Environmental performance of aquaculture in Rondônia state, Brazil

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http://dx.doi.org/10.1590/0034-737X201562020011

ABSTRACT

The objective of this study was to analyze the environmental performance of aquaculture in the city of Colorado do Oeste, Rondônia State, Brazil. Fifteen fish farmers were interviewed. For data collection, structured interviews were carried out, using a questionnaire based on information supplied by the United Nations Food and Agriculture Organization (FAO). The questionnaire considered 12 items, organized into three main topics: a) social and legal standards b) environmental standards c) standards of food safety and hygiene. Aquaculture in the city of Colorado do Oeste, Rondônia presents two fish production systems: extensive and semi-intensive. In the semi-intensive system, stocking rate was one fish per m^3, on average; tambaqui (*Colossoma macropomum*), tilapias (*Oreochromis spp*.), pirarucu (*Arapaima gigas*) and pintado (*Pseudoplatystoma spp.*) were the species farmed at the largest number. The rate of water renewal was due to the greater availability of natural food in this system. Water renewal was constant in the ponds (1,500 liters per minute). In the semi-intensive system using dug ponds, alevins were stocked and fed during the entire rearing time with natural and exogenous food. The extensive system relied on the natural production of the pond, with stocking density limited by the production of natural food. The little renewal of water made the cultivation tank itself acted as a decantation lake, with the occurrence of oxidation and sedimentation of residual organic matter, consisting of feces, debris and organic fertilizer. Production of reduced effluent volume took place in the extensive system, compared to the cultivation area. In addition, there was high water turbidity, caused by high concentration of planktonic organisms, and low concentrations of dissolved oxygen in the water. Data showed that nine estates of the interviewed fish farmers had critical environmental performance (less than 30.0%). Six estates of fish farmers had bad environmental performance (between 30.0 and 50.0%) (Coefficient of sustentainability = green square x 100 ÷ Total Questions less the yellow squares).

Keywords: Amazonian aquaculture, environmental aquaculture management, sustainable development

RESUMO

Desempenho ambiental da aquicultura em Rondônia, Brasil

Com o presente estudo objetivou-se analisar o desempenho ambiental da aquicultura no município de Colorado do Oeste, estado de Rondônia, Brasil. Foram entrevistados 15 piscicultores. Para a coleta de dados foram realizadas entrevistas estruturadas, utilizando-se de questionário elaborado a partir das indicações dadas pela Organização das Nações Unidas para a Agricultura e Alimentação (FAO). O questionário considerou 12 itens, organizados em três assuntos principais: a) padrões sociais e legais; b) padrões ambientais; c) padrões de segurança alimentar e higiênicos. A aquicultura no município de Colorado do Oeste, Rondônia, apresenta dois sistemas de produção de

Received on 21th December, 2011 and accepted on 24th March, 2015.

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peixes: um extensivo e outro semi-intensivo. No semi-intensivo a taxa de estocagem foi em média de um peixe por m^3; as espécies mais criadas foram o tambaqui (*Colossoma macropomum*), as Tilápias (*Oreochromis spp.*), o Pirarucu (*Arapaima gigas*) e o Pintado (*Pseudoplatystoma spp.*). A taxa de renovação de água se deveu à maior disponibilidade de alimento natural neste sistema. Houve constante renovação de água nos viveiros (1.500 litros por minuto). No sistema semi-intensivo em viveiro escavado os alevinos foram estocados e alimentados durante todo tempo de criação com alimento natural e exógeno. O sistema extensivo foi dependente da produção natural do viveiro, com densidade de estocagem limitada pela produção natural de alimento. A pequena renovação de água fez com que o próprio tanque de cultivo atuasse como lagoa de decantação, ocorrendo oxidação e sedimentação da matéria orgânica residual, composta por fezes, organismos mortos e adubo orgânico. No sistema extensivo ocorreu produção de reduzido volume de efluente em relação à área de cultivo; houve elevada turbidez da água, causada pela alta concentração de organismos planctônicos; na água havia baixa concentração de oxigênio dissolvido. Os dados mostraram que nove propriedades de piscicultores entrevistados apresentaram desempenho ambiental crítico (inferior a 30,0%). Seis propriedades de piscicultores apresentaram desempenho ambiental péssimo (entre 30,0 e 50,0%) (Coeficiente de sustentabilidade = quadros verdes x 100 ÷ Total de questões menos os quadros amarelos).

