Ecology and Environmental Impact of *Limnoperna fortunei*: Introduction

Demetrio Boltovskoy

Abstract Comparisons between *Limnoperna fortunei* and much more thoroughly researched *Dreissena* species have been helpful in orienting work on the golden mussel, but they also encouraged unwarranted extrapolations to *L. fortunei* of ecological traits and effects of the zebra mussel on the systems invaded. A growing body of evidence indicates that while these mussels are functionally similar, intrinsic and environmental differences are responsible for the fact that their impacts on the waterbodies colonized often differ significantly. Interpretation of the impacts of the golden mussel on the ecosystems invaded is complicated by a priori judgments on the harm associated with this introduction, which often hamper objective analysis.

Keywords *Limnoperna fortunei* · Golden mussel · Impact · Ecology · Zebra mussel · *Dreissena*

The mechanisms by which *Limnoperna fortunei* modifies living conditions for other organisms are largely the same as those described for the zebra mussel (Karatayev et al. 1997; Ward and Ricciardi 2007; Kelly et al. 2010; Burlakova et al. 2012), but the final results of these interactions are not necessarily alike. Although in comparison with *Dreissena polymorpha*, which has been intensively studied for over a century (Karatayev et al. 2012), our knowledge of *L. fortunei* is still in its infancy, data at hand consistently show that intrinsic dissimilarities between the two species, as well as environmental differences between Europe-North America and South America (Karatayev et al. 2010), are responsible for significant differences in the impacts involved. Studies on the golden mussel have traditionally used *D. polymorpha* as a model, which resulted in useful guidelines for defining potential

---

D. Boltovskoy (✉)
Facultad de Ciencias Exactas y Naturales, Instituto de Ecología, Genética y Evolución de Buenos Aires (IEGEBA), Universidad de Buenos Aires-CONICET,
Ciudad Universitaria, 1428 Buenos Aires, Argentina
e-mail: demetrio@ege.fcen.uba.ar

Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia'-CONICET,
Buenos Aires, Argentina

D. Boltovskoy (ed.), *Limnoperna fortunei,* Invading Nature - Springer Series in Invasion Ecology 10, DOI 10.1007/978-3-319-13494-9_8

interactions and fruitful research topics, but these similarities have often proved misleading when extrapolating to *L. fortunei* the effects of the zebra mussel on the systems invaded (Boltovskoy et al. 2006, 2013; Cataldo et al. 2012; Boltovskoy and Correa 2015).

The huge Paraguay-Paraná-Uruguay floodplain river system invaded by *L. fortunei* in South America has very marked differences with the colder, clearer and more oligotrophic North American waterbodies colonized by *Dreissena*. The mean transport of POC by the Paraná River has been calculated at 1 Tg/y, 20–40 % of it being labile and available for biologic consumption (Depetris and Pasquini 2007). This suggests that filtering organisms are not food-limited (Sylvester et al. 2005). Furthermore, because indigenous filter-feeding benthic animals in the Río de la Plata watershed are scarce, most of this organic matter is flushed out into the ocean through the Río de la Plata estuary (Boltovskoy et al. 2006). *L. fortunei*, the first and only abundant macrobenthic filter feeder in this ecosystem, is intercepting an important proportion of this particulate organic matter and retaining it in the system for use by a wide array of animals. This trophic shift involves not only *L. fortunei* larvae and adults, but also many other invertebrates whose abundances are enhanced by *L. fortunei* beds. In addition, the organic matter-enriched sediments derived from the "shunt" of suspended POC to the bottom as feces and pseudofeces further contributes to enhancing benthic invertebrate abundances (Sylvester et al. 2007, Sardiña et al. 2008). Although on local scales some effects of this mechanism have been explored, on the ecosystem scale we still have a very limited understanding of these potential influences and many others, including the biomagnification and transfer of contaminants (Villar et al. 1997), thermal shifts due to changes in the light environment (Yu and Culver 2000), the homogenization of faunal compositions across environments (Sardiña et al. 2011), "invasional meltdown" effects, (Ricciardi 2001), etc.

Key pieces of information for weighing the potential effects of *L. fortunei* in these lotic systems are reliable estimates of its abundances over reasonably large areas. These estimates, however, have not yet been achieved, largely because assessment of average densities over large areas is complicated by the fact that beds of *L. fortunei* have an extremely patchy distribution. Thus, practically all data available refer to very restricted areas.

