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REVIEW PAPER

Current state of plant conservation translocations across Europe: motivations, challenges and outcomes

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Abstract
Plant translocation is a conservation technique increasingly used around the world. In Europe, numerous unpublished initiatives have resulted in scattered information in grey literature that is difficult to access. This represents a major obstacle to the exchange of information and experience among scientists, practitioners and competent authorities. To help filling this gap, we launched a large-scale questionnaire survey with 39 questions relating to methods, motivations, problems encountered and outcomes, supplemented by a screening of scientific publications, grey literature and national/regional databases. We gathered data on 3211 plant translocations across the European continent carried out on 1166 taxa in 28 countries, which represents the largest dataset of its kind in the world to date. Target translocated species were mainly forbs from grassland habitats and had a conservation status of greater concern nationally than globally. Practitioners mainly used plug plants originating from a single source (the geographically closest to the target site). Weather events and plant diseases were the most often unanticipated problems noticed by respondents. Through monitoring, it was found that most populations flowered but often did not reproduce and could not persist for more than five years, showcasing the challenge that translocations still present for conservationists. This work will be useful in linking conservationists and enabling them to save time and resources by more easily identifying the best practices suited to their target species, with the ultimate aim of improving the science and practice of plant translocations in Europe and beyond.

Keywords Plant reintroduction · Population reinforcement · Assisted colonization · Ecological replacement · Species recovery · Ecological restoration

Introduction

The biodiversity crisis facing humanity today calls for urgent action to prevent, halt and reverse loss of biodiversity, as stated by the UN Decade on Ecosystem Restoration (2021–2030; https://www.decadeonrestoration.org/). To halt the decline in biodiversity, two approaches can be considered: in situ conservation of habitats and populations through

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the management of natural and semi-natural areas, or active conservation through restoration. In addition to the restoration of habitats through large-scale sowing of characteristic plant species, the translocation of rare or threatened species is an increasingly used complementary technique around the world (Gaywood and Stanley-Price 2022; Swan et al. 2018; Zimmer et al. 2019). Conservation translocations are defined as “the intentional movement and release of a living organism where the primary objective is a conservation benefit” (IUCN/SSC 2013). This small-scale (as species-based) approach can be integrated into large ecosystem restoration projects, even if this can sometimes be challenging (Bartholomew et al. 2023).

Plant translocations are complex and some studies have shown limited success, especially in the medium or long term (Drayton and Primack 2012; Godefroid et al. 2011). Therefore, it is essential to gather and share as much information as possible on the methods used, the experiences and the possible causes of success or failure (Fenu et al. 2023; Heywood 2019). Results of most translocations have not been published, the data remaining in notebooks or in internal reports that are frequently difficult to access (Godefroid et al. 2011; Miller et al. 2014). Surveys, grey literature and institutional databases thus represent an invaluable source of data that can help analyse the situation in several regions of the world. Instructive syntheses have been made for the Mediterranean Basin (Fenu et al. 2023) and for some countries such as the United States of America (Bellis et al. 2023), Australia (Silcock et al. 2019; Whitehead et al. 2023), China (Liu et al. 2015; Ren et al. 2020) and Italy (D’Agostino et al. 2024).

The European continent has a long history of threatened plant translocations, with the first cases reported in the literature dating back more than four decades (Abeli et al. 2021; Cranston and Valentine 1983; Pigoti 1988; Sainz-Ollero and Hernandez-Bermejo 1979). However, the unpublished records of the Botanical Society of Britain and Ireland mention some attempts at outplanting native species in southern England in 1955 and even one in 1783 (Dalrymple et al. 2012). In the 1990s, the IUCN Re-introduction Practitioners Directory already reported several dozen plant translocations carried out in Europe (Soorae and Seddon 1998). However, such published cases remain very rare and most often provide little information on the methods, results and obstacles encountered (Fenu et al. 2023). Over the past 20 years, the recent outbreak of mitigation translocation programs following the destruction of protected species has only increased the amount of grey literature (Doyle et al. 2022). To improve the success rate of translocations, all necessary data must be made available so it can be used for further analyses and exchange between geographic context in order to ensure that mistakes are not repeated in the future.

With 44 countries and almost as many different languages (https://www.worldometers.info/), Europe represents a significant challenge for anyone wishing to collect unpublished data on a continental scale. Moreover, stakeholders taking part in translocations can be numerous and diverse. While academics are often involved, many translocations are carried out by local, regional or provincial authorities, nature conservation associations, charitable organizations or various foundations with whom communication outside the context of the country may be complicated due to the language barrier. This represents a great obstacle to any pan-European exchange and hampers the possibility to learn from each other and to exploit synergies with respect to technical skills and experiences.

To address this situation, we formed an unprecedented network of practitioners in plant translocations, from whom we collected as much information as possible on the current and former translocations in Europe. This work was accomplished with the support of the COST Action ‘ConservePlants’ (https://www.cost.eu/actions/CA18201/), which has brought together 154 scientists from 40 different countries. The main objective was to build a database that is spatially and temporally as complete as possible in order to contribute to knowledge in the science and practice of European plant translocations. In this contribution, we detail the content of the database and present some key figures reflecting the breath of information gathered across the continent. We specifically addressed the following questions: (1) What was the need and motivation behind the translocation action? (2) What protocols were used for the translocation itself and for the subsequent assessment of translocation success? (3) What were the main obstacles encountered by practitioners during their translocation project? (4) What were the main reasons for success or failure?

Methods

Questionnaire survey

Within the COST Action 'ConservePlants'—An integrated approach to conservation of threatened plants for the 21st Century (https://www.cost.eu/actions/CA18201/), we produced a questionnaire comprising 39 questions divided into the following categories (Appendix S1): contact information, basic biological and geographical information of the study species, translocation details, reasons which motivated the choices, obstacles, translocation results, references and notes. The questionnaire was created using Google Forms and was also available as an Excel spreadsheet or Word document. The invitation to complete the questionnaire was emailed on June 30, 2022 to 353 recipients from 35 European countries (geographical Europe) with a letter contextualizing the process. The list of recipients targeted people known to be involved in translocations, as well as members of the COST Action.

