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# Monitoring time of conservation-driven and mitigation-driven plant translocations in Europe

Margaux JULIEN<sup>1,2</sup> (0000-0003-4105-5545), Bertrand SCHATZ<sup>1</sup>(0000-0003-0135-8154), Alexandre  
ROBERT<sup>3</sup>, Bruno COLAS<sup>4\*</sup>(0000-0003-0004-8218)

<sup>1</sup>CEFE, CNRS, Univ Montpellier, EPHE, IRD, Montpellier, France

<sup>2</sup>Ecotonia, 60 rue tourmaline, 13510, Eguilles, France

<sup>3</sup>CESCO, MNHN, CNRS, Sorbonne Université, CP 135, 57 rue Cuvier, 75005 Paris, France

<sup>4</sup>Écologie Systématique et Évolution, Université Paris-Saclay, CNRS, AgroParisTech, 91190 Gif-sur-  
Yvette, France

\* corresponding author: [bruno.colas@universite-paris-saclay.fr](mailto:bruno.colas@universite-paris-saclay.fr)

## Abstract

Species translocations are increasingly used to improve the conservation status of threatened species, restore communities, or in response to mitigation hierarchy. Post-translocation monitoring is an essential step in any translocation protocol, as only demographic data collected over a sufficiently long period can be used to estimate whether a translocated population is viable and thus determine whether translocation is successful. We gathered European monitoring data from 575 plant translocation units to document monitoring time and determine how it varies. We examined this variation by translocation motivation between conservation-driven translocations (undertaken outside the mitigation hierarchy) and mitigation-driven translocations. We also compared the monitoring time to the type of biological material translocated and the number of individuals.

We show that mitigation-driven translocations were more monitored in the first few years after translocation but for a shorter time than conservation-driven translocations. The same was observed for translocations made with diaspores compared to translocations made with plants. Moreover, monitoring time increased with the number of translocated plants but not with the number of diaspores. Although conservation-driven and mitigation-driven translocation programs exhibited distinct temporal monitoring patterns, both motivations of translocations were associated with rapid discontinuation of the monitoring. Indeed, after four years monitoring continued in only 37.9% of non-extinct population units. After ten years, this percentage falls to 11.8%. We recommend that translocations be monitored more assiduously over longer periods, and that the monitoring data be readily available to improve future translocations.

**Keywords:** Plant translocation · Monitoring time · Conservation translocation · Mitigation hierarchy

## 1. Introduction

Translocations are human-induced movements of living organisms into natural or semi-natural ecosystems. The main objective of conservation translocations is to improve the conservation status of a species, locally or globally, or to restore natural ecosystem functions or processes (IUCN/SSC 2013). This is the case of translocations initiated by conservationists (researchers or practitioners) to obtain viable populations through reinforcement, reintroduction, introduction or assisted migration, with an explicit conservation goal. In this article, we will refer to these translocations as *conservation-driven translocations*, as opposed to *mitigation-driven translocations*, which may or may not have such a population viability objective. Mitigation-driven translocations consist of moving individuals threatened by a change in land use. These translocations have emerged and become widespread in many countries with the application of legal procedures for protected species under the mitigation hierarchy (avoidance, minimization, rehabilitation/restoration, offset; BBOP 2012). Depending on the development project and national or regional regulations, translocation proposals may appear as reduction (“minimization” step) or accompanying measures in the mitigation hierarchy (for France, see Julien et al. 2022a). Although the initial motivation for mitigation-driven translocations is to comply with legal procedures, these translocations may be conservation translocations according to the IUCN definitions if they have incorporated a population viability objective (IUCN/SSC 2013). However, in many cases, mitigation-driven translocations are only intended to save individuals without having projected the impact that this might have on the population, species or ecosystem. In this case, therefore, mitigation-driven translocations cannot be considered conservation translocations.

While conservation-driven translocations are often initiated and conducted by naturalists or scientists with good knowledge of the translocated species and some background in population biology, this is not necessarily the case for mitigation-driven translocations which are often undertaken by private environmental consultants under contract to developers (Germano et al. 2015; Bradley et al. 2020; Julien et al. 2022a). As a result, mitigation-driven translocations are quite controversial. They

are sometimes seen as a tool used by developers to gain easier acceptance of their projects without much concern for the outcome of the translocation, which is very uncertain (Fahselt 2007).

