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A NATIVE GALAXIID AND AN INTRODUCED POECILIID FISH AS NEW HOSTS TO THE INVASIVE COPEPOD *Lernaea cyprinacea* IN PATAGONIA, ARGENTINA

*Un galáxido nativo y un pez poecílido introducido como nuevos huéspedes del copépodo invasivo
Lernaea cyprinacea en la Patagonia Argentina*

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Abstract. The cosmopolitan invasive copepod *Lernaea cyprinacea* has spread rapidly into Argentinean Patagonia. Specimens of *Galaxias maculatus* and *Cnesterodon decemmaculatus* were analyzed from an ichthyologic collection. These two infected fishes by *L. cyprinacea* enlarge the list of natural hosts in Argentina. The presence of this parasite could represent a threat to fish populations and environmental health due to its pathogenicity.

Keywords. *Lernaea cyprinacea*, *Galaxias maculatus*, *Cnesterodon decemmaculatus*, Patagonia, Argentina.

Resumen. El copépodo cosmopolita invasivo *Lernaea cyprinacea* se ha extendido rápidamente a la región Patagónica, Argentina. En este trabajo se analizaron especímenes de *Galaxias maculatus* y *Cnesterodon decemmaculatus* de una colección ictiológica. Estas dos especies de peces infectadas por *L. cyprinacea* se suman a la lista de hospedadores naturales en Argentina. La presencia de este parásito podría representar una amenaza para las poblaciones de peces y la salud ambiental debido a su patogenicidad.

Palabras clave. *Lernaea cyprinacea*, *Galaxias maculatus*, *Cnesterodon decemmaculatus*, Patagonia, Argentina.

INTRODUCTION

The family Lernaeidae comprises around 110 species of copepods, all of which are parasites of freshwater fishes and greatly adapted to a parasitic lifestyle, with extensive morphological adaptations (Boxshall and Halsey, 2004). The largest genus within this family, *Lernaea*, has been studied intensively due to its economic importance. The most common species is *Lernaea cyprinacea* Linnaeus, 1758, a cosmopolitan copepod known as the “anchor worm”. It is originally from Eurasia and was unintentionally co-introduced with parasitized cyprinid fish stocks onto almost every continent (Avenant-Oldewage, 2012). This parasite infects a great variety of fish species, and has been recorded on adult and larval anurans, axolotls and aquatic insects (Carnevia and Speranza, 2003; McAllister *et al.*, 2011; Salinas *et al.*, 2016). Once the copepod is co-introduced into a new area it is able to infect novel hosts, becoming a co-invasive parasite, and reaching new environments where its original host is absent (Lymbery *et al.*, 2014; Gagne *et al.*, 2015; Waicheim *et al.*, 2019).

In South America, there are records of *L. cyprinacea* in native and introduced fishes from Colombia, Brazil, Uruguay, Chile and Argentina (Gabrielli and Orsi, 2000; Carnevia and Speranza, 2003; Piazza *et al.*, 2006; Alvarez-León, 2007; Habit *et al.*, 2015). Piaszecki *et al.* (2004) indicated that *L. cyprinacea* was co-introduced into South America at the beginning of the 20th century, along with the translocation of specimens of *Cyprinus carpio* Linnaeus, 1758 (the common carp). However, it is likely that co-introduction of the parasite occurred long before this, since records of carp introduction in Argentina date back to the 19th century (Ringuelet *et al.*, 1967; Welcomme, 1988). In Argentina this copepod has spread, and is now widely distributed, with formal records in several provinces (Gilbert *et al.*, 1993; Man-

cini *et al.*, 2008; Plaul *et al.*, 2010; Biolé *et al.*, 2012; Ramallo and Terán, 2014; Waicheim *et al.*, 2017, 2019; Soares *et al.*, 2018). Although it is not clear how and when *L. cyprinacea* was first introduced into Patagonia, this parasite could have been co-introduced into the Patagonian Colorado River along with *C. carpio* during an extraordinary flood from the Salado River in 1983 (López Cazorla and Sidorkewicz, 2002). In the Negro River the parasite seems to have been co-introduced long before the introduction of *C. carpio*, along with the translocation of infected *Cheirodon interruptus* (Jenyns, 1842) from Buenos Aires province, which was used as bait fish (unpublished data). The first record of the genus *Lernaea* in Patagonia dates back to the 1990s in the non-native fish *Oncorhynchus mykiss* (Walbaum, 1792) and the native *Percichthys trucha* (Valenciennes, 1833) and *Odontesthes hatcheri* (Eigenmann, 1909) from the Colorado and Negro rivers (Gilbert *et al.*, 1993; Ortubay *et al.*, 1994; Colavincenzo, 1996). *Lernaea cyprinacea* was later reported in the non-native fish *C. interruptus* in the Negro River (Plaul *et al.*, 2010). In an extensive survey in Patagonia, Waicheim *et al.* (2019) confirmed the molecular identity of *L. cyprinacea*, and reported the infection in *P. trucha* and *O. hatcheri*, both native species, and in the introduced *O. mykiss*, *Jenynsia lineata* (Jenyns, 1842), *C. carpio* and *C. interruptus*.

