LIFE Platform Meeting
Reintroduction of species: a tool for the restoration of habitats
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Background document

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Nature in a worrying state

Due to human actions there has been a substantial and largely irreversible loss in the diversity of life on Earth, which is more rapid in the past 50 years than ever before (MEA 2005). As a densely populated and urbanized region, Europe especially suffers from this biodiversity crisis. Initial results from the first major health check of species and habitat types protected under the Habitat Directive show that at least 50% of vascular plants and 65% of habitat types of European conservation interest have an unfavourable conservation status (Commission of the European Communities, 2009). Habitat fragmentation and isolation in a hostile surrounding matrix probably plays a large role in these negative results. Between 1990 and 2000, 800 000 hectares of Europe's land cover has been converted to artificial surface (Sharrock & Jones 2009), showing that urbanisation is ongoing. Significant conservation efforts at the species, population and genetic levels across Europe are critically urgent. The European Red List identifies those species that are threatened with extinction at the regional level, in order that appropriate conservation action can be taken to improve their status. The first assessment of Europe's Vascular Plants shows that at least 467 species are threatened, representing 26% of the 1,826 species assessed (Bilz et al. 2011). The EU Biodiversity Strategy indicates that there is some political will, but the targets will not be met by 2020, showing how much work there is still to do.

Habitat and habitat

There are two meanings for the concept of habitat

"In the first instance, habitat is typically defined as an area containing the particular combination of resources and environmental conditions that are required by individuals of a given species or group of species to carry out life processes".../... "a second meaning has become more prevalent, whereby the term has been used to refer to areas of similar vegetation or land cover, as in the notion of "habitat types""; (Miller et Hobbs, 2007).

In the context of this platform meeting we adopt (mainly) the second meaning as this is consistent with the definition of habitats in the Directive where they are described by lists of plants and categorised on the basis of vegetation units (not all of the same hierarchic level) or as landscape features/land cover units (mud flats, screes, ...).

Furthermore it is not surprising that almost all the restoration of habitats in the context of the LIFE programme are focusing on the restoration of habitats in the sense of the Directive and therefore primarily on the restoration of the vegetation, including by reintroducing plant populations. Reintroductions of animal species aimed to the restoration of habitats are scarce, whilst the reintroduction of animal species for the sake of these species is a frequent action.

Nevertheless there are some examples of reintroduction of an animal species to restore habitats or habitat functionalities or even to support the reintroduction of another animal species.

Due to the filters to restoration, mainly the fragmentation of the landscape, the small size of several remnants of habitats and the frequent lack of soil seed bank, the reintroduction of species conceived for the sake of the restoration of habitats is in many cases the only solution. However, up to now, only few projects practice this method.

This is the motivation for the organisation of this very specific platform meeting focusing on the reintroduction of species conceived as a tool for the restoration of habitats.

Pure in situ conservation measures alone cannot reverse the trend, active restoration is also necessary

The best place to conserve plant biodiversity is in the wild, where a large number of species present in viable populations can persist in their natural habitats with their associated ecological interactions. However, degraded and altered habitats have become a major portion of the landscape mosaic, and for the foreseeable future accelerating demands for natural resources will continue to degrade habitat and push an increasing number of plants towards extinction. It has been therefore more and more recognized that simple conservation of habitat in their existing status (quality of the habitat versus the reference, area, distance from other plots of the same habitat) alone will not be enough to stop the ongoing trend of increased species extinctions (Guerrant et al 2004). Habitat restoration, i.e. the re-establishment of the physical conditions of the former natural habitat, is a well-founded conservation approach that may allow many plant populations to recover without the use of introduced propagules (Menges 2008). However, as many plants have transient seed banks, and many are dispersal-limited, spontaneous recovery of rare plant populations in restored sites may be constrained by the absence of naturally occurring propagules. In this case, the reintroduction of individual plants in the wild may be an essential measure to conserve threatened species (Maschinski & Haskins 2012) and restore habitats in a favourable conservation status. This includes, in extremely degraded locations, the reintroduction of almost complete communities.

