IMPROVEMENT OF YELLOW EELS' MOVEMENTS THROUGH FISH LIFTS

JOSÉ MARIA SANTOS
Centro de Estudos Florestais, Universidade de Lisboa, Tapada da Ajuda
1349-017 Lisboa, Portugal

JOÃO OLIVEIRA
Centro de Estudos Florestais, Universidade de Lisboa, Tapada da Ajuda
1349-017 Lisboa, Portugal

RUI RIVAES
Centro de Estudos Florestais, Universidade de Lisboa, Tapada da Ajuda
1349-017 Lisboa, Portugal

TERESA FERREIRA
Centro de Estudos Florestais, Universidade de Lisboa, Tapada da Ajuda
1349-017 Lisboa, Portugal

JOÃO PÁDUA
EDP Labelec, Rua Cidade de Goa n.º 4
2685-039 Sacavém, Portugal

Fragmentation of the river continuum by high dams and subsequent reduction in habitat availability has been cited as an important factor contributing to population decline of inland stocks of European eel (*Anguilla anguilla*). Eels have typically difficulty using traditional fishways because water velocities and turbulence limit their upstream movements. However, when it comes to use fish lifts, performance is often unknown. Upstream yellow eel passage was continuously monitored at the Touvedo fish lift (Lima River, northwest Portugal) by a combination of video-recording and electrofishing sampling during two annual sampling periods to analyze the effect of reduction of the free gap between the bars of the trapping cage on eel escapement: i) August 11 to September 12, the pre-treatment phase when the free gap was 23 mm and ii) March 13 to February 14, the post-treatment phase when the free gap was reduced to 5 mm. Upon reduction of the free gap of the trapping cage, the number of lifted individuals increased more than threefold (1207 to 3852 individuals), though the seasonality of movements and the environmental triggers of migration remained similar during both periods. Differences in population size–structure were also noted between the pre- and post-treatment phases, with a significant higher proportion of smaller individuals found during the post-treatment. Reducing the free gap between retention bars of fish lifts may decrease escapement of small yellow eels, therefore expanding the use of such facilities for this and other small-sized species individuals.

1 INTRODUCTION

The populations of the European eel (*Anguilla anguilla*) have been continuously declining throughout its distribution area since the 1980s [1]. It is likely that the causes for such decline are due to a multitude of factors (e.g., water quality degradation, overfishing, introduced pathogen) of which the loss of habitat as a results of disruption of longitudinal connectivity due to weir and dam construction, is one of the most important [2]. As a result, there is an urgent need for research on eel movement patterns across barriers in a tentative to define management actions to improve fisheries stocks. Though many studies have been undertaken on the migratory ecology of downstream migrating silver eel, much less information is available on the movements of upstream yellow eels and also on their ability in using fish lifts, the most cost-effective mitigation measures for high dams. The objective of this study was to determine if a reduction on the gap width of the fish lift trapping cage improved eels movements through the fish lift, while reducing escapement of smaller-sized individuals.

2 MATERIAL AND METHODS

2.1 Study area

The Touvedo hydroelectric power plant located 47 km from the river mouth is the first large obstacle to fish migration. The dam (42 m high) acts as a tailwater reservoir, modulating the high flows turbined by Alto Lindoso dam 16.5 km upstream, by storing them temporarily before returning them to the river with flows equal or lower than 100 m^3/s.

The Touvedo Dam is equipped with a fish lift, which was originally conceived to accommodate movements of diadromous and local potamodromous species. The lift features three entrances: two rear entrances located above the turbine gates and a wing entrance located 20 m downstream to take advantage of the attraction flow of the turbines. The attraction towards the entrances is achieved by discharging a maximum flow of 4.5 m^3/s equally distributed between the entrances. The current creates a flow in the attraction circuit, against which the migrating fish swim. Once in the circuit, the fish swim towards the lift cage, which is periodically raised and emptied at 4-h intervals.

