

# Development of reservoir fisheries management in Brazil based on imported paradigms

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**ABSTRACT.** A paradigm is characterized as a network of conceptual, instrumental, and methodological commitments that guides the direction and methodology of scientific research. Thus, a paradigm defines what should be studied, what questions should be asked, what tools should be used, and what rules should be followed in interpreting results. The aim of this paper is to analyze how fisheries management emerged and developed in Brazil, considering that science's progress as a series of paradigms. Management actions related to reservoir fishery are not frequent in Brazil and, when applied, they did not generate good results, because they usually were based on poor technical and scientific information or in paradigms developed in the temperate region (North America). Fish passages (ladders) were the first attempt to minimize the impacts of damming, followed by regulation of fishery and stocking programs. However, it seems that the paradigm that led the researches (imported from the United States) was not appropriated for reservoir management in most Brazilian reservoirs. We agree that some other reasons contributed in some extension to the failure of management actions: i) inadequacy and insufficient data availability; ii) inappropriate approach used to perform management; iii) absence of monitoring studies; iv) policy inadequacies; and v) deficiencies in the integration among the hydroelectric companies. Recently, hydroelectric companies started to develop research in basic limnology and fish, in order to improve data quality to better support reservoir fishery management actions. We suggest that this situation is happening or maybe happened in other countries in South America and other parts of the world.

**Key words:** paradigms, reservoir, fisheries management, hydroelectric companies.

**RESUMO. Desenvolvimento do manejo da pesca em reservatórios no Brasil com base em paradigmas importados.** Um paradigma é caracterizado como uma rede conceitual, instrumental e metodológica que guia a direção e a metodologia da pesquisa científica. Portanto, o paradigma define o que seria estudado, quais as questões a serem perguntadas, quais ferramentas seriam usadas e quais as normas a serem seguidas na interpretação dos resultados. O objetivo desse estudo é analisar como o manejo da pesca emergiu e se desenvolveu no Brasil considerando o progresso da ciência como uma série de paradigmas. Ações de manejo relatadas para a pesca não são frequentes no Brasil e quando aplicadas não apresentaram bons resultados, porque usualmente foram baseadas em informações técnicas e científicas inadequadas ou em paradigmas desenvolvidos em regiões temperadas. As escadas de peixes foram as primeiras tentativas para minimizar os impactos dos barramentos, seguidas pela regulação da pesca e peixamentos. Entretanto, parece que o paradigma que norteava estas pesquisas (importados dos Estados Unidos da América) não foi apropriado para o manejo de reservatório na maioria do território brasileiro. Além disso, outros motivos podem ter contribuído para alguns fracassos das ações de manejo, tais como: i) dados disponíveis inadequados e insuficientes; ii) a abordagem inadequada usada para realizar o manejo; iii) ausência de estudos de monitoramento; iv) políticas inadequadas e v) deficiência na integração entre as companhias hidrelétricas. Recentemente, as companhias hidrelétricas começaram a desenvolver pesquisas em limnologia e ictiologia com o propósito de obter informações para dar uma maior fundamentação científica às ações de manejo da pesca em reservatórios. Aparentemente, situação similar a do Brasil pode estar acontecendo em outros países da América do Sul e outras partes do mundo.

**Palavras-chave:** paradigmas, reservatório, manejo da pesca, companhias hidrelétricas.

## Introduction

Each individual branch of science has its own set of achievements from which evolve the basis of study, though and teaching. From time to time, some of the achievements reach the status of paradigm. Paradigm is a conceptual system that serves as a model or pattern that directs scientific endeavor within a discipline. A paradigm is characterized as a network of conceptual, instrumental, and methodological commitments that guide the direction and methodology of scientific research, and also provides new points of view and generates new attitudes (Ventura, 2000). It is signaled by the formation of specialized groups of scientists, publications on journals and books. Thus a paradigm defines what should be studied, what question should be asked, what tools should be used, and what rules should be followed in interpreting the results (Kuhn, 1970).

