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Growing, losing or introducing? Cage aquaculture as a vector for the introduction of non-native fish in Furnas Reservoir, Minas Gerais, Brazil

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Cage aquaculture has been developed in many countries, including Brazil. This form of production, although economically productive, may cause several impacts to the environment. Considering the historical relationship between aquaculture and species introduction, our study investigated the potential of cage aquaculture in spreading non-native species into hydroelectric reservoirs. We interviewed 19 fish farmers in Furnas Reservoir, Grande River basin. All producers have grown exclusively Nile tilapia (*Oreochromis niloticus*), an African fish, and all producers reported the occurrence of fish escapes. Releases were mainly accidental, but highly frequent during some management procedures, such as length classification, fish capture and juvenile stocking. Escapes were also reported due to cage damage and deliberate releases. These results indicate that, in cage aquaculture facilities, fish are frequently released to the external environment. When raising non-native species (*e.g.* Furnas Reservoir), these facilities constitute an important vector for fish introductions.

A aquicultura em tanques-rede é destaque em diversos países, inclusive no Brasil, por se tratar de uma prática produtiva. No entanto, esta forma de cultivo também apresenta pontos negativos, entre eles a possível introdução de espécies. Em vista disso, o presente trabalho investigou o potencial da aquicultura em tanques-rede na disseminação de espécies não-nativas. Para isso, foram entrevistados 19 aquicultores do reservatório de Furnas, bacia do rio Grande. Todos os produtores consultados cultivam exclusivamente Tilápia-do-Nilo (*Oreochromis niloticus*), espécie de origem africana, e todos relataram a ocorrência de escapes de indivíduos dessa espécie. Os escapes foram principalmente acidentais, com elevada frequência durante o manejo de classificação, a despesca e a estocagem de juvenis. Aquicultores também relataram fugas decorrentes do rompimento dos tanques, além de solturas deliberadas. Os resultados indicam, portanto, que a perda de peixes para o meio externo é frequente em sistemas de tanque-rede. Ao lidar com espécies não-nativas, esses sistemas (tanques-rede) constituem importante vetor para a introdução de peixes.

Key words: Escapes, Introduced fish, Management, Neotropic, *Oreochromis niloticus*, Tilapia.

Introduction

Aquaculture is the artificial production of aquatic organism, especially for human consumption (Campbell & Pouey, 2005). The activity is, according to the United Nations, a strategic activity for sustainable food production (Halwart *et al*., 2007), able to provide food with high protein content, creating jobs in developed and developing countries, and alleviating fishing pressure on wild stocks. Among aquaculture modalities, cage aquaculture is a particular type of fish production, characterized by high productivity (Scorvo-Filho *et al*., 2008). It has been developed consistently in many countries, particularly in South Asia (Halwart *et al*., 2007) and, currently, in Brazil. In fact, federal programs have stimulated the implantation of cage aquaculture in some Brazilian hydroelectric reservoirs (Agostinho *et al*., 2007), as a means of increasing fish production in public waters.

As any intensive production system, however, cage aquaculture may cause substantial impacts to the environment (Diaz *et al*., 2001; Dempster *et al*., 2004). The lack of adequate planning, inattention with ecological knowledge or mismanagement may create several difficulties, with negative consequences on biodiversity. Among the problems, the introduction of non-native species has been documented across the globe (Naylor *et al*., 2000), including Brazil (Agostinho *et al*., 1999; Orsi & Agostinho, 1999; Agostinho *et al*., 2007; Vitule, 2009). Fish releases are

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inevitable in such systems, considering that cages have direct contact with the external environment, often in poor conditions of confinement and handling (Agostinho *et al*., 2007). It is worth noting that Brazilian fish farmers and managers, often unaware about the risks associated with species introductions, have historically raised non-native fish, such as tilapine species (genera *Tilapia* or *Oreochromis*) (Agostinho *et al.*, 2007; Vitule, 2009; Vitule *et al*., 2009). These fish have a long history in aquaculture, basically because of specific biological traits (*e.g.* tolerance, prolific) and high productivity levels (Canonico *et al*., 2005) - especially if compared to the performance of native fish species.