Post-translocation monitoring is essential to understand and evaluate the results of the operation. Data on individuals (survival and reproduction of translocated individuals), populations (age or stage distributions, demographic rates, population size), and ecosystems (interspecific interactions, structure and dynamics of the community) can provide information to improve knowledge of the translocated species and the practice of translocation (Berger-Tal et al. 2020; Monnier-Corbel et al. 2022), especially if non-translocated populations are monitored simultaneously with translocated populations (*e.g.*, Colas et al. 2008) or if the translocation protocol includes an experimental design (*e.g.*, planting in different light conditions, Zimmer et al. 2016). As many authors have already pointed out (Albrecht et al. 2011; Godefroid et al. 2011; Dalrymple et al. 2012; Liu et al. 2015; Diallo et al. 2021; Piazza et al. 2011), the outcome of translocations is scattered throughout scientific and grey literature and can sometimes be difficult to access (*e.g.*, activity reports of environmental consultancies). In particular, data from translocations that are considered failures by their proponents are not often shared, even though this data may be particularly valuable for future translocations, especially in identifying errors in preparation and/or protocol (Seddon et al. 2007; Abeli and Dixon 2016; Piazza et al. 2011).

Although there is no universal definition of translocation success, ecological monitoring of translocated populations (and, in particular, the variation in their abundance) provides valuable diagnostics of the impact of these practices on ecological systems. Considering that the goal of a conservation translocation is to achieve a viable translocated population (IUCN/SSC 2013), monitoring is expected to (i) indicate the occurrence of population extinction, and (ii) provide data on temporal variation in abundance, which can be used to assess population viability (Brook et al. 2006). The most relevant data for estimating the long-term viability of a population are often measurable over the long-term (Sarrazin 2007; Robert et al. 2015; Seddon and Armstrong 2019) because the early dynamics of a

translocated population is partly driven by stochastic and transitory processes that do not necessarily reflect its longer-term dynamics. It is still useful to have indicators of success in the short, medium, and long-term (Monks et al. 2012; Commander et al. 2018). However, short-term monitoring can lead to over-hasty conclusions about the outcome of translocations because it does not necessarily capture long-term dynamics (Albrecht et al. 2011; Drayton and Primack 2012). Yet, in a meta-analysis of plant translocations, Dalrymple et al. (2012) showed that monitoring was often short, leaving little opportunity to observe breeding or recruitment events.

In this context, we investigate the post-translocation monitoring time on European plant translocations. We analysed monitoring time according to the motivation of the translocation between conservation-driven and mitigation-driven translocations as defined above. We also studied the influence on monitoring time of the type of plant material translocated between (i) diaspores, *i.e.*, structural units (fruits, seeds, cuttings) that separate from parent plants and disperse before producing new vegetative or reproductive individuals, and (ii) vegetative or reproductive plants, as well as their numbers. We expect that in comparison to mitigation-driven translocations, conservation-driven translocations will result in more prolonged post-translocation monitoring, as the initiation of the translocations has not been imposed by an external environmental authority and is therefore likely to generate an intrinsic motivation to observe the outcome of the initiated work. Similarly, because it takes more effort to translocate vegetative individuals than to sow seeds and to translocate a large number of individuals rather than a small number, we expect longer monitoring in transplanted populations than in sown populations and in those where many individuals were translocated than in those where few were translocated. Some authors have shown that survival is more significant when adult individuals are used and that a large number of translocated individuals allows a greater chance of success (Menges 2008; Godefroid et al. 2011; Dalrymple et al. 2012; Reiter et al. 2016), which may motivate longer monitoring to observe success. In addition, mitigation-driven translocations are more controversial, especially for animal translocations, and it has been suggested that they are performed

with less care than conservation-driven translocations (Silcock et al. 2019; Bradley et al. 2020; Julien et al. 2022a). We can therefore expect shorter monitoring time.

## **2. Materials and Methods**

### **2.1. Terminology**

In this study, we use the term “translocated population unit” (TPU) to describe a group of individuals of the same species translocated to a given recipient site with a specific type of biological material (*e.g.*, seeds, seedlings, etc.). We use the term “operation” to refer to translocations of multiple TPUs undertaken by the same organization and forming part of the same spatial or technical set (*e.g.*, same protocol or provenance of biological material). We use the term “one monitoring” to refer to the entire monitoring of a single TPU, which may have taken place over several years, and the term “monitoring data” to refer to all the monitoring information to which we have access. Finally, a translocated population refers to a group of individuals of the same species resulting from a translocation operation in a given recipient site (according to the TransLoc database, see below). A translocated population can be composed of different types of translocated biological material, with multiple translocation events and protocols. We chose to work with TPUs to have homogeneous groups and facilitate statistical analyses.

### **2.2. Data collection**

We used the TransLoc database (<http://translocations.in2p3.fr/>) to collect conservation translocation monitoring data in various formats (peer-reviewed and non-peer-reviewed articles, reports, and raw data). Missing information (*e.g.*, the missing years for a particular TPU) was obtained by contacting the organizations in charge of post-translocation monitoring (mostly environmental consultancies, botanical conservatories, or researchers).

