Aquaculture and its effects on the environment

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Abstract

The document argues that aquaculture production systems in the world are part of the economic and social development of fishing communities involved in the exploitation of this resource, indicating a secure major source of food production in the coming years, resulting in a direct generation of employment and a reduction in poverty. However, beyond these contributions their negative environmental impacts should be studied to identify and establish mitigation proposals that meet environmental laws and regulations in order to ensure sustainability, in this context there is a demand for institutional participation and by various interest groups, but above all there is an obligation of fish farmers to assume responsibly to these commitments and include environmental management in production processes.

Key words: sustainable aquaculture, management, environment.

Introduction

Worldwide, aquaculture has increased in the past three decades , which has meant economic and social growth for the sectors involved in this activity which has contributed significantly to the generation of employment and the production of rich, high quality protein food for human consumption. Globally, aquaculture plays an important role in focusing the efforts in eradicating hunger , providing food and generally improving peoples health and quality of life.

In this regard and in order to promote sustainable fisheries and aquaculture in the long term , the 1995 conference of the United Nations Food and Agriculture Organization (FAO) adopted the Code of Conduct for Responsible Fisheries and Aquaculture , establishing the foundation for the principles and standards of behavior for responsible practices to ensure the conservation, management and effective development of living aquatic resources with respect for the ecosystem and biodiversity ,and recognizing their nutritional, economic , social , environmental and cultural importance.

This article aims to describe the enormous potential for economic and social development of aquaculture practices , the main effects and impacts that occur in the environment as a result of the implementation of this activity , and how environmental management

systems address these problems by proposing alternatives to minimize their impact through decision making and actions aimed at achieving sustainable development for these production systems with the dilemma of knowing the environmental effects that are generated and how environmental management systems pose this problem in an effort to resolve them. In this paper the contributions made by various researchers on the subject are reviewed in order to present an overview of the action methods.

The aquaculture in the world

World aquaculture production continues to grow in the new millennium and has acquired unimaginable dimensions , evolving in the field of technological innovation and development and has adapted excellently to meet the food needs required by the population. In 2011 it reached a record level high of 63.6 million tonnes (Fig. 1). Another very important element to mention is the documented record of some 600 aquatic species grown worldwide with various systems and installations, with different levels of input use and technological complexity using fresh, brackish and seawater, contributing significantly to the capture fisheries production established through crop systems, particularly in inland waters (FAO , 2012).

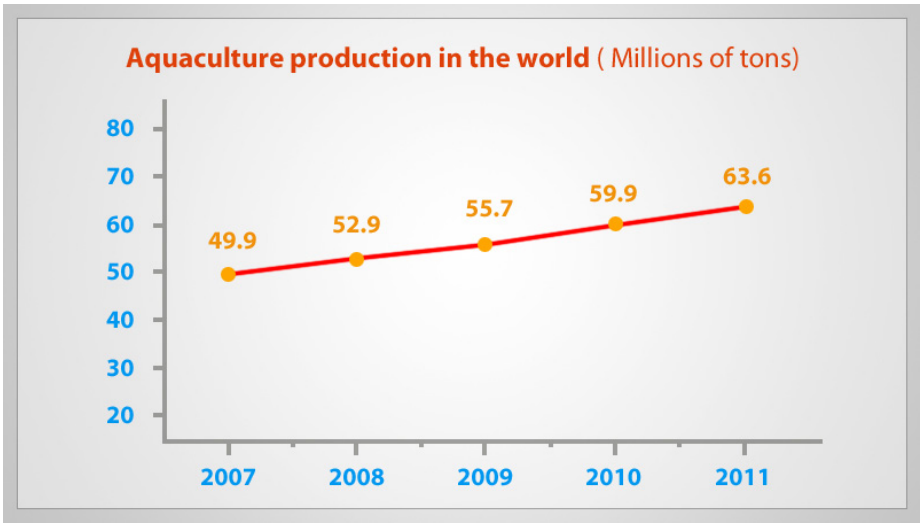

Figure 1: Aquaculture production in the world (FAO 2012)

The variation of the global aquaculture production between the years 2007 to 2011 is set in the order of 13.7 million tonnes of fish

products , which is an equivalent to a continuous increase of 27.5 % for this period.