A relatively new science with limited information available

Safeguarding endangered plant species from extinction by restoring depleted populations through reintroduction or reinforcement of new individuals or reintroduction of several species, in combination or not, with more or less heavy restoration measures of the abiotic environment (hydrological restoration, top soil removal, P-phytoextraction, ...) is a rather young discipline. The first scientific paper on plant reintroductions published in an international journal dates back over 37 years (Sainz-Ollero & Hernandez-Bermejo 1979) and the number of peer-reviewed publications has been increasing ever since (Figure 1), although at rather modest levels. The true importance of this conservation measure is however, much higher, since many failed attempts remain unpublished (Berg 1996) because negative findings are less publishable or regarded as uninteresting (Fahselt, 2007; Menges, 2008). Furthermore, case studies, best practices and experiences of reintroduction most often remain in the so called “grey literature”, often in the local language, i.e. in regional and more applied journal or booklets, or even in good technical or monitoring reports of LIFE projects lost somewhere in an archive storage, rather than being published in the international scientific literature (Hodder and Bullock, 1997; Fischer and Lindenmayer, 2000). A survey conducted among the conservation community combined with examination of the grey literature has shown that more than 600 reintroduction programs have been tried or are currently ongoing worldwide (Godefroid & Vanderborght 2011), and the last five years allow to add a few hundred trials more to this figure that currently exceeds 1000 reintroductions, which corresponds to previous estimates (Allen 1994; McKay et al. 2005). This shows that within 30 years species reintroductions have become an established component of the conservation measures around the globe. Even if in most of the cases the reintroduction or population reinforcement focuses more on the fate of a given species or few species, rather than on habitat restoration based on these reintroductions, knowledge and experience are progressively accumulated. This knowledge is useful for reintroductions with the restoration of habitats as target.

