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The non-indigenous parasitic copepod *Neoergasilus japonicus* (Harada) (Cyclopoida) from central Mexico: the earliest invasion in continental America

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Abstract

The Eastern Asian ectoparasitic copepod *Neoergasilus japonicus* (Harada, 1930) is a widely spread species with a high prevalence on many freshwater teleosts. It was recorded for the first time in Europe 45 years ago and continued its invasion to new geographic regions. Its presence in North America was first detected in 1993, followed by only two other continental records. In this work we present an illustrated record of *N. japonicus* from plankton samples collected during 1990 in a microreservoir of central Mexico. We confirm that this parasitic copepod was already present in continental America at least 3 years before previously known. This is the third published record of this Asian copepod in the Neotropical region. Its occurrence in Mexico is attributed to different events of introduction by human agency. This report supports the notion that *N. japonicus* is more widespread in Middle America than previously thought and it is intended to aid in the historical monitoring of the invasion of this species.

Key words: biological invasions; introduced species; parasitic copepods; freshwater systems

Introduction

Ergasilids are ectoparasitic copepods infecting different freshwater, estuarine, and coastal teleost families in both natural environments and in culture conditions (Nagasawa and Inoue 2012). Among the 27 genera currently contained in the cyclopoid family Ergasilidae, the genus *Neoergasilus* is easily distinguished for a thumb-like spine on the outer margin of the second exopodal segment of the first legs (Boxshall and Halsey 2004). *Neoergasilus japonicus* (Harada, 1930) is a widespread species that has been recorded from numerous freshwater fish species mainly in eastern Asia, Europe, and North America (Hudson and Bowen 2002). The spread of this Asian species has been monitored since it was first recorded in Taiwan in the 1920s and was successively reported from other parts of the continent, including China and Russia. It first reached Europe in the 1960s and the latest continental records include Germany, Italy, and Turkey (see Table 1). This copepod was eventually introduced to the Americas, and first reported from Cuba in 1985 by Prieto et al. (1985). The available data also suggest that it was first recorded in North America eight years later (1993), when it was found in Alabama, in the United States (Hayden and Rogers 1998). Shortly after this first record, it was observed in the Great Lakes area (Hudson and Bowen 2002; Kipp et al. 2013).

This species was reported from south-east Mexico as a parasite of three endangered teleost species; it is the southernmost record of *N. japonicus* in the Americas (Suárez-Morales et al. 2010). During a survey of the aquatic biota of the state of Aguascalientes in central Mexico, several specimens of *N. japonicus* were recorded from plankton and littoral samples obtained in a microreservoir during 1990, that is, 3 years before the presumed first record of this parasite in North America (Hayden and Rogers 1998). We provide original illustrations of the specimens examined. The relevance of this record is discussed in terms of the distribution of this parasite in Mexico and the Americas.

Table 1. Date of first discovery and continental spread of *Neoergasilus japonicus*, modified from Hudson and Bowen (2002) and Knopf and Hölker (2005). Records after 2005: *Alfonso and Belmonte (2010), **Suárez-Morales et al. (2010), ***Soylu and Soylu (2012), ****present survey.

Continent of discovery	Country	Date	Reference
Asia			
	Taiwan	1920s	Harada (1930)
	China	1950s	Yin (1956)
	USSR	1951	Dogiel and Akhmerov (1952)
	Japan	1976	Urawa et al. (1991)
	India	2009	Kumari et al. (2009)
Europe			
	Hungary	1965	Pónyi and Molnar (1969)
	Czechoslovakia	1967	Hanek (1968)
	France	1978	Lescher-Moutoué (1979)
	Great Britain	1980	Mugridge et al. (1982)
	Finland	1985	Tuuha et al. (1992)
	Germany	2001	Knopf and Hölker (2005)
	Italy	2010*	Alfonso and Belmonte (2010)
	Turkey	2012***	Soylu and Soylu (2012)
America			
	Cuba	1985	Prieto et al. (1985)
	Mexico	1990****	present survey
	U.S.A.	1993	Hayden and Rogers (1998)
	Mexico	2010**	Suárez-Morales et al. (2010)

Material and methods

A total of 5 adult females of *N. japonicus* were recovered from the examination of more than 800 plankton samples collected from more than 450 localities representing several freshwater environments (i.e. lakes, permanent and ephemeral ponds, large and small reservoirs) in the state of Aguascalientes, central Mexico. The only site where this species was collected was Los Arquitos reservoir (21°55′28″N; 102°23′25″W), visited September 5, 1990. The specimens were fixed and preserved in a 4% formalin solution. Some specimens were dissected under the stereomicroscope in order to perform the taxonomical examination. Selected specimens were deposited in the collection of Zooplankton held at El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal (ECO-CHZ), Quintana Roo, Mexico.