The freshwater fish fauna of Argentinean Patagonia is composed of a small group of approximately 36 species, including indigenous species and several introduced fishes (Pascual *et al.*, 2007). In particular, northern Patagonia shows an overlap of species from the Austral and Brazilian subregions (Almirón *et al.*, 1997; Aigo *et al.*, 2008). The Brazilian fishes inhabiting the north of Patagonia are *Astyanax eigenmanniorum* (Cope, 1894), *Astyanax pampa* Casciotta, Almirón and Azpelicueta, 2005, *Cheirodon interruptus*, *Oligosarcus jenynsii* (Günther, 1864), *Co-*

ryodoras paleatus (Jenyns, 1842), *J. lineata*, and *Cnesterodon decemmaculatus* (Jenyns, 1842) (Liotta, 2005; Alvear *et al.*, 2007; Baigún *et al.*, 2002; Aigo *et al.*, 2008; Pérez, 2008; Pérez and Lopez Cazorla, 2008; Crichigno *et al.*, 2016; Rauque *et al.*, 2018). The introduction of species is considered a major cause of biodiversity loss, as introduced species can lead to the co-introduction of novel diseases into new areas and threaten native species, causing local extinctions (Primack, 1998; Lymbery *et al.*, 2014; Tompkins *et al.*, 2015).

Cnesterodon decemmaculatus is a small viviparous poeciliid fish native to Central and North Argentina, South Brazil and Uruguay; it is tolerant of low oxygen levels and since being introduced has become abundant in some north Patagonian environments (Ortubay *et al.*, 1997; Pascual *et al.*, 2007). The native *Galaxias maculatus* (Jenyns, 1842) is a small scaleless fish abundant in many Andean Patagonian lakes. This prey fish has an exceptionally wide

distribution, occurring in Australia, Tasmania, Lord Howe Island, New Zealand, Chatham Island, and southern Chile and Argentina (Berra *et al.*, 1996; Macchi *et al.*, 1999). The aim of the present study is to report, for the first time, the parasitic copepod *L. cyprinacea* in specimens of *G. maculatus* and *C. decemmaculatus* from the Negro River, Patagonia.

MATERIALS AND METHODS

Eleven *G. maculatus* and one specimen of *C. decemmaculatus* were captured from Rio Negro River in the locality of Villa Regina (39°10'1.48''S, 67°5'31.98''W) during January 2015. One specimen of *G. maculatus* was captured from Rio Negro River during January 2019 in the locality of Chimpay (39°11'41.00''S, 66°6'45.21''W) (Fig. 1). All the specimens of *G. maculatus* and *C. decemmaculatus* were found to be infected by *L. cyprinacea* (Fig. 2; Table 1). One specimen of

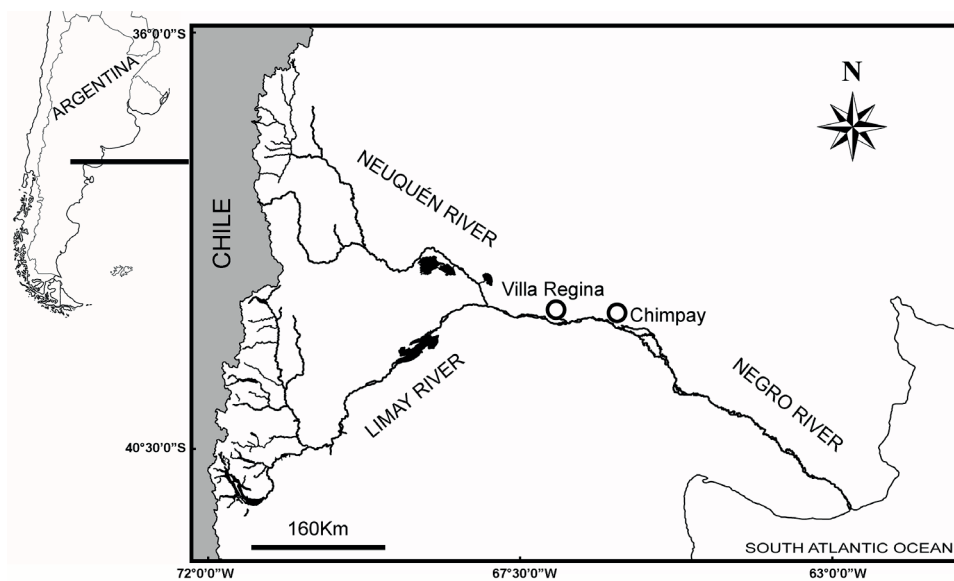


Figure 1 - Localities of fish collections in the Negro River in Northern Patagonia (open circles).