Palavras-chave: gestão ambiental da aquicultura, desenvolvimento sustentável, aquicultura amazônica.

INTRODUCTION

Continental water resources are an essential component of all terrestrial ecosystems. The general shortage of water, the gradual destruction of freshwater resources and aggravation of pollution in many regions of the world, with the progressive encroachment of incompatible activities, have demanded increasingly planning and integrated management of these resources (Ostrensky *et al*., 2008). In Brazil, the Executive Group of the Fishing Sector (EGFS) was created by Decree 1697/1995, aiming at reconciling the political aspirations of the government sector. Its objective was to require the development of the sector, proposing to the Board of Natural Resources Policies, a national policy for Aquaculture and Fisheries and coordination of the design of their actions.

From 2003, a more definitive structure focused on socioeconomic theme adopted by the public sector was used and developed. It was created by the issue of Provisional Measure (PM) 1038/2003, the Special Secretariat of Aquaculture and Fisheries (SSAF / PR), linked to the Presidency. This Provisional Measure, in its article 23, states that fishing should be developed respecting environmental legislation, maintaining the division of skills historically established. Federal Legislation (Law 9433 of 1997 (Brazil, 1997)) clearly linked the issues of Water Resources with environmental issues. In this principle, it cannot be disregarded that water is also the raw material of agriculture and livestock productive system.

Sustainable development is the reasoned and responsible use of natural resources without harming the economic value of the natural asset for future generations. Responsible fish farming and sustainable aquaculture are often used as synonyms, but responsible is more acceptable due to the great importance that this word implies for sustainability. Responsible aquaculture is to make fish farming profitable, with consciousness (Eler & Millani, 2007). Aquaculture currently presents itself as an emergent economic activity in the competition for water resources. It faces the challenge of shaping up the concept of sustainability, which implies to aggregate new values to the technology and to the management and commercialization practices of the sector. The previous presentation of the aquaculture sector contributes to define the context of the research; however it is not enough to establish its framework. There is a concept lacking, which is sustainable development (Lorenzo, 2010).

With respect to this author, the term sustainable development was used by the Brundtland Commission to designate the development that meets the current needs without compromising the ability of future generations to meet their own needs (United Nations, 1987). Therefore, sustainable development involves a pattern of resource use, which aims to meet human demands while preserving the environment so that these needs can be met not only in the present, but also by future generations. This author comments that sustainable development is conceptually regarded as the

intersection of three constituent parts (Figure 1). These three dimensions refer to environmental sustainability, economic sustainability and socio-political sustainability.

Encouraging aquaculture sustainable development in Brazil to reconcile environmental preservation with the distribution of social and economic benefits generated by it is the task for those who compose the national aquaculture scope. Transforming the immense Brazilian potential, often released as a result of the country's continental dimensions, its unique water availability and its unrivaled diversity of fish species cultivated in real competitive advantage, will not be possible without structural information and strategic planning. The objective of this work is to analyze the environmental performance of aquaculture in the city of Colorado do Oeste in the Rondônia State.

Aquaculture Certification Council (ACC) is an international non-governmental organization that grants a stamp to certify the application of management practices ensuring social and environmental responsibility, standards of food safety and hygiene and traceability on chain production of aquaculture businesses. It is an educational and volunteer program that allows businesses to meet national and international requirements. The certification program considers 12 items, which were organized into three main issues: a) social and legal standards, composed by items of property rights and compliance with laws**,** community relations and worker safety; b) Environmental Standards, consisted of conservation items of protected areas, management of effluents, sediment management, soil and water conservation, origin of post-larvae and fry, disposal of inputs and wastes; c) Safety and hygienic standards for food consisted of management of drugs and chemicals, microbial sanitation, collection and transportation.

