



Swedish Crop Wild Relatives: towards a national strategy for *in situ* conservation of CWR

Jens Weibull ^{*,a} and Jade Phillips ^b

^a Swedish Board of Agriculture, SE-230 53, Alnarp, Sweden

^b School of Biosciences, University of Birmingham, Edgbaston, B15 2TT, Birmingham, UK

Abstract: In 2015, the Nordic countries (Sweden, Denmark, Finland, Norway and Iceland) initiated a project to help strengthen the efforts of conservation and use of crop wild relatives (CWR) across the region. Policy recommendations that were put forward included creating national strategies for each Nordic country and adopting and implementing complementary *in situ* conservation as the main approach for safeguarding CWR across the region. The present work explores in greater detail the situation for Sweden. Taxa rich areas and areas where potential data bias may be prevalent are located. An eco-geographic map is constructed to help determine how genetic diversity may be portioned across the country within populations of taxa. An *in situ* complementarity analysis accounting for taxa richness, eco-geographic richness and the protected area network in the country is also presented. Possible reasons for diverging results, as compared to the regional analysis, are discussed. The document serves as a starting point for further in-depth research on CWR distribution, conservation and use within Sweden.

Keywords: crop wild relatives, protected areas, ELC-analysis, Sweden

Citation: Weibull, J., Phillips, J. (2020). Swedish Crop Wild Relatives: towards a national strategy for *in situ* conservation of CWR. *Genetic Resources* 1 (1), 17-23. doi: [10.46265/genresj.2020.1.17-23](https://doi.org/10.46265/genresj.2020.1.17-23).

© Copyright 2020 the Authors.

This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Already back in 1979, the Nordic countries established what was probably the first regional genebank for the *ex situ* conservation of seeds of agricultural and horticultural plants. For many years, the (then) Nordic Gene Bank stood as an example of foresight regarding long-term conservation and use of plant genetic resources. Although occasional attempts were made to raise the issue of *in situ* conservation at the Nordic level (Blixt *et al.*, 1992), concrete work and activities never took off. Decades later, during the period 2015-2019, the Nordic countries (Sweden, Denmark, Finland, Norway and Iceland) joined forces and initiated two subsequent projects to help strengthen the efforts of conservation and use of crop wild relatives (CWR) across the region. Whereas the first project focused on reviewing and

revising previously published compilations of CWR taxa, and their prioritisation, the second one put more emphasis on developing guidelines. As a result, policy recommendations were put forward that included creating national strategies for each Nordic country, and adopting and implementing complementary *in situ* conservation as the main approach for safeguarding CWR across the region (Weibull *et al.*, 2016).

A central activity of the second project (Wild genetic resources – a tool to meet climate change) included an Eco-geographic Land Characterisation (ELC) analysis. Using eco-geographic diversity as a proxy for genetic diversity is a well-known technique (Parra-Quijano *et al.*, 2012) that has been employed for certain Nordic countries (Phillips *et al.*, 2016), but not previously for the entire Nordic region. Based on more than 971,000 occurrence records, and using ELC and so-called Complementary Conservation Analysis (Rebelo, 1994), Fitzgerald *et al.* (2019) were able to single out those protected areas (PAs) in the region harbouring the largest number of priority CWR. The number one complementary PA site was in Aalborg Commune in

*Corresponding author: Jens Weibull
(Jens.Weibull@jordbruksverket.se)

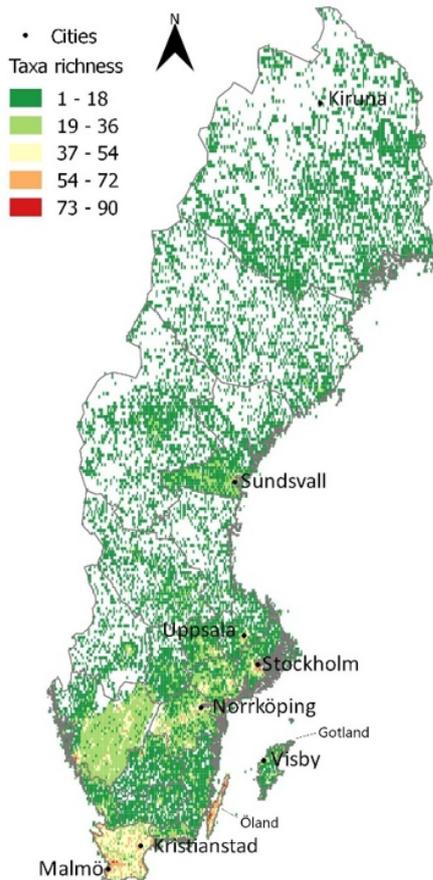


Figure 1. The taxon richness of priority CWR across Sweden.