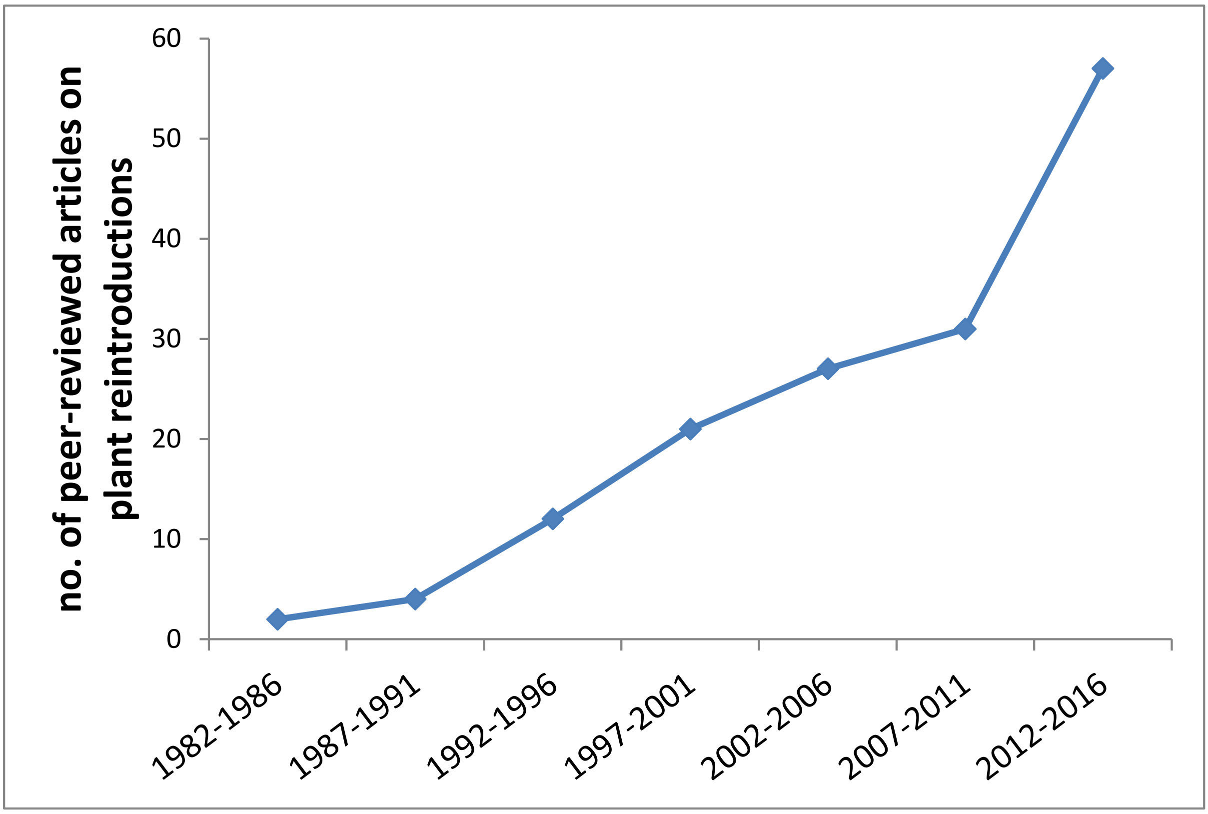

Figure 1. Number of peer-reviewed papers published on plant reintroductions in function of the time (5-yr periods), according to a search in Thomson's on-line Web of Science database, using the following query: (reintroduc* OR translocat* OR outplant* OR re-establish* OR transplant* OR reinforce*) AND plant

Reintroductions are supported and even recommended by international conventions

Reintroduction of native species has become increasingly important in conservation worldwide. Species reintroductions have been increasingly acknowledged in international treaties and legislation, including the Convention on Biological Diversity, the Bern Convention, the Global Strategy for Plant Conservation, the European Strategy for Plant Conservation, the Gran Canaria Declaration on Climate Change and Plant Conservation, and the European Habitats Directive 92/43/EEC. These agreements have increased public acceptance of reintroduction efforts as an integral component of biodiversity conservation. As a result, many reintroduction efforts have been initiated. In the last ten years, the European Union consistently supported reintroductions through specific projects approved under the LIFE programme (http://ec.europa.eu/environment/life/index.htm). There are currently dozens of LIFE projects involving plant reintroductions in e.g. Spain, Italy, Germany, France, Finland, Sweden, and protocols and factsheets have been developed to provide guidance for reintroduction measures (e.g. Basey et al 2015, IUCN/SSC 2013).

As already mentioned, the platform meeting “Reintroduction of species: a tool for the restoration of habitats” focuses on the restoration of habitats. However this does not diminish the importance of the mentioned international conventions providing a frame for the actions.

Reintroduction is not revegetation but restoration

Plant reintroductions should not be confused with large-scale revegetation programs. Many of these are implemented around the world for the greening of public spaces (e.g. parks, roadsides). These programs often involve private companies in charge of seeding large areas using seeds collected from plants grown in nurseries. In these programs, seed provenance is not always optimal and the industrialized multiplication of plants may result in genetically altered material compared to those of surrounding native populations (Byrne et al 2011). In contrast, reintroductions of endangered species are usually focussed on one or few species and target their conservation at the population or species level. They are usually conducted on a small scale and with carefully selected and prepared plant material (Godefroid et al 2016). According to their aims and methodology, plant reintroductions can be divided into reintroductions s.s., assisted migrations and reinforcements (Table 1).

Reintroduction is the release and management of a plant into an area in which it formerly occurred, but in which it is now extinct or believed to be extinct. In this sense, a reintroduction is opposed to the term “introduction” which is the release of a species outside of its historical range, commonly known under the term assisted migration or colonisation. Assisted migration, a so far rather conceptual measure refers to the concern that suitable habitats may shift outside the current natural species ranges due to ongoing climate change and that, in case of dispersal limitation, species’ migration into those new habitats has to be assisted to ensure their survival (Weeks et al. 2011, Maschinski & Haskins 2012). Reinforcement is an effort to increase population size and genetic diversity by adding individuals to an existing population. This is particularly important if the declining population is known to suffer from genetic impoverishment and inbreeding depression, so the addition of new genetic material can restore the genetic constitution of the population ([1]).

Table 1: Different types of reintroductions and their definitions.

