New record of non-indigenous cladoceran *Pleuroxus denticulatus* Birge, 1879 (Cladocera: Chydoridae) in the European Russia

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ABSTRACT: Biological invasions require thorough and comprehensive research. During a field investigation in a mouth area of a tributary of the Gorky Reservoir (Middle Volga) an non-indigenous species *Pleuroxus denticulatus* Birge, 1879 (Crustacea: Cladocera) was encountered. It is one of most common species of Chydoridae in Canada and USA. Morphology of studied specimens fully agrees with earlier descriptions of the species. The role of the species in the zooplankton community of the mouth area river was not significant. Discovery of *P. denticulatus* in the mouth area of the Shacha River (Kostroma Area) is the second record of its presence in European Russia and its fourth record in the entire country. The mouth area of the Shacha River can apparently act as a local pool for further dispersion of this species into other streams and lakes of the Volga basin, including its major reservoirs.
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KEY WORDS: Cladocera, mouth area river, non-indigenous species, Russia.

Новая находка чужеродного ветвистоусого рачка *Pleuroxus denticulatus* Birge, 1879 (Cladocera: Chydoridae) в Европейской России

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РЕЗЮМЕ. Биологические инвазии требуют всестороннего и комплексного исследования. В рамках экспедиционных исследований в устьевой области притока Горьковского водохранилища (Средняя Волга), был обнаружен чужеродный вид *Pleuroxus denticulatus* Birge, 1879 (Crustacea: Cladocera). Это один из самых распро-

страненных видов Chydoridae в Канаде и США. Морфология изученных экземпляров полностью согласуется с более ранними описаниями вида. Роль *P. denticulatus* в гидробиоценозе была не значительной. Роль вида в сообществе зоопланктона устьевой области реки была не значительной. Находка *P. denticulatus* в устьевой области р. Шача (Костромская область) является второй находкой этого вида на территории Европейской России и четвертой находкой на территории всей России. По всей видимости, устьевая область р. Шача может являться источником расселения этого вида в новые водоемы и водотоки бассейна р. Волги и ее водохранилищ.
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КЛЮЧЕВЫЕ СЛОВА: Cladocera, устьевая область реки, чужеродный вид, Россия.

Introduction

Biological invasions are originally natural processes ensuring dispersal of species at a slow pace (Hollebone, Hay, 2007). However, dramatic increase in human migrations, global transportation and other anthropogenic activities in 20th–21st centuries has accelerated the spreading of non-indigenous species, changing the initial speed and nature of this process (Mooney, Cleland, 2001; Olden *et al.*, 2004).

Biological invasions cause changes in indigenous ecological communities and lead to global faunal homogenization, exacerbating the global biodiversity crisis (Olden *et al.*, 2004; Hollebone, Hay, 2007). For this reason, biological invasions demand comprehensive researches. A noticeable lag between a non-indigenous species arrival and manifestation of consequences of this event makes it necessary to provide a continuous ecological monitoring of aquatic communities. This approach to reveals the spreading of species, and facilitates its control.

Pleuroxus denticulatus Birge, 1879 was described from Wisconsin state, USA (Birge, 1879). It is one of most common species of Chydoridae in Canada (Chengalath, 1987) and USA (Shan, Frey, 1983). The species has penetrated South to Central America (Shan, Frey, 1983). *P. denticulatus* was also recorded in the Old World, but only a few records were accompanied by reliable descriptions and illustrations. The first reliable European record was from Germany (Flossner, Kraus, 1977); morphological analysis has revealed no significant differences between German and American populations. Later, *P. denticulatus* was recorded in rice fields of Lombardy and Emilia-Romania regions of Italy (Margaritora, 1983), in the Ter River basin in Spain (Alonso, 1996), and in the Danube basin in Slovakia (Hudec, Illyova, 1998; Hudec, 2010). Amoros (1984) included this species in the key of French Cladocera, but provided no detailed distribution.