We built our database by keeping only those TPUs for which we had at least one post-translocation estimate of abundance. This abundance estimate (hereafter: 'TPU size') could be a total number of individuals, flowering individuals, flowering stems or inflorescences, leaf clusters or apices, or even an occupied area, but it necessarily had the same unit if several years of data were available. Any abundance estimate could include translocated individuals, offspring of these individuals, and possibly migrants. TPUs were excluded in the case of population reinforcements, when they were not clearly distinguished from the rest of the original population (less than 20 TPUs in this case). These choices were made to facilitate a comparison between TPUs (details of TPUs in Supplementary Document 1).

In July 2022, the TransLoc database contained 735 translocated populations, of which 156 (21.2%) met our criteria after collecting additional information for this study. These 156 translocated populations were divided into 351 well-identified TPUs. To increase our dataset, we contacted various organizations (mainly French departments, environmental consultancies, botanical conservatories, and natural area stakeholders) to access data on additional translocations, which allowed us to increase our database to a total number of 575 TPUs. Among them, 271 were from mitigation-driven translocations, and 304 were from conservation-driven translocations. They were from all over Europe, with the majority from France (73%).

Every TPU of our dataset had an operation code (several TPUs could be part of the same operation), a species name, a number and a type of translocated material, a year of translocation, and a type of organization in charge of the monitoring. The number of diaspores or plants released (sown or transplanted) in a TPU was noted  $N_R$ . Then, we noted  $N_0$ , the first post-translocation TPU size, when monitoring occurred either in the same year as the translocation (*e.g.*, at the end of the year when the plant material was translocated at the beginning) or in the following year. The TPU sizes of the following years were noted  $N_1, N_2, \dots, N_t$ . In all analyses, we considered an annual time step between  $N_t$  and  $N_{t+1}$ . The maximum possible number of years of monitoring for a given TPU depended on the



year of translocation. Time series of TPU sizes could have missing data for one or several years; sometimes, after an extinction, they could also stop or no longer be reported. In cases where extinction was documented, we noted the reason given by the authors for the extinction.

### **2.3. Accessibility of the monitoring data and limitations of the study.**

The monitoring data studied here are derived from translocations of various plant species with various stakeholders involved. Due to the difficulty of accessing these monitoring data, we had to contact the people involved in monitoring directly. We encountered several difficulties when requesting access to these reports: some stakeholders claimed that the reports were the property of a third party, often a development company. Other stakeholders wished to keep their data confidential for fear of competition between consulting firms or to keep the opportunity for publication for themselves. Finally, we also came up against the lack of availability of these stakeholders, especially among the instructive services to whom developers are supposed to send all their monitoring data (in the case of France) because translocations only represent a small part of their work and taking the time to communicate their data to us was not always possible. Among the monitoring that we have collected, some are truncated. Despite our research, we have not always been able to determine if we were unable to obtain the monitoring or if it was really interrupted. This is especially true in the years after scientific publications where it is even more difficult to access, which was already noted by Dalrymple et al. (2012) in a meta-analysis on translocations. Heterogenous data accessibility is also reflected in the spatial distribution of our data, mainly located in France. We collected mainly internal reports (67%) written in the language of the authors' country.

Finally, a limitation of this study is the type of monitoring we chose to keep: only monitoring for which a population indicator is given, the abundance estimate. There is no consensus on which indicators should be used in monitoring, which considerably limits meta-analyses on the topic (Dalrymple et al. 2021). We excluded from our dataset many populations where only translocated

individuals were followed without looking at their offspring.

## 2.4. Data analyses

We mapped all translocated populations in our dataset using their GPS coordinates. For every TPU, we determined the ideal number of years of monitoring, which is simply the number of years between translocation and either a documented extinction or the year of data recovery (2021). Given the data disparity in quantity between France and the rest of Europe, we conducted separate analyses for France and the other countries and compared with analyses including all data.

We investigated whether the duration of post-translocation monitoring was related to the motivation of translocation (conservation-driven *versus* mitigation-driven), the number and type of translocated biological material (diaspores *versus* plants, *i.e.*, whole plant, bulb, rhizome, etc.), the type of organization in charge of monitoring, and a simplified classification of biological types forms based on Raunkiaer's classification (Raunkiaer 1934): (i) woody (chamaephyte and phanerophyte), (ii) non-geophyte (hemicryptophyte), (iii) geophyte (geophyte and hydrophyte), and (iv) annual (therophyte). For each TPU, a post-translocation monitoring vector (the monitoring status) was filled with "1" for years in which monitoring occurred and "0" for years without monitoring. We considered NA years after 2021 because we acquired the data this year, as well as all years following a documented extinction because we did not expect the monitoring to continue. This vector was analyzed as a response variable using a generalized linear binomial mixed-effects model. The name, meanings and modalities of the variables are detailed in Table 1. This model was carried out by considering only the first ten years because there is little data after 10 years.

