculture in the recent past. However the definition from the FAO (1988) has been accepted by many to be a more comprehensive definition. According to the FAO:

"Aquaculture is 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, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resources, with or without appropriate licenses, are the harvest of fisheries."

2.2. Types of Aquaculture

Aquaculture is practiced in three types of environment (freshwater, brackish water, and marine) worldwide for a great variety of culture organisms. Freshwater aquaculture is practiced mainly in ponds, cages, pens, tanks and raceways. Brackish water (salt and fresh water mixed together) aquaculture is mainly practiced in ponds situated in coastal areas. Marine aquaculture may employ either fish cages or substrates made from stakes, ropes, and rafts (FAO, 2005).

In relation to the types of aquaculture, four distinctive types can be identified. The first and more primary form of aquaculture is fish farming. Fish farming is the culturing of fish in enclosures such as ponds, cages, pens, raceways etc. The main environment of focus is freshwater. The freshwater environment distinguishes this type of aquaculture from mariculture, where species are reared in enclosures in the sea. In mariculture, not only fish are cultivated. Some mariculture may involve the cultivation of plants and other animals besides fish.

The other popular types of aquaculture worth mentioning are algaculture and integrated multi trophic aquaculture. Algaculture, where various species of micro and macro algae are cultured, is more popular in Asia and least common in Africa. Integrated multi trophic aquaculture (IMTA) comes in many forms. It basically involves the combination of different species (may be plants and animals) with different nutritional needs under one culture system where the waste products of one species are used as input (feed or fertilizer) for another species. A common form of IMTA is integrated fish farming – where the production of fish is combined with the rearing of farm animals or crops (e.g. a fish-rice or a fish-pig system).

The most common type of aquaculture practiced in Ghana is fish farming. Therefore, the attention of this study would be focused more towards it.

2.3. Aquaculture in Ghana

Aquaculture (fish farming) in Ghana, previously reported to be dominated by small scale operators with great potential for development and largely underexploited (Hiheglo, 2008), is a fast growing industry especially along the Volta Lake. Hiheglo further reports that earthen ponds had accounted for over 98% of fish farms before 2003, dominating the southern and middle belts of the country while concrete ponds, used more rarely, were and are still normally small and mostly used in hatcheries. Pens and cages have been more recent additions since 2003. Rurangwa *et al.* (2015), in a recent report on aquaculture development in Ghana, observed that in recent times however, cage fishery has become the more prominent among the structures used for aquaculture, developing fast especially between 2009 and 2014 as a commercial activity. With an average annual growth of 73%, Rurangwa *et al*. claim cage fishery now contributes nearly 90% of the total production from aquaculture with the Volta Lake/ River being the main point of activity.

Due to its natural suitability for tilapia culture, several individuals and organizations have taken advantage of this to invest in tilapia cultivation on the the Volta Lake with the expectation of developing sustainable businesses through this venture. In the last decade, according to Rao *et al.* (2012), there have been an influx of intensive farms along the Volta mainly owned by foreign nationals and few Ghanaian companies who have the capacity to procure huge cages and skilled labour to man these farms. The proliferation of the cage fishery can be well appreciated in the rise in production levels within these last few years. Figure 1 shows the contributions of the various aquaculture systems to national aquaculture production from 2009 to 2014.