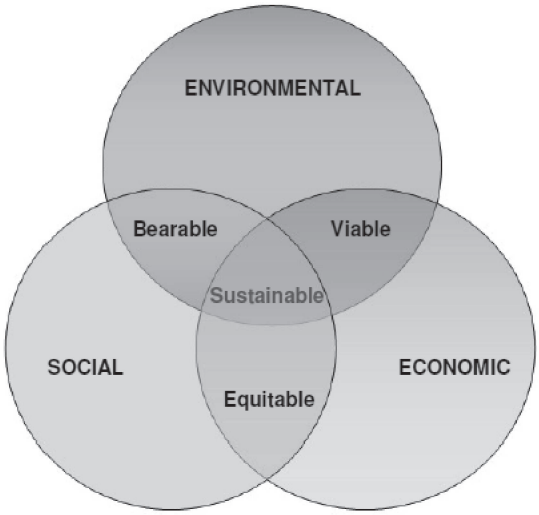

Figure 1. Scheme of the three dimensions of sustainable development
Source: Lorenzo (2010).

MATERIAL AND METHODS

The study was carried out in Colorado do Oeste, Rondônia State. Fifteen fish farmers were interviewed. The population of fish farmers used to calculate environmental performance in Colorado do Oeste in 2011 was 23 and the sample size used to calculate the environmental performance was fifteen. Structured interviews was used for data collection.

The questionnaire for conducting the assessment of environmental performance in the fish properties sought a theoretical approach to the level of sustainability that has producers in order to appraise their environmental performance. The questionnaire was formulated from information given by *Food and Agriculture Organization* of the United Nations (FAO, 1995) to develop a sustainable aquaculture through its Code of Conduct for Responsible Aquaculture (CCRA).

The questionnaire was generated to give assistance to each of the previous items, placing the study at the level of international requirements (Carrasco, 2006). The fifty-six questions were grouped into twelve items. During the questionnaire application, different dimensions and forms of sustainable crop management were exposed (FAO, 1995). In addition to applying the questionnaire, explanatory talks on current trends of sustainable development and how those rules are applied were held every day, necessary and compulsory, in the case of products exported. The time spent was at least one hour of interview with each fish farmer.

There were three types of answers: Yes, No and Not Applicable. The green color indicated the action in favor of environmental performance, the red one indicated detriment of the environmental performance and the yellow indicated the non-applicability of the question. The color was independent of the "Yes and No" answer. In some cases, it would be positive to say "yes" and in others, it would be negative. Comparing the feedback with the marked tables, the coefficient of sustainability was determined. The questionnaire was analyzed independently for each farm and through the following equation, the level of sustainability (Banco do Nordeste, 1999) was determined:

Coefficient of sustentainability = green square x 100 ÷ Total Questions - yellow squares.

All questionnaires were scanned and converted into a spreadsheet file. Data analysis was performed using a statistical package for Windows SPSS (Statistical Package for Social Science) software version 19.0 (2010) and Microsoft Office Excel 2007 software.

For data collection, structured interviews were carried out. The interviews were conducted by applying questionnaires elaborated from Table 1.

Fish farming in the city of Colorado do Oeste, Rondônia State, has two fish production systems: extensive and semi-intensive. In the extensive system, commercial diets are rarely used and fish are fed traditionally with agricultural by-products or animal waste. The product does not exceed 4,500-5,000 kg/ha/year. However, production costs are low and profits are high. This system is characterized by the use of species such as *Colossoma macropomum, Oreochromis* spp., *Arapaima gigas* and *Pseudoplatystoma spp.*

Fish farmers use extruded feed with four different safety levels. The size of the feed pellets is 8-10 mm for a level of assurance 1, 15-20 mm for the level of assurance 2, 10-15 mm for the level of assurance 3 and 6.4 mm for the level of assurance 4. All three feeds with assurance level with 28% of crude protein (CP) are used in omnivore fish in the fattening stage. The feed with 32% CP is used in omnivorous fish in the juvenile phase.

