Environmental and Economic Assessment of Fee-fishing in São Paulo State, Brazil

Paulo Choji Kitamura

Julio Ferraz de Queiroz

Ruy Bessa Lopes

Fernando G. de Castro Jr.

Claude E. Boyd

Paulo C. Kitamura and Julio F. Queiroz, Embrapa Meio Ambiente, Rodovia SP 340 – km 127,5, Cx.P. 69, CEP 13.820-000, Jaguariúna, São Paulo, Brasil.

Ruy B. Lopes and Fernando G. C. Jr., Instituto de Zootecnia, Rua Heitor Penteado, 56, Cx.P. 60, CEP 13.460-000, Nova Odessa, São Paulo, Brasil.

Claude E. Boyd, Department of Fisheries and Allied Aquacultures, Auburn University, AL 36849

Address correspondence to: Claude E. Boyd, Department of Fisheries and Allied Aquacultures, Auburn University, AL 36849

ABSTRACT. According to feed producers, aquaculture in Brazil generates an annual income of about US $200 million and is growing at an annual rate of 15%. More than 300,000 people are involved, including fish and shrimp farmers, feed companies, technicians and equipment manufacturers. The growth of the aquaculture industry has given rise to concerns about such environmental issues as water pollution and the conversion of land to ponds. “Fee-fishing” is the maintenance of ponds so that people can fish from them, primarily by line, usually for an entrance fee and for a fee paid per kilogram of fish caught. Attendant activities on the farm site, such as restaurants and ecorural tourism, also generate considerable revenues. Fee-fishing started on marginal areas unsuitable for agriculture or other activities, but it has recently expanded rapidly to occupy former farmland and areas of land close to the large urban centers. Fee-fishing either supplements the income or is the main source of income for many people. It generates $60 million (U.S.) per year at the Piracicaba River watershed in São Paulo State alone. The annual average net income of the fee-fishing farms studied equals 46% of the total costs, with variations from 8% to 120% over the total costs per year. In 22% of the fee-fishing areas, the pH and dissolved oxygen are controlled, and in the worst cases (almost 6% of the sites sampled), none of the physical and chemical parameters of water quality are controlled. The fee-fishing farms evaluated in this study usually have low-quality water. Only 6% of the fee-fishing farms have some sort of effluent treatment system. Fee-fishing farms should improve management to enhance their attractiveness to tourists and to prevent negative environmental impacts.

KEYWORDS: Fee-fishing, Piracicaba River watershed, environment, evaluation

INTRODUCTION

The expansion and intensification of aquaculture in Brazil is causing social, economic, and environmental problems that require a solution. These problems are aggravated by the lack of an effective environmental policy to assure the sustainability of aquaculture development.

Brazil has a great potential for aquaculture development because of its large territory and coastline; its suitable ecological conditions for the culture of several fish, crustaceans, and shellfish species; and its large hydrographic basins (Lovshin and Cyrino 1998). The southeast region contains almost 80% of the aquaculture industry in Brazil, and it is also where other forms of agriculture are most intensive, such as the production and processing of fruits and vegetables, as well as flower growing. Sites that previously had been used only for agriculture now support many non-agricultural activities such as industry and commerce. Intensive agriculture, industry and commerce all require high inputs of money, human resources, and technology and may stress on water resources and water quality. The combination of traditional agriculture with fish culture, industry, and commerce represents a rich socioeconomic diversity, new job opportunities and a potentially better quality of life. Yet this mix of ventures also introduces a new dynamics into the region.

The present study focuses on fee-fishing in some counties of the Piracicaba River watershed in São Paulo State, Brazil. Descriptive data is presented that is relevant to improving farm management, formulating policy, and stimulating cooperation for environmental protection.

The Piracicaba River Basin

The Piracicaba River watershed has an area of 12,746 km^2. Its main tributaries are the Atibaia, Corumbataí, Jaguari, and Piracicaba Rivers, and the Americana, Atibainha, Cachoeira and Jaguari reservoirs. Pastures make up 57% of the watershed area; they are used mainly for cattle ranching. The major water uses include public and industrial supply, agricultural irrigation, and the reception of domestic and industrial effluents. The main industries are cellulose and paper production; food, sugar and alcohol production; textiles; tannery; metallurgy; and chemical and petrol refining.