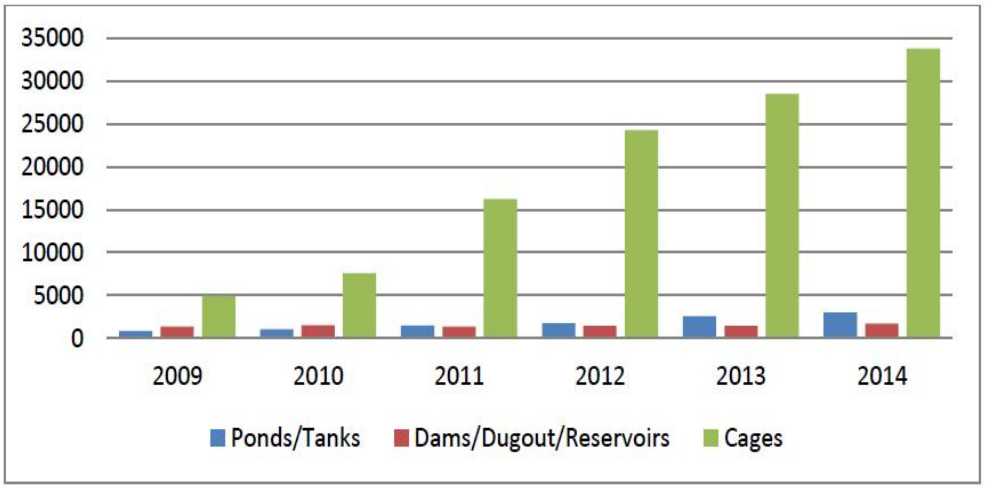

Figure 1: Annual aquaculture production in Ghana between 2009 to 2014 (production in tons) (from Rurangwa et al., 2015).

Unfortunately, it has been reported that unregulated human activities such as farming with agrochemicals along the banks and even within the Volta Lake (fishing with harmful chemicals) are threatening the viability of the business investments in aquaculture on the Volta Lake (Ghana News, 2013). The news item further claims that reports from the Ghana Standards Authority had revealed loads of agrochemicals, organophosphates and some volatile organic compounds in both water (Volta Lake) and meat (flesh) respectively. These chemicals, as earlier started, are believed to emanate from run-offs and leaching of toxic chemicals from surrounding farms, as well as domestic and other industrial sources.

2.4. Negative Effects of Aquaculture

Notwithstanding the enormous pluses aquaculture brings to the Ghanaian economy, some possible minuses are likely to surface if good practices are not observed and astute measures put in place. Some undocumented impacts have already been reported though. For example, a special report by Koranteng (2015) on the Modern Ghana website (an online newspaper) documents health distresses raised after fishermen trapped fish with dichlorodiphenyltrichloroethane (DDT), a colourless crystalline pesticide, on the Volta Lake.
Some of these negative impacts would be outlined and discussed in this study. Reviews by FAO (2005), Chen *et al.* (2000), Faruk *et al.* (2008), Hall *et al.* (1992), Carpenter *et al.* (1998), Holmer (2010) among many others have provided the basis for the ensuing discussions on these impacts.

2.4.1. Chemical Pollution

Successful fish farming ventures in recent times require intensification (Al Mahmud *et al.,* 2012), with the use of chemicals as a means to achieve this (Faruk *et al.,* 2008). These chemicals are used for various purposes and at various stages of the production cycle. These include the prevention and treatment of diseases (disinfectants and algacides), control of aquatic pests (pesticides), as well as protecting farm infrastructure from fouling (biocides) (Rodgers and Furones, 2009). Further, studies have shown that chemical use is not restricted to health management but also for soil and water quality management (Faruk *et al.,* 2008) as well as in feed formulation, growth promotion and the final processing of the fish (Rodgers and Furones, 2009); though in the case of soil and water quality management it may only apply to specific culture systems. A list of these chemicals cannot be exhausted by this study. However, some commonly used ones are worth mentioning. These include: sodium chloride, formalin, malachite green, methylene blue, potassium permanganate and hydrogen peroxide (GESAMP, 1997). The important thing to note about the use of these chemicals is the proper application in its right dosage. This simple requirement most often than not, is ignored posing serious risks to the recipient environment.
Salmon farming, practiced under mariculture, is claimed to be one of the most harmful aquaculture production systems. With open net-cages that are positioned directly in the ocean, waste products, various culture chemicals, as well as disease and parasites may be released directly into the underlying waters, putting other species in the water in harm's way. But with this, other factors (e.g. water depth, water volume, level of intensification, and the distance from the coast) must play in synergy for this to happen auspiciously.
Sediments (soil particles) store higher levels of trace metals (chemicals) than water leading to serious problems due to their toxicity and tendency to bioaccumulate (Chen *et al*., 2000). If these trace metals, e.g. cadmium, lead, zinc, chromium, copper, and nickel that accumulate in the sediment are eaten by some zooplankton or sediment-eating fish, they have the tendency to be accumulated in fish tissues hence incorporating into the aquatic food chain. The process of biomagnification starts when these chemicals are not digested and excreted in the organisms but rather passed on to species higher up the food chain through feeding relationships. These organisms higher up the food chain experience a higher load or concentration of the chemical than those at lower levels. Studies have found that when humans eat fish with exceeding maximum permitted concentrations of these substances, it may pose serious health risks (Cheng *et al*., 2012).
Other sources of chemicals introduced into the water culture milieu are anti-foulants used on fish farm cage nets which eventually accumulate in the benthic organisms and sediments below the net cages (Costello *et al*., 2001; Dean *et al*., 2007).

