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ELODEA CANADENSIS MICHX. IN LATVIA

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The spatial distribution, dynamics and habitat preferences of invasive aquatic plant species *Elodea canadensis* were studied and its suitability as an indicator of water quality in Latvia was discussed. The study is based on analysis of herbaria, literature sources and field survey data that were summarized in distribution maps over three periods of time. The habitat preferences were analyzed on the basis of the above-mentioned sources and water monitoring data.

Key words: *Elodea canadensis*, invasion, distribution, controlling factors, Latvia.

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INTRODUCTION

Since the end of the 19th century the Canadian waterweed *Elodea canadensis* Michx. has spread has over most of Europe, and is known as invasive neophyte species in most of Europe except for the Arctic and most of the islands (Tutin et al. 1980). This fact allows placing the species among the most successful non-native invaders. On the basis of the latest estimations, *E. canadensis* has established in 26 European countries (Lambdon et al. 2008), while its congeners the non-native *E. nuttallii* (Planch.) H. St. John and *E. callitrichoides* (Rich.) Casp. are rare or absent in most of Europe. Due to their morphological similarities, similar habitat preferences and weedy growth, *Elodea* species have been often misidentified (Simpson 1984, 1988; Bowmer et al. 1995), particularly in the early invasion phases. In Latvia, it is assumed that the widespread *E. canadensis* is the only established species of the genus *Elodea* being a successful invader in different water bodies and streams. Most probably, *E. nuttallii* or other *Elodea* species had been introduced as aquarium plants in Latvia as well; however, up to now no naturalized populations are recorded.

In its introduced range, *E. canadensis* is well-studied from various aspects such as the invasion success and related competitive ability, responses to various environmental variables (Pagano & Titus 2004), ecological life history (Nicols & Shaw 1986), growth in relation to temperature (Madsen & Brix 1997), phenotypic plasticity (Simpson 1988), allelopathic activity (Ehrhard et al. 2004; Ehrhard & Gross 2006) and impacts on native aquatic communities (Josefsson & Andersson 2001). Barrat-Segretain (2001, 2005) studied the competition between two non-native invaders *E. canadensis* and *E. nuttallii*, where the latter appears to be a stronger competitor.

Considerable amount of data on the distribution of *E. canadensis* had been accumulated over the last 130 years since the naturalization of the species in Latvia. As early as in 1937 the Latvian botanist K. Starcs emphasized the lack of knowledge on the actual distribution of *E. canadensis*. Later on the occurrence frequency of this species was roughly estimated as 'common' in several sources of literature (e.g. Bickis 1935; Starcs 1937). Nevertheless, over more than a century, there had not been any published papers on its actual distribution and habitat preferences in Latvia, although this could increase our understanding of the invasion phenomena and its extent in the Baltic region

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Assuming the lack of knowledge on the invasion pattern of the particular species, the aim of our study was to analyze the current spatial distribution, dynamics and habitat preferences of *E. canadensis* and to discuss the suitability of this species as an indicator of water quality in Latvia.

SPECIES STUDIED

Taxonomy

The American botanist H. St. John recognized 17 species of the genus *Elodea* in a series of papers published between 1962 and 1965 (Simpson 1984), but later on his work proved to be unsatisfactory. Recent revisions of the genus have reduced the number of species to five (Preston & Croft 2001). *E. canadensis* is a submerged perennial aquatic herb. The dark green, translucent leaves are stalkless, linear-oblong, oblong-lanceolate, oblong, oblong-ovate or ovate, rarely linear-lanceolate, widest at middle of leaf. Leaf apices are broadly acute or obtuse, rarely narrowly acute, to 6-13 mm long and 1-4 mm wide, in whorls three (rarely more, sometimes two). Leaf margins are minutely recurved. Petals are <5 mm long, much longer than sepals.

The leaves of the morphologically similar congener species *E. nuttallii* are linear or linear-lanceolate. Leaf apices are narrowly acute or acuminate, leaves most cases are narrower than 1.75 mm (mean 1.4 mm), usually no longer than 10 mm (mean 7.7 mm). *E. nuttallii* is distinguished from *E. canadensis* by narrower leaves. Leaves are folded, somewhat with undulate margins (visible with hand-lens), flaccid and pale green (Rich & Jermy 1998).

