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MASTERARBEIT

Assisted migration as a concept for species recovery and conservation –

Checklist for a management strategy to reduce biodiversity loss

verfasst von

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1 Introduction

1.1 What is assisted migration?

Assisted migration, which is also known as assisted colonization, managed relocation or benign introduction, is the translocation of species beyond their recent and historical ranges as protection from human-induced extinction (Ricciardi et al., 2009b; Seddon et al., 2012). It is another management possibility to reduce biodiversity loss and to facilitate the survival of selected species threatened by climate change.

Assisted migration is a controversial conservation strategy widely discussed in literature and in the conservation community primarily concerning with biodiversity loss through climate change. Many conservationists support restoration, reintroduction and, if necessary, assisted migration (Hoegh-Guldberg et al., 2008; Schwartz et al., 2009; Shoo et al., 2013), whereas others have ethical concerns or fear biological invasions (Ricciardi et al., 2009b). While the debate goes on, the intentional movement of species beyond their common and historical ranges is translated into action around the world for example in the United Kingdom (Willis et al., 2009), in China (Liu et al., 2012), Australia (Burbidge et al., 2011), New Zealand (Saunders et al., 2001), the United States (McLachlan et al., 2007) or Canada (Gray et al., 2011), sometimes without any obvious framework or risk assessment. A political statement or the regulation of this strategy has been demanded; however, a standardized procedure for conservation projects using assisted migration is also urgently required. Any management action must be based on a standardized framework that has been developed using scientific research. Many conservation strategies (e.g. habitat protection, restoration, reintroduction, re-enforcement) exist that could solve different problems, but the difficulty is selecting the right one(s) for a specific conservation project. Ex situ and in situ conservation do not exclude one another; rather these practices complete conservation success (e.g. *Dracocephalum austriacum*; Schumacher et al., 2013). Ewen et al. (2011) emphasized how important closing the gap between theory and practice is. Botanical gardens play an important role in scientific research and in the implementation of conservation strategies including assisted migration (Havens et al., 2006; Vitt et al., 2010).

International and national studies or projects provide information and advice regarding where, when and how assisted migration is possible or desirable (Richardson et al., 2009; Regan et al., 2012). Instructions for reintroductions are found, e.g., in the IUCN Guidelines for

Reintroductions and in several publications (see Ewen et al., 2012 for a survey), and the current aim is obtain a similar tool for assisted migration. In 2013, the IUCN widened their guidelines for all conservation translocations. These guidelines are a helpful tool and should be known by conservation biologists. Although they are applicable to assisted migration, they do not discuss this strategy on its own. Additionally, because they are based on general principles without giving examples, the IUCN Guidelines for Reintroductions and other Conservation Translocations (2013) are not practical.

1.2 Research questions

Based on critical analyses of some assisted migration projects and practical considerations, I will draft a checklist for this conservation strategy (particularly for Europe, where this strategy is relatively new). The key issues are as follows: Which parameters should be considered before assisted migration is implemented? Does Austria already have assisted migration projects? Is assisted migration an option for endangered taxa in Austria, and if so, which taxa are best suited for this strategy?

I will count up the parameters that which should considered before any action, including ecological, genetic, socio-economic and practical thoughts. The primary questions will include the following: When is assisted migration the best conservation tool to prevent a species from extinction? Are potential negative effects to be expected? Is the implementation of assisted migration possible?

Through a standardized evaluation of benefits and risks, this checklist intends to make the process of planning projects easier and more successful. It should help conservationists to decide whether assisted migration is an optional conservation strategy for their project and to avoid negative effects caused by wrong or ill-considered decisions.

In my opinion, assisted migration is neither the last resort, nor the ultimate solution, but another concept to stop biodiversity loss.

The proposed checklist will be used to prepare management proposals for some highly threatened plant species in Austria. I will select these species from a list of threatened species that are in ex situ institutions in Austria (Hölbling, 2013) and will prefer highly endangered, rare taxa for which Austria has a high responsibility. When the checklist provides a positive result, then some management ideas will follow. They will answer the following questions: Why is assisted migration a good choice to prevent this species from extinction? Where and how is the plant translocation possible? Who can perform the translocation and how long will it take? What is the source for the used plant material? How is success measured and who will do the monitoring?

2 Fundamental principles and example projects

2.1 Conservation strategies

Protecting habitats is a conservative conservation tool with the great advantage that it protects many species, including those that remain unknown, as well as natural processes. However, protected areas are often too small or fragmented to facilitate long-term viable populations (Hannah, 2011). Due to climate change, range shifts of many species toward the poles or to higher latitudes are expected (Parmesan et al., 2003). These new inhabited areas can lie outside protected areas (Zografou et al., 2014). Range shifting is impossible for some species because their habitats are naturally (e.g. mountain tops or islands) or human induced isolated (Burbidge et al., 2011). Other species will be able to adapt or to evolve, but some will fail because they respond too slowly to the new conditions and become extinct (Hellmann et al., 2012). Apart from climate change, the continued isolation of protected areas is another problem that can be partly solved by enhancing connectivity (Hannah, 2011). Corridors facilitate natural range shifts and genetic exchange, but they do not help all species. To conserve biodiversity more has to be done than landscape and habitat preservation, e.g., assisted migration (Loss et al., 2011).

The conservation translocation spectrum has several possibilities. Conservation translocation is the overarching term for the deliberate movement of species with the objective to conserve species, populations or ecosystems (IUCN, 2013). One of these translocation approaches is reintroduction. A species is moved into a part of its historical range from which it became extinct. If the reintroduction is successful and if the species is established in its former natural range again, then this process is called re-establishment (IUCN, 1998). The difference between reintroduction and assisted migration is that for assisted migration, species are introduced into completely new places where they have never been before. The knowledge of historic ranges is limited (Hellmann et al., 2012) and sometimes wheater a translocation is a reintroduction or an assisted migration is unclear. Past projects where no historical record of moved species was found were called reintroduction. However, today this situation would be classified as assisted migration (Mueller et al., 2008). Reintroduction is widely accepted, but some species cannot not be introduced into their former range because there is no longer a suitable habitat or the habitat is predicted to disappear in subsequent years (Osborne et al., 2012). Introducing these species outside their range is much more controversial, although the new area is adjacent to the original one.

Re-enforcement is a conservation tool for supporting species in their common range by adding individuals to an existing population (IUCN, 1998).

Reintroduction, re-enforcement and assisted migration are conservation strategies for selected species. Restoration and ecological replacement are concepts with an ecosystem approach that refer to ecosystem functions and to habitat quality (Table 1).

Table 1: Overview of conservation strategies

		Conservation target	
		species	ecosystem
Introduced species	native	reintroduction, re-enforcement	restoration
	non native	assisted migration	ecological replacement

The restoration of a degraded, destroyed or transformed ecosystem refers to assisting or initiating its recovery (SER, 2004). It is successful when an ecosystem sustains itself, displays natural abiotic and biotic flows, is resilient to natural stress and provides original ecosystem services (LeFevour et al., 2007). Similar to reintroduction and assisted migration projects, planning a restoration requires not only ecological and environmental, but also economic, social and political considerations. Restoration is the chance to compensate for human-induced damage and to test theories regarding the function and structure of ecosystems (Cairns et al., 1996). Restoration could orientate on the original, historical conditions with native species used for restorations, but ecosystems are not static, and future conditions and evolution should be taken into account (Harris et al., 2006; Seastedt et al., 2008; Thomas, 2011).

If a suitable habitat for a species reintroduction or for assisted migration does not currently exist, then one possibility is to restore or to create this habitat to support the species in the future (Osborne et al., 2012). Another option is the integration of the translocation of a species outside its recent and historical range into a restoration project. It represents a chance for threatened species that have not been there before and that are now highly endangered in their natural range (Loss et al., 2011).

If the conservation of the species is the reason for its translocation, it is assisted migration.

However, if the restoration of ecosystem functions is the target, the approach is called ecological replacement. Similar to assisted migration, it refers to the translocation of species outside their recent and historical range, but not primarily for the conservation of the transferred species. The aim of ecological replacement is to fill a free ecological niche that results from the extinction of native species and to restore ecological functions. The most suitable species are chosen for substitution of extinct species, e.g., close relatives or subspecies (Seddon et al., 1999). Ecological replacement could also reduce the native species' extinction rate and reduce management costs (Thomas, 2011).

In my opinion no clear difference between the restoration of ecosystem functions and species conservation exists because one facilitates the other. The question is not to decide whether conservation biologists should manage species or communities and ecosystems. They must do both by integrating single species management into that of the ecosystem. Moving species, particularly outside their historical range, must not harm communities or ecosystem functions; rather the new species should fit in (Jones et al., 2012). A restored ecosystem represents a backbone for an assisted migration project of species depending on habitat structure or specific biotic interactions. Depending on the plant community, key species must be established before the assisted migration of a threatened species could be implemented.

In post-agricultural or -mining degraded landscapes, the habitat structure must be restored first. Soil improvement and reforestation can accelerate a natural ecosystem's recovery. An example of a reforestation project is the corridor creation in the Piedras Blancas National Park in Costa Rica. This project focuses on the connection of isolated forest patches through restoration and reintroduction and not on assisted migration, although non native species are also used (Weissenhofer et al., 2008). It demonstrates that the creation of a habitat structure is the first step to restore an ecosystem and that conservation strategies could be combined. With its protected and expanding forests, Costa Rica is expected to be the first carbon-neutral country by 2021 (Pearce, 2008).

Additionally there is also the possibility to move genotypes from one population to another. Genetic assisted migration can be used for the following three reasons: to rescue populations from fitness loss (e.g. due to inbreeding depression), to increase the genetic variation and enhance evolutionary potential, or to introduce a mix of genotypes for restoration (Shoo et al., 2013).

Apart from in situ strategies, ex situ conservation, which is defined as "the conservation of plant species outside their natural habitats" (Hawkins et al., 2008), is also possible. It supports in situ conservation by holding resources for restoration, reintroduction and assisted migration projects. Although a project could not be implemented or may have failed, the species is not extinct. Ex situ conservation "provides a safety net against extinction" (Havens et al., 2006). As mentioned previously, linking in situ and ex situ efforts and bringing together all available possibilities will become important for reducing biodiversity loss (Havens et al., 2006; Ewen et al., 2011; Prichard et al., 2011).

2.2 The role of botanical gardens

BGCI (Botanic Gardens Conservation International) manages the data for more than 2.500 botanical gardens worldwide (Pritchard et al., 2011), which host more than 100.000 species or approximately one third of plant biodiversity. With this capacity botanical gardens clearly play an important role in conservation. Botanical gardens are the primary institutions involved in ex situ conservation (Sharrock, 2012). They are principally known for collecting living plant material and for storing seeds, but the horticultural collection is only one of many diverse tasks (see Havens et al., 2006; Primack et al., 2009; Hardwick et al., 2011; Pritchard et al., 2011).

I want to focus on the points relevant for assisted migration.

First, botanical gardens provide scientific knowledge and practical experience regarding growing plants that can indirectly support in situ projects (Havens et al., 2006). They are a testing ground that studies taxonomy, conservation genetics, physiology and anatomy, and plant responses to changing conditions, e.g., climate change. Plant species that are grown outside their natural distribution, e.g., more to the north, facilitate the observation of species reactions to altered climate conditions. With a basic understanding of plant behaviour, future suitable habitats, range shifts or invasiveness can be predicted to some extent (Primack et al., 2009). Recent assisted migration projects have demonstrated that well understood plant species interactions with their biotic and abiotic environment could enhance a project's success (see 2.3 An overview of assisted migration so far). Botanical gardens have developed strategies to collect plant material for potential target species for assisted migration (Vitt et al., 2010). Herbaria provide insight into the former distribution of species (Primack et al., 2009) and help to identify whether suitable habitats lay in- or outside a species' range.

Second, ex situ collections maintain the resources required for restoration, reintroduction and assisted migration projects and so they are the basis for in situ conservation. The stored plant material is put as disposal for in situ projects or directly used by gardens for their owned and managed areas. Ex situ plant conservation organizations are an essential link between ex situ and in situ conservation (Havens et al., 2006), but although they are fundamental to ecological restoration, only a few are involved (Hardwick et al., 2011). Target 8 of the Global Strategy for Plant Conservation (GSPC) notes that combining ex situ and in situ is crucial: “At least 75 per cent of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes” (Sharrock, 2012). The importance of recovery and restoration programmes, including assisted migration, will increase because they are also fundamental to reach Target 7 of the GSPC: “At least 75 per cent of known threatened plant species conserved in situ.” (Hawkins et al., 2008; Sharrock, 2012). Threatened species often live in rare habitats that are endangered on their own or deteriorated. For in situ conservation, the suitable habitat has to recover first.

In Austria Target 8 is raised on the roadmap to 2020 (Kiehn, 2011): eighty per cent of native threatened species should be held in ex situ institutions until 2015. A special focus is given to endemic species because they are at a higher risk of extinction due to their small distributions and population sizes (Hölbling, 2013). International conservation policy focuses on in situ approaches, whereas ex situ conservation is relegated to a subordinated role. However, hybrid strategies, e.g., restoration, reintroduction or assisted migration, depend on ex situ resources and could not be implemented without them. Universities obtain research and education instructions that do not consider their potential contribution to conservation. Therefore, universities lack resources and have fewer chances to obtain support from aid programmes (Schumacher et al., 2013). Botanical gardens can play a more active role in conservation, but they often lack financial incentives, e.g., from the CBD (Pritchard et al., 2011). A survey of ex situ plant conservation organizations indicated that only 12 per cent of the budget was spent on internal conservation actions and not on science (Havens et al., 2006). To reach Target 8 of the GSPC, the understanding of ex situ conservation as a complementary part to in situ conservation must be strengthen and financial capacities must increase.

Third, botanical gardens are responsible for education and for public awareness (Havens et al., 2006; Primack et al., 2009). The importance of plant biodiversity, rare species and their conservation (also including assisted migration) is communicated through workshops, guided tours or special events, e.g., the annual “Raritätenbörse” at the Botanical Garden of the University in Vienna. The public is informed regarding the problems caused by invasive alien species and the responsibility and chances every private gardener has, e.g., by growing native species instead of exotic ones. With the possibility of creating novel ecosystems and of altering the world’s appearance, the debate regarding restoration and assisted migration should not be held only by the scientific community; this debate should move to the public (Lawler et al., 2011). Botanical gardens can communicate different conservation aspects and the need for taking action.

Fig. 1: Raritätenbörse, 2014

Fourth, botanical gardens represent a worldwide network that exchanges and shares information, techniques and plant species (Hawkins et al., 2008; Sharrock, 2012). This network could be also used to bring conservationists to an update regarding the implementation and success of plant species' assisted migration. Recent translocations provide much useful information for future projects, but a large part of the related information is not widely accessible and particularly plant translocations lack conclusions or analyses (Burbidge et al., 2011).

A problem for botanical gardens is the limitation of space. Collected species that are represented with only a few individuals potentially face inbreeding depression or genetic drift. Additionally, not all species can be immediately taken into ex situ collections. Species that should be stored first are prioritised because they are critically endangered or they can be used for restoration or for assisted migration in the future. Whether a species is suitable for an in situ project is sometimes not directly evident, but the species can be collected, stored and monitored in a botanical garden. Ex situ conservation is not as problematic and expensive for plants as for other organism. Time is running out for threatened species and with protecting them in ex situ facilities, the decision for assisted migration can be made later, after considering all options (Havens et al., 2006; Vitt et al., 2010). Hölbling (2013) documented which threatened species in Austria are in ex situ collections, where and how often they are stored and which of those species are unprotected through ex situ conservation and should be collected first. Due to limited space and resources, endangered species are often held in only one garden and are therefore at risk of extinction in that garden. “Emphasis must not only be on increasing the number of threatened species in ex situ collections but on assessing and ensuring the conservation value of such collections”. Assisted migration can solve the spatial problem and support a botanical garden’s work. This integrated approach lies between in situ and ex situ conservation, as well as between free-living and human-controlled approaches (Prichard et al., 2011).

Because of all of their knowledge, research and resources, the assisted migration of plants must start at botanical gardens.

2.3 An overview of assisted migration so far

The intentional movement of species is nothing new. Since humans are trading, various species, especially plants, have been introduced into new locations (Kiehn, 2012). These plants are used as food, medicine or simply as decoration (Vitt et al., 2009). Today, commercial plant nurseries host a lot of exotic species. They also extend, by their cultivation activities, natural range limits, e.g., of native European plant species by a mean distance of 1.000 km more to the north (Van der Veken et al., 2008). In our modern world, fast exchanges over large distances are possible, causing a new problem: invasive alien species. Creating unpredictable problems with a species becoming invasive is the primary concern associated with assisted migration. Many studies emphasize how important the knowledge of dispersal pathways (Wilson et al., 2009), species life history traits and characteristics (Myers et al., 2003; Keel, 2007) and biotic interactions (Hellmann et al., 2012; Kranabetter et al., 2012) is.
The understanding of what assisted migration is and what it can do differs. American and Australian scientists must deal with large degraded landscapes due to mining and to intensive agriculture and focus on large-scale restorations (Marris, 2009; Gray et al., 2010; Grady et al., 2011). These scientists consider what role assisted migration can play in these restorations and in commercial forestry. In Australia and, in particular, New Zealand, invasive alien species cause not only immense economic problems, but also problems for biodiversity because island ecosystems are vulnerable to invasive alien species. Introduced mammalian predators are the key factor for population declines of birds, e.g., the kakapo. Native endemic species face extinction. Assisted migration in New Zealand focuses on the translocation of species from one island to another (Laws et al., 2012; Seddon et al., 2012; Jones et al., 2012). The concept of assisted migration has been less well known in Europe, but is beginning to emerge now. Assisted migration projects attempt to help a single species to survive, particularly those species endangered due to a changing climate, by transferring them more to the north or to higher elevations (Willis et al., 2009).
While the scientific community still debates if assisted migration is a useful conservation strategy, projects are turned into action around the world, sometimes with careful risk assessment and sometimes without scientific advice. An example for the latter are the Torreya

Guardians. They call themselves guardians because they want to protect the Florida Torreya (*Torreya taxifolia*) from extinction. The species range is limited, and with climate change, its habitat will most likely be even more reduced. The Torreya Guardians move the plant about 500 km northward where a more suitable habitat is expected in the future. If the Torreya Guardians acquire the seed material legally and ask for the landowner's permission, there are no political or legal limitations or prohibitions (McLachlan et al., 2007). Such a project implemented by people with conservation efforts, but without a scientific framework or a benefit and risk assessment, intensifies the call for political regulation and for a standardized procedure (McLachlan et al., 2007; Schlaepfer et al., 2009; Price, 2010). Mark W. Schwartz, who is a plant ecologist from the United States, thinks that *Torreya taxifolia* should not be moved. He also mentions an important point: Assisted migration should be scientifically evaluated and considered as an option for any conservation project, although it turns out as the wrong strategy, but ignoring this conservation tool is unjustifiable (Schwartz et al., 2009). An example for a scientifically based assisted migration project is a test study of butterflies (*Melanargia galathea*, *Thymelicus sylvestris*) in the United Kingdom. Fragmentation is expected to stop natural expansion and so the species was translocated to habitats more to the north and outside its range, which were predicted to be suitable by climate models. Negative effects are expected to be unlikely because the biology and the biotic interactions are well researched. This test study demonstrated that the species could be established there. The butterflies' natural colonization of new habitats may be assumed too slow and may lag behind. With careful consideration of possible risks and cost-effective implementation, the human-mediated migration is successful (Willis et al., 2009).