Tambaqui farming in the city of Colorado do Oeste has shown great results. The technology package used in the production of tambaqui by the semi-intensive system is the pond/dam, where production is divided into two phases: growing phase, with 60-day cycle and fattening phase with 240 to 300-day cycle. In general, semi-intensive system can be classified as one with costs between low and average and production also classified within these magnitudes. Although they are small producers, they use diets, inputs and a density of 1 to 4 fish per m^2. In semi-intensive system, fish are also cultivated in dug ponds, where alevins are stocked and fed throughout the growing season. Water is enriched with organic or inorganic fertilizers to increase the amount of natural foods such as phytoplankton and zooplankton, and with products available in the farm such as cassava, corn, fruits and vegetables that supply the fish. Most of health problems that occurred in the experiment city are related to diseases caused by fungi and bacteria.

Far from being a problem, semi-intensive production can be seen as positive, since, in most cases, the major producers of cultivated aquatic organisms are countries whose production is based on small properties (Valenti *et al.*, 2000). In both systems, the production was sold to two fishing industry, one in State of Mato Grosso, and the other located in Vilhena, Rondônia State. The viscera of the fish, whether not sent to the fishing industry, are given as feed to pigs, poultry and carnivorous fish in the farm. The technology used is practically null. Some owners and staff have conducted training courses offered by Emater in Rondônia State. Regarding associations, this does not exist. The way of fish production in the study city is based on the principles of family aquaculture, a way of production dominated by the interaction between management and labor. The establishment members of the family farming in the study city are those managed by the farmer who uses more family labor than hired. It is the family aquaculture that has great capacity to absorb labor and generate income, but not to create jobs.

Table 1. Classification of the environmental performance in Colorado doe Oeste, 2011

Criterion	Classification
Less than 30%	Critical
Between 30 and 50%	Bad
Between 50 and 70%	Adequate
Between 70 and 90%	Good
More than 90%	Excellent

Source: adapted from Carrasco (2006)

Regarding size of the enterprises, a division by the extension of the water on the farms used for fish rearing was registered. For classification purposes, this study considered as small producers those who have less than 2000 m^2 of water on the property; medium producers are those with between 2000 and 10,000 m^2 of water and large producers are those who have above 10,000 m^2 of water. The area of water per individual fish farmer in Colorado do Oeste in 2010 was 344,700 m^2; the fish produced per year was 193,100 kilogram; the fish sold was 161,00 unit per year; the number of fry purchased was 169,000 units; the feed consumed was 321,950 kilograms; the average cost of feed per cycle was R$ 310,760.00 and the production estimate was 274,500 ton/year.

RESULTS AND DISCUSSION

Cultivation of *Colossoma macropomum* in Colorado do Oeste has shown satisfactory results. The technological package used in the semi-intensive production of *Colossoma macropomum* was ponds dam where the production was divided into two phases: growing phase, 60-day cycle and fattening phase, with 240-300-day cycle. Productivity did not exceed the range of 4,500 - 5,000 kg of fish/ha/year.

The semi-intensive fish cultivation can be classified as the one with costs ranging from low to medium and the production classified within these magnitudes (New, 2003). Although they are small producers, they used feed, other inputs and density in the range of 1-4 fish per m^2. The cultivation of fish in ponds where alevins were stocked and fed over cultivation period was also developed in this semi-intensive system. The water was nutritionally enriched with inorganic fertilizer,

composed by urea simple formulations and formulations associated with nitrogen, phosphorus and potassium. The objective of using those formulations were to increase the amount of natural food in the water of the tanks such as phytoplankton and zooplankton. Fish farmers provided to fishes natural byproducts available in the rural properties such as remains of cassava, corn, fruits and vegetables.

