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A review of research on *Pinus cembra* in Austria, with special reference to the conservation of genetic resources

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Abstract

Swiss stone pine (*Pinus cembra*) is restricted to the uppermost subalpine forest belt in the Central Alps, and the Austrian high mountain National Parks are important for this species. Climate change threatens this habitat, as an upslope migration "escape" is often not possible. However, this pattern seems to have recurred throughout the post-glacial history.

We would like to present results from a literature and data survey regarding past and present distribution of the species. A striking feature is that many places mentioned in older literature (ca. 1900) as rare outposts often do not seem to have any more trees. Seed harvest data from the past few decades will be reviewed, as well as the establishment of genetic conservation stands and seed orchards. The role of the Austrian National Parks for conserving *Pinus cembra* will be discussed.

Keywords

Swiss stone pine, *Pinus cembra*, conservation, genetics, National Parks, Austria

Introduction

Swiss stone pine has found admirers throughout the recent centuries (e.g. NEVOLE 1914, FIGALA 1928, FUSCHLBERGER 1928), but has also experienced severe set-backs in these environments. The species occupies the upper zone of mountain forests. Geographically, it is restricted to the inner, continental Alps; "outposts" occur in the Carpathians. The upper limit is given by climatic factors. Additionally, high pastures (*Almen*) have depressed the vertical distribution of of *P. cembra*. Apparently, the species had a much wider distribution during the glacial periods, and must have been in contact with its current sister species, the Siberian pine (*Pinus sibirica*). It has thus retreated to The Alps. The *Hohe Tauern* and *Gesäuse* National Parks (plus Biosphere Park *Nockberge*) thus form important refuges at present. Will they be able to maintain this role in the face of climate change? What measures could prevent such a scenario, and what can protected areas contribute to that goal? We will try and summarize current genetic knowledge on this species, in order to guide management and conservation efforts in this critical phase.

Methods

The past and current distribution of *P. cembra* in Austria was assessed on the basis of a literature survey; the Austrian Forest Inventory; databases of gene conservation and natural forest reserves at the Federal Research Centre for Forest Research (BFW); and our own excursions. During visits, the number of trees at a site was estimated, and the presence of young trees was recorded. Sources for genetic information were also drawn from the literature.

Results

The current distribution of *P. cembra* in Austria comprises much of the Central Alps, which are characterised by a more continental climate, from the Vorarlberg to Styria. It is rarer north of the Lower Inn, Salzach and Enns rivers. The North-Eastern limits are *Totes Gebirge* and *Gesäuse* (Fig. 1). The easternmost stands in the Central Alps are in the *Seethaler* and *Seckauer Alpen*. An isolated outpost is *Petzen* mountain in Southern Carinthia. At a visit in autumn 2012, the number of trees present there was estimated to between 30 and 50. In all this distribution area, the tree species is scattered and fragmented.

The Austrian Forest Inventory lists 15 000 ha of stone pine production forests, two thirds of which are forests with protective functions, all in the elevation class of above 1200 m asl. The Austrian Forest Inventory does not cover, however, typical *P. cembra* stands when they are above the timber line. Information was also gathered from stone pine stands present in gene conservation and natural forest reserves. There are approximately 20 entries in a BFW database. All these stands are well within the main "core" distribution area of the species.

When this actual distribution pattern is compared to reports collected more than 100 years ago (NEVOLE 1914), a number of questions arise. Many "outposts" mentioned by NEVOLE (1914) were communicated to him by correspondents (*'Gewährsmänner'*). Many of the locations are on the outer border of the distribution area, for example *Gamsstein* near Palfau. It may be due to an introduction (JANCHEN & NEUMAYER 1942) and has disappeared. Although direct human intervention by cutting and planting blurs the picture, an in-depth comparison may give a clue as to minimum viable population sizes. For example, NEVOLE (1914) reported of a mysterious decline of stone pine in the *Sabathy* area near Judenburg; today, this is a vigorously expanding population, but only few very old trees are present. Given the discussion in FUSCHLBERGER (1928), FIGALA (1928) and PAMPERL (1929) regarding the usefulness or harmfulness of nutcracker birds (*Nucifraga caryocatactes*), it would also be important to know whether people in former times and in certain areas actively promoted or suppressed this bird. Nowadays it is undisputed that the bird and the tree species are symbionts.

Figure 1: The northeastern-most stand of *Pinus cembra* in Austria: *Wolfbauern-Hochalm*, National Park *Gesäuse* (copyright: B. Heinze).

