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NOTE

First record of the harpacticoid genus *Harpacticella* in the Pacific Northwest, USA: another probable introduction

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ABSTRACT: We report the first occurrence in the Pacific Northwest, USA, of the harpacticoid copepod genus *Harpacticella* (Family Harpacticidae), which has previously been recorded only from Asia and from an atoll in the Indian Ocean. *Harpacticella paradoxa* (Brehm, 1924) is native to streams, lakes and estuaries in Japan and China. *H. paradoxa* was found in plankton samples taken in 2000 and 2004 from 2 geographically separated estuaries (Samish and Klamath River Estuaries, USA) at salinities ranging from 0 to 15 psu. *H. paradoxa* was also found associated with plants sampled in 2006 from a freshwater reservoir in the Columbia River, Washington State, USA. Because the genus *Harpacticella* has previously been found only in Asia and the Indian Ocean; is probably easily transported on ship hulls or in ballast; and appears to have a disjunct regional distribution, we regard it as a probable introduced species to North America.

KEY WORDS: Introduced species · Harpacticoida · *Harpacticella paradoxa* · Pacific Northwest USA

INTRODUCTION

Estuaries along the west coast of North America have experienced multiple invasions by planktonic copepods native to east Asia. The most notable examples include the San Francisco Estuary, which has been invaded by 5 calanoid and 3 cyclopoid copepod species, and the Columbia River Estuary, which has seen the introduction of 4 calanoid and 1 cyclopoid copepod species (including 1 calanoid species not yet found in the San Francisco Estuary). One result of these invasions is that these copepods often dominate the mesozooplankton assemblages in their invaded habitats (Orsi & Ohtsuka 1999, Bollens et al. 2002, Bouley & Kimmerer 2006).

In contrast to these planktonic invasions, no confirmed records of established non-native benthic or epibenthic harpacticoid copepods have been reported in the Pacific Northwest. However, invasions by non-native harpacticoid copepods have been reported in other regions. For example, in the Laurentian Great Lakes, several sand-dwelling harpacticoids are regarded as introduced (Horvath et al. 2001), and the meiofaunal harpacticoid *Enhydrosoma lacunae* Jakubisiak is regarded as having been introduced to the eastern tropical Pacific from the Caribbean (Gómez 2003).

In this paper, we report the first record of the Asian harpacticoid copepod genus *Harpacticella* (Family Harpacticidae) in 2 estuaries and one freshwater reservoir on the west coast of the United States. *Harpacticella paradoxa* (Brehm, 1924) was found in plankton net samples and plant washings taken as part of periodic surveys of estuaries in the region designed to sample invasive invertebrates.

MATERIALS AND METHODS

Material for this study came from 2 research projects. The first was a plankton survey of estuaries on the west coast of North America, conducted in late summer/early autumn 2000 and 2004. Plankton samples were collected from 32 estuaries, located between the

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Campbell River, British Columbia, Canada, and the Russian River, California, USA (Fig. 1). Plankton was sampled at each of 5 sampling stations, at bottom salinities of ~ 0, 1, 3, 5, and >9 psu, which were located using a YSI portable salinity-temperature meter. Sampling occurred within 1 h of flood slack tide. At each station, one vertical plankton tow was taken from a small (4 m) boat, using a 0.5 m diameter, 0.073 mm mesh plankton net. The net was lowered to the bottom, depth was recorded, and the vertical orientation of the line was maintained by maneuvering the boat. After approximately 30 s, the net was pulled to the surface at a speed of approximately 0.5 m s^{-1}. In both sampling years, harpacticoid copepods from the genus *Harpacticella* were found at several sampling stations in 2 estuaries (Samish and Klamath River estuaries) during sorting and enumeration of plankton. Samples containing *Harpacticella* were re-examined and representative adult male and female individuals were removed for further study.

