Ex situ conservation of threatened seashore plants – time out for populations hit by global change?

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Seashore meadows of the Bothnian Bay harbour several unrelated rare plant species with a disjunctive distribution in the Arctic and northern parts of the Baltic Sea (Fig. 1). This group of species was originally named by Fries (1865) as the *Primula sibirica* group according to the former Latin name of the Siberian primrose (now: *Primulan nutans* Georgi subsp. *finmarchica* (Jacq.) A. Löve & D. Löve var. *jokelae* L. Mäkinen & Y. Mäkinen). Originally Fries (1865) pointed out a dozen taxa sharing this kind of distribution. However, since then estimates of the number of species belonging to the group have varied from more than thirty species (Ericson & Wallentinus 1979) to six 'core' species (Eurola 1999).

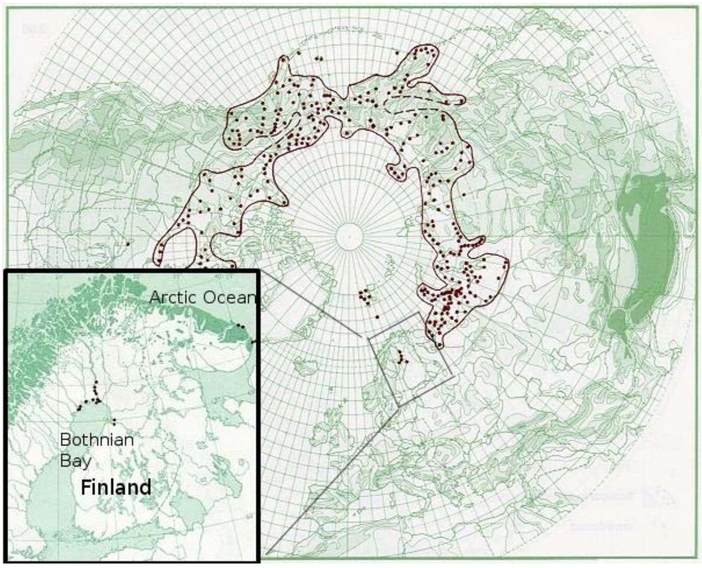

Figure 1. Distribution of the Arctic pendant grass in the Northern Hemisphere and Scandinavia as an example of disjunct distribution (maps courtesy of the Swedish Natural Museum).

Recent phylogeographic studies on the namesake of the group, Siberian Primrose, have shown that the disjunct distribution in Scandinavia was formed during the post-glacial period when the species was following the retreat of the ice sheet (Kreivi et al. unpublished). Hence the southern populations in the Bothnian Bay and the arctic populations all originate from the same glacial refugium. It is not known whether other species in the groups share the same phylogeographic history, but it is obvious that the Bothnian Bay populations of most *Primula sibirica* group species are to some extent genetically divergent from the arctic ones and many of them represent endemic subspecies or varieties. However, being predominantly Arctic species these Bothnian Bay populations represent the southernmost limit of species' distribution, and they are now facing a situation where there is no escape from the impact of global warming by spreading north.

The distribution of these species in the Bothnian Bay has considerably narrowed in the past decades as the number and size of extant populations has declined (Rautiainen 2006). Changes in traditional land-use, especially the cessation of cattle grazing and haymaking as well as eutrophication due to scattered loading from arable lands have often been pointed out as causes of the demise of these species (Laamanen et al. 2005). However, the former explanation is not always applicable to shore plants that occupy the hydrolitoral zone that has never been grazed and mowed, and hence, other factors may have a key role. For example, our recent analyses on the population dynamics of one of such species, Arctic pendant grass (*Arctophila fulva* Trin. var. *pendulina* (Laest.) Holmb.), have indicated that increase in the intensity of winter and summer disturbances (e.g. ice scouring and storms causing floods on flat shores) may markedly contribute to the population dynamics of these species (Rautiainen 2006, Rautiainen et al. 2007). These kinds of changes in climatic variation imposed by global warming are already taking place both locally and globally (Jylhä et al. 2004, Emanuel 2005). Hence, the predicted impact of global warming to climatic variation in the environment may be of primary concern in planning sustainable management for threatened plant populations.

Many seashore species also rely predominantly on clonal growth in occupation of the virgin soil, which is reflected both in their population dynamics (Rautiainen et al. 2004, Rautiainen 2006) as well as the genetic structure of subpopulations (Kreivi et al. 2005). The capability of clonal populations to maintain their genotypic diversity is regarded lower than sexual populations (Balloux et al. 2003) and prolonged exclusive clonal growth can eventually lead to a monoclonal population even on the basis of genetic drift (Honnay & Bossuyt 2005). Moreover, the lack of recombination hinders adaptation to the changing environment and makes the population more vulnerable to a selective sweep (e.g Silvertown & Charlesworth 2001), which effectively narrows the genotypic diversity.