The genus *Elodea* is taxonomically difficult in its native range: plants are variable in vegetative characters, therefore flowers are necessary for a confident identification. Phenotypic plasticity and varying morphological characters are often observed. All species of *Elodea* are dioecious, and almost all the plants currently established in Europe are female, so there is a negligible possibility of hybridization. In the native range of the species fruits are rarely found, probably because the sexes rarely grow together. In Europe almost all populations currently known are female (Preston & Croft 2001) including Latvia. Reproduction is mainly by vegetative means. Plants of *E. canadensis* die down in the winter, regrowing from underground stems in spring. Plants produce rather unspecialized turions in early autumn but reproduction and dispersal is probably also achieved by the spread of undifferentiated fragments. The plants fragment readily, and the fragments produce adventitious roots (Preston & Croft 2001).

Geographical distribution in native range

Both *E. canadensis* and *E. nuttallii* are native in North America, where they commonly occur throughout most of the temperate zone in the U.S. and frequent in southeast Canada (Simpson 1984). According to Preston and Croft (2001), the range of *E. nuttalii* is more southerly biased. In the native range *E. canadensis* grows mainly in calcareous waters (Bowmner et al. 1995; Haynes, www.efloras.org).

Spread in Europe

E. canadensis became established in Europe in the 19th century carrying over on American

timber that had been rafted down the rivers (Simpson 1984). Other pathways of introduction into different regions of world might have been exchange of plant materials amid botanical gardens, planting the species as aquaria plants, transportation of fishes (Starcs 1937) and unintentional attaching to transport vehicles (Kozhova & Izhboldina 1993). The fragments are distributed also by birds, boats or anglers.
The introduction to Europe and the spreading history of *Elodea* species was described by Simpson (1984). Firstly, it was brought to Ireland (1836, in other sources 1817 and 1828), from where it spread to other West European countries. According to Hultén & Fries (1986) and Mossberg & Stenberg (1992), Tutin et al. (1980), *E. canadensis* commonly occurs in West, Central and East Europe. The species is comparatively rare in South Europe; in North Europe it reaches the north of the Bothnian Gulf.

As early as the middle of the 19th century, *E. canadensis* was characterized as a harmful waterpest, which caused troubles for sluices, shipping, fisheries and swimmers by overgrowing the waters and overwhelming the streams and lakes with its large biomass (Seezen 1866; Herder 1891; Simpson 1984). The attention of the Baltic nature researchers was first attracted by K. Diercke in 1865 mentioning its ability of rapid spreading and harmfulness (Seezen 1866). At that time the species was still not present in the East Baltic region, however, soon, in 1872, it was first recorded in Latvia (Starcs 1937), in 1884 – in Lithuania (Gudžinskas 1997), and in 1905 in Estonia (Kukk et al. 2001). A description of the early invasion phase in the European part of Russia was provided by F. Herder (Herder 1891), who described the spread of *E. canadensis* in Newa River and its tributaries since ca. 1881, blocking the mouths of the rivers.

In 1937, Latvian botanist K. Starcs (1937) gave an insight into the invasion of *E. canadensis*, emphasizing its rapid spread over streams and water bodies in Latvia. In the 1930s and 1950s *E. canadensis* was reported as well established throughout the country, often very abundantly (Bickis 1935; Siliņš 1935; Starcs 1937; Pētersone 1953).

MATERIAL AND METHODS

Data on the distribution and habitat types were obtained from following sources: herbaria of the Institute of Biology, University of Latvia (LATV), herbaria of the University of Latvia, Faculty of Biology (RIG I, RIG I, RIG III), herbaria of Nature Museum of Latvia, data base on lakes and rivers by Agency of Environment, Geology and Meteorology of Latvia, literature and field survey data collected by the authors of this paper. Herbaria specimen were revised and identified in a case if some specimen might be misidentified as other species belonging to genus *Elodea*.

The distribution map was prepared using 5 × 5 km grid covering all the territory of Latvia. All localities drawn as points were selected and joint to the grids, thus generalizing the distribution and simultaneously avoiding a recurrence of some records in the same localities. The map was prepared by applying ArcGIS 9.1 software.