While in America aquaculture has been growing in recent years with 600.942 tonnes reported in 2004 , by 2010 the records indicate the production of 543.428 tons. The difference in absolute numbers -57.514 tons, represents a decrease from 2004 of -9.6 %. (FAO, 2012)

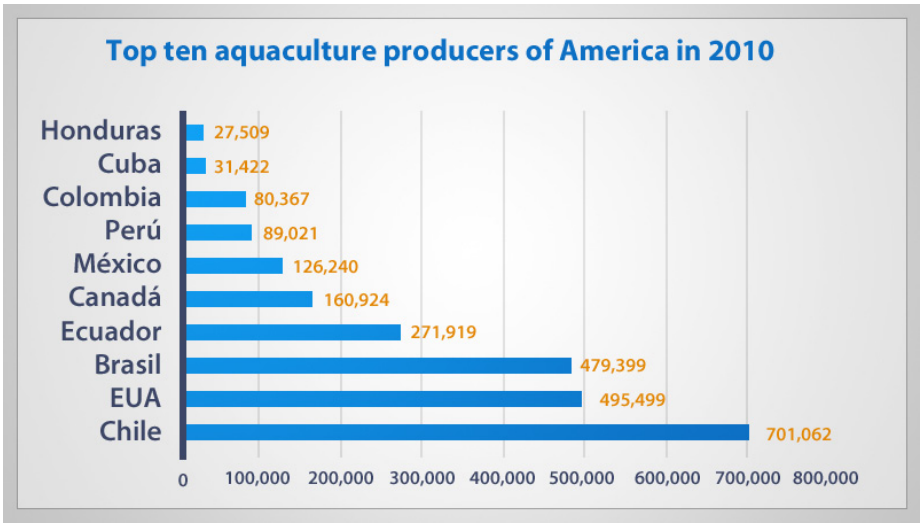

Figure 2: Top ten aquaculture producers of America in 2010 (FAO 2012)

Chile , with its long coastline and excellent sanitary, environmental and labor conditions successfully entered relatively early during the flowering of modern aquaculture. The spectacular growth of salmon was definitely responsible for the growth rate in the sector shown until the late twentieth century , ranking within the top 10 countries with increased aquaculture production in the world (Parada, 2010 , p. 144) and first in the Americas (Fig. 2)with aquaculture production for 2010 of 701.062 tons- this is equivalent to 27.2 % of all fish products produced in America. Mexico is in sixth position according to the records with 126.240 tonnes at 4.9 % of the total aquaculture production in America , with shrimp being the most exploited resource as a farming system product.

Panorama of aquaculture in Mexico

In Mexico commercial aquaculture production has increased which has made this practice an activity with great potential for development ,

providing social and economic benefits and translate into alternatives for the production of food sources.This is done by application of skills and knowledge focused on the cultivation of various species of aquatic animals and plants.

The potential for fisheries and aquaculture is huge. Mexico has 11,592 km of coastline, of which 73 % corresponds to the coastline of the Pacific Ocean and 27 % to the Gulf of Mexico , Caribbean Sea and Islands. Mexico has 12,500 km ^{2} of coastal lagoons and estuaries and 6,500 km ^{2} of inland waters such as lakes , ponds, and rivers (SAGARPA, 2011) , which makes it a region of great importance for furthering and promoting its development. Competitive advantages are the right climate in much of its territory for growing many commercial species , proximity to the world's largest seafood market (the U.S.) and native species with excellent characteristics for aquaculture including white and blue shrimp (Martinez et al. , 2009).