Seventy people answered the questionnaire. For the purposes of analysis, responses that were too specific were aggregated into categories. Where seed quantities were provided in grams or kg (20 cases), the weight was converted to seed number using the Seed Information Database (SER et al. 2023). For question 28 (Appendix S1), we asked respondents to tell us how important certain aspects were to making decisions on site selection. The proposed categories were: extremely important, important, minor importance, unimportant, not considered, do not know. For analysis purposes, we converted these decreasing levels of importance into numerical values (5 for "extremely important" down to 0 for "do not know"). The responses collected from the questionnaire represented 1446 cases of translocations. A case is defined here as a translocation of a species to a given location at a given time. In rare instances, some respondents have, for practical reasons, grouped several cases into a single row (when a species was reintroduced at the same time in several nearby locations), with the result that the number of cases reported here is somewhat lower than reality.

Literature review

In addition to the responses to our survey, we also searched for all available information in the scientific literature, existing regional databases and the grey literature in English, French, Dutch and Spanish. We searched in Web of Science and Scopus databases using the keywords: reintro* OR re-intro* OR translocat* OR conservation translocat* OR reinforce* OR re-inforce* OR reenforce* OR re-enforce* OR assisted migration OR assisted colonization OR assisted colonisation OR conservation introduction OR ecological replacement OR augment* OR restor* OR restock* OR re-stock* OR reseed* OR re-seed* OR managed relocation AND release OR conserv* OR sustain * OR recover. We also extracted data from the following translocation databases: TransLoc (Europe; http://translocations.in2p3.fr), Trans-Planta (Spain; Vicente Moreno et al. 2017), and IDPlanT (Italy; Abeli et al. 2021; D'Agostino et al. 2024), and we used European data from a previous survey (Godefroid et al. 2011). As an increasing number of ecological restoration projects include a translocation component, we searched the European Commission LIFE Public Database (https://webgate.ec.europa.eu/life/publicWebsite/search) for projects in which plant translocations were implemented.

Database preparation

Since we merged several data sources into one large data set, we identified and deleted the duplicates that inevitably appeared. Translocations identified outside the questionnaire ultimately represent 1765 additional cases that were formatted according to the questionnaire template. Where a published source did not provide information to all questionnaire fields, we included the case but left the corresponding fields blank.

The botanical taxa and family names provided were sometimes divergent depending on the taxonomic referential used. When multiple synonyms have been provided for a single taxon, we used the name accepted by POWO (2023).

Results

Basic biological and geographical information

The compiled database comprised 1166 translocated taxa in 28 countries. Most taxa (57%) were translocated only once, but many also underwent several dozen translocations (e.g., *Silene hifacensis* 83 cases, *Arnica montana* and *Scabiosa canescens* both 63 cases, *Juniperus communis* 54, see Appendix S2). The European countries that documented most translocations were Spain (940 cases), followed by Germany (645) and France (457) (Fig. 1a). Most translocations were reported in the Mediterranean and continental bioregions (39 and 38% of the translocations, respectively) (Fig. 1b). The main habitats in which these translocations took place were grasslands (34%), woodlands (20%) and coastal areas (15%) (Fig. 1c).

In total, 122 plant families were incorporated in our database, with the Asteraceae and Caryophyllaceae representing more than 300 translocation cases each (12% and 10%, respectively). The majority of translocated taxa were perennial forbs (59% of the cases), followed by annual forbs (13%). Sixty-two cases were reported for ferns (1.9%), eight cases for lichens (0.2%), seven for clubmosses (0.2%) and only one case for horsetails. Most translocated taxa (57%) were nationally threatened (critically endangered (CR), endangered (EN), or vulnerable (VU)) or even extinct in the country (2% extinct in the wild (EW) or regionally extinct (RE)). However, this also meant that 41% of the translocations were undertaken on species that were not threatened in the respective country (but this also includes the non-evaluated taxa and some that may have been translocated for other conservation purposes, such as the restoration of priority habitats). The globally threatened or extinct taxa only represented 14% of the translocation cases, the vast majority being listed as not evaluated (NE: 58%) or least concern (LC: 24%) (Fig. 2). According to the data

