PROCEEDINGS OF SCIENCE

Denmark explores: engaging citizen scientists nation-wide to monitor phenology

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To broaden the diversity of participants and obtain the full benefit of citizen science in terms of engaging and including all levels of society, new means of targeting citizens are being explored. We present the recent nature campaign *Our Nature* and its success in attracting and engaging citizens of all ages and experience levels. *Our Nature* resulted from a unique partnership between natural history museums, the Danish Nature Agency, Outdoor Council, and the Danish Broadcasting Corporation and proved as being an excellent model in reaching 75% of the population and reaching individuals that had no prior connection to nature. *Our Nature* served as an excellent platform from which to engage citizens in a new country-wide phenology monitoring research project—*Denmark Explores.* In the first two years of the project, over 2,000 phenology observations were submitted from across the entire country. The data collected has already resulted in the publication of one research article, demonstrating that citizen science data, even if collected over short time periods, can be highly valuable to study the effects of climate change on biodiversity. Extensive evaluation of the *Our Nature* campaign revealed that there is currently a huge untapped source of citizens willing to explore nature and partake in citizen science activities.

Engaging Citizen Science Conference 2022 (CitSci2022)
25-26 April 2022
Aarhus University, Denmark

[*]Speaker

PoS(CitSci2022)071

1. Introduction

A Partnership for Nature: The year 2020 was set as the year for nature in the Denmark-wide campaign *Our Nature* ("Vores Natur"). *Our Nature* sprang out of a partnership between natural history museums, the Danish Nature Agency, Outdoor Council, and the Danish Broadcasting Corporation (Danmarks Radio). Two objectives were set for *Our Nature*: 1) to create new partnerships across green organisations, and 2) to get people without prior connection to nature to experience it.

***Engaging a Nation*:** *Our Nature* was launched in March 2020 and, despite this coinciding with the onset of the COVID-19 pandemic and Denmark's first lockdown, the success of the project cannot be disputed. Activities and events were created across the entire country to attract citizens to experience the benefits of nature—both out in nature and on-screen—regardless of their prior connection to nature. A total of 2,661 activities across Denmark were held in 92 of the 99 municipalities. Three-quarters of the public heard about *Our Nature* and of these 70% reported to have gained a greater interest in getting out into nature.

***Denmark Explores – Citizens register seasonal events in nature*:** Amongst the experiences offered to citizens through the *Our Nature* campaign was a new citizen science initiative called *Denmark Explores* ("Danmark Udforsker") where citizens were called on to observe and monitor phenology—the timing of seasonal biological events—assisting researchers in understanding how climate change and climatic differences across the country affect biodiversity. A simple web-based app was developed for citizens to register their findings and view other registrations.

Phenology has emerged in recent decades as a key metric to measure how species respond to climate change [1,2]. Natural events such as the arrival of songbirds or the blooming of spring ephemeral wildflowers are known to be amongst the most affected by warming global temperatures and earlier onset of spring [3,4]. Unfortunately, because phenology data sets are rare and often limited in geographic and temporal scope the effects of climate change on phenological events remains poorly investigated [2,5]. So why not engage a nation in monitoring phenology?

2. Results

In 2020, more than 1,100 phenology registrations were made for *Denmark Explores* by 440 citizen scientists for over 50 different phenology events. The most popular events included the first-time dandelion heads were seen in seed, the first-time beech trees were confirmed to leaf-out, and the first sighting or call from the common cuckoo. The project was continued in 2021 bringing the total observations to 1,978, and both years of data resulted in an excellent distribution of observations across Denmark (**Figure 1**).

The data collected by citizen scientists captured geographic variation unlike any other phenology data collected in Denmark to date. For example, citizens' observations for the sign of the first beech tree leaf-out were well distributed across Denmark (**Figure 2A**). Danes have been observing leaf-out dates for beech trees for decades; however, only the very first confirmed leaf-out is recorded. For the first time, we now have data that spans the entire country

and captures the full range of geographic and climatic variation. From two years of observations, we can already detect differences in early spring temperature, registered across the country, influence the timing of beech tree leaf-out (**Figure 2B**).

