SNP genotyping and environmental niche modelling using herbarium specimens of the northern dragonhead, *Dracocephalum ruyschiana* (Lamiaceae)

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Maintenance of genetic diversity is a central aim of species conservation, given its positive effect on species survival and adaptation in a changing environment. Data from different time points is key for understanding how populations behave under various conditions. In this regard, herbarium specimens are an invaluable source of information from the past. Still, utilizing archived biological material for studying trends of genetic diversity offers challenges such as DNA degradation and the lack of standardized, cost- and time efficient methods.

We have studied change in genetic structure and diversity through time in the northern dragonhead *(Dracocephalum ruyschiana,* Lamiaceae; Fig.1; Nygaard et al. 2022), a plant species that has experienced a drastic population decline and habitat loss in Europe. A microfluidic array consisting of 96 SNP markers selected from modern Norwegian populations (Kleven et al. 2019) was applied on 130 herbarium specimens. The selected specimens were collected from year 1820 to 2008, mainly from Norway but also from Sweden, Russia, Belarus, Ukraine, Switzerland, and France. The obtained genotype data were compared with data from 355 modern Norwegian samples generated using the same SNP array (Kyrkjeeide et al. 2022) to assess genetic structure and diversity across space and through time. Finally, we used 4092 records of georeferenced herbarium specimens and species observations to model the species' environmental niche and potential distribution in Norway. We included three environmental variables: mean summer temperature, mean annual precipitation, and precipitation seasonality (coefficient of variance of monthly precipitation). The final spatial prediction of Northern dragonhead resulted from averaging across seven different distribution models, all with five replicated runs (Nygaard et al. 2022).

The SNP array successfully genotyped all included herbarium specimens. The call rate varied from 96–100 % and 95–100 % for historical and modern samples, respectively, indicating that the proportion of successfully genotyped loci was little affected by the age of the specimens. The genotyping success may, however, be dependent on inherent biology among species, and preservation techniques and conditions.

Within Norway we were able to compare genetic diversity and structure between historical and modern samples of norther dragonhead, thereby adding a temporal monitoring aspect. Our results displayed similar genetic structure and diversity

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Biodiversity conservation, Genetic diversity, Microfluidic SNP array, Retrospective monitoring, Spatiotemporal stasis

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Fig. 1. Northern dragonhead, *Dracocephalum ruyschiana*. CC BY Tiril Myhre Pedersen, Artsdatabanken.no.

across space in Norway and limited genetic changes through time. Across Europe, the Norwegian population separated as a distinct genetic cluster. Given the genetic divergence between regional populations within Norway, and more so from populations outside of Norway, continued protection of Northern dragonhead remains relevant. The captured genetic diversity across Europe was, however, significantly and negatively correlated with distance from Norway. This negative correlation is likely due to ascertainment bias of the SNP array, which should be solvable with appropriate design adjustments. As such, this standardized, modern monitoring method also seems promising for retrospective monitoring using herbarium specimens.

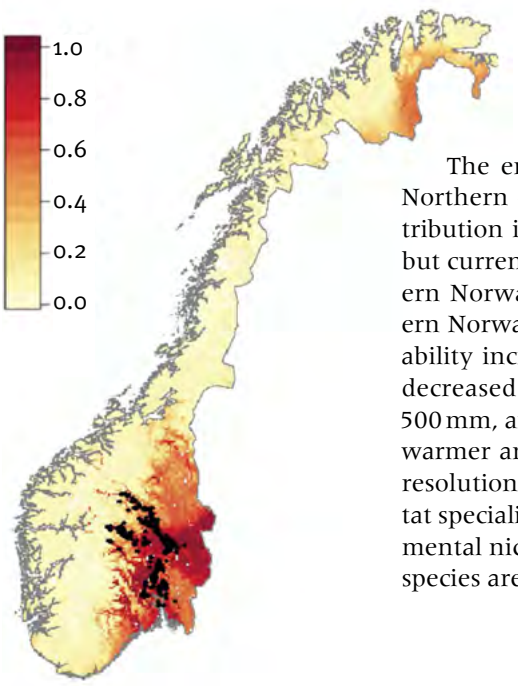

Fig. 2. Spatial prediction of Northern dragonhead across Norway based on 4092 occurrence records, displayed as black points. Darker red color represents higher modeled niche suitability, and yellow color represents lower suitability.

The environmental niche modelling results suggest that Northern dragonhead has not fully achieved its potential distribution in Norway. Our results revealed potentially suitable but currently unoccupied niche space in central and northeastern Norway, as well as the inner parts of the fjords in western Norway (Fig. 2). According to our results, the climate suitability increased with mean summer temperature > 10°C and decreased when mean annual precipitation increased over 500 mm, anchoring the distribution of Northern dragonhead to warmer and drier regions. Despite limitations in climatic data resolution and considering that northern dragonhead is a habitat specialist, geographical representations of modeled environmental niches can still provide valuable information on where species are not likely to thrive.

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