Survival of *Argulus japonicus* (Branchiura: Argulidae) on a cyprinid in drought-induced brackish waters in a Japanese lake

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**Abstract.**—Two specimens of a freshwater fish parasite *Argulus japonicus* Thiele, 1900 were found to be mixed in a sample of over 600 specimens of a brackish-water fish parasite *Caligus orientalis* Gusev, 1951 in a glass vial kept at Hiroshima University. These specimens were all collected in September 1973 from the body surface of a moribund Japanese white crucian carp, *Carassius cuvieri* Temminck & Schlegel, 1846, in drought-induced brackish waters of Lake Shinji, Shimane Prefecture, Japan. This collection indicates that *A. japonicus* can survive in brackish waters under unusual climate conditions.

**Key words**: fish parasite, *Caligus orientalis*, concurrent infection, salinity tolerance, Lake Shinji

*Argulus japonicus* Thiele, 1900 is an ectoparasite of freshwater fishes (Poly, 2008; Neethuling & Avenant-Oldewage, 2016). This species was originally described using material from Japan (Thiele, 1900), where it has been reported from cyprinids in inland waters and almost exclusively those fishes reared at fish ponds and aquaria (Nagasawa, 2011a, 2011b, 2017, 2018; Nagasawa et al., 2010, 2012, 2013, 2018; Yamauchi & Shimizu, 2013; Nagasawa & Sato, 2014; Nagasawa & Miyajima, 2018; see Nagasawa, 2009 for the earlier literature). Nevertheless, Yamauchi et al. (2011) collected *A. japonicus* from an aquarium-held fish reared in brackish waters (salinity: 1–7‰). This collection is interesting because *A. japonicus* had never been recorded from salt waters. In this paper, I report on my observation to support Yamauchi et al.’s finding on the survival of *A. japonicus* in brackish waters.

Recently, I found two specimens of *A. japonicus* and 605 specimens of copepod *Caligus orientalis* Gusev, 1951 (Siphonostomatoida: Caligidae) in a glass vial kept at the Laboratory of Aquatic Pathology, Hiroshima University, Higashi-Hiroshima, Japan. The latter species is known as a brackish-water fish parasite (Nagasawa, 2004). Based on a specimen label, all of these specimens were collected from the body surface of a moribund Japanese white crucian carp, *Carassius cuvieri* Temminck & Schlegel, 1846 (written as “kawachi-buna” in Japanese) (body size unknown), by Hiroya Suzumoto (Mitoya Inland Branch, Shimane Prefectural Fisheries Experimental Station) on 11 September 1973 in brackish waters of Lake Shinji, Shimane Prefecture, Japan.

Lake Shinji (79.1 km², 6.4 m in maximum depth, 35°27′01″N, 132°56′58″E at its center) is connected to the Sea of Japan through a brackish-water lake and two short channels. In the summer of 1973, there was a serious drought around the lake, which caused a marked increase in lake water salinity up to 12.7‰ at the surface and 16.3‰ near the bottom [Suzumoto, 1974; chlorinity values (C) reported by this author are here transferred to salinity values (S, ‰) using an equation: $S = 0.030 + 1.8050 \times C$]. Under such unusual conditions, marine and brackish-water fishes from the nearby brackish-water lake and the Sea of Japan invaded Lake Shinji, where the co-invading parasite *C. orientalis* reproduced and heavily parasitized *Carassius cuvieri* (reported
as Carassius auratus) in the brackish-water region (Suzumoto, 1974). Suzumoto (1974) examined those fish and reported on the heavy infection of C. orientalis but did not state the concurrent infection with A. japonicus. He probably overlooked the two specimens of A. japonicus mixed in the sample of over 600 specimens of C. orientalis.

The specimens of A. japonicus consisted of one male and one female, measuring 4.0 × 2.5 mm and 4.8 × 3.1 mm, respectively (Fig. 1). They were damaged, probably due to rough removal from the host fish and/or infection in brackish waters. Thus, their detailed morphological features were not observed well, but they correspond to A. japonicus described by Tokioka (1936) and Yamaguti (1937). The male specimen somewhat resembles that of Argulus coregoni Thorell, 1864 but has not a digitiform process on the dorso-posterior margin of the second leg, which is one of the reliable features to characterize A. coregoni (Tokioka, 1936; Yamaguti, 1937). In Lake Shinji, A. japonicus was previously collected from common carp, Cyprinus carpio Linnaeus, 1758 (Nagasawa et al., 2009).

The present finding of A. japonicus from the fish in the drought-induced brackish waters of Lake Shinji indicates that A. japonicus can survive in such salt waters, as previously observed in an aquarium (Yamauchi et al., 2011). The salinity of Lake Shinji strikingly increased in July 1973 (Suzumoto, 1974), and the parasite specimens were sampled on 11 September 1973. Thus, A. japonicus most likely could survive for about two months in brackish waters. In other words, the species is able to tolerate salinity change for a certain period.

Carassius cuvieri is endemic to Lake Biwa and the Yodo River system, central Japan, and has been introduced to many Japanese rivers and lakes, including Lake Shinji. The Hii River...
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flows into the western end of Lake Shinji, and the salinity of the lake increases from the western coast towards the eastern area (Date et al., 1989). While C. cuvieri is generally regarded as a freshwater species, it is actually euryhaline as it is known to occur even in the brackish lower reaches of the Nagara River, a big river in central Japan (Suzuki & Kimura, 1977, 1978). In Lake Shinji and its adjacent region, C. cuvieri usually occurs in the lower reaches of the Hii River and the western (freshwater) area of the lake (Koshikawa, 1985), where the individual of C. cuvieri examined by Suzumoto (1974) perhaps became infected by A. japonicus. Moreover, because of its salt tolerance, this individual is considered to have survived along with A. japonicus in the drought-induced brackish waters.

Argulus flavescens Wilson, 1916 and A. kosus Avenant-Oldewage, 1994 are known to occur in both fresh and salt waters in North America (Causey, 1960; Cressey, 1972; Suárez-Morales et al., 1998) and South Africa (Van As et al., 1999), respectively. These species are completely separated from A. japonicus in their geographical distribution, and, most probably, their euryhaline characteristic has evolved independently. For understanding their occurrence and host utilization within their distributional range, it is desirable to experimentally access their tolerance to various salinities.

The specimens of A. japonicus are deposited in the Crustacea collection of the National Museum of Nature and Science, Tsukuba, Ibaraki Prefecture, Japan (NSMT-Cr 26691).

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