The role of urbanization on the impact of fish invasive species

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Abstract. Invasive species and habitat degradation, which is promoted by the land cover change as a consequence of urbanization, are serious problems that impact the native fish assemblages in rivers and streams all over the world. Then this article promotes a bibliographic review that brought together models that predict the relation between habitat degradation and invasive species, and also studies of specific cases involving those variables, focusing on a better understanding of how the habitat degradation affects the action of invasive species over the native fish diversity, as they seem to be correlated. To determine if the impact of invasive species is enhanced by the habitat degradation or habitat degradation and invasive species are two separated impacts to the aquatic ecosystems that act separately on the native fish diversity. The present study finds out that the habitat degradation facilitates the invasion of rivers and streams by alien fish species and possibly a greater impact of them in the native fish assemblage, being the decrease of habitat complexity a factor of extreme importance in this relation. With these discoveries, more efficient management recovery plans for rivers and streams impacted by these factors can be elaborated, and strategies to preserve preserved areas as well.

**Keywords.** Invasive species, urbanization, habitat destruction, freshwater fish, diversity, impact.

1. Introduction

The population growth results in increase of urbanization, thus causing the land-cover change [1], this physically consists mainly of increase of impervious surface areas, which play an important hole in the flow regime of water bodies, and lead to the habitat degradation of aquatic ecosystems. Streams are very susceptible to the effects of urbanization, given their position in landscape [2]. Urbanization has a lot of effects, changing the chemistry of water (dissolved oxygen, pH, nutrients), channel morphology, hydrology, ecosystems processes, and other biotic and abiotic variables. Because it is associated with pollution release, loss of riparian forest, the building of dams and introduction of invasive species [2,3].

Invasive species and habitat degradation are two common causes associated with the loss of biodiversity in aquatic ecosystems [4], introduced species could impact fish diversity by predation, competition, introduction of parasites and diseases, altering ecosystems processes [5] and niche replacement [6]. Interestingly, it has not yet been well characterized if invasive species could be seen as an independent factor in the decline of native freshwater fish assemblage, as habitat degradation. But those factors can act together, in literature the principal's hypothesis of this interaction could be exemplified in the conceptual models made by Virgilio Hermoso et al. (2011) (Fig 1). Being the main question to this article if the impact of invasive species is enhancing by the habitat degradation (Fig. 1 D) or habitat degradation and invasive species are two separated impacts to the aquatic ecosystems that could be related to loss of native fish diversity, and one doesn't potentiates another (Fig 1 A-C).

It's essential to understand the relation between loss of native fish diversity, habitat degradation and invasive species, to plan efficient actions to combat this loss of biodiversity. Since if native invasions are potentiates by habitat degradation, mobilizing resources for preservation and regeneration of aquatic ecosystems could break the expansion of already established alien species, otherwise if habitat degradation are not correlated with the impact generated by invasive species it could be more efficient work in solutions species specific to mitigate and control the invasion.
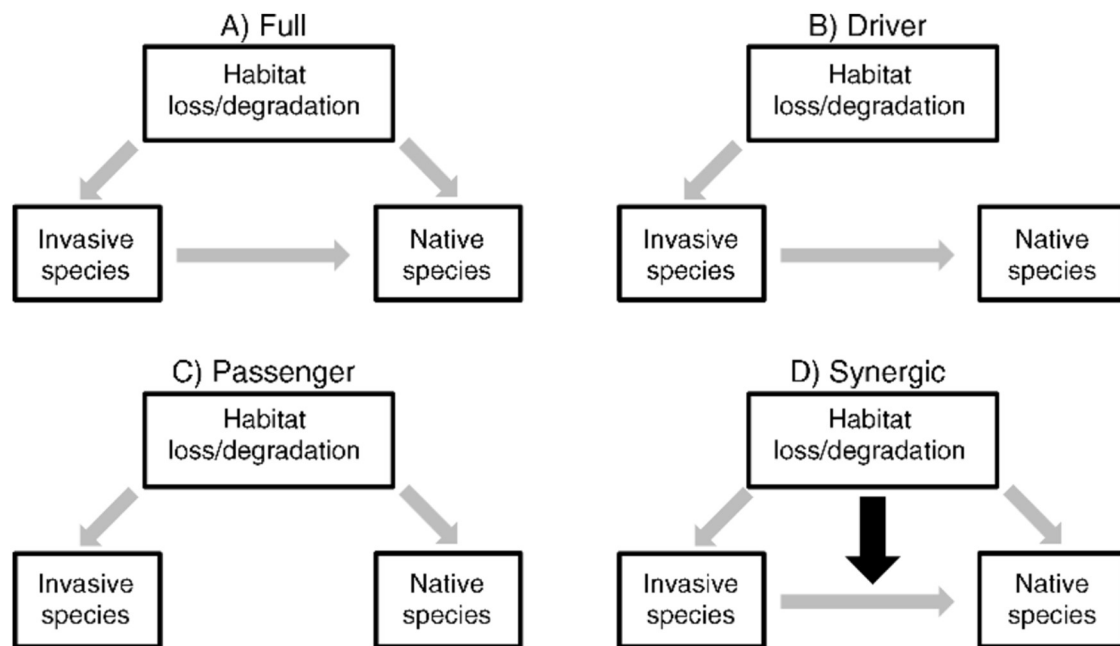
Fig. 1 - Conceptual models explaining alternative pathways responsible for the decline of native assemblages, including the two most commonly cited causes of biodiversity loss: habitat degradation and invasive species. (A) A full model, where both factors are responsible for the decline of native assemblages. (B, C) Two alternative pathways, where invasive species act as drivers of native decline (only invasive species would have direct effects on natives) or passenger (habitat degradation would be the leading cause of the decline of native species). (D) An additional interactive pathway, where habitat degradation could be enhancing (i.e., numerically or functionally mediated processes according to Didham et al. [2007]) the per capita effect of invasive species. [7]