Type	Location of target site	Plant material	Application
Reintroduction	within the species' historical range, but species not longer present	young or adult plants, or seeds	re-establish populations where the species has/have been gone extinct or is/are lacking for complete restoration of a given habitat in a favourable conservation status
Reinforcement	within the species' historical range and species present	young or adult plants, or seeds	Ensure persistence of populations that are strongly declining or about to go extinct
Assisted migration/colonisation	outside the species' historical range	young or adult plants, or seeds	Establish new populations of a species because the historical distribution area cannot provide suitable habitats anymore
Revegetation	Within the species' historical range, species might be present or not	cut fresh or dried hay, or seed mixtures	Establish vegetation cover on bare soil
Habitat restoration	Within the species' historical range, species might be present or not	cut fresh or dried hay, or seed mixtures	Re-establish the original vegetation in a degraded area

Plant reintroduction remains a risky business

The key question when dealing with plant reintroductions as a conservation measure is whether a planned reintroduction will be successful or not. The first problem in this respect is the definition of what "successful" actually means. Recruitment is considered the best measure of success (Pavlik 1996, Godefroid et al 2011), because it indicates that the population is self-sustaining through the development of successive generations. A recent study by Godefroid et al (2011) indicated that survival, flowering and fruiting rates of reintroduced plants are generally quite low (on average 52%, 19% and 16%, respectively). Information on recruitment is monitored for less than one third of the reintroduction attempts, and most case studies reported no or only sporadic recruitment. This suggests that many plant reintroductions may be unsuccessful over the long-term (Godefroid et al. 2011).

Given this rather unsatisfactory success rate, most efforts should be dedicated to the improvement of current protocols and the minimization of potential risks. Reintroduction failure can result from reasons predominantly intrinsic to the methodology or environmental factors as opposed to the biology of the introduced plants. This is probably also related to the absence or the

[1] It is important to note that the populations are often declining first because of the degradation of the habitat : loss of area, encroachment of semi-natural open habitats, eutrophication, unsatisfactory management measures,… these primary causes should be corrected before thinking to reintroduce or to reinforce populations.

impoverishment/modification of the soil ecosystem and the soil communities after agricultural intensification for example. In the literature, unsuitable restoration sites or management practices, desiccation and herbivory, and competition with non-native species are often cited as the major factors causing mortality in reintroduction experiments (Bottin et al. 2007, Godefroid et al 2011, Maschinski & Haskins 2012). Moreover, too low number of plants or propagules reintroduced in the wild is also frequently stated (Bottin et al 2007). Translocations involving species at risk are especially challenging because their ecological requirements are often narrower than common species. This illustrates that reintroduction is still a very delicate procedure and many things have to be considered already in the early planning phase to provide best chances for its success (Godefroid et al 2016). This emphasises the importance of the preparatory steps and decisional matrices leading to the decision to reintroduce or not, and how to implement the reintroduction if this option is decided.

What has to be considered when planning and conducting reintroductions?

Planning a species reintroduction carefully is the pivotal to the success of these conservation measures (Godefroid et al 2016). Here, we describe the most important points that have to be considered before starting a reintroduction and give the recommendations that the current state of knowledge allows. Table 2 summarises these points for a concise overview.

Profound understanding of the species' or group of species biology and ecology

Life history traits such as breeding system, seed production, viability and dispersal capacities, clonal propagation ability, patterns of genetic diversity and structure, and ecological niche requirements will determine the strategy and methodology of a reintroduction (Montalvo et al. 1997, Weeks et al 2011). For instance, self-incompatible insect-pollinated plant species will require larger and denser flowering translocated populations than self-compatible plant species, because of higher sensitivity to genetic drift (random changes in the frequency of alleles) and Allee effects (positive correlation between population density and individual fitness) (Reed 2005, Weeks et al 2011). Also, the life cycle of the species plays an important role for the reintroduction design. For instance, for long living species such as perennial plants or trees, the habitat choice becomes even more crucial, because, in contrast to short-lived species, their long regeneration time impedes rapid adaptive evolution to changing habitat conditions. This is of particular signification and importance for the restoration of forest habitats and especially in valley bottoms. Most importantly, the understanding of the species biology and ecology only makes it possible to match ecological demands of species at the target and the source sites and therefore is critical for the selection of both.

Careful choice of the target site

As stated previously, an unsuitable target site is one of the most cited reasons for the failure of reintroduction measures. Therefore, the target site has to be carefully evaluated so it matches the species abiotic and biotic demands. Best practice usually is to compare a potential target site to a site in the vicinity where the species still occurs in stable or growing populations. In general, environmental similarities (including the biotic environment) of source populations relative to the transplant site should be maximized when choosing source materials, and geographic distance may not always be a good measure for similarities (Breed et al 2013). If the choice is between several potential source sites, also the genetic status of the source populations has to be considered and the question arises which source population are most appropriate and whether material from different populations should be mixed (Weeks et al 2011).For habitat restoration on very degraded locations the approach includes other aspects such as: bibliography of ancient studies and floristic data; material in herbariums; diachronic analysis of old maps (Ferrari, Cassini,..); soil studies; ...