Cage aquaculture, therefore, may become an important vector for the introduction of non-native fish into Brazilian freshwater environments, basically because (i) the activity is growing rapidly in many hydroelectric reservoirs, located in different basins, (ii) farming procedures have poor environmental guidance (Agostinho *et al*., 2007), and (iii) current governmental initiatives have attempted to authorize the broad cultivation of non-native species in aquaculture facilities (Law Project N° 5.989-B, 2009). Based on this perspective, the present study consulted fish farmers in Furnas Reservoir, Grande River basin, Brazil, to evaluate the potential of cage aquaculture in spreading non-native fish. Applying questionnaires to the fish producers, we investigated which fish species are raised in the reservoir, the occurrence of fish escapes, and the phases in which escapes are more frequent.

Material and Methods

Study area

Furnas Reservoir (Fig. 1) is the third of a series of impoundments constructed along the Grande River, upper Paraná River basin. The dam is located between São José da Barra and São João Batista do Glória towns (Minas Gerais State). The dam was built in 1963, creating one of the largest reservoirs in the country (1,440 km^2).

Fish production began more than a decade ago, and this large reservoir has been exploited intensively by cage aquaculture (Novaes, 2010). In addition, several aquaculture zones are being implemented throughout the reservoir, which will cover circa 3,096 ha of direct influence (Secretaria de Estado de Ciência, Tecnologia e Ensino Superior de Minas Gerais, 2007). According to this report, a single zone may contain more than 13,200 cages, to produce around 5,000 ton of fish/year. Tilapia *Oreochromis niloticus* (Linnaeus, 1758) has been the target species. Although this fish is non-native (African origin), and Brazilian law prohibits the introduction of species (Federal Law N^o 5197), authorities have allowed the production in closed systems (*e.g.* cages) in this reservoir.

Methodology

To evaluate the potential of cage aquaculture in releasing fish to the environment, this study interviewed fish farmers working in Carmo do Rio Claro town (MG), between November 2010 and January 2011. We consulted 19 independent fish farmers, using a questionnaire (Tab. 1), which took 30 minutes to be answered. All were interviewed individually, selected randomly from a group of circa 60 producers working in the town.

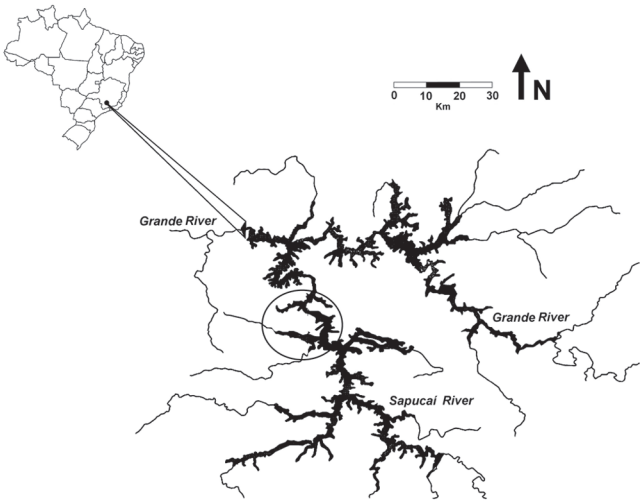

Fig. 1. Furnas Reservoir, Minas Gerais, Brazil. The circle indicates the study area (Carmo do Rio Claro town).

This research applied a simple questionnaire, which addressed three key issues (Tab. 1). Questions were prepared in order to determine the size of the aquaculture facility (number of cages), the species in cultivation, and the occurrence of escapes. When escapes were reported, we investigated the moments (phases of cultivation) in which escapes occur. For each question, we calculated the frequency of occurrence (%) of each answer.

To avoid misunderstandings, research goals were explained to every farmer, asking if there was any restriction on providing information. This procedure was used to clarify the seriousness of this investigation and to explain that it was not related to enforcement actions carried out by governmental agencies (Costa-Neto, 2006; Azevedo-Santos *et al*., 2010).

Table 1. Questionnaire applied to producers working with cage aquaculture in Furnas Reservoir, Minas Gerais, Brazil.

Questions
1) How many cages do you have?
( ) 10 to 19 ( ) 20 to 29 ( ) 30 to 39 ( ) 40 to 49 ( ) > 50
2) Which fish species do you raise?
3) Have you notice fish escapes in your farm?
( ) Yes ( ) No
If affirmative, when/how?
( ) During length classification;
( ) When juveniles are added to the cages;
( ) Intentional releases (*i.e.* deformed, unhealthy or stunt fish)
( ) When fish are removed from the cages;
( ) Due to cage damage;
( ) Other reasons. Please justify.