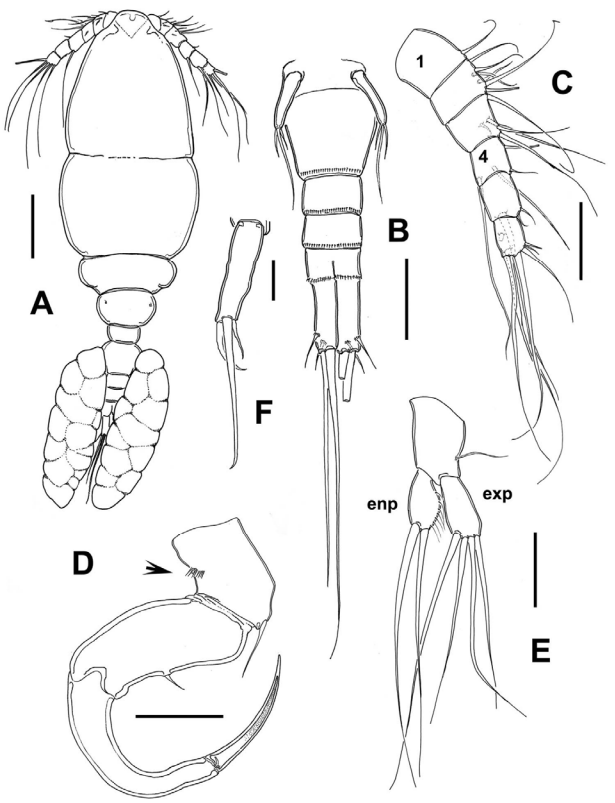
The Los Arquitos reservoir is located at 1929 m above sea level in the municipality of Jesús María in the state of Aguascalientes, central Mexico. This is a small old reservoir, built in 1900–1901, supplied by the Rio Moricinique, with a total capacity is of 0.54 million m^3.

Results

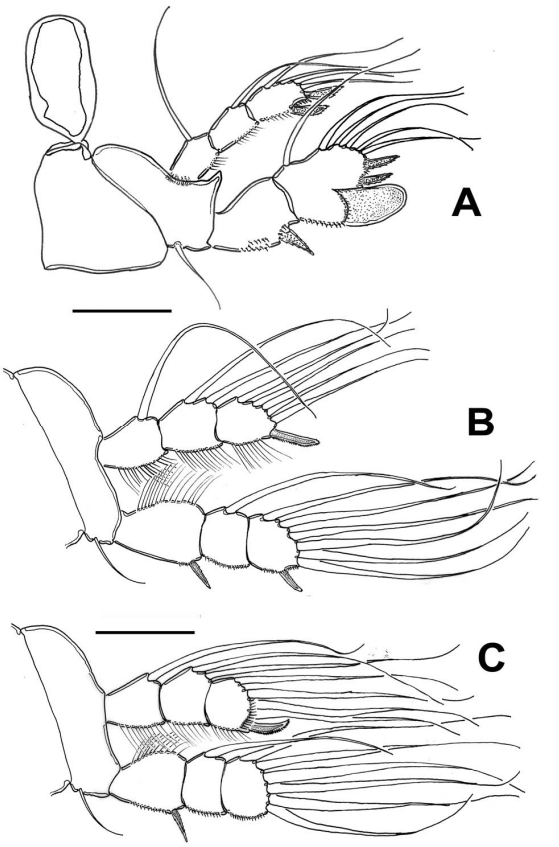
Family Ergasilidae von Nordmann, 1832
Genus *Neoergasilus* Yin, 1956
Neoergasilus japonicus (Harada, 1930)
(Figures 1–2)
Material examined. Two adult females and two juvenile specimens, undissected, ethanol-preserved, from plankton sample, Los Arquitos, Aguascalientes, Mexico, September 5, 1990, vial (ECO-CHZ-08974); two juvenile specimens, dissected, from same site, date of collection, slides mounted in glycerine, sealed with Entellan® (ECO-CHZ-08973).