From a historical standpoint, different paradigms are present in the distinct fields of science (Zarur, 1994; Gzyl, 1995; Lopes, 1999; Kammerbauer, 2001; Lugo, 2001). Due to new perspectives on views which lead researches/discoveries, the adequacy of a paradigm may be challenged by observations that contradict the existing concept (anomalies; Kuhn, 1970). Further examination of these anomalies may create a crisis situation among the scientific community working under the existing paradigm. This crisis can lead to revolution and that may expand the present paradigm to incorporate the anomaly, or the creation of a new paradigm (Kuhn, 1970). The new paradigm implies a new and more rigid definition of the field. To be accepted, the new paradigm has to be seen better than the competitors, and solve few more problems. Thus, practitioners recognize it is accurate, but never the new paradigm will explain all the facts which it can be confronted. A shift in paradigm is not just an increment in knowledge. It involves the reconstruction of concepts and reevaluation of prior facts, and imposes entirely new questions to address (Graham *et al.*, 2002).

The objective of this paper is to analyze how fisheries management emerged and developed in Brazil. We applied Kuhn's view on how science progress, as a series of paradigms. We describe the paradigms that led reservoir fishery management research in the United States that influenced researchers in Brazil. Then, we report how reservoir fishery management evolved in Brazil. To better evaluate this, we overviewed dam constructions, we broadly described reservoir fishery and its importance in Brazil, and we identified the entities

responsible for reservoir fishery management and the main actions taken since the 1900s. We also assessed how management actions influenced Brazilian laws related to mitigation of impacts of dam constructions. We note that adoption of imported paradigms was not appropriated to lead reservoir management in most of Brazilian States.

## Paradigms in reservoir fishery management

Reservoir fisheries management is a young science that emerged early this century (Miranda, 1996). This author made a historical interpretative review of how fishery management developed in the United States. With the constructions of dams, there were indications that reservoirs had different characteristics than lakes (Thornton *et al.*, 1990). Thus, they required new management and research approaches. This prompted investigations that generated unique knowledge and ultimately a new set of concepts and beliefs, the paradigms (Miranda, 1996).

The first paradigm was the "biological desert" and influenced reservoir fishery management in the United States during the 1920s and 1930s (Miranda, 1996). It was considered that after an initial high productivity, reservoirs became largely unproductive, and this called for actions on harvest restrictions, such as closed season and gear, and on stocking (natural reproduction was inadequate to sustain reservoir fish populations, and fishing could be improved by releasing fish). The need for stocking prompted the construction of hatcheries throughout the United States. In the 1940s, the biological desert paradigm was questioned. Results from investigations began to identify that catches in reservoirs were greater than before impoundment (the anomaly according to Kuhn, 1970). There was little reason to believe that impoundments were biological deserts after some seasons. Some results of researches conducted during the 1930s and 1940s questioned the ongoing paradigm, and led to development of a new paradigm with a new set of research questions and management approaches.

The new "biomanipulation" paradigm (Miranda, 1996) emerged as a result of the researches conducted in the 1940s. Biologists recognized that the productivity did not decline, but the community composition in the reservoirs was different than before. Under the umbrella of this paradigm, research and management of reservoir fisheries concentrated on control of species composition, availability of fish, and promotion of fishing. Several strategies were developed, such as, drastic water level fluctuation with purpose to restructuring

community composition through influences on spawning, predator-prey dynamics, development of macrophytes, and increasing primary productivity. Stocking was seen as a remedial tool rather than a necessity for increasing fish abundance (Miranda, 1996).

The biomanipulation paradigm was reformulated in the 1950s, strongly influenced by the progressive increase in angling effort, a reduction in dam construction, and changes in angler attitudes. The increased fishing effort called back regulations with purpose to control overharvest of abundant stocks, adjust size composition of the stocks, and maintain enough predators to control prey abundance in the system. This paradigm still guides present management approaches and investigation in the United States. Recreational fishery is the most important there, and under the biomanipulation paradigm the goal of fishery management was chiefly to maximize harvest. Miranda (1996) suggests that this paradigm has been reformulated and identifies that the increase in angling (effort) is the main force driving to reformulation. He also suggests that reservoir fishery management in the United States may be under a new reformulation or paradigm shift to accommodate social concerns.

Ideally, management requests an ecosystem approach (Likens, 1992), including water quality, food web, biotic and abiotic interactions, population and community structures. However, actual knowledge on responses of aquatic resources to fishery exploitation is poor. The situation is more precarious if we consider other components of the ecosystem. Then, to promote sustainable exploitation, it is necessary to establish a good knowledge of aquatic resources through biodiversity surveys, including species distribution and requirements, ecological processes and functioning and implantation of a database accessible to researches and decision markers.