There have been undocumented reports of persons experiencing various health complications of various degrees after eating fish treated with unnamed chemicals during production from fish farms across the country.

2.4.2. Nutrient Pollution

Several studies have shown the most severe impact of cage culture to be organic enrichment of the seabed (e.g. Gowen and Bradbury, 1987; Iwama, 1991; Hall *et al.*, 1990; Hall *et al.*, 1992). These researchers have found through various studies that just a percentage (between 23 – 54 %) of the carbon, nitrogen and phosphorus supplied to fish through their feed is retrieved through harvest. The significant amount ends up on the seabed, either as wasted food or as faecal excretions.

Apart from uneaten feed, another major source of nutrients from fish farming operations is fish excrement that falls into the water column. Both types of discharge (uneaten feed and excrement) do contain nitrogen and phosphorus which are biodegradable and digestible hence may not be subject to bioaccumulation and subsequent biomagnification. These discharges are dispersed into the underlying water where they are incorporated into the systems of bacteria and other phytoplankton. These nutrients are necessary conditions in the process of photosynthesis in the aquatic environment. These nutrients, in summary, have the potential to enhance the growth of aquatic plants and algae leading to enrichment of the water body known as eutrophication. Eutrophication is characterized by the excessive growth of micro plants and algae due to the increased availability nutrients, one of three limiting growth factors needed for photosynthesis.

Some deleterious effects of eutrophication include dramatic consequences for drinking water sources, fisheries, and recreational water bodies (Carpenter *et al*., 1998). Though the nutrient loadings cannot be solely blamed on aquaculture practices (majority of nutrients for eutrophication is from agriculture run-off), the contribution from aquaculture cannot be overlooked.

Blooms of noxious or foul-smelling algae are formed on the water body as evidence of eutrophication and the presence of excessive nutrients in the water body. This process limits light penetration into pond impeding processes that are associated with light. When these dense blooms of phytoplankton die, their decomposition which is aerobic in nature, depletes the waters further of oxygen, creating anoxic conditions that make life processes in the pond almost impossible. Not all blooms are so harmful. However, harmful ones have been noted that have been linked to degradation of water quality, destruction of economically viable fisheries and posing public health risks (Burkholder *et al*., 1992).

Several instances of eutrophication have been reported in areas where aquaculture is practiced all over the world. One example, Isotalo *et al.* (1985) reports, occurred in Finland in a sheltered archipelago leading to ecologically undesirable consequences. Tangen (1977) and Jones *et al*. (1982) had also documented instances of mass fish kills in various fish farms around Asia, though the GESAMP (1991) later claimed there were no evidences to prove that the occurrence of these harmful events were as a result of the release of waste materials from the aquaculture set ups.