The microspatial structure and surprisingly large genetic variation in the Arctic pendant grass subpopulations indicates sexual founding events in the past (Kreivi et al. 2007). Genetic variation in the Siberian primrose, which is both sexual and clonal, is currently studied. Interestingly, there are two different incompatibility types (so called *pin* and *thrum* types) in Siberian primrose, which may in large populations effectively prevent self-pollination but in small isolated populations lead to a stochastic Allee effect when the frequency of one of the incompatibility types reaches one (see e.g. Endels et al. 2002).

In general, knowledge on spatial genetic structure and the type of dynamics is crucial when feasible and cost effective policies both for management and monitoring are planned. A special problem with seashore species is often unpredictable impact of sea forces. For example, the dynamics and reproduction of the Arctic pendant grass is largely governed by disturbance caused by wintry ice scouring and autumn floods (Rautiainen et al. 2004, 2007; Rautiainen 2006) and demographic data from many years seems to point out that occasional spring flooding caused by south western storms, that were rare in the past, may effectively hinder sexual reproduction in Siberian primrose (Björnström et al. 2007). One main prediction in climate models (e.g. ACIA 2005) is the loss of winter ice cover in the Bothnian Bay in the future, which also means the loss of ice scouring exposing soil for secondary colonisation. Also the rising sea level will counteract the geological isostatic land uplift (Johansson et al. 2001) that creates virgin land for plants to colonise. In fact, the mean sea level in the Bothnian Bay has in recent years been c. 5 cm higher than predicted on the basis of the linear historical trend (Johansson et al. 2004), which means a considerable reduction in the rate of new land formation. The third study species, Common glasswort (*Salicornia europaea* L.), that does not strictly belong to the *Primula sibirica* group, is an annual non-clonal species confined to chloridic saline patches of seashore meadows. The occurrence of these kind of patches is negatively dependent on the rainfall depth in early summer (Siira 1985). Unfortunately, one of the predicted changes in climate of the area is the increase in rainfall depth.

These predictions and climatic data, readily available in public databases, can be used as guidelines in planning concrete management measures tested together with *ex situ* conservation. The former includes transplanting within populations to promote population growth and between populations to mitigate threats caused by narrow genetic basis. *Ex situ* conservation in the botanic garden may have a supportive role in the procedure as a stage where the genetic diversity and the amount of plant material available is secured prior to re-introduction to the habitat. Strengthening populations with external or original genetic material has turned out to be a feasible but often overlooked tool in avoiding inbreeding depression and enhancing the viability of small populations (e.g. Madsen 1999, Heschel & Paige 1995). However, the use of transplants must be based on strict guidelines in order to avoid potential pitfalls of breaking locally adapted genotypes or causing selective sweep and therefore ex situ conservation and gene banking are of crucial importance. There is a dearth of information on how to protect genetic diversity of small plant populations in more or less ephemeral habitats. In this project models of habitat change in seashore meadows and its predicted consequences to long-term population dynamics and genetic structure are used to connect climatic information to the basic level of biodiversity. This information is further used in assessment of the feasibility of different in situ and ex situ conservation methods.

In practice, common glasswort can readily be micropropagated either from somatic tissue or from seeds *in vitro* on recently developed medium (Fig. 2) based on brackish water. Arctic pendant grass that does not produce viable seeds (Rautiainen et al. 2004),has also turned out to be very difficult to grow in a garden and, hence, *in vitro* cloning method is being developed. Pure cultures can be routinely maintained in the micropropagation laboratory of the Botanical Gardens of the University of Oulu. *Ex situ* conservation of Siberian primrose has turned out to be the easiest task: the species can be grown in the gardens on an artificial seashore (Fig. 3). Seeds of Common glasswort and Siberian primrose are also dried to low moisture content and stored in deep freeze and subsequently subjected to a series of viability tests.

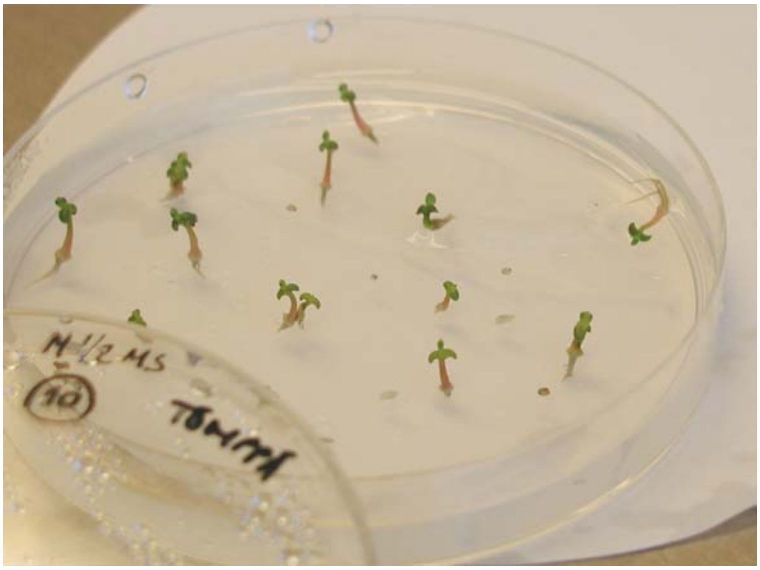

Figure 2. Seedlings of the Common glasswort on Agar medium.