**Table 1.** Explaining variables used to model the post-translocation monitoring time. All random effects are factors.

Model variables	Description of the modalities
<b>Fixed effects</b>	
PostMonitYear	Number of years after translocation (quantitative variable from 0 to 10)
Motivation	Conservation-driven / Mitigation-driven (binary variable)
NumberBiolMat	Number of “individuals” translocated; positive entire value (quantitative variable)
BiolMat	Type of translocated biological material: Plant / Diaspore (binary variable)
Organisation	Type of organisation in charge of the monitoring: Conservatories / Environmental consultancies / Laboratories / Managers of natural areas / Others (qualitative variable)
BiolType	Biological type of the translocated species: Woody / Non-geophyte / Geophyte / Annual (qualitative variable)
<b>Random effects</b>	
Operation	Unique code for each operation. Several TPUs can have the same code.
Year	Year of translocation from 1971 to 2020
Family	Taxonomic family, 44 modalities

We first built a model with the set of explanatory variables and interactions that we thought were relevant to explain the monitoring time (Model 1). This model had convergence and collinearity problems, so we built other less complex models, by removing interactions and parameters (organisation and biological type) that were revealed to be non-essential to the analysis. We

determined the best model (Model 2) by a model selection procedure using the Akaike information criterion (AIC), the results of which are presented in Supplementary Material 2.

(Model1) *Logit(Monitoring status)*

$$\begin{aligned}
&= \textit{PostMonitYear} + \textit{Motivation} + \textit{Organisation} + \textit{BiolType} \\
&+ \log(\textit{NumberBiolMat}) + \textit{BiolMat} + \textit{PostMonitYear: Motivation} \\
&+ \textit{PostMonitYear: BiolType} + \log(\textit{NumberBiolMat}): \textit{BiolMat} \\
&+ \textit{PostMonitYear: log(NumberBiolMat): BiolMat} \\
&+ \textit{PostMonitYear: Organisation} + (1|\textit{Operation}) + (1|\textit{Year}) + (1|\textit{Family})
\end{aligned}$$

(Model2) *Logit(Monitoring status)*

$$\begin{aligned}
&= \textit{PostMonitYear} + \textit{Motivation} + \log(\textit{NumberBiolMat}) + \textit{BiolMat} \\
&+ \textit{PostMonitYear: Motivation} \\
&+ \textit{PostMonitYear: log(NumberBiolMat): BiolMat} + (1|\textit{Operation}) + (1|\textit{Year}) \\
&+ (1|\textit{Family})
\end{aligned}$$

## 2.5. TPU extinction

The interruption of monitoring can sometimes be related to the extinction of the TPU. Indeed, when a translocation fails, it does not seem useful to continue the monitoring for as long as a translocation where individuals are still present. We considered a TPU to be extinct in year  $t$  if (1) the estimated TPU size was zero in year  $t$  and monitoring stopped after  $t$ , or (2) the estimated TPU size was zero in year  $t$  and all subsequent years.

For each time following the translocation year, we determined for each TPU its monitoring status: extinct TPU, interrupted monitoring (while TPU size was  $> 0$  on the latest monitoring year), ongoing monitoring. We then calculated the percentage of extinct TPUs, interrupted monitoring and ongoing monitoring for each post-translocation year. We then plotted these percentages on time for all TPUs, and according to the motivation of translocation and the type of biological material.

We used R 4.1.2 for all analyses and the *tidyverse* library (Wickham et al. 2019; R Core Team 2020). The *lmerTest* and *lme4* libraries were used to make the models and the *performance* and *effects* libraries to verify the models and plot the effects (Fox 2003; Bates et al. 2015; Kuznetsova et al. 2017; Lüdtke et al. 2021). Figures were modified using Inkscape 1.0.2 software. The map was done with QGIS 3.16.12.