Species	Aquaculture Production (tons)				
	2007	2008	2009	2010	2011
Shrimp	111,787	130,201	133,282	104,612	109,815
Tuna	2,882	2,923	2,762	2,008	3,689
Tilapia	73,580	71,018	73,373	76,986	71,135
Oyster	46,491	42,148	38,974	47,611	43,757
Carp	21,798	24,157	22,620	24,231	18,528
Trout	4,345	4,917	6,065	6,919	8,480
Catfish	2,801	3,041	3,145	3,384	2,929
Sardine	1,483	2,338	1,876	1,806	1,226
Shrimp	46	24	21	26	18
Black Bass	1,234	1,221	1,379	1,354	1,044

Table 1: Participation of aquaculture in Mexico , tons of live weight by species (Figure prepared from data taken from " Statistical Yearbook of aquaculture and fisheries "). SAGARPA , 2007-2011. Mexico

The most predominant cultivated species is shrimp , its position in the international market for its economic value is relevant. For years it has been one of fishery products with high commercial value , followed by the production of cichlids belonging to the family cichlidae . However, the behavior of aquaculture production between 2007 and 2011 has been asymmetrical , with the maximum values of marine and inland aquaculture reported in 2009 as 285.019 tons ,with a decrease 262.853 tons occurring in 2011.

Shrimp farming in Mexico

In Mexico , the exploitation of blue shrimp began in the thirties, when significant populations were found in the protected waters of the Pacific. From then until the fifties it was an extractive activity dominated mainly by private and foreign initiative. In the Gulf of Mexico it was not until 1947 when the fisheries were initiated in Ciudad del Carmen , Campeche , twenty years after the research program for shrimp culture sponsored by various organizations and public and private institutions emerged.Its first achievement was the intensive cultivation of blue shrimp at the Center for Scientific and Technological Research in Puerto Peñasco Sonora (Bortolini and Garcia , 2004).

Due to the economic feasibility that shrimp farming represented in the southernmost states of Mexico, such as Oaxaca's " closed estuary" and Chiapas' " The Capulines ", shrimp cultivation can trace its beginnings back to 1980 with the construction of pilot stations of stocked ponds using with postlarvae from the wild. These projects were promoted by the Ministry of Federal Fisheries, which provided a range of information and knowledge that were subsequently applied to the crop first semi intensively in shrimp cages and later by intensive aquaculture through the construction of shrimp farms operating under controlled conditions using high planting densities .

Growing freshwater aquaculture species

Regarding production volumes , today the most important fish species for freshwater aquaculture are represented by the " mojarra " tilapia and carp. Cicliculture in Mexico began with the introduction of an African cichlid genus Tilapia with three species: *Sarotherodon aureus, Sarotherodon mossambicus and Tilapia zilli* , which were imported on July 10, 1964 from Auburn , Alabama in the United States and placed in ponds at the Ciclícola Temazcal Station , Oaxaca, Mexico . The development of Cirpiniculture began with the introduction of the carp *Cyprinus carpio communis* escamuda in 1872 , after the goldfish *Carassius auratus* was introduced. The popularity of carp began with the Israel carp, *Cyprinus carpio specularis*, through a national distribution program conducted by the National Ejido Credit Bank in 1956 known as Rural Fish Farming program (Rosas , 1982).

Although these two species of fish (mojarra tilapia and carp) were introduced, they are now present in almost all bodies of water are considered unique because of their easy handling and adaptation , toleration of wide temperature ranges and low oxygen, readily acceptance of a balanced food supply , have a high feed conversion , and have short product cycles. Today these are the two species that support major fisheries of inland waters (Table 1).

