THE IMPACT OF INVASIVE SPECIES ON URBAN ECOSYSTEMS

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Abstract. The intensive development of urban ecosystems in the last few centuries, but also the awareness of the importance of harmony between man and nature, has led to an increase of research into the factors affecting the biodiversity. Climate change, habitat fragmentation, the spread of invasive species, pollution are among the main factors harmful to the dynamics of ecosystems and their resilience. After loss of habitats, invasive alien species are the second most important cause of global biodiversity loss. Urban lakes, even if most of them have artificial origin, with a low α-diversity, meet an important role in the well-being of human population. The resilience of the urban ecosystem caused by anthropogenic impacts is much lower than in natural ecosystems due their simple structure. With the introduction of exotic species, their impact is produced by several cumulated factors, namely: new pathogens, high rates of reproduction, food competition and a weak or absent of higher consumers control. These conditions favour their expansion to the detriment of native species. Legislative and population awareness measures have to be taken, regarding access routes for invasive species, their environmental effects and economic loss and not least the application of integrated control actions.

Keywords: Bucharest lakes, non-indigenous species, *Ameiurus* genus, ecosystem services.

Rezumat. Impactul speciilor invazive asupra ecosistemelor urbane. Dezvoltarea intensă din ultimele secole a ecosistemelor urbane dar şi conştientizarea importanţei armoniei dintre om şi natură, a dus la o creştere a cercetărilor privind factorii care afectează biodiversitatea. Schimbările climatice, fragmentarea habitatelor, răspândirea speciilor invazive, poluarea, sunt printre principalii factori dăunători asupra dinamicii ecosistemelor şi a capacităţii lor de rezilienţă. După pierderea de habitate, speciile invazive reprezintă a doua cea mai importantă cauză a pierderii biodiversităţii la nivel mondial. Lacurile urbane, chiar dacă majoritatea au o origine artificială, cu o diversitate redusă, joacă un rol important în bunăstarea populaţiei umane. Datorită structurii lor simple, rezilienţa ecosistemelor urbane ca urmare a impactului antropic, este mult mai scăzută decât in cazul ecosistemelor naturale. Odată cu introducerea speciilor exotice, impactul lor este produs de mai mulţi factori cumulativi şi anume: agenţi patogeni noi, rate ridicate de reproducere, competiţia pentru hrană şi un control slab sau absent al consumatorilor superiori. Aceste condiţii favorizează extinderea lor în detrimentul speciilor indigene. Sunt necesare măsuri legislative şi conştientizarea populaţiei umane privind căile de acces pentru speciile invazive, efectele lor asupra mediului şi pierderile economice şi nu în ultimul rând aplicarea unor acţiuni de control integrat al populatiilor non-native.

Cuvinte cheie: lacuri din Bucureşti, specii non-indigene, genul *Ameiurus*, servicii ecosistemice.

THE CHARACTERISTICS OF URBAN LAKES

The intensive development of human society in the last centuries as a result of industrialization has led to a need for concentration in cities much higher than in rural areas. As a result of the expansion of the urbanization process, a new ecosystem type appeared, urban ecosystems, where energy inputs are artificial and the dominant species is taken over by man. Urban ecosystems are different from natural ones, because they als include, besides the natural component, the built-up component and the socio-economic environment (BOTNARIUC & VĂDINEANU, 1982; NASELLI-FLORES, 2008). Within these systems we find parks and water bodies that provide a range of services in the well-being of the human population such as air purification, modulation of temperature and humidity in the atmosphere.

Urban lakes are in most cases man-made and few of them are natural ecosystems in cities. Artificial ones resulted either from excavation works, or were built to be recreational parks. For this reason, urban lakes generally tend to be small in the surface (max 10 km^2) and depth (max 6 m) and are not very complex in the trophic network. Much of the water that feeds them comes from springs and rainfall. Physico- and chemical traits depend on the extent of the source of supply but also on the influence of the city on microclimate conditions (SCHUELER & SIMPSON, 2001). There are five types of urban ecosystems: nature reserves, ornamental lakes, garden pounds, drainage systems and industrial pounds (HASSALL, 2014).

POnds are much simpler in terms of α-diversity compared to large lakes or rivers, but are characterized by a greater diversity of environmental conditions, thus reflecting β-diversity. In order to preserve the biodiversity of urban ecosystems, it is not only sufficient to know the richness of species and their share in the ecosystem, but also their importance in the ecosystem function. Thus, common species are cosmopolitan and cannot serve as indicator, keystone, flagships, umbrellas species, etc. (VERMONDEN, 2010).