The United Kingdom is described as "an ideal location for translocated species" with natural ranges outside the country, e.g., the Iberian lynx (*Lynx pardinus*) or the Spanish imperial eagle (*Aquila heliacea adalberti*). Britain contains only a few endemic species, but an anthropogenic modified landscape (Thomas, 2011).

A more complex and mainly successful assisted migration project in China has been described by Liu et al. (2012). Twenty-nine orchid species were translocated from 350-400 m to 1.000 m above sea level because their source side was flooded for a hydropower project. A movement 600 m higher in elevation also results in a 3,6°C colder average temperature and a less tropical forest composition. The number of translocated individuals varied among the species, depending on its availability. Overall, about sixty per cent of monitored individuals survived, and only one species went extinct (Liu et al., 2012). This project demonstrated that not all species are equally suitable for assisted migration and emphasized the need for research and knowledge regarding each species traits, specific demands, interactions and life cycle. With the uncertainty of a project's success, a good idea is additional ex situ conservation.

Huang (2008) also emphasized that assisted migration will not work for many species. This approach appears to be simpler than it is and will not help rare species because too little is known regarding these species. He mentioned rare coral species that are endangered by trade; if they are moved to new habitats, they would be harvested even more.

Vitt et al. (2010) used species distribution models of *Cirsium pitcheri*, a species endemic to the dunes of the Great Lakes in the USA, to prioritize populations for seed collections. The best suitable climate is predicted to be outside its current range, whereas its common populations at the southern edge of Lake Michigan are predicted to disappear. This model is supported by the fact that the southern populations have declined by half in the last years. The species distribution model of *Cirsium pitcheri* considers nineteen bioclimatic factors. Grady et al. (2011) found a relation between the mean annual maximum temperature and the aboveground net primary production (ANPP). Differences are found among species, but local genotypes appear to be best adapted to climate, and the ANPP declined with an increasing transfer distance (and thus, an increasing mean annual maximum temperature).

Vitt et al. (2010) and Grady et al. (2011) emphasized the importance of climatic factors, but other stressors can also be important. The species distribution model for Tecate cypress (its taxonomic status remains unclear, so formerly *Cupressus forbesii* is known as *Hesperocyparis forbesii* or *Callitropsis forbesii* now), which is a rare tree with limited seed dispersal in California and Mexico, demonstrated that the most serious effect on population persistence is the average fire frequency. The fire frequency increases with urbanization and could be facilitated by climate change. Second, the study notes that the assisted migration of Tecate cypress is a possibility with low risks and that the habitat loss harms the source patches more than the loss of individuals for assisted migration (Regan et al., 2012).

Assisted migration has been used to improve commercial fishing in southern Australia and in Tasmania. Lobsters are moved from deep water to the coast. This translocation results in improved growth and egg production. The conservational aspect is that fewer large, high value lobsters must be harvested to make the same profit and tha the human effect on the ecosystem is moderated (Green et al., 2010).

Another project primarily implemented for economic reasons is the assisted migration adaptation trial (AMAT). In British Columbia, sixteen tree species have been planted outside their comfort zone, but not outside their historical range, to observe how they will react to the warming climate. The trees should get used to higher temperatures (Marris, 2009). The mismatch of genotypes and their environment is called adaptational lag and results in higher rates of tree mortality and weak forests (Gray et al., 2011). Maladapted trees are growing poorly, and the commercial forestry industry is interested in a solution to maintain healthy, productive forests. Daniel Simberloff, an invasion biologist, thinks the AMAT is “a waste of time” and that we do not know enough about insects and pathogens (Marris, 2009).

Ricciardi et al. (2009b) are also convinced that assisted migration is not a useful conservation strategy. These researchers argue that we do not sufficiently understand ecosystems and their spatial and temporal dynamics. The effects of introductions cannot be well predicted. Any risk assessment is based on conservation biologists’ trust in their research. The effects of ecological invasions can be fatal, e.g., the introduction of pathogens, and due to a time lag the effects are often discovered too late. Inter- and intracontinental translocations of mammals and translocations to remote and coastal islands have been compared and remote island and intercontinental transfers appear to have more numerous and higher effects. However, in California and in the Great Lakes, non native freshwater fish cause declines or extirpations of native species independent from their origin, so the risk of intracontinental translocations should not be underestimated. Assisted migration is an “ecological roulette” that creates new problems (Ricciardi et al., 2009b). Davidson et al. (2008) and Fazey et al. (2009) also support a rejecting attitude.

Ricciardi et al. (2009b) have been criticised several times by the scientific community for their rejecting and conservative position (Vitt et al., 2009; Schlaepfer et al., 2009; Sax et al., 2009).

Many biologists agree on a ranking of conservation strategies as a response to climate change (Heller et al., 2009; Mawdsley et al., 2009; Hannah, 2011). The leading strategy that is preferred in most cases is the establishment of protected areas because that way most elements of biodiversity, including even unknown or undescribed species, are likely to be protected. Those protected areas must be connected to facilitate exchange and to create viable populations because some protected areas are too small to host a population. If such attempts do not seem to be feasible, then assisted migration is suggested. When translocations are impossible, ex situ conservation is referred to be the last option (Hannah, 2011). Loss et al. (2011) proposed an integrated strategy that prefers habitat connectivity to improve the landscape. They take genetic considerations into account because genetic diversity is a source for adaptation that can help species survive in the face of climate change. If a species cannot be saved by facilitating its natural range shift with habitat connectivity and with genetic management, then assisted migration can be considered.

Hannah (2011) and Loss et al. (2011) do not consider assisted migration as an equally good conservation strategy as habitat protection and connectivity because this approach is more risky and because the outcome is uncertain. They prefer to attempt conservative strategies first, but both can imagine the need for assisted migration for some species. Habitat management, conservation genetics and a careful use of assisted migration should be combined into an integrated strategy (Loss et al., 2011).

Facilitated migration is a quite similar approach to habitat protection and to connectivity enhancement. The conditions for natural migrations, habitats and corridors should be secured. With this legal and forward planning strategy, assisted migration might become unnecessary (Ruhl, 2010).

A recent decision guide for choosing an optimal conservation action (Shoo et al., 2013) also prefers traditional options. The key arguments are the increasing costs and the uncertainty of success with assisted migration (Shoo et al., 2013). Rout et al. (2013) developed a quantitative framework to decide for translocations and to select species. In a decision tree, the risks for the source population and the effects on ecosystems are compared with the project's success. Habitat selection, socio-economic and practical aspects are not considered.

A linear decision framework that assesses whether assisted migration is an option to protect a selected species from extinction is suggested by Hough-Guldberg et al. (2008). However, assisted migration is not that easy and the circumstances are often not clear enough to answer questions simply with yes or no. This linear approach cannot take competing interests from different stakeholder groups into account. It is only a first step to identify cases where assisted migration is not the best conservation strategy. A multidimensional evaluation is an improved tool to assess this complex topic from different point of views (Richardson et al., 2009). A framework that pays attention to many aspects for planning a translocation including assisted migration has been published by Burbidge et al. (2011). These researchers emphasize the importance of monitoring and the analysis of recent assisted migration projects.

2.4 The situation in Austria

Actually, 40 per cent of Austria's c. 3300 native plant species (3600 taxa, cf. Fischer et al. 2008) are more or less threatened; 5.8 per cent of species are at a high risk of extinction.

Fischer et al. (2008) identified habitat loss as the primary reason for biodiversity decline in Austria. During the last 100 years, land use change severely reduced dry grassland habitats. The remaining small isolated patches are endangered by giving up extensive land use and invasive alien species. Dry grassland patches in the eastern part of Austria are highly diverse. They host endemic species as well as western populations of the Pontic-South-Siberian floristic region's characteristic taxa. The Botanical Garden of the University of Vienna harbours a Pannonian display with many highly threatened species from this floristic region and cares for their health, security and reproduction. The Pannonian display was founded for education, research and conservation purposes; visitors should become aware of their beauty and value for conservation. Today, monitoring data, research and practical knowledge are available for conservation projects (Schumacher et al., 2013).

Extremely few published data and considerations related to assisted migration in Austria exist so far. The two LIFE-Projects "Pannonian Dry Grasslands" and "Bisamberg Habitat Management" included conservation actions for *Artemisia pancicii* and *Dracocephalum austriacum*. Both species were botanical researched, but a detailed analysis demonstrated that information about population size, genetic diversity and associated species were absent or wrong. Additional studies and practical observations improved conservation efforts (Schumacher et al., 2013).

One example for a successful conservation project is the small-scale (re-)introduction of *Artemisia pancicii* on the "Bisamberg". *Artemisia pancicii* is native to this area in Lower Austria (also to the Hainburger Berge) and in Burgenland (Fischer et al., 2008). This plant reproduces only vegetatively and is genetically clonal, so considerations related to the conservation of the gene pool are simple. In spring 2010, cuttings from a Bisamberg location were transferred to two new locations at the Bisamberg after having been multiplied at the Botanical Garden of the University of Vienna to found new populations. The habitats were selected via aerial pictures and inspections on foot. The presence of typical dry grassland species, e.g., *Carex humilis* was positively valued and a negative influence on the native community was a criterion to exclude locations. Whether the introduction occurs in or just outside the species historical range remains uncertain, but without historical records, the new populations lie outside the species range, and the project can be rated as an assisted migration. The monitoring data demonstrated that one introduction was more successful than the other, where the population declined during the first year, but increased during the second year (Schumacher et al., 2013).

Assisted migration was also considered for *Dracocephalum austriacum*. This species is native to Lower Austria, to the eastern edge of the Alps and to the Hainburger Berge (Fischer et al., 2008). Through intensive searching at the LIFE-Project's beginning, new populations were discovered and so new conservation options arise. Management actions, e.g., clearing the sites from shrubs and trees, helped *Dracocephalum austriacum* to recover. A backup in a botanical garden is not secured because the species seems to be short-lived ex situ and to be killed by fungal diseases. Cultivated individuals must not be used for in situ conservation because an infection risk exists and so plant material for assisted migration is not available. Additionally knowledge about the species' biotic interactions (plant community, mycorrhizae), genetic diversity and establishment is lacking (Schumacher et al., 2013). Thus, the in situ management of recent populations is preferred to ex situ conservation or to translocation.
Both projects give an idea about the careful considerations required for assisted migration projects in Austria. I believe that many Austrian species could benefit from this conservation strategy in the future and that my checklist can provide guidelines and assist standardized scientific evaluation.

3 Discussion

3.1 Ethical concerns

"I think more than anything the fear of assisted migration is about who we think we are, what we think our place in the world is. It's about the hubris of thinking we can just reorganize life on earth."

Jessica J. Hellmann (Marris, 2008)

Assisted migration is one of the most controversial conservation strategies that divide conservation biologists into great supporters (Willis et al., 2009; Schwartz et al., 2009) and opponents (Davidson et al., 2008; Ricciardi et al., 2009b). This discussion has such an emotional character because of its association with ethical attitudes and personal opinions. As Jessica J. Hellmann, who is a biologist from the University of Notre Dame, Indiana, suggests, the questions are as follows: Are we allowed to do this? Can we be “planetary managers” (Minteer et al., 2010) who design ecosystems as we like them and move species wherever we think they will fit into our construction?

The question “What we are willing to do to conserve ecosystem functions as well as biodiversity?” ideally should be answered by the entire society because it determines what role humans will play in future ecosystem management. Assisted migration is thought to be anthropocentric and another human intervention in nature, but other conservation strategies also fit this description (Lawler et al., 2011). Humans depend on natural resources, and protecting those resources means securing their own well-being.

In fact, the intentional design of ecosystems has already been done. With the restoration of ecosystems, the recovery of degraded landscapes is assisted (SER, 2004) and whether this recovery is allowed in this region again is a human decision. If the restoration of ecosystem functions is the primary target, not only native species are facilitated (ecological replacement, Seddon et al., 1999). Again, what organisms should live in such an area is a human decision. Another example of the anthropogenic design of nature is gardening. What seems to be an “innocent” hobby is part of a successful industry that is worth billions of dollars. Gardeners often do not know what is native or not, but they want to decorate their homes, e.g., with beautiful flowers. This situation causes a trade of exotic new plants from all over the world (Mack et al., 2001). Every gardener can create a little world of nature that he imagines as he moves species, normally being unaware of what he does and what risks his actions could have. The responsibility connected with every deliberate movement of species into new areas, including those by private persons, should become generally aware.

Southgate et al. (2008) described the theological point of view and emphasized the intrinsic value of species. Conserving biodiversity is a human duty because God cares for every single species. He told Noah to save a pair of every species on earth. We should learn from this story and keep our planet healthy because "Earth is our only ark" and if assisted migration is necessary, then this approach should be performed.

The historical role of the conversationalist was as a preserver that protects ecosystems from destruction. This role has changed, on one hand because of newly emerging problems that caused more pressure on natural systems and one the other hand because scientific research opened new options (Minteer et al., 2010).

The use of natural resources increases and so do fragmentation, land-use, deforestation, habitat destruction and the climate changes. The human ignorance of these increasingly urgent problems requires new conservation strategies, such as assisted migration. All conservation efforts, from the classical protected area to the well-discussed field of assisted migration, will help to reduce biodiversity loss, but will not prevent us from re-thinking our lifestyle (Southgate et al., 2008). Assisted migration is a type of techno-fix that gains more time, but that is not a sustainable solution. The primary problems, such as fragmentation and climate change, are induced by human activities, such as intensive land use (Fazey et al., 2009). Southgate et al. (2008) noted that the Western society is focused on consumption, sometimes including the consumption of things that are never required or enjoyed. These researchers see "the current loss of touch with reality, the failure to grasp the impact of carbon-intensive lifestyle and its implications for the future" as the key point. This lifestyle does not appear to be changing soon, so actions other than preservation should be taken, e.g., a carbon tax that increases from one year to another. The more ecosystem damage is stopped, the less conservation projects, including those uncertain and risky projects, will be required (Southgate et al., 2008).

Is rejecting assisted migration possible because more human influence on nature than exists already should not occur? Intentional and unintentional movements of species around the world can have many effects, e.g., problems with invasive alien species, and the translocations will not stop. The need for management actions will remain (Myers et al., 2003). New invasive alien species will continue because of climate change, which facilitates some species and which harms others (Mueller et al., 2008). However, why should we not use translocations for conservation, if we can minimize or prevent negative effects? In my opinion, every ecosystem is influenced by human activities and untouched wilderness does not exist. Climate change and the increase in deposited nitrogen are global problems that affect every ecosystem, including protected areas. The anthropogenic effect on nature has become so strong that we will have to manage future ecosystems if we do not want to accept severe biodiversity loss. If the extinction of some species can be stopped, more will be gained than lost (Keel, 2007; Hoegh-Guldberg, 2008). However, taking uncertain or high risks, e.g., long distance translocations, is not required (Keel, 2007; Ricciardi et al., 2009b; see next chapter). The best conservation strategy should be found and implemented for every species. Deciding according to the best scientific knowledge and using all available information, including local conditions, are important.

3.2 Critical analysis of assisted migration

"Conservation under current circumstances is about managing change; retaining or restoring past community composition is no longer feasible."

Chris D. Thomas (2011)

Natural ecosystems underlie dynamic processes, but those processes cannot be directly compared with the results of severe human-made effects. Traditional conservation approaches will be insufficient to protect biodiversity in the 21st century (Hoegh-Guldberg et al., 2008; Minteer et al., 2010; Loss et al., 2011; Shoo et al., 2013). I agree with Thomas (2011) that we should not attempt to retain and restore the past, but that we can learn from former ecosystems and communities. Studying past community composition or traditional land use can help to create diverse ecosystems and to protect species native to destroyed or declining habitats. Some threatened species would find suitable habitats outside their range, but are unable to reach them. Wisely used assisted migration is a helpful tool to mitigate biodiversity loss. Plant species face a lot of threats (climate change, fragmentation and habitat loss, invasive alien species, pests and pathogens) and some are in danger of becoming extinct. The effect of climate change on plants, both physiologically and on the community level, are well documented (Keel, 2007; Hawkins, 2008; Breed et al., 2011; Thomas, 2011). Climate change leads to a rise in temperature and to an increase in weather extremes. Species that cannot migrate or evolve fast enough are "trapped in habitats to which they are no longer adapted" (Southgate, 2008). A recent study (Zografou et al., 2014) demonstrated that butterfly communities in a national park changed during the last thirteen years. Some species are expected to expand their ranges outside the borders of the protected area and, therefore, to leave it. Additional management actions will be required when habitat protection is insufficient. Conservation biologists must assess all options and rethink the role of protected areas when key species move away (Zografou et al., 2014).

A global warming of 2-3°C during the next 100 years is expected to threaten up to the half of the world's plant diversity to extinction (Hawkins et al., 2008). Plants are expected to migrate higher in elevation or more to the north, but global warming and range shifts are uncertain and predicting how the world will change until 2050 or 2080 is difficult. Knowledge regarding species dispersal, their future ranges and suitable habitats is fundamental for assisted migration. Shortsighted models are less uncertain and so conservation focuses on the near future, e.g., to 2020. In some areas where a suitable habitat is predicted to occur, these conditions cannot be currently found, so growing maladapted species will not work there. Trees are most vulnerable in their juvenile stage and require a suitable habitat when planted and during their juvenile stage (Gray et al., 2011).

Many studies that mention climate change focus on an average temperature rise, but global warming is not the only problem. Severe weather extremes such as colds or droughts cause also additional stress. Only a few studies have documented the effects of these weather events on conservation efforts. One example is the assisted migration project in southwestern China. Herbivory led to higher mortality than extreme cold and no correlation was found between a severe drought and mortality. Thus, biotic interactions can have a greater effect than climate conditions and climate should not be overestimated. In this study transplant shock was relatively low because larger plants were used. They were tougher and had more time to acquire mycorrhizal fungi (Liu et al, 2012).

Some studies have suggested that assisted migration is only a tool to mitigate climate change (Keel, 2007; Hoegh-Guldberg et al., 2008; Hällfors et al., 2014b). With prioritising species endangered by climate change, other factors (especially fragmentation) that lead to extinction can be underestimated, even if their consequences are easier and more precise to predict. Currently, land use change is the biggest threat to plant biodiversity in Austria (Fischer et al., 2008). Intensified land use causes the fragmentation of natural habitats and a higher nitrogen input that changes abiotic conditions. Land use change continues and shapes a landscape dominated by agriculture and cities, whereas isolation and climate change harm the remaining rest of natural ecosystems (Hannah, 2011).

Fragmentation affects “the population dynamics, genetic diversity, and overall fitness of species and poses serious threats to the integrity and long-term sustainability of the entire ecosystem” (Rossetto, 2006). In a diverse landscape, species live in spatially and temporally dynamic metapopulations. The subunits are linked through gene flow and the local extinction and recolonisation of subunits occur naturally. If a subpopulation is cut off, gene flow is restricted and natural recolonisation is impossible. The isolation of habitat patches leads to smaller populations, a decline in genetic diversity (inbreeding depression, genetic drift), fitness and adaptive potential. Isolated habitat patches have lower resistance and resilience (Myers et al., 2003) and they increase species vulnerability to disturbances. Edge effects, which are the disturbances of the transition zone between the habitat and the surrounding area, have a greater effect on small patches (Rossetto, 2006).

