BioInvasions Records (2022) Volume 11, Issue 1: 173–180

Rapid Communication

# The Ponto-Caspian quagga mussel, *Dreissena rostriformis bugensis* Andrusov, 1897, is established in Ireland

Jan-Robert Baars[1,*], Martina B. Caplice[1], Oscar Flynn[1], Kate O'Leary[1], Heather Swanwick[1] and Dan Minchin[2,3]

[1]*UCD, Invasive Ecology Laboratory (InEco), School of Biology and Environmental Science, University College Dublin, Belfield, Dublin 4, Ireland*
[2]*Lough Derg Science Group, Marina Village, Ballina, Killaloe, Co Clare, Ireland*
[3]*Marine Research Institute, Klaipėda University, University Avenue, LT 92294 Klaipėda, Lithuania*
**Corresponding author*
E-mail: *janrobert.baars@ucd.ie*

**Citation:** Baars J-R, Caplice MB, Flynn O, O'Leary K, Swanwick H, Minchin D (2022) The Ponto-Caspian quagga mussel, *Dreissena rostriformis bugensis* Andrusov, 1897, is established in Ireland. *BioInvasions Records* 11(1): 173–180, https://doi.org/10.3391/bir.2022.11.1.17

**Received:** 31 July 2021
**Accepted:** 5 October 2021
**Published:** 13 January 2022

**Handling editor:** Agnese Marchini
**Thematic editor:** Stelios Katsanevakis



## Abstract

The quagga mussel *Dreissena rostriformis bugensis* was identified in a horizon scan of species likely to arrive in Ireland. We report on the first records of this dreissenid from two lakes, a reservoir and interconnecting navigable river sections on Ireland's largest river, the Shannon, during July 2021. The abundance in Lough Ree was greater than in the larger downstream lake of Lough Derg. Specimens occurred to depths of 24 m and 32 m in each of these lakes respectively. Highest densities were in the southern region of Lough Ree attached to piles supporting floating pontoons and quay walls. Here *D. r. bugensis* outnumbered the *D. polymorpha* present. It was present at lower densities downstream to Lough Derg and the Parteen Reservoir. This species has a wide range of colour morphs from a pale yellow to dark concentric or longitudinal banding.

**Key words:** dreissenid, invasion, alien, non-native, Shannon catchment, aquatic bivalve, first-record

## Introduction

The Ponto-Caspian bivalve *Dreissena rostriformis bugensis* Andrusov, 1897 is an aggressive freshwater bivalve. Once established it can result in significant changes to the benthos and to water quality (Reynolds and Aldridge 2021). By possessing a byssus it can attach in large numbers to each other and to firm structures, resulting in reduced flows in abstraction pipework and screens as well as the fouling of boat hulls and other firm surfaces which can lead to high economic costs (Connolly et al. 2007). Its filtration ability can result in clearer water (Cross et al. 2010), thereby altering phytoplankton composition and causing a possible decline in some planktonic crustaceans as was noted in Lake Erie in North America (Zhang et al. 2011). In Ireland, the closely related *Dreissena polymorpha* (Pallas, 1771) arrived in 1993/4, modifying the ecological component of lakes and causing heavy fouling of craft and blockages of municipal water pipes (Minchin et al. 2002). It is expected that *D. rostriformis bugensis* will

behave in a similar way. Both species are readily capable of spreading through interconnected waterways to lakes and reservoirs. This occurs by downstream dispersal of their larvae and with leisure craft movements upstream and to other river catchments through interlinking canals and possibly trailered craft.