Denmark covering 88 target species in two ELC zones. The surprising fact that the first complementary PA site in Sweden firstly appeared as number 13 on the Nordic list and, secondly, was represented by a PA site in the mountain region close to Norway called for an extended analysis.

The work presented below takes a specific Swedish perspective and aims to answer the following questions: (1) How common are Nordic priority taxa in Sweden and how are they distributed over the country? (2) Will a targeted ELC analysis provide an eco-geographic map of higher resolution? (3) How well does taxon diversity and genetic proxy diversity coincide with the existing distribution of PAs? (4) Will we be able to pinpoint specific sites in Sweden where active *in situ* conservation of CWR may begin? We began by locating taxa rich areas and areas where potential data bias might be prevalent and continued by constructing an eco-geographic map to help determine how genetic diversity could be portioned across the country within populations of taxa. An *in situ* complementarity analysis accounting for taxa richness, eco-geographic richness and the PA network in the country was also performed. We see this work as a starting point for further in-depth research on CWR distribution, conservation and use within Sweden.

Methods and Results

Priority CWR in Sweden

In line with the Nordic level approach, priority CWR for Sweden were identified from the regional list of priority CWR (Fitzgerald *et al*, 2018). Therefore, the Swedish priority list contained 121 naturalized and indigenous taxa. Data on the taxa distribution was gathered from Swedish LifeWatch (<https://www.analysportal.se/>) and limited to data gathered between the years 1990-2018. Distribution data was combined for duplicated taxa from the initial list, e.g. *Barbarea vulgaris* and *Barbarea vulgaris* var. *vulgaris*, to limit duplication of results. In total, 102 priority taxa were used for Sweden that altogether consisted of 617 320 occurrence points. Number of occurrences per taxon ranged from 29 646 (*Vaccinium myrtillus* L.) to less than 100 (*Brassica nigra* (L.) W.D.J. Koch, *Lactuca quercina* L., *Rubus allegheniensis* Porter, *Trifolium alpestre* L. and *Trifolium pratense* var. *maritimum* Zabel). The taxa with fewer than 100 occurrences should be considered for further research and surveying efforts to confirm their distribution and levels of vulnerability.

Analysis of species richness and bias

To identify areas of species richness and data bias the TomBio Tool in QGIS software QGIS (2020) was utilised. Analysis of taxon richness (Figure 1) shows clearly that the south and east of Sweden, including the island Öland in the Baltic Sea, are the areas containing the highest number of different taxa.

The areas in the north of Sweden appear to be the least rich in priority taxa, however these areas also have the lowest number of recorded taxon occurrences (Figure 2).

This is to be expected since these areas cover two thirds of the country and to a very high degree overlap with the three boreal zones (southern, middle and northern) and the alpine zone\$, i.e. bio-geographical zones characterised by lower winter temperatures, shorter vegetation periods and lower habitat diversity. An exception to this general picture includes the coastal area along the Bothnian Gulf all the way up to the Swedish-Finnish border at Haparanda which is characterised by slightly more favourable climate and, thus, growing conditions.

Although there are more CWR occurrence data in the areas in the southern third of the country, especially around large cities, this pattern is not completely reflected within the taxon richness map. Historically, occurrence data tend to be collected on an ad hoc, non-systematic, basis and closer to cities due to ease of access (Chapman, 2005). The pattern of CWR occurrences in Figure 2 also mirrors the demography of Sweden¹ and, as an additional effect, the location of main educational centres (universities, colleges). Therefore, any potential bias this may cause in the

¹ See e.g. <https://sedac.ciesin.columbia.edu/data/set/grump-v1-population-density/maps/2?facets=region:europe>