Of course, climate change is a huge problem, but different species are endangered by different threats. Although every threat can cause problems on its own, the addition of stressors is often the ultimate reason for population declines (Marris, 2009). The accumulation of threats is more difficult to predict and often underestimated. To choose the right conservation strategy for a species, a careful consideration of all relevant threats, including cumulative effects, is required (Prance, 2006; Tingley et al., 2013). The effects of climate change on plant species range shifts higher in elevation or latitude are well documented (Keel, 2007; Hawkins et al., 2008; Thomas, 2011), but “averaging behaviour across diverse species to find overall trends” cannot precisely predict what will happen to a particular species at one location (Tingley et al., 2013). Assisted migration is a chance to save biodiversity and its implementation can help all endangered species, regardless of whether these species are threatened by climate change, fragmentation or habitat loss.

Generally, assisted migration should not be refused. Ricciardi et al. (2009b) pointed out the negative effects of translocations and that biologists lack ecological understanding. However, if a minimal risk is not accepted and if time goes by with research without taking actions, less will be left for protection. McLachlan et al. (2007) said that “This war will have to be fought with the army we have, not the army we want”. The monitoring of every conservation project helps to improve the next project. Management actions also create a chance to study ecological principles and plant communities (Myers et al., 2003). Conversationalists who do not accept this strategy as an option to stop biodiversity loss (Davidson et al., 2008; Ricciardi et al., 2009b) should be able to suggest an equally successful or better alternative. All conservation possibilities should be compared and assessed.

Completely rejecting a strategy because of its uncertainty is like “putting one’s head in the sand” (Schwartz et al., 2009).

I agree with the critics that no unnecessary or high risk should be taken and that translocations can have severe negative effects (Ricciardi et al.; 2009b), but rejecting translocations as a precaution is no reason to ignore a chance to protect biodiversity. We do not lack as much ecological understanding as Ricciardi suggests (Sax et al., 2009). They show extreme examples and consider only the highest effect by multiple introductions (Schlaepfer et al., 2009; Vitt et al., 2009). Continent to continent translocations may cause severe problems such as biological invasions or the spread of pathogens and diseases. Continent to remote island translocations are expected to have the highest effect. These movements of species are risky and uncertain (Ricciardi et al., 2009b). Extinctions due to invasive alien species have occurred in isolated environments with a high rate of endemic species or after translocation into a new biogeographic region (Thomas, 2011). More than ninety per cent of extinctions caused by non native species have occurred on islands, and compared with the many introduced species, only a few have become extinct (Sax et al., 2008). Many habitats were historically uniform and today, the species face human-made limitations. I do not suggest large distance translocations for Austria and agree with Keel (2007) that “assisted migration should move a plant just fast enough to track shifting habitats and is not intended for long-distance introductions”. Even intracontinental translocations of threatened species, such as considered, e.g., by Thomas (2011) from the European continent to the United Kingdom, are one step too far. I would use assisted migration in Austria first for native species that have been proven to lack the capacity to expand their range on their own to the extent required to secure their survival according to model predictions. These species would include several local endemics and species on mountaintops or other fragmented habitats. The colonisation, e.g., of a mountaintop, but not of the adjacent, perhaps higher one, could have occurred by chance. With translocations just outside a species’ range, the risks can be estimated better than with large distance transfers. Moving species can be cheaper and easier than building corridors (Willis et al., 2009). European landscapes are highly fragmented and large connected areas of wilderness, as found in Australia or in the United States, often do not exist. The migration of species with a low reproduction rate or limited and slow dispersal can be accelerated by assisted migration and they can get across anthropogenic barriers. Short distance translocations, including those outside the species’ common and historical range, are less likely to cause problems with invasiveness than large distance transfers (Wilson et al., 2009). After a careful risk assessment translocation in form of a short distance assisted migration in a fragmented landscape to prevent a species from extinction seems acceptable (Vitt et al., 2009).

As suggested by Loss et al. (2011), an integrated strategy seems to be a good idea because habitat loss and fragmentation, as main reasons for declining biodiversity, should be stopped by connectivity first and, if necessary, then should be supported by assisted migration projects for selected species. Corridors can support species migration on their own and additional human interventions, e.g., translocations and the risks involved, become unnecessary. However, Lawler et al. (2011) believe that the risks of enhancing the connectivity of a landscape and assisted migration are quite similar. The receiving ecosystem will have to cope with new species and that does not depend on the way the species come. A corridor will facilitate the movement of more species, including pathogens and those unpredicted or unknown. An assisted migration project moves only one selected species, which makes the risks more predictable and controllable. Although both conservation tools have the same goal, namely to help species to move to suitable habitats, corridors are more accepted than assisted migration. Deciding for a conservation strategy is an ethical issue because enhancing the connectivity seems to recreate “the natural order of things”, whereas assisted migration is thought to be another human intervention in natural processes (Lawler et al., 2011).

I do not see assisted migration as the last resort and agree with Richardson et al. (2009) that it should be taken into consideration equally with the classic strategies. A strict order when it comes to choose the right conservation tool should not exist. First, what the conservation subject is, i.e., a natural ecosystem, an ecosystem function or a species, should be clear. The intentional movement of a species outside its range can be considered for restoring ecosystem functions (ecological replacement; Seddon et al., 1999) or protecting species from extinction (assisted migration; Ricciardi et al., 2009b).

Vitt et al. (2010) are not convinced about assisted gene flow and described this method as relatively risky. For Austria, I want to focus on assisted migration at the species level and do not consider genetic assisted migration on its own. Endemics and rare species often exist as only one population, so introducing new genotypes to enhance their fitness or evolutionary potential is impossible. The introduction of genetic material from populations outside Austria to populations inside could be implemented for two reasons: to rescue the population from fitness loss or to boost a populations’s genetic variation and to enhance its evolutionary potential (Shoo et al., 2013). For both cases, detailed genetic research is necessary to minimize the risk of losing genetic variation in the source and the sink population. With limited resources conservation biology should focus on taxa with a high extinction risk in favour of genes.

It is difficult to estimate if with an increasing genetic variation a species can evolve fast enough to track changing conditions, e.g., climate change. Genetic assisted migration cannot help if a species is endangered by habitat loss because a population that does not spread cannot maintain the added genetic diversity. A single human-aided genetic input to an isolated population is not a long-term solution because no natural, self-sustaining reinforcements exist. Introducing too different genotypes can lead to outbreeding depression (Kramer et al., 2009; Burbidge et al., 2011; Shoo et al., 2013).

Genetic assisted migration can be considered for commercial forestry to prevent adaptational lag. Reciprocal transplant experiments demonstrate where introduced genotypes outperform local ones. Southern sources grow better more to the north (Gray et al., 2011).

The AMAT (assisted migration adaptation trial) in British Columbia is not real assisted migration; it is a reintroduction to survey the effects of climate change on commercial forestry. However, taking the next step and planting trees outside their recent and historical ranges is not difficult. The interest in moving trees for economic reasons is high because commercial forestry will have to find a solution to productivity loss caused by climate change (Marris, 2009). Social pressure to keep managed forests healthy also exists (Fernández-Manjarrés et al., 2010). I can understand that point and do not think that translocations for economic reasons should be banned, but they should also be scientifically evaluated and assessed. Future forestry should be arranged as a more natural forest supporting biodiversity through natural structure and composition. Seeds from commercial plantings can affect protected areas and facilitate invasive alien species. If assisted migration is rejected by scientists, it must not be implemented by the forestry industry. I agree with Stone (2010) and Fernández-Manjarrés et al. (2010), who suggested that conservationists should advise all assisted migration programmes, including those in managed forests.

Green et al. (2010) are convinced that introducing lobsters into coastal sites will reduce the pressure on local populations. The introduced lobsters are growing and reproducing faster, so less high value individuals will be harvested. However, I doubt on the conservational success of this project, because I expect a greater use of the increasing resources.

Regan et al. (2011) evaluated the potential of assisted migration for Tecate cypress, but the effects of translocated individuals on the native ecosystem were not discussed. This theoretical study only focused on the tree’s biology and on the effects on its remaining source populations. It cannot provide answers to socio-economic, ethical or political questions that arise with any assisted migration project. On its own, this study does not allow its implementation.

I agree with Hannah (2011) and Loss et al. (2011) because the need for protected areas will remain and neither reintroductions, restorations nor assisted migration projects can replace them. In a reserve, all natural processes, such as natural catastrophes (e.g. fire, avalanches, etc.) or evolution, are protected. A natural ecosystem could never be compared with a human-made. Minteer et al. (2010) call them the "poor cousins of unaltered wildness". We lack understanding regarding biotic and abiotic interactions and processes. Many species remain unknown, but in a reserve they are protected although never noticed. With assisted migration, we attempt to help selected species to survive in a world where they could no longer exist without human intervention, but a broad application is unlikely. This conservation tool would not be possible for most species for several reasons, e.g., high risks, less knowledge of ecosystem functions or of the species itself, too expensive or impossible implementation (Loss et al., 2011). The main part of biodiversity will be protected in some areas. Assisted migration is a strategy that can help a single species where other conservation tools fail. The selection of species is subjective because they seem to be threatened, important, easy to move or only because they are more charismatic than others are. Well researched organisms, e.g., mammals or vascular plants obtain greater attention than fungi and microorganisms. Assisted migration provides a solution for some species and for the rest well-linked protected areas, reintroductions and ex situ storage is required (Regan et al., 2011; Hannah, 2011; Loss et al., 2011).

Deciding to use assisted migration is not easy and should be performed with a checklist step by step for every single species. If assisted migration is suspected to be the best strategy, the checklist can confirm it. A careful benefit and risk assessment can prevent negative effects (Sax et al., 2009; Burbidge et al., 2011). To my mind, a scientific evaluation of every assisted migration project is compulsory (Schwartz et al., 2009). The challenge is to find the golden mean between benefits and risks.

3.3 A checklist for assessing the framework for potential assisted migration

"We expect that future "assisted migration biologists" will find themselves in similar position to today's invasive species biologists: looking for useful generalizations in theory and struggling with unforeseen idiosyncrasies in practice."

McLachlan et al. (2007)

In recent years different assessments and aids to decision-making for assisted migration (Hoegh-Guldberg et al., 2008; Richardson et al., 2009; Laws et al., 2012; Shoo et al., 2013) and for all translocations (Burbidge et al., 2011, IUCN, 2013) were suggested. I will take them into account.

The following checklist is a framework for assessing and planning assisted migration to protect a species from extinction. It makes a standardized procedure and decision possible. All relevant effects can be well considered. This checklist is similar to the IUCN Guidelines for Reintroduction, which is mainly addressed to scientists, because its use requires ecological knowledge. An interdisciplinary working group (see IUCN, 1998 and 2013) will obtain the best result because expert knowledge in different special fields improves the benefit and risk assessment.

The focus of this checklist is on assisted migration projects for plants, but many questions are also important for other organisms.

Each species is different and should be evaluated on its own (Vitt et al., 2009), but paired or multispecies assisted migration could be considered, too (Hawkins et al., 2008).

Assisted migration should be only implemented for biodiversity conservation (and not, e.g., for economic reasons) and when all other conservation possibilities are checked and none is better (but perhaps equal).

The checklist explains to what criteria attention must be paid to and which questions must be answered before an assisted migration project is implemented.

3.3.1 Legal situation

The first step for planning a conservation action is to make sure that it is legal. Policies and regulations for the movement of species using assisted migration are lacking and this increases the risk of biological invasions and threatens recent conservation work. Three assisted migration position types were identified: strong advocates, absolute rejecters and balanced considerers. The only acceptable position is the last one and it should be stipulated by law (McLachlan et al., 2007).

<u>What is the international legal basis for assisted migration?</u>

An international legal framework for conservation is the Convention on Biological Diversity (CBD). Article 8 refers to in situ conservation and Article 9 to ex situ conservation.

Article 8 (f): “Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies” (CBD, 1992). Assisted migration is a strategy that facilitates restoration as well as species recovery.
Article 8 (h): “Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” (CBD, 1992). Deliberate introductions, including assisted migration, should not harm native organisms and with a careful risk assessment negative effects could be avoided.
Article 9 (c): “Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions” (CBD, 1992). Ex situ conservation supports in situ conservation, as explained previously (see 3.2. The role of botanical gardens) and assisted migration is a possible conservation action for the recovery of threatened species in the wild.

The legal framework for conservation in the European Union is the Council Directive 92/43/EEC of 21.5.1992 on the conservation of natural habitats and of wild fauna and flora. According to Article 22 “Member States shall:

(a) study the desirability of re-introducing species in Annex IV that are native to their territory where this might contribute to their conservation, provided that an investigation, also taking into account experience in other Member States or elsewhere, has established that such re-introduction contributes effectively to re-establishing these species at a favourable conservation status and that it takes place only after proper consultation of the public concerned;

(b) ensure that the deliberate introduction into the wild of any species which is not native to their territory is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider it necessary, prohibit such introduction” (Council Directive 92/43/EEC, 1992).

Article 22 (a) addresses reintroductions, but does not refer to assisted migration although some points would count for it, too. For instance, considering the experiences of other member states is also a good idea. The concerned public should be informed and taken into account for all types of conservation projects. Article 22 (b) is in force for all deliberate introductions of non native species to their territory, including assisted migration. This article protects the wild native fauna and flora and their habitats and makes the prohibition of introductions possible.

Is the implementation of assisted migration regulated by law?

The IUCN Guidelines for Reintroductions (1998), a framework for the implementation of reintroductions and a helpful tool at the planning stage of assisted migration projects, as well as the IUCN Guidelines for Reintroductions and other Conservation Translocations (2013) that directly support assisted migration, have no international legal basis (Osborne et al., 2012).

CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an agreement that regulates the international trade of endangered taxa, but no law exists that prohibits or regulates the intentional movement of threatened species (also for conservational reasons) inside a state, e.g., as the Torreya Guardians do. In the United States, government agencies develop plans to protect biodiversity, but they lack regulations regarding newly introduced species for conservational reasons (McLachlan et al., 2007). I agree with McLachlan et al. (2007) and Mueller et al. (2008), who believe that "policy should limit unsupervised translocations". These actions perhaps performed with good intentions, but without a scientific evaluation, could have several negative consequences. Dove Sax, a conservation biologist, summarizes: "They have every right to try and fix a problem that they don't see anyone else dealing with. It makes me nervous to think that any group could move any species they wanted" (Stone, 2010).

In Australia, the draft national guidelines for fauna translocation, which are based on the IUCN guidelines, were adopted by Australian regulatory authorities. The Australian Network for Plant Conservation produced guidelines for plants and flora translocations are implemented similar to fauna (Burbidge et al., 2011). Such national guidelines do not exist for Austria, and even for Australia, Burbidge et al. (2011) concluded: "The current policy positions of jurisdictions that will regulate AC (assisted colonization) are unclear."

Beside the Council Directive 92/43/EEC (1992) on the conservation of natural habitats and of wild fauna and flora, no additional law exists that prohibits or regulates the intentional movement or establishment of legally acquired plant material in Austria.

Is there any other political or legal regulation?

All political and legal regulations on a provincial, national and international level should be checked before the implementation of assisted migration. Paying attention to all involved countries, including those involved indirectly through introductions in border areas or when a species is expected to expand its range into a neighbour state, is important (IUCN, 1998 and 2013).

Other limitations could be, e.g., land ownership, if the area that has been predicted to be a suitable habitat for assisted migration is private or forest law regulations, e.g., for adjacent woodlands to prevent pests.
Forest planting policies use the advantage of growing local adapted trees, and in British Columbia, the movement of seeds was restricted to 200 km from their origins and 200-300 m down- or uphill. A change in policy occurred when foresters and politicians were scared by climate change forecasts. Seeds could be transported 500 m higher in elevation from then on (Marris, 2009). This example demonstrates that such rules are not stable and could change with policy-makers' opinions.

3.3.2 Risk assessment

This part of the checklist must be considered in an extremely careful, transparent and precise way. Introduced species can have severe effects on native organism and ecosystems (Essl et al., 2002; Myers et al., 2003; Ricciardi et al., 2009b) and assisted migration should be considered well enough to prevent the indigenous flora and fauna from invasions. Conservation biologists agree on a benefit and risk assessment where negative consequences are weighed against the possibility for extinction (McLachlan et al., 2007; Hoegh-Guldberg et al., 2008; Burbidge et al., 2011; Hannah, 2011; Lawler et al., 2011, IUCN, 2013). Predicting how translocated species will affect an ecosystem is difficult (Ricciardi et al., 2009b; Lawler et al., 2011), but species where negative effects have been documented or expected should be excluded from assisted migration considerations. The risk assessment helps to identify those taxa where assisted migration is not an option. In the cases where a "substantial uncertainty about the risks of a translocation outside indigenous range remain, such a translocation should not be undertaken" (IUCN, 2013).

Is it a (highly) threatened species?
Keel (2007) presented plant candidates for assisted migration: "endemic species with limited range, an endangered species, a species that is not an effective disperser, a species that requires a unique habitat, a species with narrow environmental tolerances, compressed latitudinal or altitudinal range, species with only one or a few populations, small population size, less competitive than invasive species or other native species". Endangered species can be found, e.g., on national red lists and they often belong to more than one candidate group mentioned by Keel (2007), e.g., species with narrow environmental tolerances live in a small

habitat and can be less competitive in a changing climate than migrating (and invading) generalist species. Thomas (2011) saw narrow endemics that face dispersal barriers at the greatest risk of extinction. Kramer et al. (2009) considered the "losers in a rapidly changing climate" as species with a long generation time, small ecological amplitudes or low additive genetic variation (a low evolutionary potential).

For a species clearly in rapid decline, extremly rare or endemic, action must be taken immediately, and assisted migration seems to be more acceptable as a solution for these endangered taxa (Hunter, 2007). By their biological features proving causes for their decline or limitations, such species are expected to pose a lower risk for invasiveness and are unlikely to be strong competitors in the new environment because they have become highly threatened in their natural range. However, if the species is threatened because of habitat loss, it can be a competitor to native species in the target habitat.

Plants face different problems and with the addition of stressors identifying the major threat can be difficult (Hunter, 2007). I do not think that assisted migration is only an option for species threatened by climate change, but the reason for their extinction risk should be evaluated to help to find the best conservation strategy.

In 4.1 Selection of species, I explain how species were selected for assisted migration in Austria.

Is it expected to carry dangerous pests or parasites?

Newly introduced diseases are a serious risk for native organisms. Plants are hosts and with their translocation they could be vectors for the spread of parasites and pests. Differences in host specification and host changes exist and the use of new hosts is possible (Essl et al., 2002). Identifying infected plants could be difficult because these plants may not display symptoms. Parasites may not cause problems in their native range because their hosts are immune (Myers et al., 2003; IUCN, 2013). Before a species is introduced into a new habitat, especially if it is outside its common range, it should be considered which diseases it could carry and spread theoretically and if they would be new to the target habitat. A particularly high risk for generalist pathogens that have no history at the target site exist (IUCN, 2013). If the transfer distance is short, then the risk of introducing a completely new disease is small. The plant material used for assisted migration should be screened for pests and parasites, or, as the IUCN formulated in 1998 for reintroductions, an "appropriate health and genetic screening of release stock" is necessary. In 2013, the IUCN called for a pathogen risk assessment for all translocations.