Interpretation of the effects of *L. fortunei* on the ecosystem is further complicated by the fact that interactions are multiple, intricate and very dynamic, depending not only on the species and compartments considered, but also on regional conditions, season, interannual differences, etc. (Kelly et al. 2010; Boltovskoy et al. 2013; Boltovskoy and Correa 2015). Furthermore, through the action of multiple stressors, mussels can have opposite effects on the same variable (see Fig. 1 in Chapter "Nutrient recycling, phytoplankton grazing, and associated impacts of *Limnoperna fortunei*" in this volume). For example, mussel respiration and the decomposition of their feces and pseudofeces tend to decrease dissolved oxygen concentrations, whereas clarification of the water-column and the associated enhancement of macrophyte growth have the opposite effect (summarized in Boltovskoy and Correa 2015). Feedback effects have been described where the nutrient recycling activity of *L. fortunei* enhances the growth of toxic cyanobacteria, whose blooms in turn kill the mussel's larvae (Boltovskoy et al. 2013; see Chapter "Nutrient recycling, phytoplankton grazing, and associated impacts of *Limnoperna fortunei*" in this volume). The complexity of the relationships involved is illustrated by the fact that after a century of intensive studies on *D. polymorpha,* there is still no agreement on some of its fundamental effects on the environment, such as its impact on cyanobacterial blooms (Juhel et al. 2006a, b, Dionisio Pires et al. 2010).

Complications for interpreting the significance of these effects are even more critical when attempting to label the impacts as negative or positive. Unfortunately, the ecology of introduced species is too often associated with attempts to demonstrate that invasive organisms are fundamentally different from indigenous species, and particularly that their effects are detrimental to the ecosystem. This perspective has often hampered objective analysis and has accomplished little for advancing our understanding of how these species interact with their new environment (Davis et al. 2011, but see also Simberloff and signatories 2011). Just as not all nonindigenous species have large effects (Byers et al. 2002), different invaders can have different net effects, and the same or very similar species can have dissimilar effects in different areas.

The fact that most introduced species have had negative effects on the biota (Simberloff 2003) leaves little doubt about the potential harm involved in every new introduction. However, if eradication is not a viable option, assessment of its interactions with the local biota should be objective and untainted by the fact that other introductions have been harmful. Our results indicate that, after having established itself, *L. fortunei* interacts with other organisms like any other species and some of the outcomes of these relationships can be perceived as negative (e.g., enhancement of cyanobacterial blooms, grazing on some phyto- and zooplankton, introduction of new fish parasites), whereas others are probably positive (e.g., food for larval and adult fishes, enhancement of benthic abundance and diversity).

As far as we know, in South America the range of *L. fortunei* is still limited to the Río de la Plata and a few minor basins (see Chapter "Colonization and spread of *Limnoperna fortunei* in South America" in this volume). Infestation of the next large watershed—the Amazon, has not been reported to date, but is most probably inevitable. The Cuiabá River, a tributary of the Paraguay River, which has been colonized by *L. fortunei* at least since 2000 (Boltovskoy et al. 2006) is only 150 km from the Teles Pires River in the Tapajós River basin, within the Amazon watershed (Calazans et al. 2013). Both this proximity and the fact that the Amazon is navigable to ocean liners of virtually any tonnage, including ships with ballast water from infested ports along the Paraná-Uruguay-Río de la Plata waterways and the Guaíba basin (where compliance with international water ballast regulations is rather loosely enforced; Boltovskoy et al. 2011), suggests that sooner or later *L. fortunei* will invade this basin and, eventually, other South and North American freshwater bodies (Ricciardi 1998; Boltovskoy et al. 2006; Karatayev et al. 2007). An intriguing question is to what extent the lessons learned in South America will serve as a predictor of impacts elsewhere.

Acknowledgments This work was partially financed by grants from the University of Buenos Aires, Argentina (UBA X-020 and 20020100100035) and from the Argentine Agencia Nacional de Promoción Científica y Tecnológica, Argentina (PICT 2007 1968) to DB.

References

Boltovskoy D, Correa N (2015) Ecosystem impacts of the invasive bivalve *Limnoperna fortunei* (golden mussel) in South America. Hydrobiologia 746:81–95

Boltovskoy D, Correa N, Cataldo D, Sylvester F (2006) Dispersion and ecological impact of the invasive freshwater bivalve *Limnoperna fortunei* in the Río de la Plata watershed and beyond. Biol Invasions 8:947–963

Boltovskoy D, Almada P, Correa N (2011) Biological invasions: assessment of threat from ballast-water discharge in Patagonian (Argentina) ports. Environ Sci Policy 14:578–583

Boltovskoy D, Correa N, Bordet F, Leites V, Cataldo D (2013) Toxic *Microcystis* (cyanobacteria) inhibit recruitment of the bloom-enhancing invasive bivalve *Limnoperna fortunei*. Freshw Biol 58:1968–1981

Burlakova LE, Karatayev AY, Karatayev VA (2012) Invasive mussels induce community changes by increasing habitat complexity. Hydrobiologia 685:121–134

Byers JE, Reichard S, Randall JM, Parker IM, Smith CS, Lonsdale WM, Atkinson IAE, Seastedt TR, Williamson M, Chornesky E, Hayes D (2002) Directing research to reduce the impacts of nonindigenous species. Conserv Biol 16:630–640

Calazans SHC, Americo JA, Fernandes FD, Aldridge DC, Rebelo MD (2013) Assessment of toxicity of dissolved and microencapsulated biocides for control of the golden mussel *Limnoperna fortunei*. Marine Environ Res 91:104–108

Cataldo D, Vinocur A, O'Farrell I, Paolucci E, Leites V, Boltovskoy D (2012) The introduced bivalve *Limnoperna fortunei* boosts *Microcystis* growth in Salto Grande Reservoir (Argentina): evidence from mesocosm experiments. Hydrobiologia 680:25–38

