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Rapid Communication

First record of quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1897) (Bivalvia, Dreissenidae) from Mexico

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Abstract

The freshwater mussel *Dreissena rostriformis bugensis* (Andrusov, 1897) has been identified as an invader on different continents. Here, we report the first record of quagga mussel species in México. We detected quagga mussels in El Carrizo reservoir in the Mexican state of Baja California on July 12, 2014. Additional studies in both regions indicated that this species is spreading in the Colorado River basin. However, no specimens were detected in the sites examined in the Mexican portion of the Colorado River Basin. Further sampling is required to assess the invasion area.

Key words: *Dreissena rostriformis bugensis*, quagga mussel, invasive species, Baja California, Mexico

Introduction

The quagga mussel *Dreissena rostriformis bugensis* (Pallas, 1771) is indigenous to the whole Dnieper-Bug estuary, Dnieper River delta, and lower Ingulets River, a zone located in Ukraine (Mills et al. 1996; Zhulidov et al. 2010). By 2004, the quagga has expanded its range to the Romanian section of the Danube River (Micu and Telembici 2004). The first observation in Western Europe was in a freshwater section of the Rhine and Meuse estuary in The Netherlands (Molloy et al. 2007). Bij de Vaate (2010) suggested that ballast water or transport by inland shipping could be potential dispersal mechanisms of quagga mussel in Western Europe. The quagga mussel was first discovered in North America in the Great Lakes in 1989 (Mills et al. 1993). A possible mechanism of introduction is that the mussel was carried in the ballast tanks of ships from Ukranian ports. To date, there are reports of the presence of quagga mussel in 13 states in the United States (Benson 2013).

An unknown mollusk was first noticed about three years ago in the facilities of a drinking water plant in Tijuana (Mercado-Juárez 2014). The water supply of this plant comes from El Carrizo reservoir, which is the end point of the Colorado River-Tijuana aqueduct. The negative impacts of the presence of this mollusk in the Tijuana area include those caused by fouling of drinking water intake pipes and structures. In the last year, The State Commission of Public Services of Tijuana (CESPT for its Spanish acronyms), the government organization that operates drinking water and wastewater plants in Tijuana, stated an increment of the density of this mollusk in pipes and structures of drinking water plants. This situation has increased the cost of cleaning these structures. The volume of the shells removed every three months from the El Florido drinking water plant was 163 cubic meters and CESPT has calculated a cost of 38 million pesos (around 3 million US dollars) to change pipes, filters and tanks to get rid of the fouling organism (Mercado-Juárez 2014). We identified this mollusk as quagga mussel