In this context the development of aquaculture has a broad perspective, but significant progress is necessary to establish a parallel with the technical work : training of farmers on breeding and planting , the arts of capture , monitoring and management systems , monitoring quality , etc. . , which would allow them to breed , plant , maintain and properly use resources that occur in inland and coastal waters (Cifuentes et al. , 1999). From this point of view aquaculture establishes itself as an alternative to food production, but it is clear that the activity also brings in more or less direct impacts on ecosystems affecting large areas near crops and natural populations living in that region . Due to these effects there are multiple ecological problems (Rivero et al. , 2003) : poor management of a resource due to its uncontrolled and irrational exploitation , overexploitation , the existence of unfavorable conditions in the type of development and even the lack of an environmental culture .

Environmental problems

In the 1970s firms has not yet considered the environmental variable in the production process (FUNIBER , 2010) .Damages to the environment were not taken into account, therefore it was clear that development was confined to economic and social growth for years , but not reflected in the environmental area. This disregard of companies of the environmental impact that their activities were having was evidence of the degree of the consumption of natural resources at such an extent that the pollution levels have produced environmental impacts have caused an impact on the planet that we still see today. However, these practices have been changing. For more than a decade society has been organizing and creating awareness about the care of the environment in such a way that the governments of the countries of the world continue to pursue efforts to establish legal initiatives that permit aquaculture and fisheries management.

In various ways of interactions that occur between businesses and the environment are found production processes , distribution

and marketing. These processes require raw materials , energy and water - the latter considered a scarce limited natural resource. It is during these production processes when a number of pollutants are generated , creating this dependent link between production systems and the generation of wastes. In this context development must strike a balance to address interrelated objectives , such as how to change the pauses between production and consumption, reduce poverty and monitor economic growth and productivity , according to the available natural resources and their regenerative and replacement capacity (Nicholas, 2010).

The different modes in aquaculture practices have diversified over time.Technical and production strategies as well as the variety of cultured organisms are growing, some operating at a small scale aimed mainly consumption, to building huge ponds with intensive production systems in the modes of inland and maritime trade all of which are common practices with processes that have caused negative environmental impacts.

The United Nations Organization for Food and Agriculture (FAO, 2011) document "Development of aquaculture, aquaculture ecosystem approach " states that the ecosystem approach to aquaculture as a strategy should be the means to achieve or reach a higher level of policies that reflect the objectives and relevant development agreements at national , regional and international levels directed towards sustainability , equity, and resilience of interlinked social-ecological systems .

Actions undertaken for sustainable aquaculture development are based on lines of action that go beyond food production , economic development for poverty alleviation and food security . Application protocols for best management practive have been consolidated so that the environment, society and economy have been defined as the basis for sustainable development of this activity. Within this vision work many producers in the industry,coupled with the demands of interest groups, consumer and environmental organizations. Through this perspective it is as if the codes of conduct and best practices in aquaculture can address a number of issues and concerns (IUCN, 2010) which tend to focus on reducing environmental impact , productivity, product quality , health and animal welfare , food safety , economic aspects and more recently its position on sustainability in general.

Environmental degradation by aquaculture practices

The exponential growth of aquaculture has caused serious concerns among governments, environmental groups and society itself for any damage that it is generating. It need to be considered as an activity where one must be cautious in the process of expansion. How and where it is done can affect water quality and adversely affect ecosystems , both in rivers and in the sea (Bordehore , 2005) which are strongly affected by farm waste.

Aquaculture activities threaten the conservation of biodiversity which is a global concern because its loss dramatically decreases humanities quality of life. Man has caused the decline of biodiversity in marine and freshwater organisms particularly for causes related to aquaculture.The possibility of improving fish grown by hybridization has been considered by some farmers as a solution to the problems of low yield. However, it has not always given satisfactory results. If these hybrids reach the natural environment they could exchange genes with the parental species and cause unpredictable consequences . (Pérez , 1996)