Careful choice of the source population(s)

The choice of the populations used as a seed source is a crucial decision for the success of reintroductions or reinforcements (Bottin et al. 2007). Indeed, population characteristics may influence plant fitness (e.g. plant size and growth) and the quality and quantity of produced seeds (Godefroid et al. 2016). Small and isolated populations may experience pollination failure, high genetic drift effects, and higher inbreeding levels, which may lead to reduced genetic diversity, between-population genetic divergence and inbreeding depression (Montalvo et al 1997). Survival of propagules from stable source populations can be twice the rate of those from declining populations (Godefroid et al. 2011). As declining populations have probably lost some rare alleles, their genetic diversity is likely to be lower than that of stable populations. Genetic diversity in the source gene pool may influence the colonising ability and persistence of a population (Montalvo et al 1997). Small populations may show reduced plant vigour and seed set and increased seed abortion rates (Van Rossum et al. 2006). Thus, large, stable or expanding populations are definitely better seed sources than small, isolated and declining ones.

Mixing source populations

The question, whether source populations should be mixed to increase genetic diversity and evolutionary potential depends on the species' biology and the status of the source and target populations, respectively. A clear argument against the mixing of source populations is, if the populations are strongly differentiated and expected to be locally adapted to their habitat. Then, mixing would risk disrupting those specific adaptations and outbreeding depression might be the consequence and compromise the success of the reintroduction. However, when the target or source populations are known to suffer from genetic erosion and inbreeding, mixing source populations can significantly improve the conditions of the genetically limited material (Weeks et al. 2011, Breed et al. 2013).

Capture genetic variability of source populations

When sampling plant material of an endangered species, it is often also about capturing the genetic variability of the populations. This becomes particularly important if the plant material is collected for long-term ex situ conservation, e.g. seed banking, because here, the genetic variability of endangered populations, or even a whole species, is intended to be secured. There has been much emphasis on guidelines for preserving plant genetic resources in the literature, but numbers and methods have been revised as knowledge and modelling possibilities have developed (Guerrant et al. 2004). The European Native Seed Conservation Network recommends the sampling of minimum 50 individuals per population and 5 populations per species (ENSCONET 2009). While the scientific debate on optimal sampling strategies is ongoing and strongly depends on the biology of the target species, a conservative approach, i.e. sampling more than the minimum number of individuals might be wise.

Transplantations should include a large number of individuals

Demographic and genetic theories both predict that the persistence time of a population increases with its initial size (Robert et al., 2007). Also, the fitness of a population has been shown to increase with its size (Reed 2005). Hence, the introduction of few individuals can lead to loss of genetic diversity due to inbreeding or post-introduction genetic drift. Consequently, smaller populations are generally less capable of adapting to novel environments, as the result of the loss of adaptive genetic variation (Montalvo et al 1997). Although there is danger in seeking universal levels for minimum viable population sizes (Robert et al., 2007), the number of reintroduced individuals is frequently lower than those suggested by various authors: 1000 (McGlaughlin et al. 2002) or 1500 to 2500 (Pavlik 1996). Thus, the more individuals transplanted the better, but feasibility clearly sets the limits for most reintroductions here (this is then a socio-economic filter to the restoration).

Use transplants rather than seeds!

Reintroductions of perennial species have a lower success rate when seeds rather than transplants are planted (Menges 2008, Godefroid et al. 2011). The disadvantage of using seeds to start new populations is that seeds will only rarely germinate and grow into new plants in the wild, and that the seedling stage is the most vulnerable part of the plant life cycle. Physically adverse environments, or strong seed predation may therefore limit the possible success with directly sown seeds. Moreover, seed production is often limited in endangered plants, making the production of seed numbers sufficiently large for seeding programs impossible. Hence, the use of seedlings or mature plants instead of seeds may often be favoured in order to establish sustainable populations (Godefroid et al 2011). This is of course mostly applicable when it is about reintroduction of one or a few species to complete the list of characteristic species of a given habitat and in the same time improve the conservation of these species (this is for example the case with some *Gentiana* sp or *Helichrysum arenarium* in the context of the project LIFE Herbages). When restoring grassland, the use of bulk collected seeds or spreading fresh hay is often a good first step. Later on, after 3 or 5 years for example, the list of species may then be completed by more sophisticated techniques such as the use of plants.