Morphology

Total body length average of adult specimens =0.70 mm (range of adult specimens: 0.70–0.73 mm, *n*=2) measured from anterior end of cephalothorax to posterior margin of caudal rami, excluding caudal setae. Length of juvenile specimens: 0.63–0.68 mm, n=4. The general morphology of these specimens, including the mouthparts and swimming legs, as described by Hayden and Rogers (1998) and Kim and Choi (2003) (see Figures 1, 2).



Figures 1 A-F. *Neoergasilus japonicus.* Adult female from Aguascalientes, central Mexico. **A**. habitus, ventral view; **B**. urosome, showing fifth legs, ventral view; **C**. antennule; **D**. antenna showing basal row of spinules (arrowed); **E**. fourth leg with 1-segmented rami showing endopod (end) and exopod (exp); F. fifth leg. Scale bars: A=0.1 mm; B-F= 0.05 mm.



Figures 2 A-C. *Neoergasilus japonicus*. Adult female from Aguascalientes, central Mexico. **A**. first swimming leg with modified thumb-like exopodal spine; **B**. second swimming leg; **C**. third swimming leg. Scale bars: **A-C**= 0.05 mm.

Remarks

When compared with values of other adult populations of *N. japonicus*, our specimens' size average is within the overall range known for this species: 0.70–0.75 mm (Kim and Choi 2003; Suárez-Morales et al. 2010). The central Mexico individuals have a size range closest to that of specimens from southeast Mexico (0.67–0.71 mm), but also to those from the Great Lakes area (0.71 mm) (Hudson and Bowen 2002). The Mexican populations are among the smallest known (Suárez-Morales et al. 2010). The specimens from Alabama (0.74–0.79 mm) (Hayden and Rogers 1998), Korea (0.75 mm) (Kim and Choi 2003), and Turkey (0.76 mm) (Soylu and Soylu 2012) are the largest recorded for this species.

Hosts

Unknown, but the reservoir is inhabited by two introduced fish species, the black tilapia *Oreochromis mossambicus* (Peters, 1852) and carp *Cyprinus carpio* Linnaeus, 1758.