Regarding the introduction of exotic species, almost all modern aquaculture is based on a relatively small number of species that have spread throughout the world : including carp (Cyprinus carpio) , rainbow trout (Oncorhynchus mykiss) , some species of tilapia , Oreochromis niloticus especially , and O. aureus molluscs , the Japanese oyster, Crassostrea gigas and the American oyster, C. virginica and crustaceans Macrobrachium rosembergi and several species of marine shrimps of the genus Penaeus (Pérez , 1994)

The activity has a negative impact on the receiving bodies of water , particularly where production is greater than 10 tons per year (Velasco et al. , 2012) In this sense, ways are sought to reduce the impact through the enactment of environmental laws and regulations that regulate the activity through sustainable management and in a voluntarily manner through the application of basic environmental management tools and best aquaculture and environmental practices.

It is true that from the point of view of the economy of the producers and the technological tools available in the market , it is difficult to reduce the discharges of wastewater enriched with organic

matter with high concentrations of nitrogen and phosphorus- a product of the undigested food and feces. This leads to nutrient enrichment , and may affect large areas near crops and biodiversity inhabiting the receiving water bodies (lakes, rivers , estuaries and marshes) . It is clear that the environmental impact depends largely on the species, culture method , stocking density , feed type and watershed conditions (Borja , 2002).

Eutrophication problems start when man pollutes lakes and rivers with excess nutrients that generate the acceleration of the process and causes the algae growth , the death of fish and other aquatic flora and fauna , and the creation of anaerobic conditions. This process is the result of the use of phosphates and nitrates as fertilizer on agricultural crops , organic matter in garbage, detergents made from phosphates, which are dragged or thrown into rivers and lakes (Oceanographers Without Borders) .

The trophic status of lakes is a fundamental concept in their management , which means the relationship between the nutrient status of a lake and the growth of the organic matter. The process of changing from one trophic state to a higher level is through the addition of nutrients . Agriculture is one of the main factors of eutrophication of surface waters (Ongley , 1997) . Notwithstanding the latter , in ponds for growing fish and crustaceans the use of a rich chemical fertilizer of P , C , N and K was widespread in recent decades ,with the goal of increasing the natural productivity of the waters of these aquaculture systems through phytoplankton production, which is considered as the first link in the food chain in an aquatic environment (live food for the organisms that are being grown) This resulted in obvious wastewater discharges to receiving bodies with nutrient enriched water that may be the source of eutrophication in rivers, lakes , coastal lagoons and marshes.

Another of the impacts from aquaculture that may be cited are chemical compounds used to treat some viral and bacterial type diseases are also difficult to predict. Experiences indicate what may occur when compounds entering the food chain (Espinoza and Almada, 2012), with a potential for bioaccumulation in links above or maybe cause long-term damage sue to its cumulative impact .

Regarding the use of herbicides with glyphosate as the active ingredient , these compounds are potentially causing toxicological and environmental damage in aquatic systems and can cause delayed growth of organisms like algae and fish, histopathological changes ,

alterations of enzymatic parameters , decreased sexual activity and biochemical changes . In the human body they can cause toxicity in the liver and placental cells , act as an endocrine interrupter device , generate respiratory, gastrointestinal , dermatological and neurological conditions, as well as fragmentation of the genetic material. (Salazar and Aldana, 2011).

It also warns that as a result of overexploitation of resources and changes in land use , there may be changes to the habitats in areas where farmers remove mangroves to establish pools for breeding species of economic importance (Uribe et al . , 2009), particularly in cases of grow-out shrimp in coastal areas and in similar conditions during construction of aquaculture farms located in inland waters.

The factors affecting the quality of the cultivated product and the sustainability of the activity are good water quality, avoiding contaminated sites and good water renewal. The current in the area should be sufficient to prevent the accumulation of waste products (feces and food waste) which generate low oxygen levels(Borja , 2002).

Finally, most of these potential impacts on the environment can be managed and minimized by knowledge of the different processes and through the responsible management and proper location of fish farms (IUCN, 2007).

