The use of participative fisheries monitoring to detect dam impacts on goliath catfish (*Brachyplatystoma rousseauxii*) populations in the Bolivian Amazon

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Introduction

Dams are considered as one of the main drivers of habitat degradation in the Amazon river basin. One of the most cited impacts of these dams is on long-distance migratory fish species, the completion of their life cycle depending on river connectivity, the hydrological cycle and the availability of suitable upstream spawning habitats.

Two dams (Jirau, Santo Antônio) constructed in cascade in the main channel of the middle Madeira River, close to the Bolivian-Brazilian border, generate a series of downstream social and environmental impacts, but the upstream impacts in the upper Madeira basin, most of it located in Bolivian territory, have not yet been assessed.

The dorado undertakes the longest migrations known in the Amazon river system, and it is expected that the populations of this species in the Bolivian and Peruvian Amazon are impacted significantly by the Madeira dams. The objective of this study is to assess if the closure of the San Antônio dam has provoked changes in catch per unit effort in the dorado commercial fisheries in Bolivia by using fishers monitoring capacity as a tool to detect upstream dam impacts on fisheries yield.

Material and methods

The study was conducted in the Ichilo River, which is an Amazon headwater of the Mamoré river, tributary of the Madeira River. The main landing site in the study area is Puerto Villarroel.

Santo Antônio and Jirau dams, located in the Madeira River more than 1 5000 km downstream from the study site, were constructed in different stages between 2008 and 2016. Both dams are equipped with fish transposal systems which are reported to have a low efficiency for target migratory fish.

A participative monitoring system of catches was set up in Puerto Villarroel, Catches were recorded daily during 12 months a year. Fishing forms were filled daily by fishers, providing catch data by species, individual fish weight, fishing method, fishing time and other general information related to fishing habitat and crew members. One filled form generally covered fishing trips of between 4 and 20 days. The raw data were used to calculate the Catch per Unit Effort (CPUE) as kg/fisher*day.

In the river channels, four fishing methods were used in the catfish fisheries: hooks fixed to drifting boys (locally denominated as “bidónes”), fixed hooks on lines (“espineles)”, longlines, drifting gill nets with large mesh size. Effort data for these methods were pooled.

Differences in % contribution of dorado to catch and differences in CPUE before and after dam closure were tested by a non-parametric test (Kruskal-Wallis one-way ANOVA on ranks).

Results And Discussion

Before dam closure, dorado accounted for 3.9 (± 2.1) % (range 0.93-8.8%) of total catches and represented 8.3% of catfish catches in rivers (Figure 1). After dam closure, the dorado only accounted for 0.3% of total catches. Before dam closure, annual CPUE of dorado fluctuated between 0.34 and 1.56 kg/day/fisher, with a mean of 0.78 (± 0.39). After dam closure, there was a significant drop to low annual CPUE levels (below 0.12 kg/fisher/day) (Kruskal Wallis $H = 6.43$; $p = 0.01$).

Previously, it has been shown that the Madeira hydroelectric dams exert a negative impact on downstream fish populations and affect fisheries yield and catch composition (Santos *et al.* 2018). In the Madeira river basin, the San Antônio and Jirau dams were recently shown to affect fishery stocks in the downstream Madeira river, and in particular on the populations of dorado (Lima 2017).

The present study shows that the Jirau and Santo Antônio dams, built in cascade, also affect upstream fish populations of dorado, capture per unit effort (CPUE) data providing a strong evidence of this impact. The exceptional migratory behavior of dorado makes them very sensitive to interruption of hydrological connectivity by dams, which negatively impacts the drifting larvae to the estuary or to the lower Amazon River and the preadults swimming upstream. The Jirau and Santo Antônio dams are both equipped with fish transposal systems, but the efficiency of these systems has been questioned in repeated occasions, and it is now generally assumed that they do not allow successful passage of goliath catfishes.

How to interpret the individuals that are still captured after 2015? There are three possibilities. It may be individuals that returned to the upper Madeira before the dams’ closure. A second possibility is that it be individuals hatched in Bolivian headwaters after dam closure but which could not complete downstream drifting to the estuary, being trapped in the reservoirs, upstream of the dams. These individuals are called by Hauser (2018) ¨forced residents¨, migrants which are forced to stay upstream. The third option is that these individuals are natural ¨residents¨, which-comprised 14% of the total sampled population before the dams (Hauser 2018). Some, or all, of the remaining dorados after dam closure may be ¨residents, which possibly can complete their whole life cycle in Bolivian headwaters and would therefore not be affected by the presence of the dams, although so far there is no empiric evidence that these residents also spawn in the headwaters of the Bolivian or Peruvian Amazon. Additionally, Hauser (2018) evidenced that both natural and forced resident specimens had a lower growth than specimens performing the complete life cycle, which could impact fecundity and ultimately recruitment.