Was it used in any other conservation project?

Past experiences with a species in other conservation projects, e.g., reintroductions or restorations can help to understand how it behaves in a new environment and if the ecosystem is negatively affected (Mueller et al., 2008). Recent knowledge base can also help to identify those taxa with a high invasion potential (Vitt et al., 2009). Before the implementation of assisted migration, many issues require attention and there is not enough time, nor money to start a complete research programme (Hunter, 2007). However, data could be already be available for many species. Information can be collected from previous projects, experiments, botanical gardens including herbaria, historical records or future models that forecast climate change, species distributions and population dynamics. Paleoecology can demonstrate how species reacted to a changing climate in the past (Vitt et al., 2009; Lawler et al., 2011). The study of invasive alien species' ecology can also help to understand basic ecological processes and interactions (Hunter, 2007).

At the planning stage assisted migration projects will benefit from expert reviews.

Is the species a weed in any other part of the world?

The introduction of nonnative species can have extremely negative consequences. Although a species is endangered in its home range, it could be invasive in another part of the world. Island ecosystems are particularly vulnerable. Many species have already been documented to cause problems, but continue to be introduced to new tropical islands, e.g., *Miconia calvescens*, which was brought to Tahiti for ornamental reasons in 1937. This invasive plant has an effect on about fifty endemic species, and some of them are highly threatened now (Kiehn, 2012).

If the considered species is documented to be a weed somewhere, then it should not be moved through assisted migration becaude it could also become a weed in the new environment (Myers et al., 2003). Additional data are provided by botanical gardens that use weed risk assessment. These gardens monitor their collections and identify those taxa with the ability to be invasive (Primack et al., 2009).

Can the species be dangerous to any other species or to the ecosystem?

According to Myers et al. (2003) the following three basic interactions must be considered: plant-environment, plant-herbivore and plant-plant. If the introduced species is a keystone species it can have a high impact, e.g., by altering the food web. An introduced species can be dangerous to another species directly, e.g., through competition, hybridization, disease transmission (IUCN, 2013) or indirectly by altering an ecosystem, e.g., as an ecosystem engineer or if it changes the habitat conditions such as the soil biochemistry or hydrology. A nitrogen-fixing plant (e.g. Fabaceae) changes soil conditions and facilitates its own growth. Other taxa can alter natural disturbances, e.g., fire. The grass *Andropogon* in Hawaii is a fire-enhancer. *Bromus tectorum*, which is an invader in North America, also increases the possibility and severity of fires (Myers et al., 2003). In Austria *Acer negundo* can change a riverside forest's structure by forming a second tree layer. The increasing shade hinders the establishment of native tree seedlings, e.g., willows.

These examples demonstrate that a species and its effects on both on the ecosystem and on other species must be well researched for a serious risk assessment. The assisted migration implemented by Willis et al. (2009) mimicked natural range expansion in the United Kingdom and was extremely unlikely to have negative consequences. Two butterfly species were transferred to areas outside their range, but the native species there coexist with the introduced butterflies elsewhere.

Has the species the potential to be invasive?

To answer this question the species ecology and life circle must be studied, but this topic is so complex that a risk will always remain, although it is minimized.

In Austria, fourty-three per cent of alien plant taxa are among five plant families that are also very diverse with native taxa: Asteraceae, Poaceae, Brassicaceae, Fabaceae and Rosaceae. However, species-rich families, such as Orchidaceae and Primulaceae, do not display any alien species (Essl et al., 2002).

Predicting the invasiveness of a species is extremely difficult and no standardized rule exists. "Life history traits" provide information about the fitness of a species, e.g., pollination, growth form, seed number and size. Those characteristics help to plan the establishment of a species and so the project's success. Additionally, some life history traits are typical for invasive species and could indicate translocations that are more risky. Alien plant invaders are split up into two groups: "tall, spreading competitors and small, short-lived, fast-growing species with high reproductive output" (Myers et al., 2003). Essl et al. (2002) counted successful alien plant species characteristics: short-lived, a short juvenile period, many seeds, asexual reproduction and very tolerant.

Some additional questions that can help to identify taxa with a higher invasion risk are:

Is it a specialist or generalist? Alien species that are generalists are more successful than specialists are (Essl et al., 2002).

Is it fast or slow growing? Weeds are fast-growing, short-lived species and these traits can facilitate invasiveness (Myers et al., 2003).

How does it reproduce? A species can spread efficiently with a high reproductive output (many small seeds) and this output increases the potential to be invasive. Species that are able to reproduce sexually and vegetatively have an advantage over those with only one reproductive method. Rapid growth and reproduction are typical for plants in an early succession stage (Myers et al., 2003).

How does it disperse? Species with specific biotic interactions are less able to become invasive, e.g., a co-evolved pollinator limits dispersion because a species could not establish a population outside the pollinator's range. The pollination and dispersal vectors play a role in dispersal success (Myers et al., 2003; Keel, 2007). Species that are poor dispersers are not expected to be invasive because their range is naturally limited (Keel, 2007).

The knowledge of dispersal pathways is crucial for assisted migration. Wilson et al. (2009) concluded: "Biological invasions are often the result of multiple introductions from multiple sources to multiple locations." He describes the following six basic dispersal ways: leading edge-dispersal, corridor dispersal, jump dispersal, extreme long-distance dispersal, mass dispersal and cultivation. The last two only occur by human mediation. The main differences between natural and human-mediated introductions are that natural introductions occur over a long time and are genetically limited, whereas humans introduce large genetic diversity fast. Natural long-distance dispersal, e.g., to oceanic islands, is extremely rare and when it happens, only one or a few individuals from one origin are transported (Wilson et al., 2009). The consequences for assisted migration are that if natural migration is accelerated and imitated to mitigate climate change, genetic diversity should not be overrepresented. Movements over a short distance are more likely to occur naturally. They can represent high genetic diversity and so they are more suitable for assisted migration. To protect biodiversity the full extent of genetic diversity must be conserved, but a long-distance translocation is unlikely to host a species' genetic diversity. Assisting long-distance migration from several origins to only one target area is not a solution.

To summarize the aspects mentioned above, the main question is:

How well has the species been studied?

The success of conservation depends on the understanding of ecological principles and how this knowledge can be implemented (McLachlan et al., 2007). If life history traits, abiotic and biotic interactions are well documented, it is likely to properly assess a species' behaviour and ecological role in a new habitat, as well as the project's risks. Information should be collected from "publications, reports, species action plans and consultations with relevant species experts including both professional and amateur naturalists" (IUCN, 2013). A lack of information will hinder every conservation project.

Ricciardi et al. (2009b) called assisted migration "planned invasions". I think that the conservation of endangered species outside their natural range means being an alien species, but not being invasive. Ricciardi et al. (2009b) demonstrated extreme examples of translocations that could not occur naturally, e.g., the movement of freshwater fish between lakes. I consider assisted migration as a strategy to facilitate natural movements of plants and agree with Vitt et al. (2009) that assisted migration is a conceivable option in geographically continuous ecosystems that are now fragmented and dispersal-limited.

In addition to the likelihood of an invasion, its severity must be considered, too. Mueller et al. (2008) concluded that the invasion risk for species moved under intracontinental assisted migration is small, but when a species becomes invasive, the likelihood to cause severe problems is as high as with distant invaders. Generally, assisted migration is more suitable for plants because a lower invasion risk exists compared with that for other taxonomic groups, e.g., fish (Mueller et al., 2008).

3.3.3 Habitat selection

Selecting a habitat for assisted migration is a wide topic that could be discussed on its own in another master thesis. First, habitat selection depends on what type of habitat is chosen: a natural, semi-natural or anthropogenic modified and highly influenced habitat. No suitable habitat may exist and it may have to be restored before a species conservation programme can take place (Osborne et al., 2012). Aerial pictures can indicate possible target habitats and a decision can be made after several visits (Schumacher et al., 2013).

Current and predicted future distribution models are required to identify suitable habitats (Hawkins et al., 2008). For example, Willis et al. (2009) and Gray et al. (2011) used climate envelope models that predict the distribution of a species relating to climate. However, they did not show how sensitive a species is and if it can adapt to the changing conditions (Rout et al., 2013). A summary of all published papers (until 2010) that use population models to predict reintroduced populations was presented by Armstrong et al. (2012). Modeling can put the knowledge from autecological studies into a landscape context (Osborne et al., 2012).

Environmental and population variables can be identified through population and habitat viability analyses (IUCN, 1998).

I will compare and analyse two assisted migrations to a natural ecosystem, with one to an anthropogenic environment (see 4 Management proposals). The following questions are important for all habitats.

Does the habitat offer what the species requires?

First, all available information should be collected to determine species requirements. Additionally the IUCN Guidelines for Reintroductions (1998) suggest detailed studies of wild populations to obtain further information. Data from closely related species can be used for modeling alternative conservation strategies and for identifying possibilities at an early stage (IUCN, 2013).

All ecological criteria should be checked: abiotic factors, e.g., soil conditions, climate, water and nutrition, as well as biotic factors and interactions, e.g., food chain (predators, herbivores), symbiotic relations (e.g. mycorrhizae, pollination), associated taxa (IUCN, 2013), pests and pathogens (Hellmann et al., 2012). Current populations of a target species must not grow under most favourable conditions because threats can force them to sub-optimal habitats (IUCN, 2013). Similar to reintroductions assisted migration “should only take place where the habitat and landscape requirements of the species are satisfied” (IUCN, 1998). The target habitat could be natural, semi-natural or anthropogenically modified. Releases to more than one location allow the species to select its most favourable habitat, to survive local disturbances and to develop subpopulations (IUCN, 2013).

The most frequently attributed reason for low success rates in reintroductions is the lack of habitat quality and that could be also true for assisted migration (Godefroid et al., 2011; Osborne et al., 2012).

Are the resources sufficiently accessible to the introduced species?

To illustrate this question, we also could ask: Can we expect “free niches” in the selected habitat? The ecological niche is a multidimensional system. It is a species’ specific attribute that describes under which conditions a species exists. Under this definition every species creates and occupies its own niche (Colwell, 1992), so introduced species can lead to the formation of new niches, but no “free niches” exist. The niche concept illustrates that resources should not only exist theoretically before the implementation of assisted migration, these resource should be accessible for the introduced taxa. Plants grow in their persistent niche, but for a long-term self-sustainable population conditions that allow a species to reproduce, the recruitment nice must be found (Liu et al., 2012).

Ecologists talk about ecological licences that could be used by introduced species or that could be left vacant when species become extinct. Anthropogenic activity can create new licences, e.g., in cities (Essl et al., 2002) and could be used for assisted migration. I will consider human-created locations in Vienna as habitats for *Lepidium perfoliatum*.

Can appropriate conditions be restored?

If a habitat does not provide all biotic/abiotic conditions expected to be necessary to support a species' survival, then it is not suitable. However, if no better fitting habitats exist, restoration is an opportunity to create the required situation. Before starting the implementation, management actions focus on the factors that are expected to be critical for the project's success (Nichols et al., 2012). The creation of spatial structure, the change of abiotic conditions or the transfer other species could occur for fundamental biotic interactions. Management efforts to prepare a location before a plant reintroduction result in a higher survival rate (Godefroid et al., 2011).

Paired or multispecies assisted migration must be considered in some cases (Hawkins et al., 2008), e.g., special plant-pollinator interactions (IUCN, 2013). Less attention has been given to co-evolved taxa so far, but this topic must be dealt with in future assisted migration planning (Burbigde et al., 2011).

Observations in the Botanical Garden of the University of Vienna have demonstrated general differences in the implementation of assisted migration between plant communities, e.g., calcareous and siliceous grasslands. For calcareous grasslands species that create spatial structure are planted first. Then the target species are introduced to the grassland. They can be established now because they need the structure and the presence of taxa that grow in their natural community. This procedure did not work for siliceous grasslands so far; here each species must be brought in individually (personally reported by Kiehn, 2014).

How far is the selected target habitat from the species recent range?

As mentioned previously (3.2 Critical analysis of assisted migration and 3.3.2 Risk assessment), assisting migration over a long distance is not an option. Those translocations are unlikely to occur naturally and might result in biological invasions. With an increasing translocation distance there is a higher risk of spreading diseases (IUCN, 2013). In contrast, short distance jumps are less risky and can prevent species from extinction or restore ecosystems (Keel, 2007; Wilson et al., 2009; Vitt et al., 2009; Vitt et al., 2010; Thomas, 2011). It can be also argued that species have spread to a nearby habitat on their own without human intervention.

Assisted migration should occur within a geographic region to a location that lacks local endemics (Thomas, 2011).

In many cases knowing the exact historical range of a species is difficult (Hellmann et al., 2012). If a habitat close to its common range is selected and the species' history is not documented, it could be a reintroduction. However, this definition is less important because the checklist points can be considered for reintroduction, too. One example where whether the habitats chosen for a transplanted population are part of the historical range is unclear is *Artemisia pancicii* at the Bisamberg in Lower Austria (Schumacher et al., 2013).

<u>What is surrounding the selected habitat?</u>

Selecting the target habitat for assisted migration includes paying attention to the surrounding area and how it will be influenced. The transferred species can potentially spread or carry diseases (IUCN, 2013). In particular, this situation could be a problem if protected areas or threatened taxa exist in the surrounding environment. Another factor is the vulnerability of the surrounding environment and its populations. It must be taken into consideration that geographically isolated sites are more likely to host endemic species or genetically different populations. Economic loss for adjacent agricultural land is also a risk.

Hunter (2007) identified the ideal first site for translocations as one that was historically connected, but that is now surrounded by anthropogenically modified landscapes. In the case of negative effects, the human-dominated area works as a barrier.

Transferring a species to a degraded or restored habitat is more acceptable for many people than transferring it into or near the wilderness (Hunter, 2007). As a consequence more communicative work is necessary when a natural or protected area is involved or influenced.

<u>Is the target habitat persistent or will it be degraded during the next one hundred years?</u>

All recent and future threats to the target habitat must be considered (ongoing climate change, fragmentation, pollution, expected biological invasions, potential changes in landuse). A habitat selected to host an endangered species must not be degraded too much. I think that considering one hundred years is realistic for a calculation because all models that calculate beyond one hundred years are very uncertain. One hundred years would be sufficient time to manage the habitat until it is self-sustainable or for additional translocations to other habitats, if required (Regan et al., 2011).

Optimally, the introduced populations must be secured from negative human activities. If any negative activity is expected, then it should be minimized, otherwise implementing the project would not be sensible (IUCN, 1998). Assisted migration is not an option when the species is expected to be more harvested or hunted as could occur, e.g., to rare coral species (Huang, 2008).

Endangered species must be protected when moved to a new area, particularly when these species are are expected to become extinct in their native habitat. After finding a suitable future habitat and establishing a population there, strong legal protection must follow (Chapron et al., 2008). Godefroid et al. (2011) demonstrated that plant reintroductions into protected areas are more successful than those into unprotected areas because more individuals survive. These results are easier to recognise after several years.

3.3.4 Genetic considerations

As mentioned previously (see 3.2 Critical analysis of assisted migration), this checklist is intended to evaluate assisted migration as a strategy to introduce taxa outside their common range. Genetic assisted migration that moves genotypes would require other considerations and is a solution for different initial situations, e.g., a locally threatened population of a common species with low genetic variability.

To establish a new population outside a species' range requires some considerations about the species' genetics. A genetic risk assessment can avoid negative effects on the genetic level both on the moved species (inbreeding or outbreeding depression, genetic drift) and on other taxa (heterosis). Plant conservation genetics guide projects to minimize extinction risk and to boost resilience, adaptive potential and survival (Kramer et al., 2009). Genetic risk assessments are developed to prevent genetic invasions in revegetation programmes, but are often not used (Burbidge et al., 2011).

In a survey of plant reintroduction programmes a higher survival rate of target species was detected for those projects that incorporated genetic diversity into their design (Godefroid et al., 2011).

What is the genetic structure between and within populations?

For assisted migration the genetic diversity of a species must be studied both between and within populations. The knowledge of a species' life cycle (breeding and mating system, dispersal pathway) and natural populations can help to establish a genetically representative viable population (Kramer et al., 2009; Burbidge et al., 2011). The translocation of species with a high genetic diversity, e.g., *Dracocephalum austriacum*, is more complicated than for more uniform species that primarily clonally reproduce. The more diverse genotypes exist, the more can be lost. A source population with a low genetic diversity is more likely to be fully represented in the new population (Groombridge et al., 2012).

The sampling of a species that only vegetatively reproduces (e.g. *Artemisia pancicii*) is easy because all individuals are genetic clones and because the population can be founded with the vegetatively propagated offspring of only one individual. However, with every translocation more than one individual will be moved because a high risk of accidental extinction exists. Paying attention to reproduction is also important for self-incompatible species because they are at a higher risk of genetic erosion (Kramer et al., 2009).

How often and how many individuals should be released to establish a population?

First of all, realising that no universal minimum population size exists is important. The propagule pressure (namely, how often and how many individuals are released) required to establish a self-sustaining population depends on the life history traits (Wilson et al., 2009), breeding system (Godefroid et al., 2011) and genetic diversity of a species. The higher the genetic diversity, the larger the newly established population must be. Enough individuals should be released to minimize the risk of inbreeding depression and genetic drift. Genetic erosion increases a species' extinction risk in a changing world because resilience and evolutionary potential decline with the loss of genetic diversity. It also concerns the entire ecosystem. With genetic erosion aboveground net primary production declines, trophic levels are altered and the invasion risk increases (Kramer et al., 2009).

Studies have demonstrated that the loss of genetic diversity can be avoided when many founder individuals are used, when immigration from other populations occurs or when the population is able to expand quickly (Groombridge et al., 2012). Jamieson et al. (2012) noted that "often the most important management action to prevent or minimize genetic problems is to maximise population growth".

Populations with a high genetic diversity, short lifetime and high reproductive output will have a greater adaptive potential (IUCN, 2013).

Fant et al. (2013) determined that reintroduced populations of *Cirsium pitcheri* had higher genetic diversity than native populations. However, reintroduced populations also had a higher inbreeding coefficient due to true inbreeding and due to the Wahlund effect driven by genetic sub-structuring. In small, reintroduced populations, only a few individuals flower and reproduce each year, indicating that considering not only the number of translocated individuals, but also the effective population size is important.

<u>Where does the material selected for translocation originate?</u>

First, whether the plant material used for assisted migration is already available should be verified. If the material is in an ex situ institution, then the next step is to discover its origin. With an unknown origin whether collecting new or additional material is necessary or whether the material could be used nonetheless, e.g., because it has been genetically or phenotypically analysed and assigned should be assessed; Obtaining new material may be impossible because the species is extinct in the wild or extremely rare. Using resources from ex situ collections is advantageous because it saves time and money. However, the two genetic bottlenecks that the used ex situ material went through, when collected and when individuals were selected (Groombridge et al., 2012) for assisted migration, should not be forgotten.