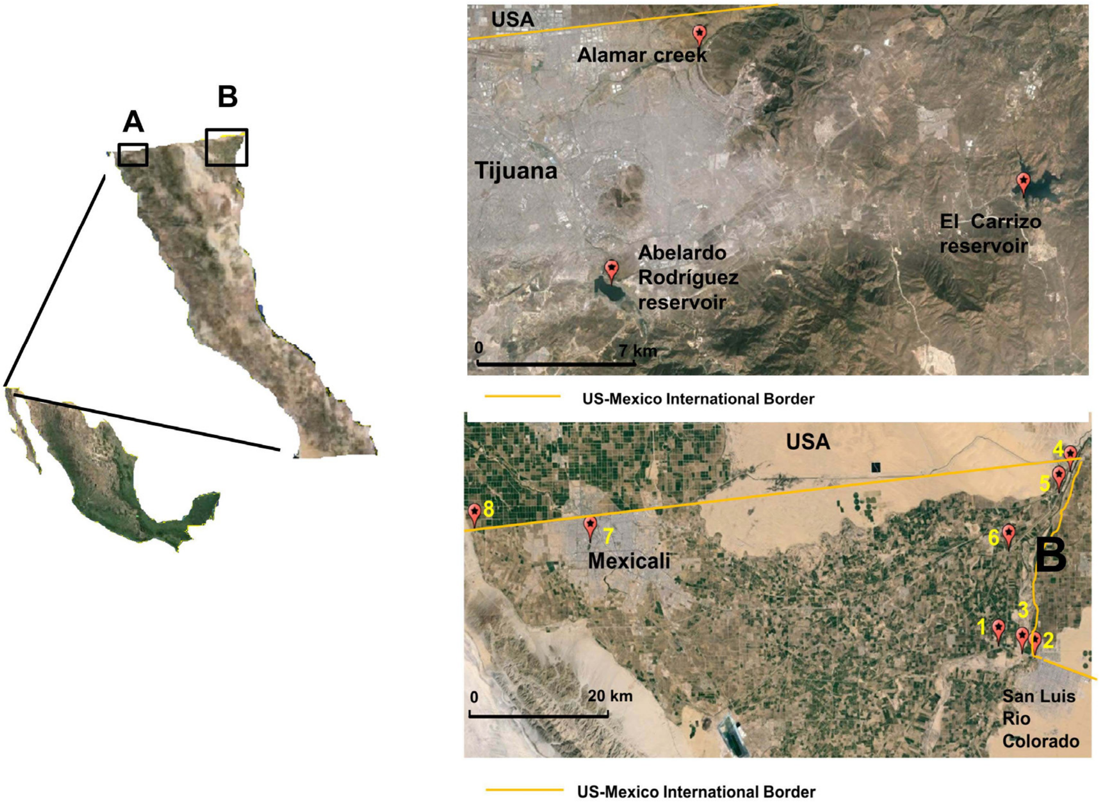

Figure 1. Sampling locations in the state of Baja California, México showing A) zone of Tijuana, Baja California. B) Area of the Mexicali Valley, Baja California, México.

Dreissena rostriformis bugensis from collected specimens in El Carrizo reservoir. This paper describes the first record of quagga mussel in México.

Materials and methods

Two campaigns to detect quagga mussels were conducted on July 12, 2014 in El Carrizo reservoir, Abelardo Rodriguez reservoir, Alamar Creek in the Tijuana area and on August 2, 2014 on eight sites in the valley of Mexicali. All the sites are located in the state of Baja California in the northwestern part of Mexico. Sampling sites are shown in Figure 1. Detection of mussels was conducted by looking for signs of mussel clusters in the hard substrate in each site.

The criteria used to identify the specimens were those described by Mackie and Schlosser (1996) and Benson et al. (2014). Specimens were housed in the mollusk collection of the Yucatán Peninsula at the Agricultural and Biological Sciences Department of the Autonomous University of Yucatán. The area of Tijuana has a dry mediterranean climate with distinct summer and winter seasons. The average annual temperature is 21°C and an average annual precipitation of 220mm, with over 90% occurring during the period from November to April (Implan 2002). However, the climate in the area of Mexicali is hot and dry. The average temperature between October and May is 23°C and the average maximum temperature between June and September is 42°C. The daytime temperature in surface water in this region exceeds 30°C (Minckley 1979). The average annual rainfall is 132 mm (XXI Mexicali City Council, 2014).

Results

Characteristics of the examined sites and records of quagga mussel are shown in Table 1.

We detected freshwater mussels only in El Carrizo reservoir on July 12, 2014 (Figure 2). It is known that the dreissenid species can have different phenotypes; even if they have the same genotype due to different environmental conditions (Claxton et al. 1998). We identified them as *Dreissena rostriformis bugensis.*

They were found mainly in clusters containing numerous individuals and were firmly attached to solid objects, mainly on submerged rocks at shallow depth (0.5 – 1m).

The specimens of quagga mussel collected in El Carrizo reservoir have a total length ranging from 11.43 to 28.6 mm and a weight ranging from 0.231 to 3.6g (Figure 2). The substrate consisted of rocks and mud. Surface water temperature was 25°C; with an electrical conductivity of 1222 µS/cm. Shoreline vegetation is scarce with Chamise *Adenostoma fasciculatum,* narrowleaf yerba santa *Eriodictyon angustifolium* and other small plants such as brittlebrush *Encelia farinosa.* The aquatic vegetation detected was *Enteromorpha* sp.

Discussion

The spread of freshwater dreissenids could have potentially undesirable effects in river and lagoon ecosystems. Documented ecological effects of these species include: ecosystem change by reduction of phytoplankton numbers or biomass (Birnbaum 2006); modification of natural benthic communities associated with an increased number of benthic invertebrates (Ward and Ricciardi 2007); habitat alteration by high density colonization in soft substrates can impede fish foraging (Beekey et al. 2004); colonization of hard substrates affects spawning fishes (Marsden and Chotkowski 2001); competition for space with native species (Strayer et al. 1998); and modification of nutrient regime (Bruesewitz et al. 2006). Another ecological impact is the bioaccumulation of pollutants which may harm animals further up the food chain (DAISIE 2006). Negative economic impacts include those caused by the fouling of intake pipes, ship hulls, navigational constructions and aquaculture cages (Idaho Invasive Species Council 2009).