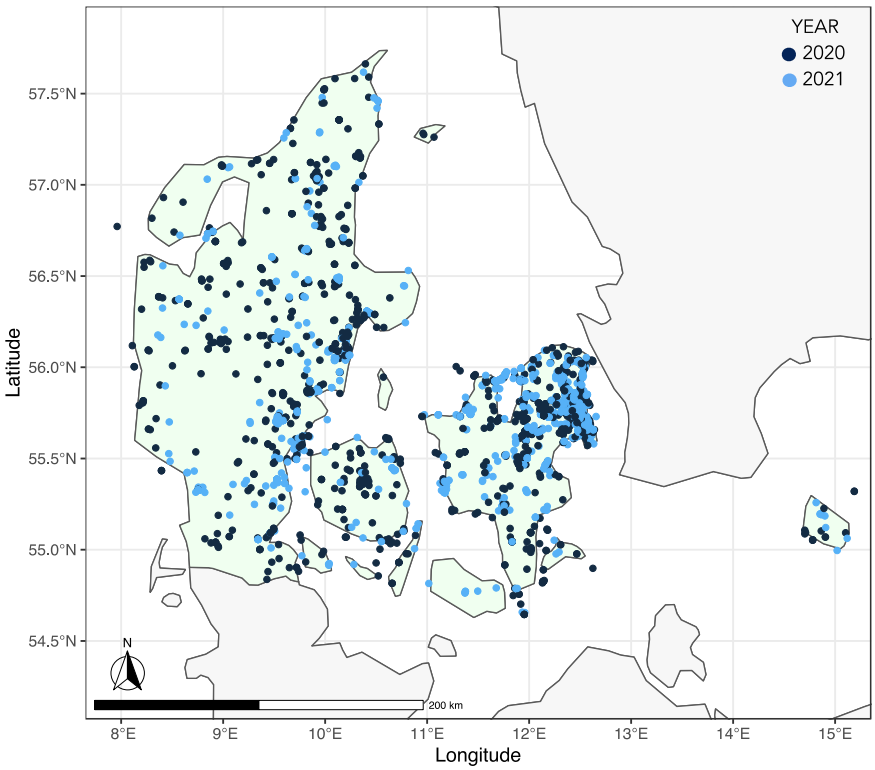

Figure 1: Distribution of phenological observations from Denmark Explores in 2020 (n=1100) and 2021 (n=878).

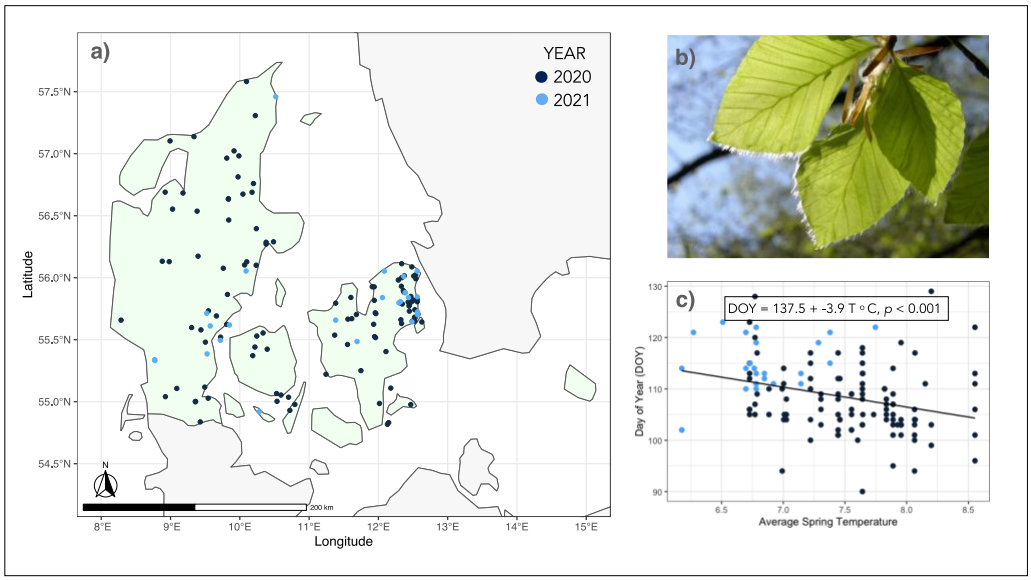

Figure 2: a) Citizen Science observations of beech tree leaf-out across Denmark; **b)** photo of beech leaves (© Biopix); **c)** linear regression of the average spring temperature in Denmark on the day of year observed for first leaf-out. Regression line shown in black.

The data from Denmark Explores' first year has been used in a research article comparing herbarium and citizen science phenology datasets for their relative sensitivities in detecting the response of flowering to climate over time and space in Denmark [6]. We explored spatial and temporal relationships between temperature and flowering time and tested whether citizen science phenological datasets with wide geographical coverage can be a surrogate to phenological data spanning long time periods. It was found that if observations are numerous enough and cover the extent of Denmark's climatic regions, even a single year of data can be used to detect response of flowering time to spring temperature, and combing citizen science and long-term data derived from natural history collections provide an even more effective method for detecting climatic effects on phenology.

3. Synthesis

Citizen science projects often include the goal of empowering and educating citizens in topics such as nature conservation. However, citizen science participants are often characterized as amateur naturalists or individuals already activated in biodiversity conservation issues. Extensive evaluation of the *Our Nature* campaign revealed that there is currently a huge untapped source of citizens willing to explore nature and partake in citizen science activities.

The *Our Nature* campaign helped to broaden the diversity of participants in *Denmark Explores,* thereby obtaining the full benefit of citizen science in terms of engaging and including all levels of society. The partnerships built as part of the *Our Nature* project will be further fostered to promote this citizen science initiative and further develop *Denmark Explores* in the years to come.

Citizen science initiatives such as *Denmark Explores* have huge potential to expand the data available for climate change studies and improve knowledge of species-specific responses, even though these studies have a short time span [6]. Promoting *Denmark Explores* using the power of the Our Nature campaign allowed us to reach and engage citizens that are not the usual participants in citizen science biodiversity monitoring projects and helped reach our goal to get new people out to experience local nature.

Acknowledgements

The Our Nature and Denmark Explores projects were made possible by generous funding support from the 15 Juni Fond, Aage V. Jensens NaturFond, and Nordea Fond. Learn more about Denmark Explores the Spring ("Danmark Udforsker Foråret") at **www.danmarkudforsker.dk**.

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