2. Materials and methods

To make the present study, was made a literature review using google scholar as the major research tool, the research was based in articles that analyzed specific cases of invasive species evaluating the relation between habitat destruction and alien species in the loss of native fish diversity, was used as well ecological models that predict the loss of biodiversity using those variables. Were chosen articles that have different hypotheses of the question in discussion, towards a better understanding how invasive species play with habitat destruction affecting the native fish diversity.

For reach those materials used in this work, the research was guided by a group of keywords: diversity, invasive species, river health, freshwater fish, disturbance, impact, habitat degradation/complexity, urbanization and urban ecology. The results of this search were examined and the relevant to the question of the study selected, based on the date of publication giving priority to more recent studies, and by where they are published only selecting articles that come from good journals and databases. Furthermore, the references of these selected articles were examined, and some other materials were selected, in addition, books were also used to understand concepts. This methodology was selected to look at the research in a systematic way at topics of interest, besides to have

a broad review about what the principal's theories about this question are currently debated in the academia.

3. Results

In order to understand the role of invasive species in the loss of native fish diversity, and its relation with habitat degradation generated by urbanization, this study brings together the results of different articles that evaluate species specific invasions and models that predict the role of nonnative species in different scenarios. In the case of the study "Invasive tilapia juveniles are associated with degraded river habitats" from Ana R. Linde et al. (2008) they defend that the habitat degradation makes environments more susceptible to colonization by invasive species, since they analyzed the distribution of pearl cichlid (native) and tilapia (nonnative) juveniles, in a gradient of habitat degradation and find that in areas where the habitat was degraded tilapia juveniles were more abundant than in preserved ones. Being in the most preserved site only contains 5% of tilapia juveniles and in the most polluted the invasive species represent 68% of the juveniles [6].

Also defending that the habitat degradation have a positive effect in the impact of invasive species is the article "Are alien fish a reliable indicator of river

health?" from M. J. Kennard et al. (2005) which theorizes that habitat degradation makes environments more susceptible to nonnative species and in addition the impact generated by the alien species on the native fish assembly is greater than the impact of the degradation on these habitats. They sampled a study area with numerous streams and rivers that reflected a known gradient of anthropogenic disturbance, and used sites with less human impact (preserved ones) to predict the number of native fish species expected to occur at the test sites if they don't have been degraded. The results demonstrate that sites where alien fish were present have significantly higher intensities of disturbance caused by human land-use practices, and the increase of species richness, numerical density and biomass density of native fish is correlated with the decrease of relative abundance and biomass of alien fish. Although it was also reported that "Sites predicted to contain a relatively high number of native species also often contained a high relative abundance and bio-mass of alien species" [5].

From the assumption that habitat degradation potentiates the impact of invasive species over native fish diversity, the study "Habitat simplification increases the impact of a freshwater invasive fish" from M. E. Alexander et al. (2014) investigates how the habitat simplification, one of the impacts of urbanization, affects the action of invasive species. For this the researchers quantify the predation of largemouth bass on the prey Poecilia reticulata, the guppy, by manipulating simulated habitats with different levels of complexity and prey density, and the results showed that in the highest habitat complexity the consumption of prey was the smallest, moreover as the habitat became less complex attack rate have a significant declined as well as the handling time, which suggests better predator performance [8].