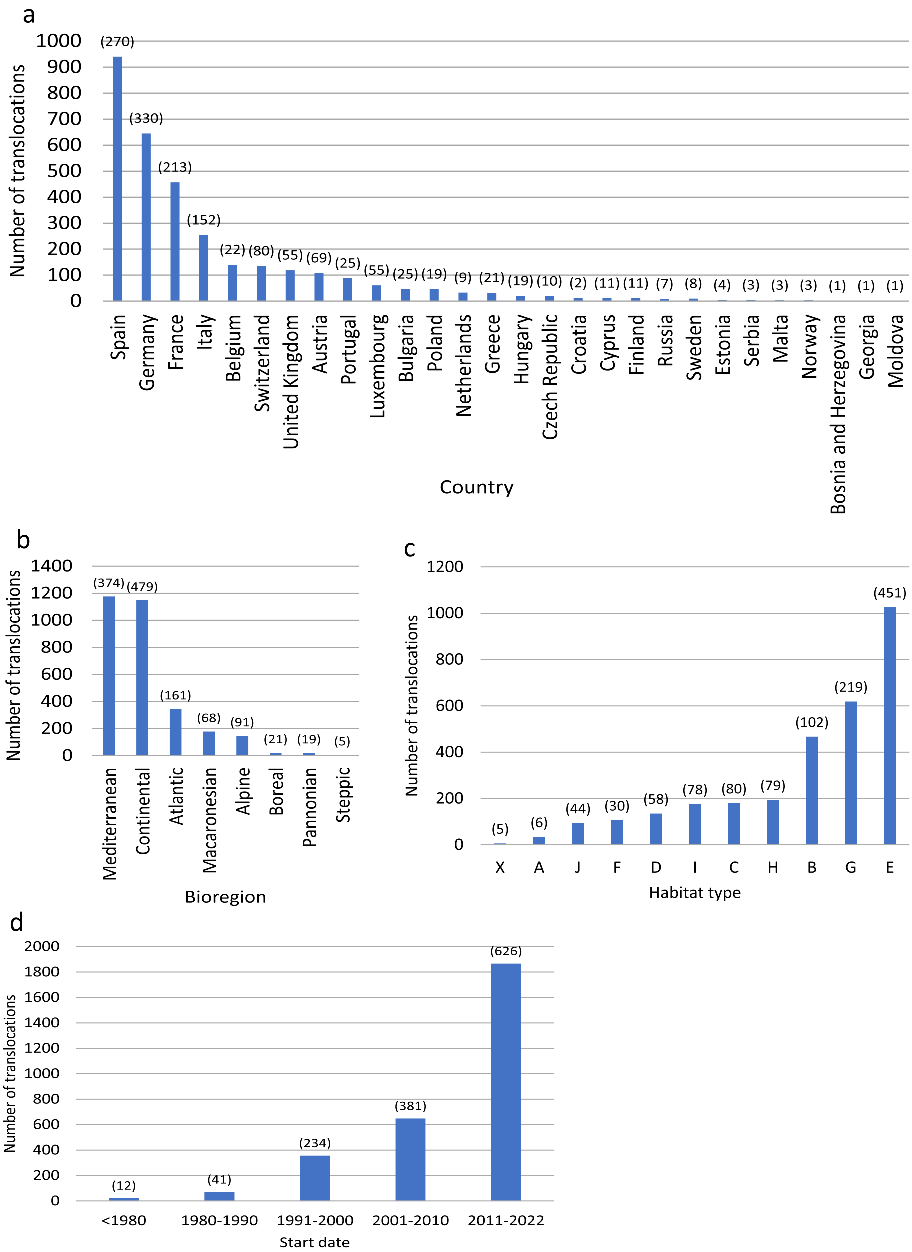


Fig. 1 Number of plant translocations per **a** European country (n = 3211), **b** bioregion (n = 3030), **c** habitat (n = 3028) and **d** project start dates (n = 2953). The number of taxa corresponding to each category is denoted in parentheses. Habitat types according to the EUNIS classification: A: Marine habitats, B: Coastal habitats, C: Inland surface waters, D: Mires, bogs and fens, E: Grasslands and lands dominated by forbs, mosses or lichens, F: Heathland, scrub and tundra, G: Woodland, forest and other wooded land, H: Inland unvegetated or sparsely vegetated habitats, I: Regularly or recently cultivated agricultural, horticultural and domestic habitats, J: Constructed, industrial and other artificial habitats, and X: Habitat complexes

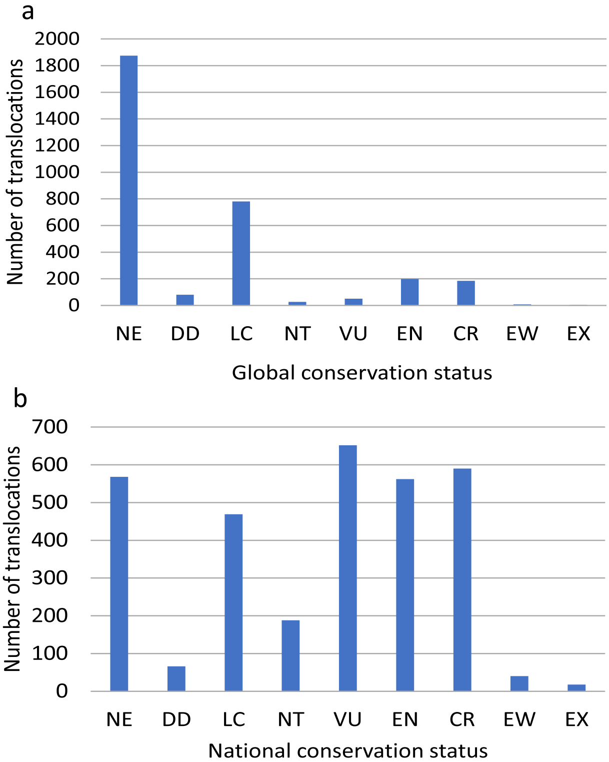


Fig. 2 Number of translocations by conservation status of the taxa concerned (**a** global scale n = 3200; **b** national scale n = 3147). *NE* not evaluated, *DD* data deficient, *LC* least concern, *NT* near threatened, *VU* vulnerable, *EN* endangered, *CR* critically endangered, *EW* extinct in the wild, *EX* extinct

collected in this survey, 24% of the taxa listed in Annex II of the Habitats Directive have been translocated at least once somewhere in Europe (representing 405 translocations out of 3211).

Motivations and criteria behind the implementation of translocations

The main motivation (35%) for implementing translocations as a conservation approach was to reduce the risk of extirpation/extinction of a species listed at a state/provincial level (Appendix S3). In 72% of the translocations, a single source population was used. Spatial proximity to the release site was the main reason (43%) for choosing the source populations (Appendix S4). The most important factor in deciding where to translocate a species was that the habitat met species biotic and abiotic needs, followed by the absence of threats at the translocation site and minimal risk to the translocated species and the recipient ecosystem, while the least important one was that no known pathogens existed at the translocation site (Appendix S5).

Analysis of translocation practices

Reintroductions and reinforcements were approximately equally represented, and accounted together for 72% of all reported translocations, followed by assisted colonisations (17%). For the preparation and implementation of their projects, most of the respondents (62%) declared that they followed the IUCN guidelines, while the others relied on local guidelines, action plans or expert judgement. Most of the reported translocations (63%) were implemented in the last decade (2011–2022) and 22% took place between 2001 and 2010. Only 22 translocations (0.74%) started before 1980 (Fig. 1d).

Plug plants were the most frequently used type of material (70%), followed by seeds (24%), while 6% of translocations encompassed both methods. Seeds mainly came from ex situ seed banks (44%), were harvested directly from the wild (34%) or garden collected (16%) (Appendix S6). In most cases (52%), fewer than 100 plants were translocated. Only 14% of the cases involved 500 plants or more (Fig. 3a). Twenty-nine percent of seed-based projects used fewer than 1000 seeds, but 41% used more than 10,000 (Fig. 3b).

Outplantings were mostly conducted as single events (82%), with a small minority conducted over two years (10%), rarely more. The Euclidean distance between source population and translocation site was less than 10 km in 48% of the cases and more than 100 km in 8% of them. Distance to the nearest natural population was less than 10 km in 64% of the cases and more than 100 km in 3%. The success of the translocations was mainly evaluated by monitoring survival (reported in 28% of the cases), reproduction (24%) and recruitment (23%; Fig. 4).

