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Expansion of the invasive bivalve mollusk *Dreissena bugensis* (quagga mussel) in the Don and Volga River Basins: Revisions based on archived specimens

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Abstract

Archived specimens of *Dreissena*, collected as part of a long-term biomonitoring effort in the lower Don and Volga River systems and dating back to 1979, were re-examined. Originally identified as *Dreissena polymorpha* or variants thereof, some of the specimens were identified to be *Dreissena bugensis*. Based on this new evidence, the invasion history of *D. bugensis* in these two river systems was re-evaluated. The finding of *D. bugensis* in the lower Volga River in the early 1980s rather than in the late 1980s/early 1990s indicates that its spread was much slower than earlier believed. Apparently, widespread dispersal was greatly facilitated by the completion of the reservoir system in the Volga River in the late 1980s which created conditions that were more conducive to this species. Upstream dispersal in both the Don and Volga Rivers was likely a function of human-mediated transport.

Key words: Volga-Don canal; nonindigenous species; biological invasions; aquatic invaders; Ponto-Caspian region.

1. Introduction

The range extension of the quagga mussel (*Dreissena bugensis* Andr., 1897) provides a striking example of how rapidly a species can colonize new environments once outside its native habitat. This species was first described in the Yuzny (South) Bug River (Dnepr-Bug Liman estuary), Ukraine at the end of the 19th century (Andrusov 1890). Its distribution remained confined within the Dnepr-Bug River region until the 1940s when the construction of canals allowed it to spread through the reservoirs and river systems of the Black Sea basin (Zhuravel 1951; Kharchenko 1995). More recently, in the 1990s, it was found outside its native range in the Volga

River system and in low-saline waters of the north Caspian Sea (Reid, Orlova 2002; Orlova *et al.* 2004). Although absent from western Europe (Bij de Vaate *et al.* 2002), it became established in the North American Great Lakes in 1989 (May, Marsden 1992), and is still spreading within this system (Nalepa *et al.* 2001). Because of world-wide concern over biological invaders, there has been a concerted effort to predict future range extensions and assess ecological risks associated with species such as *D. bugensis* that have an invasion history (Ricciardi, Rasmusson 1998; Leppakoski *et al.* 2002; Ricciardi 2003). Since future predictions are based on past tendencies, a clear documentation of the chronology, pathways, and circumstances associated with dispersal patterns is critical to the assessment process.

The introduction of *D. bugensis* into the Volga River system was significant for several reasons. For one, it was the first time this species occurred outside its native watershed and second, it allowed this species to greatly expand its range in Eurasia. There are uncertainties, however, of when this species became established in the Volga River, and thus it is unclear how it arrived and then spread through the system. According to previous reports, the first record of *D. bugensis* in the Volga River system was in 1992 in reservoirs along the mid-portion of the river (Antonov 1993). It was suggested then that the invasion pathway was through the Volga-Don Canal, which connects the Don River system (Black Sea basin - native range) and the Volga River (Volga River basin - extended range). *D. bugensis* was not reported from the Don River at the time, so these first colonizing individuals must have been from the Black Sea basin. A recent re-examination of archived specimens, however, showed that *D. bugensis* was present in the lower Volga River and the lower Don River in the early 1980s (Zhulidov *et al.* 2004). Thus, this raises questions concerning the timing of the invasion process and the vectors contributing to the establishment and spread of this species in the Volga River.

In this paper, we further re-examine archived specimens of dreissenids collected at several locations in the Don and Volga Rivers. We then reconstruct the invasion history of *D. bugensis* though the Volga River system.

