

## Environmental Perception of the São Francisco Riverine Population in Regards to Flood Impact

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**ABSTRACT** The São Francisco river discharge regularization, which regulates floods on the riverine population land, has promoted changes in land use associated to the implementation of irrigated areas, leading to a destruction of natural riverbank vegetation and an increase in soil and bank erosion. Past river and land use involved fishermen and landholders in a complex relationship which provided for the practice of both activities: fishing and agriculture, without any constraint. The objective of this work was to understand and analytically interpret the perception of the riverine population regarding the natural or artificial floods caused by the operation of dams in the São Francisco River Basin, in its lower course. A survey related to the perception of the riverine population concerning to flood occurrences at the lower Sao Francisco river municipalities was carried out, especially in regards to the 2004 flood, with the evaluation of the produced externalities through intentional and non-probabilistic questionnaires. To the riverine population, natural floods were always historically recognized as being positive, with the practice of agriculture on the flooded lands possible and also working as a nursery area for fish, promoting the local biodiversity conservation. With the river discharge regularization throughout the year, a decrease of fish quantity, biodiversity, and waterlogged land farming (marginal lagoon) was reported. The social and environmental costs resulting from the policies of development in the São Francisco River Basin were not considered by the policymakers.

### INTRODUCTION

In the hydrographic basin of the São Francisco River the use of natural resources through disorganized human activities has been progressively impacting the environment, the quality of river water, and the socio-economic conditions.

The dams have been pointed out as being the main responsible reason for environmental changes observed in the last few years, principally concerning flood control. The break in traditional farming, as seen with rice cultivation on waterlogged land farming (marginal lagoon), the occurrence of periodic floods, and the absence of new contributions of nutrients through floods have made soil fertility drop year after year. Various areas have been inundated for the formation of lakes, representing a great environmental loss, with the threat or the

disappearance of various species of fauna and flora; the hydrological regimen of the river (system of floods and ebb tides) has been altered, compromising the traditional economic activities (waterlogged land farming and local fishing) (Holanda et al. 2005). With the decline of the population of fish, the majority of fishing communities have become impoverished and left with few alternatives for generating income for the subsistence of their families (Gutberlet et al. 2007).

According to Gondim Filho et al. (2004) historic floods occurred in the years 1919, 1925, 1943, 1946, 1949, 1979, 1983, 1992, and 2004. A river flood is characterized by a relatively great outflow of superficial run-off. However, inundation is characterized by channel overflow. In this way, a flood cannot cause inundation, mainly if works of control were constructed for this purpose, such as the construction of reservoirs for abatement (Villela and Mattos 1975).

The seasonal occurrence of ebb tides and natural floods has been part of the awareness of the riverine population of the Lower São Francisco, being part of their lives and something concrete that they have lived. There is a very strong connection regarding the use of the river

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as a source of leisure, food, and above all, as a space identified by its inhabitants' way of living and stories that tell of their life experiences. It is necessary that a list of the knowledge and practices of the population be documented, studied, and valued, particularly the traditional population (Indians, mulattos, riverines, rubber plantation workers, descendents of slaves, etc.). Pedroso Júnior and Sato (2005) refer to the intricate web of relationship that characterizes these traditional populations as a component of a dynamic and complex socio-cultural and environmental system. The agriculture and fishing, despite being part of the reality lived by those people, have specificities and particularities that make them different. In the Lower São Francisco the command of the land and the river would involve the fishermen-agriculturalists in a complex and elaborate knowledge that would allow the practice of both activities: fishing and agriculture, without great problems.

It is necessary to understand the relationship between social-ecological knowledge and the responses toward environmental changes for the management and sustainable use of resources, biological diversity and ecosystems. Traditional knowledge plays a crucial role in the institutional memory of ecosystem change and management practices that build social-ecological resilience (Berkes and Folke 2002). Olsson et al. (2004) propose that the adaptive comanagement connecting institutions and organizations across levels and scales facilitate information flows and contribute to the resilience of social-ecological systems. Thus, Carlson and Berkes (2005) point some ideas about co-management. One of them brings to the surface the concept of co-management not as a fixed state but as a process that takes place along a continuum.