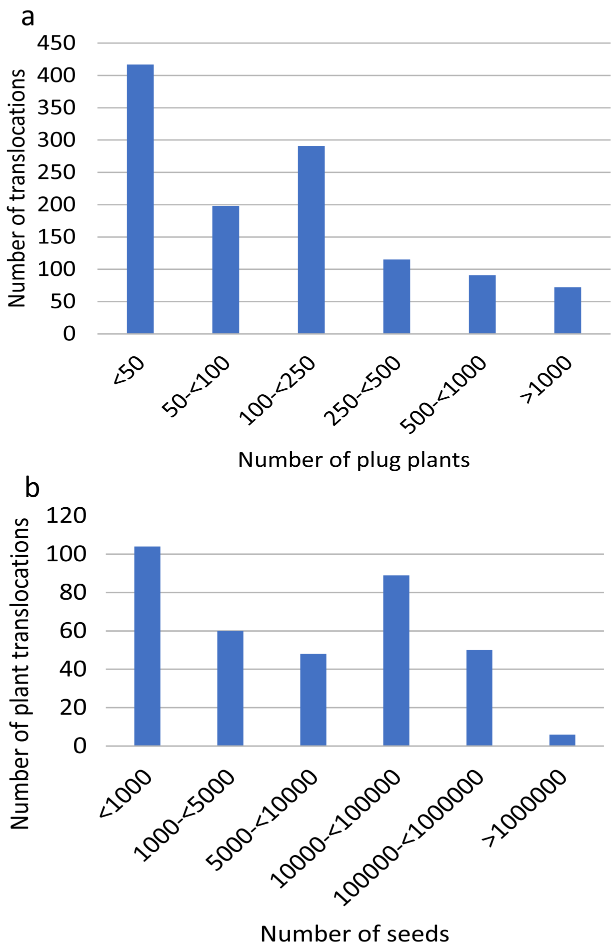


Fig. 3 Number of **a** plug plants (n = 1182) and **b** seeds (n = 357) used per translocation case

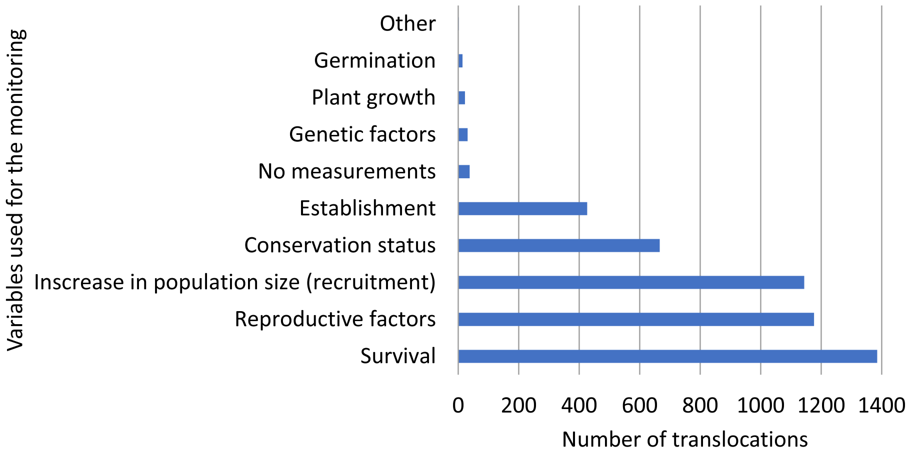


Fig. 4 Variables used to assess translocation success among monitored projects (n = 1661, more than one answer possible per translocation case)

Provincial/regional governments were the main funding bodies (25%), followed by the European Commission (20%), local NGOs (19%), charitable organizations (18%) and universities/research institutes (8%) (Appendix S7).

Obstacles and difficulties

Seventy-seven percent of respondents reported having faced difficulties during their projects, among which plant mortality was the most frequently cited (25%), ahead of time constraints (19%) and difficult terrain (not easily accessible: 15%). Financial or political obstacles were very rarely mentioned (2 and 1%, respectively; Fig. 5a).

The distribution between foreseen and unforeseen problems showed that weather and/or environmental events were the most unexpected (100% unforeseen), followed by plant diseases. Obstacles such as time constraints or insufficient personnel were mostly foreseen (Fig. 5b).

Translocation outcomes

In terms of very short-term survival, 40% of the populations have fewer than 20% of surviving plants one year after translocation (including the seed-based translocations (i.e. seed-to-vegetative-plant ratio), Appendix S8). The number of plants recorded during the last monitoring was in most cases (68%) fewer than 50. In only 8% of the translocations, this number was at least equal to 500 plants (Fig. 6). Seventy-eight percent of respondents observed flowering or fruiting individuals in the translocated populations. Forty-four percent of respondents reported that the transplants produced a second generation. Of those who quantified this, most (59%) reported fewer than 50 recruits in the restored populations (Appendix S9). Regarding medium-term survival, 47% of translocations did not persist > 5 years. For 25% of the cases, the translocated population had persisted for more than 5 years, but was not considered self-sustaining,