Cautious use of ex situ cultivated plant material

Performing reintroductions using seeds from plants cultivated ex situ, e.g. in a botanical garden, can sometimes be necessary when seed material from wild populations is not available or the species is extinct in the wild. However, since plants in ex situ collections are usually regenerated in small and isolated populations, they are likely affected by genetic erosion, inbreeding depression and deleterious mutations (Ensslin et al. 2015). Recent studies have shown that the genetic diversity of ex situ populations decreases with increasing duration of cultivation, indicating deleterious effects of genetic drift and inbreeding and suggesting a decrease of fitness of the plants due to the ex situ cultivation (Ensslin et al. 2011). Furthermore, shifts in traits such as germination and flowering time, and a decrease in stress tolerance to drought and competition may further reduce the value of ex situ collections for reintroduction projects (Ensslin et al. 2011, 2015). Therefore, the use of ex situ material for reintroduction of endangered plants should be, if possible, avoided. If the use of ex situ cultivated material is indispensable, cultivation time should be minimized, as the described negative genetic effects become stronger the more generations the plants spend ex situ (Basey et al. 2015, Ensslin et al. 2015). This last option was adopted by the LIFE-project Herbages. The plants used for plantation in habitats to be restored were produced directly from seeds collected in natural source populations.

Preparation and management of the reintroduction site increases the chances of success

Reintroductions do only make sense if neither large-scale management regimes nor climatic or edaphic conditions preclude a self-sustaining population. They also have often to be accompanied with habitat restoration measures. Management of the reintroduction site through either preparation for planting (e.g., top soil removal, fencing) or post-planting management (e.g., manual weeding, watering) increases the probability of reintroduction success (Godefroid et al. 2011). This is also obvious when the reintroduction of species is specifically aimed to the restoration of habitats: the starting situation of the habitat is, by definition, not good or even simply bad.

Table 2: Overview of the issues that have to be considered when planning a reintroduction of a threatened plant species.

Important issues	Specifications	Rules of thumb
Species biology	Mating strategy, pollination mode, lifecycle, mutualists, pollinators, pathogens	Choice of reintroduction site, seed sources and transplant design have to be individually tailored to the species' biology and ecology
Target site selection	Soil type and depth, climate, vegetation type, occurrence of invasive species, management regime	Maximise ecological similarity of your target site with stable or increasing populations in the vicinity (especially stable in already well-managed habitats).
Source population selection	Size and status (declining or expanding), ecological and geographic distance to target site	Local material should be preferred unless other issues proof unsuitability of local populations as seed donors. Mixing source populations may be favoured if source populations face genetic problems
Capture genetic diversity	Number of samples per population	Current protocols state to sample at least 50 plants per population to capture its genetic variability (which is automatically reached for most of the species in case of bulk collection of seeds in grassland habitats in favourable conservation status).
Propagule type and numbers	Seeds, whole plants or other plant parts	If feasible, young or adult plants should be transplanted. At least several hundreds of plants or thousands of seeds should be used for a reintroduction

Ex situ material	Seed bank or cultivated collection	Cultivated material should be avoided, frozen seed bank material can be used
Management	Mowing and grazing regimes, removing bushes and competitive invasive species	Reintroductions do only make sense if the continuation of the appropriate management regime can be assured

Why are reintroductions seen so critical?

Although species introductions are internationally acknowledged and recommended, there is an apparent reluctance of many local stakeholders and practitioners to support or allow reintroduction programs, including in Flanders (Vanreusel & Verheyen 2003, Geertsma 2013). The arguments mostly pushed forward against species reintroductions are summarized below.

Seed collection could harm wild populations

The survival of most plant populations depends on seeds from one year being available in the following year(s). This is most acute in annual species and is least acute in long-lived perennial species. Scientific studies have shown that for most perennial species, short-term seed harvest of any intensity and frequency are unlikely to cause short-term extinctions (Guerrant et al. 2004). By precautionary principle, international standards regarding seed collection in wild populations recommend to collect no more than 20% of the total mature seeds available on the day of collection (ENSCONET 2009). This rule of thumb can minimise risks to the future survival of plant populations, and particularly in the case of endangered species in small populations. Also, repeat collections of a species from the same site for two consecutive years should be avoided unless we reduce the quantity of seed taken to a level well below the 20% limit in each year.