Figure 3. Siberian primrose in the Botanical Gardens, University of Oulu (photo courtesy of Lassi Kalleinen).

References

ACIA 2005. *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge.

Balloux, F., Lehmann, F. and de Meeûs, T. 2003. The population genetics of clonal and partially clonal diploids. *Genetics 164*: 1635-1644.

Björnström, T., Strengell, H., Tuomi, J., Siikamäki, P. & Hyvärinen, M. 2007. *Comparative demography of Primula nutans var. jokelae on seashore meadows invaded by* Salix shrubs (manuscript).

Fries, Th.M. 1865. *En botanisk resa i Finnmarken*. Botaniska Notiser 1865:42-58.

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature 436*: 686-688.

Endels, P., Jacquemyn, H., Brys, R. & Hermy, M. 2002. Changes in *pin-thrum* ratios in populations of the heterostyle *Primula vulgaris* Huds: Does imbalance affect populations persistence? *Flora 197*:326-331.

Eurola, S. 1999. Kasvipeitteemme alueellisuus. *Oulanka Reports 22.*

Ericson, L. & Wallentinus, H-G. 1979. Sea-shore vegetation around the Gulf of Bothnia. *Wahlenbergia 5:* 1-142.

Heschel, M. & Paige, K. 1995. Inbreeding depression, environmental stress, and population size variation in scarlet gilia (*Ipomopsis aggregata*). *Conservation Biology 9*: 126-133.

Honnay, O. & Bossuyt, B. 2005. Prolonged clonal growth: escape route or route to extinction? *Oikos 108*: 427-435.

Johansson, M., Boman, H., Kahma, K.K. & Launiainen, J. 2001. Trends in sea level variability in the Baltic Sea. *Boreal Environmental Research 6*: 159-179.

Johansson, M.M., Kahma, K.K., Boman, H. & Launiainen, J. 2004. Scenarios for the sea level on the Finnish coast. *Boreal Environment Research 9*: 153-166.

Jylhä, K., Tuomenvirta, H. & Ruosteenoja, K. 2004. Climate change projections for Finland during the 21st century. *Boreal Environment Research 9:* 127-152.

Kreivi, M., Huttunen, S. & Aspi, J. 2006: Isolation and characterization of polymorphic microsatellite markers from *Primula nutans* (Primulaceae). *Molecular Ecology Notes 6*:334-336.

Kreivi, M., Rautiainen, P., Aspi, J., & Hyvärinen, M. 2005: Genetic structure and gene flow in an endangered perennial grass, *Arctophila fulva* var. *pendulina*. Conservation Genetics 6:683-696.

Kreivi, M., Rautiainen, P., Aspi, J., Hyvärinen, M. 2007. *Spatial genetic structure and the roles of sexual and clonal reproduction in an endangered grass,* Arctophila fulva var. pendulina (manuscript).

Laamanen, M., Fleming, V., Kauppila, P. & Olsonen, R. 2005. Helcom Eutro. The Bothnian Bay basin report. Helsinki Commission. Development of tools for a thematic eutrophication assessment. http://sea.helcom.fi/ dps/docs/ documents/ Monitoring_and_Assessment_Group (MONAS)/EUTRO_202,_202005/3-1.pdf

Madsen, T., Shine, R., Olsson, M. & Witzell, H. 1999. Restoration, of an inbred adder population. *Nature 402*: 34-35.

Rautiainen, P. 2006. Population biology of the *Primula sibirica* group species inhabiting frequently disturbed seashore meadows: implications for management. *Acta Universitatis Ouluensis* A453.

Rautiainen P., Aikio, S. & Hyvärinen, M. 2007. A spatially explicit model on the patch dynamics of *Arctophila fulva* var. *pendulina*. Submitted to Ecological Modelling.

Rautiainen, P., Laine, A.-L., Aikio, S., Aspi, J., Siira, J. & Hyvärinen, M. 2004: Seashore disturbance and management of the clonal *Arctophila fulva*: Modelling patch dynamics. *Applied Vegetation Science 7:* 221-228.

Rogers, S.O. & Bendich, A.J. 1985. Extraction of DNA from milligram amounts of fresh herbarium and mummified plant tissues. Plant Molecular Biology 5: 69-76.

Siira, J. 1985: Saline soils and their vegetation on the coast of the Gulf of Bothnia, Finland. Ann. Bot. Fennici 22: 63-90.

Silvertown, J. & Charlesworth, D. 2001. *Introduction to Plant Population Biology. 4th edn*. Blackwell Science, Oxon.