2. Materials and methods

Samples of *Dreissena* were collected yearly at four sites in the Don River (Sites 2, 3, 4, 5; Fig. 1) and two sites in the Volga River (Sites 6, 7; Fig. 1) as part of a biomonitoring program that was initiated in 1979. One site was directly east (Site 6) and another directly west (Site 5) of the Volga-Don Canal (Fig. 2). This artificial waterway was completed in 1952 and serves as an important shipping corridor (Volf 1971). It also provides a pathway by which species move between the Ponto and Caspian basins (Grigorovich *et al.* 2003). The canal is 101 km long and includes 45 km of natural river channel and reservoirs along with 13 sluices (Fig. 2). It extends from the Sarepta Cove of the Volga River (just south of Volgograd) to the Don River (Tsimlyansk Reservoir) near the town of Kalach-on-Don.

The six sampling locations were part of a larger station set within the continuing bio-monitoring program under the supervision of the Hydrochemical Institute. Dreissenids at the various sites were collected by hand from any accessible substrate along the shore. Collections were not quantitative, but care was taken to collect representative specimens randomly and in direct proportion to their occurrence. Dreissenids were dried whole (shell and soft tissue) and stored in doubled polyethylene bags. All specimens were originally identified as *Dreissena polymorpha* or variants of this species but, upon examination of specimens at a few sites, some specimens were identified as *Dreissena bugensis* (Zhulidov *et al.* 2004). As a result, all archived specimens collected between 1979 and 1996 at all monitoring sites were re-examined. Overall, about 165 dreissenid specimens were examined, and *D. bugensis* was differentiated from *D. polymorpha* based on morphological features of the shells as described in May and Marsden (1992). The absence or presence of well-developed carina, and the acute angle between dorsal and ventral surfaces of the shell were the main features separating the two species. Relative proportions of *D. bugensis* and *D. polymorpha* were determined for each site.

3. Results and discussion

Prior to our examining the archived specimens, there was no information on the presence/absence of *D. bugensis* in the Don and Volga River systems in the immediate vicinity of the Volga-Don Canal. When first examining the archived specimens, we found that *D. bugensis* was present in the Volga River system at a site near Akhtubinsk (Site 7; Fig. 1) as early as 1981 and in the Don River system at a site near Rostov-on-Don (Site 2; Fig. 1) in 1980 (Zhulidov *et al.* unpubl.). Upon re-examination of archived specimens collected at sites in the immediate vicinity of the canal in 1992, we did not find *D. bugensis*. It was not present at the Sarepta Cove site (Site 6) located just east of the canal, nor was it present at the Kalach-on-Don site (Site 5) located just west of the canal (Table I). Since *D. bugensis* was present in the Volga River near Akhtubinsk as early as 1981, the canal likely did not serve as an interme-