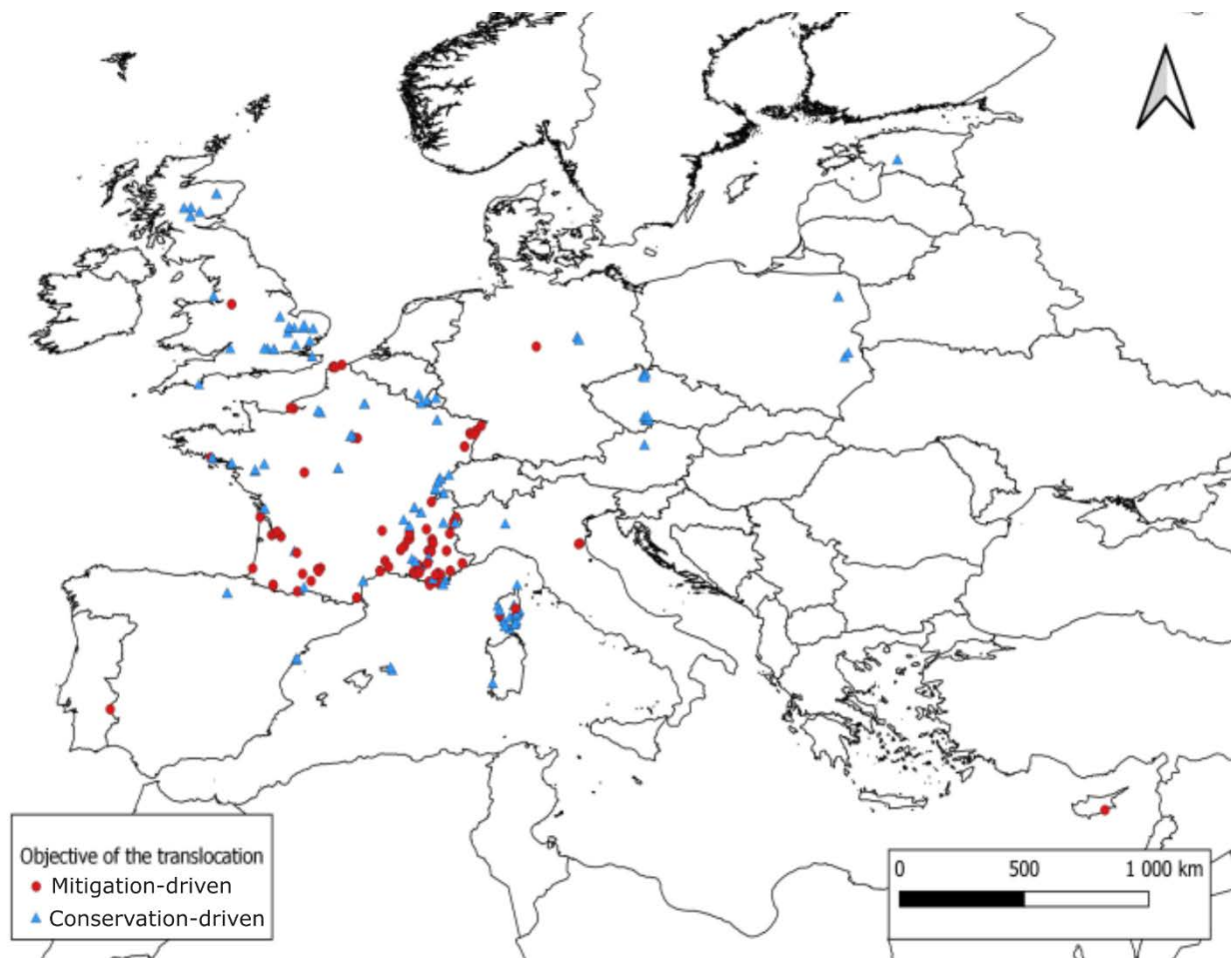
### 3. Results

#### 3.1. Location of translocations and taxon identity

The dataset included 152 species belonging to 44 families. Fifty-three percent of the translocations were mitigation-driven, and 47% were conservation-driven translocations. Monitoring time ranged from 1 to 19 years. Among all 575 TPUs, the most frequent species were *Saxifraga hirculus* (n=32), *Onosma arenaria* (n=22), *Aldrovanda vesiculosa* (n=21) and *Posidonia oceanica* (n=19) (Supplementary document 1). The most frequent families were Caryophyllaceae (n=43), Fabaceae (n=43), Boraginaceae (n=35) and Orchidaceae (n=34). If we consider species only once per operation (there may be multiple TPUs of the same species for the same operation), the most frequent species were *Aristolochia rotunda* L. (n=4), *Dianthus superbus* L. (n=4), *Rosa gallica* L. (n=4), and *Saxifraga hirculus* L. (n=4), and the most frequent plant families were Liliaceae (n=14), Caryophyllaceae (n=13), Asteraceae (n=11) and Orchidaceae (n=10).

Most TPUs (72.7%) were located in France and, more precisely in the southeast of France, (Fig. 1) with the United Kingdom having the second largest amount of data. As for the other European countries, the TPUs were mainly from Western Europe.

Many diaspores or plants have been translocated after *ex situ* passage (62.1% of the TPUs), in cold storage (for seeds) or in gardens (for vegetative plants). Individual monitoring of the translocated individuals was performed in only a few TPUs (11.8%).