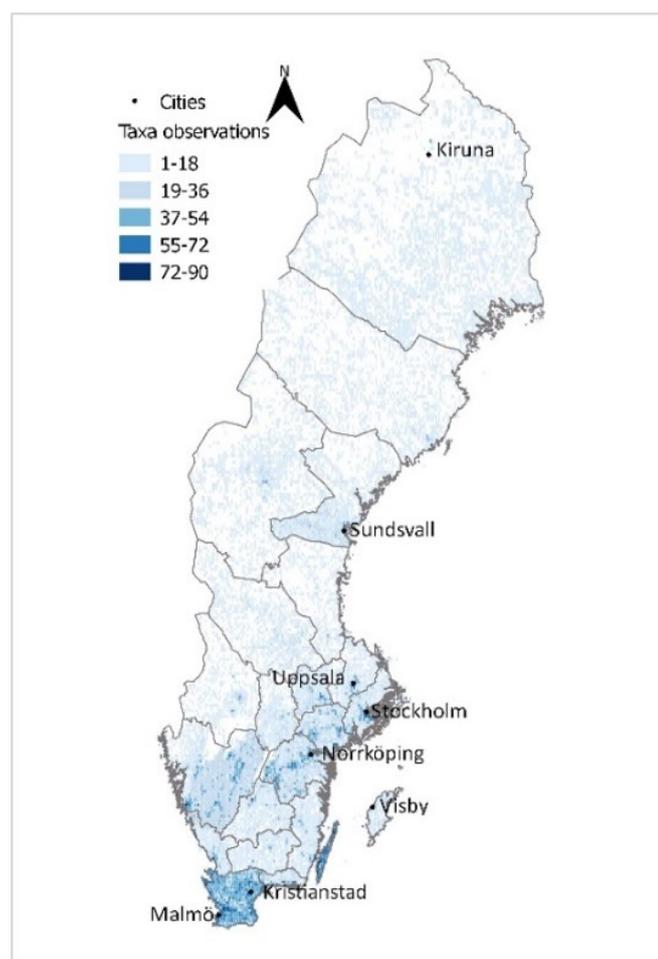


Figure 2. The number of occurrences of the priority taxa across Sweden.

results should be acknowledged. This also shows a need to further survey those areas showing gaps in occurrence data to limit any biased results in future work. More surveying in the northern and western boreal and alpine regions of Sweden will help to fill in gaps in our knowledge on CWR distribution and increase the accuracy of predictive analyses using Geographic Information Systems.

Developing an Eco-geographic Land Characterization map

Eco-geographic maps take account of environmental variables that combined create unique adaptive scenarios for plant species. A combination of geophysical, edaphic and bioclimatic variables that have the greatest influence on abiotic adaptation of the species are then used to create an Eco-geographic Land Characterization map (ELC map). The resulting ELC zones can be used as a substitute to represent genetic diversity (Parra-Quijano *et al.*, 2012). Thus, if populations are conserved both *in situ* and *ex situ* across their eco-geographic range (i.e. within all their ELC zones), this will ensure that the full range of genetic diversity is protected.

The eco-geographic map for Sweden was created with the CAPFITOGEN software (Parra-Quijano *et al.*, 2016) using the following environmental variables: isothermality (average temperature range/annual temperature

range), elevation, aspect of slope, ‘northness’, ‘eastness’, topsoil organic carbon content, topsoil pH, and topsoil depth². Figure 3 (left) shows the ELC map comprising 25 ELC zones at a resolution of 1 km² cells. The large-scale pattern of ELC zones agrees reasonably well with the dominating land use classes of the country (Figure 3, right), which indicates that the ELC analysis does provide a useful estimate of vegetation characteristics and habitat diversity.

Complementarity analysis

The complementarity analysis is an important concept for ensuring efficient conservation of resources. As described by Rebelo and Siegfried (1990), the analysis uses an iterative selection approach in which the cell, or PA, with the highest taxon number is selected first. These taxa are subsequently excluded from the analysis and the location with the next highest number of different taxa is selected, upon which the procedure is being repeated until all taxa are conserved across a network of reserve locations. The complementarity analyses were created using CAPFITOGEN software (Parra-Quijano *et al.*, 2016). Our complementarity analysis of the priority CWR within the network of PAs identified eight complementary areas that altogether conserve 101 (99%) of the priority taxa (Figure 4).

The PA complementary network ensures that the largest number of different taxa are protected. In Sweden, the majority of suitable PAs, as regards priority CWR, were found to be located in coastal zones of Southern Sweden. The number one priority reserve, Kristianstad Vattenrike – a UNESCO-MAB Biosphere Reserve – is the number one priority location as it contains the highest number of unique taxa (85 of 102 taxa; Table 1). With the addition of the two following PAs – Stora Alvaret, a Birds Directive PA, and Tjälmejaure-Laisdalen, a Ramsar Site in Lapland – 93% of the unique taxa on the Swedish priority list are covered.

Using the eco-geographic map, we can determine which ELC zones are within each of the complementary PAs. This will help to determine how well represented the eco-geographic zones are within the proposed network, which may then help to determine the range of genetic diversity among populations that is captured within the network. In our study, 13 of the 24 ELC categories, or 54 %, are represented within the proposed PA complementary network.