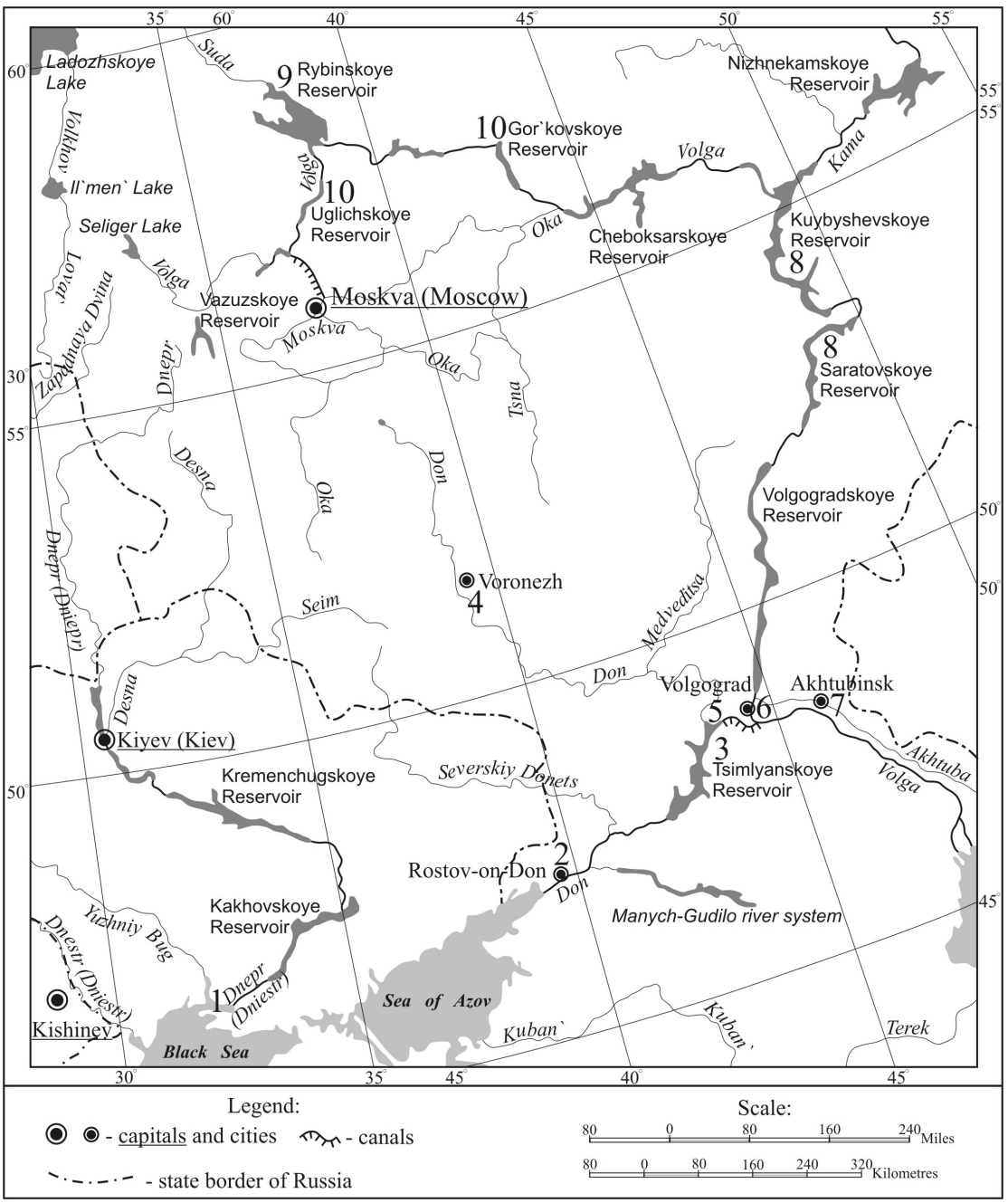

Fig. 1. Location of sampling sites in the Don and Volga River systems. Sites 2-7 were locations where archived specimens of *Dreissena* were re-examined. The other sites are mentioned in the text or given in Table 1.

diate source of mussels to the river as suggested previously (Orlova *et al.* 2003). Most likely the source of the Volga River population found near Akhtubinsk was from mussels present in ship ballast water, or from individuals attached externally to ship structures (biofouled). The source most likely was from the parent population in the Black Sea basin since *D. bugensis* in the Don River system was very rare in the early 1980s (Zhulidov *et al.* unpubl.). The evidence suggests that ship traffic also contributed to the spread of *D. bugensis* in the Don River system. It was found at an upstream site near the city of Voronezh (Site 4; middle Don River) in 1996, which was 4-6 years before it was found at some downstream sites (Sites 3 and 5) in 2000 and 2002.