Risk of outbreeding depression

Outbreeding depression occurs when a cross between two individuals from different populations, which themselves are phenotypically adapted to their environments in different ways, produces an offspring that is intermediate in phenotype and not suitably adapted to live in either environment. Some authors have raised concerns about outbreeding depression when using multiple-source populations. For instance, experimental mixing of gene pools of very distant populations (>1000km) of *Agrostemma githago*, *Papaver rhoeas* and *Silene alba* revealed negative outbreeding effects in the F2 generation (Keller et al. 2000). However, Fenster & Galloway (2000) did not find any outbreeding over intermediate distances (several 100 km), and suggested that if distances among populations are not too large, outbreeding depression may be of little concern to conservation. The risk of outbreeding depression stands against the positive effect of mixing for genetic variability and evolutionary potential (Breed et al 2013). Moreover, geneticists usually consider the risk of negative effects via inbreeding depression higher than the risk of outbreeding depression (Frankham et al. 2011).

Species-based vs ecosystem-based approaches

Many conservationists and policy-makers argue against a species-based approach to conservation (Van den Berge 2004), largely on the grounds that there are so many species requiring attention that such an approach would not be cost-effective. A single or an individual method can obviously not address the management of biological resources. However, it can be achieved through an integrated approach balancing all available approaches. For instance, an approach of conserving the habitat has an input for the conservation of single species, but also vice versa. Integrating information from both approaches is particularly powerful, and this is precisely what has been achieved in several reintroduction projects, particularly those funded by the LIFE program (see point 5 below). It has also to be considered that conspicuous and charismatic species often have a strong positive effect on acceptance and support of conservation measures in the public and the tourist sector, which can be essential for maintaining conservation areas in the light of high land use pressure and shortening of financial resources (Walpole & Leader-Williams 2002). Therefore, reintroducing flagship species, as done with *Arnica montana* in the LIFE project 'Herbages' in the Ardennes grasslands can significantly increase the public awareness and appreciation of protected areas, whilst besides *Arnica montana* it is the whole list of species of the related habitat that is reintroduced to restore it.

Introduction of invasive species

Some people invoke the risk that the introduced species may become invasive and thereby may harm the existing ecosystem by displacing other species. This scenario can only happen in the case of assisted migration/colonisation, i.e. if a species is transferred outside its natural range. While this is one of the major reasons why assisted migration is predominantly seen very critical, the risk of creating novel invasive species by assisted migration has been shown to be very low in the case of intracontinental migration (Mueller & Hellmann 2008). Climate change, however, is a fact and ongoing. While we surely lack the knowledge to predict all consequences of these measures, there will be species not being able to track their habitats with climate change (Corlett & Westcott 2013), and the question whether we will try to help these species to survive or not will be inevitable in future.

Regarding the first three objections mentioned above, the risks identified can be managed by a careful preparatory phase. This emphasizes the importance of the decisional matrices. Furthermore these objections provide no solution to the challenge of the restoration of habitats in a favourable conservation status. In the context of the management and restoration of the Natura2000 network in fragmented landscapes submitted to heavy negative influences: industrialisation of farmland, nitrogen deposition, desiccation of former wetlands and of valley bottoms, lack of specific management of semi-natural open habitats, ...there are no other options on the table.

Examples of innovative reintroduction projects in Belgium

Reintroduction science is still in its infancy. Despite the huge number of ongoing projects, concepts comprising the ecological and evolutionary mechanisms relevant to reintroductions are poorly developed, which may be one reason of the rather low success rates. Scientific research on reintroductions is essential to develop our understanding of reintroductions as a conservation tool. In Flanders, several reintroductions of animal species have taken place (grass snake, beaver, hamster), but few programs have been developed with plants except for a few attempts with *Dactylorhiza praetermissa* (Jacquemyn et al. 2016) or *Liparis loeselii* (Van Landuyt et al. 2015). The first Belgian habitat restoration project involving large-scale plant reintroductions is the LIFE project "Herbages" (LIFE11 NAT/BE/001060) started in 2013, which is led by Natagora, and where the Botanic Garden Meise has transplanted four critically endangered species (*Dianthus deltoides*, *Helichrysum arenarium*, *Arnica montana* and *Campanula glomerata*) into their native range in southern Belgium. For each of these four species, a population of 500 to 700 young individuals was transplanted in 3 to 6 different sites. After transplantation, all plants were precisely mapped to facilitate their long-term monitoring.