The Piracicaba watershed is an important industrial region that has gone through major transformation during the last decade. It is the third largest industrial area in Brazil after the metropolitan regions of São Paulo and Rio de Janeiro.

Agriculture is the most important activity and encompasses 318,383 ha. Sugar and alcohol from cane are the main agricultural products. Agricultural management usually relies on high technology and the intensive use of mechanization and chemicals. Additionally, according to the Report of the Water Resources Situation (Relatório da Situação dos Recursos Hídricos 1996), more than 118 companies were in secondary sector activities in the Piracicaba and Capivari watersheds by 1995. São Paulo State Company for Basic Sanitation (CETESB) in 1995, for the Piracicaba and Capivari watersheds, issued 336 installation licenses and 288 operational licenses for the following major industries: mineral extraction, metallurgy, electronics and communication, transport material, furniture and paper, chemistry, plastics, textiles and food. The CETESB bulletin indicates the increasing demand for water in these watersheds (Relatório da Situação dos Recursos Hídricos 1996). CETESB data suggest that effluents from waste treatment systems contribute 86,040 kg BOD/day, of which 75.2% is domestic and 24.8% is industrial (Table 1).

Fee-fishing and the Environment

The major concerns about fee-fishing found in the literature are in regard to the economic management of the farms, such as production costs and prices, markets, commercialization and marketing (O'Grady 1983; Russel and Mullahy 1983; Lovshin et al. 1986; Shaw 1986; Cichra and Carpenter 1989; Insull and Nash 1990; Torloni et al. 1990; Mafra and Sauer 1991; Masser et al. 1993; Williams 1993; Cichra et al. 1994a, 1994b).

Scientific studies on ecological management issues are not very detailed, such as on water quality, characteristics of watersheds, protection of water sources and riparian vegetation, and soil conservation (Symposium on the Economic Aspects of Fee-fishing 1965; Bennett 1971; Alabaster 1982; Insull and Nash 1990; Zaniboni 1997). Recently, Boyd et al. (2000) evaluated environmental issues within the catfish industry in Alabama and proposed a series of Best Management Practices (BMPs) to improve the management there. Similar BMPs could be adapted to other aquacultural systems, including fee-fishing in Brazil.

The demand for fee-fishing is concentrated near urban centers, probably because most of the clientele comes from there. In 1996, according to the Fisheries Institute of the Secretary of

Agriculture and Supply of São Paulo State, more than 500 fee-fishing farms were located in the state. Recent data provided by the Brazilian Environmental Institute (IBAMA) showed that this number has increased to more than 2,500 fee-fishing farms in São Paulo State alone. The majority of these farms are concentrated in regions close to the district capital of São Paulo State, with a population larger than 18 million.

MATERIALS AND METHODS

This study was conducted at the Piracicaba River watershed. From nine different counties, a total of 18 fee-fishing farms were selected. The farms visited were randomly selected from the population of fish producers and other aquaculturists registered at the Department of Water and Electrical Energy (DAEE 1997). Regardless of the individual registrations to obtain permits for water use, all the tanks, ponds or lakes on the same farm were considered as part of the same business if they were used for the fee-fishing operation.

Fee-fishing data and field information were collected through personal visits to farms to observe site conditions and to complete a questionnaire by interview; water samples were collected for water quality analyses. The questionnaire had both open and closed questions and considered the following subjects: identification of the farm, historical and general information, technical characterization of the system, and economic and environmental evaluation.

Field water quality determinations were carried out for the following parameters: transparency measured with a Secchi disk, dissolved oxygen measured with a digital oxymeter (Model OXY 300), and pH measured with a digital pH meter (Model AT100). Water samples were also collected from all farms and transported to the laboratory for analyses of nitrite, nitrate, ammonia and some heavy metals (aluminum, lead, mercury, nickel, and zinc). A colorimeter type LM 200 was used for these analyses, and they were performed according to methodology described by APHA (1995). The field data and the laboratory results were checked for consistency, tabulated, and analyzed using descriptive statistics (Hoffmann 1995; Gomes 2000).

