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Efficiency and selectivity of a trap and truck fish passage system in Brazil

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The construction of fish passages has been one of the strategies adopted by the Brazilian energy sector in order to diminish the effects of barriers on fish communities. However, studies of the efficiency of these mechanisms are scarce. The present study evaluated the efficiency and selectivity of the first trap and truck fish passage system in Brazil, installed in Santa Clara Dam, Mucuri River. The species composition in the Santa Clara Dam fish lift was compared to the original composition of Mucuri River fish fauna and with the populations that gather downstream of the dam during the reproductive season. The proportion of previously tagged individuals translocated by the lift was used to estimate its efficiency. During the 2003/2004 reproductive period, 67,841 individuals of 32 species passed through the lift, which corresponds to 66% of the lower Mucuri river fish richness. Less than 0.5% died or were injured during the passage. When compared to the river's population, less representative captures of smaller individuals and marine species were observed. However, the composition and structure of the community in the fish lift was quite similar to those downstream of the dam during the reproductive season. The estimated efficiency of the fish lift ranged from 0.2% for *Pogonopoma wertheimeri* to 16.1% for *Leporinus conirostris* reaching an average of 7% for all migratory species.

A construção de passagens para peixes tem sido uma das estratégias adotadas pelo setor elétrico como forma de diminuir os efeitos de barramentos sobre as comunidades de peixes. No entanto, trabalhos de avaliação da eficiência destes mecanismos são escassos. Neste trabalho são avaliadas a eficiência e seletividade do primeiro elevador com caminhão tanque instalado no Brasil, na Usina Hidrelétrica de Santa Clara. A composição de espécies no elevador foi comparada com aquela original do rio, e com a das populações que se aglomeram a jusante da barragem, durante a estação reprodutiva. A proporção de indivíduos previamente marcados transpostos pelo elevador foi utilizada como forma de estimar sua eficiência. Durante o período reprodutivo (2003/2004) 67841 indivíduos de 32 espécies de peixes passaram pelo elevador, o que corresponde a 66% da riqueza do baixo curso do rio Mucuri. Destes, menos de 0,5% morreram ou foram feridos durante a passagem. Quando comparado com as populações do rio, foram observadas no elevador capturas menos representativas de indivíduos de pequeno porte e de espécies marinhas. No entanto, a composição e estrutura da comunidade no elevador foram bastante similares àquela observada a jusante da barragem durante o período reprodutivo. A eficiência estimada para o elevador variou de 0,2% para *Pogonopoma wertheimeri* até 16,1% para *Leporinus conirostris*, sendo de 7% para o conjunto de espécies migradoras.

Key words: Fishway, Mucuri River, Ichthyofauna, Reservoir Management.

Introduction

In Brazil, the main emphasis in the management of reservoir fisheries seems to be on the rehabilitation of the fish species affected by the formation of dams. The companies are obliged to protect threatened fish species either by incorporating fish ladders in the dam design for facilitating easy migration, or by creating breeding facilities to produce fingerlings of the affected native species to be stocked in the reservoir (Sugunan, 1997).

Although only a small fraction of South American species are migratory (Petrere Jr., 1985; Godinho & Godinho, 1994), they are the most important for professional (Goulding, 1979; Bittencourt & Cox-Fernandes, 1990; Godinho, 1993) as well as amateur fishing, due to their larger size and abundance (Northcote, 1978).

For decades, the environmental legislation made fish stocking and the control of fisheries the main, and in some cases, the only strategy for the conservation of these species (Agostinho *et al.,* 2007). Although these policies continue to be

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pursued throughout the country, studies are lacking that determine their efficiency in the recuperation of species and threatened populations, as well as their cost-benefit ratio and their role in the sustained management systems of fish populations (Vieira & Pompeu, 2001). The low fishery yield in reservoirs located in the South and Southeast regions of Brazil, with a significant reduction of migratory species (CESP, 1996; Agostinho *et al.*, 1994) clearly indicates that this strategy is not satisfactory (Agostinho *et al.*, 2004; 2007).

The construction of fish passages was another strategy adopted by the Brazilian energy sector in order to diminish the effects of barriers on fish communities, mainly the migratory species. The first fish ladder in Brazil was constructed in 1911, at the Itaipava Dam, in the Pardo River, upper Paraná Basin (Godoy, 1985). In 1927, the construction of fish ladders became a legal requirement in São Paulo State (Agostinho *et al.*, 2002). With the increasing number of hydroelectric facilities in the 1960s, the necessity of fish passages was incorporated by the legislation of other states. Currently, several such structures have been installed in Brazil, including ladders and lifts.

