STUDY OF THE NECESSARY MECHANICAL MODIFICATIONS FOR THE OPERATIONAL OPTIMIZATION OF THE SANTA CLARA DAM'S FISH LIFT

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Abstract. *Among the selected strategies to reduce the impacts caused by barriers which block the fishes' migration, we can find the construction of fishways; hydraulic structures which allow the fishes´ upstream and downstream movements. The fish ladder is the most common fishway found in Brazil, although fish lifts begin to be more often used. Fish lifts with a "trap and trucking" system, have been proposed for a large number of Hydroelectric Power Plants, under license and implementation processes in the Doce, Paraíba do Sul and Jequitinhonha rivers' basins. The first "trap and trucking" type fishway, ever to begin operating in Brazil, was installed in the Santa Clara Dam, located on the Mucuri River, Minas Gerais state. The relatively complex operation of fish lifts, including a great number of electric and mechanical devices, can result in frequent interruptions of transposition activities and physical injuries to fish. When in the first operational stage of the Santa Clara Dam's fish lift , between October 2003 and February 2004, a series of potential mechanical improvements were raised, with the objective of making the transposition process safer, more practical and more efficient. The main adjustments suggested are presented in this paper, as well as the evaluation of the eventual adopted procedures. It is expected, with this study, to contribute in improvements in the project and planning of similar structures to be implemented in Brazilian Rivers.*

Keywords*: fish lift; Mucuri River;operational optimization*

1. Introduction

In South America, several freshwater fish species are migratory, executing long distance movements along the rivers during their life cycle. In Brazil, these species are the most important for fisheries, reaching large sizes (Welcomme, 1985). Migration takes place in a wide range of taxa occurring in South America, although the most conspicuous migrations are principally associated with Characiformes and Siluriformes orders.

In general, freshwater fish migration in South America can be described as following. During the wet season, the movements involve spawning migrations of adults upstream, and subsequent downstream movements of the spent adults, which are followed by similar displacements of the larvae or young (Petrere, 1985).

Many alternatives in order to minimize adverse effects of barriers on fish migration have been proposed and implemented. However, this is a complex process, which demands integrated strategies from several areas and professionals, especially from Engineers and Biologists. Among these strategies, employed to reduce the effects of barriers on fish migration, the construction of fishways can be considered the most common. They are hydraulic structures with the main objective of allowing the downstream and/or upstream passage. The recent legislation of some Brazilian states (e.g. Minas Gerais, 1997) has been obliging fishway constructions in dams, including the ones fated to reservoir formation of hydroelectric plants.

Fishways essentially consist in a water conduct, through or around an obstacle, which dissipates energy allowing the fish to swim for passage without exceeding stress. Fish ladders, locks, and lifts are considered fisways.

The fish ladder, the most common and used fishway in the world, basically consists in a series of tanks, in steps, connecting the upstream part together with the downstream, with water flowing from tank to tank (Clay, 1995). The fish go up the ladder swimming or leaping through the tanks.

The functioning of fish locks is very similar to the ones constructed for ships. These mechanisms basically consist in chambers which can be closed after fish entrance, when the water level is raised through an intake supply. For the fish exit, descendant flows are created inside the chamber, which are dissipated, with the opening of the sluice.

Fish lifts are mechanical systems, where the fish are captured in a correctly dimensioned tank, located in the dam's basis, which is elevated and opened upstream, allowing the fish to leave in the direction of the reservoir.

It is also possible to find a variant of this mechanism, known as the "trap and trucking" type. In this system, after being captured, the fish is conducted to a tank in a specially adapted truck, which will do the downstream-upstream moving (Clay, 1995).

The greatest advantage of a "trap and trucking" mechanism, is related to its versatility, relative to the release spot of the passed individuals, making it appropriate in several situations (Pompeu and Martinez, 2003).

In rivers presenting sequential barriers, the "trap and trucking" fish lift allows fish to be captured close to the downstream reservoir's dam and transported directly to the upstream reservoir. This way, recurring transposition of individuals is avoided as well as the construction of several fishways. Considering the fact that no fishway presents an efficiency of 100%, the reduction of transpositions in a certain river, would bring significant advantages to the overall system's efficiency.

The larger flexibility of the system is also a reason why it can be applied in plants that have a Power house distant from the dam. When the possibility of spill is low, even though when in higher precipitation periods, the efficiency of a fishway implemented close the dam is compromised, as the fish frequently find difficult to reach it. In this cases, the "trap and trucking" type fishway, allows the fish to be attracted and captured, close to the Powerhouse, where it can generally be observed a high concentration of shoals, and transported to the reservoir.

When compared to fish ladders, the lifts also present the advantage of permitting the adjustment of the number and time of transposition cycles, according to the time when shoals are found. This procedure, in some cases, can mean great water saving. However, this adjustment can only be obtained through the careful and detailed study of the migratory behavior of the local fish communities (Pompeu, 2005).