RESULTS AND DISCUSSION

Business Characteristics

The majority of the fee-fishing businesses at the Piracicaba River watershed in Brazil began in the 1990s. The average size of a fee-fishing business is 24 ha. The smallest and largest farms occupied 2.7 ha and 84 ha, respectively. The area occupied exclusively by the ponds ranged from 0.2 to 7 ha. The inundation area of fee-fishing corresponded to an average of 13% of the total farm area. About 61% of the fee-fishing business owners lacked any previous experience in fish culture. These percentages could indicate a continuation of the high interface of fee-fishing with ecorural tourism as suggested by Chopak (1992).

Production Systems

The average stocking density used at the fee-fishing farms was 2.3 fish per square meter. In comparison, the stocking density for fee-fishing operations in the USA varies from 0.4 kg/m^2 to 1.4 kg/m^2 (Cichra and Carpenter 1989).

The average weight of the captured fish was 1.64 kg, with a maximum of 2.85 kg and a minimum of 0.57 kg, compared to 6.4 kg and 4.1 kg, respectively, for the U.S. Considering also that the average size of the lakes was 5,479 m^2, a population of 12,875 fish is estimated, resulting in an icthyobiomass of approximately 21,115 kg per lake in operation. Assuming an average of 2.9 fish/fisherman/day, it is possible to estimate an average capture per fisherman/day of 6.76 kg. This equals a total captured stock of approximately 1,742.5 kg/month, with the possibility of reaching 6,500 kg/month per lake in operation. Over 200 fee-fishing farms in the Piracicaba River watershed are estimated, which represents a significant portion of the freshwater fish supply of 335 tons/month.

The most common cultured species in the fee-fishing farms studied were the rounded fishes such as pacú, Piaractus mesopotamicus; tambaqui, Colossoma macropomum; and tambacú, a hybrid between pacú and tambaqui; they were stocked in all ponds. The average weight of these fish was 1.3 kg. The tilapias, Oreochromis sp. and Sarotherodon sp., were present in 89% of the ponds. Their average weight was 0.4 kg. The most common tilapia species cultured and maintained in the fishing ponds were the Nile tilapia, O. niloticus, and hybrid tilapia. The Chinese carps such as the bighead carp, Aristichtys nobilis; silver carp, Hypophthalmichthys molitrix; and grass carp, Ctenopharyngodon idella, were found in 89% of the ponds. These species had an average weight of 2.5 kg. The mirror carp, Cyprinus carpio, were present in 84% of the sites. Their average weight was 1.5 kg. Curimbatá, Prochilodus scrofa, was found in 89%

of ponds and its average weight was 1.5 kg. Piau, Leporinus sp., and piauçú, Leporinus brasiliensis, were found in 73% of the ponds, with an average weight of 1.0 kg. Other species such as the African catfish, Clarias sp., were present in 67% of the ponds and had an average weight of 2.0 kg. The dourado, Salminus sp., is now being introduced and it is currently stocked in 11% of the ponds. Tucunaré, Cichla temensis, and pintado, Pseudoplatystoma coruscans, were found in only one farm.

Pond fertilization is a common practice among a majority of the fee-fishing farmers, and the most common fertilizers used are phosphate (18-20% P_2O_5), super triple phosphate (43-50% P_2O_5), ammonium sulphate (21% N) and urea (45% N). The concentrations of Nitrogen-Phosphorus-Potassium (NPK) change according to the manufacturer, but normally are: 10-34-0, 11-37-0, and 13-38-0. Fertilizer is normally applied when the ponds are dry, in order to promote primary productivity as soon as the ponds are refilled. The initial concentrations used are 9 to 15 kg of N and 3 to 5 kg/ha/year of P. Since pond soil varies considerably in its characteristics and the farm owners do not usually know how to adjust the fertilizer composition or application to the characteristics of their particular soils, the typical practice is probably inefficient. Normally, agricultural and hydrated lime are used over 6-month intervals to correct the soil pH, in order to improve the fertilization efficiency. The lime applications varied from 100 to 1,200 kg/ha. Technical assistance provided by veterinarians and biologists was observed for only 50% of the sites studied. Disease problems, pollution of the water supply sources, and a deficiency of technical assistance also are problems mentioned by fee-fishing farmers.