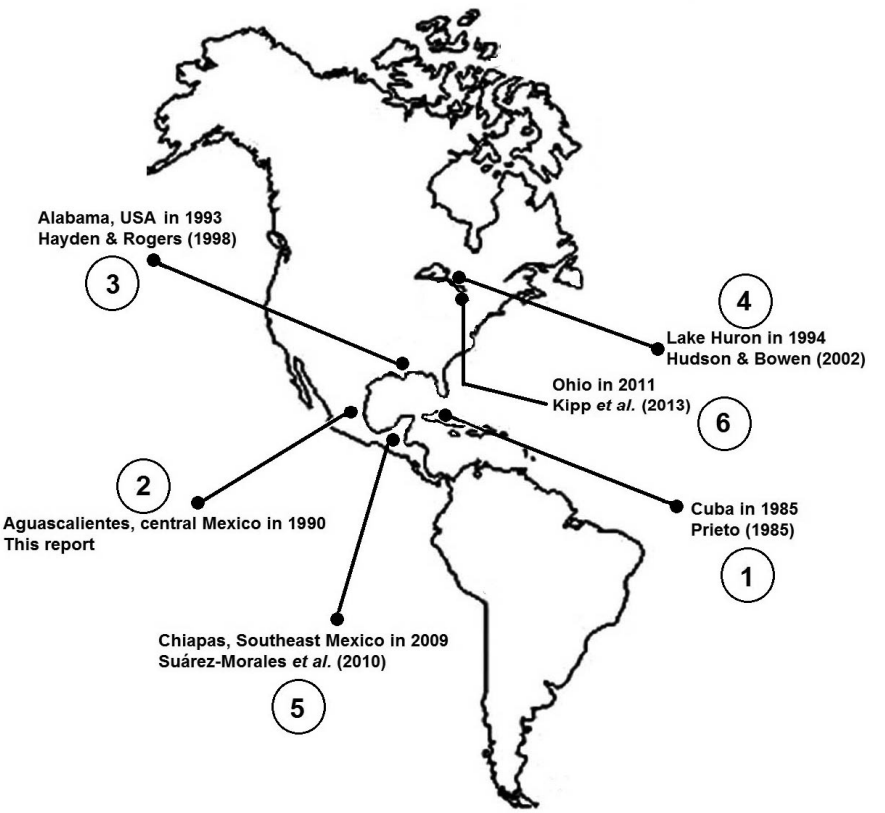


Figure 3. Chronological sequence and geographic distribution of records of *N. japonicus* in the Americas.

Discussion

Most of the research about this species deals with parasitic infection and its effects on natural and cultured fish populations (Nagasawa and Inoue 2012; Nagasawa and Obe 2013), but this ergasilid is also important in other aspects. The gravid females of *N. japonicus*, unlike most other ergasilids, are frequently found as part of the plankton community (Pónyi and Molnar 1969; Hayden and Rogers 1998; Alfonso and Belmonte 2010). In addition, pre-adult individuals are free-living, thus increasing the relevance of this species in the water column biota (Urawa et al. 1991). Tuuha et al. (1992) suggested that direct parasitological surveys may not reveal the presence of this parasite as they are usually loosely attached on the fins of their hosts. This small, inconspicuous species can easily be overlooked by casual examination of parasitized fish (Hudson and Bowen 2002) and there is a limited availability of taxonomic expertise and identification keys. These factors suggest that this parasite is probably more widespread than currently recognized. Parasitological surveys of freshwater fish should be complemented with examination of plankton samples, particularly in detecting the occurrence of this small, widespread parasitic copepod.

Neoergasilus japonicus has been recorded from a wide variety of freshwater fish families worldwide, including cyprinids, percids, centrarchids, ictalurids, and cichlids (Pónyi and Molnar 1969; Lescher-Moutoué 1979; Mugridge et al. 1982; Tuuha et al. 1992; Hayden and Rogers 1998; Hudson and Bowen 2002; Knopf and Hoelker 2005; Suárez-Morales et al. 2010). *Neoergasilus japonicus* can easily change hosts in freshwater systems (El-Rashidy and Boxshall 2009). It is also able to parasitize a wide variety of fish even in limited geographic areas (Kim and Choi 2003) and they can use both native and alien fish species as hosts (Suárez-Morales et al. 2010; Nagasawa and Uyeno 2012). These adaptive features have probably accelerated their spread worldwide.

It is a well-known fact that aquaculture is one of the most relevant means for species introductions (Taylor et al. 2001). Living non-

indigenous fish, mainly cyprinids, were probably the vector by which *N. japonicus* reached Mexico, but this parasite is currently infecting native, endangered teleost species as well (Suárez-Morales et al. 2010). The occurrence of this species in southeast Mexico (Suárez-Morales et al. 2010) suggests an anthropogenic introduction as this is an area with intense aquacultural activity (Zambrano and Macías-García 1999). The present results suggest that *N. japonicus* was first introduced in central Mexico and this was probably also a result of human agency related to aquaculture. In the area of Aguascalientes, central Mexico, many reservoirs and microreservoirs have long been used for fish culture and at least 13 introduced teleost species have been recorded in the state (Martínez and Rojas 1996).