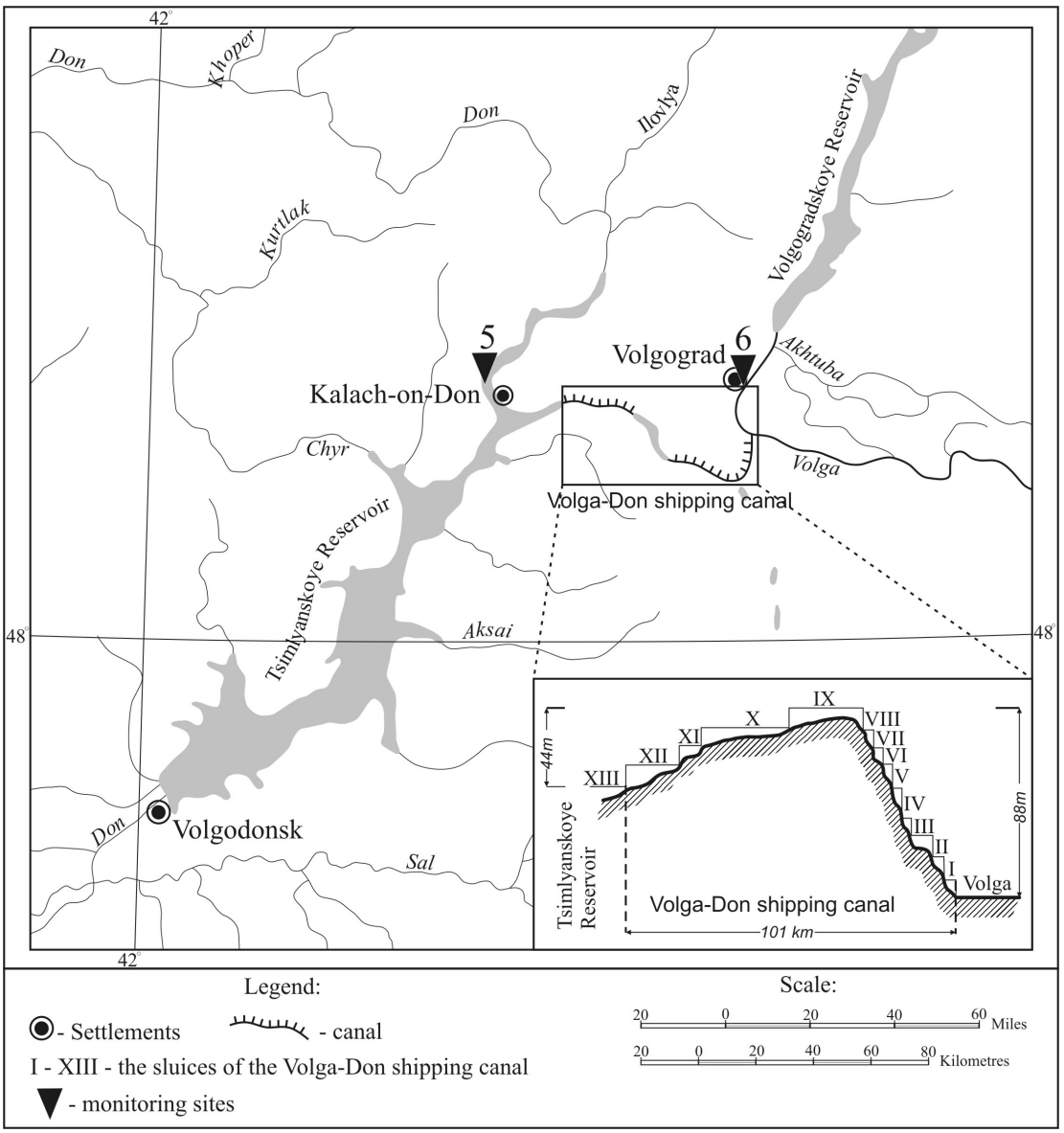

Fig. 2. Detailed illustration of the Don-Volga canal and location of sampling sites in the immediate vicinity of the canal. The canal is 101 km long and the maximum change in elevation is 88 m. The canal connects the Ponto and Caspian Basins and likely provided the pathway by which ship traffic transported *Dreissena bugensis* into the Volga River.