Subtropical and tropical regions of Asia, Africa south of Sahara are inhabited by abundant sibling-species, *Pleuroxus quasidenticulatus* (Smirnov, 1996), and records of *P. denticulatus* from China, India and Africa probably all refer to the former species (Sinev, Sanoamuang, 2013). For example, Kotov *et al.* (2011) reported *P. denticulatus* from the Zea River basin, but this record was later attributed to *P. quasidenticulatus* (Sinev, Sanoamuang, 2013). Descriptions of *P. denticulatus* from Cameroon (Chiambeng, Dumont, 2004) and from India (Gogoi *et al.*, 2018) is also clearly refers to *P. quasidenticulatus*. The only reliable record of *P. denticulatus* accompanied by description from Asia is that of Kotov *et al.* (2017) from South Korea.

The present contribution considers new record *P. denticulatus* in the European Russia and provide morphological data on our specimens.

Material and methods

In this work, we analyzed zooplankton samples taken during an expedition along the course of the Volga River. Zooplankton diversity of several mouth

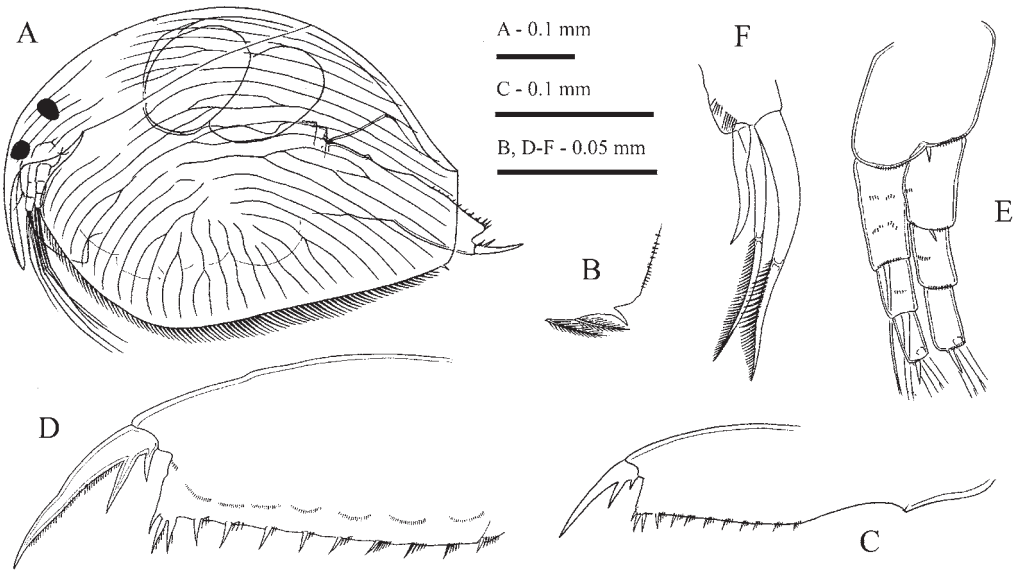

Fig. 1. *Pleuroxus denticulatus* Birge, 1897 from the Shacha River, parthenogenetic female. A — lateral view; B — postero-ventral corner of valves; C — postabdomn; D — distal portion of postandomen; E — antenna; F — Inner distal lobe of thoracic limb I.
Рис. 1. *Pleuroxus denticulatus* Birge, 1897 из реки Шача, партеногенетическая самка. A — вид сбоку; B — задневентральный угол створки; C — постабдомен; D — дистальная часть постабдомена; E — антенна; F — внутренняя дистальная доля грудной конечности I.

areas of rivers flowing into reservoirs on the Volga were examined in August 2020, including the Shacha River mouth. The Shacha is a small river with total length of 58 km and watershed area of 631 km^2. Its lower course is navigable for 4 km up from the river's mouth and its morphology is significantly altered for ship anchorage and to accommodate the needs of the Kostromskaya thermal power station.

Samples were taken by dragging a 70 ìm plankton net bottom to surface near the river shore away from aquatic plants and preserved with formaldehyde. Specimens were selected from samples under a binocular stereoscopic microscope, placed on slides (in a drop of a glycerol-ethanol mixture), studied using an optical microscope (Olympus CX41) and measured. Three specimens from Shacha River were dissected for analysis of appendages. For SEM examination, specimens were subject to critical point drying, coated with gold-palladium and studied using scanning electron microscope CamScan S2. Measurements were determined using an eyepiece-micrometer; all drawings were made with a camera lucida.