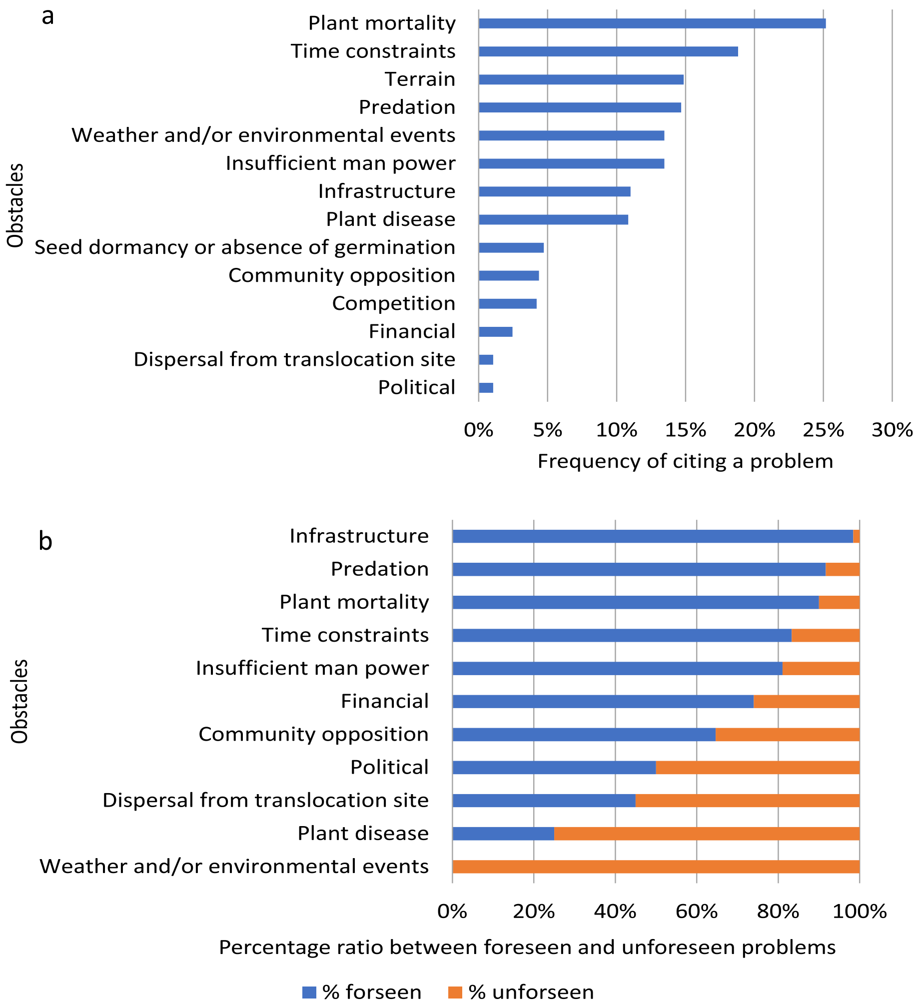


Fig. 5 Obstacles identified by respondents during translocations; **a** frequency of citing a problem (n = 801); **b** percentage ratio between foreseen and unforeseen problems (n = 340). More than one answer was possible per translocation case

whereas 28% of the restored populations were estimated to be self-sustaining, with dynamics comparable to natural populations (Fig. 7).

Among the reasons to explain translocation success, the appropriate selection of the target area was cited first (22%), ahead of a good knowledge of the species' biology/ecology (18%). Conversely, failures were estimated to be mainly due to stochastic weather events (17%) and weed competition (13%) (Fig. 8).

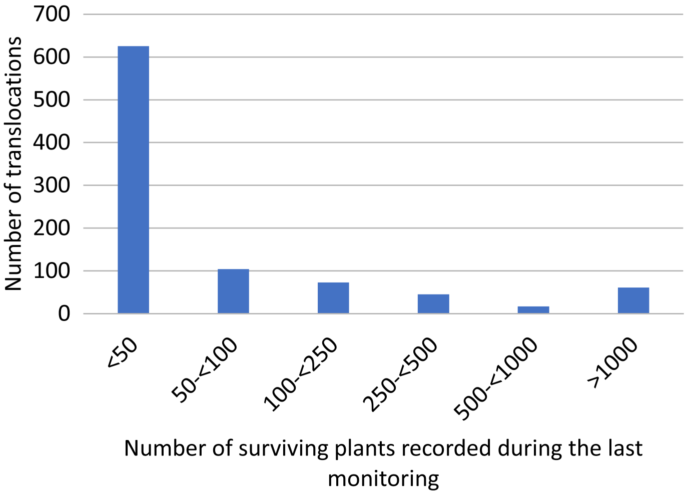
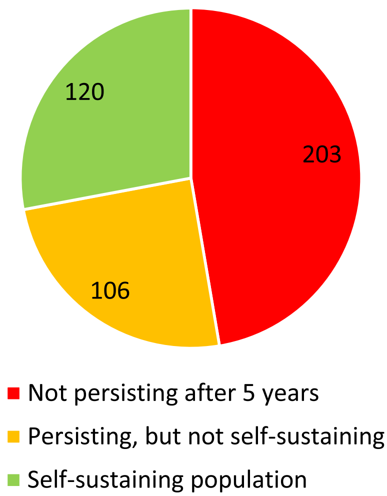


Fig. 6 Number of surviving plants recorded during the last monitoring (n = 925)

Fig. 7 Medium-term success (5 years) and estimation of the self-sustainability of the restored populations (n = 429), with a self-sustaining population defined as remaining stable or increasing in size



Discussion

Plant translocations in Europe: how far have we come?

The dataset generated by our European survey coupled with a search in four languages in scientific literature, grey literature and national/regional databases is, to our knowledge, the largest one ever compiled in the world. On the scale of this continent, it fills a gap highlighted more than a decade ago (Godefroid and Vanderborght 2011). We were able to trace 3211 translocations involving 1166 taxa, showing that Europe is not lagging behind other regions of the world in terms of number of projects implemented: syntheses carried out in several countries outside Europe mention 428 plant species