The occurrence of this freshwater mussel in El Carrizo reservoir is most likely to be the result of transporting water from the Colorado River or the introduction of sports fishing boats from a zone where this mussel species is present. The infestation of quagga mussels has been detected in lakes and reservoirs in the U.S., including the state of California since 2007, where 25 reservoirs are infested by quagga mussels. Almost all of them are located in Southern California and receive water from the Colorado River (California Department of Fish and Wildlife 2011). The infested U.S. reservoirs closest to El Carrizo reservoir are Lower Otay and Sweetwater reservoirs, located approximately 25 and 35 kilometers northwest, respectively. El Carrizo reservoir is located eight kilometers east of the urban zone of Tijuana. The reservoir was built in 1977 to store water from the Colorado River-Tijuana aqueduct, with a maximum capacity of 30 million cubic meters and a maximum depth of 286.22m (CESPT 2013).

We visited eight points in the Mexicali and San Luis Río Colorado Valley and no freshwater mussel cluster or individual was detected in the inspected channels and reservoirs. The absence of quagga mussel may be as a result of the environmental conditions in the water bodies (ponds and canals). In this zone there is a high fluctuation of water level due to the heavy demand of water for agriculture and domestic use. Daytime water temperatures in the summer were estimated by Minckley (1979) to exceed 30°C (86°F), but approaching 40°C (104°F) only when insolation was accompanied by high relative humidity (Deacon and Minckley 1974). Antonov and Shkorbatov (1990) determined the effect of temperatures on Ukraine populations of *D. rostriformis bugensis*. The onset of mortality was at 28.1°C. Fifty percent mortality was recorded at 29.1°C. They also recorded the first *D. bugensis* with fully opened shell at a temperature of 29.7°C. Another study had shown a rapid mortality of *D. bugensis* at 30°C (Spidle 1994).

It is possible that some areas in the Mexican portion of the Colorado River basin suffered seasonal mussel colonization during certain times of the year. But some parameters such as low dissolved oxygen and high temperatures can effectively eliminate the settled mussel populations on a regular basis (Mackie and Claudi 2009). Mihuc et al. (1999) reported a seasonal colonization by zebra mussel in a subtropical river: the veligers coming in from upstream locations settle during autumn and winter and are eliminated the following summer by a combination of high ambient temperature and low dissolved oxygen. The colonization of quagga mussel in the Mexican portion of the Colorado River may be possible where temperature and dissolved oxygen conditions are not limiting.

A high number of the exotic crayfish (*Procambarus clarki)* and an exotic clam (*Corbicula fluminea*) were observed in El Carrizo reservoir during the sampling period. The

Table 1. Characteristics of examined sites and records of quagga mussels.

Site	Coordinates	Characteristics	Estimated number
Sites examined in the Tijuana area			
El Carrizo reservoir	32º28′30″N 116º41′27″W	Water supply for this reservoir comes from the Colorado River basin via the Colorado River-Tijuana aqueduct. The banks are stony and vegetation is scarce.	Seven clusters and 20 individuals
Abelardo Rodriguez reservoir	32º26′25″N 116º54′06″W	Water supply for this reservoir comes from drainage of Las Palmas Creek. The banks are stony with scarce vegetation.	0
Alamar Creek	32º32′31.20″N 116º51′27.56″W	Stony riverbanks, water comes from discharges of wastewater treatment plants located in Tecate. Riparian vegetation is predominant in the banks.	0
Sites examined in the Mexicali Valley			
Colonia Miguel Alemán Pond, Site 1	32º30′07.76″N 114º50′53.01″W	Water of this pond comes from the canal of the Morelos Dam. Extensive vegetation in the banks of the pond*.	0
Sánchez Mejorada Canal, Site 2	32º29′11.94″N 114º47′33.52″W	The canal banks are densely covered by tule (*T. domingensis*).	0
Wellton-Mohawk Canal, Site 3	32º29′34.15″N 114º48′43.67″W	Water comes from agricultural drainage. This is a concrete lined canal.	0
Morelos Dam canal, Site 4	32º42′20.77″N 114º43′50.05″W	The canal bank was stony with dense vegetation*.	0
Presa Matamoros, Site 5	32º42′54.83″N 114º44′57.88W	*Salvinia molesta* exists in abundance in this site*.	0
Ejido Pachuca, Site 6	32º36′38.06″N 114º49′49.36″W	Concrete lined canal, facilities to control water flow in the canal.	0
Bosque de Mexicali, Site 7	32º37′49.26″N 115º29′9.88″W	Stones in the banks, water that supply the pond comes from the Colorado River.	0
Sedimentation ponds in the Colorado river-Tijuana Aqueduct, Site 8	32º38′55.23″N 115º39′52.29″W	Pond with large stones in the banks, no vegetation.	0