Target 8 of the Global Strategy for Plant Conservation (GSPC) emphasizes the importance of integrating ex situ conservation into recovery and restoration projects (Sharrock, 2012). However, assisted migration could be considered a conservation option for all species and not only for those species that are currently stored ex situ.

Loss et al. (2011) raised an important additional question: Is using material that includes the full genetic diversity or selecting better fitted material to enhance success, as is being performed by the commercial forestry industry, better (Marris et al., 2009)? I think that the answer to this question depends on what should be achieved with the conservation project. With assisting the migration of a threatened species that cannot survive in its home range, intraspecific diversity should be represented and conserved in new populations (Hawkins et al., 2008). If the source population’s genetic diversity has already declined, taking plant material from several origins can be considered. For reintroductions, Godefroid et al. (2011) recommended the use of a stable population as the source rather than a declining one that could have lost rare alleles. However, if individuals that are genetically too dissimilar reproduce, fitness is reduced through outbreeding depression (Kramer et al., 2009; Burbidge et al., 2011).

Traditionally, the plants used for restoration are from sources close to the target site because they match the predominant conditions (Vitt et al., 2010). “Plant populations are often adapted to local conditions” such as soil type, winter temperature, water conditions, local herbivory and pathogen pressure. However, in the case of restorations of significantly degraded landscapes, strategically mixing source populations is practical and cost-effective (Burbidge et al., 2011). The material can be a mixture of local genotypes and of those genotypes more adapted to the future situation (Sgrò et al., 2010; Shoo et al., 2013). Genotypes at the edge of a species’ distribution are adapted to extreme conditions on the limits of tolerance. Populations that live in a warmer climate in the southern part of a species range can be transferred more to the north to increase restoration success (Gray et al., 2011), but moving locally adapted genotypes to a new, dissimilar environment may result in fitness declines (Kramer et al., 2009).

The genotypes from more distant populations increase genetic diversity and adaptive potential and those benefits must be weighed against the risk of outbreeding depression (Burbidge et al., 2011).

Is hybridization a risk?

Plant species could be also endangered by hybridization (Essl et al., 2002). In the case of assisted migration, whether the moved species could form hybrids with native ones should be checked. Translocating threatened taxa to an area where their genetic identity is mixed up does not make sense. In extreme cases hybridization can lead to extinction (IUCN, 2013).

If closely related species are in an area where interspecific hybridization is possible, the next step is to assess whether the genetic mixture can be tolerated, e.g., because the hybrid species is less compatible or because hybridization is extremely unlikely (Ricciardi et al., 2009b). Intraspecific hybridization can occur between distant genetic lineages and lead to heterosis, where hybrid genotypes outcompete other species or where outbreeding depression results in fitness reduction (Burbidge et al., 2011). Outbreeding depression is less studied than inbreeding depression. However, it also requires management actions because this situation can lead to extinction in extreme cases (Kramer et al., 2009). Considering differentiation between source populations and their historic isolation helps to predict the risk of outbreeding depression (Burbidge et al., 2011).

3.3.5 Socio-economic aspect

Conservation biology cannot act without paying attention to social criteria. Social values depend on cultural and historical backgrounds and can change over time (Richardson et al., 2009). The protection of biodiversity is a matter of concern for the enire society and of course, an economic aspect exists. Assisted migration should not harm any ecosystem or native species, including humans. Communication is of vital importance for assisted migration because conflicts or negative attitudes can be avoided. It “should start at the planning stage, followed by reporting on progress at key stages” (IUCN, 2013).

<u>Is an economic loss or gain predicted?</u>
Severe effects of introduced species have been well documented (Essl et al., 2002; Mueller et al., 2008; Ricciardi et al., 2009b) and the potential effects on economic interests must be considered. Economic losses can be, e.g., the spread of agricultural weeds, changes in water or nutrient availability or the decrease in harvested species populations through competition or toxicity (IUCN, 2013).
If economic loss is inevitable, the second question is: <u>Can it be estimated and financially compensated?</u> If the loss is too high or if financial resources are insufficient to compensate for the loss, the project cannot be implemented and other conservation strategies must be considered.
In contrast, introducing species can also result in profit. They can be harvested in a sustainable way (Green et al., 2010), improve ecosystem functions or attract tourists (Seddon et al., 2012). “Sustainable economic opportunities should be established for local communities” (IUCN, 2013). However, an economic gain is an additional benefit and making a profit out of every assisted migration is not an objective.

<u>Does the introduced species have an effect on local people?</u>
Local people can be directly or indirectly influenced by introductions through consequences for their property or on the ecosystem (IUCN, 2013). The introduced species can have a negative effect on the health of the local community and their farm animals, e.g., it is toxic or leads to an allergic reaction. Toxic species should not be introduced near a settlement (Hoegh-Guldberg et al., 2008). An effect on a cultural value, e.g., on a totem species of traditional owners in Australia, can also occur (Burbidge et al., 2011). The IUCN (2013) expects that introductions of species outside their native ranges will be more likely to have negative

effects than reintroductions. This expectation can explain a pessimistic attitude regarding assisted migration in local communities. The assisted migration of species with a possible negative influence on people can be performed at an extremely remote habitat or another conservation strategy should be found.

Is the species charismatic and can the project be easily communicated?

Public participation that facilitates a project's implementation (through volunteer labour or knowledge) will increase with the success of communication. Convincing people of the necessity of an assisted migration of a charismatic, e.g., a rare tree such as *Torreya taxifolia* or a "beautiful" species, e.g., a colourful butterfly or an orchid with impressive flowers, is easier (Hunter, 2007; Stone, 2010). Species that are effective as publicity and liked by people can be moved, but inconspicuous, unpopular taxa can be also moved, with additional public relations work required.

Information regarding all persons involved is an important part of every conservation project and all benefits and risks should be revealed, especially for assisted migration (Burbidge et al., 2011). The IUCN (1998) stated: "The project should be fully understood, accepted and supported by local communities." Public media, events or lectures in the local authority will present the project. Internet resources and social media can offer additional knowledge (IUCN, 2013). Botanical gardens provide information for restoration projects (Hardwick et al., 2011) and they could widen their responsibility for assisted migration.

Public relation activities, including education, should continue after the project's implementation (IUCN, 1998). Education is particularly important because of its key role in securing future plant conservation (Hawkins et al., 2008).

With increasing urbanization, societies are expected to lack an understanding of nature and to become alienated from the natural world (Seddon et al., 2012). Plant conservation is especially unpopular because pubic media and education at schools is focused on animals (Hawkins et al., 2008). Conservation projects, including assisted migration, make an experience with nature possible and help to realize the importance of conservation.

3.3.6 Implementation

Although assisted migration may be acceptable for ecological and socio-economic reasons, implementation may not automatically be possible.

The IUCN (1998 and 2013) recommends the coordination of government agencies, landowners and conservation organizations.

Can the target habitat be reached?

This question refers to the target site's location and to its accessibility. If conservation biologists cannot travel to the location or if the plants cannot be transport there without destroying another habitat or private property, then the project cannot be implemented. Laws et al. (2012) identified potential sites for the translocation of the Guam Micronesian kingfisher (*Todiramphus cinnamominus cinnamominus*). The used framework paid attention to local infrastructure and demonstrated its important role in conservation planning.

Is enough plant material available?

With any translocation project, an adequate number of individuals must be moved to the new habitat (also see 3.3.4 Genetic considerations). Before implementation, sufficient plant material (living material or seeds) must be confirmed available. As shown for reintroductions, transferring seedlings is better than transferring seeds because seeds often fail to germinate (Godefroid et al., 2011). The plant material can be stored in an ex situ institution, e.g., in a botanical garden or in a seed bank. Considering the translocation of species already kept ex situ is advantageous. Botanical gardens are a good source for plant material and these institutions have experience in breeding it (Havens et al., 2006; Primack et al., 2009). I will consider assisted migration for species that are available from the Botanical Garden of the University of Vienna (see 4.1 Selection of species).

Vitt et al. (2010) proposed instructions for a seed collections that represents a species' genetic diversity. This collection could be difficult for extemely rare species because the release of a few plants can endanger the source population and this situation would be even more disastrous for endemic species. However, Groombridge et al. (2012) provided many examples where severely bottlenecked animal species recovered due to a reintroduction project, e.g., the Mauritius parakeet (*Psittacula echo*). For reintroductions, the IUCN (1998 and 2013) determined that the removal of individuals must not harm the captive stock or wild source population and called for an assessment of possible negative effects. I also recommend this procedure for assisted migration.

Due to limited time and resources, species that could be used for restoration or for assisted migration are collected first. The plants are stored now and the decision regarding how to use these plants can be made later (Vitt et al., 2010). This forward-thinking approach secures resources for assisted migration.

How much will the project cost and who will fund it?

Assisted migration is similar to reintroduction a "long-term project that requires the commitment of long-term financial and political support" (IUCN, 1998). In addition to the benefit and risk assessment, a finance scheme should be created during an early planning stage. It contains costs for collecting and raising plant material, for the implementation, monitoring and personnel costs. The costs can vary depending on the biology of the translocated species (Hunter, 2007). Then, adequate funding that finances all stages of the project (IUCN, 1998), including monitoring, success evaluation and data analysis, should be found. Possible sponsors are ministries (e.g., the Austrian Ministry of Life), government departments (e.g., the Environment Agency Austria), the state departments for conservation (the nine states are appropriate for conservation), universities, research funds, national and international conservation organizations or the European Union (LIFE programmes).
Planned funding should be flexible because calculating the exact costs is impossilbe (IUCN, 2013).
Shoo et al. (2013) believed that a more intensive management action is more expensive. However, to protect a single species from extinction, assisted migration is expected to be cheaper than the creation of a corridor (Lawler et al., 2011) or to be as cost-effective as other conservation strategies (Willis et al., 2009).

Is the local community involved with the project's implementation?

At the planning stage, who will implement the project should be decided: governmental or non-governmental agencies, only professionals or additional nonprofessionals. The number of people involved is important for determining the personnel costs.
Non-governmental groups can assist at the planning stage (Laws et al., 2012), with the implementation and financially.
If possible, the local community should be involved in the project's implementation (IUCN, 1998). Local people's attitude can have a strong influence on a project's success. This holds true not only for the reintroduction of large carnivores (Seddon et al., 2012), e.g., the Eurasian brown bear (*Ursus arctos arctos*) in Austria, but also for smaller animals and plants. Nature reserves that involve local communities are more successful. Conservation projects and the sustainable use of natural resources cannot be realized without local people (Prance, 2006).

Information and the chance participate will increase the acceptability and volunteer labour can reduce costs. Local people also provide knowledge regarding their region. Seddon et al. (2012) concluded: “In many cases community engagement is not just a useful part of translocation planning, nor even just a prerequisite for success; rather it is one of the desirable outcomes.” Engaging the public also helps to change negative views of assisted migration, e.g., as the introduction of dangerous aliens.

3.3.7 Monitoring and research

Monitoring and research considerations are quite similar for all translocations. The IUCN Guidelines for Reintroductions (1998) provide some important thoughts to make each translocation a “carefully designed experiment”. Monitoring is an “integral part of conservation design” and should be considered in an early planning stage (IUCN, 2013). Monitoring data are required for deciding about adaptive management, assessing a project’s success, researching and developing new models for future conservation programmes (Nichols et al., 2012, IUCN, 2013).

<u>What are the targets and when are they reached?</u>
Assisted migration could be used for the conservation of a single species or in a restoration project to support other species or ecosystems. The project’s targets and the success criteria should be defined and listed before the implementation. The IUCN Guidelines for Reintroductions (1998) intend the “identification of short- and long- term success indicators and prediction of programme duration, in context of agreed aims and objectives.” Many indicators only focus on the short-time success. However, species with a long generation time, complex population dynamics or climate change effects could not be sufficiently assessed (Burbigde et al., 2011).
No standardized definition on the success of assisted migration exists. According to the IUCN (1998), the aim of any reintroduction is the establishment of “a viable, free-ranging population in the wild” that “requires minimal long-term management”. In 2013, the IUCN expected a broader benefit of any conservation translocation, namely the positive impact at “a higher level of organization than the individual”. I think that this expectation is a good objective for assisted migration.

The Australian Department of Conservation and Land Management suggests that a translocation is considered successful if the population is self-perpetuating, maintaining ninety per cent of the source population' genetic diversity and independent of expensive, non-routine management actions (CALM, 1995). The threshold of ninety per cent of the source population' genetic diversity is high and I would not consider a translocation with less genetic diversity, but with a long-term stable population, as failed. Additional genotypes could be added later or translocated to another target location. Natural selection in the new environment could lead to the disappearance of maladapted genotypes over a longer period. For clonal species, e.g., *Artemisia pancicii,* evaluating genetic diversity is not necessary and other success indicators are required, e.g., its survival rate or its spread. The definition of expensive management is subjective. Plant species differ (e.g. in reproduction, growth, resource useage, life history, etc.) and so do their success criteria and the indicators that could be used.

Vegetative growth, reproductive output and recruitment are evaluated to assess the success of reintroductions, but these indicators are inefficient for long-lived plants that could to be valued through population viability analysis (Burbigde et al., 2011).

<u>Who will pay for and perform the monitoring and for how long?</u>

Indicators are assessed with monitoring success. As mentioned previously, many success indicators are only short-term (Burbigde et al., 2011). Monitoring these indicators is easier and the likelihood of a project's success is higher, but the main reason for a shortsighted view is the lack of financial resources for long-time monitoring. The monitoring costs depend on the target area's extent and location, the number of moved individuals and the frequency of monitoring visits. They should be included in the costs for the entire project.

Demographic, ecological or behavioural studies can be performed using all or a sample of monitored individuals. An evaluation of cost-effectiveness and translocation techniques can help to improve future projects (IUCN, 1998 and 2013).

With assisted migration, a taxon is moved to a place where it has never been before, so longer and more detailed monitoring is required than for introductions within a range (Burbigde et al., 2011). Reintroduction monitoring is often planned for four years, but should last for a longer time, namely for a minimum of ten years (Godefroid et al., 2011).

This monitoring could be performed by conservation biologists who planned and implemented the project or by the committed local community who send the data to these biologists. Similar to implementation, volunteer labour can reduce costs.

When is an intervention necessary?

Monitoring the health and survival of individuals provides the data required for management actions (IUCN, 1998). Besides the monitoring of health and distribution, an observation of potential ecological or genetic invasions is necessary (Burbigde et al., 2011).

An intervention is necessary if an introduced species population is declining and at risk of extinction, if it is spreading too far and fast or if it is causing any negative effects on the ecosystem or on local communities. The management threshold should be fixed before the implementation.

Will all data be publically available?

All data, including negative results, should be publically available for research and for future projects. Everyone who is involved in the project should document his/her work. The "data should allow direct comparison" (IUCN, 2013).

Publications in scientific and popular literature will occur (IUCN, 1998 and 2013) and a bias toward positive results is expected (Godefroid et al., 2011).

A description of the assisted migration's success or failure should be available from an internet platform, e.g., hosted by the university that plans and implements the conservation project, by an international institution, such as the IUCN or, especially for plants, the BGCI. Such a platform that summarizes all recent assisted migration would immensely improve benefit and risk assessment. Research can be coordinated and knowledge can be exchanged (Hardwick et al., 2011).

In Austria the "ARGE österreichischer botanischer Gärten" has set the goal to create an information platform for the coordination of conservation work. On the European level, the "Action Plan for Botanic Gardens in the EU" contains a working programme for European botanical gardens that should connect the ex situ institutions and coordinate their actions. This programme would include assisted migration projects (Unrath, 2004).

Future conservation projects will depend on the exchange of information and those who will be part of an information network can successfully implement these projects.

4 Management proposals for highly threatened plant species in Austria

4.1 Selection of species

Facing several threats, plant species can migrate or adapt, otherwise they will become extinct. Some species are more vulnerable to changing conditions, e.g., endemics, because they have a restricted range and occur on only one place on earth (Hölbling, 2013). Taxa with a long generation time or with poor dispersal, those taxa that live under extreme conditions and specialists (including specialized biotic interactions) are also vulnerable. Some species are endangered because they cannot migrate on their own, e.g., because they live on mountaintops (Hawkins et al., 2008) in the Alps or live in a highly fragmented habitat, such as dry grasslands in eastern Austria. In 3.3.2 Risk assessment, I summarized the characteristics of plant species that are suitable for assisted migration. However, how can taxa be selected in practice? Next, I will explain my selection process.

I want to consider assisted migration for species that are already kept ex situ. Botanical gardens should play a more active role in conservation because they are an important link between in situ and ex situ conservation (Havens et al., 2006). To achieve the GSPC Target 8, there their plant material must be used for recovery and restoration projects. Using already available plant material is also advantageous for assisted migration. This useage reduces costs because none or less material must be collected. Additionally, botanical gardens provide information, research data and practical experience for their hosted species (Havens et al., 2006; Primack et al., 2009) and they can support the translocation.

Hölbling (2013) collected data from all endangered plant taxa that are protected in any ex situ institution in Austria. She also noted their origin and how endangered they are. First, I selected highly threatened species at risk of extinction in Austria. Then I reduced the list to those species for which plant material was collected in Austria and that originated from a well-known origin (see Annex II).

From the remaining thirty-three species, two are listed on Annexes II and IV of the Council Directive 92/43/EEC (1992) for Austria: *Artemisia laciniata* and *Stipa styriaca*. The Member States must designate nature reserves for species on Annex II. Those species on Annex IV are of community interest and are strictly protected. Conservation actions should be taken, if necessary. *Artemisia laciniata* and *Stipa styriaca* are priority species and Austria is highly responsible for them.

These species are suitable for assisted migration for more than one reason:

Artemisia laciniata reproduces asexually and is genetically clonal. Similar to *Artemisia pancicii* (see 2.4 The situation in Austria), genetic thoughts are quite simple. The FWF funds a project for the in vitro propagation of *Artemisia laciniata*, so considering for what the bred plant materal can be used is even more useful.
Stipa styriaca is a local Austrian endemic and only ex situ cultivated at the Botanical Garden of the University of Vienna. If the kept material is insufficient, the Botanical Garden has permission for additional collection.
Next, I examined in how many ex situ institutions the species are. Eleven of the remaining thirty-one species are only kept by the Botanical Garden of the University of Vienna. A species held in only one botanical garden is at risk of ex situ extinction, so I select the third species from these eleven. Distribution is a possible criterion, but all of these species are resident in eastern Austria. Thus, I concentrated on species that are extinct in an Austrian state. I selected *Lepidium perfoliatum* from the five potential taxa because it lives in dry grasslands and is salt-resistant. Due to its location, the Botanical Garden of the University of Vienna has a high responsibility for Pannonian dry grassland species. *Lepidium perfoliatum* is extinct in Lower Austria and its populations in Vienna are not steady. Its salt resistance makes introductions to new locations in the city promising.

4.2 *Artemisia laciniata*

Artemisia laciniata (Asteraceae) is mainly distributed in central Asia and a part of the Pontic-South-Siberian floristic region. In Austria, the Pannonian species can be found only in the Seewinkel (Burgenland) today because its former populations in Lower Austria are extinct (Fischer et al., 2008). This occurrence is the only one in the European Union (Schratt-Ehrendorfer et al., 2005a).