2.2 Performance of eel movements

Eel passage through the fish lift was monitored during two annual sampling periods to analyze the effect of reduction of the gap width (i.e., the free gap between the bars of the trapping cage): i) August 2011- July 2012, the pre-treatment (reference) phase corresponding to a gap width of 23 mm and ii) March 2013 – February 2014, the post-treatment phase, after reducing the width to a 5 mm free spacing. Monitoring was performed with an automatic video recording system consisting of a video camera (Bosch, mod. MR700) and a video recorder (Bosch, mod. LTC455). The camera was placed on the top of the fish lift, allowing the collection of lift cage images during the final ascension. In order to obtain clearer images for identification and estimates on eel lengths, the cage was sealed with 20 x 20 cm white quadrates. The video recorder stored the video files which were later analyzed using the software Bosch Divar Archive Player v3.22. Collected fish data included the timing of eel passage (day and hour), the number of eel per cycle, and the estimated total length of individuals.

To assess the performance of movement passage through the fish lift in relation to the actual eel numbers that effectively reach the dam base, eel capture was performed monthly on a 340-m long river segment immediately below the dam, using a combination of boat and wadeable electrofishing. The entire width of the river was fished by walking slowly upstream in a zigzag pattern to ensure full coverage of all habitats. After the sampling, eels were identified, counted, measured (total length, TL, to the nearest 1.0 cm), and returned to the river alive.

2.3 Data analysis

The number of individuals that used the fish lift and the corresponding captured downstream the dam during the two annual sampling periods (pre- and post-treatment phases) were initially plotted on a histogram, on a monthly basis, to search for seasonal activity patterns. Non-parametric Wilcoxon matched-paired tests were then conducted to search for significant differences on eel numbers through the fish lift before and after reduction of the gap width of the fish lift. The same test was performed on the catch data to assess for eventual differences on eel downstream abundance during both sampling periods.

Size distributions of eels that successfully used the fish lift during the pre- and the post treatment phase were compared using the Kolmogorov-Smirnov test [3]. This analysis provided an assessment of the effect of reducing the gap width by comparing the shape of eel length distributions before and after the implementation of this measure. Chi-square ($\chi2$) tests of proportions were then run for each size-class to search for significant differences in the percentage relative abundance. Size-classes were defined according to [4] but were further partitioned, in 5-cm intervals, to allow a more detailed analysis on retention/escapement of individuals.

3 RESULTS

A total of 1207 eels used the fish lift during the pre-treatment phase when the gap width was 23 mm. After reducing the gap width to 5 mm (post-treatment phase), the number of lifted individuals increased more than threefold, to 3852 individuals and this was significant (Wilcoxon match-paired test, $Z=2.31$, $P=0.021$). Seasonal activity varied across the year but the pattern was similar between both periods, with almost all movements

(98.4%) occurring during summer and early autumn (July-October) and with no virtual activity on winter and spring (Figure 1).

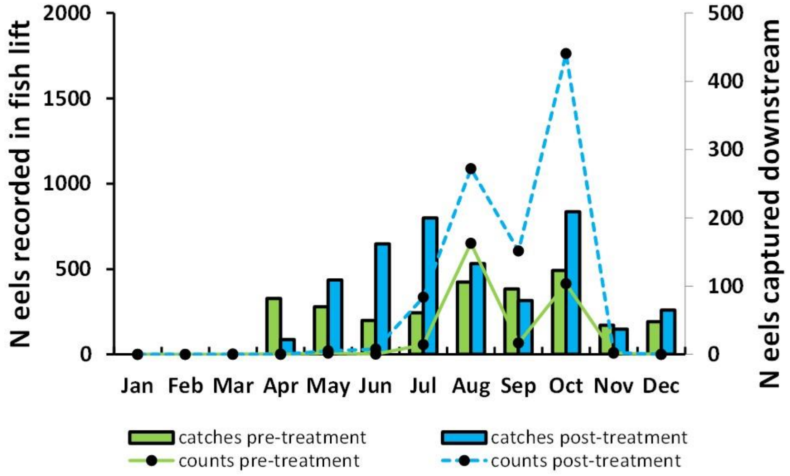

Figure 1. Eel counts through the fish lift (lines) and correspondent catches downstream Touvedo dam (bars) during the pre- and the post-treatment phase.