Grid cell complementarity analysis

The grid cell complementary network takes account of the number of taxa across the whole of Sweden (not

² The dataset used in this publication was made available by the Swedish Forest Soil Inventory, with responsibility in the Department of Soil and Environment, SLU. The authors are solely responsible for the interpretation of data. url: <https://www.slu.se/miljoanalys/statistik-och-miljodata/miljodata/webbtjanster-miljoanalys/markinfo/markinfo/kartor/> (accessed 2020-04-23)

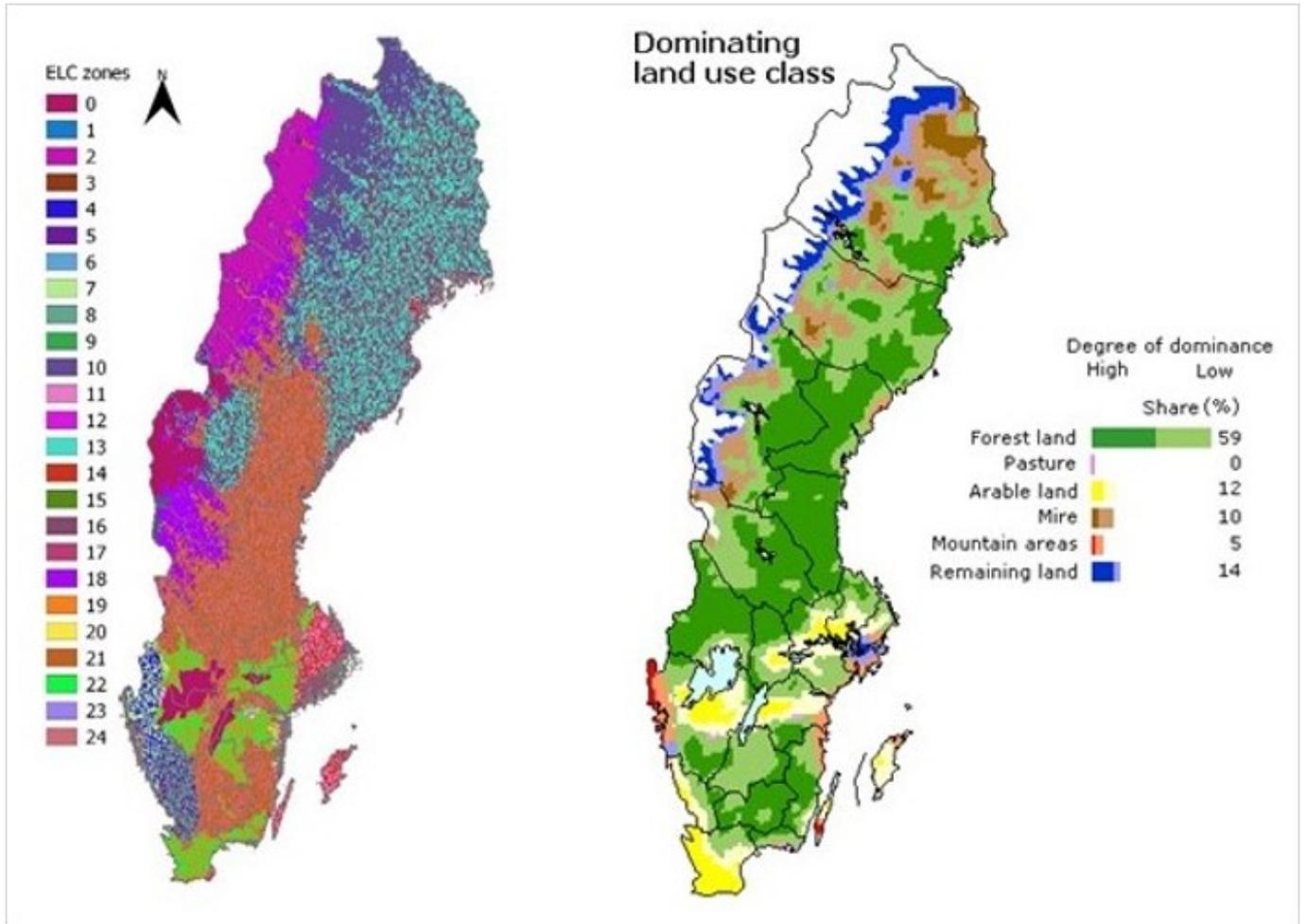


Figure 3. The Swedish Eco-geographic Land Characterization map at a 1 km² resolution (left), and a schematic view of dominating land use classes in Sweden (right).