There is evidence to suggest *D. rostriformis bugensis* was confined to a small area to the north-west of the Black Sea in the Dnieper River Delta and Southern Bug River where it is considered to be native (Son 2007). From there, it spread within the Ponto-Caspian to the freshwater region of the Azov Sea, appearing in the northern Caspian Sea region in the mid-1990s and advancing up the Volga River in Russia (Orlova et al. 2004). It subsequently spread to the Romanian region of the Danube River by 2004 (Popa and Popa 2006) and by 2006 it may have spread through the Danube River, the Main-Danube Canal to the Rhine Delta in The Netherlands (Molloy et al. 2007). Although this is possible, Bij de Vaate (2010) provides a case for its arrival in the Rhine with ships' ballast water which is also considered to be the vector for its arrival in the Great Lakes of North America (Grigorovich et al. 2003). In 2007 it was found in the Main River in Germany (van der Velde and Platvoet 2007). It also spread further west to the river Moselle in France where it was recorded in 2011 (Bij de Vaate and Beisel 2011). Within a decade, it appeared in a stream, in part of the Thames Catchment, Britain (Aldridge et al. 2014). According to Matthews et al. (2014) it has spread more rapidly than the zebra mussel, *Dreissena polymorpha*, and since has fouled a number of reservoirs (Reynolds and Aldridge 2021). The Quagga mussel has also been spreading in North and Central America since it was first recorded in 1989 in Lake Erie in the Great Lakes (Mills et al. 1993). Since then, it has spread to the Upper Mississipi in the 1990s (Grigorovich et al. 2008) and to Lake Mead in 2007 (Wong et al. 2010). In 2014 it was found further south in Mexico (Wakida-Kusunoki et al. 2015).

In a recent horizon scan of impacting species likely to arrive in Ireland, *D. rostriformis bugensis* was considered a high-risk invader (Lucy et al. 2020). This follows a horizon scan for Britain (Roy et al. 2014) which also considered this species to be of high risk. We report the first occurrence of *D. rostriformis bugensis* in Ireland, appearing in two lakes and a reservoir and interlinking river sections in the Shannon catchment in early July 2021.

## Materials and methods

Sites in Lough Derg were visited by road and in Lough Ree by boat, using a rapid assessment approach during 2 to 14 July 2021. This followed the initial finding of three specimens on 28 June 2021. Sampling involved the use of a scraper mounted on an extendable pole to which a mesh pocket was attached. The blade of the scraper used was either 10 cm or 15 cm to

detach mussels from vertical piles supporting marina pontoons or quay walls. All the detached mussels collected within the meshed pocket were sorted, identified and weighted. Estimates of density were calculated from the scraper blade width, the length of the vertical draw and the number of successive scrapes undertaken. This provided estimates of numbers and biomass per $m^2$. Twenty-three separate sites were visited throughout the Shannon River.

Fifty-seven dredge samples deployed from 5 m to 36 m in Lough Ree and Lough Derg provided qualitative data. The dredge used had previously been used to acquire the clam *Corbicula fluminea* (Müller, 1774) and is described in Minchin and Boelens (2018).

Our specimens conformed to the illustrations of original material of *D. bugensis* described by Andrusov (1897) illustrated in Rosenberg and Ludyanskiy (1994). We also submitted photographs of the internal and external shell features to Dr Mikhail Son who stated that these corresponded to the typical *D. bugensis*/*D. rostriformis bugensis* in Ukraine.

The difference in outline shapes and colour patterns of *D. polymorpha* and *D. rostriformis bugensis* (Pathy and Mackie 1993; van der Velde et al. 2010) were utilised to distinguish between the species. Small individuals up to 2 mm shell length required microscope examination at x 40. Shell length was measured from the anterior to posterior shell exterior.

## Results

There were clear differences in abundance between the two Shannon lakes with greater levels of abundance in Lough Ree within the small lakes co-joined to the south-east of Lough Ree (Table 1). Lower numbers were found in Lough Derg, with the species absent in samples at some sites (Figure 1).

Three year-class modes were present in Lough Ree, with specimens attaining a shell length of 34 mm. While both *D. rostriformis bugensis* and *D. polymorpha* were present at the same sites, *D. rostriformis bugensis* dominated, representing up to 72% of all dreissenids present. Shells had a wide range of colour morphs. Shell patterns were not always symmetrically displaced on each valve. Pale specimens were frequent (Figure 2).

Dredging found quagga mussels over a depth range of < 5 m to depths of 24 m in Lough Ree, down to 32.5 m in Lough Derg. In our current findings, specimens were more frequent between depths of 2 to 10 m.