The resilience of ecosystems is closely related to biodiversity, the tolerance capacity of organisms and their involvement in key control processes. If the natural variations of environmental factors are characterized by normal dynamics, ecosystems have recovery mechanisms based on "*ecological memory*". The degradation of ecosystems caused by anthropogenic impacts affects the ability to recover with effects in changing the biotic component or breakdown of the food web (CARPENTER & COTTINGHAM, 1997; BENGTSSON et al., 2003). The cumulated natural and anthropogenic disturbing factors affect the resilience of ecosystems, especially in the cases with low diversity (VINEBROOKE et al., 2004). In order to reduce the anthropogenic impact on aquatic biodiversity, it is

necessary to prevent species losses including the economically less important levels, such as invertebrates or aquatic plants. Unfortunately, only a certain biotic component that can easily adapt to the pressure factors that characterize urban ecosystems is favoured, and these are often the exotic species. These anthropogenic changes of aquatic ecosystems make it difficult to preserve and protect native species (FRANKLIN, 1988).

The conscious introduction of exotic species has been accomplished for a very long time, man being tempted to bring exotic plants and animals either for economic or decorative purposes. Even though these were often kept under controlled conditions, some of them got into the environment and have changed the fate of many ecosystems.

THE FEATURES OF INVASIVE SPECIES

The Convention on Biological Diversity (CBD) considers invasive species as one of the major threats to biodiversity and natural capital and refers not only to foreign species introduced from other areas, but also to species introduced and spread *outside their natural habitat or present distribution* (HANEL et al., 2011).

In Romania, 47% of the territory is represented by natural and semi-natural ecosystems, bringing important contributions to European biodiversity (BĂNĂDUC, 2008). As in the rest of Europe, in Romania, there are many species that acclimated and became invasive, affecting the native component significantly (BĂDEANU et al., 2009).

For example, along the Snagov Lake, the most significant invasive species in this Protected Area are: *Nelumbo nucifera* (also known as Indian lotus, sacred lotus, bean of India, Egyptian bean), *Dreissena polymorpha* (Zebra mussel), *Lepomis gibbosus* (pumpkinseed, pond perch, common sunfish) and *Carassius gibelio* (Prussian carp, silver Prussian carp or Gibel carp) (*** ANPLS Mangement Plan, 2015).

"Visible" examples of invasive fish species in the urban lake ecosystems in Bucharest are bullheads species, Ameiurus (Ictalurus) found in Bucharest. In the Colentina River, the brown bullhead (*Ameiurus nebulosus*) was introduced accidentally, showing a strongly invasive character, becoming the dominant species especially in the Herăstrău, Floreasca, Tei and Plumbuita lakes (STĂNESCU & GAVRILOAIE, 2011). We consider that the anthropogenic impact produced by the fragmentation of the Colentina River has contributed to the decline of habitats, the vulnerability of the native species that have undergone also the competitive pressures, among other things, with these invasive species (BĂNĂDUC, 2008). Ictalurid genera from Siluriformes Order (Le Sueur, 1814) have also been identified in isolated lakes, such as those in the parks of Bucharest (GAVRILOAIE, 2008) or in Văcărești wetland (DRĂGAN et al., 2013).

Initially recognized as species of the genus Ictalurus and subsequently Ameiurus: *Ameiurus nebulosus*, *Ameiurus melas* and *Ameiurus natalis*, were taken from the Mississippi River basin in 1871 as decorative fish for aquariums and ponds (BÉRES et al., 2017). Subsequently, they began to develop aggressively, being thus referred to as invasive species in almost all countries of Europe. Native species prefer warmer and small depth waters being spread in ponds or shallow lakes or in the downstream sections of small and medium streams. Having reached the natural habitats, these species have spread in most European countries. *Ameiurus nebulosus* is the most widespread species, being mentioned in 23 European countries, compared to *A. melas* found in 18 of them. In the Balkan countries, Belgium, UK or Turkey, it is considered to bear a high risk of invasiveness (COPP et al., 2016). Scientific literature highlights the presence of the species *Ameiurus nebulosus* in the more cold European areas, not particularly favorable to this genus. In some cases there has been a replacement of *A. nebulosus* with *A. melas* (BÉRES et al., 2017). Due to the difficulty of taxonomic classification of species based only on morphological features, it is possible that in some ecosystems the two species coexist or produce hybrids and not be properly scientifically evaluated (MOVCHAN et al., 2014).

The studies conducted in various countries across Europe showed that *Ameiurus* species tolerate high pollution conditions with high turbidity, low oxygen concentration and high water temperatures. Their high adaptability and tolerance to precarious conditions has made this species the most widespread foreign species in Europe, with a highly invasive potential risk (RIBEIRO et al., 2008). Such conditions are common in the urban aquatic ecosystems. The success of their spread is supported not only by environmental conditions but also by the diversity of their feeding regime and reproductive strategies such as numerous multi-spawning, nest-guarding spawnings (NOVOMESKÁ & KOVÁČ, 2009; COPP et al., 2016).

Besides the high adaptability to the different types of ecosystems, bullhead species exhibit a high degree of interspecific competition for food and space resources. Bullheads have a varied feeding regime, as the following were found in their guts contents: detritus, algae, snails, fish eggs, insects, worms, fish, crayfish, etc. (*** GISD, 2015; COLLIER et al., 2018). In addition, they affect native species by changing turbidity conditions and predator-prey encounter rates. For example, in European aquatic ecosystems, the pike (*Esox lucius*) is vulnerable to competition with bullhead species (KREUTZENBERGER et al., 2008).