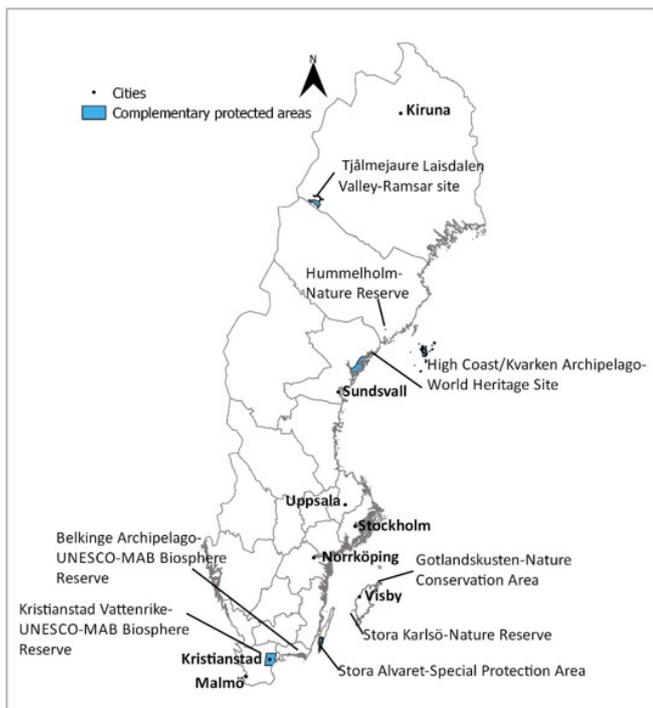


Figure 4. The eight protected areas needed to conserve 101 priority CWR taxa.

just within PAs). The grid cell complementarity analysis revealed that to protect the same 101 priority taxa, altogether 10 (5 km²) locations are required (Figure 5). The majority of these are found in the south of Sweden along the coast and in the east of Sweden around Stockholm and Uppsala. While the number one grid cell, located near Stockholm, includes 76 different taxa the three top cells in Sweden protects close to 90 % of the priority taxa.

Overlaying both the PA complementary and grid cell complementary networks shows where locations overlap. This serves to help identify which locations to investigate further for potential *in situ* protection of CWR. In Sweden, it would be most efficient to focus initial *in situ* conservation efforts within those PAs that are located in the south such as Kristianstad Vattenrike, Stora Alvaret and Gotlandskusten. These PAs are also close to priority grid cell complementary locations.

Discussion

The rationale for carrying out this extended analysis was the fact that Sweden came out rather poorly in the study by Fitzgerald *et al* (2019). The southern

Table 1. Protected Area Complementarity Analysis. The 'number of taxa' is the total number of different taxa in the protected area. The 'number of additional taxa' is the number of unique taxa within that protected area (i.e. these taxa are not found in any of the previous protected areas).

Protected area	Designation	Number of taxa	Number of additional taxa	Priority	Cumulative %
Kristianstad Vattenrike	UNESCO-MAB Biosphere Reserve	85	85	1	84,2%
Stora Alvaret	Special Protection Area (Birds Directive)	71	6	2	90,1%
Tjålmejaure-Laisdalen	Ramsar Site, Wetland of International Importance	19	3	3	93,1%
Blekinge arkipelag	UNESCO-MAB Biosphere Reserve	77	2	4	95,0%
Gotlandskusten	Nature Conservation Area	66	2	5	97,0%
Stora Karlsö	Nature Reserve	43	1	6	98,0%
Höga kusten/ Kvarkens arkipelag	World Heritage Site	42	1	7	99,0%
Hummelholm	Nature Reserve	14	1	8	100,0%
	Total		101		

parts of the country, known to have been repeatedly inventoried since the mid-1800s and whose flora is very well mapped (e.g. Weimarck and Weimarck, 1985; Sterner, 1986; Genberg, 1992; Rydberg and Wannorp, 2001; Fröberg, 2006; Edqvist and Karlsson, 2007; Johansson *et al*, 2016; Johansson and Petersson, 2016), were surprisingly underrepresented as compared to the findings of other countries. When comparing our results with those of Fitzgerald *et al* (2019), we observe some immediate differences. Whereas both studies have three sites in common – Höga kusten (World Heritage Site), Gotlandskusten (Nature Conservation Area) and Hummelholm (Nature Reserve) – all other locations differ. In particular, we note that our two top locations – Kristianstad Vattenrike (UNESCO-MAB Biosphere Reserve) and Stora Alvaret (Special Protection Area - Birds Directive) – were not even included in the joint Nordic analysis.

