Management of invasive species *Solidago canadensis* in Ostrava region (Czech Republic)

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Abstract. In this article authors deal with the possibilities of population management of *Solidago canadensis* species, which is not indigenous in Czech Republic and invasive. The study areas were chosen within the Poodri PLA, which is situated near the city Ostrava in Moravian-Silesian region. Invasive species *Solidago canadensis* as well as all the other invasive species in general poses a threat especially in the protected landscape areas such as Poodri PLA thanks to disrupting their natural ecosystems and reducing their exceptional biodiversity. *Solidago canadensis* can achieve those goals mainly thanks to the ability of quick propagation not only sexual one by seeds, but also asexual (vegetative) by rhizomes and thanks to releasing allelopathic substances which has negative impact on other plant species for example inhibition of their germination and growth. By these means it relatively quickly sets up monodominant covers, displaces original and rare plant species and poses threat to further development of the landscape of Poodri PLA. Management was proposed and applied on 5 study areas in Poodri PLA and after that the effectiveness was evaluated. There were chemical (application of herbicides) and mechanical (mowing) methods and their combinations used.

1. Introduction

The research presented in this article took place in Moravian-Silesian region near the city of Ostrava, within the Poodri PLA. Poodri Protected Landscape Area (PLA) was established by the Ministry of Environment of the Czech Republic on 27th March 1991 [1]. Poodri PLA is one of the very few regions in the Czech Republic where an almost natural water regime can still be found and where the symbiosis between an uncontrolled, naturally meandering lowland river and its alluvial meadows and forests can still be seen today [1]. Most of the area is formed by floodplains, there are biotopes closely related to water: alluvial meadows, floodplain forests and permanent or periodic pools [2]. Also, a relatively dense system of ponds and drainage channels is typical here [2].

Major problem in Poodri PLA is the spread of invasive alien plant species (IAP). One of these species is Canadian goldenrod (*Solidago canadensis*), a perennial herb of the Asteraceae family, originally from North America. Thanks to its low demands on habitat, efficient vegetative (by rhizomes) and generative (by seeds) propagation and also proven allelopathic impacts on surrounding vegetation is *Solidago canadensis* easily able to form a dense, monodominant, successful association, which suppresses other species and can reduce natural biodiversity in the area [3, 4].

The main challenge and goal of this research was to propose proper methods of management and then evaluate their effectiveness. The result of this research should be focused on the efficiency of various means of interventions against populations of *Solidago candensis*, but of course it is also a beginning of the long-term research and efficiency of individual methods of elimination will become more relevant.
in future when there will be more data for comparison. Management on experimental areas which were selected after consultation with experts from Nature Conservation Agency of the Czech Republic (NCA CR) included mechanical methods (mowing) and chemical methods (application of herbicides) or combinations of both.

2. Materials and methods

The research areas on which the impact of various methods of management and their effectiveness on populations of *Solidago canadensis* was studied, as mentioned before, were selected within the Poodri PLA, more specifically in the area around the brook Ondrejnice, which is right-sided tributary of the river Odra, not far from the urban district Ostrava – Proskovice (Figure 1). This locality is basically an alluvial meadow which brook Ondrejnice flows through and our research areas with dense presence of *Solidago canadensis* were situated mainly along the banks of the brook.

![Figure 1. selected research areas.](image)

The whole research started on May 2017 when the research areas were selected and including the terrain works lasted until spring 2018. There were 7 of the areas in total from which 5 of them were experimental ones (A1, A2, A4, A6, and A7) where management was proposed and 2 control areas (A3 and A5) where no intervention has taken place and served to observe a standard lifecycle and development of Canadian goldenrod. Control areas also served to compare the effectiveness of the methods used. All the research areas had about 100 m² and were square shaped.

In addition to that, within every research area there was selected a representative 1x1 m square with dense occurrence of Canadian goldenrod. On these representative squares all the individuals were counted, their height was measured, and all the inflorescences were collected in order to determine total number of produced seeds. The determination of total number of seeds took place in the laboratory. First 1000 seeds were separated from the rest of the sample by tweezers and weighed on analytic scales in beaker. After that the rest of the sample were added in the beaker and this total weight of the sample were divided by weight of the 1000 seeds and afterwards multiplied by 1000 (number of seeds).

The following interventions were performed on the research, experimental areas:

- Mowing – mowing with scrub-cutter close to the ground.
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3. Results

The management lasted from July 2017 to April 2018 when the field survey was conducted to determine the state of populations of *Solidago canadensis* after interventions. Mowing on experimental areas took place in July 2017 and spraying month later in August.

3.1 research area A1 – spraying (HERBISTOP)

This area is located on the sunny bank of brook Ondrejnice and *Solidago canadensis* covered around 60% of the whole area (100 m$^2$). Individuals were all around 190 cm high and in representative square (1x1 m) there were 179 stems counted.

After the application of herbicide HERBISTOP we can find damaged but also undamaged individuals in the area which were not probably hit by the spray and continue blooming. Individuals hit by the spray had burned brownish photosynthetic organs. During the field survey next year in April the young individuals were counted again and there were 146 of them which is not a big difference to the situation before the management. Sample from the representative square made up by inflorescences burnt after the application of herbicide weighed 1,9091 grams and contained 51,389 seeds.

3.2 research area A2 – mowing and spraying (BANVEL)

This area is just about 100 metres far from the previous area against the stream and is also on the sunny bank of the brook. The difference here is that *Solidago canadensis* is denser and covers up to 80 % of the area. In the area with the densest cover was again established a representative square where 157 stems were counted. Height of the individuals was from 190 cm to 200 cm.