The objective of this work was to understand and analytically interpret the perception of the riverine population regarding to the natural or artificial floods caused by the operation of dams in the São Francisco River Basin, in its lower course, between the municipalities of Propriá and Brejo Grande up to the Saramén village, at the mouth of the river.

## MATERIALS AND METHODS

### Characterization of the Studied Area

The São Francisco River has an extension of

approximately 2,700 km, divided into four parts: the Upper, the Medium, the Sub-Medium, and the Lower São Francisco. In its lower course there is the border between the States of Bahia and Pernambuco, and between the States of Alagoas and Sergipe, running a total of 274 km, with a decrease in altitude of 220 m in 40 km, to reach the lower plane of the coast, where it flows to the ocean (Pereira et al. 2007).

The economy of the Lower São Francisco is based on the farming of rice and on local fishing. However, being a small cultivated area and without commercial value, the socio-economic situation of its inhabitants is made difficult. There are no big industries and its commerce, once promising, is nowadays incipient. The projects of irrigated agriculture developed in the waterlogged land of the São Francisco, along with the Xingó Hydroelectric Dam, the last dam cascade in the river channel, interfered with fishing in the region, as they changed the entire river ecosystem.

### Collection and Analysis of Information

Several field trips were conducted in the period of October 2004 to April 2005 for direct observation of the situation in the region with accompanying photographs taken throughout the study, utilizing vehicles to cover the studied land areas and motorboats to cover the river channel. In the beginning, field trips were conducted throughout the river course beginning in the Municipality of Propriá up to the mouth of the river, passing by the Municipalities of Neópolis, Ilha das Flores, and Brejo Grande (Fig. 1).

Secondary data was collected from public organs and newspapers edited in the State of Sergipe. The collection of information tried to describe, in an analytical way, the perceptions and interpretations of the riverine population regarding to the occurrence of floods in the region of the Lower São Francisco before and after the construction of dams, especially between the municipalities of Propriá and Brejo Grande, evaluating the external factors produced as a consequence of such hydrological events, specifically the flood that occurred at the beginning of February 2004.

Initial visits to the studied area were carried out to define the extent of the research, to establish sampling, and to determine the data collection techniques. The sampling defined for the