Results

Most fish farmers reported a large number of cages (> 40; Fig. 2), but facilities with different sizes were registered in the study area (10 to > 50 cages). Nile tilapia (*O. niloticus*) was the only species under cultivation - including different strains, such as supreme and "tailandesa" (Thai).

All fish farmers reported the occurrence of fish escapes. Accidental escapes prevailed, but intentional releases also occurred (Fig. 3). Analyzing production phases, virtually all farmers reported accidental escapes during length classification (LC) and when fish are removed from the cages (FR). In addition, many noted accidental releases when juveniles are stocked in the cages (JS). A lower number reported escapes due to cage damage (CD) (Fig. 3).

Discussion

According to fish farmers, fish escapes are common in Furnas Reservoir. All aquaculturists reported the occurrence of fish releases, mostly unintentional. Considering that cage aquaculture in Furnas Reservoir is essentially based on tilapia (*O. niloticus*), we predict that non-native fish are being frequently released to the external environment. Cage aquaculture may represent, therefore, an important vector for the release and introduction of non-native fish.

Farmers informed that escapes occur during different stages of the production chain (Fig. 4). However, releases are facilitated during some procedures, such as length classification, fish removal and juvenile handling. Length classification is important to group fish into similar size classes (Carvalho *et al*., 2010), considering that growth is variable among individuals. This procedure is routinely applied to standardize fish stocks, helping the farmer to select marketable individuals. During classification, however, fish accidentally escape or are released into the external environment - including the discard of stunt fish. Together with classification, fish farmers informed that escapes are common when grown fish are removed from the cages, to be processed and sold. Due to accidental reasons (*e.g.* fish leap out of the dip net), mismanagement (fish are dropped into the water) or misconduct (*e.g.* release of stunt or deformed individuals), some fish are released into waterways. Finally, a number of producers also informed that escapes occur when juveniles are stocked in the cages, particularly because smaller fish pass through the mesh. It occurs because fish length is not standardized within shipments, and small-sized individuals are stocked together with larger fish. Classification procedures carried out before confinement, or the installation of inner screens with small mesh sizes (*e.g.* nursery), could avoid the escape of young fish. Considering these three routes together (*i.e.* classification, fish removal, and juvenile handling), we suspect that a considerable amount of fish is released in the reservoir, especially because they are routine procedures.

A lower number of aquaculturists reported escapes due to cage damage (26%), even though this form of introduction is often cited in the literature (see Agostinho *et al*.,1999; Agostinho *et al*., 2006). Cages are now manufactured with durable material (galvanized wire mesh), so the action of external agents and weathering is significantly reduced (V.M. Azevedo-Santos, personal observation). We highlight, however, that damaged cages may release a large amount of fish to the environment, because the whole stock is lost at once. In addition, some fish farmers in Furnas Reservoir still use old cages, so this problem may be underestimated.

It is worth noting that a high number of cages is installed in Furnas Reservoir (> 5,000; Novaes, 2010), so tilapia may be constantly escaping to the reservoir. The occurrence of releases is environmentally alarming. Although *O. niloticus* is declared established in Furnas Reservoir (see Azevedo-Santos *et al*., 2010), tilapia is non-native, so it may disturb native populations or ecosystems processes. Several impacts have been reported in different ecosystems around the world, caused by the

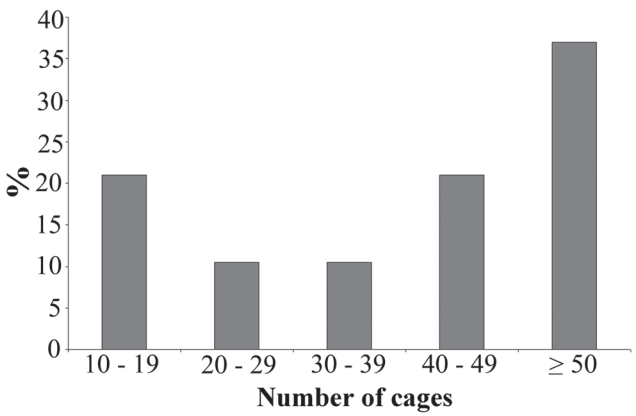

Fig. 2. Frequency of fish farmers (%) operating different number of cages in Furnas Reservoir (n = 19).