*Plant species observed in the canal banks included: *Tamarix ramossisima* Lebed, *Prosopis glandulosa* Torrey var. *torreyana* (L. Benson) M. Johnston, *Phragmites australis* (Cav.) Steudel, *Parkinsonia microphylla* Torr., *Salix exigua* Nutt., *S. gooddingii* C. Ball., *Sesbania herbaceae* (Mill.) McVaugh, as well as aquatic plants *Naja marina* L., *Stuckenia pectinata* (L.) Börner and the filamentous algae *Enteromorpha* Link.

Figure 2. A) Individual quagga mussel, B) view of *Dreissena rostriformis bugensis* cluster from El Carrizo reservoir. Photograph by F. T. Wakida.

introduction of both *Dreissena* species is generally associated with an increased benthic macroinvertebrate density and taxonomic richness (Ward and Ricciardi 2007). Biodeposition of organic waste and dense colonization of the benthos by zebra mussels has also substantially altered benthic communities; many invertebrates benefit from the increased food resources and complex habitat (Ward and Ricciardi 2007).

Additional sampling and monitoring is necessary to evaluate the mussel distribution and impacts of this new exotic species in Baja California and establish measures for its control and eradication.

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References

Antonov PI, Shkorbatov GL (1990) Ecological- physiological characteristics of Dreissena of the Lower Reaches of the Dnieper River. In: Vid iyego areale. Biologiya, ekologiya i produktivnost'vodnykh bespozvonochnykh (Species in its distribution range. Biology, ecology and production of aquatic invertebrates), pp 126–130 (In Russian)

Beekey MA, McCabe DJ, Marsden JE (2004) Zebra mussels affect benthic predator foraging success and habitat choice on soft sediments. *Oecologia* 141: 164–170, http://dx.doi.org/10.1007/s00442-004-1632-1

Benson AJ (2013) Chronological history of zebra and quagga mussels (Dreissenidae) populations in North America, 1988–2010. In: Nalepa TF, Schloesser DW (eds), Quagga and Zebra Mussels: Biology, Impacts, and Control, CRC Press. Boca Raton, FL, pp 9–32, http://dx.doi.org/10.1201/b15437-6

Benson AJ, Richerson MM, Maynard E, Larson J, Fusaro A, Bogdanoff AK (2014) *Dreissena rostriformis bugensis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL, http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=95 (Accessed 28 July 2014)

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, http://dx.doi.org/10.3391/ai.2010.5.2.13

Birnbaum C (2006) NOBANIS – Invasive Alien Species Fact Sheet – *Dreissena polymorpha*. http://www.nobanis.org/files/factsheets/Dreissena_polymorpha.pdf (Accessed 28 July 2014)

Bruesewitz DA, Tank JL, Bernot MJ, Richardson WB, Strauss EA (2006) Seasonal effects of the zebra mussel (*Dreissena polymorpha*) on sediment denitrification rates in Pool 8 of the Upper Mississippi River. *Canadian Journal of Fisheries and Aquatic Sciences* 63: 957–969, http://dx.doi.org/10.1139/f06-002

California Department of Fish and Wildlife (2011) Dreissenid Mussel Infestations in California. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=39027 (Accessed 3 August 2014)

CESPT (2013) Historia de los acueductos en Tijuana y Playas de Rosarito. Fuentes de abastecimiento [History of the aqueducts in Tijuana and Playas de Rosarito. Sources of water supply] https://www.cespt.gob.mx/culturaagua/pdf/articulos/Acueductos(03).pdf (Accessed 4 August 2014)

Claxton WT, Wilson AB, Mackie GL, Boulding EG (1998) A genetic and morphological comparison of shallow- and deep-water populations of the introduced dreissenid bivalve *Dreissena bugensis*. *Canadian Journal of Zoology* 76(7): 1269–1276, http://dx.doi.org/10.1139/z98-064