Environmental Management

From the perspective of sustainability , environmental management in aquaculture has implications that go beyond making commitments to continual improvement, compliance with environmental laws and regulations, planning , the adoption of strategies to maximize the reduction in consumption of resources with the decrease in production costs and replanted through the definition of environmental policy implementation takes on an enormous importance of an organized and systematic way that all of these actions are measured and evaluated by the degree of compliance of the management system. In the best cases the resources are adjusted to improve results. These environmental policies establish the principles for prevention and minimization of negative impacts.

In order to accomplish this ideal form of organization, among the sectors involved in environmental management are: general government,

public and private productive sectors, associations of various kinds, universities and research centers and the general population , which results in a shared responsibility with community participation at different times, forms and levels (Barn and Ferrando, 2007).

From this point of view it is desirable to implement environmental management systems as tools for the prevention and reduction of pollution . It is also important that in all productive processes natural resources and energy are used and these in turn are transformed into products. Waste must be managed properly through minimization practices , assessment and deposition , thus the existence of guidelines for sustainable management are essential tools for political and technical managers and administrations , aquaculture producers, and other users. (IUCN, 2007). From these considerations the environmental management systems are being implemented in many sectors of the industry in order to help organizations comply with legal requirements to minimize impacts on the environment , reduce waste and gain an advantage in the market (Gavine et al. , 2007) .

In addition to these requirements , another way to get a company to be environmentally friendly is the awareness of its members that there is responsibility for the protection and the conservation of the environment, which entails the use of clean technology that allow a minimal use of natural resources ,a reduction in waste production ,an allocation of economic costs representing environmental protection and the implementation of environmental management systems and audits.

Sustainable aquaculture

The concept of sustainability since its introduction as a subject of analysis has undergone various interpretations with a common denominator, all contextualized within the framework of development. The main condition is to ensure resources for future generations, and that they are always available despite the means that man takes to get from them the means to survive and grow in development. This involves the use of technological tools and education as ways of acting in a conscious and orderly manner.

It is from the conception of the term sustainable development that a series of scientific interpretations arise , basing these principles

on ecological , social , political and economic sustainability, but with established limits and minimum requirements that imply that sustainable development at no time should endanger the natural systems that maintain all forms of life on Earth. The care and exploitation of water resources , soil, atmosphere and living organisms are elemental parts of our environment, so it is urgent that in the short term technological development is an essential part of our needs as individuals , trying to avoid the disruption of these natural resources due to exploitation and development, decreases the carrying capacity of planet earth. Given these paradigms , aquaculture is determined by a set of regulations from environmental law . In this sense, this economic activity will apply both general environmental legislation and specific legislation developed in pursuit of sustainable aquaculture . (Bermúdez , 2007)

With this approach , sustainability can be divided into three process-related dimensions : an ecological system as the foundation of life on the planet , the economic system , which considers the production of goods and services, and the social system, that allows active participation of society and institutions. By establishing these strategies for achieving sustainable development, a comprehensive plan of action and legal support through the signing of agreements and regional and international treaties can be developed. Based on the environmental management mechanisms and policies of the exploitation of natural resources , an approach of sustainable aquaculture is the approach towards an equilibrium of the three components of sustainable development : there can be no social and economic development if we do not responsibly use our resources.

Figure 3 shows how the three strategic dimensions of development interact to form sustainable aquaculture.

An important aspect to consider is the risk that sustainable development becomes a simple element of marketing and image (García et al. , 2011) , being necessary to work together in order that the development philosophy does not remain as a fashion and can be actually implemented in a proper and effective manner.