Fig. 2: *Artemisia laciniata*

4.2.1 Application of the checklist to *Artemisia laciniata*

<u>Legal situation</u>

As a member state of the European Union, Austria must implement the Council Directive 92/43/EEC (1992) on the conservation of natural habitats and of wild fauna and flora.

Artemisia laciniata is listed on Annexes II and IV and so management actions must be taken. Austria has a high responsibility for this species because the last occurrence in the European Union is on its national territory.
The translocation will occur inside Austria and the species is not expected to expand its range into a neighbour state, so no other countries are involved. The remaining population of *Artemisia laciniata* is in the National Park Neusiedler See-Seewinkel, Burgenland (Schratt-Ehrendorfer et al., 2005a). Suitable target habitats can also lie inside the reserve's management zone. Therefore, the assisted migration project must fit into the National Park's concept and law. It can be integrated into conservative efforts and management actions.
From a legal (and social) point of view, assisted migration to a location inside the National Park is easier than on private owned land. However, the protected area hosts other threatened taxa and habitats and is highly valuable for conservation. Negative effects on this region have consequences that are more serious and less tolerable than for (sometimes isolated) private grounds far away from the conserved ecosystems.
Plant material can be easily and legally acquired. It is available from ex situ institutions (Botanical Garden of the University of Vienna and Blumengärten Hirschstetten) and its origin is known (Hölbling, 2013).

Risk assessment

Artemisia laciniata is a highly endangered species (see Annexes II and IV of the Council Directive 92/43/EEC, 1992) and threatened by extinction in the entire European Union. It is a priority species. This taxon is also strongly protected by the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 1979) and is classified as threatened by extinction (1) on the National Red List (Niklfeld et al., 1999) and on the Red List of Burgenland (Herzig, 1997).
Artemisia laciniata is not expected to carry dangerous pests or parasites, but a health screening is necessary for all individuals that are selected for assisted migration. This screening can be performed by the ex situ institution responsible for the plant material.
Thus far, this species has not been used in a conservation project so far, but *Artemisia pancicii* was selected for an assisted migration project in Austria (see 2.4 The situation in Austria). Due to the close relation between those taxa, conclusions from the recent project can help to assess and plan the movement of *Artemisia laciniata*.
This species is extremely rare in Europe and is not known to be a weed anywhere in the world. To assess the plant's invasive potential, I will comment on its life cycle and

reproduction. *Artemisia laciniata* is a half-rosette perennial forb. The taxa *Artemisia* flowers from late summer to autumn (August to October) and the unobtrusive inflorescences are wind pollinated (Schratt-Ehrendorfer et al., 2005a). However, Jäger (1987) did not find juvenile plants in Mongolian forests and the Austrian population also reproduces vegetative only. Similar to *Artemisia pancicii*, *Artemisia laciniata* asexually reproduces through belowground runners from the rhizome and spreads slowly and ineffectively.

Artemisia laciniata is not a key species, is not expected to alter ecosystem processes or the habitat structure and is less competitive. In conclusion this species is very unlikely to become invasive.

Although some information (see Schratt-Ehrendorfer et al., 2005a) that was collected to develop criteria and indicators to assess the conservation status of species and to implement the Council Directive 92/43/EEC (1992) are available, there are also some knowledge gaps, e.g., biotic interactions, also exist.

Habitat selection

To decide on a translocation site, the recent distribution of the species must be studied to determine what type of habitat is required and why. In Austria, *Artemisia laciniata* can be found on only one location today: the “Zitzmannsdorfer Wiesen” in the National Park und Natura 2000 conservation area (Site of Community Interest, SCI) Neusiedler See-Seewinkel. This habitat is situated on the northeastern shore of the Neusiedler See between Winden am See and Podersdorf. This population is so unique because it is far more to the west (about 3000 km) than the species’ main distribution area in Mongolia and in Siberia (Schratt-Ehrendorfer et al., 2005a). The Pontic-South-Siberian floristic region reaches Eastern Austria and contributes taxa to the grasslands (Schumacher et al., 2013). Although *Artemisia laciniata* is a relatively common species in eastern woodlands, it is missing in the central region of Pannonian vegetation. It went extinct in Germany more than one hundred years ago and cannot grow in Hungary due to degraded habitats (Jäger, 1987; Schratt-Ehrendorfer et al., 2005a). This situation emphasizes the high conservation value of the remaining isolated population in Austria.

In central Asia, *Artemisia laciniata* grows in forests with *Larix decidua* and natural woodlands, as well as in anthropogenically modified habitats, such as meadow grasslands and forests with birches and poplars in the montane zone. In Asian woodlands, the amount of precipitation is higher in summer, whereas the summer in the Pannonian region is dry. In Europe, this plant grows in seasonally wet grasslands of the colline zone. *Artemisia laciniata*

is slightly competitive, but can address the salty and half-bog soil there. Only under these conditions it has an advantage against other European species (Jäger, 1987).
Artemisia laciniata is found in a seasonally wet, less salty region of the “Zitzmannsdorfer Wiesen” which is assigned to the Succiso-Molinietum caeruleae (Schratt-Ehrendorfer et al., 2005a). Other typical species are *Molinia caerulea, Achillea aspleniifolia* and *Serratula tinctoria* (see Ellmauer et al., 1993 for more species). The corresponding habitat type of the Council Directive 92/43/EEC (1992) is a semi-natural, tall-herb, humid meadow: 6410-*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (Schratt-Ehrendorfer et al., 2005a).
If the species historical range in the National Park area has been larger, this possibility has not been documented, but *Artemisia laciniata* was found in a second location in lower Austria, thirty-five km more to the east than Vienna. The plant grew on the “Salzheide” near Lassee in a hollow with a sandy soil. Due to the near ground water, the conditions were wet. When the ground water level was lowered, the habitat became too dry and *Artemisia laciniata went* extinct (Wendelberger, 1959). This drained site is no longer suitable for *Artemisia laciniata* and I do not believe that the ground water level will be raised again, so reintroduction is impossible at this location.
In conclusion *Artemisia laciniata* should be transferred to a humid, moderate salty grassland habitat. I suggest a short distance jump because the required conditions can be found around the Neusiedler See close to the remaining population. Visiting the area will help to identify suitable sites. An assisted migration project inside the National Park is only possible in the management zone.
The Neusiedler See and the small lakes and salty puddles that surround it cannot exist without a relatively high ground water level, so humid soil conditions are guaranteed in the National Park. Assisted migration in the reserve’s territory means that the selected habitat is secure from degradation and drainage and that the population will not be harmed by excessive collection. Translocateing such a rare and highly threatened species to a place where it is not protected does not make sense. *Artemisia laciniata* still exists in the National Park and negative effects on other organisms are not likely.

Genetic considerations

Artemisia laciniata reproduces vegetatively and although it could produce viable seeds, sexual reproduction would not play a role in practice (Jäger, 1987; Schratt-Ehrendorfer et al., 2005a). As a consequence all individuals are likely to be genetically clonal. Similar to

Artemisia pancicii genetic considerations are simpler for genetically uniform populations because no considerations regarding genetic erosion, inbreeding depression or a population's genetic representativity exists.
To establish two new populations of *Artemisia pancicii*, ninety-nine plants consisting of 422 (264 to location A, 158 to location B) rosettes were moved in spring 2010 (Schumacher et al., 2013). The assisted migration project of *Artemisia laciniata* could orientate on this scale and translocate about 200 rosettes per selected target site during the next spring. However, the project could also be started with a smaller number if 200 rosettes are not available because the only surviving population of *Artemisia laciniata* in the European Union is so small that any other viable population is a gain. The Austrian plant material will be provided by the Botanical Garden of the University of Vienna. Currently, a FWF project funds its in vitro reproduction through tissue culture. For the assisted migration project plants from the small, unique population in Burgenland will not be used.
Hybridization is theoretically possible with only one species: *Artemisia santonicum*. Apart from *Artemisia laciniata*, it is the only Pannonian *Artemisia* species in Austria that lives in wet grassland habitats in Seewinkel. The other *Artemisia* species cannot deal with the high salt concentration (Fischer et al., 2008). However, *Artemisia laciniata* is not expected to sexually reproduce, so hybridization is extremely unlikely.

<u>Socio-economic aspect</u>

With a target habitat inside a National Park, normally, no impact on human lives or property occurs. However, the National Park Neusiedler See-Seewinkel's management zone partially consists of small, fragmented patches. Depending on the selected habitat, an influence on the surrounding agricultural used land and on the villages is possible, but *Artemisia laciniata* spreads low and is less competitive (Jäger, 1987). This species is not toxic and has no ability to be a weed. No economic loss or direct effect on local people is predicted.
Hunter (2007) suggested that communicating a species' transfer to a protected area could be difficult. However, *Artemisia laciniata* is an extremely rare taxon that is already protected by the National Park, so explaining the need for additional occurrences is relatively easy. This assisted migration project can be integrated into the National Park's public relation work. Additionally, the reserve has a core zone that is fragmented, relatively small in comparison to other National Parks and influenced by agriculture and tourism (NP Neusiedler See-Seewinkel, 2014b and 2014d). The lowland, with its varied landscape of protected and agriculturally used areas, is easy to overlook. The public does not notice this reserve as

uninfluenced wilderness and so the human-mediated expansion of a species range will be easier to communicate.
Apart from the drainage of habitats, extreme over-collection of individuals was another threat to *Artemisia laciniata* in Austria and in Germany (Wendelberger, 1959). With the translocation inside the National Park's territory, negative human effects on the endangered species can be minimized. Visitors are not allowed to leave official pathways or to collect protected plants.

Implementation

The assisted migration of *Artemisia laciniata* will be implemented in cooperation with the National Park Neusiedler See-Seewinkel and Burgenland's state department for conservation (Department 5).
The long history of traditional land use has strongly influenced the region around the Neusiedler See. The mosaic of diverse habitats still exists today and must be managed. The National Park Neusiedler See-Seewinkel protects a unique landscape, highly threatened species and traditional land use. This situation causes a relatively small core zone and a large management zone in comparison to other National Parks. On one hand the large management zone requires permanent attention and actions taken, but one the other hand it creates the opportunity to implement conservation projects that could not occur in the core zone.
The National Park's management zone is highly fragmented and some patches are quite small. Therefore, the patches are not only highly influenced by the surrounding landscape and by the villages, but also can be easily reached. The "Zitzmannsdorfer Wiesen" patch is not so small (about 650 ha), but isolated from the core zone and lies between Winden am See in the north and Podersdorf in the south (NP Neusiedler See-Seewinkel, 2014b and 2014d).
Sufficient plant material will be available for the implementation because the FWF funds a project for the in vitro propagation of *Artemisia laciniata* at the University of Vienna under the lead of Dr. Andrea Kodym. The costs for raising plant material are covered, but for the implementation, monitoring and personnel costs must be estimated for the implementation. Adequate financial support must be found.
The local communities are already involved in the National Park's projects and management actions. Many local people work for the reserve and they can also help with the assisted migration project's implementation. Information regarding assisted migration and *Artemisia laciniata* can be displayed through an exhibition in the National Park visitor centre in Illmitz. One of the National Park's tasks is education. The reserve offers different tours, particularly

for schools and young people (NP Neusiedler See-Seewinkel, 2014a and 2014c), and these tours would be a good opportunity to present this assisted migration project.

Monitoring and research

This assisted migration project is species-based. The target is to establish a genetically clonal, viable population of *Artemisia laciniata*. Success indicators are the survival rate and size of rosettes, their condition and vegetative reproduction. The number of rosettes was used as an indicator for the success of the establishment of *Artemisia pancicii* (Schumacher et al., 2013). Schumacher et al. (2013) published monitoring data for two years. This period remains too short for a final statement regarding the stability of the new populations. Godefroid et al. (2011) recommended ten years of monitoring for reintroduction projects and I agree and suggest a minimum of ten years of monitoring for assisted migration. Calculating a longer period is not considered realistic because the monitoring is unlikely to find financial support. The requirement for extended monitoring can be evaluated after the ten year period. This monitoring could be performed by the National Park staff.

In addition to the new *Artemisia laciniata* population(s), the remaining population should also be observed. The beginning of the assisted migration project is the time to obtain an update regarding the existing population, its condition and size. From then on, the original and the new sites can be monitored, studied and compared to learn more about this species and to adapt management actions. Negative population trends can be identified during an early stage. Schratt-Ehrendorfer et al. (2005a) described that the annual reaping per hand in autumn of the remaining population at the “Zitzmannsdorfer Wiesen” is not optimal and that new management strategies must be considered. *Artemisia laciniata* flowers from August to October, so the problem could be that the reaping occurs too early and could be solved by shifting the action to late October. The adjustment and monitoring of these actions will help with the development of a management plan for the assisted migration sites.

All steps of the project will be properly documented and the data will be made public through publications. Information will be available from the National Park Neusiedler See-Seewinkel and from the Botanical Garden of the University of Vienna.

4.2.2 Management proposals for *Artemisia laciniata*

The existing Austrian population is small, isolated and unique and moving *Artemisia laciniata* to additional locations will reduce its extinction risk. This species is not expected to be

invasive or to cause problems to organism or to ecosystems. For *Artemisia laciniata*, assisted migration is not only a possible solution; rather it is a required conservation action.
First, new sites must be found through the analysis of aerial pictures and of habitat maps, as well as through visits to the potential sites. Anticipating that a suitable habitat will lie inside the management zone of the National Park Neusiedler See-Seewinkel, the project must be coordinated with the reserve and with the responsible nature protection agencies of the Burgenland. Then the costs will be estimated. Financial support and staff must be found. Assisted migration will be implemented under scientific instructions. Monitoring is crucial to evaluate the project's success and will be installed for all *Artemisia laciniata* populations to survey their health, development and population trends. Observations and monitoring data facilitate management adaptations and research. Public relations work will be coordinated with the National Park and with the Botanical Garden of the University of Vienna. The National Park centre in Illmitz can host an exhibition and inform visitors and local residents.

4.3 *Stipa styriaca*

Stipa styriaca (Poaceae) is a species endemic to Austria. Today, it is found in Styria, west of Graz, near Judenburg and in Carinthia, in Mühlen near Neumarkt, Oberes Görtschitztal (Kammerer, 2006; Fischer et al., 2008). Although the taxonomic status (species or subspecies rank) of this taxon remains unclear (Schratt-Ehrendorfer et al., 2005b), it is highly protected by the Directive 92/43/EEC (1992) of the European Union.

Fig. 3: *Stipa styriaca*

4.3.1 Application of the checklist to *Stipa styriaca*

<u>Legal situation</u>

The legal situation is similar to that for *Artemisia laciniata*. *Stipa styriaca* is also listed on Annexes II and IV of the Council Directive 92/43/EEC (1992) and plant material with a

known origin can be provided by the Botanical Garden of the University of Vienna (Hölbling, 2013). However, *Stipa styriaca* grows in the alpine region, whereas *Artemisia laciniata* is a component of the continental region of the European Union (Ellmauer et al., 1999).
Austria has high responsibility for *Stipa styriaca* because this species is an endemic species with a limited range. Austria must designate protected areas for all species of Annex II. Forty-one Special areas of Conservation exist in Styria and *Stipa styriaca* grows inside the protected area "Pölshof bei Pöls" (Amt d. Stmk. Landesregierung, 2011).
Similar to *Artemisia laciniata*, the assisted migration project will occur inside Austria and this species is not expected to expand its range into a neighbour country, so no other countries are involved.
If suitable target habitats are privately owned and cultivated lands, an agreement with the landowners and farmers must be made.

Risk assessment

Stipa styriaca is an Austrian endemic and, therefore, a highly protected rarity in the European Union (see Annexes II and IV of the Council Directive 92/43/EEC, 1992; Appendix I of the Bern Convention, 1979). Its conservation has a high priority (Council Directive 92/43/EEC, 1992).
This species is also listed on the national Red List as critically endangered (Bernhardt, 2011; GBIF, 2013) and is protected in Styria and in Carinthia (Schratt-Ehrendorfer et al., 2005b). According to Bernhardt (2011), fewer than one hundred mature individuals exist.
No record has indicated that *Stipa styriaca* carries dangerous pests or parasites, but similar to *Artemisia laciniata*, a health screening of all individuals that are selected for assisted migration is compulsory.
This species has not been used in any other conservation project, but Kammerer (2006) developed a management plan to preserve the Carinthian population. Reintroduction is not possible because *Stipa styriaca*'s historic and recent natural ranges are equal.
The endemic species has never been documented outside Styria and Carinthia, so it cannot currently be a weed in other regions of the world. Its recent distribution is so small because its habitat is declining and because its ability to spread seems to be low. The eighty to one hundred cm high, long-living perennial tuft grass has spikelets composed of one fertile floret and a moderate reproductive output. Cleistogamy is common is the genus *Stipa* and *Stipa styriaca* is expected be self-fertilizing. Dispersion is anemochor (wind) or epizoochor (animal

fur). The caryopses can insert themselves through hygroscopic movements into animal fur (Schratt-Ehrendorfer et al., 2005b).
In conclusion, *Stipa styriaca* is a rare, endemic, non-competitive species (Kammerer, 2006) and, similar to *Artemisia laciniata*, is not expected to alter ecosystem processes or the habitat structure. It is very unlikely to become invasive or dangerous to other taxa.
The best sources for information are a report for the European Union by Schratt-Ehrendorfer et al. (2005b) and a management plan for the Carinthian population by Kammerer (2006), but *Stipa styriaca* is not well researched. Studying its genetic structure will help to verify its taxonomic status and to reveal potential differences between its subpopulations.

Habitat selection

To select a target habitat for assisted migration, the historic and recent range and requirements of the species must be examined and evaluated.
Stipa styriaca grows in the submontane and montane zone on inner alpine dry meadows (Bernhardt, 2011) and in “silicate-dry-grasslands of black mica schist” (Amt d. Stmk. Landesregierung, 2011). The genus *Stipa* is an indicator for light, dry and low-nutrient sites (Zimmermann et al., 1989) and *Stipa styriaca* is mainly found on south-exposed rocky slopes (Amt d. Stmk. Landesregierung, 2011). Extensive cultivated land could also be a suitable habitat for the endemic species (Zimmermann et al., 1989).
According to the Council Directive 92/43/EEC (1992), the corresponding habitat types are 6211: Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) in alpine valleys and 6240: Sub-Pannonic steppic grasslands (Kammerer, 2006). Communities with *Stipa styriaca* are assigned to the Stipo-Poion xerophilae and, therefore, to the Brometalia erecti (Zimmermann et al., 1989; Schratt-Ehrendorfer et al., 2005b). The Stipo-Poion xerophilae are an intrazonal phenomenon in the rain shadow of large mountain ranges in Tyrol, East Tyrol, Salzburg, Carinthia and Styria (Mucina et al., 1993). Co-occurring species are *Alyssum montanum*, *Astragalus cicer*, *Artemisia campestris*, *Carex humilis*, *Onobrychis arenaria*, *Potentilla arenaria* and *Veronica spicata* (Melzer, 1963). Kammerer (2006) listed important and frequent co-occurring species in Carinthia, e.g., *Festuca rupicula*, *Galium verum*, *Inula salicina*, *Koeleria pyramidata*, *Artemiasia campestris*, *Phleum phleoides* and *Origanum vulgare*.
In Fischer et al. (2008), *Stipa styriaca* is said to occur naturally in Pöls near Judenburg (Oberes Murtal) in Styria and in Mühlen near Neumarkt (Oberes Görtschitztal) in Carinthia. It was cultivated on the Gulsen near Kraubath in Styria and whether the population still exists

(Fischer et al., 2008; GBIF, 2013) or is extinct (Schratt-Ehrendorfer et al., 2005b; Kammerer, 2006; Natura 2000 Steiermark, 2014b) is uncertain. A possible reason for the population's disappearance at this location is the limiting and toxic effect of heavy metal ions (Natura 2000 Steiermark, 2014a). Therefore, a reintroduction to this site is not advisable. In Styria *Stipa styriaca* can be definitely found on only two places in the area between Pölshof and Götzendorf near Pöls today (Kammerer, 2006). These sites are inside the Special Area of Conservation "Pölshof bei Pöls". The protected area is small: it covers only 7,9 ha (Amt d. Stmk. Landesregierung, 2011). There are two other Special Areas of Conservation near the endemic species' range: "Ober- und Mittellauf der Mur mit Puxer Auwald, Puxer Wand und Gulsen" (Natura 2000 Steiermark, 2014a) and "Hochlagen der östlichen Wölzer Tauern und Seckauer Alpen" (Natura 2000 Steiermark, 2014c).