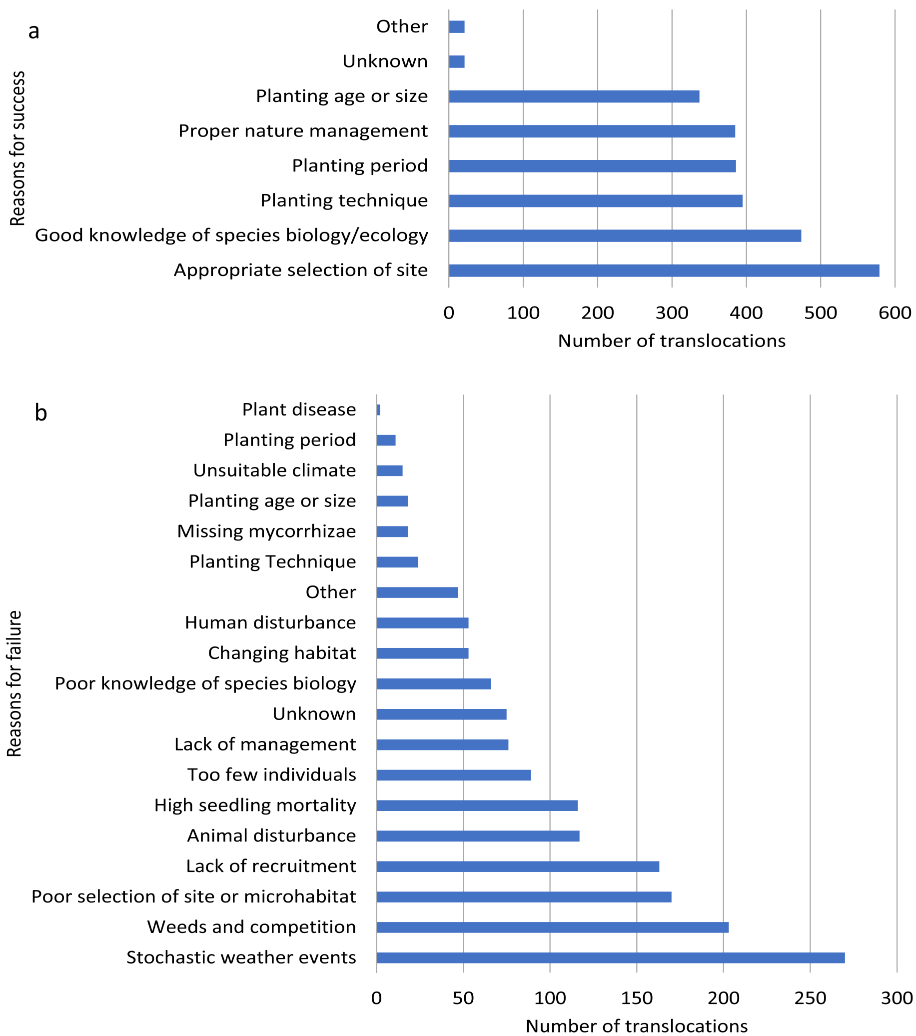


Fig. 8 Reasons for **a** success (n = 2604) or **b** failure (n = 1586) based on the respondents' impressions or on data collected by them. More than one answer was possible per translocation case

already translocated in the USA (Novak et al. 2021), 376 in Australia (Silcock et al. 2019), 249 in New Zealand (Coumbe and Dopson 1999) and 206 in China (Ren et al. 2020). For Europe, the TransLoc database (http://translocations.in2p3.fr) has included 953 cases involving 460 European plant species. Our research effort has identified three times more translocations, which provides a hugely improved overview of what is being done in Europe. This also highlights the need to work on the barriers to translocations being recorded in public databases and to encourage practitioners to add their information and experiences into existing databases.

The data collected covers 28 of the 44 European countries listed by the United Nations, of which 20 are members of the European Union, across eight biogeographical regions. In general, translocations have been rarely implemented in Boreal, Steppic and Pannonian biogeographic regions. The relatively good state of ecosystems and the lower degree of landscape fragmentation in the Boreal bioregion may explain this phenomenon, with the consequence that plant translocations do not seem to be a priority among conservation approaches in some northern European countries (Rannveig Thoroddsen, pers. comm.). However, low financial resources and funding opportunities and less widely spoken English (especially for non-EU countries) might also have contributed to a lesser use of translocation as a conservation measure in some countries, as classic in situ conservation measures such as habitat protection and management are costly and may use up all existing resources. Furthermore, in politically unstable countries (e.g. in the Steppic bioregion), species conservation might not be a priority. Cultural aspects also play a role, e.g. in many post-communist countries where conservationists are rather conservative, with the result that translocations are not very popular, although the situation has changed slightly over the last 10 years. National legislation sometimes also restricts the implementation of translocations, such as in the Czech Republic where translocations are currently only permitted on historic sites and with local seeds. In areas more impacted by human activities, as well as in those with a high rate of endemism, translocations seem to have become a common practice, such as in the Mediterranean, especially in Spain where more than half of the translocations reported (65.6%—617 out of 940) have been carried out in a very small territory of the country, the Valencian Community, which represents 4.6% of the surface area of Spain and 0.2% of Europe. The large number of translocations reported for the Mediterranean bioregion makes sense since it is a biodiversity hotspot (Myers et al. 2000) with c. 60% of all native taxa occurring only in this region and c. 37% being narrow endemic species (Thompson 2020). It is also consistent to see that the majority of European translocations have taken place in grasslands which are the most threatened habitats in Europe (European Commission 2020; Janssen et al. 2016) and whose restoration must be urgently prioritized (Staude et al. 2023).

The survey results also highlighted that many species have been translocated in several regions of Europe. For instance, *Arnica montana*, a European endemic, has undergone 63 translocations in four different countries. Among many other examples, the aquatic fern *Marsilea quadrifolia* has been translocated 16 times in eight different countries. For several taxa, there have been transnational interactions between projects (as is often the case for LIFE or Interreg programmes). Collaborations therefore exist, but it is also very unlikely that this has been the case for all the species translocated on multiple locations and countries in Europe. So clearly, a common and well-referenced database can greatly help to avoid repeating mistakes in the future and to save resources by facilitating the exchange of information between stakeholders. The present database can also be used to identify potential inconsistencies when considering species translocations at a transnational scale, and can help to harmonize priorities between regions or states and to promote the establishment of translocation programs at relevant biogeographical scales throughout Europe.

Motivations behind implementing European translocations

Target species had a conservation status of greater concern nationally than globally, suggesting that red lists in individual countries often include taxa that are at the edge of their range in the country. Translocations may therefore have been motivated by regional priorities rather than by global risk, a phenomenon that has already been highlighted in North

America (Brichieri-Colombi and Moehrenschlager 2016) and in France (Diallo et al. 2023). In Europe, nature conservation is organised on the regional level in many countries, for instance in Germany, Austria, Spain, Switzerland, Belgium, and Italy. Hence, regional differences in species distributions play a large role in the decisions of where and to which species resources are allocated to, and our dataset evidenced this for several species (e.g. in France *Arnica montana* is on the red list of some departments but not at the national level). In the present survey, the main reason for translocation was to reduce the risk of extirpation/extinction of a species listed at a national or regional level. This indicates that translocations in Europe are mainly used for species conservation programmes and less often for scientific projects or for mitigation purpose. Mitigation translocations are, however, strongly increasing worldwide (see Diallo et al. 2023; Doyle et al. 2022; Julien et al. 2023), but often have more limited objectives than conservation translocations and are therefore not considered in the same way. This may suggest that mitigation translocations might be underrepresented in our dataset because this information is less easily accessible (Doyle et al. 2022, 2023), as many of these translocations are conducted by private consulting firms that do not give their data away.

European approaches compared to other continents

As in Australia (e.g. Silcock et al. 2019), the vast majority of translocations that have taken place on the European continent have been implemented in the last two decades (Fig. 1d). It confirms that in Europe too, the science and practice of translocations are still in their infancy, even though the first case reported in our database dates back to 1908 and several others were carried out in the 1950s, 1960s and 1970s, which is earlier than the first case reported in 1985 in the United States (Guerrant 2012). European translocations were more numerous in the region with the highest plant species richness and number of narrow endemics (i.e. the Mediterranean one), a phenomenon also noticed within Australia (Silcock et al. 2019).