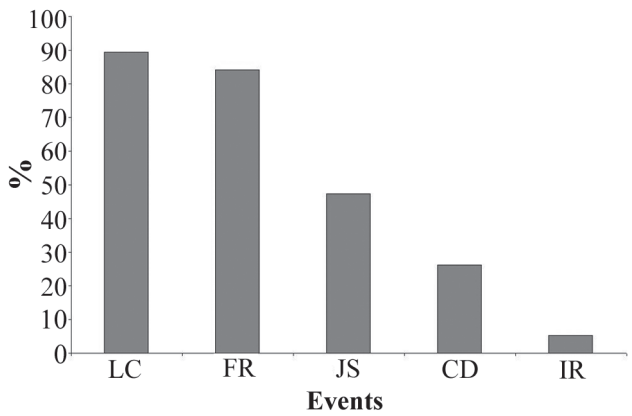

Fig. 3. Frequency of fish farmers (%) reporting the occurrence of fish escapes during different events of the production chain (n = 19). Accidental: length classification (LC); fish removal (FR); juvenile stocking (JS); cage damage (CD). Deliberate: intentional releases (IR).

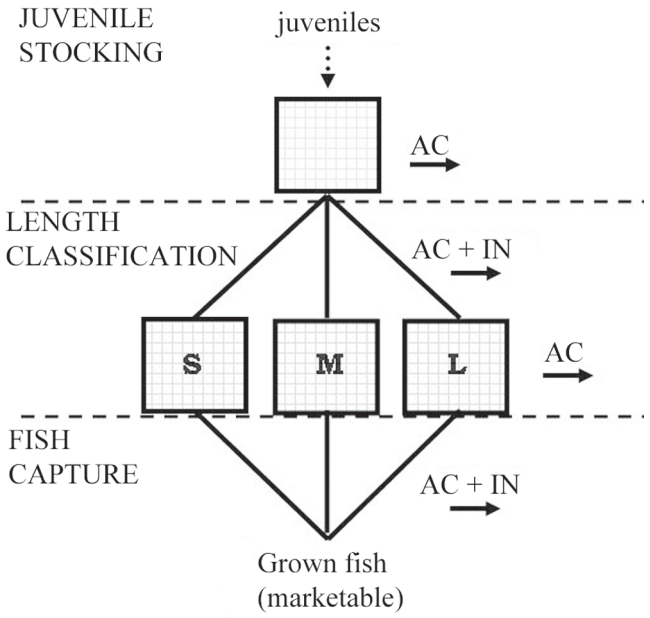

Fig. 4. Main events along the production system (*i.e*. juvenile stocking, length classification and fish capture) and the moments in which escapes occur (solid arrows: AC = accidental; IN = intentional). S = small-sized fish; M = medium-sized; L = large-sized.

introduction of tilapine species (Canonico *et al*., 2005; Vitule *et al*., 2009). In Furnas Reservoir, for example, Figueiredo & Giani (2005) showed that tilapia feeding behavior can increase eutrophication, deteriorating water quality. In addition, tilapia, in tropical environments, has high invasive potential (Canonico *et al*., 2005; Zambrano *et al*., 2006). Frequent escapes in Furnas Reservoir, therefore, may facilitate the colonization of contiguous river stretches within the Rio Grande basin, where tilapia is absent or not established (and releases are prohibited). Finally, we stress that cultivation of different strains may cause the introduction of resistant types and the maintenance of high genetic variability in the wild - processes that may facilitate establishment and range expansion -, in addition to complicating decision-making procedures about permissions and regulations (Costa-Pierce, 2003).

In conclusion, results indicate that releases from cages are frequent, even in systems that have been regulated and planned (*i.e.* Furnas Reservoir). Releases were mainly due to inattention or mismanagement, but deliberate releases also occurred - fish farmers usually discard stunt, unhealthy or deformed fish. Considering that Brazilian government has actively encouraged cage aquaculture in public waters (including all large basins, such as Uruguay, Paraná, São Francisco, Tocantins Rivers), fish farmers must receive appropriate technical instruction, so escapes can be minimized. We point out, however, that escapes cannot be fully controlled (intentional or accidental), basically because cages remain in direct contact with the external environment. Considering that species introduction is a strong homogenizing force (Rahel, 2007), and that fish escapes are common in cage aquaculture facilities, we recommend prudence and responsibility in aquaculture programs - encouraging, for example, the cultivation of native species. The recent law proposed by the Brazilian government, authorizing the broad cultivation of non-native species in aquaculture facilities (Law Project N.º 5.989-B, 2009), has neglected the "escaping" issue and all implications and complexity that follow species introduction. If this law is approved, the flow of non-native fish into freshwater ecosystems will increase - complicating the management and conservation of native biodiversity.

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