Economic Evaluation

Economic evaluation showed a great variability of results. Both very simple and very sophisticated fee-fishing operations with many associated services could provide high profits. The major fee-fishing businesses studied were established in the last 5 years. Several businesses started as complementary or marginal economical activities, yet nowadays are the main source of income for their owners. In general the fee fishing operations studied were family businesses.

The major characteristics that differentiate one farm from another are infrastructure of reception (guides, child care, fishing equipment, and fish processing); location and facility of access; water quality; size of the fish and availability of fish stocks; number of fish species; offering of amenities (natural woods, rivers with clean water, playground); and the associated services (bar, restaurant, apartments, and picnic areas). Often more than 10 farms are located close to each other. All these characteristics indicate a saturated market, which demands a lot of facilities to allow a particular fee-fishing operation to succeed. According to statements of the fee-fishing owners, many of these facilities are now expected in this market. This fact implies a specialization within the business, with demands for bigger operations with a bigger power to attract customers.

The average annual income of the farms studied was U.S. $169,992, varying from a minimum of U.S. $50,000 to more than U.S. $200,000. The main sources of income were the entrance fee, bar and restaurant, and the fees for captured fish (Table 2). These results evidence the success of businesses that offer services in addition to fishing, as well as a bigger selection of fish and a denser fish stock in the ponds. The average of the annual direct costs of production was estimated at U.S. $75,870. The main costs were the purchase of the fish stocks (62% of the total costs), maintenance of the infrastructure (19%), and salaries (12%). The other expenses for fish feed, chemicals and fertilizers are considered secondary costs (Table 3).

These figures can point to some problems with management. The amount of fish purchased to stock the ponds is one of the bottlenecks of the fee-fishing business. It shows the weak integration between the fish producers and the fee-fishing owners. Nowadays, almost all the fish stocks are produced by a third party. Two related reasons for the small proportion spent on fish feed could be the high mortality and high turnover of the fish in the ponds. The small proportion spent on wages could be due to the seasonal nature of the fee-fishing business and also to the fact that many employees are only part-time.

In general, the results showed a high profitability of the fee-fishing business, representing a gross annual income greater than 100% of the direct costs of production. Considering depreciation as well, the average net income corresponded to 45.8% of total costs with a range of 8% to 120%. This high profitability has promoted the expansion of fee-fishing. However, according to the fee-fishing owners, market forces will lead to stabilization during the next few years, implying a smaller profit in comparison with current levels. Moreover, profits are always less certain in fee-fishing because it is inherently seasonal due to the fish biology and to the preference of customers for warm weather.

It is estimated that fee-fishing contributes more than $60 millions (U.S.) per year in the Piracicaba River watershed regional economy. Despite its intrinsic variability, for a nascent industry in a rural area, these financial results are extremely positive. They indicate more jobs and income, and a move away from traditional agriculture.

Water Quality and Environmental Evaluation

The results of the physical and chemical water quality parameters analyzed are summarized in Table 4. pH was checked at 89% of the fee-fishing farms visited, but at only 6% of them was measured a full set of variables including pH, dissolved oxygen, oxygen saturation, and transparency. In 22% of the businesses, the pH and the dissolved oxygen were checked, and in 6% of the sites no physical and chemical parameters of water quality were checked.

The average water temperature was 25ºC with a maximum of 27ºC and a minimum of 22ºC. These figures are normal for fish culture ponds in Brazil and do not cause any negative effects on feeding behavior or in the respiration of fish.

The average dissolved oxygen concentration in the ponds was 3.8 mg/L with a maximum of 6.0 mg/L and a minimum of 1.5 mg/L. Although more than 50% of all the fee-fishing farms had aerators, 39% of all of them had dissolved oxygen concentrations outside the National Code of Environment (CONAMA) standards. Probably these results were a consequence of many factors, such as size of the lakes, absence of water renewal and recirculation, high stocking and feeding rates, and heavy fertilization.