Fish lifts present two disadvantages though, when compared to fish ladders, which are more emphasized when using the "trap and trucking" system. They present higher operational costs, as it demands a larger number of operators and more complex equipment maintenance. Besides that, suspicions have been raised by society concerning its operational execution by the contractor.

Generally, fish ladders have been preferentially constructed in barriers up to 25 meters high. For higher heads, fish locks and lifts have been utilized more frequently. This fact is associated to high costs of fish ladders and little knowledge on the fishes' physical capacity concerning transposition in higher heads (Clay, 1995).

Fishways such as the "trap and trucking" fish lift, have been proposed for a great number of power plants, under license or implementation processes, on the Doce, Paraíba do Sul and Jequitinhonha Rivers´ basins, east of Brazil. The first "trap and trucking" fish lift ever to operate in Brazil, was implemented in the Santa Clara Hydroelectric Power Plant's dam, which is located on the Mucuri River, Minas Gerais state. Therefore, this paper had the objective of proposing mechanical modifications for the operational optimization of the Santa Clara Dam's fish lift.

2. Study area

The Mucuri River is an independent drainage in the east coast of Brazil, where at least four freshwater migratory characins and eight marine fish species can be found. The Santa Clara Power Plant was built in 2001 in the middle course of the Mucuri River (Fig. 1). The dam is 60 m high and the reservoir has an area of 15 km^2. Its powerhouse is equipped with three Francis turbine units, operating with 160 rotations per minute. The three independent conventional spillway gates are 11.5 m wide and 15.8 m deep each.

Figure 1. Santa Clara Power Plant

In November, 2003, a "trap and trucking" fish lift began operating in the Santa Clara Power Plant's dam, located 200 m downstream the dam, immediately after the tailrace (Fig. 2). It includes an attraction (collection) channel, an elevator, and a truck equipped with a tank. An operational cycle of the fishway takes about 35 minutes, and consists of the following sequence of events. Fish are attracted to the entrance of the collection channel by a flow of 3 m^3/s. The collection channel is 1.8 m wide, 16 m long, and its deep varies with Mucuri River level, from 40 cm up to 3.5 m. A fish elevator is located in the upstream extremity of the channel. The operational cycle begins with the movement of a mechanical screen, located 8 m upstream the channel entrance, which crowds the fishes in the direction of the elevator. The elevator has a capacity of 4 m^3, and requires 10 minutes to travel from the collection channel to the level where the fish are transferred to a truck equipped with a tank with the same capacity. When the elevator is empty, it is returned to its initial position, and the truck carries the fish to the reservoir, in a trip of approximately 15 minutes, where they are released.

The Santa Clara Power Plant's trap and truck system is currently in use, operating during the official legal migration period, from November to March. During this migration period, every day, operation cycles are performed each two hours, from 8:00 am up to 06:00 pm.

Figure 2. Santa Clara dam's fish lift with a "trap and trucking" system

3. Methodology

When in the first operational stage of the Santa Clara Power Plant's fish lift, between October 2003 and February 2004, the operation of this fishway was daily monitored. Possible mechanical improvements were raised, with the objective of making the transposition process safer, more practical and more efficient.

4. Results and discussion

During the four months of activities, 67841 individuals of 32 species were transposed by the fish lift (Tab. 1). In average, 106 fish were transported per cycle, with a maximum of 5021 individuals. In 255 transposing cycles, no individuals were transposed.

Only 0.48% of the transposed fish died or was injured during the complete transposition cycles. However, marine specimens, which present a habit of leaping when in the elevator chamber, and the Siluriformes, fish which swim on the bottom, were more injured, when compared to the migratory fish and the total transposed community (Fig. 3). Although this mortality value is low, it is important to point out that mortality rates are frequently higher in mechanical fish way systems, like lifts and locks, when compared with fish ladders.

The relatively complex operation of fish lifts, including several electric and mechanical devices, can result in frequent interruptions of transposition activities, which can last for a long period of time. During the studied migration period, during about ten days, at least 2 hours' interruptions were observed. Besides, its maintenance cost is extremely high when compared to fish ladders. These are the reasons why stationary mechanisms (with no mobile parts), such as ladders, have been more often used in France, because although they are expensive in an Engineering point of view, they are more trustworthy and easier to be maintained (Larinier, 2002).

The experience in Santa Clara was of great value for the correction of some procedures and modifications of equipment which showed to be inadequate in some situations. Thus, several proposals of modifications were made in order to improve the existent mechanism's efficiency and also to direct future projects. Some of these modifications were already implemented during the following migration period, on the years 2004/2005.

Table 1. Total number and relative abundance of the 32 fish species registered during the fish lift's activity.