During the study period, water temperature was quite high 26.8±1.9 °C, dissolved oxygen content 6.7±0.5 mg/l (saturation 74.9±7.7%), water electrical conductivity 268.2±16.7 uS/cm, total dissolved solids 193.5±12.0 mg/l, water salinity 0.14±0.01 ppt, transparency over Secchi disk small 0.8±0.1 m, depth varied 4.0±1.1 m.

Taxonomy

Superorder Cladocera Latreille, 1829
Order Anomopoda G.O. Sars, 1865
Family Chydoridae Dybowski
et Grochowski, 1894
Genus *Pleuroxus* Baird, 1843
Pleuroxus denticulatus Birge, 1879
Figs 1–2.

MATERIAL EXAMINED. Twelve specimens from the mouth area of the Shacha River (right-side tributary of the riverine part of the Gorky Reservoir), near the town of Volgorechensk and discharge outlet of the Kostromskaya thermal plant (57°27′52″ N, 41°11′42″ E), 81 m above sea leve, Kostroma Area, European Russia.

MORPHOLOGY OF PARTHENOGENETIC FEMALE. Morphology of studied specimens fully agrees with the earlier descriptions of the species (Birge, 1879; Flössner, Kraus, 1977; Shan, Frey, 1983; Hudec, 2010; Kotov *et al.*, 2017; Korovchinsky *et al.*, 2021).