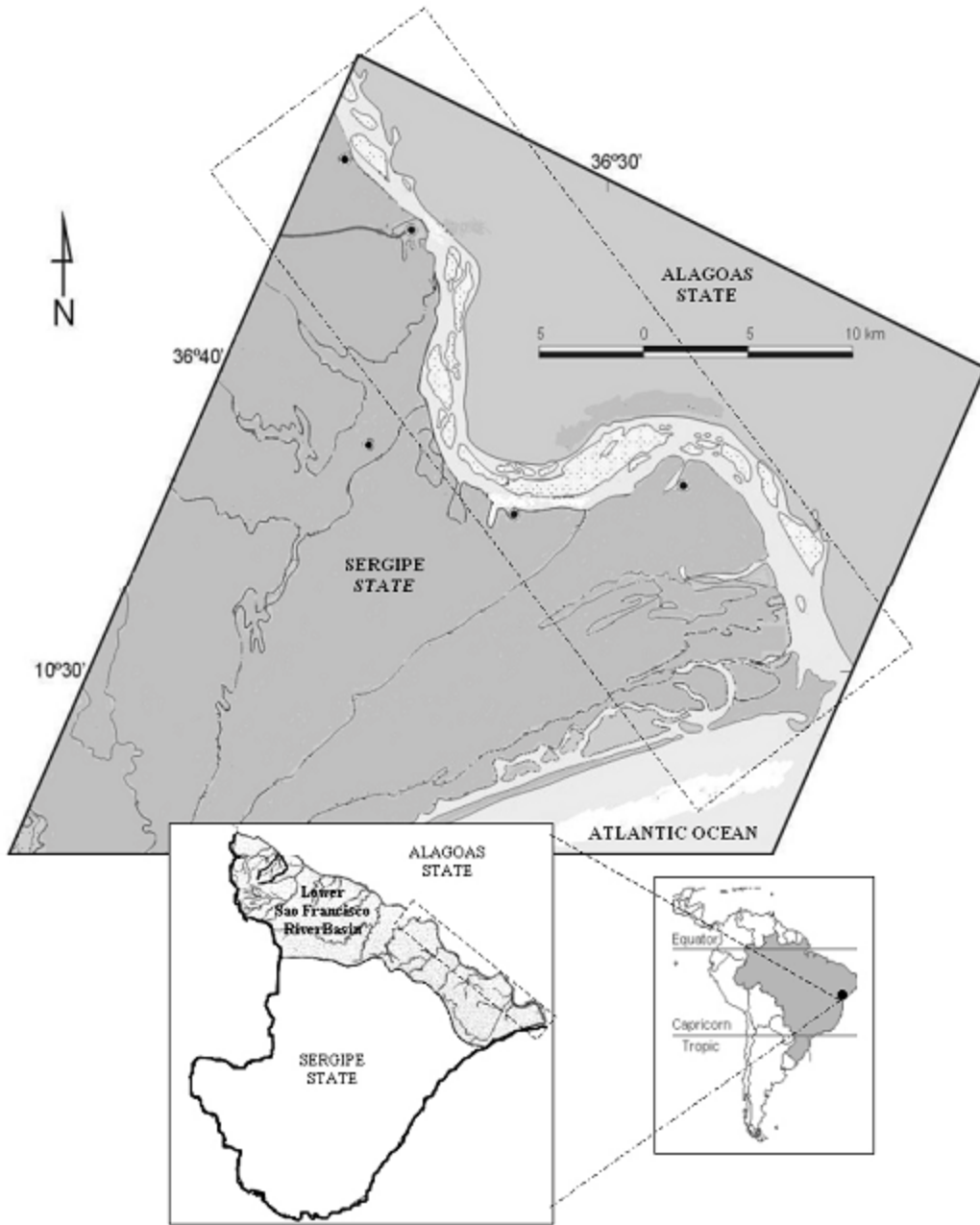


Fig. 1. Localization of the Lower São Francisco River, Brazil.

application of a questionnaire was of a non-probabilistic intentional type, in which the sample is determined by the researcher and the interviewer addresses a specific group in order to know their opinion and gain a prior knowledge of the population and its proportionality (Levin 1989; Mattar 1999). The group chosen for the interview was the riverine population because they experience the constant and dynamic changes of a river's outflows regulated by dams. The instrument used to perform the interviews was the mixed questionnaire, containing structured and semi-structured questions. A total of one hundred and thirteen interviews were performed during the months of November, and December 2003 and January, February and March 2004.

For the best systematization and spatial comprehension of the collected information, the division of the lower course of the river into five segments upriver was considered due to the changes in direction of the river gully and their effects on the activities developed by the riverine population. Segment I was considered to be the Villages of Saramén and the extinct Povoado Cabeço at the river estuary; Segment II was considered to be the Municipalities of Brejo Grande and Ilha das Flores; the Villages of Serrão, Betume, and the Municipality of Neópolis were considered to be Segment III, while Segments IV and V were formed by the Cotinguiba-Pindoba Irrigated Perimeter and the Municipality of Propriá, respectively.

## RESULTS AND DISCUSSION

### Brief hydrological analysis of the floods

From the total run-off of the São Francisco, 70% originates from the precipitation occurring in the State of Minas Gerais, about 2,700 km far from the mouth of river, along the upper course, with rains concentrated more strongly in the period between November and March. In spite of the fact that the rainy period in the Lower São Francisco presents a different behavior, being more concentrated in April and June, and its influence is not verified by the occurring outflows. Therefore, the period from December to March is the most critical in relation to the occurrence of floods in the basin of the São Francisco. It is in this period that procedures aimed at flood control are intensified, in particular,

in reservoir operations and alert systems. Different from the great flood of 1979, the floods that occurred in 2004 were provoked by precipitation that occurred predominantly in the region of the Sub-Medium São Francisco, promoting peaks of outflow in the month of February of more than 9,933 m<sup>3</sup>/s (Fig. 2).