Specie	Common Brazilian name	Abundance	
		N	%
Migratory species			
Prochilodus vimboides	Curimatá	23,012	33.92
Leporinus conirostris	Piau-branco	5,825	8.59
Leporinus steindachneri	Piau-capim	4,943	7.29
Brycon ferox	Piabanha	1,075	1.58
Leporinus copelandii	Piau-mutengo	38	0.06
Prochilodus affinis	Curimatá	24	0.04
Total		34,917	51.48
Marine species			
Centropomus undecimalis	Robalo	541	0.80
Centropomus paralellus	Robalo	350	0.52
Mugil curema	Tainha	172	0.25
Charanx latus	Xaréu	1	0.00
Achirus lineatus	Linguado	1	0.00
Total		1065	1.57
Siluriformes species			
Pogonopoma wertheimeri	Cascudo-preto	670	0.99
Parauchenipterus striatulus	Cumbaca	71	0.10
Pseudauchenipterus affinis	Ferrolho	15	0.02
Trichomycterus spp.	Cambeva	15	0.02
Rhamdia quelen	Bagre	10	0.01
Pimelodella vittata	Mandi	4	0.01
Hypostomus affinis	Cascudo-areia	3	0.00
Hypostomus luetkeni	Cascudo-chicote	1	0.00
Total		789	1.15
Other species			
Astyanax intermedius	Lambari	24,775	36.52
Astyanax bimaculatus	Lambari-do-rabo-amarelo	5,694	8.39
Cyphocharax gilbert	Sagüiru	439	0.65
Oligosarcus acutirostris	Bocarra	48	0.07
Geophagus brasiliensis	Cará	42	0.06
Cichla monoculus	Tucunaré	27	0.04
Hoplias malabaricus	Traíra	24	0.04
Awaous tajassica	Peixe-flor	6	0.01
Oreochromis niloticus	Tilapia	5	0.01
Pachyurus adspersus	Corvine	4	0.01
Characidium spp.	Bananinha	3	0.00
Brycon vermelha	Vermelha	2	0.00
Gymnotus carapo	Sarapó	1	0.00
Total		31,070	45.8
General total		67,841	100.00

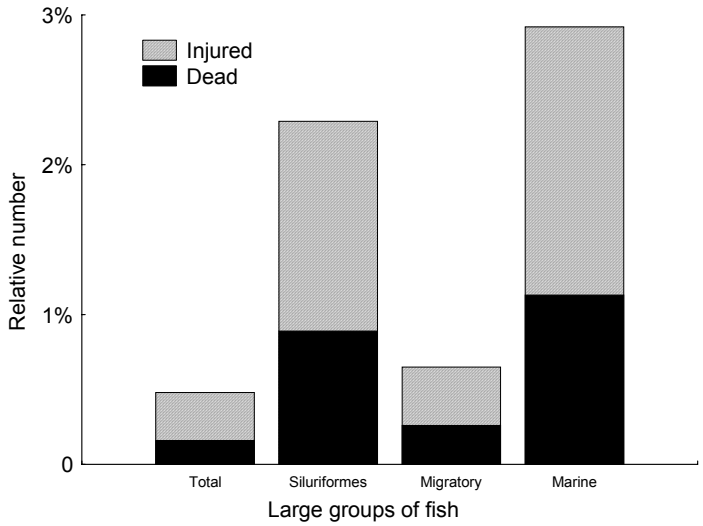

Figure 3. Relative number of injured or dead individuals during the lift's operation in the Santa Clara Power Plant

The proposed modifications, which had the main objective of reducing the mortality rate in the mechanical structures and allowing a better specimens transfer from the elevator chamber to the truck, were as follows:

- Protection for the command central equipment, so as to avoid the constant electric and mechanical failures, making it a safer and more efficient system. (Fig. 4);

Figure 4. Protection for the command central equipment, so as to avoid the constant electric and mechanical failures

- Installation of guide rails, in order to enable an easier return of the elevator chamber to the attraction flow canal;
- Increasing of the length of the truck's tank outlet, so as to enable an easier release of fish in the reservoir;
- Decreasing of the distance between the crowder and the wall, with the objective of avoiding the smashing of bottom species and the escape of individuals during the operation of this gate, and installation of rubber protection in the side of the chamber in order to avoid fish escape during its ascent, making the system more efficient (Fig. 5);

Figure 5. Rubber protection in the side of the chamber in order to avoid fish escape during its ascent

- Installation of a flexible protection, inside the iron screen, to avoid fish injuries in the specimens jumping inside the elevator chamber (Fig. 6).

Figure 6. Flexible protection, inside the iron screen, to avoid fish injuries in the specimens jumping inside the chamber

Considering the number of transposed fish, it is possible to state that the "trap and trucking" type fish lift in the Santa Clara Power Plant is as efficient or even more efficient than the few fishways implemented in South America, that have any kind of available data which allows comparisons (Pompeu, 2005). Therefore, it can be considered applicable to the Brazilian reality, especially on the rivers of the east basin. Its greatest applicability in this region is based on the absence of migratory bottom species (Siluriformes), as this specie showed a larger mortality and injury rate, by the contact with mechanical parts of the lift.

Despite being simple, these proposed mechanical modifications were capable of severely reducing the number of injured and dead fish, freshwater or marine fish, as well as the interruptions of transposition activities due to electrical and mechanical failures. Therefore, it is expected that, through this paper, a contribution has been given concerning the improvement of future projects of fish lifts to be implemented in Brazil.

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