Genetic research was started in the late 1950ies by Kurt Holzer with the selection of phenotypically superior trees for seed production (HOLZER 1958, 1960, 1961, 1969, 1970, 1974, 1989). A collection of grafts of these trees still exists near Vienna (*"Plantage Tullnerbach"*). The last formal report is by FEUERSINGER (1992). His main conclusions are that given the irregular flowering and seed production, a high number of selected trees is necessary for such a plantation. Graftings from trees from continuous stands below the timber line show better growth. Around the timber line, growth is slightly reduced. Trees retain their characteristics when grafted, even after at least 30 years. At the same time as the collection of the material for the grafts, seeds were collected. The resulting seedlings have been planted at *Tullnerbach* and in *Seethaler Alpen*. Both plantings still exist. For *Tullnerbach*, FEUERSINGER (1992) found out that height growth of offspring from trees immediately above the timber line is reduced. Trees originating from above the timber line retain on average one needle year less, and the needles are shorter, but denser. However, further above (approx. 200 m higher in elevation), growth of certain offspring cohorts is very good again. This may be due to the nutcracker's behavior of caching seeds collected in the lower continuous stone pine belts way above the timber line at places protected from too much snow cover (so that the caches are easy to find in winter). The resulting trees retain the genetic information for somewhat faster growth. In *Seethaler Alpen*, thinning has removed trees, but many still stand there. The area is next to a shooting range of the Austrian army and thus difficult to access. The plantation has developed into a quite uniform stand; there are no immediately apparent growth differences among the groups of trees.

At present, 101 forests have been registered for harvesting purposes (ZWERGER 2011). The majority of these are in the Inner Alps. Forty-seven individual commercial harvests of stone pine seeds have been registered between 1998 and 2011 (data provided by T. Franner, BFW). The sum of all harvested cones is 22 711 kg; single harvests are often approaching 1000 kg. The highest numbers of harvesting operations were in 2003 and 2009. Many of the registered seed harvest stands are never harvested. A large part of these seeds are sown in one particular nursery (Nikolsdorf, East Tyrol). A second seed orchard is officially registered as a harvest entity, owned by the Austrian Federal Forest Company ÖBf, consisting of 53 clones. There are no official records of seeds harvested between 1998 and 2011 (seed that is not commercialised by ÖBf does not show up). According to the manager, there is little demand for the seeds.

With the availability of genetic markers, researchers soon had an interest in this species. Probably the first was SZMIDT (1982) who found unusually high differentiation at isoenzyme gene markers. BERGMANN & HATTEMER (1995) did not find big differences in genetic variation between stone pine and *Pinus sylvestris*. LEWANDOWSKI & BURCZYK (2000) found some evidence for self-pollination, but not for inbreeding among related trees, in a stand in Northern Italy. STEFSKY (2001) analysed such markers in tree stands along different altitudes in *Kötschachtal* in Salzburg (National Park *Hohe Tauern*). The markers were less variable than in other tree species, and no meaningful differences were found among the stands or between old and young trees. BELOKON et al. (2005)

analysed a few population samples from The Alps and the Carpathians. They found slightly elevated differentiation among populations, higher genetic diversity in the Carpathians, and also some evidence for inbreeding.

GUGERLI et al. (2001) compared chloroplast and mitochondrial DNA between Alpine (*P. cembra*) and Sibirian (*P. sibirica*) stone pines; both species were very similar. A nearly complete *P. cembra* chloroplast genome sequence in GenBank (Accession No. FJ899574.1; tree from *Turracher Höhe*) is identical to a *P. sibirica* sequence (Accession No. FJ899558.1). GUGERLI et al. (2009) found a gradual decline of chloroplast DNA diversity from East to West in Switzerland. This fits to the evidence from fossil pollen that The Alps were re-colonized from the South-East. HÖHN et al. (2009) analysed samples from The Alps and the Carpathians and again found higher diversity in the East, despite the isolated character of the Carpathian populations.

MOSCA et al. (2012 a, b) analysed a number of nuclear genes in populations from Northern Italy. Some of the genes showed evidence for being affected by natural selection. There were some signs of geographical clustering of genetic variants. Some variants showed clines when compared to winter precipitation values at the sites where samples were collected.

Discussion

A striking feature of the distribution of *P. cembra* in the Austrian Alps is the abrupt eastern border. The stands in *Seethaler* and *Seckauer Alpen* or at *Turracher Höhe* are among the best, yet east of these, no more stone pine stands can be founds. Why do the trees not extend further east? The elevations of the mountains are lower towards the east, and at lower elevations, spruce (*Picea abies*) and larch (*Larix decidua*) are more competitive. However, this is no apparent clue as to why the trees cannot be found on the next mountain to the east of e.g. *Zirbitzkogel* in *Seethaler Alpen*. Similar thoughts apply to the *Hochschwab* massif, where on the other side of the *Schoberpass* road, very nice stone pine forests thrive in *Seckauer Alpen*.

