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C.S.I. PhenoBiota – Research with Plant Newcomers from all over the World – A citizen science project to study the phenology of invasive plant species under aspects of climate change

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Abstract

In a unique Europe-wide approach, students and other citizen scientists in Styria (Austria) were involved in researching and documenting the phenological development of invasive plant species under the influence of climate change. Supported by experts, they tested modern field research instruments and educational tools, laying the foundation for a long-term, nationwide Citizen Science network. The observations could be used to help make the management of invasive plant species more efficient and to raise awareness about their effects.

Introduction

In the project name *C.S.I. PhenoBiota – Research with Plant Newcomers from all over the World*, C.S.I. stands for Climate Science Investigation. The project deals with the phenology of invasive plant species in connection with climate change. Its aim, in a unique Europe-wide approach, was to collect data about the phenological development of six invasive plant species in particular, with the help of citizen scientists, to raise awareness about invasive species and to gain knowledge about their individual growth phases. The data collected should lead to more efficient neophyte management. Furthermore, the project allows citizen scientists – especially students – to gain insights into the cycles of nature and to become familiar with modern research methods combined with practical scientific work. The citizen science project was realized by the Eisenwurzen Nature and Geopark (Styria) in collaboration with eight educational institutions and five research and corporate partners, from May 2020 to April 2023. Partners were the Agricultural Research and Education Centre Raumberg-Gumpenstein, GeoSphere Austria, *Berg- und Naturwacht* (Mountain and Nature Guard) Styria, the *Regionalmanagement Bezirk* Liezen, and LACON Consulting.

The plant species investigated were the Canadian and giant goldenrod (*Solidago canadensis*, *Solidago gigantea*), ragweed (*Ambrosia artemisiifolia*), Himalayan balsam (*Impatiens glandulifera*), giant hogweed (*Heracleum mantegazzianum*), robinia / black locust (*Robinia pseudacaciae*), and Japanese knotweed (*Fallopia japonica*) (Figure 1). For the purposes of this project, the two species of goldenrod were considered together. They were selected because most of them are already widespread in Styria (and Austria more widely), and they are easily recognizable for the general public. Four of these species were introduced as ornamentals; robinia / black locust is of forestry importance, while ragweed was introduced accidentally. Ragweed pollen causes respiratory problems, and giant hogweed causes serious burns to the skin when touched (Land Steiermark 2023). All invasive neophytes displace native plant species and ultimately change entire ecosystems. This causes problems not only for nature conservation, but also for agriculture and forestry, resulting in financial losses (Land Steiermark 2023). Japanese knotweed can even lead to the destruction of infrastructure such as roads and protective walls along water bodies. Two of the invasive plant species chosen for the project are on the current list of EU Regulation No. 1143/2014 – namely, giant hogweed and Himalayan balsam.

Figure 1 – Flowering Himalayan balsam (Impatiens glandulifera). © Claudia Plank

While there is already a relatively large amount of research on invasive neophytes, the phenological growth phases – from seedling to fruiting, leaf fall, and death of what is above ground – remain relatively unknown. To date, there has been no phenological observation of neophytes in the Pan-European Phenological (PEP) Network, *"a European infrastructure to*

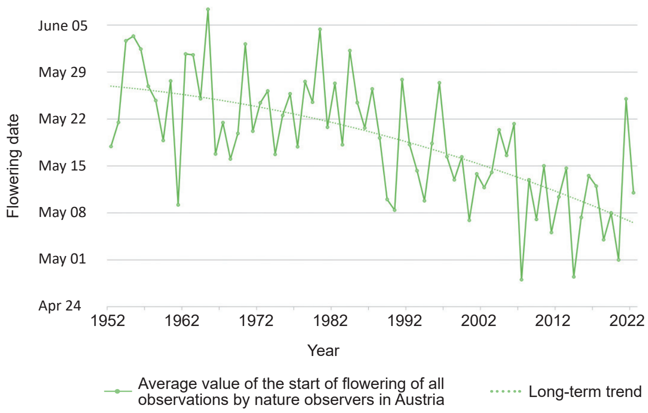

Figure 2 – Phenological observations for black elder (Sambucus nigra), from 1952 to 2022. The long-term trend shows an earlier onset of flowering of almost three weeks. Unpublished data by Geosphere Austria 2023

promote and facilitate phenological research, education, and environmental monitoring. The main objective is to maintain and develop a Pan European Phenological database (PEP725) with open, unrestricted data access for science and education" (Templ et al. 2018). Austria is part of this network. In Austria, phenological observation data have been systematically collected since the foundation of the *Zentralanstalt für Meteorologie und Erdmagnetismus* (Central Institute for Meteorology and Geomagnetism) in 1851. Thanks to this long history of data, for example for black elder (*Sambucus nigra*), the trend towards earlier flowering, which is related to climate warming, can be observed (Figure 2).

Within the C.S.I. PhenoBiota project, partners developed comprehensive, age-appropriate school lessons, and analogue and digital observation materials, which they took into schools. Pupils were allowed to develop their own research questions and project ideas. They observed and documented the phenological phases of selected plant species over the course of the year, related them to the climate, and learned to draw professional conclusions.

