

## Short Communication

## Evidence of reproductive activity of the invasive common carp *Cyprinus carpio* (Linnaeus, 1758) (Teleostei: Cyprinidae) in a subtropical coastal system in southern Brazil

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### Abstract

The common carp *Cyprinus carpio* is an omnivorous, highly fertile fractional spawner and a generalist species that can live in a wide range of biotic and abiotic conditions. The combination of these features contributes to their high invasiveness potential allowing its rapid spread and increased biomass. The species has already established in 91 out of 120 countries where it has been introduced, especially due to aquaculture and ornamental activities. This work, based on the presence of *C. carpio* inhabiting the Patos-Mirim system, Rio Grande do Sul, Brazil, provides the first evidence of advanced stages of gonadal development in both sexes, reinforcing the view that the species can adapt to regional environmental conditions and suggests high potential for establishment of self-sustaining populations in this system.

**Key words:** invasive fish; Patos-Mirim System

### Introduction

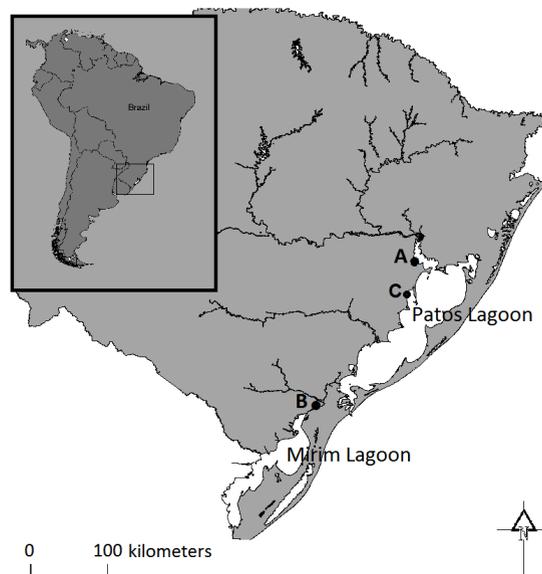
Fishes are among the most introduced group of aquatic animals in the world (*i.e.* 624 species, Gozlan 2008). The introduction of a non-native species in an ecosystem is generally likely to present an ecological risk if the species is able to integrate itself successfully, resulting in possible detrimental effects on native species or even on ecosystem functioning (Gozlan et al. 2010). The common carp *Cyprinus carpio* (Linnaeus, 1758) has been nominated as one of the 100 of the "World's Worst" invaders (GISP 2005).

*C. carpio* is native to Eastern Europe and Central Asia. It is a generalist, eurythermal, and euryhaline fish, which can live in a wide range of biotic and abiotic conditions. In its natural environment, this species can survive cold winters and salinity levels up to 5 psu, and it can tolerate low concentrations and super saturation of dissolved oxygen (Banarescu and Coad 1991). The species is omnivorous and tends to consume

food of animal (larvae and aquatic insects, macro invertebrates and zooplankton) and plant origin (Weber and Brown 2009). *C. carpio* grows rapidly, achieves sexual maturation in the second year of life, is highly fertile (<2 million eggs per female) and is a fractional spawner (Balon 1975). The combination of these features allows rapid spread and increased biomass of the species contributing to their invasiveness potential (Troca and Vieira 2012).

Non-native species have primarily been introduced into new ecosystems through human activity, either deliberately or unintentionally (Gozlan et al. 2010). It is known that the great bulk of global fish introductions and translocations have been carried out for aquaculture purposes (Welcomme 1988, Naylor et al. 2001, De Silva et al. 2009). *C. carpio* is used in aquaculture worldwide, and has already been introduced to 120 countries and established in at least 91 (Casal 2006). This species has most of the attributes expected for a successful invasive

**Figure 1.** The Patos-Mirim System in coastal in southern Brazil. Barra do Ribeiro Village (A) São Gonçalo Channel (B) and Tapes (C).



species. It has a well documented successful invasion history with wide distribution and abundance (Koehn 2004).