## Discussion

The population in Lough Ree is firmly established, is likely to have been present for a number of years and is locally the dominant fouling species. The likely scenario is for the quagga mussel to expand its population rapidly (Strayer et al. 2019) as Irish climatic conditions are suitable for such expansion. *D. rostriformis bugensis* is capable of tolerating water temperatures

**Table 1.** Relative abundance of the two dressenid species in the Shannon.

| Site | Decimal Lat | Decimal Long (minus) | Scrapes | *D. polymorpha* Est Numbers $m^2$ | *D. bugensis* Total numbers $m^2$ | *D. bugensis* Prevalence % | Sample Total wt g |
|---|---|---|---|---|---|---|---|
| Parteen Dam Quay | 52.76139 | −8.47500 | 12 | 3252 | 12 | < 0.01 | 948 |
| Ballina pile | 52.72667 | −8.44500 | 6 | 1648 | 34 | 2.08 | 773 |
| Scarriff Harbour | 52.90528 | −8.52861 | 24 | 1.3 | none | . | 12 |
| Garrykennedy piles | 52.90528 | −8.34111 | 4 | 2206 | 86 | 3.92 | 731 |
| Mount Shannon Quay | 52.92861 | −8.43083 | 12 | 456 | 4 | 0.97 | 364 |
| Dromineer Pier | 52.92583 | −8.27889 | 8 | 1097 | 5 | 0.45 | 404 |
| Rossmore Quay | 53.01694 | −8.31166 | 6 | 344 | none | . | 294 |
| Terryglass | 53.06083 | −8.20583 | 12 | 333 | 3 | 0.01 | 430 |
| Banagher | 53.19278 | −7.99166 | 12 | < 1 | < 1 | n/a | < 10 |
| Shannonbridge | 53.27944 | −8.04944 | 12 | 609 | 16 | 2.66 | 1462 |
| Ballyglass pile | 53.45111 | −7.93056 | 6 | 5226 | 2650 | 33.64 | 7877 |
| Hodson Quay | 53.46722 | −7.98666 | 3 | 1970 | 4105 | 67.75 | 3004 |
| Kylenure Point pile | 53.46444 | −7.92333 | 5 | 2308 | 4520 | 66.19 | 2139 |
| Glasson pile | 53.45777 | −7.88916 | 6 | 1847 | 4963 | 72.88 | 2014 |
| Portrunny Quay | 53.59166 | −8.06027 | 6 | 1383 | 2173 | 61.10 | 2267 |
| Lanesborough | 53.67444 | −7.99250 | 8 | 20 | none | . | 9 |
| Tarmonbarry | 53.73917 | −7.92111 | 3 | 2390 | none | . | 2109 |
| Roosky | 53.83222 | −7.91916 | 3 | 1243 | none | . | 399 |
| Dromod Harbour | 53.85444 | 7.92472 | 3 | 3677 | none | . | 2987 |
| Jamestown | 53.92306 | −8.03000 | 3 | 37 | none | . | 22.4 |
| Carrick-on-Shannon | 53.94306 | −8.09500 | 3 | 1347 | none | . | 1061 |
| Coothall | 53.98167 | −8.16083 | 3 | 2247 | none | . | 1171 |
| Lough Key | 53.98694 | −8.23750 | 3 | 11003 | none | . | 4640 |

from 0 °C, by surviving under ice (Spidle et al. 1995) and has an upper thermal tolerance limit of 28 °C (Spidle et al. 1995) which is unlikely to be reached in Ireland. It will almost certainly spread through navigable routes in lakes, rivers and canals as well as over land by boats, as happened during the expansion of the zebra mussel (Minchin et al. 2006). Overland spread could also facilitate the colonisation of *D. rostriformis bugensis* in the upper reaches of estuaries where salinities do not exceed between 1 and 5 (Spidle et al. 1994). More recently, it has been shown wet surfaces may be capable of transferring the veliger stage (Choi et al. 2013), this could result in additional vectors being involved in further spread such as angling equipment (Mueting et al. 2011) including waders (Aldridge et al. 2014).

It is presently unclear how the species arrived in Ireland; but in the past, species arriving in Britain often subsequently appear in Ireland (Minchin 2007). In the case of *D. polymorpha* there is evidence that its 1993/4 arrival in Ireland was through the transportation of fouled leisure craft by trailer and ferry from the midlands of Britain (Pollux et al. 2003). This may have been the seminal site of inoculation with downstream dispersal of veligers to Lough Derg based on the greater abundance of the *D. r. bugensis,* recovered from Lough Ree.