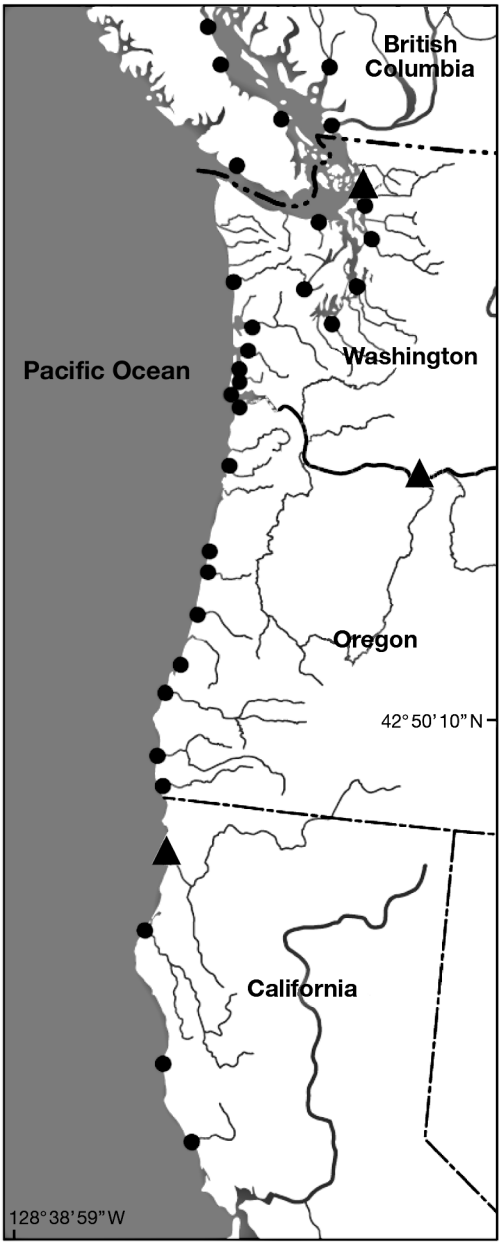

Fig. 1. Location of samples examined for non-indigenous invertebrates (●); locations at which *Harpacticella paradoxa* was found (▲)

As part of a non-indigenous species survey in the middle Columbia and lower Snake Rivers, Washington State, USA, we collected invertebrates from non-quantitative plankton net samples, and from washings of bottom sediment/vegetation samples, in September 2006. In one sample from a reservoir on the Columbia River, *Harpacticella* were found from plant washings.

Specimens of male and female *Harpacticella* from each location were dissected in a drop of 50:50 water: glycerin solution, and transferred to a streak of the solution on a glass slide. A cover slip was placed on the slide and ringed multiple times with clear nail polish. The copepod appendages were photographed with a Nikon Coolpix 8700 digital camera mounted on a Zeiss compound microscope with a phototube. In several cases, a single image of an appendage was created by combining several individual photographs in order to enhance the resolution (focus) of the entire appendage.

RESULTS AND DISCUSSION

We found adult male and female *Harpacticella paradoxa* at 3 geographically separated locations (Fig. 1, Table 1). At 2 of these locations (Klamath River Estuary and Lake Celilo, Columbia River), it occurred in fresh water, and at one location (Samish River Estuary) it occurred at salinities ranging from 0.1 to 15 psu. In all cases, juvenile copepodid stages and gravid females were also found. Harpacticoid copepods were a common component of the estuary plankton net samples, and *H. paradoxa* co-occurred with a variety of other benthic/epibenthic harpacticoids in the families Ameiridae, Canthocamptidae, Ectinosomatidae, Laophontidae, Tachidiidae, and Tisbidae. This is the first report of this species from brackish water: previous records were from fresh water (Table 2). It is also the first report of the genus *Harpacticella* outside of Asia with the exception of one record from Aldabra Atoll in the Indian Ocean near Madagascar (distribution summarized in Chang & Kim 1991).

Several attributes of the occurrence of *Harpacticella paradoxa* in the Pacific Northwest fit the criteria for exotic species designation proposed for peracarid crustaceans (Chapman & Carlton 1991), and suggest that it has been introduced.