After the mowing in July followed by spraying on young vegetation with herbicide BANVEL in August we can see a significant impact on the population of *Solidago canadensis* and obvious effect of this combination of methods. After the weakening of population by mowing in the first phase, following spray also eradicated many other young individuals. Despite that fact, a month later we can find a local focuses of sprouting individuals but only few of them compared to the situation before the management. In few cases young individuals sprouted from the mowed stems. During the last field survey in April there could be seen a huge difference between the numbers in population and noticeable effect of method mowing followed by spraying. From the original number of 157 individuals now sprouted only 20 of them. Because of the mowing before the start of bloom, there were no inflorescences collected from this research area, but they were collected from the control area A3 which is just next to the control area and in the future the numbers of seeds and weight of the samples will be measured between those two areas. The sample from the control area weighed 19.7417 grams and contained 159,636 seeds.

3.3 research area A4 – mowing

This area isn’t unlike the previous two utterly sunny. Nearby willows from one side and alder grove from the other gives this area partial shadow. *Solidago canadensis* creates almost monodominant cover here with 95% of the whole area and reaches up to 210 centimetres. Within the representative square were counted incredible 377 individuals.
Only mowing alone as a method doesn’t look effective in a short-term effect and needs to be repeated at least for several years to be effective so in the future of this research will be probably combined with spraying. After the area was mowed, it also got sunnier, and the stress caused by mowing compelled *Solidago* to invest energy into quick reproduction and led to even bigger and quicker sprouting mostly from the mowed stems and whole population got paradoxically increased in numbers and optically more colonized by *Solidago*. Mowing would need to be applied at least for 5 consecutive years to tire the population of *Solidago* [7]. In April next year there were 286 young sprouting individuals in representative square, but because it was very early phase of population, its number will probably grow. Also, same situation like on area A2 occurred. Because the population has been mowed before the start of blooming, we had to take sample of inflorescences from the control area A5 right next to the research area and it weighed 32,9834 grams and contained 331,000 seeds.

3.4 research area A6 – spraying (BANVEL)

Area A6 is like 20 metres against the stream of the brook from area A4 and in this example and at the same time in the only example is completely shady. It is caused by bank cover which consisted of tall shrubs and tall oak which spreads above the whole area. Because of it stems doesn’t grow too tall and reaches height around 170 cm maximum plus the population isn’t too dense, *Solidago canadensis* covers around 75% of the whole area. In the representative square there were 162 individuals counted. After the area was sprayed by herbicide BANVEL, the population of *Solidago* is manifestly damaged. In places where herbicide made contact with the plant, there are burned yellow spots visible. Whole population is wilted, and inflorescences are either twisted down or fell of the plant completely. Compared to the individuals who hasn’t come to the contact with herbicide outside the research area A6, the individuals within area A6 have smaller and wilted panicles and almost with certainty won’t bloom again. After re-count of individuals in April 2018, there were only 4 new sprouting individuals in the whole area, nevertheless we should probably look to the fact that it was also highly covered with molehills and Solidago just started to grow so counting in future should be more conclusive. Sample of inflorescences was this time taken on the representative square inside the area and consisted of 20 damaged and wilted inflorescences. It weighed around 0,4251 gram and contained only around 10,000 seeds.

3.5 research area A7 – mowing and spraying (HERBISTOP)

Area A7 lies several metres against the stream from the A6 but is not, completely but only partially shady again because of the bank cover consisted of tall shrubs like elderberries or viburnums. *Solidago* reaches heights around 200 cm and creates dense cover which occupies about 80% of the area. There were 158 individuals in representative square before the management. After the mowing in July and spraying on young sprouting individuals a month later in August is obvious that unlike on area A4 where only mowing took place, *Solidago* doesn’t tend to sprout from the mowed stems in area A7 and lack energy needed to resist the herbicide thanks to the previous mowing and a lot of them dies because of it. In April 2018, during the re-count there were 124 young individuals found, but as well as in the case of other research areas, short time of research and lack of data needs to be considered and therefore it is hard to state any certain judgments. This area was mowed before the start of bloom so there weren’t any inflorescences to collect and so it will be done next year.
4. Discussion
This research focused on finding the most effective way how to deal with the invasive species *Solidago canadensis* was inspired by the methods of other institutions or persons who already fought with it in the past. Now let’s have a quick look on some of them. For example, mowing before the start of blooming was partially inspired by Končeková et al. [7] who came to the conclusion that this method can reduce the expansion of this species but adds that it is a long-term process which can last even several years because of the fact that it is perennial herb and in addition to that it can have a large soil seed bank. Combination of mowing with the application of herbicides is mentioned in landscape care standards of Nature Conservation Agency of the Czech Republic (NCA CR) and also used by the employees of the Krkonose Mountains National Park [8] where this method also seemed to be effective.

5. Conclusion
This research was focused on the management of invasive species *Solidago canadensis* in Poodri PLA, particularly in the first step by its proposal, in the second by its realization on the chosen research areas and in the final step by evaluation of all the interventions and collected data’s. As the most effective method to fight with this invasive species was evaluated the method of mowing before the start of the blooming followed by the spraying herbicides on the young sprouting individuals. All the research regarding this article however lasted for only one vegetative season so the results can’t be considered entirely conclusive and, in the future, will need to continue as proposed to acquire more data to evaluate and get a better idea of the efficiency of the chosen methods. This is a pilot project and will serve as a base for another research.

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