Davis MA, Chew MK, Hobbs RJ, Lugo AE, Ewel JJ, Vermeij GJ, Brown JH, Rosenzweig ML, Gardener MR, Carroll SP, Thompson K, Pickett TA, Stromberg JC, Del Tredici P, Suding KN, Ehrenfeld JG, Grime JP, Mascaro J, Briggs JC (2011) Don't judge species on their origins. Nature 474:153–154

Depetris PJ, Pasquini AI (2007) The geochemistry of the Paraná River: an overview. In: Iriondo MH, Paggi JC, Parma MJ (eds) The Middle Paraná River. Limnology of a subtropical wetland. Springer Verlag, Berlin, pp 143–174

Dionisio Pires LM, Ibelings BW, van Donk E (2010) Zebra mussels as a potential tool in the restoration of eutrophic shallow lakes, dominated by toxic cyanobacteria. In: van der Velde G, Rajagopal S, Bij de Vaate A (eds) The zebra mussel in Europe. Backhuys Publishers, Leiden, pp 361–372

Juhel G, Davenport J, O' Halloran J, Culloty S, Ramsay R, James K, Furey A, Allis O (2006a) Pseudodiarrhoea in zebra mussels *Dreissena polymorpha* (Pallas) exposed to microcystins. J Exp Biol 209:810–816

Juhel G, Davenport J, O'Halloran J, Culloty SC, O'Riordan RM, James KF, Furey A, Allis O (2006b) Impacts of microcystins on the feeding behaviour and energy balance of zebra mussels, *Dreissena polymorpha*: a bioenergetics approach. Aquat Toxicol 79:391–400

Karatayev AY, Burlakova LE, Padilla DK (1997) The effects of *Dreissena polymorpha* (Pallas) invasion on aquatic communities in Eastern Europe. J Shellfish Res 16:187–203

Karatayev AY, Padilla DK, Minchin D, Boltovskoy D, Burlakova LE (2007) Changes in global economies and trade: the potential spread of exotic freshwater bivalves. Biol Invasions 9:161–180

Karatayev AY, Burlakova LE, Karatayev VA, Boltovskoy D (2010) *Limnoperna fortunei* versus *Dreissena polymorpha*: Population densities and benthic community impacts of two invasive freshwater bivalves. J Shellfish Res 29:975–984

Karatayev A, Claudi R, Lucy F (2012) History of *Dreissena* research and the ICAIS gateway to aquatic invasions research. Aquat Invasions 7:1–5

Kelly DW, Herborg L-M, MacIsaac HJ (2010) Ecosystem changes associated with *Dreissena* invasions: recent developments and emerging issues. In: van der Velde G, Rajagopal S, bij de Vaate A (eds) The zebra mussel in Europe. Backhuys Publishers, Leiden, pp 199–210

Ricciardi A (1998) Global range expansion of the Asian mussel *Limnoperna fortunei* (Mytilidae): another fouling threat to freshwater systems. Biofouling 13:97–106

Ricciardi A (2001) Facilitative interactions among aquatic invaders: is an "invasional meltdown" occurring in the Great Lakes? Can J Fish Aquat Sci 58:2513–2525

Sardiña P, Cataldo D, Boltovskoy D (2008) The effects of the invasive mussel, *Limnoperna fortunei*, on associated fauna in South American freshwaters: importance of physical structure and food supply. Fund Appl Limnol/Archiv für Hydrobiologie 173:135–144

Sardiña P, Chaves E, Marchese M (2011) Benthic community responses to invasion by the golden mussel, *Limnoperna fortunei* Dunker: biotic homogenization vs environmental driving forces. J N Am Benthol Soc 30:1009–1023

Simberloff D (2003) Confronting introduced species: a form of xenophobia? Biol Invasions 5:179–192

Simberloff D, signatories (2011) Non-natives: 141 scientists object. Nature 475:36

Sylvester F, Dorado J, Boltovskoy D, Juárez A, Cataldo D (2005) Filtration rates of the invasive pest bivalve *Limnoperna fortunei* as a function of size and temperature. Hydrobiologia 534:71–80

Sylvester F, Boltovskoy D, Cataldo D (2007) The invasive bivalve *Limnoperna fortunei* enhances benthic invertebrate densities in South American floodplain rivers. Hydrobiologia 589:15–27

Villar CA, Stripeikis J, Tudino M, D' Huicque L, Troccoli O, Bonetto C (1997) Use of invasive bivalves as biomonitor organisms for metal pollution at the Río de la Plata basin. In: 7° Conferencia Internacional sobre la Conservación y Gestión de Lagos (Lacar 97), San Martín de los Andes (Argentina)

Ward JM, Ricciardi A (2007) Impacts of *Dreissena* invasions on benthic macroinvertebrate communities: a meta-analysis. Divers Distrib 13:155–165

Yu N, Culver DA (2000) Can zebra mussels change stratification patterns in a small reservoir? Hydrobiologia 431:175–184