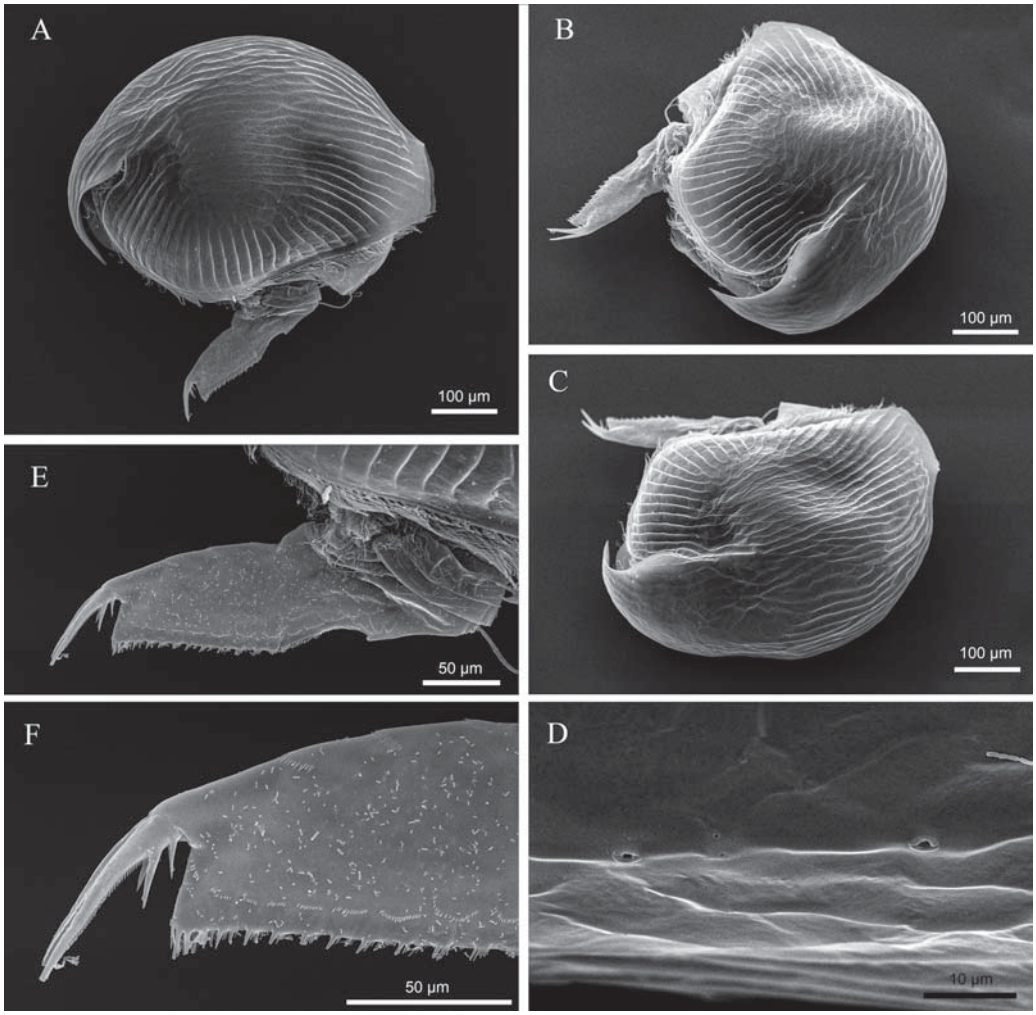

Fig. 2. *Pleuroxus denticulatus* Birge, 1897 from the Shacha River, parthenogenetic female. A, B, C — same specimen in lateral, frontolateral, and dorsolateral view; D — head pores; E — postabdomen; F — distal portion of postandomen.
Рис. 2. *Pleuroxus denticulatus* Birge, 1897 из реки Шача, партеногенетическая самка. A, B, C — тот же экземпляр сбоку, переднебоковом и дорсальном виде; D — головные поры; E — постабдомен; F — дистальная часть постабдомена.

Body (Figs 1A, 2A, B, C) ovoid in lateral view, weakly compressed laterally, moderately high, maximum height before midline. Height/length ratio about 0.7 in adult. Dorsal margin of body highly arched, posterior margin of valves almost straight, ventral margin of valves strongly convex. Posterodorsal angle of valves well-defined.

Posteroventral angle of valves (Fig. 1B) with 1-3 sharp narrow denticles, posterior denticle always clearly curved down. Valves (Figs 1A, 2A–B) and head shield (Fig. 2C) with prominent linear sculpture, with minute dot-like depressions between the lines, especially well-developed in central part of valves (Fig. 2B). Eyes larger than ocellus. Rostrum of moderate length, pointing downward or slightly curved posteriorly, in frontal view triangular, with pointed tip (Fig. 2B). Head shield with two major head pores (Fig. 2D), postpore distance about four interpore distance, two minute pores at midline, located somewhat closely to anterior major pore. Labral keel large with convex anterior margin, with blunt or rounded apex.

Postabdomen (Figs 1C–D, 2E–F) long, low, weakly narrowing in postanal portion, postanal margin weakly concave to straight, anal margin irregularly concave. Length about 4 heights, distal (anal + postanal) portion three times longer than preanal, postanal portion two times longer than anal. Distal angle acute, prominent, with slightly rounded apex, postanal angle not defined, preanal angle well-defined. Preamal margin with about 10–12 marginal denticles, 3–4 distalmost denticles located very close to each other on distal angle; each denticle accompanied with cluster of several thin setulae. Postabdominal claw (Figs 1D, 2F) slightly curved, with two robust basal spines, length of the distal spine about 0.3 claw length, proximal spine two times shorter that distal one.

Antenna I short, without peg at the base, antennular seta located at 1/3 of appendage length from its distal end, with nine terminal aesthetascs of subequal size. Antenna II short, basipodite with a minute spine distally (Fig. 1E). Basal segment in both branches much longer than middle and apical segments. Antennal formula: setae 0-0-3/0-1-3, spines 1-0-1/0-0-1; all antennal spine very small. Morphology of thoracic limbs typical for the genus. Inner distal lobe of limb I with two large setae setulated distally, subequal in length (Fig. 1F) and a shorter naked seta.

According to literature data (Korovchinskiy *et al.*, 2021), the body length *P. denticulatus* varies between 450 and 680 μm. Lengths of adult females in the Shacha River mouth were 510-680 μm.