The average pH was 7.2, with a maximum of 8.4 and a minimum of 5.7. About 11% of the fee-fishing farms had ponds that were outside of the normal standards. The water acidity in two of the places visited could be related to an excess of feed given by the users, in order to facilitate the capture of fish.

The average water transparency was 26 cm with a maximum of 50 cm and a minimum of 11 cm. In 39% of the sites visited, the transparency did not correspond to CONAMA standards, and the majority had a transparency below 20 cm. This could be due to the apparently high primary productivity in those sites.

The results obtained for nitrite, nitrate, ammonia, and heavy metals (nickel, zinc, aluminum, mercury and lead) are indicators of contamination problems, which demand more precise and sophisticated studies and laboratory analyses. The average nitrite levels were 0.07 mg/L with a maximum of 0.21 mg/L and a minimum of 0.01mg/L, and all the sites sampled were within the normal standards. The average nitrate levels observed were 4.6 mg/L with a maximum of 14.5 mg/L and a minimum of 1.0 mg/L, and only two fee-fishing sites did not meet the normal limits.

The average concentration for ammonia was 0.9 mg/L with a maximum of 2.3 mg/L and a minimum of 0.12 mg/L. Not all the farms sampled complied with the normal standards, that are recommended for the maintenance of aquatic organisms without undesirable results such as gill diseases. These high ammonia concentrations could result from feeding with pellets containing high percentages of protein (Boyd and Tucker 1995, 1998).

The preliminary results obtained by the use of portable water analyses indicated in many cases the presence of heavy metals in concentrations above the permitted limits of CONAMA Resolution Number 20. Part of these water quality problems could result from inappropriate management on the fee-fishing ponds while part of them could result from the source of water used. Residues or remaining treatment wastes found upstream from the fee-fishing lakes could be affecting the pond water. Only more detailed research with special regard to water quality indicators could confirm the source of problems.

At the same time that this study was conducted, the São Paulo State Company for Basic Sanitation (CETESB) also monitored the water quality of Piracicaba River at six different sites every two months. The main objective of CETESB was to verify if the water quality parameters correspond to the standards established by CONAMA Resolution 20/1986, which classified freshwater streams according to 4 different classes. Each class corresponds to its predominant uses such as: 1) Special Class, destined to domestic supply without previous disinfecting and also for protection of aquatic communities, recreation and irrigation of vegetables and fruits; 2) same as Class 1 after conventional treatment; 3) destined for the domestic water supply after conventional treatment for irrigation of plants, culture of cereals and green crops; and 4) destined for navigation, landscape harmony and other less exigent uses.

All the sites at the Piracicaba River were Class 2 according to CONAMA standards as enforced by Federal Resolution No. 20 of June 18, 1986. Annually these water quality data are published in a special report prepared by CETESB, which is summarized for 1997 in Table 5, for comparison with the fee-fishing data obtained through this study.

According to the sites sampled by CETESB at the Piracicaba River, the concentrations of fecal and total coliformes, and phosphorous exceeded CONAMA standards for almost all the samples collected. At some sites the concentrations of dissolved oxygen, ammonia nitrogen and phenols also did not meet the CONAMA standards of water quality.

Given the water quality results obtained for the fee-fishing farms and some of the water quality parameters of Piracicaba River presented in Tables 4 and 5, it is apparent that water quality at most of the fee-fishing farms studied is low compared to the input water pumped directly from the Piracicaba River. Almost all the water quality parameters evaluated for the fee-fishing farms studied, such as dissolved oxygen, pH, transparency, nitrate, and ammonia, had a high percentage of samples outside the CONAMA standards. The only exception was nitrite concentration, which did not exceed CONAMA standards for any of the water samples analyzed. This is evidence that the effluents of the fee-fishing operations located at Piracicaba watershed are impacting water quality during the dry season. Although the results obtained for heavy metals through the colorimeter kit were not precise, the results obtained by CETESB for heavy metals at the Piracicaba River were determinate. Excluding manganese and total chrome, all the other metals analyzed by CETESB, such as barium, cadmium, copper, iron, lead, mercury, nickel and zinc did not show any significantly high concentrations, yet they did not fall within CONAMA standards (Table 6).