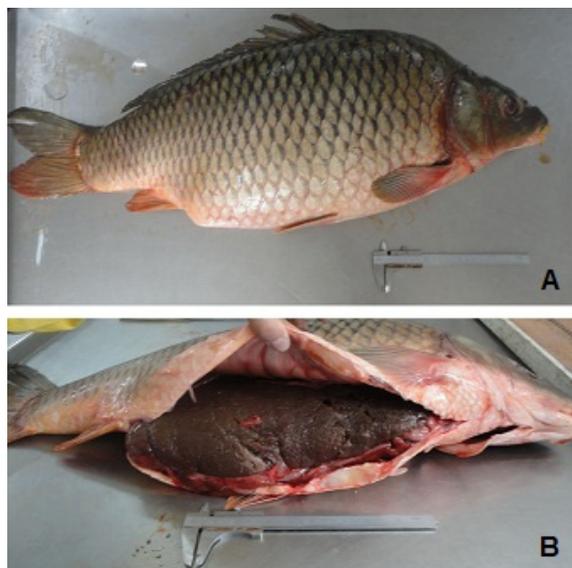
*C. carpio* is one of the most widespread introduced species in the Americas, with high probability of habitat expansion (Zambrano et al. 2006). In Brazil, it was introduced at the end of the nineteenth century, according to the 1898 official records for commercial aquaculture (Welcomme 1988). *C. carpio* has been introduced to most of the country and has established sustainable populations in the states of Rio de Janeiro, Rio Grande do Norte and Santa Catarina (I3N Brasil 2012).

In Brazil this exotic fish can escape into natural waterways because fish farming is commonly practiced adjacent to these environments (Orsi and Agostinho 1999). At present, *C. carpio* is the second most cultivated freshwater fish species in the country (~81,000 ton/year) and the Rio Grande do Sul state is the principal producer (58%) (IBAMA 2007). Farming of *C. carpio* is presently practiced adjacent to Patos Lagoon (less than 0.01km from the edge of the lagoon in some cases) (Troca 2009) and the species has been reported from this watershed (Garcia et al. 2004, Milani and Fontoura 2007, Leal et al. 2009). To date there has been no report of *C. carpio* reproducing in this ecosystem. This paper presents evidence of reproductive activity of *C. carpio* in the Patos-Mirim System and discusses the consequence of these results.

## Material and methods

The Patos Lagoon is ca. 250 km long and 60 km wide, covering an area of 10,360 km<sup>2</sup> along the coastal plain of Rio Grande do Sul in southern Brazil (Figure 1). The estuarine zone is restricted to the southern portion of the lagoon (ca. 10% of total area) (Seeliger et al. 1998). The lagoon's drainage basin (201,626 km<sup>2</sup>) is one of the largest in Latin America. The lagoon and adjacent coastal area support one of the most important fisheries in the warm-temperate southwestern Atlantic, with about 5,000 artisanal and 3,000 industrial fishermen temporarily or permanently involved in fishing activities in this region (Haimovici et al. 2006). The estuary is an important nursery for several of the most important species in these fisheries (Chao et al. 1985, Vieira and Castello 1996).

The Mirim Lagoon is shared between Brazil and Uruguay. It has an area of 3,749 km<sup>2</sup>, and is linked to the Patos Lagoon through the São Gonçalo Channel, forming the biggest lagoon system in South America. Mirim Lagoon basin performs an important role in the maintenance of water balance in the adjacent Taim's wetlands, which are recognized as a Biosphere Reserve by the UNESCO and as feeding and breeding grounds for migrant birds, fishes and reptiles (Alba et al. 2011).



**Figure 2.** Female *Cyprinus carpio* (A) caught in April 2011 in the São Gonçalo Channel with mature gonads (B). Measured TL (total length) = 67.0 cm, BW (body weight) = 10,620 g and GW (gonad weight) = 1,926.5 g.



**Figure 3.** Histological section of a *Cyprinus carpio* ovary showing high frequency of oocytes with complete vitellogenesis (Hematoxylin-Eosin).

*C. carpio* specimens were collected by fishermen hired by a local project for monitoring the occurrences of non-native species in the catches. The project was conducted between January 2010 and December 2011, with sampling

conducted every two months. The specimens collected are stored whole frozen or fixed in 10% formaldehyde. The gonads were removed and histologically processed according to the protocol by Beçak and Paulete (1976).