In order to analyze the abiotic factors controlling the abundance of *E. canadensis* in lakes, data from the Agency of Environment, Geology and Meteorology of Latvia on total phosphorus, total nitrogen, conductivity and pH were used. Data on the species abundance were taken from the same source, it was estimated using seven-point scale where 1- rare, 2 – occasional, 3 – common, 4 – abundant, 5 – very abundant, 6 – predominant, 7 – dominant.

RESULTS AND DISCUSSION

Distribution dynamics

The large amount of herbaria sheets collected in the late 19th and early 20th century suggest that herbaria of *E. canadensis* was actively collected and localities recorded, particularly in its early invasion phase being well-known from West

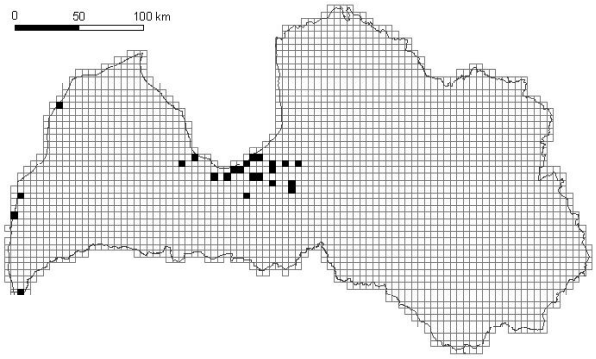

Fig. 1 Distribution of *E. canadensis* before 1900.

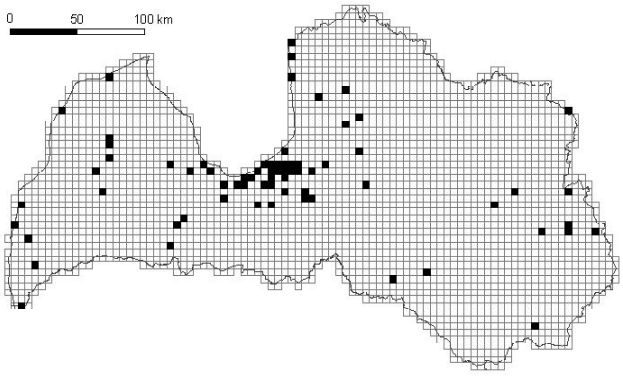

Fig. 2 Distribution of *E. canadensis* (1901-1950).

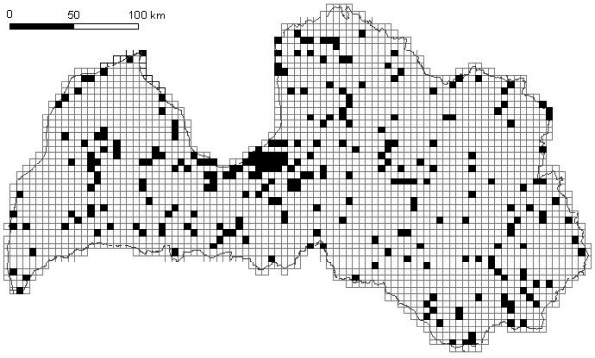

Fig. 3 Distribution of *E. canadensis* (1951-2008).

European published sources as a rapid, perhaps 'dangerous' and 'weedy' non-native invader.

The first record of *E. canadensis* was reported from Riga, 1872 or according to other data 1878 from Riga (Starcs 1937). Early records show that the distribution pattern was related to the harbors (Riga, Liepāja, western Baltic coast in Latvia), thus allowing an assumption that transport of timber might have been the initial source of species arrival in Latvia (Lehmann 1895). Up to 1900, it was recorded mainly in the surroundings of Riga including Jūrmala to the south of Riga Gulf, the northern part of the Lielupe River basin and at the Baltic coast in West Latvia (Fig. 1). By the mid 20th century, the species was found in all regions of Latvia, though the localities were scattered (Fig. 2). In the beginning of the 21st century the species was common throughout the country (Fig. 3).