However, evaluation studies are scarce, and as in other actions connected to the management of fishing resources in reservoirs, most of the fish passages were never monitored, despite the high investments and efforts involved (Agostinho *et al.*, 2002). In this context, efficiency can be defined as the proportion of fish that utilize the fish passage facility (Novak *et al.,* 2003), and selectivity refers to the selection of different species or size classes.

The studies performed in South America have mainly concentrated on fish ladders (Fontenele, 1961; Godoy, 1987; Godinho *et al*., 1991; Agostinho *et al.*, 2002; Fernandez *et al.*, 2004; Vono *et al*., 2004), focusing on their selectivity concerning a particular fish species.

In this paper, we evaluated the efficiency and selectivity of the first trap and truck fish passage system in Brazil, installed in the Santa Clara Power Plant, Mucuri River.

Material and Methods

Study Area

The Mucuri River is part of independent basins which drain the east region of Brazil, having a total drainage area of 15,100 km^2 (CETEC, 1983). The basin's hydrological regime is characterized by two well-defined seasons, dry and rainy, with larger flows from November to April, when the breeding of most of the region's fishes takes place (Pompeu, 2005). The river can be divided into two environmental units, according to their physiographic characteristics: its upper and middle courses show a larger declivity, rapids and a predominantly rocky bottom; its lower course, however, is characterized as a deposition system, with small declivity, predominantly sandy bottom, with the existence of a seasonally flooded Atlantic Rainforest (Mata Atlântica), utilized for cocoa cultivation, and wetlands and mangroves near the coast.

Santa Clara Dam is located on the Mucuri River, in a transitional zone between these two physiographic units, approximately 80 km from the river's mouth on the Atlantic Ocean (UTM 24373189E; 8020748N) (Fig. 1). Dam construction began in 1999, and the first turbine became operational in February, 2002. The concrete dam has a maximum height of 60 m and is 240 m long. In November of 2003, a fish passage with a trap and truck system became operational in the Santa Clara Hydroelectric Plant. It is located 200 m downstream of the dam, immediately after the tailrace. It includes an attraction (collection) channel, an elevator, and a truck equipped with a tank. An operational cycle of the fish passage takes about 35 minutes, and consists of the following sequence of events. Fish are attracted to the entrance of the collection channel by a 3 m^3/s flow, supplied from the reservoir. The collection channel is 1.8 m wide, 16 m long, and its depth varies with the 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 of the channel entrance, which crowds the fish 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 an approximately 15-minute trip, where they are released 500 m upstream of the dam. It has been operated during the rainy season, with cycles every two hours during the day.

Sampling and Analyses

The species composition in the Santa Clara Dam's fish lift was compared to the original composition of lower Mucuri River fish fauna and with the populations that gather downstream of the dam, in the tailrace, during the reproductive season (October to March).

Fish samplings were performed every three months, between October of 1998 and July of 2001, in the lower Mucuri River at three stations, located 1, 40 and 80 km downstream of Santa Clara Dam, respectively. Fish were caught with gillnets (20 m long, with 3 to 12 cm stretch mesh), seines (5 m long and

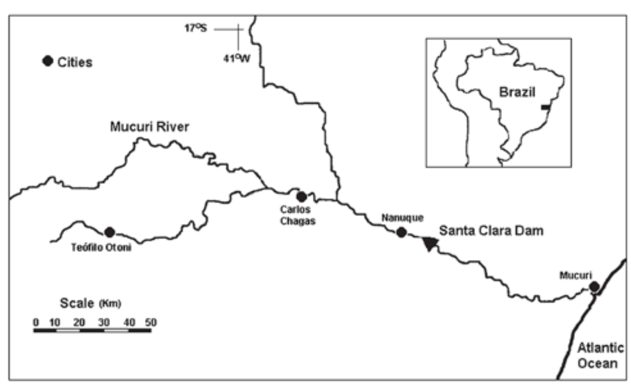

Fig. 1. Mucuri basin, indicating the location of Santa Clara Dam.