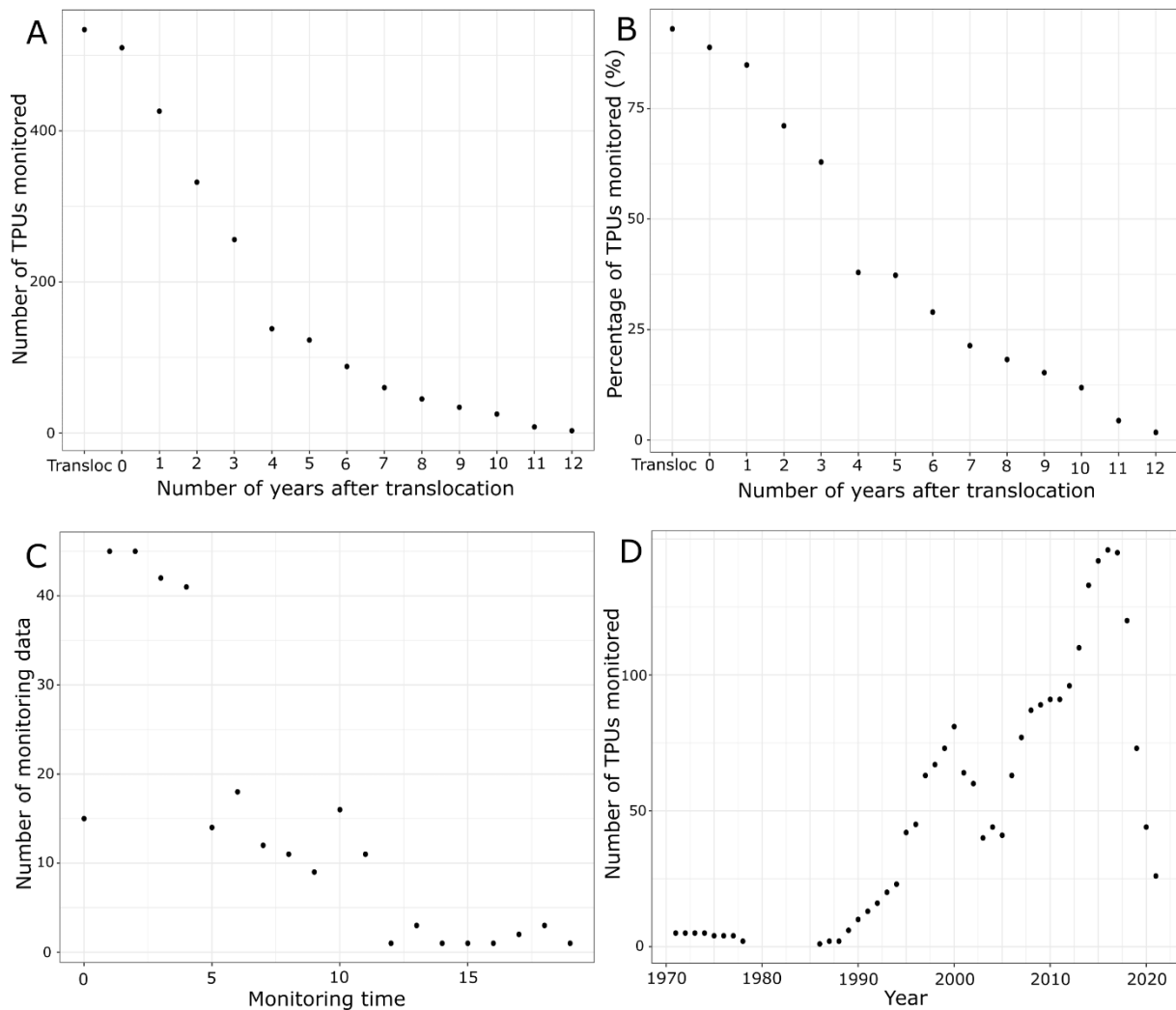


**Fig. 1:** Distribution of available TPUs in Europe.

### 3.2. Description of the monitoring time

Monitoring generally lasted less than 5 years (Figure 2C). The mean duration of monitoring was 4.59 years ( $n=575$ ; median=3). The number of TPUs monitored dropped drastically between years  $t=0$  and  $t=4$  after translocation (Figure 2A). From year  $t=5$  onwards, the decrease in the number of monitoring is smaller. More important is the percentage of TPUs monitored relative to the expected number considering the limit to 2021 and extinctions. It can be seen in Figure 2B that this percentage decreases

very quickly, with 37.9% of them being monitored in the fourth year after the translocation. After ten years, this percentage falls to 11.8%.



**Figure 2.** Availability of monitoring data. A: Number of TPUs monitored in each post-translocation year. B: Percentage of TPUs monitored relative to the expected number of TPUs monitored. C: Monitoring time since translocation. D: Number of TPUs monitored available per year. The graphical results were similar when using only French and only non-French data (not shown).

Many translocations have occurred since 1990, explaining why most monitoring data is recent (Figure 2D). There were two peaks of monitoring data, one in 2000 and one in 2017. The first peak corresponded mainly to conservation-driven translocations and the second one to mitigation-driven translocations (see Supplementary Document 3).