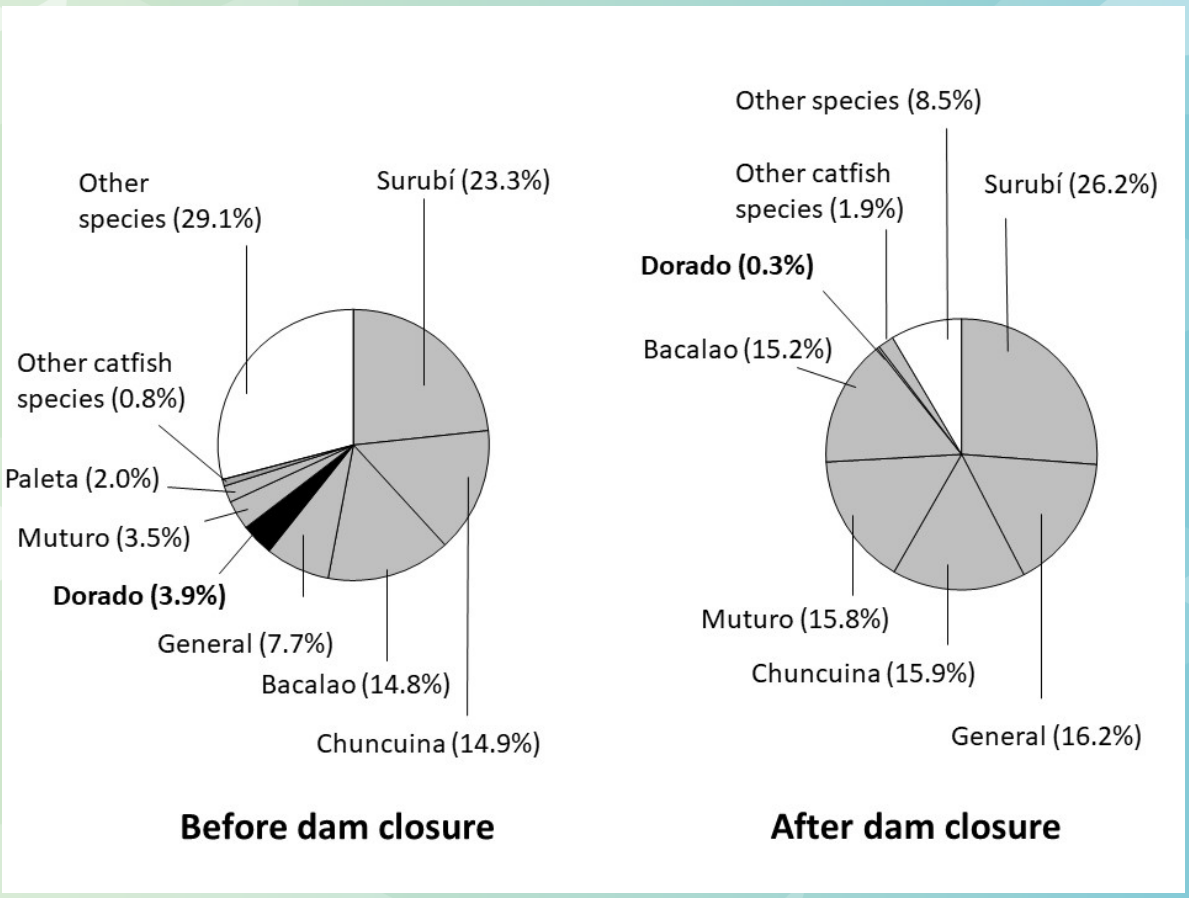

Figure 1. Contribution of catfish and non-catfish species to landings in Puerto Villarroel from 1998 to 2007 (before dam closure) and from 2015 to 2017 (after dam closure) using all fishing methods in lakes and rivers. Catfish species contributing < 1% of the catches are pooled within "other catfish species". The category "other species" includes all non-Siluriformes orders. The catfish species mentioned are surubí (*Pseudoplatystoma fasciatum*), paleta (*Sorubimichthys planiceps*), general (*Phractocephalus hemiliopterus*), bacalao (*Brachyplatystoma filamentosum*), chuncuina (*Pseudoplatystoma tigrinum*) and muturo (*Zungaro zungaro*).

We conclude that dams are expected to affect negatively the upstream Bolivian dorado population and would eventually lead to a significant reduction in population size in the near future if migratory movements are permanently blocked (Van Damme et al. 2011).

Dams can exert pervasive effects on large migratory catfish, the dorado being a species with a high extinction potential due to its complex biological cycle. No less important, this study demonstrates that in absence of scientific data, participative fisheries monitoring represents a powerful tool for studying the behavior of migrating species and for mapping dam impacts. Fishers knowledge has been recognized as valid method to detect migratory patterns (Baigún 2015) and integrated in fisheries management in large floodplain rivers (McGrath and Castello 2015). This topic may be of particular interest for several river basins of South America, where the accelerated development of hydroelectric dams poses a potential threat to the sustainability of artisanal fisheries, and where long-term monitoring programs are not feasible.

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