Both dreissenid species result in changes to biomass (Heiler et al. 2013), biodiversity and water quality (Reynolds and Aldridge 2021) and will result in economic costs, particularly where abstraction has not considered their fouling impacts. The full impact of these effects will depend upon the extent of their populations. In the Great lakes of North America *D. rostriformis*

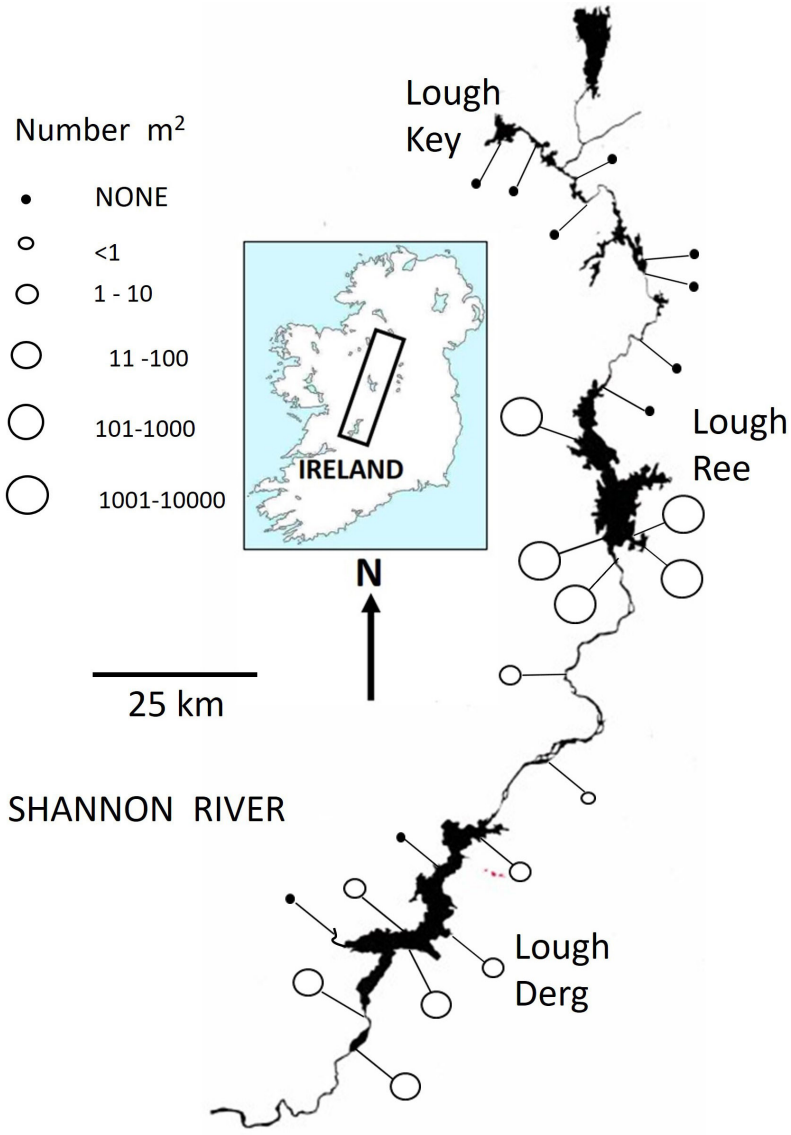


**Figure 1.** Relative abundance of the quagga mussel in the Shannon.

**Figure 2.** Selection of colour morphs of *D. rostriformis bugensis,* from the river section between loughs Ree and Derg. Photograph by Dan Minchin.

*bugensis* appears to become dominant over *D. polymorpha* within the cooler deeper water, extending down to depths in Lake Erie of 130 m (Mills et al. 1996). Furthermore, *D. rostriformis bugensis* has a greater capability than *D. polymorpha* to form druses over softer sediments which can result in increased biomass at depth. Consequently, the biomass in the hypolimnion of Irish lakes is likely to increase. This could lead to possible consequences of depleting oxygen especially during prolonged high atmospheric pressure events of windless days and high temperatures. This species, in association with the biomass from the earlier invaders of *D. polymorpha* and *Corbicula fluminea,* within this zone make such an event more likely to take place.