The C.S.I. PhenoBiota school projects

School lessons

The project partners developed lesson plans and teaching folders for the individual school levels. The *Berg- und Naturwacht* Styria, HBFLA Raumberg-Gumpenstein Research Institute, and Styrian Eisenwurzen Nature and Geopark visited seven schools in the district Liezen (Styria) several times and introduced them to the world of neophytes and phenology in a playful way. For example, the terms *neobiota*, *neophyte* and *neozoic* were explained using the well-known game Hangman and a memory game, as well as by searching for traces in the open air.

The folders compiled for the educators contain information on neophytes (their origin, benefits, risks, and phenology), experiment plans, handicraft and game instructions, and even cooking recipes. The students planted hedges at their schools with native shrub species such as black elder, alder buckthorn (*Frangula alnus*) and dog rose (*Rosa canina*), and used them as living, native, sources for phenological data. They then looked for connections between the phenological growth stages of invasive plant species and climatic conditions in order to draw conclusions about climate change.

Throughout the project, various experts organized field excursions for the school students and provided exciting insights into their professions. Students also visited research institutions in the region and gained valuable insights into their working environments.

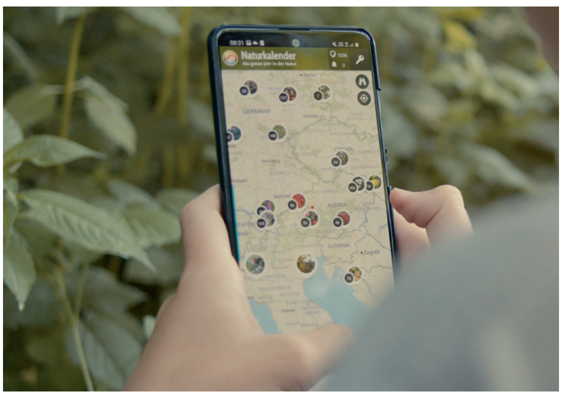

Figure 3 – Nature Calendar app for observation of invasive neophytes and native plants. © Marco Schupfer

Phenological observations

To deduce the different growth stages of the neophytes, the students had to count the number of leaves on individual plants as well as to note the onset of their flowering and fruiting. These data were recorded on observation sheets specially developed for the six neophytes and for native reference plants (e. g. black elder). In addition, the onset of each of the 10 phenological seasons (early spring, first spring, full spring etc.) was recorded by observing living reference plants, including hedges. There is only one phase in winter (GeoSphere Austria 2023). Initial observations were made and data collected (May 2021 to April 2023); more data are needed to be able to draw conclusions about the phenological phases of the invasive neophytes.

The project partners provided older students with the Nature Calendar app for use on smartphones, which was designed specifically for the phenological

Figure 4 – The kit for investigating invasive neophytes. © Marco Schupfer

Figure 5 – The kit for relating findings to climate change. © BAfEP Liezen

monitoring. Within our project, we developed a new function specifically for observing invasive neophytes (Figure 3). All data gathered from the observation sheets and the Nature Calendar app were forwarded to GeoSphere Austria and are currently being stored in a database for future analysis as the data density and observation period increase. The information gathered will be of interest to a range of stakeholders, from climate scientists to biologists and medical professionals.

Tutoring

An important aspect of the project was the involvement of students at the *Bundes Bildungsanstalt für Elementarpädagogik* Liezen (BafEP, Federal Training Institute for Elementary Education) who were training as early-years (pre-school, kindergarten) teachers. Together with their tutors, they developed experiments and illustrative materials for neophytes and climate change, which were included in two kits (Figures 4, 5). Over the course of several sessions, the BAfEP students introduced their educational materials to kindergarten children and subsequently improved them in collaboration with specialists in early-childhood education and project team experts.

The BAfEP students wrote their final-year dissertations in parallel to the development of the kits, as the

Figure 6 – From left to right: Goldenrod, Himalayan balsam, Japanese knotweed and roots/rhizome and stems of goldenrod & Japanese knotweed on 21 June 2023; Japanese knotweed and goldenrod, showing roots and leaves © Renate Mayer

Figure 7 – Planting invasive neophytes, and monitoring their growth. Left: Japanese knotweed; right: Himalayan balsam. © *Renate Mayer*

young children tried out the experiments and games in school: *"Discovering climate change with children aged 3–6 with the help of planning, observations and experiments in the Styrian Eisenwurzen region"* (Jug et al. 2023), and *"What's blooming? Research using plant newcomers from all over the world with children aged 3–6"* (Gindel et al. 2023).

Intercultural communication

Neophytes are alien plants, and in this context we tend to talk about *fighting*, *uprooting*, etc. For pupils with a migration background, however, it was important that we should use different, non-violent, language. Throughout the project, therefore, the schoolteachers and the BAfEP students were accompanied by an expert in intercultural communication. Several workshops were run, one of which was held for the BAfEP students to support them in writing their dissertations.

