

Risk assessment and management of invasive mussels of the genus *Dreissena* in the water basins of Bulgaria

Teodora Angelova Trichkova

SUMMARY

Freshwater mussels of the genus *Dreissena* – the zebra mussel *D. polymorpha* and the quagga mussel *D. rostriformis bugensis* are among the most aggressive aquatic invaders, which have great potential to cause ecological and economic damages. The main aim of this work was to assess the risk of invasion by *Dreissena* mussels in water basins of Bulgaria and to develop risk management guidelines for vulnerable and already infested water bodies. This included the following objectives: 1) To study the distribution as well as the pathways of introduction and spread of *Dreissena* species in Bulgaria; 2) To study the influence of environmental factors on *Dreissena* distribution; 3) To design and apply a Multi-Criteria Decision Analysis framework to support the *Dreissena* species risk management in Bulgaria.

The study area included the inland water bodies in all Bulgaria (rivers, lakes, reservoirs) and the Danube River. The water bodies were analysed by drainage basins (the Danube River, Black Sea, Aegean Sea) and by smaller river basins. A total of 82 standing water bodies and 261 river sections were studied in the period 2002–2012. Considering the pathways of introduction and spread, as well as the consequences for aquatic ecosystems and the economy by *Dreissena* invasions, a risk-based Multicriteria Decision Analysis process was designed and applied and it included the following stages: 1) Statement of the decision problem and formulation of fundamental decision objectives; 2) Identification of decision makers; 3) Generation of alternatives/ management actions for prevention and control; 4) Delineating a set of *Dreissena* risk categories/ threat conditions, against which the evaluation criteria would be considered; 5) Listing and description of evaluation criteria, by which to judge alternatives according to risk categories and gathering value judgments on relative importance of criteria; 6) Ranking/ selecting final alternatives based on the listed evaluation criteria; and 7) Communication of results to decision makers, stakeholders (incl. scientists) and other interested parties at all stages.

The results have shown the presence of the two species of the genus *Dreissena* in Bulgaria. Until 2012, the zebra mussel *D. polymorpha*, which is a native species to Bulgaria, was recorded in 60 water bodies, belonging to the three drainage basins, including the Danube River. Of them, five water bodies are a part of the species native range, while in 55 water bodies the zebra mussel was translocated. Here we report 49 new inland water bodies with

presence of *D. polymorpha* for the period 2005-2012. The alien quagga mussel *D. r. bugensis* was found in the Bulgarian section of the Danube River and in four inland water bodies within the Ogosta River catchment. These are the first records of the species from Bulgaria and the first records from standing water bodies in Central and Western Europe.

Five regions/ river basins were studied in more details: the reservoirs in north-western Bulgaria and the Lesnovska River basin (the Danube River drainage basin), the Kamchiya River basin (the Black Sea drainage basin), and the reservoirs within the catchments of the Struma River and Sazliyka River (the Aegean Sea drainage basin). Based on the results, the pathways of introduction and spread of *Dreissena* mussels in the inland waters of Bulgaria were identified. They were associated mainly with human activities and were grouped as follows: 1) Corridor pathway – transport of larvae or adult mussels through canals connected directly to the Danube River, other infested water bodies or water bodies from the native range of *D. polymorpha*; 2) Transport contaminant – unintentional introduction of larvae and adult mussels transported with stocking material or aquaculture, live food and bait; 3) Transport stowaway – moving of larvae or adult mussels attached to transport vessels – boats or other vessels for fishing, sport or recreation; 4) Transport stowaway – moving of larvae or adult mussels attached to equipment; and 5) Unaided secondary natural dispersal of larvae and adult mussels that have been introduced by means of any of the other pathways.

High abundance of *D. polymorpha* was recorded in many of the studied reservoirs and sand-pit lakes (e.g. Chepintsi Lake, Negovan Lake, Stoikovtsi Reservoir, and Rabisha Reservoir). In the Ogosta Reservoir, the population of *D. r. bugensis* had much higher abundance than that of *D. polymorpha*, especially at higher depths. The population of *D. r. bugensis* in the Danube River differed morphologically from that in the Ogosta Reservoir, most probably due to the different ecological conditions.

The influence of certain environmental factors, such as: altitude, biogeographical region, surface area, depth, substrate type, water velocity, water temperature, dissolved oxygen, pH, conductivity, calcium concentration, Secchi disk transparency, and salinity, on *Dreissena* distribution in Bulgaria was studied. The water bodies with a presence of *Dreissena* were located at altitudes from 0 to 719 m a.s.l. and had a surface area over 25 ha and a maximum depth from 5 to 60 m. The mussels were found at depths up to 30 m; *D. polymorpha* occurred more frequently at depths up to 10–15 m, while *D. r. bugensis*, which prefers higher depths, occurred up to 24–30 m. Most abundant self-sustaining populations were recorded in water bodies, which offer a high substrate diversity. Conductivity and calcium concentration were the most important parameters among the physical and chemical factors for the distribution of the mussels. The highest number of water bodies with presence of *Dreissena* had conductivity from 200 to 500 $\mu\text{S}/\text{cm}$. A high percentage of the lakes and

reservoirs with *Dreissena* had also conductivity values above 500 $\mu\text{S}/\text{cm}$ but the populations in these water bodies were not stable and the mortality was high. The mussels were not found in waters with a calcium concentration of <20 mg/l. Most of the water bodies with *Dreissena* had a calcium concentration in the range of 25–50 mg/l, in waters with a concentration of >70 mg/l the mortality of mussels was high. Regarding the other water physical and chemical parameters (temperature, Secchi disk transparency, dissolved oxygen, pH, and salinity), the water basins in Bulgaria offered to a great extent suitable conditions for the ecological and physiological requirements of the *Dreissena* mussels.