A large number of translocations in Europe were implemented using material stored in ex situ seed banks (Appendix S6). This is in line with a recent global survey showing that 70% of the responding seed bank facilities have already used their stored collections for plant translocations (White et al. 2023). The pattern raised here might be linked to the long history of wild seed banking in Europe that has some of the oldest and largest seed bank storage in the world (Pérez-García et al. 2009; Rivière and Müller 2018). While seed banks are still underutilized in supporting large scale restoration efforts (Wambugu et al. 2023), it seems that European facilities have been participating in knowledge transfer on conservation need (Rivière and Müller 2018), on seed germination (Carta et al. 2022) and are already actively involved in plant translocations (White et al. 2023). A significant number of projects have reported using garden-collected seeds (Appendix S6). We do not have similar information for other continents, but this trend deserves in-depth analysis as it is likely to compromise plant quality and the success of reintroductions. Indeed, garden-cultivated plants, especially those propagated over extended periods and several generations, have a high probability to undergo genetic and phenotypic changes as a result of rapid adaptative selection to garden conditions, genetic drift and inbreeding issues related to the small number of mates. This can lead to the selection of traits not adapted to the natural environment or to the loss of essential genetic variability needed for evolutionary resilience (De Vitis et al. 2014; Ensslin et al. 2015, 2018, 2023; Ensslin & Godefroid 2020; St. Clair et al. 2020). It must be recognized that there are extreme cases in which there is no possibility of collecting seeds in situ, either they are not accessible, or their collection would jeopardize the viability of the existing population dynamics, or the seeds do not present sufficient quality or quantity from wild specimens present in natural populations known to date (e.g. *Cistus heterophyllus, Silene hifacensis, Corema album*). In these cases, the production of mother plants for the multiplication of ex situ material is inevitable (Ferrer-Gallego et al. 2019). It should be noted, however, that if cultivation is carried out over a low number of generations (up to 4), the genetic integrity of natural populations can be maintained (Conrady et al. 2022).

Translocated populations in Europe frequently consisted of very few plants (usually less than 100), a trend that has already been highlighted in global reviews (Dalrymple et al. 2012; Godefroid et al. 2011) as well as in the United States (Guerrant 2012) as in Australia (Silcock et al. 2019). This approach can jeopardize the long-term persistence of the restored population if it does not reach a minimum viable size (Nabutanyi and Wittmann 2022), especially as significant initial losses of translocated plants have been reported by survey respondents. This situation can even occur under optimal conditions in a well-chosen recipient site, due to transplantation shock and non-suitable micro-site conditions (Guerrant and Fiedler 2004). Fitness problems in plant species generally occur in small, fragmented populations (Aguilar et al. 2006, 2019; Frankham et al. 2014). For instance, reproduction of *Primula veris* and *Gentiana lutea* is less successful in populations of less than 200 and 500 plants, respectively (Kéry et al. 2000). For *Cirsium pitcheri*, Bell et al. (2003) found that more than 400 transplants of one-year rosettes, or 1600 seedlings, or 250,000 seeds would be required to create a viable restored population. An in-depth analysis of translocations carried out in Australia has shown that using at least 500 individuals increases the chances of creating a viable population provided that recruitment is observed (Silcock et al. 2019).

Reintroductions and reinforcements represent the vast majority of translocation types in Europe, which differs from the Australian approach where 80% of the cases consisted in introductions to new sites within the species' distribution area (Silcock et al. 2019). This may be due to a different mindset in the European continent which could make obtaining a permit more difficult in the event of introduction compared to a reintroduction (i.e. to a site where the species was once present). Our survey also showed that assisted colonization (also called assisted migration, see Vitt et al. 2010) has been little considered in Europe. The reasons behind this lack of interest may be varied, but it is likely that there is some reluctance due to controversy and potential risks like maladaptation, invasiveness or disease spread (Ferrarini et al. 2016; Kracke et al. 2021; Loss et al. 2011; Van Daele et al. 2022). Moreover, Europe consists of a large number of rather small countries, and nature conservation can be a regional competence, which makes translocations across regional and national borders administratively complex. Language barriers further exacerbate this pattern. This might also discourage attempts to take climate change and species distribution modelling into account. However, a particular case is the Valencian Community (Spain), where more than half of the translocations (326 translocations, 52%) are assisted colonizations. This is partly due to the conservation policy of not interfering in the natural population dynamics with the introduction of translocated specimens (see Laguna and Ferrer-Gallego 2012) as well as the possibility offered by this technique of assisted colonization to move species to more climatologically adapted areas and avoid the impact of climate change (Ferrer-Gallego and Jiménez 2022). In North America, Seddon (2010), Pedlar et al. (2012) and McKone and Hernández (2021) called for assisted migration to be implemented on a community scale rather than at species level. Although Europe is warming twice as fast as the global average (WMO 2023), assisted colonization does not seem to be a widely adopted climate change adaptation tool, despite the availability of decision frameworks incorporating a biogeographical approach and the increasing reliability of species distribution models (Abeli et al. 2014; Casazza et al. 2021).

According to the results of our survey, the choice of the target site was mainly motivated by the (a)biotic requirements of the species (Appendix S5). A sound knowledge of the biology and ecology of the species is recognised in several guidelines as a key element in the success of the transfer (Commander et al. 2018; Maschinski and Albrecht 2017). According to the survey respondents, the primary factor motivating the selection of source populations was the geographic proximity to the target site, far ahead of the ecological similarity with the target site (Appendix S4). The latter has, however, been indicated as a better predictor of the establishment success of a translocated population (Lawrence and Kaye 2011; Montalvo and Ellstrand 2000; Noël et al. 2011; Raabová et al. 2007), but requires additional effort as the biotic and abiotic conditions of the site must be accurately documented in order to compare their ecological similarity. This geographical proximity is also what mainly motivated the choice of a single source population. Geographic proximity can, however, be misleading in that the closest populations can sometimes be genetically divergent (Orsenigo et al. 2016). Previous studies also recommended transplanting species from multiple source populations in order to increase genetic diversity and the number of compatible mates of the restored population, to counteract possible inbreeding issues in transplant progeny and to improve the chances of population establishment (e.g., Dillon et al. 2023; Frankham et al. 2019; Shemesh et al. 2018; St. Clair et al. 2020; Van Rossum and Le Pajolec 2021; Van Rossum et al. 2022). This recommendation does not seem enough considered yet, possibly due to the high costs of performing genetic analyses to validate genetic admixture between populations. On the other hand, mixing different source populations can sometimes lead to outbreeding depression (e.g. see Montalvo and Ellstrand 2001), which could explain a certain degree of conservatism of local authorities trying to limit genetic pollution but thereby going against the arguments of scientists.