In order to resolve the question about how nonnative species play with habitat degradation in the impact over native fish fauna the study "Habitat Destruction, Fragmentation, and Disturbance Promote Invasion by Habitat Generalists in a Multispecies Metapopulation" from Michelle Marvier, Peter Kareiva, and Michael G. Neubert (2004) construct a multispecies metapopulation model that tracks the proportion of sites occupied by species that represent different degrees of habitat specialization, considering invasive species as habitat generalists and native species as a habitat specialist where specialists have competitive advantage over generalists in preferred habitat of the specialists. The model showed that in intermediate amounts of habitat destruction all species can coexist, but with further habitat degradation the specialist (native) species are removed from de metapopulation, only remaining habitat generalists (nonnative) and at one

point the habitat is so much destroyed that none species are found. They also showed that after a perturbation all species begin to recover, although the generalists have a temporal advantage [9].

Contrastingly the study "Invasive species and habitat degradation in Iberian streams: an analysis of their role in freshwater fish diversity loss" from Virgilio Hermoso et al. (2011) sampled the fish assemblage and characterized the habitat in the sites of the study and from that using a statistic approach build multiple regression models for each of the hypothesis characterized in the Fig 1. The fit test indicated the full and driver models were the best ones, they conclude that "invasive species are the leading driver of the decline of native freshwater fish assemblage, while habitat degradation neither directly affected biotic integrity nor influenced the per capita effect of invasive species." However, it is important to point out that observed fish biodiversity patterns may be related to sources of habitat degradation not considered in this study [7].

4. Discussion

The present study found that the habitat degradation generated by urbanization enhances the impact of invasive species over the native fish diversity and made the aquatic environment more susceptible for invasions [5,6,8,9]. The mechanisms that defend this affirmation are that nonnative species have competitive advantages in degraded habitats compared to native species and that a diverse native fish assembled in a preserved habitat are less susceptible to the established and impact of alien species. This is based on the idea that invasive species are habitat generalists and native species are specialists [9], which is not always corroborated, although it is a widely observed pattern [5,6,8]. And can be used to understand the model of how invasive species act on the diversity of native fish in degraded and preserved ecosystems.

As shown in the introduction the habitat degradation affects the aquatic ecosystem in many different ways [2,3], but the habitat complexity as a very important variable to the diversity composition and to various ecological processes [10], because of that have a direct impact in the relation between invasive and native species [8]. Besides the habitat complexity and the other effects generated by degradation, the relation of alien and native species depends on many other variables both environmental and ecological [7]. Because it is extremely difficult for one study or model to get all those variables together, more studies are necessary to a better understanding of how these variables relate with each other.

5. Conclusions

Therefore, the study concludes that the habitat destruction generated by urbanization [2] makes aquatic ecosystems more susceptible to invasions by nonnative species and potentiates their impact in the native fish fauna [5,6,8,9]. These conclusions are important to the development plans to combat the expansion and new establishment of invasive species, in that way the management should be focus in preserve preserved areas that don't have any invasions and habitat restoration activities for areas that suffer from habitat degradation and invasive species, that must center attention to increase the habitat complexity by, for example, introducing wood debris and riparian vegetation rehabilitation [5,9].

6. References

[1] Seto KC, Güneralp B, Hutyra LR. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc Natl Acad Sci U S A,* 2012 Oct 2;109(40):16083–8.

[2] Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Ii RPM. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society,* Vol. 24, Am. Benthol. Soc. 2005.

[3] Brescovit AD et al. *Além do concreto: contribuições para a proteção da biodiversidade paulistana.* ISA, São Paulo, 2008. 364 p.

[4] Didham RK, Tylianakis JM, Gemmell NJ, Rand TA, Ewers RM. Interactive effects of habitat modification and species invasion on native species decline. Vol. 22, *Trends in Ecology and Evolution*, 2007, p. 489–96.

[5] Kennard MJ, Arthington AH, Pusey BJ, Harch BD. Are alien fish a reliable indicator of river health? *Freshwater Biology*, 2005 Jan;50(1):174–93.

[6] Linde-Arias AR, Izquierdo JI, Moreira JC, Garcia-Vazquez E. Invasive tilapia juveniles are associated with degraded river habitats. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 2008 Sep;18(6):891–5.

[7] Hermoso V, Clavero M, Blanco-Garrido F, Prenda J. Invasive species and habitat degradation in Iberian streams: an analysis of their role in freshwater fish diversity loss. *Ecological Applications*, Vol. 21, 2011.

[8] Alexander ME, Kaiser H, Weyl OLF, Dick JTA. Habitat simplification increases the impact of a freshwater invasive fish. *Environmental Biology of Fishes*, 2015 Feb 1;98(2):477–86.

[9] Marvier M, Kareiva P, Neubert MG. Habitat Destruction, Fragmentation, and Disturbance Promote Invasion by Habitat Generalists in a Multispecies Metapopulation. *Environmental Biology of Fishes*, Vol. 24, Risk Analysis, 2004.

[10] J. David Allan, María M. Castillo. *Stream Ecology.* Springer, Dordrecht, 2007. 444 p.