## Results

The present work reports the capture of four individual of *Cyprinus carpio* with mature gonads in the Patos-Mirim System. The first female was caught in September 2010 by artisanal fishermen in Barra do Ribeiro village (30°17'27"S, 51°18'11"W), measuring TL (total length) = 50.5 cm, BW (body weight) = 2,396 g and GW (gonad weight) = 58.5 g. The second female measured TL=67.0 cm, BW = 10,620 g and GW = 1,927g (Figure 2), and was captured in April 2011 in the São Gonçalo Channel (32°03'15"S, 52°30'30"W). Two mature males were caught in November 2011 in Tapes (30°40'41"S, 51°23'36"W) measuring TL = 45.0 and 60.8 cm and BW = 2,917 and 2,844 g respectively. The histological analysis revealed that the ovaries were in an advanced stage of development and had numerous vitellogenic follicles (Figure 3). Only two individuals were deposited in the ichthyological collection of the Federal University of Rio Grande (FURG 2558, FURG 2656). The gonads of all individuals were preserved and deposited in the same collection (FURG 2693-2696).

## Discussion

The reproductive cycle and pattern of gonadal development of *C. carpio* in natural ecosystems greatly depends on the ambient temperature. Spawning occurs at a water temperature of around 18°C (Billard and Breton 1978). The climate regime at Patos Lagoon favours the reproductive cycle of this species (Piedras et al. 2006, Garcia et al. 2008), especially between October and April when the average water temperature is above 17°C (Zanotta et al. 2010).

According to Weber and Brown (2009), *C. carpio* prefers calm and shallow waters, such as flooded grasslands, to spawn. Its eggs have an adherent wrap and the larvae survive in the submerged vegetation of shallow waters even at high temperatures. This microhabitat is commonly found in the shallows waters of Patos-Mirim System and in wetlands located along its margins (Seeliger et al. 1998).

*C. carpio* has an invasion history in neighboring countries with similar climate, such as Uruguay and Argentina (Rosso 2006, Aigo et al. 2008). In the La Plata River basin *C. carpio* is considered the most abundant exotic species and also an important fishery resource (Norbis et al. 2006). In the upper reaches of the Patos Lagoon it has established in the Sinos River basin (Leal et al 2009), Jacuí River and Guaíba Lake (Garcez and Sanchez-Botero 2005).

The ecological consequences of its presence in a natural ecosystem are serious. In particular, the presence of *C. carpio* has been shown to affect (1) rooted macrophyte densities, mainly through physical disturbance and increased turbidity; (2) benthic invertebrate densities, through predation and habitat modification; (3) phytoplankton biomass, by altering the availability of various nutrients through excretion and bioturbation; (4) zooplankton abundance, either indirectly through their effects on phytoplankton or directly through planktivory by juvenile carp *C. carpio*; and (5) the abundance of native fish species, through multiple indirect effects including those described above (Kulhanek et al. 2011). The reduction of abundance of native fishes is of particular concern considering the socio-economic importance of fisheries in the Patos Lagoon (Milani and Fontoura 2007; Vieira et al. 2010)

The low incidence of *C. carpio* in the catches of artisanal fisheries indicates that the species has not yet established in the lower part of the Patos lagoon and Mirim systems, but risk analyses show high invasive potential for this species in the region (Zambrano et al 2006; Troca and Vieira 2012). One hypothesis to explain the failure to establish a sustainable population is the low propagule pressure exerted on the system. Mardini et al. (1997) identified about 26,000 fish farmers in the state of Rio Grande do Sul, but only 2,000 of these are located in the southern counties (Piedras and Bager 2007; Troca 2009). Furthermore, Troca (2009) demonstrate that only less than 5% of these (a total of 84 properties) cultivate carp *C. carpio*.

This paper documents evidence of the initial establishment of *C. carpio* and future work should be carried out in order to monitor this invasion. Surveys should, particularly focus on breeding areas to determine the presence of juveniles, which could confirm the successful establishment of the species in this system.