In the context of development, social planning turns out to be as an aspiration reconciling the principles and ecological systems. It is a necessary symbiosis of anthropogenic natural ecosystems , associated with the various political, economic , social and cultural systems on individual principles. While the original idea was to apply the concepts and resources of clean technologies , zero emissions

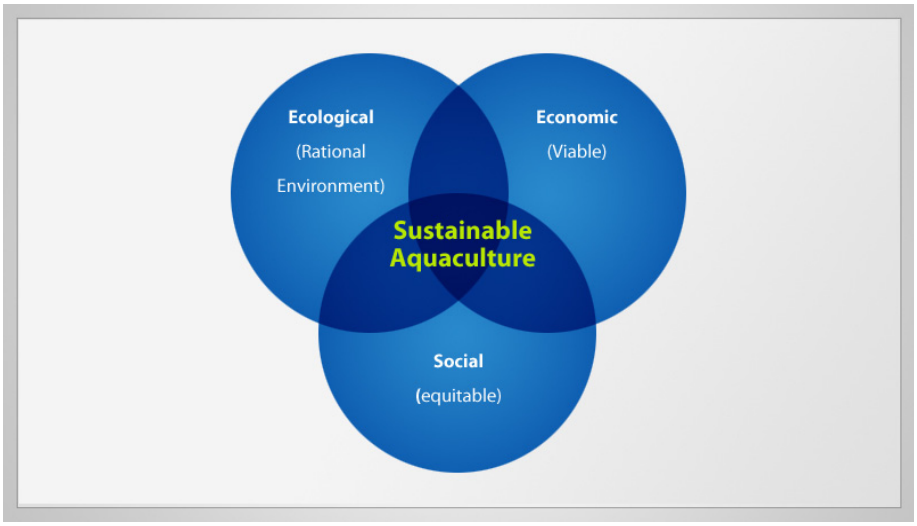

Figure 3: Elements of sustainable aquaculture . (White , et al. , 2004) . Retrieved from At a Crossroads : Will Aquaculture Fulfill the Promise of the Blue Revolution: a Sea Web Aquaculture Clearinghouse.

and environmental impact studies, and encourage scientific research in a concrete way (Pardo et al. , 2006),it is also the study and research aimed at identifying and defining aquaculture management tools - structured tools based on the use of sustainability indicators. In this sense, knowledge and adoption of these indicators by the agents of the aquaculture sector will advance , not only in the greater sustainability of productive activity , but also in improving the awareness of the managers of the activity and of society about the need to encourage a more sustainable every day management of our seas and rivers and the resources that they provide (García et al., 2011). To achieve sustainable development we must consider all variables and environmental, social and economic dimensions while identifying strategies and tools to facilitate effective integration and reactive involving the whole of society (FOESA , 2012).

The importance of sustainability of the aquaculture sector is crucial if the industry does not take the right path , so it is essential to continue to seek ways to make practices more sustainable , efficient and profitable for improving aquaculture production-for example human capacity , the use of resources and environmental management (SustainAqua , 2009).

Conclusion

Today, aquaculture is considered as a very important source of food production,compared only with agriculture and livestock source. However , the construction of large aquaculture parks that demand for its operation in the production phase the use of huge amounts of water can have real implications and impact receiving bodies (rivers, lakes, reservoirs , coastal lagoons and marshes) and affect the organisms that live there for the high loads of discharged pollutants rich in phosphorus, potassium and nitrogen which results in a process of eutrophication.

In a globalized world the expansion of aquaculture demands the optimization of production processes. It is necessary to improve these systems through the use of techniques that properly manage the natural resources that are used . However , in order for aquaculture to be sustainable ecological , economic and social dimensions must be assigned an equivalent importance value and interdependent forms of action must be permitted without departing from their related objectives, which represent balance and a trend towards strong sustainability indicators.

From this point of view , the implementation of environmental management systems by these productive sectors should be common practice , since they are regarded as true instruments to prevent and reduce pollution. These systems are an implicit application of the principles of prevention against the urgent need for sustainable aquaculture , which could be achieved by incorporating environmental variables in management policies , making it possible to identify legal and regulatory requirements ,and allowing decision-making. Above all there is one especially important element : full consciousness for the care and respect for the environment of all of the parties involved