Ecological impact (fouling on native species of mussels, snails and crayfish) and economic impact (fouling on infrastructure) was documented in many of the studied inland water bodies infested by *Dreissena*. This has indicated the urgent need of development and application of risk management guidelines related to *Dreissena* invasions in Bulgaria.

Based on our results, the main decision problem for managing *Dreissena* mussels in Bulgaria was stated: The infrastructure, economy and environment of Bulgaria are at risk from *Dreissena* mussel invasions as manifested by: 1) Increasing risk to aquatic ecosystems, biodiversity and water quality of inland water bodies; 2) Increasing vulnerability of infrastructure to biofouling; 3) Increasing economic costs due to control, management and prevention of mussel infestations, repair and maintenance of infrastructure; and 4) Recreation and tourism losses. Therefore, two fundamental decision objectives were formulated: 1) Maximise environmental quality, which may include: maximise aquatic ecosystem status, minimise negative impact on biodiversity and threatened species, minimise the impact of disposal of mussel carcasses and shells, etc.; and 2) Maximise economic benefits, which may include: maximise economic returns (power production, irrigation, water supply, fishing) and minimise economic costs (for prevention and control, infrastructure repair and maintenance, etc.).

Dreissena risk categories/ threat conditions for Bulgaria were delineated and they included three levels: low, moderate, and high threat levels. The factors that contribute to the increased risk of water bodies to *Dreissena* invasion were determined as follows: an altitude in the range 0–700 m a.s.l., affiliation to the Danube River or Black Sea drainage basins, direct connection or proximity to other infested water bodies, surface area above 50 ha, conductivity in the range of 200–500 $\mu\text{S}/\text{cm}$, moderate calcium concentration (25–50 mg/l), and accessibility by numerous human users. The inland water bodies in Bulgaria were classified at national level, using some of these criteria. Out of 344 water bodies studied, 102 water bodies, belonging to the Danube River and the Black Sea drainage basins, as well as to the Tundzha River basin, were classified as high risk of *Dreissena* invasion, 156 water bodies, belonging to the basins of the rivers Iskar, Struma, and Maritsa, were classified as moderate

risk, and 86 water bodies from the basins of the rivers Mesta and Arda were classified as low risk.

In accordance with the stated fundamental decision objectives, 42 alternatives for prevention and control of *Dreissena* invasions were proposed and discussed with decision makers. As a result, 20 management actions were selected: 11 preventive and control measures for open waters, and 9 preventive and control measures for infrastructure. Thirteen criteria by which to evaluate the predicted performance of each management action were proposed and their relative importance weights were assigned under each *Dreissena* risk category/ threat condition. The criteria ‘Slow *Dreissena* dispersal’ and ‘Maximise ecological status/ potential’ were determined as important under the three risk categories, while the criteria ‘Minimise negative impact of *Dreissena* on native species’ and ‘Minimize negative impact of *Dreissena* on infrastructure’ were found as most important under the categories moderate and high risk, i.e. in water bodies already infested by *Dreissena*. The results of the evaluation of the predicted performance of each management action showed that the highest scores with respect to most of the criteria were assigned to preventive measures, such as: ‘Regular monitoring programme’, ‘Risk modeling programme for predicting mussel distribution and spread’, ‘Programmes for education and raising public awareness’ and ‘Cleaning stations for fishing equipment, boats and recreational equipment’. We can summarise that all involved stakeholders (decision makers, scientists, etc.) selected and evaluated with the highest scores the preventive and environmentally friendly management alternatives. In addition, cost-effective preventive and control measures were preferred, which would increase economic benefits and for which there are no legal obstacles or difficulties in their application and monitoring. The implementation of the risk-based Multicriteria Decision Analysis process has demonstrated the need for wider awareness of the issues related to *Dreissena* invasions in Bulgaria and appropriate management actions, including the adoption of changes to the existing legislation if necessary.

The results of the thesis may have application in science, reservoir management and decision making. The designed risk-based Multicriteria Decision Analysis framework intend to inform and assist the decision makers in taking necessary measures to limit the risk of *Dreissena* invasions in Bulgaria. It is transparent – shows all stages of reaching a decision, democratic – all stakeholders are involved in the decision-making process, it facilitates and makes more direct the communication between stakeholders, and it is dynamic – allows a review of the management decisions and criteria depending on the threat conditions in a given water body/ basin. In addition, the model gives the opportunity for further improvement and application in other invasive species as well as in other areas, such as ecological issues, conservation of endangered species, and others.