1 mm mesh), cast nets (3 cm stretch mesh) and hand nets (1 mm mesh). Gillnets were fished in the water column for 14 h overnight. Seines were used in shallow areas or littoral zones, hand nets were employed in near-shore aquatic macrophytes and in riffles, and cast nets were used in habitats too deep to wade. The three latter methods were employed for 1-3 h and used only qualitatively. After being captured, the fish were immediately fixed in 10% formaldehyde solution and subsequently preserved in 70% ethanol. In the laboratory, each fish was measured for standard length and identified. Catch per unit of effort (CPUE) in number (CPUEn) was used to express data on numerical abundance (number of individuals per 10 m^2 of net in 14 h; CPUEn).

For the evaluation of the fish community which concentrated in Santa Clara's tailrace, between October 15th of 2002 and February 15th of 2003, fish were caught by four professional fishers using cast nets with mesh sizes of 6 and 8 cm (between opposite nodes). The fishers caught the largest possible number of individuals, in a pre-determined 300-m course immediately downstream of the dam, including the tailrace. These fishers began at 7:30 a.m. and finished at 5 p.m., during the entire period, from Monday to Saturday. After the capture, the fish were counted, identified, measured and transported to the reservoir, where they were released to avoid harmful effects.

For the evaluation of the fish lift's efficiency, immediately before the beginning of its operation, between October 16th and November 7th of 2003, fish were captured downstream of the Santa Clara Dam with cast nets (3 cm stretch mesh). All fish were tagged with an external hydrostatic tag and released in the river at the same place where they were captured. The proportion of these tagged individuals transported by the lift was used to estimate its efficiency by species, for the group of migratory ones and total fish fauna of the Mucuri River.

On November 19th of 2003, the operation of the Santa Clara Dam fish lift was initiated, and conducted for 4 months, until March 19th of 2004. During the operational period, from Monday to Saturday, six daily passing cycles were carried out, at 8 a.m., 10 a.m., 12 p.m., 2 p.m., 4 p.m. and 6 p.m. At15-day intervals, night passage cycles were also performed, at 8 p.m., 10 p.m., 12 a.m., 2 a.m., 4 a.m. and 6 a.m. A total of 636 passage cycles were performed, 588 day and 48 night cycles.

At each cycle, before releasing of the fish in the reservoir, they were counted, identified and measured. The dead or injured individuals and the tagged ones were recorded. Regression analysis was used to test the relationship between the number of dead or injured individuals and the number of fish transported in the truck's tank.

Although the movements of the Mucuri fishes were not studied, they were considered migratory, and the lift's target species, the native ones from the genera *Leporinus*, *Prochilodus* and *Brycon*, have representatives with known migratory behavior (Lucas & Baras, 2001). For four of these species (*L. conirostris, L. steindachneri, P. vimboides* and *B. ferox*), the selectivity in size was evaluated by comparing the standard size classes of the individuals observed in the lift with the size classes of the individuals caught in the Mucuri River between 1998 and 2001, and with the fishes caught with cast nets immediately downstream of the dam in 2002/2003. The lift's selectivity was also evaluated by comparing the richness of the fish assemblages caught in the lower Mucuri River and in the tailrace, with the one passed by the mechanism.

Results

In the lower Mucuri River, 49 fish species were recorded, including 34 native freshwater, five exotic and ten marine (Table 1).

Of the Mucuri's fish species, 33 were captured in Santa Clara's tailrace (2002/2003 reproductive season) and 32 were passed by the fish lift (2003/2004 reproductive season) (Table 1). During both occasions, only six species were responsible for more than 95% of the individuals, a pattern different from the lower Mucuri River's assemblage (Fig. 2). However, while four migratory species (*P. vimboides, L. conirostris, B. ferox* and *S. steindachneri*) were found in great abundance during the two events, *Pogonopoma wertheimeri* was considerably more abundant in the captures conducted in the tailrace, and the lambaris (*Astyanax* spp.) were only recorded in the fish lift.

The species recorded in the fish lift represented 66% of the region's native fish richness. Species which were not recorded in the lift were, in general, of smaller sizes (Fig. 3). Besides, only five out of ten marine species present were passed (Table 1).