Problems commonly identified in the course of projects

Our survey revealed that many problems arose during translocations, with some being expected, while others were completely unforeseen (Fig. 5b). The most frequently reported unforeseen issues were stochastic weather events. Extreme events such as increased and more intense drought periods are expected to increase due to climate change (WMO 2023), making nowadays optimal planting windows more uncertain, as strong droughts in the first years after planting can jeopardise the survival of whole translocated populations (as revealed by the survey data). This issue also enlightens the need for considering assisted migration outside current species distribution range as part of a strategy that would also include conservation genetics, and habitat connectivity and management (Bernazzani et al. 2012; Loss et al. 2011; Van Daele et al. 2022). Complementary approaches could also be considered, such as providing aftercare, e.g. watering (Monks et al. 2023; Whitehead et al. 2023) and spreading the planting period over several years to avoid losing all the material due to extreme weather events.

Limited seed dispersal from translocation sites was also a largely underestimated problem according to the present survey. Most endangered species of the European flora have a natural dispersal distance (not aided by a specific vector) of less than 5 m (Lososová et al. 2023). Restricted seed dispersal may not only hamper site colonization, but it may also result in genetic structuring at a fine spatial scale, favouring inbreeding, and so possible inbreeding depression issues, especially when combined with restricted pollen dispersal (Monks et al. 2021; Van Rossum et al. 2023). Restored populations must therefore be integrated as quickly as possible into the normal habitat management regime, or specific management measures need to be implemented in order to enhance propagule dispersal and burial from the planting area, e.g. by livestock grazing (epi- or endozoochory) and trampling or by mowing machinery (Kapás et al. 2020; Klinger et al. 2021).

Another largely unanticipated obstacle cited by respondents was plant pests and diseases, during plant cultivation and in the field. This shows how important it is to identify the propagation protocol adapted to the species and to collect information on species life history traits. Various factors, such as substrate type, watering, requirement for mycorrhiza and pathogens, can strongly influence the fitness of the plants produced (Godefroid et al. 2016). It is essential not to underestimate these aspects, and thus to plan (and to budget) sufficient time in recovery projects to carry out preliminary tests for finding the right propagation protocol before starting plant production (De Vitis et al. 2022; Godefroid et al. 2016). We suspect that this preliminary testing and information gathering phase is often overlooked in project planning as time constraints were very commonly cited (and foreseen) obstacles. A high number of translocation projects therefore might have been carried out in haste and without the required preparation, a situation that is compounded by the fact that many funding sources only support practical interventions and exclude the necessary underlying scientific research. The short-term nature of many grants can also be an issue as planning and pre-translocation actions may be rushed to meet project deadlines.

How successful have European plant translocations been so far?

Our European survey results show that most translocated populations had a relatively low survival rate, a situation that had not much improved since the last global reviews (Dalrymple et al. 2012; Godefroid et al. 2011) and that was similarly highlighted in Australia (Silcock et al. 2019). Furthermore, only 28% of the restored populations were considered by respondents to be self-sustaining (stable or increasing in size). Of course, many of these projects are too recent to judge long-term success. Some published cases show that it can take more than a decade before a translocation can be declared biologically successful or not (Bellis et al. 2023; Drayton and Primack 2012; Guerrant 2012; Menges et al. 2016; Zavodna et al. 2015). The situation can also change after a long period of time, and what seemed successful initially may eventually fail (e.g. Guerrant and Kaye 2007). Our survey showed that almost half of the populations did not persist more than five years after transplantation. This raises questions about the effectiveness of current translocation approaches. In-depth analyses linking methods and results are necessary to understand these patterns.

It should be noted, however, that monitoring of translocation success represents the category of information for which we had the least amount of data. For instance, the question of whether plants produced a second generation resulted in only 782 answers. Although this score is much better than in a global survey carried out in 2009 (Godefroid et al. 2011), the response rate is still quite low (24%), despite the importance of this variable for assessing population viability (Bellis et al. 2023; Commander et al. 2018; Menges 2008). For all fitness variables for which we requested data, the response rate ranged between 24 and 34%. The most likely reason is the absence of monitoring, or at least a monitoring period that was too short, was already highlighted by previous studies (Godefroid et al. 2011; Julien et al. 2023). To help solve this problem, project funding should include the possibility for monitoring over a longer period (i.e. for several years after the end of the project). We insist again on the importance of conducting monitoring of the restored populations involving previously identified key indicators of translocation success (e.g. Bellis et al. 2023; Commander et al. 2018; Godefroid et al. 2011; Menges 2008).

Conclusions

The combined results of the online survey and the literature search generated a database of 3211 translocation cases involving 1166 taxa across the European continent, representing to our knowledge the largest translocation database in the world to date. Our considerable effort to identify all current practitioners in plant translocations, as well as former activities via the literature survey, means that we have confidence that the database has captured the largest part of the data on plant translocations in Europe in its geographic, taxonomic and methodological diversity. This study is timely, as it responds effectively to European conservation policies (e.g. art. 11.2 of the Bern Convention, art. 22 of the Habitats Directive 92/43/EEC). Indeed, in order to help more and more species to colonise habitats that they cannot reach by natural dispersal and to mitigate impact of habitat fragmentation and intense anthropogenic land use, the number of translocations is expected to increase. However, the results of our survey reveal that the success rate for plant translocations remains rather low and that many translocations have not been carried out with the necessary care and according to available protocols. We therefore strongly advocate better dissemination of experience and validated protocols so that the quality of translocations, and so the number of restored viable and resilient populations of endangered species, increase. The database generated by this survey is intended to serve this purpose, by being an informative tool for practitioners involved in this type of conservation practice. We hope that it will facilitate exchanges between stakeholders and contribute to improve the science and practice of plant translocations in Europe and beyond. The dataset associated with this article is a snapshot in time that will need to be transformed in the future into an interactive platform that practitioners can not only consult but also feed with data relating to upcoming translocations.

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Author contributions S.G. and A.E. conceived the project. S.G., A.E., T.A., S.D. and H.B. developed the questionnaire survey. SL analysed the data. All authors contributed to data collection and revisions to the manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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