The Water Quality Index (WQI) used by CETESB showed that the upstream sites, located close to the Americana city water supply, were classified at the "good" water quality level for the whole of 1997. For the sites located downstream of Americana city the WQI varied along the entire range from good, satisfactory, bad, to very bad; but in most cases the water quality was considered satisfactory. These results verify the deterioration of water quality standards during the last five years in several sites at the Piracicaba River, especially close to the borders of Limeira and Santa Bárbara do Oeste counties. The effluents discharged all the way along its course, which runs across a very industrialized region, have heavily impacted the Piracicaba River. Domestic sewage is discharged "in natura" by many counties of considerable size, and the remaining domestic organic load equals 96% of the potential organic load (Table 7).

The Piracicaba watershed is characterized by intensive agricultural systems in which management relies on heavy applications of agrotoxics. The most common organochloride pesticides found in sediments and mollusks (bivalves) from samples collected by Silva (2000) at Piracicaba River during the rainy and dry seasons in 1997 were Aldrin, Heptachlorine, Endosulfan, Dieldrin, Eldrin and DDT. The results in Tables 8 and 9 verify that many samples are outside CONAMA standards. The high concentrations of pesticides found in molluscs in comparison to the sediment samples collected from the Piracicaba River could be related to bio-accumulation processes of the predominant benthic fauna of this habitat. The bio-accumulation process could cause severe damage to local biodiversity and also could affect the purity of the fish cultured at the Piracicaba watershed.

The majority of the fee-fishing farms studied had riparian vegetation (natural or planted) protecting the water bodies, and close to 50% of them still have natural woods. The majority had reforested in their areas at least somewhat during the last few years, and they are concerned about landscaping. Registration of the fee-fishing farms by governmental institutions for environmental protection, like the Brazilian Environmental Institute (IBAMA), Natural Resources Department (DPRN), and Water and Electrical Energy Department (DAEE), is one reason for the protection of forestry, soil and water resources.

According to the results obtained by the Consórcio Intermunicipal das bacias dos Rios Piracicaba e Capivari (1992), approximately 50% of fee-fishing farms use water from their own reservoirs. Only 6% of farms had some sort of system for effluent treatment such as a sedimentation pond. The majority of the fee-fishing farmers said that they have informal conversations with their customers about environmental issues, mostly about the importance of the riparian woods, creation of ecological trails, guided school tours, fish culture courses, open activities for restocking lakes, and water quality management.

RECOMMENDATIONS

Fee-fishing is one of the activities that have appeared in the new Brazilian rural context, especially close to the big urban centers in the Southeastern region. It has expanded greatly in recent years because it can combine with agricultural production systems or even with activities considered unusual to agribusiness such as ecorural tourism.

Fee-fishing has been developed by the farmers’ own initiative, with minimal specialized technical assistance. Perhaps because of that, the production systems adopted by the fee-fishing farms have some obvious weaknesses, such as the high stocking density, high stock rotation, poor feeding strategies, and the high capture efforts allowed. The high percentage of fish acquisition costs, at 62% of overall costs, suggested one of the bottlenecks of the system. To overcome this situation, the strategy adopted is to diversify the services offered. Associated ventures such as restaurants and snack bars represented one-third of the total income, despite their uncertainty. The incomes from these services compare favorably with the incomes from the entrance fees and from the fee per kilogram of captured fish, denoting the potential of these services for the future of the fee-fishing business.

Environmental impacts have been reduced, probably due in part to the regulations for licenses issued by environmental institutions. IBAMA, DPRN and DAEE have mandated the maintenance of legal reserves, reforestation of riparian woods, protection of the water bodies and landscape conservation.

At present there is almost a “rush” to establish new fee-fishing businesses. The small portions of land and the small supplies of water needed, coupled with the low risks for an initial investment, make this activity attractive. Even with the difficulties in obtaining a live fish supply, the profits are still significant. The average profits represented 100% over direct costs and 46% on average in terms of net income. The trend is for individual farms and for the industry to seek their own ecological sustainability for the long term. This approach demands a lot of effort to integrate and diversify the activities.

