

# Dams cause genetic homogenization in populations of fish that present homing behavior: Evidence from a demogenetic individual-based model



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## ABSTRACT

Few studies have assessed the impact of dams on the distribution of the genetic diversity of Neotropical fish species, and some of them suggest that the genetic structure of fish metapopulations is not affected by damming. However, the effects of dams on the genetic structure of populations may hinge on the biological characteristics of the species, such as homing behavior. Dams prevent some individuals from migrating from their feeding area to their natal spawning area, constraining them to reproduce in the tributaries that are closest to the barrier, and which are already being used as breeding grounds by other subpopulations. In these places, subpopulations may interbreed, thus disrupting the overall genetic structure of the metapopulation. To test this hypothesis, we developed a demogenetic Individual-Based Model that simulates the impact of permeable and impermeable dams on the genetic structure of homing populations, in both the long-term and the short-term. Our results support that genetic homogenization occurs among the subpopulations in the short-term, especially near the dam. The impact of a dam on the genetic structure is also detectable in the long-term (100 generations after the addition of the dam) when the dam is permeable (symmetrical or asymmetrical). However, when the barrier is not permeable, the genetic differentiation among the subpopulations is reestablished in the long-term. Our results suggest that conservation programs should be developed to avoid/mitigate genetic homogenization of populations of fish that display homing behavior in the short-term, and to reestablish the pre-dam genetic structure of these populations in the long-term.

## 1. Introduction

Despite the perceived economic and social benefits of dams, their impact on natural environments is frequently severe. Genetically, dams represent barriers to migration, causing the fragmentation of fish populations by changing their gene flow dynamics (Gosset et al., 2006; Heggnes and Røed, 2006; Horreo et al., 2011). Fragmentation reduces the effective size and genetic diversity of populations, and can result in local extinction (Neraas and Spruell, 2001; Jager et al., 2001; Morita and Yokota, 2002; Yamamoto et al., 2004).

Some studies have tested the effect of dams on the genetic diversity of populations of Neotropical fish species (e.g. Barroca et al., 2012; Sanches et al., 2012; Ferreira et al., 2016; Pil et al., 2018). Most of them failed to detect genetic differentiation among populations. In some of those studies, the construction of the dam had happened recently (Ferreira et al., 2016), the generation times of the fish species sampled

were long (Sanches et al., 2012), or the effective sizes of the original populations were large (Pil et al., 2018). All these characteristics are known to delay or to impair genetic differentiation among populations (Wright, 1931; Slatkin, 1995; Holsinger and Weir, 2009).

None of the studies cited above used fish populations that display homing behavior to test the impact of a dam on their genetic diversity. Homing fish that spawn in freshwaters return to the stream where they were born to spawn (Gerking, 1959), and as a result, their metapopulations (Levins, 1969) present a dendritic pattern of genetic structure (Bouza et al., 1999; Primmer et al., 2006; Östergren et al., 2012) (Fig. 1a). This dendritic genetic structure is directly derived from the dendritic network of rivers, as subpopulations in different tributaries become genetically differentiated through genetic drift and/or local adaptation (Hansen et al., 2002, 2007; Jensen et al., 2008). The genetic cohesion (Cooper and Mangel, 1999) and the spatial distribution (founding new subpopulations and recolonizing areas after local