### **3.3. Analysis of interrupted monitoring**

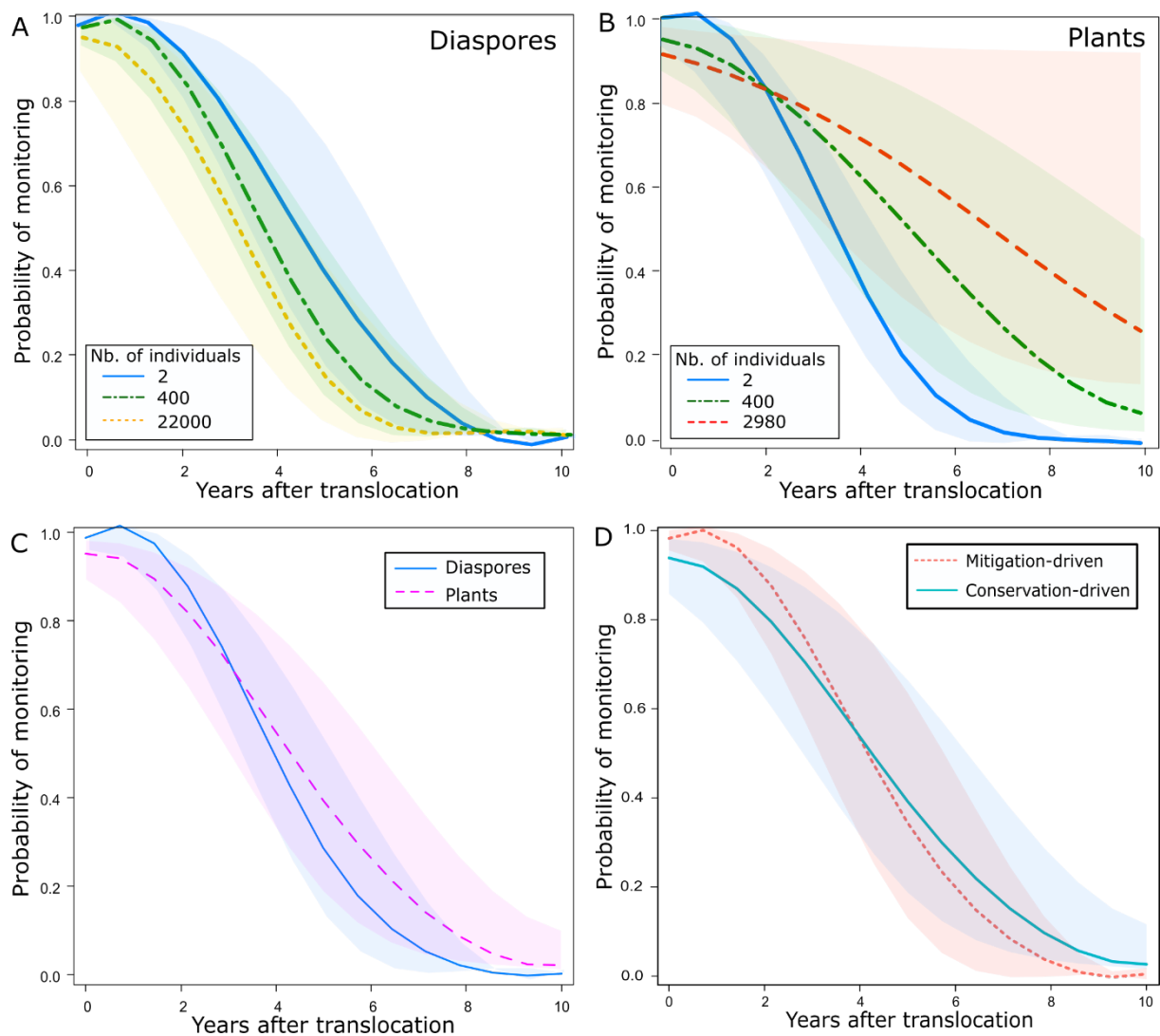
The results of the monitoring status model (Table 2) indicate that (1) the monitoring probability decreased with time since translocation (PostMonitYear variable). (2) Initial monitoring effort (*i.e.*, the probability of monitoring immediately after translocation) was higher for mitigation-driven than for conservation-driven translocations (Motivation variable). (3) However, the monitoring probability decreased more rapidly with time for mitigation-driven than for conservation-driven translocations (PostMonitYear x Motivation interaction, see fitted values in Figure 3D).

We also determined through the model that monitoring status depended on the type of biological material and the number of individuals translocated. Immediately after translocation, diaspore translocations were more often monitored than translocations of plants (Figure 3C), and the slope of monitoring status decreased over time and was gentler when many plantings were made (Figure 3B). This was not true for diaspores, whose monitoring status was the same regardless of the number of diaspores sown (Figure 3A).



**Table 2.** Results of the binomial generalised linear mixed-effects model. “Mitigation” is the reference motivation; “diaspores” is the reference for the type of biological material. Signif. codes: \*\*\* <0.001, \*\* <0.01, \* <0.05.