The most occurred sanitary issues in the experiment city are related to diseases caused by fungi and bacteria (Table 2).

The semi-intensive production can be classified as positive, since in most cases the major world producers of cultivated aquatic organisms are from countries whose production is based in small rural properties (Valenti *et al.*, 2000).

Evaluation of environmental sustainability and environmental performance are based on legal issues, giving priority to the development of an administrative and legal landmark suitable to ensure the introduction and application of environmentally responsible aquaculture practices, represented by the compliance with legal obligations, relations with the community, worker safety, conservation of protected areas, management of effluents from the ponds, management of sediment in the fattening and spawning tanks, management of medicines and therapy that each batch of fish received (Table 3).

In 100% of the cases studied, it occurred attendance to legal obligations by the fish farmers (Table 3). They stated that they obey the environmental legislation pertinent to environmental licensing for fish activity, according to legal requirements established by Conama (1986) and Conama (1997). On the State Planning, the responsibility for the environmental licensing is by State Environmental Agency, obeying state laws in force, which cannot be more permissible than the Federal Law provisions, which regulates the environmental licensing.

Relationships with the community faced problems as 100.0% of the interviewed fish farmers said that the rural property does not contribute to the community for their well-being and environmental development (health, recreation and education).

These results may be related to the fact that much of the fish production in the city of Colorado do Oeste comes from family producers and a small portion comes from aquaculture business. The lack of technological and managerial qualification in these two production processes is still fragile. There is a lack of mechanisms of public participation. Government mechanisms should not allow political interests protrudes towards technic-scientific and sociocultural issues. This leads to a latent conflict between the need for environmental protection, within the limits required by the forest legislation, with rural production required by the social function of the rural estate.

Regarding the worker safety, and relationships among them, 100.0% of the interviewed fish farmers said they provide training on general safety, personal hygiene and first aid to the employees on the property (Table 3).

Fish farming in Colorado do Oeste is funded on resources derived from other productive sectors. Most of the projects is not idealized in balance with the environment. Most enterprises seek to curtail the hiring of skilled labor and they are not concerned with rural communities. Principles of semi-intensive fish farming of low-impact, environmentally responsible, productive, sustainable and profitable requires the adoption of weighted tactics of production and diagrams responsible for the management of effluent emissions. The adequacy of stocking density of fish in the production systems helps to slow down the accumulation of metabolites and reduce the need for therapeutic agents. The waste

Table 2. Major drugs and chemicals used in aquaculture in Colorado do Oeste in 2010

Drug	Use	Source
Premix	Suplement	Pillay (1992)
Malachite green	Desinfectant	Pillay (1992)
Formol	Desinfectant	Pillay (1992)
Terramycin/Oxytetracycline	Antibiotic	Vinatea (1999)
Cloramina/Amoxilina	Antibiotic	Vinatea (1999)
Sodium chloride	Desinfectant	Pillay (1992)
Copper sulfate	Anti-algae	Vinatea (1999)
Potassium permanganate	Desinfectant	Pillay (1992)
Vitamins	Food suplement	Pillay (1992)
Dipterex	Pest control	Pillay (1992)
Sodium hydroxide	Desinfectant	Vinatea (1999)
Sodium hypochlorite	Desinfectant	Vinatea (1999)
Hormone	Reproduction	Pillay (1992)

Source: Adapted from Eler & Millani (2007)

Table 3. Answers to the most significant question groups, Colorado do Oeste, in 2011

Question	% yes	% no
Attending to legal obligations	100	0.0
Relationships with the community	0.0	100
Worker safety	0.0	100
Conservation of protected areas	60.0	40.0
Management of effluents from the ponds	0.0	100
Management of sediment in the tanks	33.3	66.7
Management of banned drugs and chemicals	6.7	93.3
Therapeutic which each batch of fish received	6.7	93.3

Source: survey data

management requires the reduction of nitrogen, phosphorus and fecal solids dissipated in the aquatic environment.