The number of eels monthly captured downstream the dam was similar between both study periods (Wilcoxon match-paired test, Z= 1.54, P=0.122). Eels were captured throughout the year (April-December), although like the fish lift recordings, the greatest catches took place during summer and early autumn (July-October), accounting for 56.8% and 61.1% of total catches during the pre- and post-treatment phase, respectively.

Differences in population size–structure were also detected between the pre- and post-treatment phases (Kolmogorov-Smirnov test, Z=5.357, P<0.001) (Figure 2). Accordingly, a significant higher proportion of smaller individuals were found during the post-treatment phase relatively to the pre-treatment period. Differences were particularly evident in the 15-20 cm class, where the proportion of individuals were higher on the post- (48.7%) than in the pre-treatment phase (29.0%) (χ^2=44.7, P<0.0001). On the other hand, the proportion of individuals belonging to the largest size-classes i.e., 25-30 cm and >30 cm, were under-represented during the post- (5.5% and 0.5%, respectively), relatively to the pre-treatment period (20.7% and 17.7%, respectively).

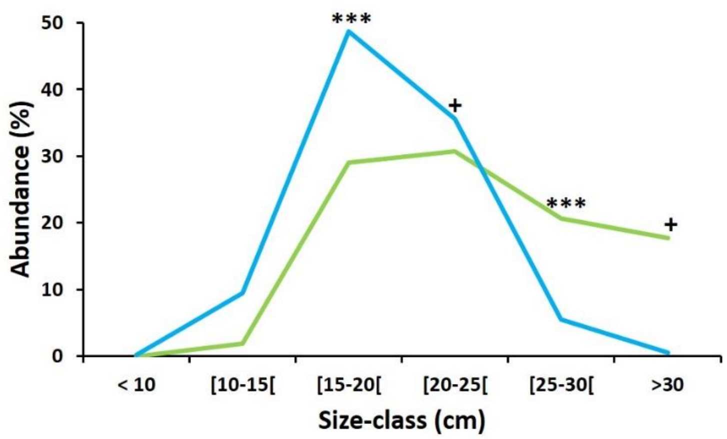

Figure 2. Size-class distribution (%) of eel through the fish lift during the pre- (green line) and the post-treatment phase (blue line). Results of the χ^2 test (+, P< 0.10; ***, P< 0.001) of comparison of proportions are also shown.

4 DISCUSSION

Fish lifts are often cited in the literature as being ineffective or showing unknown performance for eels due to high chance of escapement through the retention screens, which limits their use as practical eel passage devices [5]. Our study showed that a reduction of the gap width of the trapping cage, from 23 mm to 5 mm, led to a significant increase in the number of lifted individuals to more than threefold. It is, however, noteworthy that such an increase was not a result of a higher number of migrant eels approaching the dam base during the post-treatment phase, but instead, of a reduction on eel escapement through the screens during this period, as monthly electrofishing samples downstream did not support a significant increase in eel abundance from the pre- to the post-treatment phase. This increase in the number of lifted eels was accompanied by a significant change in the population size-structure, as a higher proportion of smaller individuals (<20 cm TL) was detected during the post-treatment phase. These findings seem clearly demonstrate that a decrease of selectivity for smaller eels can be achieved upon reducing the gap width of the trapping cage of fish lifts. However, managers and engineers should be aware that reducing the gap width does not guarantee per se a reduction of small eel escapement and a consequent higher proportion of these individuals within fish lifts. It will be previously necessary to guarantee that water velocities within the attraction circuit that lead to the trapping cage i) can be sufficiently attractive to produce positive rheotaxis on eels, i.e. >0.3 m/s [6] and ii) do not exceed the range of burst swimming speeds for the juveniles of this species (0.6-0.9 m/s, [7]).

5 ACKNOWLEDGMENTS

The authors wish to thank Cipriano Serrenho, António Leite Marinho, and Ulisses Cabral from EDP for allowing us to use their facilities and equipment (video recording system). Thanks are also due to Paulo Branco and André Fabião from Centro de Estudos Florestais for help in the field work.

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