The revised invasion chronology of *D. bugensis* in the Volga River based on our archived specimens suggests that this species did not spread as rapidly as earlier believed, and also provides better insights into habitat preferences of this species. Previously, the first record of *D. bugensis* in the Volga River occurred in the Kuyshevskoye/Saratovskoye reservoirs (Site 8) in 1992 (Antonov 1993). Based on the size of these specimens and typical growth rates, most likely it was introduced into these reservoirs between 1988-1990 (Orlova *et al.* 2004). It was subsequently found downstream in the Volga River delta/north Caspian Sea region in 1994 (Grigorovich *et al.* 2003). Conceivably the latter could have been a separate introduction via ship transport, but most likely the introduction was a result of the downstream drift of veliger larvae as suggested by Orlova *et al.* (2004). The distance between Kuybyshevskoye/Saratovskoye reservoirs (Site 8) and the Volga River delta is about 700 km, well within the 500 km per year downstream dispersal of *D. polymorpha* veligers determined for the same stretch of river (Kirpichenko 1997). This of course assumes that the *D. bugensis* population increased rapidly after the initial

Table I. Summary of available data on the invasion chronology of *Dreissena bugensis* in the Don and Volga River basins as based on revisions of archived specimens. Relative abundances given in 2002 are not based on archived specimens.

Site (see Fig. 1)	Site Description	Year Monitoring was Initiated	Year *D. bugensis* was first found	Percentage *D. bugensis* / total *Dreissena* in 2002	Reference
1	Dnepr-Bug Liman (estuary)		1890		Andrusov (1890)
2	Lower Don River, City of Rostov-on-Don	1979	1980	4 to 75 %	Zhulidov *et al.* (unpubl.)
3	Lower Don River, Tsimlyansk Reservoir	1985	2000	Approx. 1%	Present study
4	Middle Don River, 50 km downstream city of Voronezh	1986	1996	No data	Present study
5	Middle Don River Volga-Don Channel, near town of Kalach-on-Don	1992	2002	Approx. 3%	Present study
6	Lower Volga, near Volga-Don Channel, Sarepta Cove downstream of City of Volgograd	1992	1983[1]	Approx. 2%	Present study
7	Lower Volga, near town of Akhtubinsk	1979	1981	No data	Zhulidov *et al*. (2004); present study
8	Middle Volga River, Kuybyshevskoye and Saratovskoye reservoirs	No data	1992	Varied from abundant to rare in different habitats	Antonov (1993, 1996); Kalayda (2003)
9	Upper Volga, Rybinskoye Reservoir	No data	1997[2]	Varied from abundant to rare in different habitats, tends to replace *D. polymorpha*	Scherbina (2003); Orlova *et al*. (2004)
10	Upper Volga region, Gor'koyskoye and Uglichskoye reservoirs	No data	2000	Varied from abundant to rare in different habitats	Scherbina (2003)

[1] Archived specimens indicated that *D. bugensis* was at this site in 1983 but was not found when the Biomonitoring program was initiated in 1992.

[2] Samples of Dreissenidae collected in 1993 by Dr. V. Kozlovskaya, Institute for Biology of Inland Waters, were re-examined at the Hydrochemical Institute. *D. bugensis* was found at one of the sites, indicating that this species was actually present earlier than previously reported.

introduction, producing sufficient propagules for downstream dispersal. Our finding of *D. bugensis* in the lower Volga River near Akhtubinsk in 1981 would indicate, however, that population expansion in the Volga River was not rapid. The distance between the Akhtubinsk site and the Volga River delta is only 170 km, yet it took 13 years for the population to disperse downstream over this stretch. Thus, the production of propagules was likely minimal. As noted by Orlova *et al.* (2003), *D. bugensis* prefers conditions associated with a lacustrine rather than a riverine environment; that is, an environment with stable, slow changing water temperatures and low flow regimes. The spread of *D. bugensis* through the Dnepr River basin in its native range occurred only after a series of reservoirs were constructed (Mills *et al.* 1996). Likewise, although found in the Volga River in the early 1980s, its spread apparently only occurred after the flow regime of the Volga River was altered upon completion of the reservoir system in the late 1980s (Litvinov 2000). Even so, as of 2002 the proportion of *D. bugensis* within the total dreissnid population (*D. bugensis* and *D. polymorpha*) remains low in areas of the lower Don and Volga River systems (Table I), indicating conditions may still be marginal for *D. bugensis*. Once established, this species usually replaces *D. polymorpha* as the dominant dreissenid within 4-9 years (Mills *et al.* 1996). The dispersal of *D. bugensis* into upstream reservoirs in the Volga river system (Sites 9, 10) in the late 1990s could only have been a result of human-mediated transport, and would be similar to the non-contiguous, upstream "jump" dispersal pattern observed for *D. bugensis* in the North American Great Lakes (Wilson *et al.* 1999).