## Acknowledgements

We are grateful to Dr Mikhail Son of the Institute of Marine Biology, Odessa, for confirming the identity of our material. We thank Paul Murphy of *EirEco* who enabled the first opportunity to record the presence of *D. r. bugensis* on 28 June 2021. We are also indebted to Brian Quigley for helpful assistance. We thank the reviewers for their comments. All measures in this study adhered to the prevention of spread of 2019-nCov.

## Funding declaration

The field collections was supported by UCD Output-Based Research Support Scheme, and AQUENS Ltd.

## Author contributions

J-R.B., DM designed the overall study; J-R.B., MC, OF, KOL, HS, DM, conducted field surveys and sample collection and processing; the manuscript was written and reviewed by J-R.B., MC, OF, KOL, HS, DM.

## References

Aldridge DC, Ho S, Froufe E (2014) The Ponto-Caspian quagga mussel, *Dreissena rostriformis bugensis* (Andrusov, 1897) invades Great Britain. *Aquatic Invasions* 9: 529–535, https://doi.org/10.3391/ai.2014.9.4.11

Andrusov N (1897) Fossile und lebende Dreissenidae Eurasiens [in Russian]. Tipografiya M. Merkusheva, St. Petersburg, 687 pp

Bij de Vaate A (2010) Some evidence for ballast water transport being the vector of the quagga mussel (*Dreissena rostriformis bugensis* Andrusov, 1897) introduction into Western Europe and subsequent upstream dispersal in the River Rhine. *Aquatic Invasions* 5: 207–209, https://doi.org/10.3391/ai.2010.5.2.13

Bij de Vaate A, Beisel JN (2011) Range expansion of the quagga mussel (*Dreissena rostriformis bugensis* Andrusov 1897) in Western Europe: first observation from France. *Aquatic Invasions* 6: 71–74, https://doi.org/10.3391/ai.2011.6.S1.016

Choi WJ, Gerstenberger S, McMahon RF, Wong WH (2013) Estimating survival rates of quagga mussel (*Dreissena rostriformis bugensis*) veliger larvae under summer and autumn temperature regimes in residual water of trailered watercraft at Lake Mead, USA. *Management of Biological Invasions* 4: 61–69, https://doi.org/10.3391/mbi.2013.4.1.08

Connelly NA, O'Neill CR Jr., Knuth BA, Brown TL (2007) Economic impacts of zebra mussels on drinking water treatment and electric power generation facilities. *Environmental Management* 40: 105–112, https://doi.org/10.1007/s00267-006-0296-5

Cross CL, Wong WH, Che TD (2010) Estimating carrying capacity of quagga mussels (*Dreissena rostriformis bugensis*) in a natural system: A case study of the Boulder Basin of Lake. *Aquatic Invasions* 6: 141–147, https://doi.org/10.3391/ai.2011.6.2.03

Grigorovich IA, Colautti RI, Mills EL, Holeck K, Ballert AG, MacIsaac HJ (2003) Ballast-mediated animal introductions in the Laurentian Great Lakes: retrospective and prospective analyses. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 740–756, https://doi.org/10.1139/f03-053

Grigorovich IA, Angradi TR, Stepien CA (2008) Occurrence of the Quagga Mussel (*Dreissena bugensis*) and the Zebra Mussel (*Dreissena polymorpha*) in the Upper Mississippi River

System. *Journal of Freshwater Ecology* 23: 429–435, https://doi.org/10.1080/02705060.2008.9664220

Heiler KCM, Bij de Vaate A, Ekschmitt K, Oheimb PV, Albrecht C, Wilke T (2013) Reconstruction of the early invasion history of the quagga mussel (*Dreissena rostriformis bugensis*) in Western Europe. *Aquatic Invasions* 8: 53–57, https://doi.org/10.3391/ai.2013.8.1.06