Freshwater migratory species, the main target of the fish passage, comprised approximately 50% of individuals captured in the tailrace with cast nets (2002/2003), the same proportion found in the fish lift (2003/2004), while in the river, they represented only 19% of captures with gillnets (Fig. 4). For the migratory species, the relative abundance per size class was also similar when compared to the fish caught in the tail race and passed by the fish lift. However, in compar-

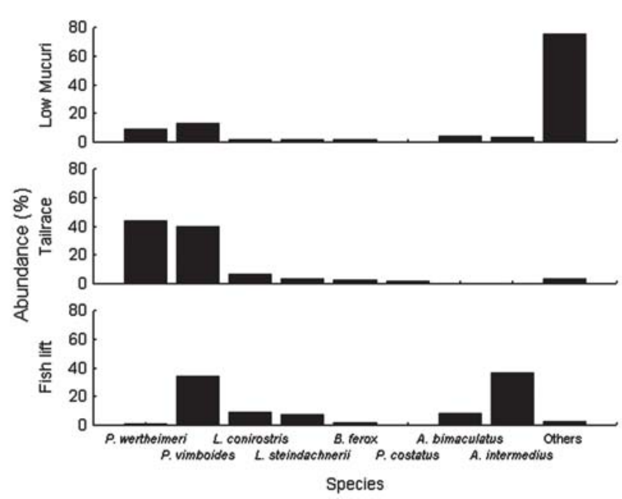

Fig. 2. Abundance (%) of captured species in the Santa Clara tailrace (2002/2003) and passed by the fish lift (2003/2004).

Table 1. Maximum recorded standard length (MRSL) of recorded Mucuri River species and abundance in the lower course (CPUEn%), in the tailrace and in the fish lift, and condition of the fish after they were transported by the trap and truck system.

Species	MRSL	CPUEn	Dowstream		Fish lift		Condition (%)	
	(cm)	%	N	%	N	%	Injured	Dead
Freshwater species								
Australoheros sp.	10.4	0.06	-	-	-	-	-	-
Astyanax bimaculatus	13.5	4.18	-	-	5694	8.39	0.02	0.00
Astyanax intermedius	6.0	2.88	2	< 0.00	24775	36.52	0.00	0.19
Awaous tajassica	20.5	0.11	1	< 0.00	6	0.01	0.00	0.00
Callichthys callichthys	14.1	0.23	-	-	-	-	-	-
Characidium sp.	5.5	-	-	-	3	< 0.00	0.00	0.00
Corydoras nattereri	6.7	-	-	-	-	-	-	-
Cyphocharax gilbert	18.2	9.99	130	0.30	439	0.65	0.00	0.00
Delturus angulicauda	17.0	2.09	3	0.01	-	-	-	-
Geophagus brasiliensis	20.5	2.37	42	0.10	42	0.06	0.00	0.00
Glanidium albescens	11.6	0.28	-	-	-	-	-	-
Gymnotus carapo	33.8	-	-	-	1	< 0.00	0.00	0.00
Hoplerythrinus unitaeniatus	19.5	-	1	< 0.00	-	-	-	-
Hoplias malabaricus	38.5	2.09	46	0.11	24	0.04	0.00	0.00
Hypostomus affinis	32.0	5.14	65	0.15	3	< 0.00	0.00	0.00
Hypostomus luetkeni	30.0	1.02	33	0.08	1	< 0.00	0.00	0.00
Leporinus mormyrops	23.5	1.81	26	0.06	-	-	-	-
Microglanis parahybae	6.3	-	-	-	-	-	-	-
Moenkhausia doceana	8.3	2.37	-	-	-	-	-	-
Otothyris travassosi	2.5	-	-	-	-	-	-	-
Oligosarcus acutirostris	19.5	18.13	1	< 0.00	48	0.07	0.00	0.00
Pachyurus adspersus	29.5	0.96	52	0.12	4	0.01	0.00	2.82
Parauchenipterus striatulus	17.5	11.91	6	0.01	71	0.10	0.00	25.00
Pimelodella lateristriga	11.0	0.51	-	-	4	0.01	1.05	1.05
Pogonopoma wertheimeri	44.0	9.26	18871	43.65	670	0.99	0.00	0.00
Pseudauchenipterus affinis	15.0	2.77	-	-	15	0.02	0.00	0.00
Rhamdia quelen	26.6	0.40	12	0.03	10	0.01	0.00	0.00
Trichomycterus sp.	15.0	0.06	-	-	15	0.02	0.00	6.67
Total		78.62	41764	44.62	66720	46.90		
Migratory								
Brycon ferox	34.5	1.98	1016	2.35	1075	1.58	0.09	1.41
Brycon vermelha	41.9	0.56	2	< 0.00	2	< 0.00	0.00	0.00
Leporinus conirostris	50.5	1.81	2948	6.82	5825	8.59	1.02	0.67
Leporinus copelandii	46.0	0.17	108	0.25	38	0.06	0.00	0.00
Leporinus steindachneri	32.0	1.30	1382	3.20	4943	7.29	0.12	1.32
Prochilodus vimboides	42.0	12.99	17017	39.36	23012	33.92	0.00	0.00
Total		18.81	22473	51.98	34894	51.44		
Exotic								
Cichla monoculus	36.0	-	7	0.01	27	0.04	0.00	0.00
Clarias gariepinnus	70.0	-	10	0.02	-	-	-	-
Leporinus macrocephalus	42.6	-	3	< 0.00	-	-	-	-
Oreochromis niloticus	27.0	0.06	129	0.30	5	0.01	0.00	0.00
Prochilodus costatus	38.0	-	656	1.52	24	0.04	0.10	0.08
Total		0.06	805	1.85	56	0.09		
Marine species								
Achirus lineatus	8.0	0.06	-	-	1	< 0.00	0.00	0.00
Bairdiella ronchus	19.1	0.28	-	-	-	-	-	-
Centropomus paralellus	35.8	0.9	148	0.34	350	0.52	0.00	1.72
Centropomus undecimalis	45.0	0.06	67	0.15	541	0.80	0.00	1.11
Charanx latus	22.5	0.11	9	0.02	1	< 0.00	0.00	0.00
Diapterus rhombeus	26.0	-	230	0.53	-	-	-	-
Eugerres brasilianus	24.4	0.11	-	-	-	-	-	-
Genidens genidens	22.0	0.85	9	0.02	-	-	-	-
Megalops atlanticus	48.0	-	29	0.07	-	-	-	-
Mugil curema	52.0	0.17	174	0.40	172	0.25	7.10	4.14
Total		2.54	666	1.53	1065	1.57		