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4. References

Andrusov, N.I. 1890. *Dreissena rostriformes* Desch. v reke Bug [*Dreissena rostriformes Desch. in the Bug River*]. Izvestiya St. Peterburgskogo Obschestva Ispytateley Prirody. Otdelenie Geologii i Mineralogii [Proceedings St.-Petersburg Society of Nature Researchers. Dept. of Geology and Mineralogy]. pp. 1-2 [In Russian].

Antonov, P.I. 1993 O proniknovenii dvustvorchatogo mollyuska *Dreissena bugensis* (Andr.) v Volzhskie vodokhranilischa [On the invasion of bivalve *Dreissena bugensis* (Andr.) into the Volga River reservoirs]. In: *Ecologicheskie problemy basseinov krupnykh rek. Tezisy Mezhdunarodnoy Konferencii* [*Ecological Problems of Large River Basins*]. Abstract, International Conference, Togliatti, 6-10 September, 1993. IEVB RAS, Togliatti, Russia: pp. 52-53 [In Russian].

Antonov, P.I. 1996. Novyi dlya fauny Volgi dvustvorchatyi mollusk *Dreissena bugensis* (Andr.) [New for the Volga fauna bivalve mollusk *Dreissena bugensis* (Andr.)]. In: *Problemy Hydrobiologii Kontinental-nykh Vod I Ikh Malakofauna. Mezhdunarodnoye Soveschaniye. Tezisy dokladov* [*Problems of hydrobiology of continental waters and their malacofauna*]. Abstr. St.-Petersburg, pp. 9-10 [In Russian].

Bij de Vaate, A., Jażdżewski, K., Ketelaars, H.A.M., Gollasch, S., Van der Velde, G. 2002. Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences* **59**, 1159-1174.

Grigorovich, I.A., Therriault, T.W., MacIsaac, H.J. 2003. History of aquatic invertebrate invasions in the Caspian Sea. *Biological Invasions* **5**, 103-115.

Kalayda, M.L. 2003. Modern role of Ponto-Caspian invaders in the Kuybyshev Reservoir. In: Pavlov, D.S. Dgebuadze Yu.Yu., Korneva L.G., Slyn'ko Yu. V. [Eds], *Invasion of Alien Species in Holarctic.* IBIW RAS, Rybinsk: pp. 429-436.

Kharchenko, T.A. 1995. *Dreissena*: areal, ecologiya, biopomekhi [*Dreissena*: range, ecology, fouling impacts]. *Gidrobiol. Zhurn.* **31**, 3-20 (In Russian)

Kirpichenko, M.Y. 1997. *Problema Obiliya v Hydrobiologii* [*Problem of abundance in hydrobiology*]. IBVB Press, Togliatti: 52 p. (In Russian).

Leppakoski, E., Gollasch, S., Gruszka, P., Ojaveer, H., Olenin, S., Panov, V. 2002. The Baltic: a sea of invasions. *Canadian Journal of Fisheries and Aquatic Sciences* **59**, 1175-1188.

Litvinov, A.S. 2000. *Energo- i Masso-obmen v Vodokhranilischakh Volzhskogo Kaskada* [*Exchange of energy and mass in the reservoirs of Volga cascade*]. Yaroslav State University Publishers, Yaroslavl: 84 p. (In Russian).