Lucy FE, Davis E, Anderson R, Booy O, Bradley K, Britton R, Byrne C, Caffrey JM, Coughlan NE, Crane K, Cuthbert RN, Dick JTA, Dickey JWE, Fisher J, Gallagher C, Harrison S, Jebb M, Johnson M, Lawton C, Lyons D, Mackie T, Maggs C, Marnell F, McLoughlin T, Minchin D, Monaghan O, Montgomery I, Moore N, Morrison L, Muir R, Nelson B, Niven A, O'Flynn C, Osborne B, Ramsay R, Reid N, Roy H, Sheehan R, Stewart D, Sullivan M, Tierney P, Tricarico E, Trodd W (2020) Horizon scan of invasive alien species for the island of Ireland. *Management of Biological Invasions* 11: 155–177, https://doi.org/10.3391/mbi.2020.11.2.01

Matthews J, Van der Velde G, Bij de Vaate A, Collas FPL, Koopman KR, Leuven RSEW (2014) Rapid range expansion of the invasive quagga mussel in relation to zebra mussel presence in The Netherlands and Western Europe. *Biological Invasions* 16: 23–42, https://doi.org/10.1007/s10530-013-0498-8

Mills EL, Dermott RM, Roseman EF, Dustin D, Mellina E, Conn DB, Spidle A (1993) Colonization, ecology and population structure of the quagga mussel in the Lower Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 50: 2305–2314, https://doi.org/10.1139/f93-255

Mills E, Rosenberg G, Spidle AP, 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, https://doi.org/10.1093/icb/36.3.271

Minchin D (2007) Rapid coastal survey for targeted alien species associated with floating pontoons in Ireland. *Aquatic Invasions* 2: 63–70, https://doi.org/10.3391/ai.2007.2.1.8

Minchin D, Boelens R (2018) Natural dispersal of the introduced Asian clam *Corbicula fluminea* (Müller, 1774) (Cyrenidae) within two temperate lakes. *BioInvasions Records* 7: 259–268, https://doi.org/10.3391/bir.2018.7.3.06

Minchin D, Lucy F, Sullivan M (2002) Zebra mussel: impacts and spread. In: Leppäkoski E, Gollasch S, Olenin S (eds), Invasive Aquatic Species of Europe: Distribution, Impact and Management. Kluwer Press, Dordrecht, pp 135–146, https://doi.org/10.1007/978-94-015-9956-6_15

Minchin D, Lucy F, Sullivan M (2006) Ireland: a new frontier for the zebra mussel *Dreissena polymorpha* Pallas. *Oceanological and Hydrobiological Studies* 34(1): 19–30

Molloy DP, Bij de Vaate A, Wilke T, Giamberini L (2007) Discovery of *Dreissena rostriformis bugensis* (Andrusov 1897) in Western Europe. *Biological Invasions* 9: 871–874, https://doi.org/10.1007/s10530-006-9078-5

Mueting SA, Gerstenberger SL, Wong WH (2011) An evaluation of artificial substrates for monitoring the quagga mussel (*Dreissena bugensis*) in Lake Mead, Nevada-Arizona. *Lake and Reservoir Management* 26: 283–292, https://doi.org/10.3391/ai.2011.6.2.04

Orlova MI, Muirhead JR, Antonov PI, Shcherbina GK, Starobogatov YI, Biochino GI, Therriault TW, MacIsaac HJ (2004) Range expansion of quagga mussels *Dreissena rostriformis bugensis* in the Volga River and Caspian Sea basin. *Aquatic Ecology* 38: 561–573, https://doi.org/10.1007/s10452-005-0311-6

Pathy DA, Mackie GL (1993) Comparative shell morphology of *Dreissena polymorpha*, *Mytilopsis leucophaeata* and the "quagga" mussel (Bivalvia: Dreissenidae) in North America. *Canadian Journal of Zoology* 71: 1012–1023, https://doi.org/10.1139/z93-135

Pollux B, Minchin D, Van der Velde G, Van Allen T, Moon-Van der Staay SY, Hackstein J (2003) Zebra mussels (*Dreissena polymorpha*) in Ireland, AFLP- fingerprinting and boat traffic both suggest an origin from Britain. *Freshwater Biology* 48: 1127–1138, https://doi.org/10.1046/j.1365-2427.2003.01063.x

Popa OP, Popa LO (2006) The most westward European occurrence point for *Dreissena bugensis* (Andrusov 1897). *Malacologica Bohemoslovaca* 5: 3–5, https://doi.org/10.5817/MaB2006-5-3