### Reservoir fishery management in Brazil

#### *Fishery in reservoirs*

Fisheries in Brazilian reservoirs may be classified in three types: 1) commercial (artisanal) fisheries undertaken by local fishers living alongside the reservoirs; 2) subsistence fisheries conducted by small farmers or day workers living along the reservoirs; and 3) recreational fisheries pursued by people from the major cities near the reservoirs (Agostinho, 1994a; Petrere, 1996; Santos and Oliveira, 1999).

Commercial fishery is common in most of the reservoirs in all basins. In the Amazon region, fishery is conducted as soon as the reservoirs are filled (e.g. Tucuruí, Balbina and Samuel reservoirs). Fish composition of the landings is variable at the beginning, but overtime, it is dominated by *Cichla* spp. (Agostinho, 1994a; Santos and Oliveira, 1999). In 1992 it was landed 300 t of these species in Samuel Reservoir (Agostinho, 1994a), and averaged 500 t from 1995 to 1997 in Balbina Reservoir (Santos and Oliveira, 1999). Species of this genus are fished mainly using hooks ("hand line" or angling). In the São Francisco River basin reservoirs, fishes are caught with gillnets, hooks and harpoon using canoes. Main species exploited are *Prochilodus marginatus* and *Pseudoplatystoma corruscans* that comprised on average 73% of the catches from 1982-85 (Petrere, 1996). In Paraná River basin, gillnets are the main gears used in reservoir fisheries, and exploit *Plagioscion squamosissimus*, *Prochilodus lineatus*, *Pterodoras granulosus* and *Hypophthalmus edentatus* (Petrere and Agostinho, 1993; Agostinho, 1994a; Petrere, 1996).

Subsistence and commercial fishery are important for indigenous people as the sole protein source and also has a relevant social role. In Itaipu Reservoir (Paraná River), commercial fishing is important to local human populations for subsistence because wages earned for most jobs are inadequate for supporting a family (Agostinho *et al.*, 1994). In reservoirs of the Iguaçu River basin (a tributary of the Paraná River), available jobs pay wages near US\$ 1 per day, while wages up to 4 per day can be earned in the commercial fishery (Okada *et al.*, 1997).

There is little information available on recreational fishery in Brazilian reservoirs. The main species targeted by anglers are *Cichla* spp. in the Amazon (Santos and Oliveira, 1999), *Cichla monoculus* (introduced) and *Plagioscion squamosissimus* in Paraná River reservoirs.

#### *Management actions*

Management actions related to fishery management are not frequent in Brazil and when applied they did not generate good results, because they usually were based on poor technical and scientific information (Agostinho, 1994a; Agostinho and Gomes, 1997) or in paradigms developed in the temperate region. Fish passage facilities were the first attempt to minimize the impacts of dams, followed by fishery regulation and stocking. Agostinho (1994a) showed the low effect of these actions. Recently, hydroelectric companies started to

conduct research in basic limnology and ichthyology with purpose to gather information to give a more scientific base for reservoir fishery management actions. Main actions are summarized below.

**Fish passage facilities:-** There are fish ladders in some Brazilian reservoirs, but their construction did not consider technical characteristics related to the dam (type, slope, water discharge and position) and nature of the ichthyofauna (Quirós, 1988; Agostinho et al., 2002). This approach increased risk of failures. Money and effort were lost, as well as opportunities. After the construction of those structures, evaluation was not conducted. Some studies, such as the ones carried out by Godoy (1957, 1975), reported the high efficiency of a fish ladder at Cachoeiras das Emas (Pirassununga, São Paulo), and Borghetti et al. (1993, 1994) reported the high number of species on an experimental fish ladder near the Itaipu Dam. But the effectiveness of fish ladders for conservation of fish stocks is still not analyzed (Agostinho and Gomes, 1997; Agostinho et al., 2002).

**Fishery regulation:-** Regulations with purpose to protect juveniles, spawning grounds and spawning season have not been efficient. These actions are limited by the lack of information on fish populations, financial resources and workforce to enforce. Absence of monitoring and a clear subject of protection are also problems (Agostinho and Gomes, 1997).

Absence of data on catch and effort of the fisheries, except for specific places (Okada et al., 1996) does not allow obtaining maximum sustainable yield that could be helpful to identify the status of the exploited stocks and could give basis to fishery regulations. Recent participation of universities and research institutes in the definition of policies is improving this situation (Agostinho, 1994b). But the absence of data will be only solved with new research programs and monitoring studies.