The Xingó Hydroelectric Plant, the last in dam's cascade of the entire hydrographic basin of the São Francisco River that began operation in 1994, provided the formation of a lake of short length and enclosed between abrupt banks. It is recognized by the electric sector as being a "non-water storage dam", because of its small reservoir, in comparison to the others of the same river. The operational characteristic of this type of dam is the low capacity of regularization, not being considered a situation that can contribute to flood control. The referred to control is made by allocating a determined volume for this purpose, which is called a "reserve volume", as occurs at the Sobradinho Hydroelectric Plant, which began operation in 1978, located in the medium course of the river, and is greatly responsible for the regularization of river outflow. The use of this volume mitigates floods from the outflows that propagate downstream of the reservoir. The allocation of a reserve volume is only possible at the plants that have water storage capacity, and consequently the capacity of regularization and abatement.

Historical data show that the average level of water in Propriá remained above the average over 41% and 28% of the time before and after of Sobradinho Hydroelectric Plant. This indicates a greater frequency of floods in the period before the construction of Sobradinho and their effect on the regularization of the river.

In the period from January to February 2004, the tributary outflow to the Xingó reservoir significantly surpassed the regularized outflow of around 2,800 m<sup>3</sup>/s, reaching more than 9,000 m<sup>3</sup>/s, and covered the inundated planes of the Lower São Francisco. It's worth emphasizing that the load of sediments, including organic sediments necessary for ictyofauna, drastically dropped after the construction of Sobradinho, leaving limpid water downstream of the dam, with a low potential for fertilizing the floodplain.

The drastic decrease of solid load, the increase of minimal outflows with maintenance of constantly repeated outflows, that is, the regularization of outflows, seasonal alterations,

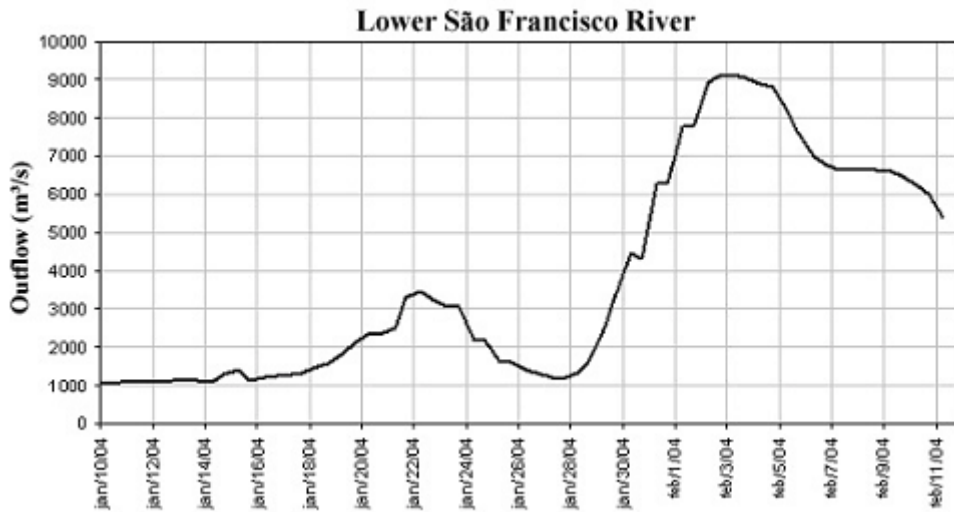


Fig. 2. Hydrogram of occurring outflows in the months of January and February 2004, in the municipality of Propriá, State of Sergipe, Brazil. Source: ANA/GEF/ PNUMA/OEA (2005).

and flood control establish an elevated level of control in regards to the behavior of the segment of the channel below the Xingó Plant.

**The Floods Before and After the Construction of Dams, From the Point of View of the Riverine Population**

The riverine population in the first four evaluated segments had planned for the arrival of a flood one time that had been forecast. These riverine people related that “part of the water ran to the marginal lagoons (waterlogged lands) where the fish found food and protection in the calm waters”, which was greatly desired as a guarantee of abundance, translated into food sustainability and source of income (Table 1), in agreement to Silvano and Begossi (2004) who describe the importance of fishermen’s ethnoknowledge to the environment sustainability. However, in segment V, referring to the draught areas of the Municipality of Propriá, the

waters invaded the city, promoting a great loss to local business and disruption to the population which suffered from the overflow of residential sewers.