DIFFERENTIAL DIAGNOSIS. *Pleuroxus denticulatus* clearly differs from most indigenous taxa of European Russia (*P. aduncus* (Jurine, 1820)*, P. uncinatus* Baird, 1850, *P. laevis* (Sars, 1862), *P. pigroides* Lilljeborg, 1900, *P. quasidenticulatus* (Smirnov, 1996), *P. trigonellus* (O.F. Müller, 1785)) in a well-developed thick linear sculpture on both valves and head shield (see Korovchinsky *et al.*, 2021). This feature is shared only by two species, *P. truncatus* (O.F. Müller, 1785) and *P. striatus* (Shödler, 1863) (see Korovchinsky *et al.*, 2021). *P. truncatus* is clearly different from *P. denticulatus* in presence of numerous denticles on anteroventral angle and on posterior margin of valves. *P. striatus* differs from *P. denticulatus* in low elongated body (height/length ration about 0.6), much longer and narrower postabdomen with rounded distal angle, with distal distal (anal + postanal) portion three times longer than preanal, and marginal denticles not forming thick cluster at the end of postabdomen.

DISTRIBUTION REMARK. Prof. N.N. Smirnov, the greatest authority in Old World Chydoridae of XX century, did not find *P. denticulatus* during his extensive studies of Chydoridae of European Russia (Smirnov, 1971). Contrasting between frequencies of species records in America and Europe strongly suggests it is a non-indigenous species in the latter region (Hudec, Illyova, 1998). The species was recently recorded in European Russia, Kostroma Area, in small rivers of Kologrivsky Forest Nature Reserve (Sirotina, 2017).

BIONOMICS. *P. denticulatus* belongs to the faunistic complex of southern thermophilic species (Kotov, 2016). Its biology and ecology are poorly studied. It is usually found among vegetation in the littoral zone or in organic-rich sediment of eutrophic lakes, ponds, reservoirs, floodplain lakes and rivers. The species' life cycle and reproduction and their dependence on duration and intensity of illumination were studied by Shan (1970).

POPULATION FEATURE. The role of *P. denticulatus* in zooplankton community in the mouth area of the Shacha River seems to be insignificant.

Discussion

The discovery of *P. denticulatus* in the mouth area of the Shacha River (Kostroma Area) is the second record of its presence in European Russia and its fourth record in the entire country. Both findings in European Russia are confined to Kostroma Area (Sirotina, 2017). Introduction of the species into the Shacha River mouth presumably was accidental. Its population is likely supported by favourable environmental conditions, namely relatively high water temperatures due to thermal pollution from the Kostromskaya power station. The previous finding of the species in European Russia also was made in Kostroma Region, to the north of our site, in 2013–2017. It is possible that *P. denticulatus* was brought there from the Shacha mouth by seasonally migrating water birds. Despite rigorous studies of zooplankton communities in the Middle Volga region, no other occurrences of *P. denticulatus* have been noted there below 57 °N.

Thus, its geographic range within the Volga basin is currently limited to its northern part, and its occurrences are still extremely rare. The mouth area of the Shacha River can apparently act as a local pool for further distribution of this species into other streams and lakes of the Volga basin, including its major reservoirs. It should be noted that the invasive Asian clam *Corbicula fluminea* (Müller, 1774) also was found in the study area (Perova *et al.*, 2017; Pryanichnikova *et al.*, 2019; Voroshilova *et al.*, 2021), which may indicate an invasion of an entire complex of

Fig. 3. Map of the record *Pleuroxus denticulatus* Birge, 1879 in the Eurasia according to literature data regarded as reliable by authors of this paper.
Рис. 3. Карта находок *Pleuroxus denticulatus* Birge, 1879 в Евразии по литературным данным, которые авторы данной статьи считают надежными.

thermophilic flora and fauna into the Shacha River mouth. Thermal pollution from the power plant could have created a buffer zone with environmental conditions that favour thermophilic species. Transformed aquatic ecosystems of this kind are unique habitats for non-local flora and fauna.

It is critical that *P. denticulatus* has not yet been subjected to serious revision. A revision of the species is required for a proper species identification, i.e. due to a high chance of its misidentification with *P. quasidenticulatus*.

Compliance with ethical standards

CONFLICTS OF INTEREST: The authors declare that they have no conflicts of interest.

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