Figure 2 - The co-invasive copepod *Lernaea cyprinacea* parasitizing two fish species from Negro River, Patagonia, Argentina (arrows). a: *Galaxias maculatus*, b: *Cnesterodon decemmaculatus* (Scale bar=1 cm).

G. maculatus (total length 48.25 mm), and one of *C. decemmaculatus* (total length 29.21 mm) from Villa Regina, and one specimens of *G. maculatus* (total length 63.37 mm) from Chimpay were deposited in the *Colección Ictiológica del Centro Nacional Patagónico, Instituto de Diversidad y Evolución Austral (IDEAUS-CONICET)* (Accession numbers: CNPICT 2019/1, 2015/12, 2015/13). These fishes were examined under stereoscopic microscope and the copepods were removed using needles and blades. The copepods were identified using Kabata (1979), Robinson and Avenant-Oldewage (1996), Boxshall and Halsey (2004), Thatcher (2006), and Waicheim *et al.* (2017).

RESULTS

In one specimen of *G. maculatus* from Villa Regina, one copepod was found parasitizing the base of the pectoral fin, and in the other specimen from Chimpay, one parasite was found in the base of the pelvic fin, whereas in *C. decemmaculatus*, *L. cyprinacea* was found in the base of the dorsal fin. In an external analysis of both host species,

we observed that copepods had caused a bloody inflamed area, disruption of tissues at the sites of penetration. The holdfast roots were found encapsulated by fibrous tissue. The copepods were identified by the following characteristics: head with 4 large, frequently-branched anchors, dorsal pair much larger than ventral, dividing into 2 branches some distance from their bases, ventral pair usually simple, neck consisting of second to fourth leg-bearing segments, more or less circular in cross section, and genital pore near posterior extremity, fourth legs on hind body, abdomen conical usually displaced dorsally. In one specimen of *G. maculatus*, *L. cyprinacea* had the remains of an egg sac. The accession number of the voucher specimen of *L. cyprinacea* is Nxxx MACN-Pa (Figure 3).

DISCUSSION

The co-invasive copepod *L. cyprinacea* has been widely co-introduced throughout the world, mostly with the translocation of cyprinids (Gabrielli and Orsi, 2000; Hassan *et al.*, 2008; Smit *et al.*, 2017). In the

Table 1 - Data of fish collection and values of infection with *Lernaea cyprinacea*.

Fish Species	Villa Regina			Chimpay		
	n	prevalence	mean intensity	n	prevalence	mean intensity
<i>Galaxias maculatus</i>	11	9.1%	1	1	1/1	1
<i>Cnesterodon decemmaculatus</i>	1	1/1	1	-	-	-