ing these fish assemblages with the natural composition of the river, less representative captures of smaller-sized individuals were observed (Fig. 5).

No significant relationship was seen between the number of fish passed per cycle and the mortality rates during their capture by the fish lift and transportation ($F = 1.898$; $p = 0.169$). Of the total of passed individuals, only 0.48% died or were injured during the complete fish passage cycles (Table 1). However, marine species and the Siluriforms suffered more injuries, when compared with the migratory Characiforms and the total passed community (Fig. 6).

During the period prior to the lift's operations, 1718 indi-

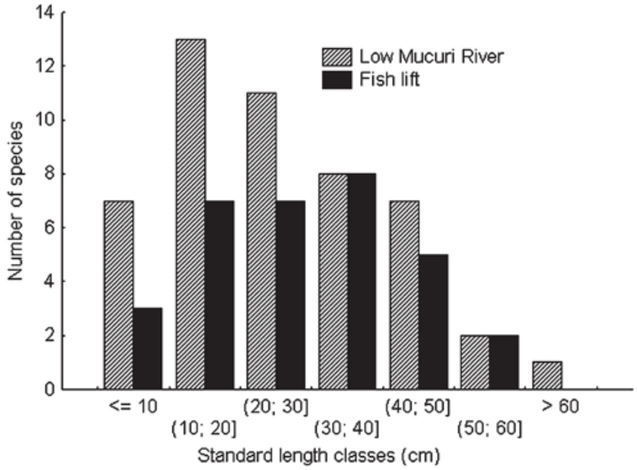

Fig. 3. Number of species by size class found in the lower Mucuri River and passed by the Santa Clara Dam fish lift.

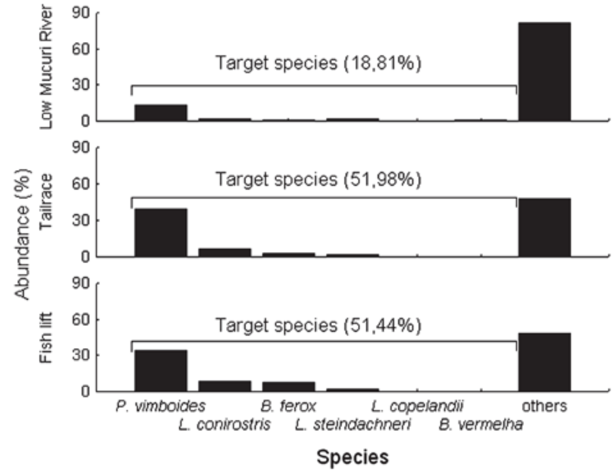

Fig. 4. Relative abundance of target species in the lower Mucuri River, in the Santa Clara tailrace (2002/2003) and in the Santa Clara Dam fish lift (2003/2004).

viduals of 21 species were tagged. However, only five species had individuals captured during the passage. The efficiency of the mechanism, estimated through the capture rates, varied from 0.2% for the cascudo-preto (*P. wertheimeri*) up to 16.1% for the piau-branco (*L. conirostris*), with 7% for the group of migratory species and 3.1% for the region's fish community group (Table 2).