Delivering Alien Invasive Species Inventories for Europe (DAISIE) (2006) *Dreissena polymorpha* Summary: Available from: http://www.europe-aliens.org/speciesFactsheet.do?speciesId=50169 (Accessed 3 August 2014)

Deacon JE, Minckley WL (1974) Chapter VII, desert fishes. In: Brown GW Jr, (ed), Volume II. Academic Press Inc, New York and London, United States, pp 385–488

Idaho Invasive Species Council (2009) Estimated Potential Economic Impact of Zebra and Quagga Mussel Introduction into Idaho. http://www.aquaticnuisance.org/wordpress/wp-content/uploads/2009/01/Estimated-Economic-Impact-of-Mussel-Introduction-to-Idaho-Final.pdf (Accessed 28 October 2014)

Implan (2002) Programa de Desarrollo Urbano del Centro de Población Tijuana 2002-2025 [Urban development plan of the City of Tijuana 2002-2025]. Periódico Oficial del Estado de Baja California, Published in December 13, 2002, No. 54

Mackie GL, Claudi R (2009) Monitoring and control of macrofouling mollusks in fresh water systems, Second Edition. CRC Press, Boca Raton, FL, 508 pp, http://dx.doi.org/10.1201/9781439804414

Mackie GL, Schlosser DW (1996) Comparative biology of zebra mussels in Europe and North America: an overview. *American Zoologist* 36: 244–258

Marsden JE, Chotkowski MA (2001) Lake trout spawning on artificial reefs fouled by zebra mussels: fatal attraction? *Journal of Great Lakes Research* 27: 33–43, http://dx.doi.org/10.1016/S0380-1330(01)70621-1

Mercado-Juarez I (2014) Plaga en la potabilizadora de la CESPT [Pest in the drinking water plant of CESPT]. Periodico Zeta published 9 July 2014, http://zetatijuana.com/noticias/reportajez/6687/plaga-en-potabilizadora-de-la-cespt (Accessed 1 August 2014)

Micu D, Telembici A (2004) First record of *Dreissena bugensis* (Andrusov 1897) from the Romanian stretch of river Danube. In: Abstracts of the international symposium of malacology, August 19–22, 2004, Sibiu, Romania

Mihuc T, Battle J, Mihuc J, Bryan C (1999) Zebra mussel (*Dreissena polymorpha*) seasonal colonization patterns in a sub-tropical floodplain river. *Hydrobiologia* 392: 121–128, http://dx.doi.org/10.1023/A:1003586524471

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

Mills EL, 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

Minckley WL (1979) Aquatic habitats and fishes of the lower Colorado River, southern United States. U.S. Bur. Rec, Lower Colo. Reg., Boulder City, NV, 173 pp

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, http://dx.doi.org/10.1007/s10530-006-9078-5

Spidle A (1994) Comparison of exotic bivalves, the quagga mussel (*Dreissena bugensis* Andrusov) and zebra mussel (*D. polymorpha* Pallas), using genetic variation and tolerance to temperature and salinity. MSc thesis, Cornell University, Ithaca, New York, 138 pp

Strayer DL, Smith LC, Hunter DC (1998) Effects of the zebra mussel (*Dreissena polymorpha*) invasion on the macrobenthos of the freshwater tidal Hudson River. *Canadian Journal of Zoology* 76(3): 419–425, http://dx.doi.org/10.1139/z97-212

Ward JM, Ricciardi A (2007) Impacts of *Dreissena* invasions on benthic macroinvertebrate communities: a meta-analysis. *Diversity and Distributions* 13(2): 155–165, http://dx.doi.org/10.1111/j.1472-4642.2007.00336.x

XXI Ayuntamiento de Mexicali (2014) Plan de desarrollo Municipal 2014-2016 [Municipal development plan 2014-2016]. Periódico oficial del estado de Baja California. Published in April 21, 2014

Zhulidov AV, Kozhara AV, Scherbina GH, Nalepa TF, Protasov A, Afanasiev SA, Pryanichnikova EG, Zhulidov DA, Gurtovaya TYu, Pavlov DF (2010) Invasion history, distribution, and relative abundances of *Dreissena bugensis* in the Old World: a synthesis of data. *Biological Invasions* 12: 1923–1940, http://dx.doi.org/10.1007/s10530-009-9641-y