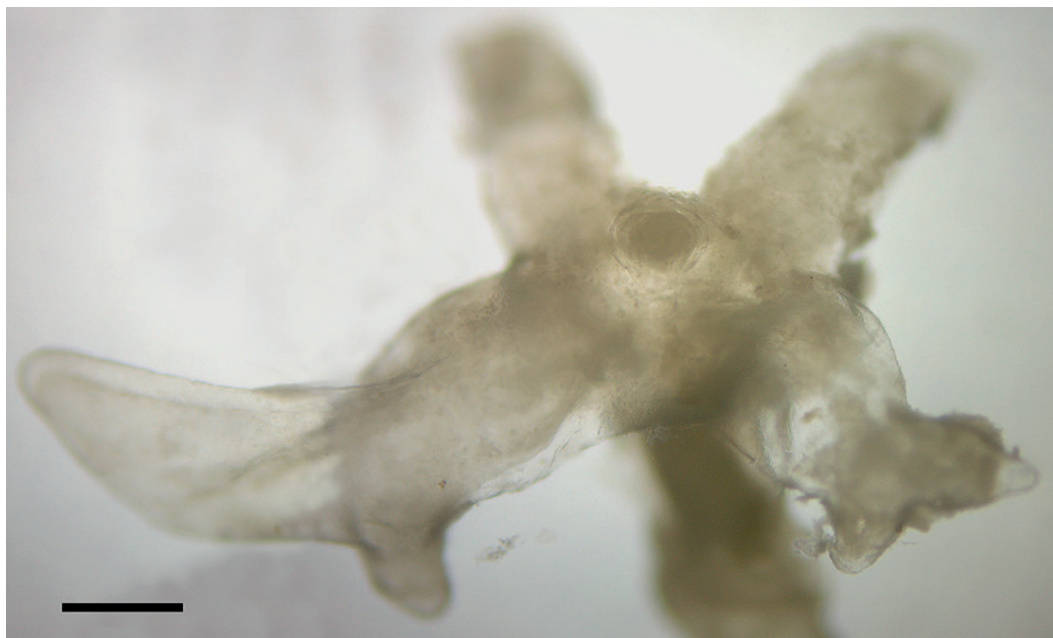


Figure 3 - Head of the anchor worm *Lernaea cyprinacea*, isolated from the fish species *Galaxias maculatus* from Negro River, Argentina (Scale bar=400 μ m).

central region of Argentina, *L. cyprinacea* has become a common parasite in wild and cultured fishes (Mancini *et al.*, 2008), and greatly affects *Odontesthes bonariensis* (Valenciennes, 1835), one of the most important fishery species in Argentina (Mancini *et al.*, 2008). Moreover, small fish species used as bait were found to be infected by the copepod, increasing the potential for parasite dispersion, as thousands of fish are commercialized in this area for fishing activities (Mancini *et al.*, 2008). In Patagonia, the first record of *L. cyprinacea* is from 1993 in the Colorado River (Gilbert *et al.*, 1993). Small Brazilian fishes like *C. decemmaculatus*, *J. lineata* and *C. interruptus* are also used as bait fish in these environments, and may act as dispersal agents for this copepod in Northern Patagonia.

In several outbreaks where *C. carpio* was highly abundant, *L. cyprinacea* was considered part of a multitietiological complex causing native fish mortalities (Villanueva

and De la Mota de Villanueva, 1986; Mancini *et al.*, 2008). *Galaxias maculatus* and *C. decemmaculatus* are remarkably smaller than the original cyprinid hosts, so infections with *L. cyprinacea* can have severe pathogenic effects on these fish hosts. It is possible that copepods interfered in mobility of these small hosts, as they were found in all cases at the base of fins. Pathogenic effects were experimentally proved for specimens of *C. decemmaculatus* by Guagliardo and Tanzola, 2012; who observed visceral cavity of fishes greatly invaded by the holdfast of copepods and ulcerative lesions rapidly infected by *Saprolegnia* sp. causing death of fishes within some weeks. Although *G. maculatus* is considered a least concern species (David *et al.*, 2014), in Argentinean Patagonia large populations are found only in Andean lakes. During recent extensive fish surveys in the Negro river, specimens of *G. maculatus* were captured in low numbers at only one of the sampled sites in the up-

per course of the river (Alvear *et al.*, 2007, unpublished data). However, there have been previous reports of its presence in the middle and lower course of the Negro River (Azpelicueta *et al.*, 1996). There is a decline in native fishes populations like *G. maculatus*, *O. hatcheri*, and *P. trucha* inhabiting the Negro River, (Gonçalves *et al.*, 2010; Crichigno *et al.*, 2016). This basin has been suffering different anthropogenic impacts like several dams' constructions, creation of irrigation systems for agricultural purposes, incorporation of different contaminants coming from the fruit industrial activities and agro industrial urban conglomerates. The introduction of alien species and the co-introduction of novel pathogens can increase the deleterious effects on fish populations (Arribére *et al.*, 2003; Waicheim *et al.*, 2014, 2019; Rauque *et al.*, 2018).

Over the last century, Northern Patagonia has witnessed major changes such as the introduction of salmonids, the construction of several dams, water extraction, increased rainfall and translocation of fish species (Baigún *et al.*, 2002; Aigo *et al.*, 2008; Pérez, 2008; Pérez and Lopez Cazorla, 2008). In the headwater of the Negro River Basin, there are reservoirs with several salmonid farms as well as lakes and rivers included in protected areas of National Parks that could eventually be affected by the co-invasion of this parasite. Considering the low specificity of this copepod (Piasecki *et al.*, 2004; Avenant-Oldewage, 2012), it is expected that in the future it will parasitize more fish species and expands its distribution range in Patagonia. Continuous fish surveillance is necessary for early detection of the invasive *L. cyprinacea* in new areas and hosts. These data are useful when applying conservation policies and for the management of species in environments with low diversity such as Patagonian rivers and lakes.

In South America, specimens of *C. decemmaculatus* were parasitized by *L. cyprinacea*

in Uruguay and in Central Argentina (Gua-gliardo and Tanzola, 2012; Carnevia and Letamendía, 2018). The two fish species recorded in the present study represent new host records for *L. cyprinacea* in Patagonia, and as far as we are aware, this is the first record of *G. maculatus* acting as host for this copepod in its entire distribution range.

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