There may be several reasons for this, but we suggest that a main cause could be the background data upon which the analysis is based. The datasets provided by the UN Environment Programme World Conservation Monitoring Centre (WCMC-UNEP) contain the entire spectrum of PAs, ranging from areas with 'strict' protection such as national parks, nature reserves, habitat protection areas, and wildlife and plant sanctuaries via so-called natural monuments (e.g. individual and unique trees) to World Heritage Sites and UNESCO-MAB Biosphere Reserves. In our analysis for Sweden, we deselected sites that could give bias to our analysis including, e.g., those representing

different habitats or purposes of protection such as HELCOM areas (Baltic Sea PAs), OSPAR (Marine PAs), and RAMSAR sites. In addition, natural monuments that commonly represent individual objects were also removed. In our view, these measures provide a better subset of PAs on which to draw conclusions.

Another aspect relates to the analysis of occurrence data. While Fitzgerald *et al* (2019) used 971,633 data points in their analysis of the entire Nordic region, we based our results on 617,320 data points from Sweden only (time frame 1990-2018). We argue that data robustness is absolutely essential to be able to draw proper conclusions from analyses at a higher level of resolution. The risk of bias when using large data sets of distribution records, such as those available from the Global Biodiversity Information Facility (GBIF), has been shown earlier (Beck *et al*, 2014). We certainly acknowledge the value of the broad Nordic analysis, but, as shown in this study, care should be taken when drawing generic conclusions to describe the situation 'on ground'.

The large differences in number of ELC zones found in the regional vs. the national analysis, respectively, may at first seem surprising. What could the reason(s) be that we observed 25 ELC zones while Fitzgerald *et al* (2019) only described 8-10 in their analysis? The fact that an analysis covering the entire Nordic Region *per se* implies a much larger geographical scale also means that the ELC variables used should try to capture the landscape over a wider range of eco-geographic 'niches'. Given that the diversity of zones vary greatly from Northern