2.4.3. Habitat Destruction

Habitats, places where organisms live, are very crucial to the survival of these organisms. That is why a major problem facing biodiversity today is the destruction of the natural habitats of organisms. Many anthropogenic activities including aquaculture production may lead to the destruction of many habitats. Habitat destruction occurs when natural or anthropogenic activities cause irreversible changes in the environment of an organism such that the organism is displaced from its habitat.

Various activities involved in various forms of aquaculture may end up destroying habitats on land and in the water. For example, waste, feed and faeces from fish farms do collect on the bottom of the water under fish cages. This surge in organic matter has an impact on the organisms living in or on the sediment by changing the composition of the sediments, resulting in changes in community structure via a reduction in species diversity and abundance.

In other aquaculture systems such as shrimp farming (practiced more in Asia and gradually gaining grounds into some other parts of the world including Africa), large parcels of ecologically-sensitive habitats are cleared for pond construction and other structures related to the production. Habitats such as mangroves, salt marshes, estuaries and mudflats are the most susceptible to this kind of destruction. For example, Gomez *et al*. (1989) reports that about 200,000 hectares of mangrove forest in the Philippines were destroyed and an estimated 25 % of the total mangrove resource in Thailand lost in the wake of aquaculture development.

Species that make their home in these places either migrate or die leading to possible biodiversity loss. These habitats also perform some ecological functions such as buffers from storms, nursery sites for fisheries and migratory homes for species of birds, fish and invertebrates. These functions are eventually lost with the removal or pollution of the habitat.

In some Asian countries such as China, the culturing of carnivorous fish like salmon that requires a high percentage of protein derived from wild fish in their feed also has a significant impact on the environment. More kilograms of wild fish are used to raise farmed salmon than the amount of salmon produced, depleting wild fish stocks rather than supplementing them.

An excerpt from an article titled, "*The pros and cons of fish farming*" in the Encyclopedia Britannica 2008 edition sums it all up:

"Coastal areas worldwide have seen habitat and ecosystem alterations in order to accommodate fish farms. Mangrove forests–complex ecosystems that lined great stretches of the coasts of Thailand, Vietnam, and China, as well as those of other countries—have been destroyed to create shrimp and fish farms (as well as other businesses). These swamps helped buffer the effects of hurricanes, cyclones, and tsunamis; it is believed that the loss of coastal wetlands along the Mississippi Delta contributed to the immense devastation from Hurricane Katrina. Other agricultural areas were also affected. The World Resources Institute estimates that "nearly half the land now used for shrimp ponds in Thailand was formerly used for rice paddies; in addition, water diversion for shrimp ponds has lowered groundwater levels noticeably in some coastal areas.""

2.4.4. Introduction of Nonnative Species and Depletion of Wild Stock

Non-native species in culture, according to the FAO (2005), are likely to escape into the wild either accidentally or by design, and can adversely impact local species through hybridization and loss of native stocks, predation and competition, transmission of disease, and changes in habitat. Similarly, disease causing organisms peculiar to farmed species as a whole are likely to get transferred between wild and farmed populations.

These farmed species, through interactions with wild fish may interbreed with the local wild stocks of the same species with a possible alteration in the overall pool of genetic diversity (FAO, 2005). On the dangers of wild stock depletions, Rao (2012) reviews that escaped fish from fish farms are harmful to ecosystem health because most of the time the cultured species may be different from the fish in the wild, hence when released can cause havoc by disrupting critical relationships in the environment. Most often, the escaping species do outcompete the original species in the environments they escape to, and may cause the extinction of that particular strain of the species, which in turn, may affect other species in the environment negatively due to the peculiar living relationships that may have existed in the ecosystem (Appleyard and Mather, 2002).

3. Global Attempts at Solving the Problem

The contribution of aquaculture to world economies has been enormous hence discontinuing it due to its adverse impacts on the environmental may not be the best solution. To this end, several conferences, and workshops have been held all over the world to address the issues and advance knowledge on sound practices in the sector. Some of these attempts have been listed in Table 1.