Invaded habitats

In Latvia, *E. canadensis* grows in different water bodies, streams and substrates. Mostly it was recorded in rivers and lakes (48 and 37 % of cases, respectively). The rest of occurrences are comprised by artificial ponds (4 %), ditches (3 %), arms of rivers (1 %), quarry ponds (1 %) and other water types (6 %). Our observations suggest that the actual occurrence of *E. canadensis* in artificial ponds might be higher than recorded. The newly created, vegetation-less artificial ponds as well as unshaded, straightened small streams provide suitable environment for establishment and rapid spread of this invasive species, mostly due to lack of competition of native aquatic plants. In natural water bodies with relatively stable native plant

communities the expansion of *E. canadensis* is hindered by competitive pressure. Our observations and some notes in herbaria materials (e.g. H. Ledus 1938, RIG II) suggest that it can overwhelm small artificial water bodies in one or few years forming dense mats and outcompeting native aquatic species, though it is not know whether it is capable to persist as dominating species in a particular site over a longer time.

Similarly to other countries in the non-native range (e.g. Riis & Biggs, 2003; Haslam 2006), in Latvia the species is capable to withstand large variety of substrate conditions (sandy, loamy, gravelly, muddy, and peaty) (Fig. 4). In rivers, *E. canadensis* prefer medium-fast flowing streams on sandy or sandy-gravelly unstable substrates where it behaves as a pioneer invader forming dense monodominant mats, while most of native plants cannot establish in such dynamic environment. Either several studies by Riis & Biggs (2001, 2003) determine that *E. canadensis* is one of few aquatic species which is able to dominate in communities in disturbed streams, suggesting that is one of most disturbance-resistant/resilient species. In lakes, abundance of *E. canadensis* is limited by higher competition of native species, water depths and light availability. In most cases, abundance vary from 2–4 in seven-point scale (Fig. 5).

Factors controlling *E. canadensis* in lakes

Analysis of factors controlling the occurrence and abundance of the species was done on the basis of water quality of 49 lakes using the data by the Agency of Environment, Geology and Meteorology of Latvia. Regarding the stability of ecosystem, lakes provide comparatively more solid conditions than streams, thus being more suitable for analysis of abiotic factors.

Similarly to its native range (Bowmner et al. 1995; Haynes, www.efloras.org), in Latvia *E. canadensis* predominantly grows in alkaline hard water lakes with pH ranging from 6–9.5. Majority of *E. canadensis* localities occur in nutrient-poor lakes. In most of cases, in lakes with *E. canadensis* the value of total phosphorus (Ptot) ranges between 0.01-0.1 mg/l and the total nitrogen (Ntot) ranges between 0.1–1 mg/l (Fig. 5) which conform to high-good status of water quality. However, this can be applied only to natural, not human-created or anthropogenically strongly affected water bodies and streams with low competitive pressure.

Though being predominantly found in alkaline, nutrient-poor waters, evidently *E. canadensis* tolerates a wide range of growing conditions from polluted, nutrient-rich to high quality waters. In exceptional cases, the species had been found in

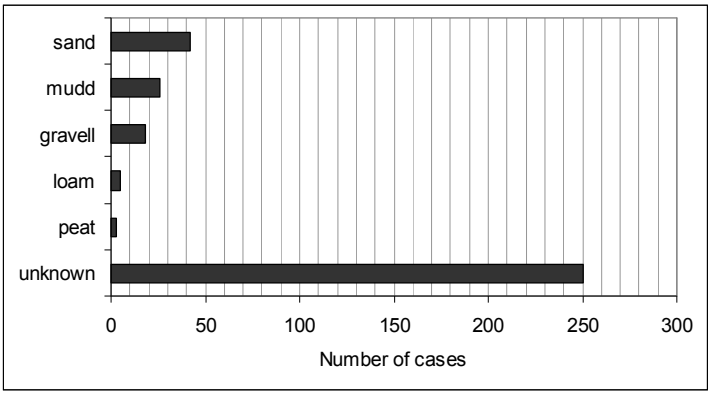

Fig. 4 Substrates in invaded sites.