Table 1. *Harpacticella paradoxa.* Occurrences in samples from the Pacific Northwest USA

Location and date	Coordinates	Salinity (psu)	Collection method
Klamath River, CA 9 Oct 2000, 2 Sep 2004	41° 31′ 03″ N 124° 02′ 11″ W	0.1–0.1	Plankton net
Samish River, WA 8 Sep 2000, 6 Sep 2004	48° 33′ 42″ N 122° 25′ 53″ W	0.1–15	Plankton net
Lake Celilo, Columbia River, WA 1 Sep 2006	45° 39′ 02″ N 120° 57′ 40″ W	0	Plant wash

Table 2. *Harpacticella paradoxa*. Previously reported locations

Location	Description	Author(s)
Talifu Lake, Yunan Province, China	With aquatic plant *Potamogeton*	Brehm (1924) Pesta (1930)
Yukawa River, Honshu, Japan	With aquatic plant *Ranunculus*	Ito & Kikuchi (1977)
Hokkaido, Japan	Forested stream	Ishida (1987)
Nikko, Tochigi Prefecture, Honshu, Japan	Mountain spring and stream	Ishida (1989)
Tokyo, Japan	Urban lakes, ponds, springs, and streams	Ishida (2003) Ishida et al. (2004)

(1) There is a human mechanism of introduction, via extensive shipping traffic across the Pacific Ocean between Asia and North America. Our finding of *H. paradoxa* in both plankton samples and plant washings suggests that either ballast water or hull fouling could have been the mode of transport of this species.

(2) *H. paradoxa* has a discontinuous regional distribution: despite our extensive coastal plankton sampling spanning multiple years, it was found in only 3 locations, and in the comprehensive plankton surveys *H. paradoxa* was found in both 2000 and 2004 at only 2 locations and nowhere else.

(3) This species appears to have a disjunct global distribution. It has been found only in Japan, China, and now North America. It is possible that it has a circumboreal distribution, because small animals such as harpacticoid copepods are easily overlooked. However, several surveys of harpacticoids in southern Alaska, USA and British Co-