Year	Conference
1991	ICLARM/GTZ conference on environment and aquaculture in developing countries
1994	FAO/NACA regional workshop on environmental assessment and management of aquaculture development in Asia-Pacific
1995	Adoption of the FAO Code of Conduct for Responsible Fisheries, including its Article 9 on Aquaculture Development
1991-1997	The GESAMP expert meetings on environmental impacts, monitoring, use of chemicals, integration of aquaculture into coastal management, planning and management for sustainable coastal aquaculture development
1997-2000	The FAO Consultations on Policies for Sustainable Shrimp Culture
1999	Consultation on the Application of Article 9 of the FAO Code of Conduct for Responsible Fisheries in the Mediterranean Region
2000	Bangkok Declaration and Strategy on Aquaculture in the Third Millennium.
2010	Global Conference on Aquaculture
2014	United Kingdom - Southeast Asia Workshop on Sustainable Aquaculture
2013	FAO/NEPAD Workshop on Climate Change, Disasters and Crises in the Fisheries and Aquaculture Sector in Southern and Eastern Africa
2014	NEPAD-FAO Fish Programme Workshop on Developing Aquaculture as a Business within an Ecosystem Approach to the Sector, Lusaka.
2014	International workshop on resource enhancement and sustainable aquaculture practices in Southeast Asia

Table 1: Attempts at resolving the aquaculture – environment conflict
Adapted from FAO (2005)

The tenets of these meetings have been applied judiciously in some countries to the mutual benefit of the economy and the environment. These tenets will be looked at in view of proposing solutions to the Ghanaian situation.

3.1. Proposed Solutions for Ghana

The solutions proposed are based on best practices in other parts of the world. The solutions have not be limited only to fish farming – which is the most common form of aquaculture practiced in Ghana. Provisions have been made to cater for the near future, envisaging that Ghana will soon embrace and move into other forms of aquaculture.

The GESAMP (1991) have observed that generally, ecological impacts from aquaculture have resulted from a lack of adequate management and planning, as well as inadequate consideration of the environmental compatibility of the chosen sites in question. The proposed solutions have therefore factored these variables in question into consideration.

3.1.1. Precautionary Approach

The precautionary principle states that:

"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof. The process of applying the precautionary principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action."

This principle or approach has been advocated for many aquaculture practices all over the world, particularly regarding the introduction and use of alien species. In Ghana, the tendency to introduce species that are doing well elsewhere under culture conditions may be high for various economic reasons. Also, new systems of aquaculture such as commercial shrimp farming, algae culture and mariculture which are yet to gain ground in Ghana, may soon be introduced for the same economic reasons.

Since the precautionary principle had been criticized in the past for generally blocking innovation and progress, a full implementation of the principle may not be in the economic interest of the nation. In such a case, the FAO has advised that "special consideration must be given to better management of aquaculture developments affecting sensitive habitats, such as, for example, estuaries, mangroves, wetlands, riparian fauna and vegetation, or specific breeding and nursery grounds" (FAO, 2005).
The necessary precautions associated with the selection of sites for production and subsequent activities during production are enshrined in the requisite documents of the Water Resources Commision, Fisheries Commission, and the Environmental Protection Agency. These precautions should be adhered to by farmers and enforced by the state.

3.1.2. Awareness Creation
Education is key in the fight against unsustainable development and exploitation of the environment. Citizens will become more responsible when they do understand the overall impact of their actions or activities on the environment. In this regard, stronger commitment to responsible aquaculture will be created among the citizenry ranging from producers, government and the general public, including consumers. The education should be holistic in nature involving all facets of publicity available in the country, with the schools and media houses championing the cause, through workshops and conferences.
The purpose of the awareness programme should be to enhance the knowledge of the citizenry on the potential ecological, social, economic, and physical impacts of uncontrolled aquaculture developments on the environment.
This awareness creation, according to Dorm-Adzobu and Amponsah (2013) has been championed by the Water Resources Commission since 2004, though the focus has not only been on aquaculture.