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## References

- Aigo J, Cussac V, Peris S, Ortubay S, Gómez S, López H, Gross M, Barriga J, Battini M (2008) Distribution of introduced and native fish in Patagonia (Argentina): patterns and changes in fish assemblages. *Reviews in Fish Biology and Fisheries* 18 (4): 387–408, <http://dx.doi.org/10.1007/s11160-007-9080-8>
- Alba JMF, Flores CA, Zarnott DH, Evia G (2011) Sustentabilidade sócio ambiental da bacia da Lagoa Mirim. Embrapa Clima Temperado, Pelotas, Brazil, 320 pp
- Balon EK (1975) Reproductive guilds of fishes: a proposal and definition. *Journal of the Fisheries Research Board of Canada* 32: 821–864, <http://dx.doi.org/10.1139/j75-110>
- Banarescu P, Coad BW (1991) Cyprinids of Eurasia. In: Winfield IJ, Nelson JS (eds), *Cyprinid Fishes: Systematics, Biology and Exploitation*. Chapman and Hall, London, pp 127–155, [http://dx.doi.org/10.1007/978-94-011-3092-9\\_5](http://dx.doi.org/10.1007/978-94-011-3092-9_5)
- Beçak W, Paulete J (1976) *Técnicas de Citologia e Histologia. Livros Técnicos e Científicos*. Editora S.A., Rio de Janeiro, Brasil, 574 pp
- Billard R, Breton B (1978) Rhythms of reproduction in teleost fish. In: Thorpe J (ed), *Rhythmic activity of fishes*. Academic Press, London, England, pp 31–53
- Casal CMV (2006) Global documentation of fish introductions: the growing crisis and recommendations for action. *Biological Invasions* 8: 3–11, <http://dx.doi.org/10.1007/s10530-005-0231-3>
- Chao LH, Pereira LE, Vieira JP (1985) Estuarine fish community of the Patos Lagoon, Brazil. A baseline study. In: Yanez-Arancibia A (ed), *Fish Community ecology in estuaries and coastal lagoons: Towards an ecosystem integration*. Unam Press, Ciudad del México, México, pp 429–445
- De Silva SS, Nguyen TTT, Turchini GM, Amarasinghe US, Abery NW (2009) Alien Species in Aquaculture and Biodiversity: A Paradox in Food Production. *Ambio* 38: 24–28, <http://dx.doi.org/10.1579/0044-7447-38.1.24>
- Garcez DS, Sanchez-Botero JI (2005) Comunidades de pescadores artesanais no estado do Rio Grande do Sul, Brasil. *Atlântica* 27 (1): 17–29
- Garcia AM, Loebmann D, Vieira JP, Bemvenuti MA (2004) First records of introduced carps (Teleostei, Cyprinidae) in the natural habitats of Mirim and Patos Lagoon estuary (South Brazil). *Revista Brasileira de Zoologia* 21(1), <http://dx.doi.org/10.1590/S0101-81752004000100027>
- Garcia LO, Copatti CE, Wachholz F, Pereira Filho W, Baldissotto B (2008) Freshwater temperature in the state of Rio Grande do Sul, Southern Brazil, and its implication for fish culture. *Neotropical Ichthyology* 6(2), <http://dx.doi.org/10.1590/S1679-62252008000200016>
- GISP (2005) *Cyprinus carpio*. Global Invasive Species Database. <http://www.issg.org/database/species/ecology.asp?si=60&fr=1&sts=&lang=EN> (Accessed 14 March 2012)
- Gozlan RE (2008) Introduction of non-native freshwater fish: is it all bad? *Fish and Fisheries* 9(1): 106–115, <http://dx.doi.org/10.1111/j.1467-2979.2007.00267.x>