Discussion

In a general way, the fish lift can be considered to have a low selectivity in relation to species, but it also showed difficulty in capturing small-sized individuals. The mesh size range used in gillnets (3-12 cm) for the lower Mucuri River, can capture smaller fish when compared to cast nets (6-8 cm) used in the tail race. This way, the similarity between the assemblages passed by the lift, and sampled in the tail race must be reflecting comparable selectivity. The efficiency of a fish lift concerning the capture of small-sized individuals is related directly to the dimensions of the screen mesh, which is supposed to be sufficiently small to prevent fish passing through it. This can lead to difficulties since very small fish require very small screen mesh sizes, which would result in maintenance difficulties (Larinier, 2002). It is important to point out that the fish lift was highly selective for *Pogonopoma wertheimeri*, a non migratory bottom catfish, which was very abundant downstream of the dam, even in the captures with cast nets, but showed a very low recapture rate by the lift. A few studies have focused on the efficiency of fish passages in South America, in terms of number of fish passed and their capacity to utilize the mechanism (Godoy, 1975; Godinho *et al.,* 1991; Fernandez *et al.*, 2004; Vono *et al.*, 2004). These studies have also indicated that many individuals of a few species have overcome the passage and a variable selectivity regarding species composition.

In the case of fish lifts, the mortality rates must also be taken into account when evaluating the mechanism. In the case of the Santa Clara fish lift, marine species and Siluriforms were particularly more sensitive, although the mortality rate for the group of passed species was kept extremely low. Even the density in the elevator and in the truck's tank does not seem to have influenced the survival capacity of the individuals during the passage process. Considering the fact that the Siluriforms, possibly because they swim close to the walls (Santos *et al.*, *in press*), have a greater probability to suffer damage due to the motion of the mechanical parts, the absence of migratory fish in this order must have contributed to minimize mortality rates or fish injuries.

Quantitative estimates of the efficiency of fish passages are only possible through tagging and recapture programs or when there is another fish passage downstream, where the number of passed individuals has been determined. Even in North America, these kinds of studies are scarce. From a databank of 213 projects for which at least one paper concerning fish passage has been published, information on the number of fish which utilized the mechanism was only available for eight mechanisms, where only three provided sufficient data for a quantitative estimate of the efficiency (Novak *et al.*, 2003).

When compared to the little information available in South America, it is possible to state that the Santa Clara mechanism seems to be more efficient than the only system that has been evaluated with similar methods. According to Oldani & Baigún (2002), only 0.68% of migratory individuals and 1.88% of individuals belonging to all species of the La Plata River, utilize the two fish lifts implemented in the Yaciretá Dam, in Argentina. Species considered target species, despite representing 30% of the captures with nets, downstream of the dam, comprised only 10% of the total number of fish passed.

Some causes were pointed out for the low efficiency of the Yaciretá fish lift (Oldani & Baigún, 2002):

(a) "Fishway dimensions are undersized by a large margin for the number and size of fish that should be passed. Elevator cross-sectional areas are small compared to the attraction

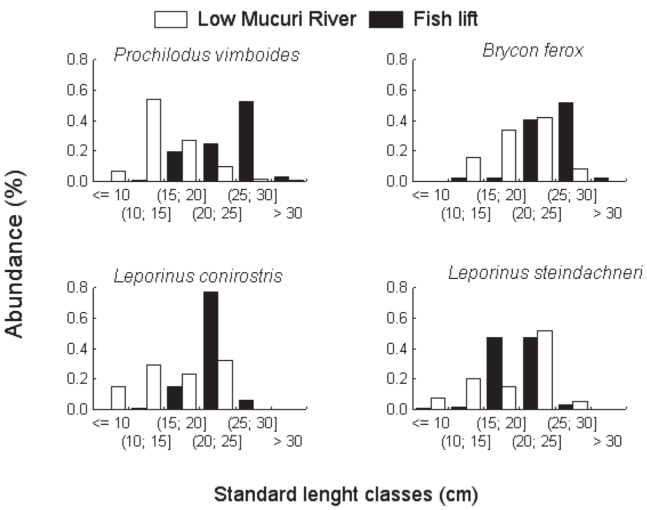

Fig. 5. Relative abundance of migratory species per size class for the lower Mucuri River, in the Santa Clara tailrace (2002/2003) and in the Santa Clara Dam fish lift (2003/2004).