Former reports often tell of over-exploitation (e.g. NEVOLE 1914). It is likely that at the edges of the distribution range, over-exploitation has led to a critically low density threshold. At present, the few trees at *Petzen* may serve as an example. We observed only very few young seedlings and trees. The next natural stands are tens of kilometres away.

A big obstacle in former times was excessive grazing on the high pastures (*Almen*, NEVOLE 1914). Young seedlings were often browsed by the animals. This resulted in very long regeneration times. Nowadays, grazing is not so much of a problem in general, as the pressure for use of the high pastures is gradually diminishing. This gives *P. cembra* a chance to re-colonise such sites. However, this may take very long, as the build-up of a strong humus layer is a prerequisite for growth. Furthermore, in some areas, high game pressure (tolerated for hunting reasons) is a problem.

Climate changes for The Alps are difficult to predict. While a general warming trend can be assumed continent-wide, it is as yet unclear what exact consequences this will have for subalpine and alpine ecosystems. Will there be more or less precipitation than today – will there be a shift in precipitation between summer rain and winter snow – will there be different temperature trends for summers and winters? Stone pine seems to be very tolerant of “continental” type climate extremes. However, the species’ competitors, larch, spruce and mountain pine, may become even more competitive. In general, an uphill “escape” is often not possible for orographic reasons. This applies especially to the Outer Alps. Under this aspect, the Central Alpine National Parks gain great importance for conservation of stone pine (Fig. 2). Given its overall slow regeneration process, there may be a critical phase in the near future.

Figure 2: A vital stand of P.cembra in National Park Hohe Tauern, where upwards migration seems possible: Stubachtal (copyright: B. Heinze).

At the same time, emphasis should be put on the genetic resources that may get lost in the Outer Alps. Active conservation measures may include the silvicultural removal of competing tree species, the support of any possible local upwards shift in stone pine distribution, and even re-planting. It would be problematic if management concepts prevent such active measures, e.g. in National Park *Gesäuse* where an outpost of stone pine still holds out. If all this is not feasible, the work by Holzer on grafting offers a possible way to conserve the genetic variants from such areas where the species may disappear soon. Such graftings could be a source of seed in the future. Plants from such seed can be translocated to areas where growing conditions remain good for the species.

The current stone pine stands in the northern parts of Vorarlberg, Tyrol and Salzburg, any remaining trees in southern Upper Austria, and the very vital populations in *Seethaler* and *Seckauer Alpen* should thus be constantly monitored for any signs of problems under climate change. Measures should be prepared for the case of such problems becoming apparent.

While the majority of stone pine forests are regenerated by natural means, it is evident that current seed harvest and planting practices do not promote genetic diversity. It would be desirable that seed be collected from all the registered seed stands. The laboratory genetic investigations already indicate lower levels of genetic variation, and a further reduction may cause problems of inbreeding in the future.

GUGERLI et al.'s (2009) observation of a gradual decrease in genetic richness from east to west also fits to BELOKON et al. (2005) and HÖHN et al. (2009). The surprisingly vigorous appearance of the easternmost populations in Styria (*Seethaler* and *Seckauer Alpen*) and the presence of the relict population at mount *Petzen* all point to a centre of genetic richness in Eastern Europe, and that The Alps were colonised from there in the form of a "retreat" during post-glacial warming. The easternmost populations in Austria should therefore receive special attention for conservation.

Conclusions

- An in-depth comparison of the number of sites, and trees at a site, reported previously and present today may give a clue as to a minimum viable population size.
- The altitudinal cline in genetically controlled growth should be taken into consideration for seed harvests.
- The stands on the easternmost edge of the distribution in Austria deserve special attention for conservation, as they are close to former glacial refugia and may still harbour high levels of genetic variation. Additionally, the northern- and southernmost stands should be actively monitored. Problems should be alleviated by silvicultural intervention.
- Decreasing pressure from grazing on high pastures (*Almen*) helps the species, but high game densities and slow regeneration mean that it will take very long for visible effects.
- There are orographic limitations for an upwards "escape" from climate change effects; the Central Alps National Parks are vital for the survival of the species.
- Techniques for the conservation of germplasm (grafting) should be utilized for emergency measures of saving material from extinction.
- Current seed harvest practices should be improved by expanding the range of stands harvested.

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