Searching for target habitats in the surrounding area (southwest Styria and northeast Carinthia) is an option to keep the transfer distance small. The analysis of maps and a visit to the area will help to identify suitable anthropogenically used habitats, such as extensive cultural dry meadows and edges of fields with a low nitrogen input or natural habitats as rocks or dry grasslands.

Reversible destroyed sites could be restored. North of Pöls, reforested spruces were removed from semi-natural dry grassland to maintain conditions for *Stipa styriaca* (Zimmermann et al., 1989). This conservation action is passive and the immigration of the threatened species to the restored sites is not guaranteed. Assisted migration as an active management action will accelerate its range expansion and secure its survival. The restored sites provide target habitats.

The extent of occurrence (EOO) is 100 km² and the quality and size of the grassland habitat is declining due to fertilization, intensified land use, the abandonment of pastoral systems, succession and forest replanting with spruces (Zimmermann et al., 1989; Bernhardt, 2011). All those threats must be taken into consideration when a new habitat is selected because the target sites for assisted migration should be protected from these threats. Natural habitats could be designated as new Special Areas of Conservation and culturally used grasslands could be preserved through contractual management. Kammerer (2006) developed a management plan for the population in Carinthia, which was threatened by fertilization and by the abandonment of cultural land use (Kamerer, 2006).

Long-term contracts with farmers and landowners will secure the species' target habitat and its management, but I doubt that concluding it will be possible for more than half a century.

Genetic considerations

Stipa styriaca was first described as a separate species in 1970 by Martinovský, but whether it deserves species rank or is a subspecific entity of *Stipa pennata* (formerly *Stipa joannis*) reains uncertain. Both species have not been genetically studied so far; therefore, it is not known how diverse they are or if they easily form hybrids. *Stipa capillata* is the only other *Stipa* species with similar habitat requirements (inner alpine dry meadows) that is distributed in Styria and in Carinthia (Fischer et al., 2008), but hybrids with *Stipa styriaca* have not been documented so far. Without genetic data, the risk of hybridization could not be excluded, but it is not high.

The single growing individuals of *Stipa styriaca* are expected to self-fertilize, thus they produce clonal descendants (Schratt-Ehrendorfer et al., 2005b). During seasons with an unfavourable weather conditions, namely, a cool and rainy summer, *Stipa styriaca* is sterile, it does not flower and its growth rate is reduced (Kammerer, 2006).

In 2006, four individuals (three sterile and one flowering) were found in Carinthia. This population is extremely small, although not all individuals were identified. The loss of genetic diversity is a high risk (Kammerer, 2006). With assisted migration, additional populations with more individuals can be established and the likelihood of genetic loss is reduced. I suggest that the new population should be founded with about twenty-five individuals. This population will be much larger than the remaining natural ones, but not all individuals will survive and only approximately one-third or -fourth will flower in one season (see Kammerer, 2006).

Stipa styriaca is an endemic species and collected plant material with a documented origin is available from the Botanical Garden of the University of Vienna (Hölbling, 2013).

Socio-economic aspect

Stipa styriaca is not competitive (Kammerer, 2006) and is not expected to cause an economic loss or a gain. For assisted migration to anthropogenically used sites, landowners and farmers will obtain a financial compensation for their work. Extensive land use is a pre-condition for the establishment of *Stipa syriaca* and farmers that cultivate their land in a careful way will be more willing to support a conservation project than those farmers that intensively use their land.

A negative effect on local residents is not expected because the endemic species is not toxic (Fischer et al., 2008) and will not cause diseases. However, I doubt that it will have a positive effect on the community, e.g., as a tourist attraction. *Stipa styriaca* is a rarity and botanists value its peculiar importance, but with its inconspicuous appearance, it is not very attractive to the public. As a consequence communication is essential for the project's success. Protecting a highly threatened endemic species is an important conservation action to stop biodiversity loss. Lectures and announcements in parish rooms and in schools will inform the involved communities and explain the need for this conservation project.

Implementation

For successful implementation, co-operation with local communities and farmers is necessary. Their support and knowledge will carry the project and simplify the search for suitable target sites, the transport and the monitoring of *Stipa styriaca*. Professionals will lead the project, but farmers will be involved with the implementation, management actions and monitoring (Kammerer, 2006).

The accessibility of habitat sites should be considered when they are selected. However, Kammerer (2006) noticed that extremely steep slopes are unsuitable.

The Botanical Garden of the University of Vienna can cultivate and provide plant material for this assisted migration project (Hölbling, 2013). If the material is insufficient, the institution has the permission to collect new material.

The estimation of costs should be performed at an early planning stage and will include the financial compensation if extensively used grasslands are target sites, the costs for personnel, transport, implementation and monitoring. The European Union, involved communities, the states of Styria and Carinthia, the League for Nature Conservation or the University of Vienna could fund the project.

Monitoring and research

The target of this assisted migration is the establishment of *Stipa styriaca* populations in natural or anthropogenically used grasslands. The extensive cultivation of grasslands (reaping and removing bushes and treelets) is a regular management practice to preserve the habitat structure and plant community, but no additional actions should be performed for *Stipa styriaca*. The endemic species should sustain itself. Success indicators are the health and survival of individuals and the number of flowers.

Monitoring data will be required for the regular reports to the European Union because evaluating the conditions of protected species is necessary. Therefore monitoring does not have a time limit and could be sponsored by the European Union.

Local residents, particularly farmers, could be involved in be monitoring because they could keep an eye on the populations. However, professional monitoring should occur during the first half of July every year, depending on the weather. Kammerer (2006) developed a clear monitoring table. All individuals should be visited, its health documented and the number of leaves, fertile and sterile shoots and Caryopses counted. Then every location should be carefully searched for new individuals. Detecting *Stipa styriaca* is difficult when it is not flowering, so the chance of finding descendants is at its highest at that time of the year. This grass was mistakenly noted as extinct because of the absence of flowering during a season with bad weather (Kammerer, 2006). This situation demonstrates that data from only one season is not meaningful and that the populations must be observed for several years.
If more than half of populations that were established through assisted migration are declining or documented as extinct for more than two years, then an intervention is necessary. After an analysis of the reason for failure, more individuals could be added, or a search for new sites must begin.
The project will be fully documented and the data will be made public through publications. Information will be available from the Botanical Garden of the University of Vienna.

4.3.2 Management proposals for *Stipa styriaca*

Stipa styriaca is a rare endemic and as priority species listed in the Annexes II and IV of the Council Directive 92/43/EEC (1992). Austria has a high responsibility for its protection and survival. Only three small populations (two in Styria and one in Carinthia) remain. Recent management proposals are habitat protection, extensive grassland cultivation and less fertilizer use to minimize nutrient input (Zimmermann et al., 1989). These actions are absolutely necessary for the survival of the last *Stipa styriaca* individuals in the wild, but with an additional assisted migration project the risks of extinction and loss of genetic diversity are much smaller. This species is not expected to be invasive or to cause problems to organism or to ecosystems.
The target habitat sites will be natural or extensive cultivated grasslands and will be selected near *Stipa styriaca*'s natural range in Styria and in Carinthia. Costs must be estimated and adequate financial support has to be found.
Co-operation with landowners and farmers is necessary and for translocation to anthropogenically used sites, financial compensation must be paid. Farmers will look after

Stipa styriaca, perform management actions and monitor health and population trends. These data are essential to evaluate the project's success and to facilitate management adaptations and research. Communication and public relations work in the local communities is very important for the success of this project because the local residents' support is required. Lectures and announcements in parish rooms and in schools will explain the requirement for this conservation action.

Similar to *Artemisia laciniata*, this assisted migration project will be implemented under scientific instructions from the Botanical Garden of the University of Vienna.

4.4 *Lepidium perfoliatum*

Lepidium perfoliatum (Brassicaceae) is native in dry grasslands of the colline zone from Eastern Europe to central Asia. In Austria, *Lepidium perfoliatum* is a rare Pannonian species. It is distributed in Burgenland (Seewinkel) and has unsteady distribution in Vienna, Upper Austria, Styria, Carinthia, Salzburg, Tyrol and Vorarlberg. This species is reported as extinct in Lower Austria (Fischer et al., 2008). According to Adler et al. (2003), it is also extinct in Vienna.

Fig. 4: *Lepidium perfoliatum*

4.4.1 Application of the checklist to *Lepidium perfoliatum*

<u>Legal situation</u>

The legal situation for *Lepidium perfoliation* is different from those situations for the other two species that were discussed previously because this species is not protected by the Council Directive 92/43/EEC (1992) on the conservation of natural habitats and of wild fauna and flora.

The Red List of Lower Austria classifies *Lepidium perfoliation* as extinct (Wiesner et al., 2010) and the Red List of Burgenland classifies it as threatened by extinction (Herzig, 1997). The target habitat will be inside Vienna and the area is expected to be owned by the city, so no other countries or states will be involved in this project.

Urban public green areas in Vienna are administered by the Municipal Department 42 (Department for Parks and Gardens). Department 42/5 is responsible for new green areas and Department 42/6 for management actions. For more information, see Hawliczek et al. (2012). The plant material will be legally acquired from the Botanical Garden of the University of Vienna (Hölbling, 2013)

Risk assessment

Lepidium perfoliatum is a rare species in central Europe. In Austria, it occurs in stable populations only in one state, in Burgenland. This species is definitely extinct in Lower Austria (Adler et al., 2003; Fischer et al., 2008). The Pannonian species range is limited to the Seewinkel, which is a unique landscape that is protected as SCI (Site of Community Interest) and National Park (see 4.2.1 Application of the checklist to *Artemisia laciniata*). Although *Lepidium perfoliatum* is not protected by the European Union, it is highly threatened in Austria (Herzig, 1997; Hölbling, 2013).

This species has been used for conservational reasons in dune rehabilitation projects (Tang et al., 2010).

Lepidium perfoliatum is a host of beet western yellow virus (Duffus, 1973). In a study by Tamaki et al. (1982), the plant was identified as a harbour for green peach aphids that are vectors of this pathogen. Economic losses through a declining yield, e.g., of beet, and through a lower sugar production are possible.

Although *Lepidium perfoliatum* is a rare plant in its native range in Europe, it is reported to be a weed in North America. It is noted as an invasive exotic in the United States in California, South Dakota, Idaho and Arizona (IPA of the US, 2014). Swearingen (2008) documented that *Lepidium perfoliatum* is invasive in four national parks in the United States: Badlands National Park (South Dakota), Death Valley National Park (California), Theodore Roosevelt National Park (North Dakota) and Yellowstone National Park (Wyoming). Excellent treatment options for weed control are tillage or “grubbing, digging or hand pulling”. Several chemical control agents are also effective (see DiTomaso et al., 2013).

The European Network on Invasive Alien Species (NOBANIS, 2014) records this species in Europe as established in Denmark and as not established in Sweden, Latvia and Norway. According to NOBANIS (2014), it is rare and not invasive in those countries.

Lepidium perfoliatum is an annual, short-living taxon with a high reproductive output (Tang et al., 2010). These life history traits are typical for invasive species (Essl et al., 2002; Myers

et al., 2003), but these characteristics do not indicate that those species must have negative effects.
This plant is fast growing and its life cycle lasts approximately sixty days. It germinates from late March to early April and disperses seed from late May to early June. Dormant seeds survive and ripen in the soil until the next spring. This seed dormancy pattern allows species to “survive in spatio-temporally variable environments”. *Lepidium perfoliatum* can form a seed bank and is adapted to desert conditions. Tang et al. (2010) explained that it depends on sexual reproduction and on a “large number of small, light and mucilaginous seeds”. A mucilaginous coat rapidly absorbs water and facilitates germination, even under dry conditions (Tang et al., 2010).
In fact, this species has the potential to be invasive, but is unlikely to be invasive in Europe. To minimize any possible risk through this assisted migration project, *Lepidium perfoliatum* will be moved to anthropogenically modified sites in Vienna. It will be isolated there and will not be able to spread as easily as in natural areas, e.g., the National Park Neusiedler See-Seewinkel.

<u>Habitat selection</u>

Burgenland is the only Austrian state where this species can be definitely found. The rare Pannonian species occurs in dry grassland habitats in the region Seewinkel. Its occurrence in Vienna, Upper Austria, Styria, Carinthia, Salzburg, Tyrol and Vorarlberg is uncertain and it is extinct in Lower Austria (Fischer et al., 2008). With a declining and rare natural habitat, *Lepidium perfoliatum* often occurs in agricultural, disturbed and urban areas (NOBANIS, 2014).
For Vienna, Adler et al. (2003) classified *Lepidium perfoliatum* as an extinct species that was common in 1850. Neilreich (1846) documented its occurrence on grasslands, screes and wastelands in the city. At that time, he described *Lepidium perfoliatum* as rare and disappearing for several years. However, in 1869, he observed that this species spread in and around Vienna. Countless amounts of *Lepidium perfoliatum* were observed because the former rare species had reproduced significantly during the last ten years (Neilreich, 1870).
In Annex III, I counted the sites where and when *Lepidium perfoliatum* was found in Vienna, beginning with the first detailed description of the Viennese flora and the species sites by Neilreich (1846). His work is often compared with recent distribution data to document the change or disappearance of habitats, populations and taxa in Vienna. *Lepidium perfoliatum* is considered extinct in the city today (Adler et al., 2003).

This species has the ability to behave as a weed (see the United States) and although it is rare, threatened and not expected to be invasive in Europe, movements to natural habitats appear more risky than those movements to anthropogenically modified areas. I suggest possible habitats in Vienna and consider assisted migration to human-made grassland patches. Due to its salt resistance, *Lepidium perfoliatum* can grow on traffic islands or beside streets, where the salt pressure on plants is high. An insurmountable area is around those selected target locations in the city. Negative effects on this unnatural surrounding are not expected. This species will be isolated there and normally will not be able to expand its range in its own. Transfers to sites in Vienna will prevent an uncontrolled spread of this species.

This assisted migration helps a species that is rare in Europe by growing it on additional sites and by securing it from extinction in Austria. Another positive aspect is that a touch of nature is brought into the city. The new locations will be relatively close to the former distribution of this species. Reintroductions are possible if the original habitats still exist or can be restored. However, the target locations will most likely lie outside the historical range.

The restored sites will be planned and intentionally constructed on favourable places. With a carefully designed grassland habitat, all the species requirements will be satisfied. These sites will be kept in a good condition and repaired or managed as necessary; therefore, they will persist for decades.

Genetic considerations

Thus far, the genetic structure of this species has not been studied. *Lepidium perfoliatum* depends on sexual reproduction, so it is not genetically uniform (Tang et al., 2010).

The plant material could be provided from only one ex situ institution in Austria, the Botanical Garden of the University of Vienna. Its origin is well documented (Hölbling, 2013).

The new population should represent the genetic diversity of the remaining population in Burgenland. *Lepidium perfoliatum* has a high reproductive output, so cultivating enough individuals is not a problem.

The traffic island habitats are isolated and all other species are placed intentionally, so hybridization with other Lepidium species can be prevented by planting taxa that are not close relatives.

Socio-economic aspect

The primaryreason for the translocation of *Lepidium perfoliatum* to sites in the city is that negative effects are unlikely. No economic losses or gains in the municipal area are predicted.

Lepidium perfoliatum is not toxic (Fischer et al., 2008) and is not expected to cause damage to human health.
Introducing a species to habitat patches in a city will trigger more attention than an introduction into the countryside. Sometimes no local residents are present, or they do not notice any change. A project that is well presented and explained can profit from high attention, e.g., through committed volunteer workers (see “Implementation” and “Monitoring and research”).
Communication is important because *Lepidium perfoliatum* is invasive in regions of the United States and explaining why this endangered species will be introduced to locations outside its range is more difficult than it is for species that have not caused problems thus far. Information boards at every translocation site will draw attention to the conservation project and provide explanations.
I would not define *Lepidium perfoliatum*’s yellow flowers as “spectacular”, but I think that people will feel sympathy for a plant that was very common 150 years ago and is now threatened by extinction.

Implementation

The accessibility to artificial sites in Vienna will be easily given if considered during the planning stage of habitat selection and construction.
Plant material will be available from the Botanical Garden of the University of Vienna (Hölbling, 2013). It can be propagated if necessary.
Tang et al. (2010) studied the seed germination of *Lepidium perfoliatum* and determined that fresh seeds do not germinate well. They must be stored for several months. He stored the seeds for four months at several temperatures from 4°C to 30°C and the germination of those seeds was enhanced compared with the fresh ones. The seeds at 30°C ripened faster than those seeds at 4°C. Most favourable for germination is seed dormancy at an altered temperature (10°C and 20°C) or at constant 20°C. Water availability is a limiting factor because its reduction causes a decreasing germination rate. Light is an important germination signal for *Lepidium perfoliatium* seeds. The effect that they are dormant in darkness hinders their germination under snow (Tang et al., 2010). These results are helpful for this project’s implementation, especially at its beginning. Water and light availability, as well as seed dormancy, will be taken into account to create the best conditions.
The costs must be estimated at an early planning stage. Financial support could be provided by scientific funds (e.g. FWF), the Municipal Department 42, the Municipal Department 22

(Department for Environmental Protection in Vienna) or the Botanical Garden. The Viennese League for Nature Conservation could also sponsor this project.
The local community can be involved in the project's implementation. People like the idea of bringing nature into a city and trends such as urban gardening are booming. Now people can help to construct and plant sites for conservational reasons. The project will have "bring endangered species into the city" as a motto. Voluntary workers will also look after (e.g. remove rubbish) and monitor the sites. Citizen participation will reduce the project's overall costs.