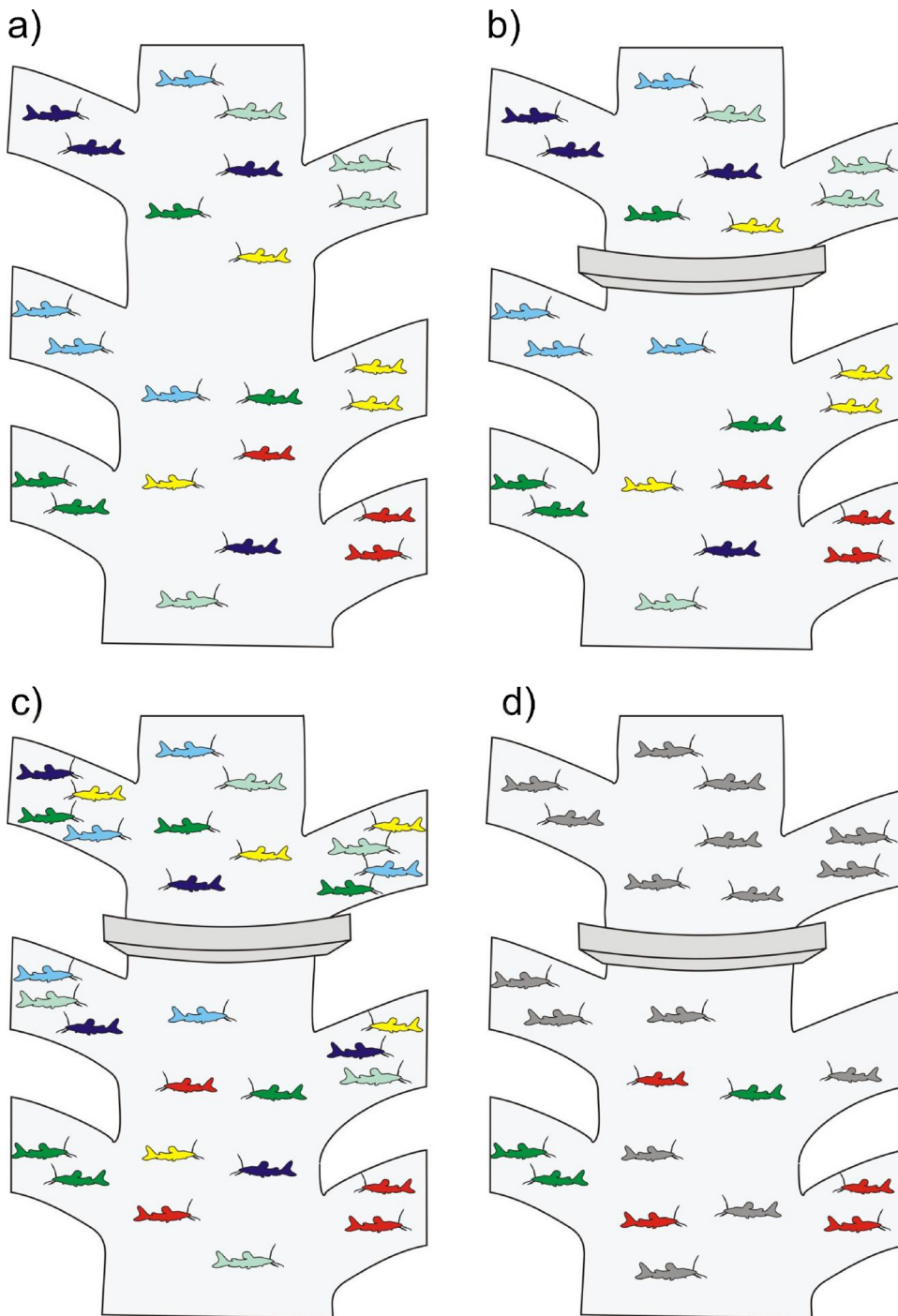
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**Fig. 1.** Hypothesized scenario delineated by Baggio (2016) and Baggio et al. (unpublished), and tested in this study. 1a: Dendritic pattern of genetic structure expected in homing populations: genetic differentiation among subpopulations that reproduce in each tributary (spawning area) and mix of subpopulations in the feeding area (main channel). 1b: The dam blocks some individuals from accessing their spawning areas. 1c: Interbreeding of isolated individuals with the subpopulations of the tributaries adjacent to the dam. 1d: Genetic homogenization of the subpopulations that reproduce in tributaries adjacent to the dam. Specimens of different subpopulations are color-coded. Individuals in the tributaries represent subpopulations from each spawning area, individuals in the main channel represent subpopulations in the feeding area.

extinction, Milner and Bailey, 1989) of the metapopulation is maintained by the dispersion of individuals (straying) (Keefe et al., 2008). Subpopulations mix in the feeding areas. Studies have suggested that some freshwater species of Neotropical fish present homing behavior (Godoy, 1959, 1975; Batista and Alves-Gomes, 2006; Godinho and Kynard, 2006; Godinho et al., 2007, 2008; Abreu et al., 2009; Pereira et al., 2009; Baggio, 2016; Duponchelle et al., 2016; Baggio et al., unpublished). Thus, understanding how dams affect homing fish populations is essential to the implementation of conservation programs in the Neotropical region.

Baggio (2016) and Baggio et al. (unpublished) suggested that the distribution of the genetic diversity of the Pintado catfish, *Pseudoplatystoma corruscans*, from the Upper Paraná River might reflect its homing behavior. Furthermore, they suggested that the lack of genetic

differentiation among the subpopulations of that species in the tributaries closest to the Porto Primavera Dam may be associated with the barrier, which might have promoted genetic homogenization by changing the migration pattern of the species. *Pseudoplatystoma corruscans*, like other migratory Neotropical fish species, usually spawn in the fast waters of the tributaries. The larvae and juveniles develop in flooded areas (e.g. lagoons) in the lower reaches of the tributaries and in the main channel, the adults feed in those same habitats and also in reservoirs (see Carolsfeld et al., 2003 for details). When a dam is built, individuals feeding in the main channel might get isolated downstream to the barrier, which may prevent their migration back to their natal spawning area (Fig. 1b). As an alternative, these individuals might reproduce in the closest tributaries downstream of the dam, as reported for other Neotropical (Sato et al., 2005, Godinho and Kynard, 2006,

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