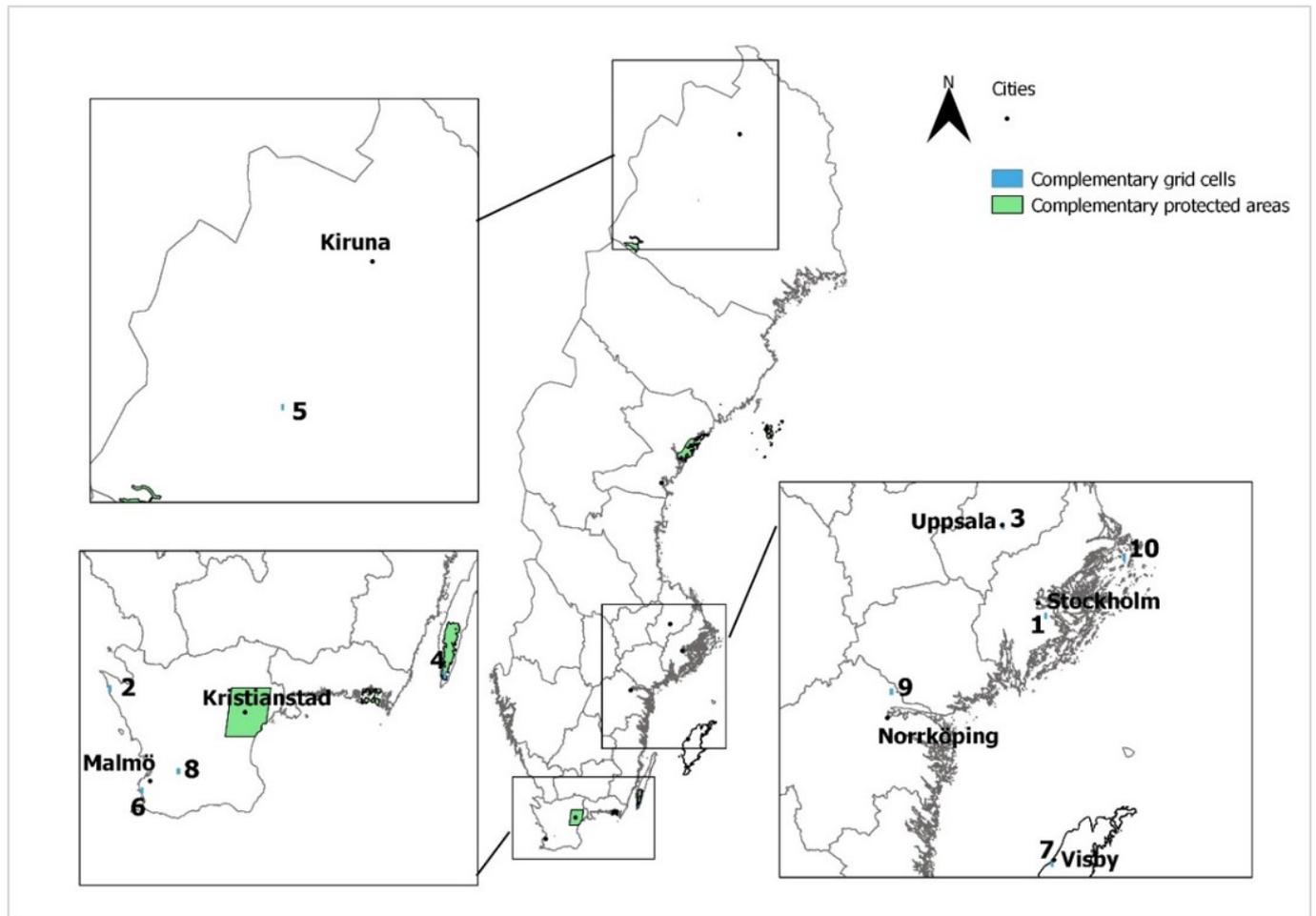


Figure 5. The protected area and grid cell complementary networks. The large black numbers on the map represent the priority grid cell locations and the blue areas are the complementary protected areas.

Iceland to South Denmark and Eastern Finland, it should be expected that Sweden – not sharing all the same niches – would only be described by a share of all the zones. While the regional analysis is important from the point of developing joint approaches, this observation highlights the importance of also looking at domestic eco-geographic variability as a basis for selecting key PAs for CWR *in situ* conservation. Finally, the observation by Fitzgerald *et al* (2019) that 58 % of the identified important PAs for CWR conservation were situated in Norway raises the notion of possible data bias, as well as the procedure by which sites for CWR diversity are being identified. Firstly, while the total number of PAs in Norway is only 27 % and 50 % of that of Finland and Sweden, respectively, the vast majority (80.6 %) are classified as Strict Nature Reserves (IUCN PA category Ia). Finland, on the other hand, is characterised by a large proportion of category VI PAs (89.5 %). The fact that such areas are “[...] often established to protect particular species or habitats rather than the specific ecological aims of category Ia” (IUCN, 2020) points to the possibility that CWR diversity is higher in category Ia areas and it is for this reason that Norway takes a lead in the Nordic regional comparison. Secondly, the finding that well-known and diversity-rich sites in several of

the countries (e.g. Åland archipelago in Finland and Öland in Sweden) did not appear in the regional analysis calls for a careful evaluation of how data points and variables are used in the analysis. Fitzgerald (personal communication) noted a general problem with coastline taxa that, “depending on the coordinate points and country map boundaries [...] in some cases end[ed] up in the sea and therefore [had to] be removed from the analysis.” From a national perspective, where priorities need to be made, it is essential that those sites comprising the widest taxon and eco-geographic diversity are selected.

Conclusion

Our extended analysis of occurrence data of Swedish CWR has helped us to identify three major PAs where *in situ* conservation could take off. Initial steps are now being taken to proceed with concrete measures within the UNESCO-MAB Biosphere Reserve Kristianstad Vattenrike. Further work is needed, however, to ensure the long-term robustness of any CWR conservation strategy within Sweden. Such planned activities are framed within the established Nordic CWR network that is led by NordGen, and include:

- An *ex situ* conservation analysis to identify any gaps in the collection of material for conservation and use outside of PAs, on the assumption that seed management of CWR is technically and economically feasible;
- A predicted distribution analysis of how populations may move under the current climate and to help identify collecting and data bias gaps across the country; and
- A climate change analysis to determine if, how and when taxa may shift their distributions as the climate changes. This will be vital in determining which *in situ* PAs will be the most effective in the long-term conservation of Swedish CWR.

Finally, from a European perspective, it would be worthwhile in the future to foster synergies with other genetic resource domains (e.g. forestry, animal) in terms of identifying conservation sites and needs. Such an approach may help to strengthen an *in situ* conservation network for CWR by adding “value” to proposed *in situ* sites.

Acknowledgements

Financial support from the Board of Agriculture, through the Swedish Programme for Diversity of Cultivated Plants (Pom), is gratefully acknowledged.

Author contributions

JP carried out most of the PA and ELC complementary data analysis during 2019, and JW re-edited the report into the present format.

Conflict of interest statement

The authors declare no conflicts of interest.