The expansion of the parasite distributional range is a by-product of the rapidly increasing rates of fish introductions related to aquacultural activities worldwide (Taylor et al. 2001; Reid and Hudson 2008; Gozlan et al. 2010). *Neoergasilus japonicus* has been known to disperse over long distances rather quickly, spreading across Europe in 20 years and then moving towards the Americas over a span of less than 10 years (Hanek 1968; Hudson and Bowen 2002; Table 1). Our finding of this species in central Mexico from samples collected in 1990 reveals that it was already present in the continent at least 3 years before Hayden and Rogers' (1998) record, at that time recognized as the first known record in continental America. There is an older American record, from Cuba (Prieto et al. 1985), where it was recorded from different teleost species. The species remained unrecorded from adjacent Caribbean islands and from the American mainland for nearly 5 years before it was detected (this survey) on the continent. During the 1960s and 1980s, Cuba received a strong aquacultural influence from the Soviet Union, including the introduction of different fish species (Coto 2006). In Russia *N. japonicus* was recorded in the 1950s (Dogiel and Akhmerov 1952; Gussev and Smirnova 1964) so it is possible that the introduction of *N. japonicus* in Cuba resulted from this process. Because of the isolation of Cuba, it is unlikely that this invasion was a stepping stone for further introductions in the Americas. The Mexican records are likely the result of independent colonization events and are more likely to represent intermediate steps of the spreading of this copepod in continental America, where it was probably introduced by aquaculture-related activities.

Currently, the southernmost record (16°N) of this species in the Americas is from the state of Chiapas, in southern Mexico. According to Suárez-Morales et al. (2010) it is expected that *N. japonicus* will eventually advance to other areas of the Neotropical region. It is probable that it is already present but undetected in these areas. Fish and plankton samples from the Neotropical region including Central and South America should be examined with more detail in order to determine the true distribution of this copepod. This illustrated report is intended to aid in the historical monitoring of the spreading process of this parasitic species.

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References

Alfonso G, Belmonte G (2010) *Neoergasilus japonicus* (Harada, 1930): a new non-indigenous copepod for the Italian fauna. *Italian Journal of Zoology* 77: 172–178, http://dx.doi.org/10.1080/11250001003591783

Boxshall GA, Halsey SH (2004) Copepod Diversity. Vols. I & II. The Ray Society London, London, 966 pp

Coto MG (2006) National Aquaculture Sector Overview. Fact Sheets - Cuba. FAO. 2006–2013. Departamento de Pesca y Acuicultura de la FAO. Rome

El-Rashidy H, Boxshall GA (2009) Parasites gained: alien parasites switching to native hosts. *Journal of Parasitology* 95: 1326–1329, http://dx.doi.org/10.1645/GE-2190.1

Gozlan RE, Britton JR, Cowx I, Copp GH (2010) Current knowledge on non-native freshwater fish introductions. *Journal of Fish Biology* 76: 751–786, http://dx.doi.org/10.1111/j.1095-8649.2010.02566.x

Gusev AV, Smirnova TS (1964) Crustacea. In: Pavlovskii EN (ed), Key to the parasites of freshwater fish of the U.S.S.R. Israel Program for Scientific Translations, pp 745–801

Dogiel VA, Akhmerov AK (1952) Parasitic Crustacea of fishes of the Amur. Uchenye Zapiski Leningradskogo Ordena Lenina Gosudarstvennogo Universiteta Imeni A A Zhdanova 141. *Seriya Biologicheskikh Nauk* 28: 268–294

Hanek J (1968) The finding of *Neoergasilus japonicus* (Harada, 1930) (Copepoda: Ergasilidae) in Europe. *Folia Parasitologica* 15: 227–228

Harada I (1930) Studies on the freshwater fauna of Formosa (I). A new copepod species parasitic on Formosan freshwater fish. *Journal of Tropical Agriculture* 2: 71–76

Hayden KJ, Rogers WA (1998) *Neoergasilus japonicus* (Poecilostomatoida: Ergasilidae), a parasitic copepod new to North America. *Journal of Parasitology* 84: 88–93, http://dx.doi.org/10.2307/3284535

Hudson PL, Bowen CA (2002) First record of *Neoergasilus japonicus* (Poecilostomatoida: Ergasilidae), a parasitic copepod new to the Laurentian Great Lakes. *Journal of Parasitology* 88: 657–663

Kim I-H, Choi S-K (2003) Copepod parasites (Crustacea) of freshwater fishes in Korea. *Korean Journal of Systematic Zoology* 19: 57–93

Kipp RM, Benson AJ, Larson J, Fusaro A (2013) *Neoergasilus japonicus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/ queries/ factsheet.aspx?SpeciesID=2595 Revision Date: 6/1/2012

Knopf K, Hölker F (2005) First report of *Philometra obturans* (Nematoda) and *Neoergasilus japonicus* (Copepoda) in Germany. *Acta Parasitologica* 50: 261–262