The integration of different activities with the actual fish culture is essential to overcome major problems such as high costs and the difficulties in obtaining live fish to stock. Fee-fishing contributes to the Piracicaba River regional economy more than $60 million (U.S.) annually. Since fee-fishing is still only a secondary agricultural activity, it is possible to consider these results as extremely positive.

Further research on water quality and a more complete study of the geography and hydrology of fee-fishing at São Paulo State is strongly recommended. These studies will support specific government decisions regarding environmental management. It will be very difficult to avoid draining the ponds without releasing some of the water into natural streams. Still, if the BMP’s proposed by Boyd and Queiroz (1997) could be applied, most of the impacts from effluents could be easily reduced. The BMP’s indicate practices to promote the efficient management of aquacultural systems. The idea is to mitigate the possible environmental impacts and also reduce the production costs. One of the BMP’s proposed is to use commercial feeds with better quality and with lower concentrations of animal protein. This practice will result in reduced water pollution in the ponds and better food conversion rates. In turn, that should reduce the need for mechanical aerators and chemical products to maintain the water quality. The approach that the aquaculture industry and the environmental institutions in Brazil will take regarding BMP's will determine the growth rate and the sustainability of the fee-fishing business in Brazil. Some of the BMPs proposed by Boyd et al. (2000) for the catfish industry in the U.S. could be used by the fee-fishing managers in Brazil to reduce production costs and improve water quality; reduce the occurrence of diseases; increase productivity and profitability; reduce fish pond effluents due to run-off, seepage, evaporation, water exchange and harvest management; and reduce sediment losses due to erosion.

REFERENCES

Alabaster, J. S., and R., Lloyd. 1982. Water quality for freshwater fish, 2nd ed. Food and Agriculture Organization (FAO) of the United Nations, Butterworth Scientific Press, Rome, Italy.

American Public Health Association (APHA). 1995. Standard methods for the examination of water and wastewater, 19th ed., Vol. 1. American Public Health Association, Washington, DC.

Bennett, G. W. 1971. Management of lakes and ponds. Van Nostrand Reinhold, New York, New York.

Boyd, C. E., and C. S. Tucker. 1995. Sustainability of channel catfish farming. World Aquaculture 26:45-53.

Boyd, C. E., and J. F. Queiroz. 1997. Aquaculture pond effluent management. Aquaculture Asia (Bangkok, Thailand) April-June (2):43-46.

Boyd, C. E., and C. S. Tucker. 1998. Pond aquaculture water quality management. Kluwer Academic Publishers, Boston, Massachusetts.

Boyd, C.E., J.F. Queiroz, G.N. Whitis, M. Rowan, J. Lee, and A. Gross. 2000. Environmental assessment of channel catfish *Ictalurus punctatus* farming in Alabama. Journal of the World Aquaculture Society 31(4):511-544.

Cichra, C. E., and L. T. Carpenter. 1989. Fee-fishing as an economic alternative for small farms. Department of Fisheries and Aquaculture, University of Florida Series No. 116. University of Florida, Gainesville, Florida.

Cichra, C. E., M. P. Masser, and R. J. Gilbert. 1994a. Fee-fishing - an introduction. Southern Regional Aquaculture Center (SRAC) Publication No. 479, Southern Regional Aquaculture Center, Overton, Texas.

Cichra, C. E., M. P. Masser, and R. J. Gilbert. 1994b. Fee-fishing - location, site development and other considerations. Southern Regional Aquaculture Center (SRAC). Publication No. 482. Southern Regional Aquaculture Center, Overton, Texas.

Chopak, J.C. 1992. Fee-fishing operations as tourist attractions. Michigan State University Department of Fisheries and Wild Life, Extension Bulletin E-2409. Michigan State University, East Lansing, Michigan.

Comitê das Bacias Hidrograficas dos Rios Piracicaba, Capivari e Jundiai. 1996. Relatório da situação dos recursos hidricos, 1995. Comitê das Bacias Hidrograficas dos Rios Piracicaba, Capivari e Jundiai. Piracicaba, Brasil.