Observing invasive alien species in Middle and Primary schools

One of the projects developed by the primary and secondary school pupils, mentored by AREC experts, was to observe the growth and phenology of plants, grown in large plastic containers, in controlled locations at participating schools. In the summer semester of 2022, pupils at three schools in the district of Liezen observed and documented the invasive species *Solidago candensis / Solidago gigantea, Fallopia japonica* and *Impatiens glandulifera*. Plastic containers (3 per school class) were filled with loose garden soil, or partly filled with compact soil containing phyllite (local soil from the valley floor [southern bank] of the river Enns). Rhizomes of both Japanese knotweed and goldenrod, and small seedlings of Himalayan balsam were planted in separate containers, which were placed in the school grounds. The weather conditions were also recorded.

The planters at the Middle School in Irdning-Donnersbachtal were placed in the north-western area of the grounds, between the school building and a hedge. There was no overhanging roof. The plants put on very little growth (Figure 6) because of heavy rainfall and the resulting waterlogging of the containers (which were without drainage holes), as well as because of the very compact nature of the local soil.

The containers at the Middle School in Stainach-Pürgg, which were placed at the foot of one of the school's west-facing walls, overhung by the roof, showed the strongest growth. The Japanese knotweed and the Himalayan balsam developed well, while the goldenrod was stunted (Figure 7).

The plants in the containers on the south wall of the primary school Aigen im Ennstal showed different growth behaviour. The pupils' experiments showed that weather conditions (water, light, temperature) had a strong influence on the length and thickness of the plants' growth.

Field research by primary schools

At the end of the school year, neophyte eradication measures were carried out in the local municipalities in cooperation with the educational institutions (Figure 8).

The educational programme included information about the plants, including their growth behaviour and impact on the landscape and society. Pupils from the primary schools in particular were highly motivated in researching the plant species, developed interesting ideas for their containment and took part in the removal measures with great enthusiasm. It was also important to compare how the growth phases of the individual neophytes correlated with those of native reference plants (e. g. black elderberry).

Super-powers of plants observed by the Altenmarkt primary school students, St Gallen

The children at Altenmarkt, St Gallen observed Himalayan balsam both in nature and in the classroom. In nature, the same spot was visited with the teachers every three weeks from May 2022 to the end of the school year, and the growth phase was recorded on an observation sheet. Black elderberry was used as a comparative plant for phenological phases. The Al-

Figure 8 – Neophyte management with pupils at the primary school in Aigen. © *Renate Mayer*

tenmarkt primary school participants wondered what superpowers the neophytes might have – *What can the giant hogweed do?* – and designed posters, which were presented to the other students.

Lessons learned and conclusions

The C.S.I. PhenoBiota project focuses on *Talente Regional*, paving the way for pupils to pursue STEM education and careers later on. The pupils had the opportunity to formulate research questions, exchange ideas with experts, gain insights into various professions and branches of education, and thus learnt about the connections between plants, the environment and climate. It was refreshing for everyone to see the enthusiasm with which students from different school levels worked together with the scientists and developed their own research questions. Especially noteworthy was the good collaboration between school students and researchers. However, this requires motivated teachers as well as interested students. We were able to find both in our project, during which it became clear that pupils' thirst for research depends on their school level. Primary school pupils were more inquisitive and more open-minded in their approach. In contrast, the student teachers from BAfEP worked both independently and together with their tutors on their kits and dissertations.

A conference marking the end of the project was attended by pupils, headmasters, teachers, experts and decision-makers (in particular the district governor), as well as by representatives of agriculture, the media and research. The pupils from the various school levels presented their activities in demonstrations, video messages and other formats. The great importance of the topic and the relevance of initiatives was emphasized by all participants.

The greatest challenge was undoubtedly to recruit a broad mass of people interested in citizen science (interested parents, siblings of pupils and so on) for the observation of the phenological phases of invasive neophytes. We used local radio stations, press releases, social media posts, letters to parents and webinars to encourage people interested in nature to take part. The team sees the first three years of the project as development work and hopes to obtain a denser dataset via the Nature Calendar app. Success will only be measurable in a few years' time. A dense set of phenological data is needed if we are going to be in a position to make a contribution to neophyte management. The project partners disseminated the topic of phenology and neophytes successfully in the region, anchoring it sustainably through the educational activities discussed here.

However, there is still a large gap in the field of the phenology of invasive plants. More data is needed for us to draw conclusions about the growth phases of individual species. The first phenological data collected on neophytes are just the start of long-term observations of the plants. Our methods will certainly need to be refined in the future.

The aim of neophyte monitoring is to tie their development in to that of native flora – our *reference* species. In the future, effective management of invasive plants could be carried out at the appropriate developmental stage without having to observe them in situ, because we know, for example, that the native species Black elderberry puts out its first leaves approximately 14 days before the neophyte Japanese knotweed, and the cotyledons of Himalayan balsam begin to emerge at the same time as the first shoots of Japanese knotweed. The identification of such windows will allow the timely planning and implementation of control measures, *adjusted in response to the actual weather-related development of the plants in any particular year*. It is important to continue collecting data on non-native invasive plants in order to find more cost-effective and time-saving methods of control. These plants cause high economic costs and displace native species that are needed for the resilience of nature, especially in face of climate change.

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Nature calender App download

Most important results of the project

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