References

- Beck, J., Böller, M., Erhardt, A., and Schwanghart, W. (2014). Spatial bias in the GBIF database and its effect on modeling species' geographic distributions. *Ecological Informatics* 19, 10–15. url: <https://doi.org/10.1016/j.ecoinf.2013.11.002>.
- Blixt, S., Fredriksson, P., and Holm, C. (1992). *In situ* conservation. Nordic Gene Bank (internal report).
- Chapman, A. D. (2005). Principles of Data Quality. url: <https://doi.org/10.15468/doc.jrgg-a190>.
- Edqvist, M. and Karlsson, T. (2007). Smålands flora [The flora of Småland] (SBF-förlaget), 880p, (in Swedish).
- Fitzgerald, H., GBIF-Norway-Helpdesk, and Palmé, A. (2018). Nordic Crop Wild Relative (CWR) Checklist. Version 1.11. url: <https://doi.org/10.15468/itkype>. accessed date: 2018-10-03
- Fitzgerald, H., Palmé, A., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Rasmussen, M., Thorbjörnsson, H., and Weibull, J. (2019). A regional approach to Nordic crop wild relative *in situ* conservation planning. *Plant Genetic Resources: Characterization and Utilization* 17(2), 196–207. url: <https://doi.org/10.1017/s147926211800059x>.
- Fröberg, L. (2006). Blekinges flora [Flora of Blekinge], ed. and others (SBF-förlaget), 856p, (in Swedish).
- Genberg, E. (1992). Östergötlands flora [Flora of Östergötland] (Berlings), 2nd edition, 215p, (in Swedish).
- IUCN (2020). Protected area categories. url: <https://www.iucn.org/theme/protected-areas/about/protected-areas-categories>. accessed date: 2020-05-14
- Johansson, B. G. and Petersson, J. (2016). Gotlands flora, Band 1 [The flora of Gotland, Vol. 1] (SBF-förlaget), 253p, (in Swedish).
- Johansson, B. G., Petersson, J., and Ingmansson, G. (2016). Gotlands flora, Band 2 [The flora of Gotland, Vol. 2] (SBF-förlaget), 712p, (in Swedish).
- Parra-Quijano, M., Iriando, J. M., and Torres, E. (2012). Ecogeographical land characterization maps as a tool for assessing plant adaptation and their implications in agrobiodiversity studies. *Genetic Resources and Crop Evolution* 59(2), 205–217. url: <https://doi.org/10.1007/s10722-011-9676-7>.
- Parra-Quijano, M., Torres-Lamas, E., Iriando-Alegría, J. M., López, F., and Molina-Pertíñez, A. (2016). Tools CAPFITOGEN - Program to Strengthen Capabilities in National Plant Genetic Resources Programs in Latin America, Version 2.0. FAO. url: <https://drive.google.com/file/d/0B7JxjDasV98BejNRMXJHJQy1hYlk/edit>.
- Phillips, J., Asdal, Å., Brehm, J. M., Rasmussen, M., and Maxted, N. (2016). *In situ* and *ex situ* diversity analysis of priority crop wild relatives in Norway. *Diversity and Distributions* 22(11), 1112–1126. url: <https://doi.org/10.1111/ddi.12470>.
- QGIS (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. url: <https://qgis.org/en/site/>. accessed date: 2020-08-10
- Rebello, A. G. (1994). Iterative selection procedures: centres of endemism and optimal placement of reserves. In *Botanical Diversity in Southern Africa*, ed. Huntley, B. J., (Pretoria, South Africa: National Botanical Institute), 231–257.
- Rebello, A. G. and Siegfried, W. R. (1990). Protection of Fynbos vegetation: Ideal and real-world options. *Biological Conservation* 54(1), 15–31. url: [https://doi.org/10.1016/0006-3207\(90\)90039-r](https://doi.org/10.1016/0006-3207(90)90039-r).
- Rydberg, H. and Wanntorp, H. E. (2001). Sörmlands flora [Flora of Sörmland] 776p, (in Swedish).
- Sterner, R. (1986). Ölands kärllväxtflora [The vascular flora of Öland], ed. and others (Forskningsrådets förlagstjänst), 400p, (in Swedish).
- Weibull, J., Fitzgerald, H., Lund, B., Palmé, A., and Þorbjörnsson, H. (2016). Conservation and sustainable use of crop wild relatives: a Nordic initiative. *Sveriges Utsädesförenings Tidskrift* 2, 53–58. url: <http://www.sverigesutsadesforening.se/data/pdf/SUT2016-2.pdf>.
- Weimarck, H. and Weimarck, G. (1985). Atlas över Skånes flora [An atlas of the flora of Scania] (Stockholm) 640p, (in Swedish).