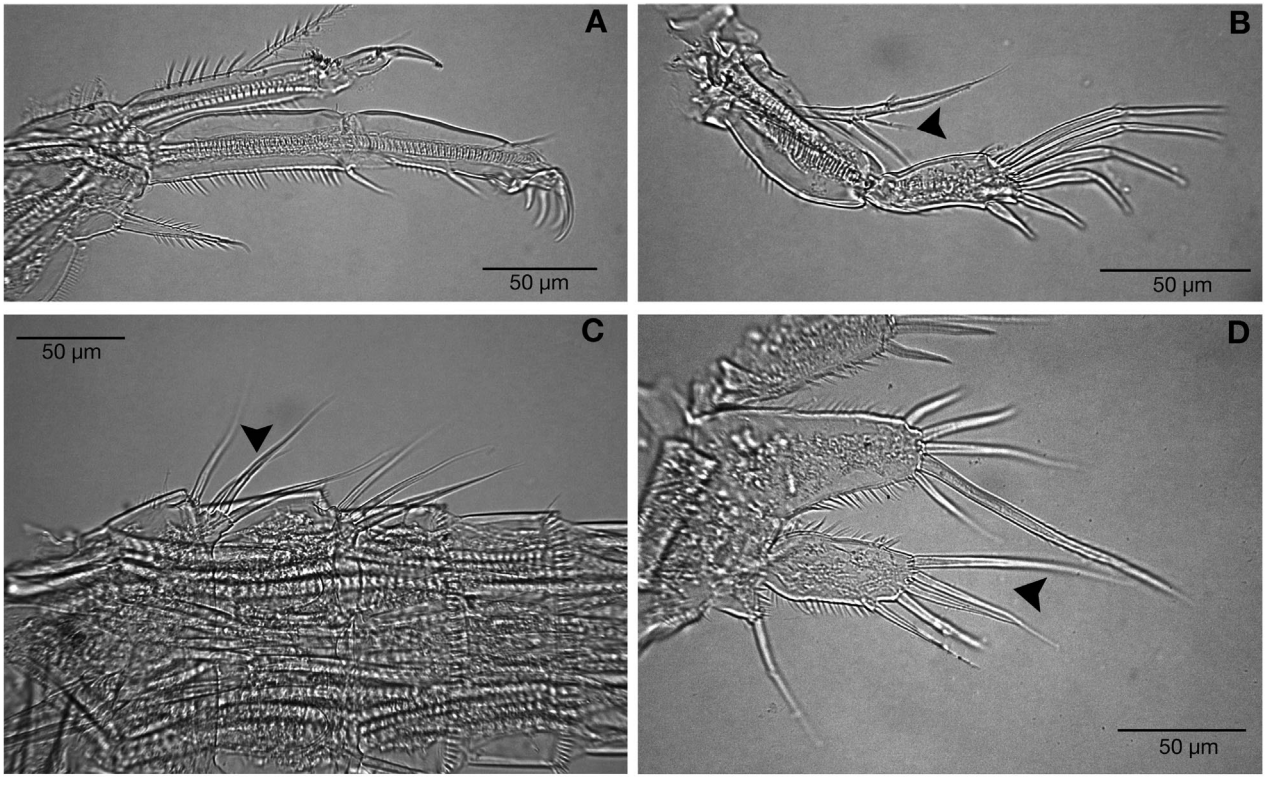

Fig. 2. *Harpacticella paradoxa.* (A) First leg of male. (B) Second antenna of female; arrow indicates lateral seta on second segment of exopodite. (C) Urosome of male; arrow indicates setae on fifth leg. (D) Fifth leg of female; arrow indicates setae on exopodite

lumbia, Canada that included habitats likely to harbor *Harpacticella* (i.e. low salinity, vegetated) did not record this genus (Kask et al. 1982, Hines & Ruiz 2000, 2001).

(4) *H. paradoxa* appears to have an exotic evolutionary origin: the genus *Harpacticella* is almost exclusively Asian.

Like many other small benthic/epibenthic organisms, harpacticoid copepods may be easily transported, and *H. paradoxa* may continue to be found in new locations. It is remarkable that this species was found more than 150 km upstream from the nearest shipping port at Portland, Oregon. It may have been introduced upstream via smaller vessels (e.g. grain barges, recreational boats), and we note that at least one other introduced Asian copepod, the calanoid *Pseudodiaptomus forbesi*, has recently become very abundant in the first 4 reservoirs of the Columbia River and has been found at least 500 km upstream (J. Cordell unpubl.).

Harpacticella is the only genus in the family Harpacticidae known to occur in fresh or oligohaline waters, and this family is easily recognized by its distinctive first leg structure (Fig. 2A). The exopod is longer than the endopod and consists of 2 long segments without any inner setae. The rudiment of the third exopod segment is embedded in the second segment and bears several curved claws and a seta. The endopod has 2 or 3 segments with one large curved claw (and sometimes a small secondary claw) and a seta. According to Itô & Kikuchi (1977), *Harpacticella paradoxa* can be distinguished from the 5 other known species of *Harpacticella* in having a lateral seta on the second segment of the antennal exopodite (Fig. 2B). In addition, *H. paradoxa* has distinctive fifth legs. In *H. paradoxa*, *H. inopinata* G.O. Sars, 1908, and *H. lacustris* Sewell, 1924, the male and female fifth leg are armed with 3 and 5 setae, respectively (Fig. 2C,D). However, in *H. paradoxa*, the fifth leg is elongated, more than twice as long as broad, whereas in *H. inopinata* it is about twice as long as broad and oval-shaped, and in *H. lacustris*, it is quadrangular, and only about 1.5 times as long as broad. While our specimens of *Harpacticella* appear to be *H. paradoxa* based on the attributes listed above and by comparison with the excellent redescription of the species by Itô & Kikuchi (1977), it is possible that they represent a very closely related undescribed species. Morphological stasis is known to occur in some copepods, such that genetic sequencing is needed for species separation (Lee & Frost 2002), and there are cases in which harpacticoid copepods identified under one species name represent several species (e.g. Huys et al. 2005). We invite taxonomic specialists and geneticists to test the hypothesis that the Pacific North American populations of *H. paradoxa* are the same population as the Asian species.

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