Although the riverine people declared that the floods were beneficial to everyone, because the run of water into the marginal lagoons augmented the quantity of fish, fertilized the soil for rice cultivation without the use of fertilizer, and created natural irrigation, the floods in the São Francisco River basin before the construction of dams had been very severe. With the construction of the Sobradinho dam a reduction in the peak of floods happened in the region of the Sub-Medium and Lower São Francisco, but did continue occurring, although controlled by the regularization of outflow promoted by the dams.

After the construction of the Sobradinho Dam, and later Xingó Dam, it is noticed through declarations of the riverine population, that to survive from what the river could provide, such

Table 1: Impact of floods on the riverine population before and after the construction of the dams.

Impacts	Before Hydroelectric dams	After Hydroelectric dams
Fishing	Increase of fish abundance	Decrease of fish abundance
Waterlogged lands	Increase of soil fertility	Reduction of soil fertility
Volume of channel water	Increase of river discharge	Reduction of river discharge
Channel sedimentation	Not perceptible	Perceptible
Algae (“cabelo” and “lodo”)	Not perceptible	Increase of population

as the abundant fishing, became very difficult. The river water lost a great number of the characteristics to which the people had already become accustomed to such as the organic sediment important to feed fish, and no longer presented the same behavior or dynamics as before. The lower turbidity of water also increases the predation of eggs of many species of fish and affects the stimulus for spawning.

The floods no longer occur every year, the quantity of water and fish has decreased considerably; in consequence, many sandbars and islands appeared in the river channel, disrupting navigation. The river channel sedimentation became increasingly more perceptible by boatmen, fishermen, and the riverine people, who report the conditions of river degradation. The secondary channels, as years went by, became shallower, inaccessible to navigation, creating difficulties for fishing activity.

In this situation, species of algae popularly known as “cabelo” and “lodo” proliferate rapidly, becoming a problem for fishing, since the fish hide among the leaves, impeding the placing of nets where that vegetation exists. When the nets are cast, they become very “dirty” with “lodo”, and because of that, the fish swim away when

noticing them. Besides that, damage to the fish netting is provoked, decreasing the material’s life-cycle. These algae can provoke irritation to the fishermen’s skin. On the other hand, some of the interviewees in segments I, II, and III declared that they considered the presence of “cabelo” to be good because it is the “place where fish and shrimp hide, and the food for them, since the water from the dam presents a shortage of food”.

### Problems faced by the Population During the Floods of 2004

Half of the riverine population in segment II, in the municipalities of Brejo Grande and Ilha das Flores, when questioned about the problems they faced during the period of the flood of 2004, declared that they had had their houses invaded by the waters and some of them were destroyed, around 18% in Brejo Grande (Fig. 3). Also, fishing was interrupted because it was during the period called “*defeso*”. The Brazilian Institute of Environment and Natural Renewable Resources (IBAMA) lays down rules for fishing during the protection period of natural reproduction in the basin from November to February. In the space from the Xingó Plant and the mouth of the San