Companhia de Tecnologia e Saneamento Ambiental (CETESB). 1997. Unidade regional de Campinas, Brasil.

Consórcio Intermunicipal das Bacias dos rios Piracicaba e Capivari. 1992. Plano diretor de captação de água para abastecimento público nas bacias dos rios Piracicaba e Capivari. Consórcio Intermunicipal das Bacias dos Rios Piracicaba e Capivari. Piracicaba, Brasil. 194 p.

Departamento de Águas e Energia Elétrica (DAEE). 1997. Assessoria Técnica/Divisão de Planejamento e Outorga. Secretaria de Recursos Hídricos, Saneamento e Obras, São Paulo, Brasil.

Gomes, F. P. 2000. Curso de Estatística Experimental. Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo (ESALQ/USP). Universidade de São Paulo, Piracicaba, Brasil.

Hoffmann, R. 1995. Elementos de Estatística Atlas. São Paulo, Brasil.

Instituto Brasileiro de Geografia e Estatística (IBGE). 1991. Censo Demográfico: resultados do universo relativos as características da população e dos domicílios, No. 21: São Paulo. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, Brasil.

Insull, D., and C.E. Nash. 1990. Aquaculture Project Formulation. Food and Agriculture Organization (FAO) of the United Nations, Fisheries Paper. No. 316. FAO, Rome, Italy.

Lovshin, L.L., V.G.C. Schartz, C. R. Engle, and U. R. Hatch. 1986. Cooperatively managed Panamanian rural fish ponds: the integrated approach. Auburn University, Auburn, Alabama.

Lovshin, L. L., and J. E. P. Cyrino. 1998. Status of commercial fresh water fish culture in Brazil. World Aquaculture 29(3):23-39.

Mafra, M. and J. L. Sauer. 1991. Custos e Formação de Preços na truticultura. Associação Brasilieira de Truticultura (ABRAT), Rio de Janeiro, Brasil.

Masser, M. P., C. E. Cichra, and R. J. Gilbert. 1993. Fee-fishing ponds: management of food fish and water quality. Southern Regional Aquaculture Center (SRAC) Publication No. 480. Southern Regional Aquaculture Center, Overton, TX.

O'Grady, K. 1983. Reservoir trout fishing in England, 1976-1981. Water Space Amenity Commission Research Report No. 6. Water Space Amenity Commission, London, England.

Relatório de situação dos recursos hídricos. 1996. Comitê das Bacias Hidrográficas dos rios Piracicaba, Capivari e Jundiaí.

Russel, C., and J. Mullahy. 1983. What price a day ticket? Pages 35-36 in Russel, C., and J. Mullahy, eds., Salmon and Trout, London, England.

Shaw, S. A. 1986. Marketing the Products of Aquaculture. Food and Agriculture (FAO) Organization of the United Nations Fisheries Technical Paper No. 276. FAO, Rome, Italy.

Silva, D.M.L. 2000. Avaliação dos compostos organoclorados na bacia do Rio Piracicaba. Dissertação de Mestrado. Centro de Energia Nuclear na Agricultura (CENA). Piracicaba, Brasil.

Symposium on the Economic Aspects of Fee-fishing. 1965. Pileggi, J., ed., Commercial Fisheries Review, vol. 27, No. 3. Bureau of Commercial Fisheries, Washington, D.C.

Torloni, C.E.C., J.R. Verani, J.A. Pereira, and J.A.S. e Filho. 1990. Análise Quantitativa e Econômica de uma Criação Intensiva de Pacú *Colossoma mitrei*, no Sudeste do Brasil. Coleção Ecossistemas Aquáticos, No. 6. Centrais Eléctricas de São Paulo (CESP). São Paulo, Brasil.

Williams, C. 1993. Economia y contabilidad elementales para piscicultores. Coleccion FAO: Capacitacion No. 19. FAO, Roma, Italy.

Zaniboni, E. F. 1997. O desenvolvimento da piscicultura Brasiliera sem a deterioração da qualidade da água. Revista Brasileira de Biologia 57 (1): 3-9.