PATHWAYS OF INVASION

In the first phase, the introduction of alien species in Europe started from 1800 and highlighted a progressive increase of alien mammals, invertebrates and plants. A similar trend was only seen for plants in North America. The second phase of biological invasion took place in the period of Industrial Revolution (1820-1840), when the development of international trade across the continents favoured the phenomenon (HULME, 2009).

Non-native species are spread out through various ways: transportation, living industry or miscellaneous (biological control, intentional release, ecosystem disturbance). Because of global human travel, the capacity of species to disperse from natural habitats to other regions has greatly extended.

The important places for the spread of exotic species are transport hubs (shipping ports, airports) (FLOERL & INGLIS, 2005). With the increase of aquarium trade at an international level, a lot of unwanted organisms may be released into the environment, with adverse ecological and economic effects. In order to mitigate the effect on ecosystems, enhanced public education programmes, regulation of aquarium trade and improved legislation on invasive species are needed (STRECKER et al., 2011). The occurrence of non-native fishes in different regions is explained by the introductions through ballast-water exchange, and introductions from aquaria (SEMMENS et al., 2004).

In urban ecosystems, the main way of introducing exotic species is represented by trade in decorative plants and pets (VAN HAM et al., 2013). Human activities favour the colonization of some foreign species, which is not possible naturally. The colonization of species is strongly influenced by regional environmental factors. They act as filters by which the success of overtaking some species is limited (RAHEL, 2002). Urban ecosystems are more vulnerable to the impact of invasive species than natural ones due to the variability of community structure and lower diversity (HILL et al., 2016).

In aquatic ecosystems, most of the invasive species have been intentionally introduced as aquaculture and some of them accidentally. The introduction of foreign fish species began in the eighteenth century and increased later on. Their invasive character has been determined by their impact on occupied habitats, native species, especially fish, by competition for food source, parasites and exotic diseases (OLDEN et al., 2004; CROWL et al., 2008). In addition, in the case of urban water bodies, we encounter exotic plants that have been introduced for decorative purpose or abandoned exotic pet animals.

ENVIRONMENTAL AND ECONOMICAL IMPACT

Thus, the factors that lead to major changes in aquatic biota are complex and generally synergetic. In other words, the increase of pressures from global change, pollution and invasive species has led to the vulnerability of many native species and the increased risk of falling into decline. As mentioned above, as a result of cumulative anthropic pressures, the resilience capacity and supply of goods and services of the ecosystems was significantly affected (POIKANE et al., 2017). The awareness of the effects of introducing invasive species on the environment has led to the need to assess the risks and develop strategies to prevent their degradation as important and long-lasting as in the case of pollution. According to TREBITZ et al. (2017), the invasive species in the US that affected fresh water systems produced annual damage exceeding 120 billion dollars. In Europe, the costs of invasive species are estimated to EUR 12 billion per year. Thus, their effects should worry not only from an environmental point of view, but also from the economic one.

CONTROLLING MEASURES

The ecological and economic effects produced over time have led to the need to assess risk according to the stage of species invasion. The effects of the impact of invasive species on native biodiversity implies the need to establish control management plans for their expansion. It is mandatory in control measures to find effective population and to have the most comprehensive information about target species such as geographical origin, preferred environmental conditions conducive to their development, invasion paths, effects on indigenous species, direct predators.

Prevention is the best measure to control the spread of foreign species. Prevention can be achieved through both social awareness and legislative measures. In the event of a low presence of non-native species, *total eradication* is the recommended action. Another measure to reduce the invasiveness of exotic species is the *rehabilitation of degraded ecosystems* favouring the native species. As an alternative to species control, where effective, *chemical compounds* such as as insecticides and pesticides can be used. Due to the consequences on human health or the risks to other useful species, *biocontrol* can be a cost-effective measure in control of alien species, based on co-evolved natural enemies (MESSING & WRIGHT, 2006; MARTEN & MOORE, 2011). The both numeric and spatial spreading of invasive species requires *integrated measures* (REO et al., 2001; HARVEY & MAZZOTTI, 2014).

For example, in the case of *Ameiurus* species, the most well-known form of fighting it was to capture as many adult individuals as possible for a drastic reduction of its stock. On the other hand, in juvenile stages when spines are less developed, they are vulnerable to predatory fish. Largest fish predators include pike (*Esox* spp.) and pike perches (*Sander* spp.) may control the *Ameiurus* population extension (*** CABI, 2018). The strategies to eradicate these invasive species are still limited because they have not been sufficiently tested (IRIARTE et al., 2005; CUCHEROUSSET, 2006; ANASTASIU et al. 2007; ENDLICHER et al., 2007; LOUETTE et al., 2013; MANTEGHI et al., 2015).

CONCLUSION

Urban ecosystems may represent a major gateway for invasive species dispersion, as a result of high human population density and their concerns of having exotic pets and decorative plants. For this reason, the management of these ecosystems must be done responsibly and especially preventively to permit the development of these living beings in nature, which can pose high risks not only at regional level but also on extended areas.

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