Kumari PS, Madhavi R, Ramakrishna R (2009) *Neoergasilus japonicus* (Harada) (Poecilostomatoida, Ergasilidae), a parasitic copepod new to India. *Indian Journal of Fisheries* 56: 287–291

Lescher-Moutoué F (1979) Présence en France du Copépode Ergasilidae *Neoergasilus japonicus* (Harada, 1930). *Crustaceana* 37: 109–112

Martínez J, Rojas A (1996) La ictiofauna del Estado de Aguascalientes. *Investigación y Ciencia, Universidad Autónoma de Aguascalientes* 19: 26–33

Mugridge RE, Stallybrass HG, Hollman A (1982) *Neoergasilus japonicus* (Crustacea Ergasilidae). A parasitic copepod new to Britain. *Journal of Zoology* 197: 551–557

Nagasawa K, Inoue A (2012) Variations in the infection level of *Neoergasilus japonicus* (Copepoda: Ergasilidae) between freshwater fishes at different sites in the Ashida River system, western Japan. *Zoosymposia* 8: 106–116

Nagasawa, K. Uyeno D (2012) Utilization of alien freshwater fishes by the parasitic copepod *Neoergasilus japonicus* (Ergasilidae) on Okinawa-jima Island, Japan, with a list of its known hosts. *Zoosymposia* 8: 81–96

Nagasawa K, Obe M (2013) Spatial distribution of *Neoergasilus japonicus* (Copepoda, Ergasilidae) on the fins of the bluegill (*Lepomis macrochirus*). *Journal of Natural History* 47: 543–552, http://dx.doi.org/10.1080/00222933.2012.747635

Prieto A, Fajer E, Vinjoy M (1985) *Neoergasilus japonicus* (Copepoda: Ergasilidae) en peces en cultivo intensivo en Cuba. *Revista de Salud Animal* 7: 407–410

Pónyi J, Molnar K (1969) Studies on the parasite fauna of fish in Hungary V. Parasitic copepods. *Parasitologia Hungarica* 2: 137–148

Reid JW, Hudson PL (2008) Rate of species introductions in the Great Lakes via ships' ballast water and sediment. *Canadian Journal of Fisheries and Aquatic Science* 65: 549–553, http://dx.doi.org/10.1139/f08-018

Suárez-Morales E, Paredes-Trujillo A, González-Solís D (2010) The introduced Asian parasitic copepod *Neoergasilus japonicus* (Harada) (Cyclopoida: Ergasilidae) from endangered cichlid teleosts in Mexico. *Zoological Science* 27: 851–855, http://dx.doi.org/10.2108/zsj.27.851

Soylu E, Soylu MP (2012) First record of the non-indigenous parasitic copepod *Neoergasilus japonicus* (Harada, 1930) in Turkey. *Turkish Journal of Zoology* 36: 662–667, http://dx.doi.org/10.3906/zoo-1101-92

Taylor RL, Williams SL, Strong DR (2001) Aquaculture: A gateway for exotic species. *Science* 299: 1655–1656, http://dx.doi.org/10.1126/science.1064875

Tuuha H, Valtonen ET, Taskinen J (1992) Ergasilid copepods as parasites of perch *Perca fluviatilis* and roach *Rutilus rutilus* in Central Finland – seasonality, maturity and environmental influence. *Journal of Zoology* 228: 405–422, http://dx.doi.org/10.1111/j.1469-7998.1992.tb04444.x

Urawa S, Muroga K, Kasahara S (1991) Growth and fecundity of the parasitic copepod *Neoergasilus japonicus* (Ergasilidae). *Bulletin of the Plankton Society of Japan* (Spec Vol): 619–625

Yin WY (1956) Studies on the Ergasilidae (parasitic Copepoda) from the freshwater fishes of China. *Acta Hydrobiologica Sinica* 2: 209–270

Zambrano L, Macías-García C (1999) Impact of introduced fish for aquaculture in Mexican freshwater systems. In: Claudi R, Leach JH (eds), Non-indigenous freshwater organisms. Vectors, Biology, and Impacts. CRC Press, pp 113–124