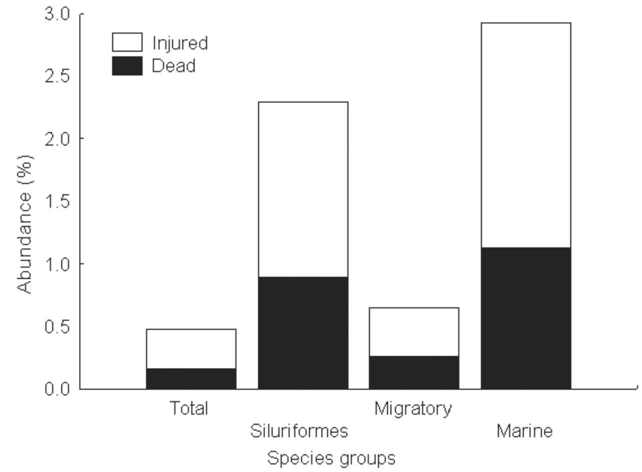

Fig. 6. Number of injured or dead fish after being passed by the fish lift according to species groups.

channel dimensions with the left elevator having only about 1.8% of the approach channel cross-section and the right elevator only 1.1%". In the case of Santa Clara, the lift channel's section represents between 4 to 5% of the river's section, and the fish community does not include large-sized species. However, more relevant is the difference in water volume available for attraction. While in Yaciretá, 1 to 2 m^3/s are used for attraction in each lift, which represents an overall value less than 0.04% of the average annual flow of the Paraná River, in Santa Clara the attraction (3 m^3/s) represents 2.2% of the average flows in the Mucuri.

(b) "Number of fish transferred by the system is limited by the number of cycles that can be completed. Even in optimal conditions, elevators cannot perform more than 24 cycles per day". In the Santa Clara lift, the same limitation is present. However, while the truck transports fish to the reservoir, the elevator can return to its initial position and start a new fish attraction process.

(c) "There is no way to regulate the number of fish that enter the elevator. Overcrowding of fish in elevators can cause serious stress and injury…" In the Santa Clara lift, during periods of large flows of fish, the mechanical screen can be lowered without running the main confining process, avoiding the entrance of new fish and diminishing this problem.

(d) "Some species of fish that are strongly rheotactic are reluctant to leave the elevators and swim through the exit channel into the upstream reservoir". In the Santa Clara fish lift, the fish are transferred from the elevator's container to the truck's tank and further to the reservoir, avoiding this problem. However, some fish, due to rheotaxis, remain in the truck's tank, which are then manually transferred to the reservoir.

(e) "The elevator entrances are very close to the turbine draft tubes so that the influence of attracting flows exiting the elevator entrance may be masked by powerhouse discharge". In the Santa Clara fish lift, this situation does not occur since the elevator's entrance is situated about 200 m from the powerhouse outtake. However, throughout the studies, large shoals could be observed next to the draft tubes, raising doubts concerning the best region for its placement, because it is not clear if they are able to move back to the region around the lift.

(f) "The geometry of the entrance to the collection channel may limit or prohibit entry of thalweg-oriented fish such as large siluriforms, since the fishway channel entrance does not connect to the river-channel bottom." The Santa Clara lift's connection channel entrance seems to perform the same limiting effect for the bottom fish's ascent, which seems to have been particularly important for the cascudo-preto *P. wertheimeri.*

The relatively complex operation of fish lifts, including the innumerous mechanical and electrical systems, results in frequent interruptions of the passage activities, which can last for long periods of time. During the reproductive period studied (four months), in ten days, there were at least 2-h interruptions in the passage activities. Its maintenance costs are also quite high when compared to fish ladders. This is the reason why static mechanisms (without movable parts) have been more utilized in France, where although they are more expensive in terms of engineering, they are more easily maintained and reliable (Larinier, 2002).