3.1.3. Introduction and Application of Environmental Impact Assessment Procedures to All Aquaculture Projects
The United Nations Environmental Programme (UNEP) defines Environmental Impact Assessment (EIA) "as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making." In simpler terms, it is a process of assessing the possible environmental impacts of a development proposal and identifying options to minimize environmental damage. The development and application of EIAs to major aquaculture projects in all aquaculture environments and routine environmental monitoring can help provide the information needed for effective environmental management actions aiming at various aquaculture establishments. A thorough assessment of the social, physical, chemical, and physical impacts of these establishments on the recipient environments is a measure well in place to save the environment.
The EPA in Ghana already has guidelines and regulations on EIA regarding aquacultural projects in the country. These should be strictly enforced.

3.1.4. Improved Husbandry and Astute Farm Management
Good husbandry practices are very essential and required in any aquaculture enterprise especially when it comes to feeding and administration of all manner of chemicals (fertilizers, drugs, anti-foulants etc.). In this regard, extension officers should be readily available to offer extension services to farmers and corporate bodies on the application of chemicals and the better use of available resources, with strong emphasis on technical and economic efficiency, to improve farm management.

3.1.5. Enforcement of Quality Control Measures
Comprehensive suites of environmental regulations relating specifically to aquaculture operations should be passed and enforced. The suite, should be akin to those used in other countries such as the United States and China, and should include regulations on types and levels of discharges, allowable structures, food safety, habitat protection, use of medication and feed among others. Legal and institutional frameworks which have been developed by bodies such as the EPA, Water Resources Commission and other related bodies should be taken seriously with issues of enforcement and monitoring of compliance with environmental regulations receiving equal attention. Some of these regulations include the Environmental Protection Agency Act 1990 (Act 490), the Food and Drugs Act, 1992 (PNDCL 305B), Fisheries Act, 2002 (Act 625), the Fisheries Regulation, 2010 (L.I.1968), Environmental Assessment Regulations, 1999 (L.I. 1652) and the Water Resources Commission (Act 522, 1996).

3.1.6. Using Vaccination for Disease Prevention
Vaccination to prevent some diseases in farmed fish in areas like the USA and China has achieved great success hence dramatically reducing the use of drugs.

3.1.7. Introduction to Marine Culture Production
Holmer (2010) has suggested that due to larger dispersal of waste products via strong currents and waves, the impacts of production from marine culture would be far lesser than inland culture with a more serene environment. This ensures fewer interactions with coastal flora and fauna so that the integrity of the community structure of the benthic environment is not compromised. To buttress this assertion, there have been studies at off-coast farms that show less benthic impact compared to coastal farms due to larger dispersion of particulate waste products (e.g. Pitta *et al.,* 2009; Holmer, 2013). This further suggests the suitability of off-coast and offshore production for sustainable development of aquaculture in the future.
Again, with respect to nutrient enrichment leading to eutrophication, this may be unlikely in open coastal waters where mariculture is normally practiced, though it can occur in semi-enclosed coastal embayments such as fjords, inlets and lagoons which have restricted exchange of water with more open coastal waters (GESAMP, 2005).

3.1.8. A Paradigm Shift to Integrated Fish Farming

Integrated fish farming, a form of integrated multi trophic aquaculture where the output (waste) of one system are used as inputs (fertilizer and feed) for another, is a less waste generating system and more sustainable compared to other forms of aquaculture. Its practice should be encouraged.

4. Conclusions

Every form and level of aquaculture will have some impact on the receiving environment. Increasing efficiency in resource usage and working to minimizing adverse environmental impacts from the practice of aquaculture will go a long way to make the practice of aquaculture more sustainable. This will require the commitment and willingness to collaborate by all those involved, either directly or indirectly, in the development of aquaculture in the nation.

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