Reynolds SA, Aldridge DC (2021) Impacts of invasive quagga mussels (*Dreissena rostriformis bugensis*) on reservoir water quality, as revealed by progressive-change BACIPS analysis. *Water Research* 197: 117105, https://doi.org/10.1016/j.watres.2021.117105

Rosenberg G, Ludyanskiy M (1994) A Nomenclatural Review of *Dreissena* (Bivalvia: Dreissenidae), with Identification of the Quagga Mussel as *Dreissena bugensis*. *Canadian Journal of Fisheries and Aquatic Sciences* 51: 1474–1484, https://doi.org/10.1139/f94-147

Roy HE, Peyton J, Aldridge DC, Bantock T, Blackburn TM, Britton R, Clark P, Cook E, Dehnen-Schmutz K, Dines T, Dobson M, Edwards F, Harrower C, Harvey MC, Minchin D, Noble DG, Parrott D, Pocock MJO, Preston CD, Roy S, Salisbury A, Schönrogge K, Sewell J, Shaw RH, Stebbing P, Stewart AJA, Walker KJ (2014) Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. *Global Change Biology* 20: 3859–3871, https://doi.org/10.1111/gcb.12603

Son MO (2007) Native range of the zebra mussel and quagga mussel and new data on their invasions within the Ponto-Caspian Region. *Aquatic Invasions* 2: 169–179, https://doi.org/10.3391/ai.2007.2.3.4

Spidle A, Marsden JE, May B (1994) Identification of the Great Lakes quagga mussel as *Dreissena bugensis* from the Dnieper River, Ukraine, on the basis of allozyme variation. *Canadian Journal of Fisheries and Aquatic Sciences* 51: 1474–1484, https://doi.org/10.1139/f94-148

Spidle AP, Mills EL, May B (1995) Limits to tolerance of temperature and salinity in the quagga mussel (*Dreissena bugensis*) and the zebra mussel (*Dreissena polymorpha*). *Canadian Journal of Fishery and Aquatic Sciences* 52: 2108–2119, https://doi.org/10.1139/f95-804

Strayer DL, Adamovich BV, Adrian R, Aldridge DC, Balogh C, Burlakova LE, Fried-Petersen H, Tóth LG, Hetherington AL, Jones TS, Karatayev AY, Madill JB, Makarevich OA, Marsden JE, Martel AL, Minchin D, Nalepa TF, Noordhuis R, Robinson TJ, Rudstam LG, Schwalb AN, Smith DR, Steinman AD, Jeschke JM (2019) Long-term population dynamics of dreissenid mussels (*Dreissena polymorpha* and *D. rostriformis*): a cross-system analysis. *Ecosphere* 10: e02701, https://doi.org/10.1002/ecs2.2701

van der Velde G, Platvoet D (2007) Quagga mussels *Dreissena rostriformis bugensis* (Andrusov, 1897) in the Main River (Germany). *Aquatic Invasions* 2: 261–264, https://doi.org/10.3391/ai.2007.2.3.11

van der Velde G, Rajagopal S, Bij de Vaate A (2010) From zebra mussels to quagga mussels an introduction to the Dreissenidae. In: van der Velde G, Rajagopal S, Bij de Vaate A (eds), The zebra mussel in Europe. Backhuys Publishers, Leiden/Margraf Publishers, Weikersheim, pp 1-10

Wakida-Kusunoki AT, Wakida FT, Leon-Sandoval JM (2015) First record of quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1897) (Bivalvia, Dreissenidae) from Mexico. *BioInvasions Records* 4: 31–36, https://doi.org/10.3391/bir.2015.4.1.05

Wong WH, Tietjen T, Gerstenberger SL, Holdren C, Mueting SA, Loomis E, Roefer P, Moore B, Turner K, Hannoun I (2010) Potential ecological consequences of invasion of the quagga mussel (*Dreissena bugensis*) into Lake Mead, Nevada-Arizona, USA. *Lake and Reservoir Management* 26: 306–315, https://doi.org/10.1080/07438141.2010.504071

Zhang H, Culver DA, Boegman L (2011) Dreissenids in Lake Erie: an algal filter or a fertilizer? *Aquatic Invasions* 6: 175–194, https://doi.org/10.3391/ai.2011.6.2.07