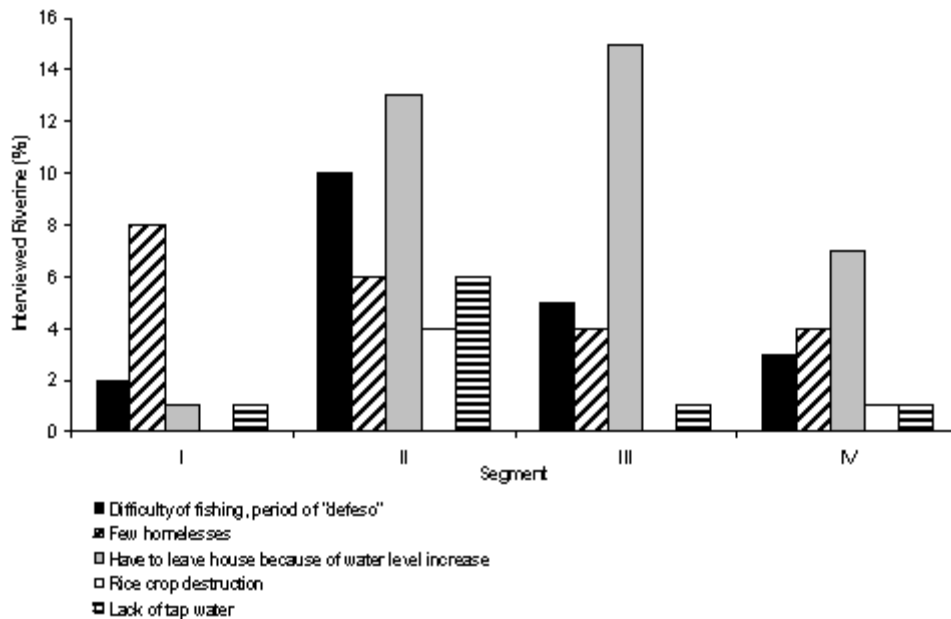


Fig. 3. Main problems faced by the riverine population during the floods of 2004.



Francisco river the professional fishing was only allowed for the species “Pilombeta” (*Anchoviella* spp.); “Pescada do Piauí” (*Plagioscion squamosissimus*), “Tucunaré” (*Cichla* spp.), “Tilápia” (*Oreochromis* spp. and *Tilapia* sp.); “Bagre africano” (*Clarias* spp.); “Apaíari” (*Astronotus ocellatus*); “Tambaqui” (*Colossoma macropomum*); “Carpas” (all the species), “Pirambeba” (*Serrasalmus brandtii*), “Piranha” (*Pygocentrus piraya*), “Cabogé” or “Tamoatá” (*Hoplosternum* sp. and *Callichthys callichthys*). This has led to what Moura and Marques (2007) pointed, to be a successful fisherman in the lower São Francisco river depends on their accumulated knowledge of fish ecology and behavior.

Although the fishermen obey the period of *Defeso*, it is reported that the quantity and species of fish are diminishing year after year. According to reports from the riverine people, there was also a repeated delay in the payment of unemployment insurance, making their lives difficult. Each fisherman member receives a payment of approximately US\$ 190.00 per month during this period.

The “defeso” is an alternative used as a phase of the adaptive renewal cycle of aquatic ecosystem. Like Berkes and Folke (2002) said that disturbances are endogenous to ecosystem’s development and periods of gradual change and periods of rapid transformation coexist and complement one another.

The farmers who practiced agriculture on the islands or near the banks lost everything. According to statements, “the river became wider, and we couldn’t get a boat due to the dirt in the river that was full of “cabelo”, with inappropriate water for consumption”. In this segment, 50% of those interviewed confirmed that they had had a loss in fish production, in plantings, and had been left with destroyed bars and soccer fields at leisure areas of the river bank.

The riverine people located in segment III, having been questioned about flood problems, responded that “in the village of Serrão the fishing was more difficult”, and approximately 60% of those interviewed had had their houses flooded. However, part of the municipality benefited from the protection of dykes constructed to ease the effects of floods in the area. In the village of Betume the situation was similar to those who lived on the river bank, with around 40% of the riverine population having had their houses flooded, 58% having losses in fishing as much as in farming. In Neópolis 50% of those interviewed declared that

“the people who lived very near the river bank had damages, but that the flood increases the fish and shrimp, and cleans the river of “cabelo” and “lodo”.

In segment V more than 30% of the interviewed riverine population in Propriá commented that they find a flood to be bad because many people lose their houses, commercial establishments, and plantings. They are without the power to fish and even to use boats. However, for 32% of the interviewees the flood was good, because it increased the number of fish, cleaned the river, and did not affect the majority of people. They remember that the flood of 1979 was controlled, there was time to save the cattle, the planting, and people had time to leave before the inundation.

The areas where the riverine people had the biggest loss were located in the municipalities of Poço Redondo and Ilha das Flores. In Propriá 4.5 tons of rice was lost. In the Cotinguiba-Pindoba irrigated perimeter, the loss was 17 tons of rice, which represents R\$ 1 million according to information from the Development Company of the São Francisco River Valley – CODEVASF.