<u>Monitoring and research</u>

The target of this project is the establishment of a *Lepidium perfoliatum* population and an appropriate community in an anthropogenically modified area that do not require regular management actions. The intended result of this assisted migration is not a wild population in a natural habitat; it is a back-up against extinction on a controlled, but semi-natural, site. Success indicators are the health and the survival of the population. In the best-case scenario, it sustains itself without losing genetic diversity.
The monitoring of the anthropogenically modified and constructed sites will be unlimited. Citizen participation through permanent surveillance is possible in a city because many people pass the conservation sites. Committed local residents and their regular reports (e.g. quarterly) about the population's condition can support professional monitoring and reduce costs. Involved institutions, such as Municipal Departments 22 and 42, could also participate in the monitoring.
Monitoring and management are easier for a human-modified site than for a natural habitat. An intervention is necessary if *Lepidium perfoliatum* uncontrollably spreads. Then, the further increase in the population must be stopped. In this context, remembering that this species is invasive in regions of North America is important; therefore, its range expansion must be closely monitored. Management actions are also required if the individuals are in poor condition or if the population is rapidly declining.
Similar to the assisted migration of *Artemisia laciniata* and *Stipa styriaca*, this project will be clearly and carefullydocumented and the data will be made public through publications. The Botanical Garden of the University of Vienna and all involved institutions will provide information.

4.4.2 Management proposals for *Lepidium perfoliatum*

The actions taken for the conservation of *Lepidium perfoliatum* will be discussed more controversially than those actions for *Artemisia laciniata* and *Stipa styriaca*, on one hand because there is no international legal basis for its protection (this species is not taken into account by the Council Directive 92/43/EEC (1992) of the European Union) and on the other hand because its assisted migration will be more risky. *Lepidium perfoliatum* is an invasive species in North America and a potential host for pathogens that cause economic losses. In this case, deciding for assisted migration is not as easy as the decisions for the other two species I discussed previously. However, actions must be taken to protect this native Austrian species from extinction. With a declining population trend for more than 150 years (Adler et al., 2003), it has become a rarity today. With the disappearance of its habitat as an important reason for extinction, I do not expect *Lepidium perfoliatum* to extend its range on its own. I suggest an assisted migration to isolated sites in Vienna. Although it is not expected to be invasive in its native range, its spread can be easily monitored there. The risk of disease transfer and its uncontrolled spread are minimized.

Co-operation of the Botanical Garden of the University of Vienna and Municipal Departments 42 and 22 of the city is a conceivable option for this project's implementation. New target locations for *Lepidium perfoliatum* will be selected together, depending on the species requirements and on the availability of sites. Whether the transfer is a reintroduction inside the species historic range (see Annex III) or an assisted migration to a location where *Lepidium perfoliatum* has not been recorded so far does not matter.

The costs that should be estimated before this project's implementation can be shared among the participated institutions. The Municipal Department 42 can perform the translocation under the Botanical Garden's scientific advice.

Information panels will inform the public about the preservation aspect of this planting. Committed local residents have the opportunity to participate in the conservation project through monitoring.

5 Summary

Assisted migration is a controversial and relatively new conservation strategy that has been tested around the world (e.g. Willis et al., 2009; Gray et al., 2011), sometimes without scientific advice or risk assessment, e.g., the Torreya Guardians (McLachlan et al., 2007). The debate becomes emotional when non native organisms are moved over large distances and introduced to sites far from their home ranges. However, a new progressive conservation strategy should not be refused because of fear from unknown consequences. With a careful benefit and risk assessment under scientific advisory, assisted migration is a promising possibility to reduce biodiversity loss. It is not restricted to species that are endangered by climate change; it could help all taxa that are threatened by extinction.

Although clear instructions are available for other conservation strategies, e.g., the IUCN Guidelines for Reintroductions, no standardized procedure has been recommended for assisted migration. Different frameworks aid decision-making (Hoegh-Guldberg et al., 2008; Richardson et al., 2009; Laws et al., 2012; Shoo et al., 2013), but they do not take all aspects into account, nor do they provide advice for planning projects.

I developed a checklist that considers legal, ecological and practical thoughts. Step-by-step questions are answered and facts are reviewed, so whether assisted migration is a suitable option for a certain species can be determined. Knowledge gaps are detected and not all questions can be easily answered. The points require complex considerations and not a simple “yes” or “no”. This checklist provides the backbone for a standardized scientific evaluation, decision and implementation, but no definite threshold number of points must be positively checked.

The Global Strategy for Plant Conservation has set the use of at least twenty per cent of threatened plant species in ex situ collections for in situ projects as a goal (Sharrock, 2012). Providing plant material, knowledge and support for assisted migration is a possibility for reaching this target. Ex situ and in situ conservation are linked because resources that are kept in ex situ institutions are used for these conservation and recovery programmes. Botanical gardens will get a more active role in biodiversity protection and can facilitate assisted migration by raising public awareness and by sharing information.

In Austria, the concept of assisted migration is widely unknown (exceptions are *Artemisia pancicii* and *Dracocephalum austriacum*; Schumacher et al., 2013), but I think that assisted migration is an option to protect endangered taxa. The extinction risk for rare species is high and controlled translocations to new sites can reduce this risk. I selected highly threatened plant species and used the checklist to demonstrate that human-mediated migration outside their natural ranges is a possible conservation action. The transfer distances for all three suggested assisted migration projects are small because I rejected the movement of species over large distances or intercontinental translocations. Short-distance jumps are expected to be less risky (Keel, 2007; Wilson et al., 2009; Vitt et al., 2009; Vitt et al., 2010; Thomas, 2011).

Artemisia laciniata and *Stipa styriaca* are extremely rare species that are strictly protected by the European Union (Council Directive 92/43/EEC, 1992) and that are not expected to be invasive. I classified the assisted migration of these taxa as not risky, but as highly beneficial for their conservation and long-term survival.

For *Lepidium perfoliatum*, the situation is different. It is invasive in parts of North America (IPA of the US, 2014), but threatened by extinction in Austria (Adler et al., 2003). Therefore I suggested a translocation to anthropogenically modified and isolated sites in Vienna where negative effects are unlikely. Negative effects, such as uncontrolled spread or disease transfer, could be detected early.

This checklist presents knowledge gaps and the project's weak points, so that specific research can be started. In addition to my ideas and proposals for the conservation of the three selected species, an adequate management plan must be developed.

In my opinion, this checklist is more than a helpful tool; rather it is a must-have for assisted migration projects. I hope that this conservation strategy will obtain more attention in Austria and is no longer seen as a risky business, but, if well considered, a chance to protect biodiversity.

6 Glossary

- Assisted colonization:
  a synonym for assisted migration (Kramer et al., 2009; Regan et al., 2012).
- Assisted migration:
  the translocation of species beyond their recent and historical range to protect them from human-induced extinction (Ricciardi et al., 2009b; Seddon et al., 2012). Although synonyms exist, assisted migration is the most common term for this conservation option (Hällfors et al., 2014).
- Benign introduction:
  a synonym for assisted migration (IUCN, 1998).
- Conservation translocation:
  the overarching term for the deliberate movement of species with the objective to conserve species, populations or ecosystems (IUCN, 2013).
- Ecological replacement:
  the translocation of species outside their recent and historical ranges to restore ecological functions (Seddon et al., 1999).
- Ex situ conservation:
  the protection of species outside their natural habitats (Hawkins et al., 2008).
- Facilitated migration:
  the conservation of conditions required for natural migrations. This conservation means to establish a habitat network: protected areas that are well connected through corridors (Ruhl, 2010).
- Genetic assisted migration:
  the introduction of genetic material from one population into another to increase population fitness and evolutionary potential (Shoo et al., 2013).
- Genetic translocation:
  a synonym for genetic assisted migration (Shoo et al., 2013).
- Managed relocation:
  a synonym for assisted migration (Kramer et al., 2009; Regan et al., 2012).

- Re-enforcement:
  a conservation tool for supporting species in their common range by adding individuals to an existing population (IUCN, 1998).
- Re-establishment:
  a successful reintroduction. The species is established in its former natural range (IUCN, 1998).
- Reintroduction:
  the movement of a species into a part of its former natural range from which it became extinct (IUCN, 1998).
- Restoration:
  assisting or initiating the recovery of a degraded, destroyed or transformed ecosystem (SER, 2004).

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9 Annexes

9.1 Annex I: Checklist for assisted migration

In this section, I present the checklist, which is easy to manage for practice. The considered questions can be ticked so that no questions are forgotten.

	Checked
<u>Legal situation</u>	
What is the international legal basis for assisted migration?	○
Is the implementation of assisted migration regulated by law?	○
Is there any other political or legal regulation?	○
<u>Risk assessment</u>	
Is it a (highly) threatened species?	○
Is it expected to carry dangerous pests or parasites?	○
Was it used in any other conservation project?	○
Is the species a weed in any other part of the world?	○
Can the species be dangerous to any other species or to the ecosystem?	○
Has the species the potential to be invasive?	○
- Is it a specialist or generalist?	○
- Is it fast or slow growing?	○
- How does it reproduce?	○
- How does it disperse?	○
How well has the species been studied?	○
<u>Habitat selection</u>	
Does the habitat offer what the species requires?	○
Are the resources sufficiently accessible to the introduced species?	○
Can appropriate conditions be restored?	○
How far is the selected target habitat from the species recent range?	○
What is surrounding the selected habitat?	○
Is the target habitat persistent or will it be degraded during the next one hundred years?	○
<u>Genetic considerations</u>	
What is the genetic structure between and within populations?	○
How often and how many individuals should be released to establish a population?	○
Where does the material selected for translocation originate?	○
Is hybridization a risk?	○
<u>Socio-economic aspect</u>	
Is an economic loss or gain predicted?	○
- Can it be estimated and financially compensated?	○
Does the introduced species have an effect on local people?	○
Is the species charismatic and can the project be easily communicated?	○
<u>Implementation</u>	
Can the target habitat be reached?	○
Is enough plant material available?	○
How much will the project cost and who will fund it?	○
Is the local community involved with the project's implementation?	○
<u>Monitoring and research</u>	
What are the targets and when are they reached?	○
Who will pay for and perform the monitoring and for how long?	○
When is an intervention necessary?	○
Will all data be publically available?	○

9.2 Annex II: Potential species for assisted migration

The following 33 species are highly threatened in Austria. The plant material stored in ex situ institutions was collected in Austria and its origin is wellknown. The asterisk (*) marks those species that are only ex situ cultivated in the Botanical Garden of the University of Vienna.

*Alyssum desertorum**
Androsace maxima
Artemisia laciniata
Blackstonia acuminata
Campanula rapunculus
*Ceratocephala orthoceras**
*Corynephorus canescens**
Crepis pannonica
Dianthus serotinus
Festuca vaginata
Gladiole imbricatus
*Glaux maritima**
Lepidium perfoliatum*
Marrubium vulgare
Melica altissima
Myricaria germanica
Ononis arvensis
Onosma arenaria
Onosma helvetica subsp. austriaca
Ornithogalum brevistylum
Orobanche arenaria
*Orobanche hederae**
*Pholiurus pannonicus**
*Plantago tenuiflora**
Pulsatilla oeniponata
Pulsatilla vulgaris
Sempervivum pittonii
Silene conica
*Spergula morisonii**
Stipa styriaca*
*Thymus serpyllum**
*Trifolium retusum**
Typha minima

9.3 Annex III: When and where *Lepidium perfoliatum* was found in Vienna

This table is adapted from Adler, W., Mrkvicka, C., 2003. Die Flora Wiens- gestern und heute. Die wildwachsenden Farn- und Blütenpflanzen in der Stadt Wien von der Mitte des 19. Jahrhunderts bis zur Jahrtausendwende. Verlag des Naturhistorischen Museums Wien, Wien.

Location	Author and Year of publication
Between Stuben- and Karolinenthore (today Stadtpark)	Neilreich, 1846 Neilreich, 1859 (year of observation: 1858)
A sandy pit behind the Belvedere	Neilreich, 1846 Höhnel, 1876
On rubble next to a swimming school in Prater	Neilreich, 1846
Agricultural used land between Belvedere and St. Marx (the Arsenal)	Neilreich, 1851 Neilreich, 1859 Halácsy, 1896
Heath on the Laaer Berg	Neilreich, 1851 Neilreich, 1859
Beside the street from Simmering to Schwechat	Neilreich, 1859
At the Heumarkt (today Stadtpark)	Neilreich, 1866
At the old Arsenal	Neilreich, 1866
Pasture and sandy pits at the Türkenschanze (today Türkenschanzpark)	Neilreich, 1866 Beck v. Mannagetta, 1890 (year of observation: 1865)
Kaisermühlen in the Prater (today area of Alte Donau)	Neilreich, 1866
Zwischenbrücken embankment (today in the twentieth district, but partly disappeared after the river control)	Neilreich, 1866
At the riverside in Kaiserebersdorf	Neilreich, 1866
Railway embankment in front of the Favoritenlinie (today Südtiroler Platz)	Neilreich, 1869
Around the former brickworks on the Laaer Berg (today the area of the Laaer wood and the Franz-Horr-Stadium)	Neilreich, 1869

In the Prater where the cavalry set up a camp in 1866 (at the right-hand side of the main avenue)	Neilreich, 1869 Neilreich, 1870 (year of observation: 1867)
Warehouses at the Winterhafen (today Freudenauer Hafen)	Janchen, 1966-1975 Forstner and Hübl, 1971
Bomb ruins in Sobieskigasse	Forstner and Hübl, 1971
Simmering	Forstner and Hübl, 1971
Dornbach	Halácsy, 1896
Döbling	Beck v. Mannagetta, 1890 (year of observation: 1876)
Nussdorf	Beck v. Mannagetta, 1890 (year of observation: 1877) Halácsy, 1896
Stadlau, opposite to the Gänsehäufel	Forstner and Hübl, 1971 (year of observation: 1910)
Along the railway in Breitenlee	Forstner and Hübl, 1971

9.4 Annex IV: Abstract

Assisted migration is a conservation strategy still relatively unknown to Central Europe. It is controversially perceived by conservationists; the primary reasons for its rejection are ethical concerns or fears regarding potential biological invasions.
The present master's thesis provides an overview of the spectrum of conservation actions with special reference to assisted migration. Recent assisted migration projects are discussed as well as the ethical aspects of this strategy.
The intentional movement of species beyond their common and historical range is practiced worldwide, sometimes without any obvious framework or risk assessment. A standardized procedure that includes a careful benefit and risk assessment and scientific advice is urgently required to decide whether assisted migration is an option for conservation actions. To facilitate such a process, a checklist was developed based on critical analyses of diverse projects and practical considerations. This checklist includes legal, ecological, genetic and socio-economic aspects. It is intended to be used as framework for planning and assessing an assisted migration project, taking all relevant issues into account.
The potential role of botanical gardens in assisted migration projects was also studied. Botanical gardens are an essential link between ex situ and in situ conservation. The Global Strategy for Plant Conservation (GSPC) sets the use of at least twenty per cent of threatened plant species in ex situ collections for in situ projects as a goal and supporting assisted migration is a possibility to reach this target.
Finally, three plant species highly endangered in Austria were selected for testing the potential usefulness of assisted migration as conservation tool. Using the criteria provided in the checklist, human-mediated migration outside their natural ranges was demonstrated as a potentially meaningful conservation action for these taxa in Austria. Benefits and risks of the proposed actions were discussed and management proposals were made.
Therefore, the studies presented in this manuscript demonstrate that assisted migration is neither the last resort, nor the ultimate solution, but another potentially useful concept to stop biodiversity loss.

Assisted Migration ist eine umstrittene Naturschutzstrategie, die in Mitteleuropa noch relativ unbekannt ist. Abgelehnt wird sie vor allem wegen ethischer Bedenken oder der Furcht vor biologischen Invasionen.
Die vorliegende Masterarbeit gibt zunächst einen Überblick über Naturschutzstrategien allgemein und insbesondere über Assisted Migration. Entsprechende Projekte werden diskutiert und zu ethischen Aspekten wird Stellung bezogen.
Assisted Migration wird weltweit praktiziert; zahlreiche Arten werden schon jetzt absichtlich außerhalb ihres derzeitigen und historischen Verbreitungsareals ausgebracht, mitunter ohne eine klare Struktur zu befolgen oder Risiken abzuschätzen. Um zu entscheiden, ob Assisted Migration sinnvoll ist, ist eine einheitliche Vorgehensweise, die Chancen und Risiken abwägt und wissenschaftliche Beratung miteinbezieht, dringend nötig.
Basierend auf kritischer Analyse von Projekten, verschiedenen Vorschlägen zur Beurteilung von Naturschutzstrategien und praktischen Überlegungen wurde eine Checkliste erstellt, die legistische, ökologische, genetische und sozio-ökonomische Aspekte berücksichtigt. Die Checkliste ermöglicht ein strukturiertes Vorgehen um ein Assisted Migration-Projekt einzuschätzen, zu planen und alle relevanten Fragen zu klären.
Die vorliegende Masterarbeit behandelt außerdem die Rolle von botanischen Gärten im Kontext von Assisted Migration. Botanische Gärten schaffen eine wichtige Verbindung zwischen ex situ und in situ Schutz. Eines der Ziele der Global Strategy for Plant Conservation (GSPC) ist die Verwendung von mindestens zwanzig Prozent der gefährdeten Pflanzenarten, die sich in ex situ Sammlungen befinden, für Naturschutzprojekte. Durch die Unterstützung von Assisted Migration-Projekten kann dies erreicht werden.
Außerdem wurden drei stark gefährdete Pflanzenarten ausgewählt und unter Nutzung der Checkliste nachgewiesen, dass die Verbreitung von Pflanzen außerhalb ihres natürlichen Verbreitungsareals auch in Österreich eine mögliche Naturschutzstrategie ist. Nach der Diskussion der Vor- und Nachteile werden Managementvorschläge präsentiert.
Assisted Migration stellt sich weder als den letzten Ausweg noch als die allerbeste Lösung dar, sondern als ein alternatives Konzept um den Verlust der Biodiversität aufzuhalten.

9.5 Annex V: Curriculum vitae

Persönliche Daten:

Iris Luise Tichelmann
geboren am 25. September 1990 in Wien
österreichische Staatsbürgerin
ledig
Vater: Dr. Franz-Michael Tichelmann, Arzt
Mutter: Mag. Bettina Tichelmann, geb. Probst, Historikerin

Ausbildung:

Volksschule der Schulschwestern vom 3. Orden des hl. Franziskus – St. Elisabeth in 1020 Wien von 1997-2001
Bundesrealgymnasium Vereinsgasse in 1020 Wien von 2001-2009; Matura mit ausgezeichnetem Erfolg
Bachelorstudium der Biologie (Schwerpunkt Ökologie) an der Universität Wien von 2009-2012; Titel der Bachelorarbeit: „Biodiversität und relevante Umweltfaktoren an einer wiederbewaldeten Fläche in La Bolsa, Costa Rica"
Masterstudium Naturschutz und Biodiversitätsmanagement an der Universität Wien von 2012-2014

Besondere Kenntnisse und Fähigkeiten:

Auslandsaufenthalt und Verfassen der Bachelorarbeit in Costa Rica
Praktikum im Nationalpark Donau-Auen
Mitarbeit bei der Vogelberingungsstation in Hohenau
Teilnahme am Workshop zur Erstellung der österreichischen Biodiversitätsstrategie 2020
Führerschein B
PADI Open Water Diver
Österreichisches Tanzleistungsabzeichen Silber

Interessen und Hobbys:

Sport (Schwimmen, Eis laufen, Ski fahren, Rad fahren), Lesen (historische Romane, Fantasy, Sachbücher), Reisen (besonders nach England und Lateinamerika), Klavier spielen, Tanzen