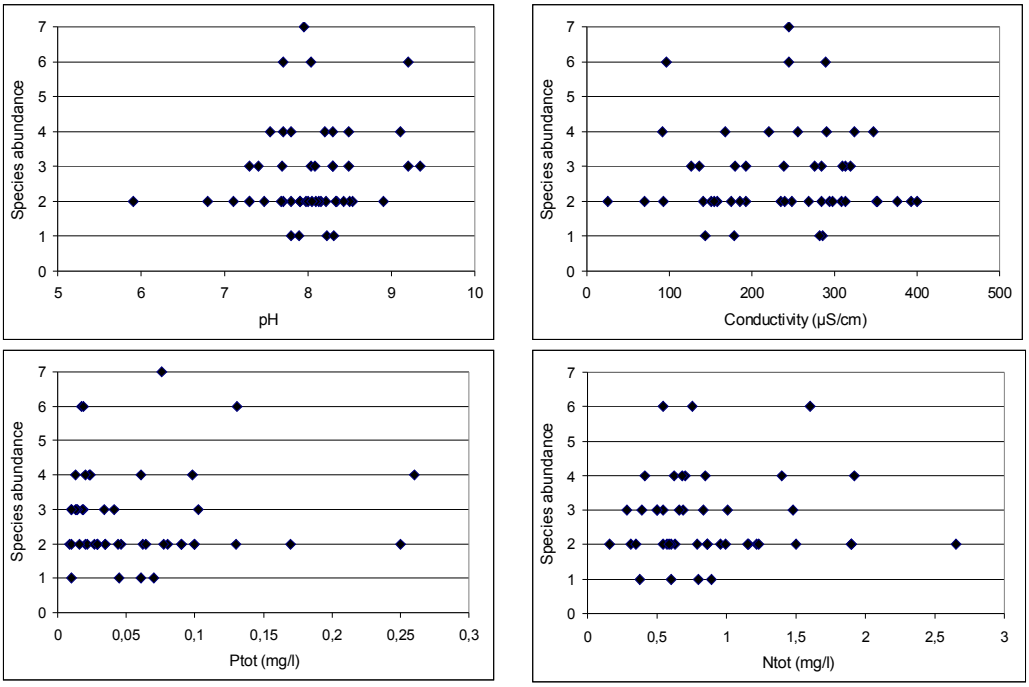

Fig. 5 Factors controlling abundance of *E. canadensis* in lakes in Latvia.

humic waters suggesting that perhaps moderately acid to acid environment, albeit not typical, is not limiting its establishment. Either the authors from various European countries mention that *E. canadensis* are able to grow in different trophic and acidity conditions: euthrophic (e.g. Walter et al. 2005), calcareous (Bowmer et al. 1995) or even brackish waters of the Bothnian Gulf in the Baltic Sea (Streftaris et al. 2005; Baltic Sea Alien..., www.corpi.ku.lt/nemo). The adaptability to euthropic waters is related to ability to purify water in metabolic process and accumulate both organic and inorganic nitrogen, thus the species could be used in removing nutrients from hypereuthropic waters (Kozhova & Izhboldina 1993; Ozimek et al. 1993). The tolerance against various environmental conditions in a combination with its dispersal strategy had assured its enormous success in the introduced range.

The above mentioned aspects allow us to propose that the behavior of *E. canadensis* is different in natural and human-created or strongly affected aquatic environments. As an 'unpredictable' and tolerant species it is not suitable as an indicator of water quality though its high abundance and presence of monospecific stands is often related to anthropogenic impacts. In Latvia, there is little knowledge on biotic factors which can be crucial in the spread of the species such as grazing pressure and competition with other plant species.

Options for management

In some European countries, management of *Elodea* species is being practiced. The biomass can be temporarily reduced by removing the stands, thus reducing their proliferation. It was described as early as on the 1930's (e.g. Starcs 1937), however, it is not known whether the management was ever practiced in Latvia. It is advised to prevent the spread by creating filters downstream before any mechanical treatment is carried out. It is essential to prevent the

dissemination of fragments after removal to avoid accidental introduction to other potentially suitable locations (e.g. Wittenberg 2005). Although attributed with weedy nature and monospecific dominance, thus largely affecting the water ecosystems as an undesired competitor and producer of large biomass, *E. canadensis* is completely naturalized in water ecosystems in Latvia, and its control in unrealistic and most probably impractical from both conservation and economical point of view.

Future perspectives

Though there is no evidence of other *Elodea* species in aquatic environments in Latvia, the intensive trade of pond ornamentals and aquaria plants might result in unintentional release of new highly invasive plants, most probably *E. nuttallii* or *E. callitrichoides* currently known from some Central- and West European countries. The invasion history of *E. canadensis* demonstrates the high capability of rapid establishment of some non-native invaders into natural environments, therefore new introductions of risky non-native aquatic plants should be avoided.

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