Another problem faced by the population concerns the water supply in the region, that according to those interviewed, the State Water Supply Company - DESO - performed the pumping of river water and distributed it to residences without any treatment. The Supply Company claimed that treating the water was impossible due to the lack of practical conditions caused by the great inundation. During the period of floods various cases of diseases of hydric transmission occurred in the population of the region.

The differences in perception of the impacts of dams on the change of the flow in the river segments show that the cultural knowledge and beliefs should influence the definition of the ecological flows. Berkes and Folke (2002) tell us that traditional ecological knowledge and adaptive processes can help to understand the relationship of living being with one another and with their environment. The differences between the groups of riverine population highlight differences in environmental perception that shall influence in the social and economic priorities.

Problems or Benefits Faced by the Population after the Flood

The riverine population from segments III and V declared: “the controlled flood is good, having

a flood every year makes the population happy with abundance, health, and pleased to see the river as in the old days, that did not harm anybody, increased the number of fish, and improved the soil”.

Around 75% of the interviewees claimed that one month after the flood the characteristics of the river for fishing and soil fertility were much better, bringing benefits to the population as an improvement in survival conditions.

It is observed that the floods brought favorable conditions to the riverine people to help them carry out their economic activities, and happiness appeared in seeing the river with aspects of the time before the construction of dams, when floods would occur periodically and they would conduct their fishing activities and/or farming in a natural way. The man of the Lower São Francisco, accustomed to fighting against the river floods, accustomed himself to this contradiction. The greatness that destroys is the same that brings the abundance of fish.

#### Alteration in the Quantity of Fishing After the Floods

In segment I (region of the mouth of the river), the fishermen declared that the river became deeper, with species of fishes appearing that had not been found in the region before. In segment II, in the municipalities of Ilha das Flores and Brejo Grande, the fish species “Xira” (*Prochilodus*

*argenteus*), Piau (*Leporinus elongatus*), Robalo (*Centropomus* spp), and “Pilombeta” (*Anchoviella* spp) increased (Fig. 4). The fishermen also claimed that the number of farmed fish increased, because they were released with the floods.

In segment III, in the Municipality of Neópolis and in the Villages of Betume and Serrão, the species of fishes that increased as a consequence of the floods were: “Xira” (*Prochilodus argenteus*), “Robalo” (*Centropomus* spp), “Tucunaré” (*Cichla ocellaris*), “Piaba” (*Moenkhausia costae*), etc. The occurrence of “Pilombeta” (*Anchoviella* spp) maintained constant, because its origin is marine. In segment V, according to local fishermen, the fishes of greatest occurrence were: “Piau” (*Leporinus piau*), “Xira” (*Prochilodus argenteus*), “Tucunaré” (*Cichla ocellaris*), “Tilápia” (*Sarotherodon* sp), and “Robalo” (*Centropomus* spp).

The increase in production of some fish was observed months after the floods. In all of the segments, fish reappeared that for a long time had not been found in the river, for example: “Mandim” (*Pimelodus* sp), “Dourado” (*Salminus brasiliensis*), “Surumbim” (*Pseudoplatystoma* spp), “Carapeba” (*Diapterus rhombeus*), “Tubarana” (*Salminus hilarii*), etc. It appears that such species of fishes found it very difficult to get through the dam barriers with the release of smaller volumes of water, and only appeared when they were released at the time of the floods.