Figure 2 shows the distribution of fish farmers in the city of Colorado do Oeste and the present approach to the coefficients of environmental performance in the sample analyzed (n = 15) and the distribution of the production area (%) as well as it shows that the first nine estates of the interviewed fish farmers had critical environmental performance (less than 30.0%). The other six estates of fish farmers had poor environmental performance (between 30.0 and 50.0%). In general, the situation of environmental performance is not in favor to all estates, regardless of the area of water of the estate, therefore farmers should get more involved with environmental issues. Issues have been found in community relationships, worker safety and relationships among them, conservation of protected areas, problems in the management of effluent from the ponds, disposal of inputs and waste, management of chemicals and drugs and traceability. Environmental sustainability analysis starts with legal issues, giving priority to the development of a suitable legal and administrative mark to ensure the introduction and application of environmentally responsible aquaculture practices.

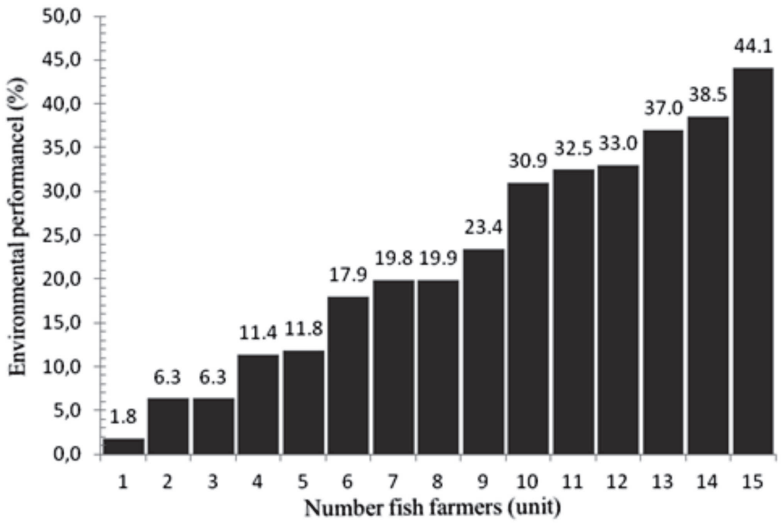

Figure 2. Approach to the coefficients of environmental performance of estates in the analyzed sample, Colorado do Oeste, 2011. Source: survey data and Borges *et al*. (2013).

CONCLUSIONS

In semi-intensive system, the average of stocking rate was one fish per m^3. There was constant renewal of water in the ponds (1,500 liters per minute). In the semi-intensive system in dug ponds, alevins were stocked and fed during the entire rearing period with natural and exogenous food.

The extensive system relied on the natural production of the pond, with stocking density limited by the production of natural food. The little renewal of water made the cultivation tank itself act as a decantation lake. In the extensive system, occurred the production of reduced effluent volume, compared to the cultivation area; there was high water turbidity caused by high concentration of planktonic organisms and water had low concentrations of dissolved oxygen. Data showed that nine estates of the interviewed fish farmers had critical environmental performance (less than 30.0%). Six estates of fish farmers had bad environmental performance (between 30.0 and 50.0%).

The current Brazilian environmental legislation, which considers the preservation of permanent areas in aquaculture is inapplicable, even after being reformulated. It does not meet the specific needs of the Amazonian ecosystem and of fish farmers and it does not consider scientific knowledge and customs of Brazilian Amazonia. Brazilian environmental legislation should be regionalized to become applicable.

The percentage coefficients of achieved environmental performance showed that aquaculture in the Rondônia State is environmentally unsustainable.

ACKNOWLEDGEMENTS

We thank Fundação de Amparo à Pesquisa de Minas Gerais (FAPEMIG) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) to become

possible the elaboration of this paper; Federal University of Lavras (UFLA) for allowing the first author to take the post-doctoral degree.

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