- Gozlan RE, Britton JR, Cowx I, Copp GH (2010) Current knowledge on non-native freshwater fish introductions. *Journal of Fish Biology* 76(4): 751–786, <http://dx.doi.org/10.1111/j.1095-8649.2010.02566.x>
- Haimovici M, Vasconcellos M, Kalikoski DC, Abdalah P, Castello JP, Hellebrandt D (2006) Diagnóstico da pesca no litoral do Rio Grande do Sul. In: Isaac VJ, Martins AS, Haimovici M, Andriuguetto JM (eds), A pesca marinha e estuarina do Brasil no início do século XXI: recursos, tecnologias, aspectos socioeconômicos e institucionais. Projeto RECOS: Uso e apropriação dos recursos costeiros. Grupo Temático: Modelo Gerencial da pesca. UFPA, Belém, Brasil, pp 157–180
- I3N Brasil (2012) Base de dados nacional de espécies exóticas invasoras, I3N Brasil. Instituto Hórus de Desenvolvimento e Conservação Ambiental. <http://i3n.institutohorus.org.br/brasil/> (Accessed 14 March 2012)
- IBAMA (2007) Estatística da pesca 2007. Brasil: grandes regiões e unidades da federação. Ministério do Meio Ambiente, Brasília, Brasil, 151 pp
- Koehn JD (2004) Carp (*Cyprinus carpio*) as a powerful invader in Australian water ways. *Freshwater Biology* 49: 882–894, <http://dx.doi.org/10.1111/j.1365-2427.2004.01232.x>
- Kulhanek AS, Ricciardi A, Leung B (2011) Is invasion history a useful tool for predicting the impacts of the world's worst aquatic invasive species? *Ecological Applications* 21: 189–202, <http://dx.doi.org/10.1890/09-1452.1>
- Leal M, Bremm C, Schulz UH (2009) Lista da ictiocenose da Bacia do Rio dos Sinos, sul do Brasil. *Boletim do Instituto de Pesca* 35 (2): 307–317
- Mardini CV, Villamil CMB, Severo JCA, Moreira KA, Beltrão L, Calone RG (1997) Caracterização preliminar do perfil da piscicultura desenvolvida no Rio Grande do Sul. Boletim FEPAGRO 6. Porto Alegre, Brasil, 24 pp
- Milani P, Fontoura N (2007) Diagnóstico da pesca artesanal na Lagoa do Casamento, sistema nordeste da laguna dos Patos: uma proposta de manejo. *Biociência* 15 (1): 82–125
- Naylor RL, Williams SL, Strong DR (2001) Aquaculture - a Gateway for Exotic Species. *Science* 294(5547): 1655–1656, <http://dx.doi.org/10.1126/science.1064875>
- Norbis W, Paesch L, Galli O (2006) Los recursos pesqueros de la costa de Uruguay: ambiente, biología y gestión. In: Menafrá R, Rodríguez-Gallego L, Scarabino F, Conde D (eds), Bases para la Conservación y el Manejo de la Costa Uruguaya. Vida Silvestre, Montevideo, Uruguay, pp 197–210
- Orsi ML, Agostinho AA (1999) Introdução de peixes por escapes acidentais de tanques de cultivo em rios da Bacia do Rio Paraná, Brasil. *Revista Brasileira de Zoologia* 16 (2): 557–560
- Piedras SR, Bager A (2007) Caracterização da Aquicultura desenvolvida na Região Sul do Rio Grande do Sul. *Revista Brasileira de Agrociência* 13: 403–407
- Piedras SR, Pouey JL, Moraes PR (2006) Comportamento alimentar e reprodutivo de peixes exóticos e nativos cultivados na zona sul do Rio Grande do Sul. *Revista Brasileira de Agrociência* 12(3): 341–344
- Rosso RJ (2006) Pecees pampeanos: Guia y Ecología. Editora L.O.L.A. Literatura of Latin America, Buenos Aires, Argentina, 224 pp
- Seeliger U, Odebrecht C, Castello JP (1998) Os ecossistemas Costeiro e Marinho do Extremo Sul do Brasil. Editora Ecoscientia, Rio Grande, Brasil, 341 pp
- Troca DFA (2009) Levantamento dos cultivos de peixes exóticos no entorno do estuário da Lagoa dos Patos (RS) e análise de risco de invasão. Msc Thesis, Federal University of Rio Grande, Rio Grande, Brazil 79 pp. Available online at: <http://www.dominiopublico.gov.br/download/texto/cp101285.pdf>
- Troca DFA, Vieira JP (2012) Potencial invasor dos peixes não nativos cultivados na região costeira do Rio Grande do Sul, Brasil. *Boletim do Instituto de Pesca* 38 (2): 109–120
- Vieira JP, Castello JP (1996) Fish fauna. In: Seeliger U, Odebrecht C, Castello JP (eds), Subtropical convergence marine ecosystem. The coast and sea in the warm temperate southwestern atlantic. Springer Verlag, New York, USA, pp 56–61
- Vieira JP, Garcia AM, Moraes L (2010) Assembléia de Peixes. In: Seeliger U, Odebrecht C (eds), O Estuário da Lagoa dos Patos: um século de transformações. FURG, Rio Grande, Brasil, pp 79–88
- Weber M, Brown M (2009) Effects of Common Carp on Aquatic Ecosystems 80 Years after “Carp as a Dominant”: Ecological Insights for Fisheries Management. *Reviews in Fisheries Science* 17(4): 524–537, <http://dx.doi.org/10.1080/10641260903189243>
- Welcomme RL (1988) International introductions of inland aquatic species. Fisheries Technical Paper vol. 294, Roma, Italy, 318 pp
- Zambrano L, Martnez-Meyer E, Menezes N, Peterson AT (2006) Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. *Canadian Journal of Fisheries and Aquatic Sciences* 63(9): 1903–1910, <http://dx.doi.org/10.1139/f06-088>
- ZanottaDC, Ducati JR, Gonçalves GA (2010) Surface temperature patterns of Lagoa dos Patos, Brazil, using NOAA-AVHRR data: an annual cycle analysis. *Pesquisas em Geociências* 37(3): 219–226