The interruption of the spawning migration,

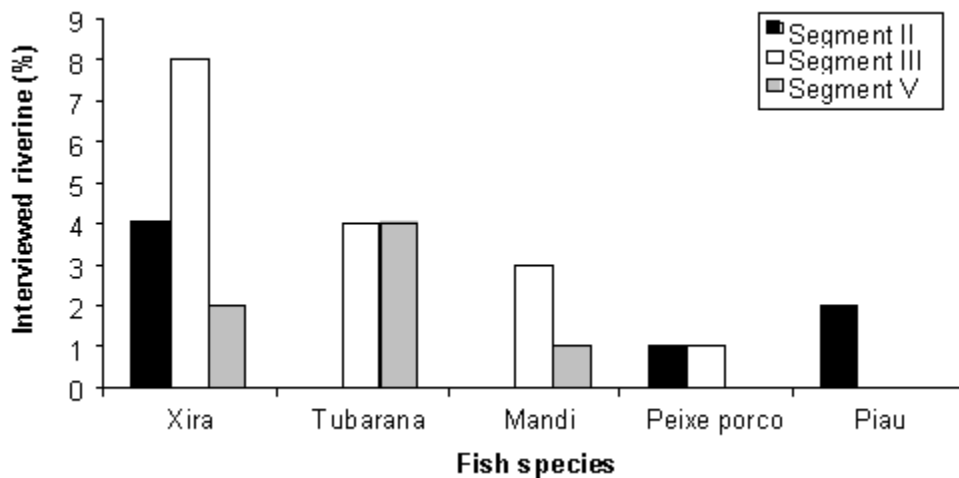


Fig. 4. Species of fish that increased in number after the floods of 2004, according to reports from fishermen.



as a consequence of the Xingó Dam construction, the absence of fish ladders at that dam, and the absence of strong currents from the floods drastically harm the biological cycle of the majority of species. The waters without sediment become limpid for a great part of the year, harming the spawning period and the protection previously afforded to the alevim against predators. The lack of adequate conditions for the reproduction of the varied species of fishes cited caused a reduction in fishing and in the ecosystem's biodiversity.

The construction of the James Bay hydroelectric project in Canada resulted in impact on estuarine fish resources, main sources of local food. Olsson et al. (2004) reported that the construction of dams to produce electricity according to seasonal demands altered the natural pattern of seasonal flow characterized by maximal flows in spring and minimal flows in winter. This caused impacts on land, wildlife, people and aquatic resources.

### **The Conflicts of Water Use in Lower São Francisco**

It identified a clear situation of conflict between the storage of water in reservoirs for energy generation and maintenance of diversity of aquatic ecosystems to enable the development of fish species of economic interest. Changes in the river flow, reducing the frequency of floods, caused negative environmental and social impacts. The reduction of sediments that brought nutrients favor the breeding and survival of fish was attributed to construction of reservoirs. The production of fish and fishermen's income decreased.

From a social standpoint, one should consider the potential for future use of the ecosystem to promote social welfare in order to enable future generations to enjoy natural resources to produce income. The solution of this conflict necessarily involves a process of negotiation. In Brazil, water resource management is decentralized, integrated and participatory. This means that there must be participation of the public authorities, users and communities, the water resources management should be integrated with environmental management, and must meet the physical diversity, biotic, demographic, economic, social and cultural rights.

The conditions for the mitigation of conflicts are unfavorable. On one side the electric sector exercises the power of decision assuming

operational control of discharges from reservoirs. In addition, fishermen and environmentalists do not have enough representation on the river basin's committee to reclaim their demands.

Considering every social-ecological problems in the lower São Francisco River, it is necessary to deal with the effects of the impacts in the seasonally flow, discharge influence from dams and traditional knowledge to reach management practices that build resilience.

### **CONCLUSIONS**

The multiple demands by the hydric resources of the São Francisco River paint a typical picture of conflict for the use of waters demanded by the policies of development and ecologic services. The operation of reservoirs, centralized for the generation of electricity and the supply of water for irrigation, considered marginal the attending of ecologic priorities. At the same time it stimulated the development of the Northeast region, it generated a strong environmental debt, such as with marginal erosion, river channel sedimentation, the growth in a large quantity of aquatic vegetation, and the decrease of sediments which harmed the reproduction and preservation of fish and navigation.

As a consequence of the regularization of outflow and control of floods promoted by the Hydroelectric Plants, there was a change in behavior in relation to the traditional activities of the region due to the lack of conditions for practicing them. A decrease in fishing, biodiversity, and waterlogged land farming was verified. The social and environmental costs resulting from the policies of development in the São Francisco River basin were not considered.

The transformations which the São Francisco River has been through since the construction of the first dams, altering the regimen of water flow in its channel, have been felt by the riverine population, be it through a forced alteration in their routine for the search for jobs and income, or be it through a forced loss of cultural identity conditioned by the currents of change that effect the river. This happens in search of a forced equilibrium by the current polices of development or that are planned by governing authorities.

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