On the other hand, when compared to fish ladders, the fish lifts have the advantage of the possibility of adjusting the number and time of passage cycles according to the largest fish flows, a procedure which can, in some cases, mean the saving of large amounts of attraction water, which can be used for generation purposes (Pompeu & Martinez, 2005). The trap and truck system can also be considered a good option for passing fish in hydroelectric plants with a powerhouse distant from the dam. When the probability of spills is low even in periods of flooding, which is a common situation in small hydroelectric plants, the efficiency of a fish passage, installed next to the dam, is compromised, since the fish fre-

Table 2. Number of fish tagged in the Mucuri River, recorded in the fish lift, tagged recorded in the fish lift and estimated efficiency for the species with tagged individuals recorded in the fish lift.

Species	Tagged in the River	Recorded in the fish lift	Tagged recorded in the fish lift	Estimated efficiency
Brycon ferox	23	1075	2	8.7%
Centropomus paralellus	1	-	-	-
Centropomus undecimalis	5	-	-	-
Charanx latus	1	-	-	-
Cichla monoculus	14	-	-	-
Clarias gariepinnus	1	-	-	-
Cyphocharax gilbert	1	-	-	-
Delturus angulicauda	1	-	-	-
Diapterus rhombeus	1	-	-	-
Geophagus brasilensis	18	-	-	-
Hoplias malabaricus	8	-	-	-
Hypostomus affinis	1	-	-	-
Hypostomus luetkeni	4	-	-	-
Leporinus conirostris	124	5825	20	16.1%
Leporinus steindachnerii	112	4943	4	3.6%
Leporinus copelandii	27	-	-	-
Oreochromis niloticus	54	-	-	-
Prochilodus vimboides	440	23012	25	5.7%
Pogonopoma wertheimeri	855	670	2	0.2%
Pachyurus adspersus	8	-	-	-
Prochilodus costatus	19	-	-	-
Total fish community	1718	35525	53	3.1%
Migratory species	726	34855	51	7.0%

quently have difficulties in reaching the mechanism. In these cases, the fish passage with a trap and truck system allow the attraction and capture of fish next to the powerhouse, where shoal agglomerations are usually observed, and their transportation to the reservoir (Pompeu & Martinez, 2003).

Another important aspect of fish lifts with a trap and truck system is the possibility of controlling which and how much fish will be passed. For migratory species, depending on the dam's location, it is essential that the obstacles are overcome in such a way that the spawning sites are reached in the desired time. However, for the resident species (which perform more local trophic or reproductive movements), the main biological goal must be to avoid population fragmentation. In this case, a fish passage system can be considered efficient if it is utilized by a certain number of individuals and not necessarily by the entire population (Larinier, 1998), and the passage must be controlled to avoid fishery depletion. Considering the difficulties in promoting downstream migration through the Santa Clara dam, which occurs only during large spills (Pompeu *et al*., 2004), the passage of marine species upriver should be strongly limited, because their breeding sites are located exclusively downstream of the dam, in the estuary. Therefore, the fish lift management plan should consider the passage in large number of only the target species, for fish and conservational reasons.

As important as the fish's capability to locate the entrance of the mechanism and pass the dam is the evaluation of the importance and effectiveness of the mechanism in maintaining the populations of migratory species, an aspect rarely evaluated (Cada & Francfort, 1995; Agostinho *et al.*, 2004). For the migratory species of the Mucuri River, the spawning sites are located upstream, and the nursery areas downstream of Santa Clara Dam. However, the passage of eggs and larvae through the reservoir and dam's spillway seems to be possible (Pompeu, 2005). Considering the selectivity and efficiency values of the fish lift in attracting shoals, this mechanism will probably contribute to the conservation of the migratory fish species of the Mucuri River. However, only a long-term monitoring of the ichthyofauna will be capable of revealing its efficiency in maintaining viable populations.

Fish passages with a trap and truck system have been proposed for a great number of hydroelectric power plants. In Minas Gerais State, they were indicated for at least ten facilities in licensing or implementation processes in the Doce, Paraíba do Sul and Jequitinhonha River Basins. Because they belong to the same bio-geographic domain, called the East Basins, these basins share the majority of migratory species with the Mucuri River (Bizerril, 1994). Therefore, it is expected that the information obtained in this study will be of great importance for the evaluation of the convenience, as well as providing subsides for the implementation and operation of this kind of mechanism in other hydroelectric plants. Additionally, this information would also be quite useful for evaluating the efficiency and better planning of conventional lifts, which have also been implemented in various dams, and which have identical attraction and capture systems.

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