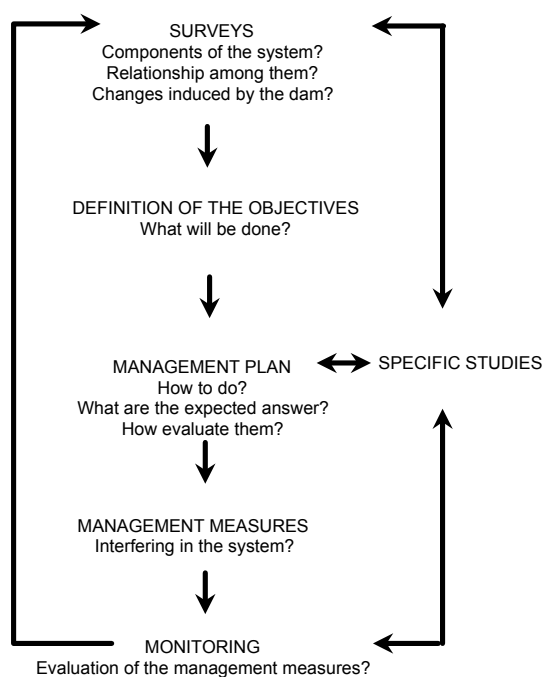
**Stocking:-** Stocking with native and non native (mainly) species was the main management tool in last decades, as an alternative for fish ladders, considered expensive and inefficient. This led to construction of hatcheries by hydroelectric companies, with a huge amount of money expended.

Although expensive and time consuming, it was hoped that the widespread building of hatcheries and subsequent stocking would improve reservoir fishery. As many as ten species were introduced during 1970-1990 in reservoirs of south and southeastern Brazil (Agostinho and Julio Jr., 1996), but in most cases unsuccessfully. Exception were small reservoirs in northeastern Brazil where the

studies developed by DNOCS (Departamento Nacional de Obras Contra a Seca) achieved success in obtaining a balanced, self-sustaining community, mainly stocking tilapia species (Paiva et al., 1994).

Constant failures in stocking programs have led hydroelectric companies to reevaluate their actions. Thus, hydroelectric companies are using their infrastructure to aquaculture and/or limnological and ichthyological studies in their reservoirs. Aquaculture is an attempt to compensate negative economic impact of reservoirs at regional level, but without consideration on conservation. Politicians' influences have to be considered in most stocking programs, as stated by De Silva (1987) that stocking in Thailand is done more for political reasons than for fisheries enhancement and the fisheries rely on endemic species (returns of stocked introduced species are very low).

**Limnological and ichthyological researches:-** In recent years, with involvement of universities and research institutes, the approach on reservoir fisheries management changed. Before taking any action, hydroelectric companies started to study their reservoirs, following the approach identified by Agostinho (1994a) (Figure 1).



**Figure 1.** Organizations of the environmental actions of surveys, studies, management and monitoring (after Agostinho, 1994a; Agostinho and Gomes, 1997).

This approach should lead to a better understanding of the functioning of the reservoirs.

Results of this approach may order fishery management, and techniques that could be applied are categorized in three groups: i) habitat manipulation (macrophytes management, water level control, spawning places and nurseries); ii) population manipulation (reduction of undesired fish species, stocking as a possible tool); and iii) fishery regulation (close fishery during spawning season and in nurseries, gear restriction, length limits, control of effort) (Agostinho, 1992). Despite of this approach seems to be very useful for reservoir management in Brazil, we note a strong influence of the studies developed in North America (see Hall and Van Den Avyle, 1986; Kohler and Hubbert, 1993; Miranda and DeVries, 1996).

### How reservoir fishery management paradigms developed in Brazil

We tried to follow every step of reservoir fishery management in Brazil. The first sign of reservoir management was identified in the form of a law. In São Paulo State there was a law that stated on the construction of fish ladders (Law No 2250/27). Alzuguir (1994) stated:

*"That law was based on the United States of America experience that adopted fish ladders or fish ways in stretches of the rivers where dams were present."*

Because that law was so polemical, discussions towards the viability of fish ladders started. Instead of studying Brazilian fish species to verify adequacy of fish ladders, an American scientist, Dr J. H. Brunson was invited to analyze the problem in 1929. The lack of information on Brazilian species did not allow Dr Brunson to conclude anything, as time was short, he reviewed American literature and asked each American State about the utility of fish ladders. The conclusion was:

*"In the United States, there are 35 states that have regulations towards fish ladders, 27 of them answered that fish ladders are not necessary, and 8 were favorable to them, because they have migratory species in their rivers."*

Dr Brunson called attention for the lack of information on Brazilian species. But his comments about the use of fish ladders in the United States were considered enough (because there were several migratory fish species in Brazil) to convince legislators about the biological support to fish ladders, finishing the polemic subject. This illustrates the unscientific way that fishery management started in Brazil. Fish ladders were well studied by Godoy (1957, 1975), but 27 years after the law was approved. Godoy's work showed that

fish ladder was useful in some cases, but there was not necessity to consider fish ladder as mandatory for all new reservoirs in São Paulo State.

Researches on reservoir fishery management based on the "biological desert" paradigm were first conducted in northeastern Brazil during the late 1920s. A group of practitioners working for DNOCS, followed the "biological desert" paradigm. Although questioned in the 30's in the United States (Miranda, 1996), the "biological desert" paradigm was not questioned in Brazil until the 80's. Apparently, this delay happened because the political scenario of that time. Management of fishery reservoirs was not a priority. However, the social and economic importance of the fishery was recognized. Because dams in northeastern Brazil were built in temporary rivers or in rivers where species richness was low, the "biological desert" paradigm worked and still works in leading management of reservoir fisheries. The success of the "biological desert" paradigm allied with the discussions towards fish ladders dictated a need for change in law. So, in 1938 the decree-law No 794 was approved adding hatcheries as option for conservation of fish stocks, when constructing a reservoir. That was a big mistake because it was a federal law, thus applied to the entire country. After the 1950s the rhythm of dam construction increased, and the "biological desert" paradigm was adopted to lead management of reservoir fisheries (in part mandatory by law), especially in south and southeast Brazil, where migratory species are important to fisheries. Actions taken by the hydroelectric companies from the 1950s to the 1980s were based on that paradigm, and most of them did not work.

This situation started to change in the early 1980s by the studies conducted at Itaipu Reservoir. A. A. Agostinho and colleagues proposed a project with purpose to understand the dynamic of fish community in that reservoir. Results of that research indicated that the actions based on the "biological desert" paradigm (that was the basis of research for other hydroelectric companies during 40 years) were not appropriate to manage reservoir fisheries, at least in the Paraná River basin. Other practitioners adopted immediately the "new" incremental change, and in 1986, managers (hydroelectric company) realized that the majority of the actions taken by them failed or were questionable:

*"... Poor basic information and poor monitoring approaches has led hydroelectric companies and environmental control agencies to inadequate management procedures in dealing with aquatic fauna." (Extrated from Seminário Sobre a Fauna Aquática e o Setor Elétrico Brasileiro, 1995).*

Agostinho and Gomes (1997), also addressing this point wrote:

*"...Management of aquatic resources in Brazilian reservoirs is rare, and when they exist, usually they are based on poor technical-scientific information".*

*"...Management techniques developed by hydroelectric companies were not satisfactorily monitored, so results in the last 20 years are questioned. Present reservoir's yields indicate that their efforts were not successful."*

As a result, in the last 15 years, practitioners reorganized their actions and limnological and ichthyological information started being collected and data have been analyzed under the umbrella of the biomanipulation paradigm.

### Conclusion

Reservoir fishery management in Brazil started in the 1910s but not scientifically. The "biological desert" paradigm identified in the United States was prompted adopted in northeastern Brazil in the late 1920s and it is still used there. The success of researches conducted under this paradigm drove Brazilian researchers to adopt it in other regions, especially in the Paraná River basin where most of the reservoirs were constructed. Without collecting any information, all actions under the umbrella of the "biological desert" were taken, for 40 years. Signs of the biomanipulation paradigm appeared in the 1980s.

Main reasons for the failure of the management actions are: i) inadequacy and insufficient data availability; ii) inappropriate approach used to perform management; iii) absence of monitoring studies; iv) police inadequacies; and v) deficiencies in integration among the hydroelectric (Agostinho, 1994a). We agree that all these reasons contributed in some extension to the failure. However, it seems that the paradigm that led researches (imported from the United States) was not appropriated for reservoir management in most Brazilian reservoirs. We suggest that this situation is happening or may happened in other countries in South America and other parts of the world. As a way of not following the same mistakes, we strongly recommend monitoring as an important tool to assess the efficacy of any adopted management action.

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