May, B., Marsden, J.E. 1992. Genetic identification and implications of another invasive species of dreissenid mussel in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **49**, 1501-1506.

Mills, E.L., Rosenberg, G., Spidle, A.P., Ludyanskiy, M., Pligin, Y., May, B. 1996. A review of the biology and ecology of the quagga mussel (*Dreissena bugensis*), a second species of freshwater Dreissenid introduced to North America. *American Zoologist* **36**, 271-286.

Nalepa, T.F., Schloesser, D.W., Pothoven, S.A., Hondorp, D.W., Fanslow, D.L., Tuchman, M.L., Fleischer, G.W. 2001. First finding of the amphipod *Echinogammarus ischnus* and the mussel *Dreissena bugensis* in Lake Michigan. *Journal of Great Lakes Research* **27**, 384-391.

Orlova, M.I., Antonov, P.I., Scherbina, G.H., Therriault, T.W. 2003. *Dreissena bugensis*: evolutionary underpinnings for invasion success based on its range extension in Europe. In: Pavlov, D.S., Dgebuadze Yu.Yu., Korneva L.G., Slyn'ko Yu.V. [Eds], *Invasion of Alien Species in Holarctic.* IBIW RAS, Rybinsk: pp 452-466.

Orlova, M.I., Muirhead, J.R., Antonov, P.I., Scherbina, G.H., Starobogatov, Y.I., Biochino, G.I., Therriault, T.W., MacIsaac, H.J. 2004. Range expansion of quagga mussels *Dreissena rostriformis bugensis* in the Volga River and Caspian Sea basin. *Aquatic Ecology* **38**, 561-573.

Reid, D., Orlova, M.I. 2002. Geological and evolutionary underpinnings for the success of Ponto-Caspian species invasions in the Baltic Sea and North American Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **59**, 1144-1158.

Ricciardi, A. 2003. Predicting the impacts of an introduced species from its invasion history: an empirical approach applied to zebra mussel invasions. *Freshwater Biology* **48**, 972-981.

Ricciardi, A., Rasmussen, J.B. 1998. Predicting the identity and impact of future biological invaders: a priority for aquatic resource management. *Canadian Journal of Fisheries and Aquatic Sciences* **55**, 1759-1765.

Scherbina G.H. 2003. The role of invasive species in macrozoobenthos structure in the Upper Volga reservoirs. In: Pavlov, D.S., Dgebuadze Yu.Yu., Korneva L.G., Slyn'ko Yu.V. [Eds], *Invasion of Alien Species in Holarctic*. IBIW RAS, Rybinsk: pp. 491-501.

Volf, M.B. 1971. Volgo-Donskoy Kanal [Volgo-Don Shipping Canal]. In: Prokhorov, A.M. [Ed.]. *Bolshaya Sovetskaya Enciklopediya* [*Great Soviet Encyclopedia*], Third Edition, Vol.5. Sovetskaya Encyclopedia Publishing House, Moscow: [In Russian].

Wilson, A.B., Naish, K.A., Boulding, E.G. 1999. Multiple dispersal strategies of the invasive quagga mussel (*Dreissena bugensis*) as revealed by microsatellite analysis. *Canadian Journal of Fisheries and Aquatic Sciences* **56**, 2248-2261.

Zhulidov A.V., Pavlov, D.F., Nalepa, T.F., Scherbina, G.H., Zhulidov, D.A., Gurtovaya, T.Yu. 2004. Relative distributions of *Dreissena bugensis* and *Dreissena* polymorpha in the lower Don River system, Russia. *International Revue Hybrobiologie* **89**, 326-333

Zhuravel, P. A. 1951. O *Dreissena bugensis* (Mollusca) Iz Sistemy Dnepra I Nedavnee EE Poyavleniye v Dneprovskom Vodokhranilische [On the *Dreissena bugensis* (Mollusca) from the system of the Dnepr River and on its recent appearance in the Dneprovskoye Reservoir]. *Zoological Journal* **39**, 186-188 [In Russian].