A demographic survey (e.g. survival, floral production, reproductive success, and population extension by clonal propagation or seedling recruitment) is recorded yearly on the field in order to assess the viability of the transplanted populations. Offspring fitness is also experimentally estimated in order to test for inbreeding or outbreeding depression. This project will hopefully not only safeguard the critically endangered species in question, but also provide valuable information for the science of reintroduction biology and motivate future similar initiatives.

Besides these four specifically targeted specie (for which the reintroduction meets actually two targets: consolidation of the status of the species themselves and a more complete restoration of the related habitats), the project implements large scale restoration of habitats. The large scale restoration of habitats includes various actions: seeding of bulk collected seeds or spraying of fresh hay in various scenarios: from grinded strokes in grasslands to be improved to former spruce plantations after cutting and heavy soil preparation work.

Furthermore the LIFE project "Herbages" (LIFE11 NAT/BE/001060) is also a good example of strong collaboration between a world reputable scientific institution, the Botanic garden of Meise, and conservationists operating in the field. So the scientific knowledge is directly transferred and implemented in the field at the scale of real ambitious habitat restoration actions. This is unfortunately not often the case. It is one of the objectives and ambitions of the LIFE programme to promote the connection between people producing and having the scientific skills and people facing the reality of the field for the conservation and the restoration of the Natura 2000 network, i.e. bridging the gap between restoration ecology (the science) and ecological restoration (the practice).

Within another research project carried out at the Botanic Garden Meise, small-scale experimental reinforcements have been implemented recently in southern Belgium in order to untangle evolutionary aspects related to the use of botanic garden grown material for reintroductions. Within this project, populations of the yellow foxglove (*Digitalis lutea*) have been reinforced using plants and seeds of the same wild origin but different histories: (1) collected directly from the wild; (2) stored for 25 years in a seed bank and (3) from garden-cultivated plants. The aim of the project is to compare the different histories of the seeds and to find out whether seeds that have been cultivated in the botanic garden still provide suitable material for reintroductions. This is important as seeds are increasingly stored in seed banks, e.g. the Seed Bank in the Botanic Garden Meise, but the effects of long-term seed storage and seed regeneration in the botanic gardens on the reintroduction outcome are unknown.

Reintroductions in a changing world: How do we proceed?

Plant reintroduction is a young discipline where we still advance by trial and error. Given the generally low success rate, the high cost of operations and the ever more rapid species extinction, we can no longer afford to work in the dark. A priority must be to make appropriate and useful information available, in order to help the plant conservation community to efficiently restore biodiversity. Disseminating the information from research projects should therefore be improved. Scientists need to better communicate the results of their research to nature conservation stakeholders in order to bridge the gap between restoration ecology (the science) and ecological restoration (the practice). Likewise, practitioners and stakeholders are encouraged to stay open to new ideas and learnings to allow restoration science and implementation move forward. A framework for rapid and effective broadcasting of information on plant reintroduction programs could help to achieve this aim. One possibility would be a set of variables for a centralized web-based interface which could provide the necessary information in a standardized and accessible form (Godefroid & Vanderborght, 2011). We believe that making appropriate information available will help to fill the existing gaps in plant reintroduction practice.

We plea for more openness and courage in a future-oriented nature conservation. We believe that the transition from a passive conservation approach to more integrated approaches including carefully chosen intervention and management will provide the effective tools to stop biodiversity loss, particularly in Western Europe, where intensive land-use has been ubiquitous for centuries. Therefore the sole restoration and management in a favourable conservation status of the existing remnants of habitats is not sufficient. The size of many of these remnants should be increased and stepping stones re-established. Massive reintroductions will be necessary to meet this objective of restoration of habitats often starting from heavily degraded situations. The exchange of experiences with neighbouring countries, particularly via LIFE projects, showed us that we don't have to be afraid to consider new ways of meeting biodiversity conservation challenges.

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