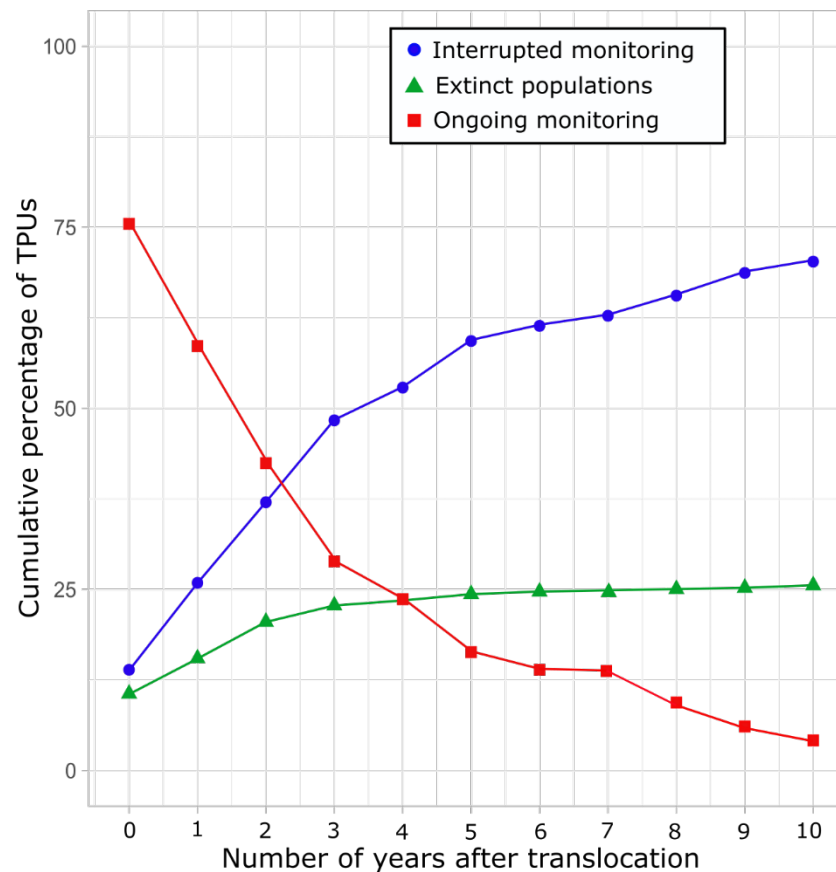
Variables and interactions	Estimate	Std. Error	Z value	Pr(> z )
Time	-1.25	0.074	-16.91	<2e-4***
Motivation – Conservation-driven	-1.30	0.54	-2.42	0.015*
log(NumberBiolMat)	-0.20	0.078	-2.54	0.011*
BiolMat - Plants	-1.29	0.33	-3.90	9.7e-05***
PostMonitYear x Motivation – Conservation-driven	0.30	0.058	5.20	2.0e-07***
PostMonitYear x log(NumberBiolMat) x BiolMat – Diaspores	0.0083	0.017	0.48	0.632 NS
PostMonitYear x log(NumberBiolMat) x BiolMat – Plants	0.086	0.012	7.04	1.9e-12***



**Figure 3.** Fitted values of the model. A. for the number of diaspores translocated. B. for the number of plants translocated. C. for the type of biological material used. D. for the motivation of the translocation.

### 3.4. TPU extinction

In year 0, 10.6% of the TPUs were already extinct, and 23.5% after 4 years (Figure 4). Most documented extinctions occurred during the first four years after translocation. Considering only the 295 TPUs 10 years or older in 2021, monitoring continued for only 7.8% of them. For 25.4% of these TPUs, the monitoring was stopped after an observed extinction, and for 66.8%, interrupted for an unknown reason. The most frequent documented causes of extinction were poor recipient site selection ( $n=10$ ), climatic conditions ( $n=9$ ), species biology ( $n=8$ ), inappropriate translocation period ( $n=5$ ), low germination rate ( $n=5$ ) and poor recipient host site management ( $n=4$ ).



**Figure 4.** Changes in the status of TPUs as a function of time since translocation.

We examined percent extinction by separating conservation-driven from mitigation-driven translocations and diaspores from plants (Supplementary Document 4). The percent extinction of conservation-driven and mitigation-driven translocations were similar. The difference between diaspores and plants was much more pronounced, with nearly 40% extinctions after 10 years for diaspore translocations *versus* just over 20% for plantings (33.8% *versus* 23.5% if we consider only TPUs older than 10 years).

#### **4. Discussion**

We documented in this study that monitoring of translocated plant populations is dramatically short, with only 7.8% still monitored 10 years after translocation. We showed that mitigation-driven translocations have a higher monitoring occurrence shortly after translocation but stop earlier in comparison to conservation-driven translocations. Similarly, translocations with diaspores have a higher monitoring occurrence shortly after translocation but stop earlier than translocations with plants. Finally, the greater the number of plants translocated, the longer the monitoring time.

The monitoring data of mitigation translocations in our dataset are more recent than for conservation-driven translocations. A peak of monitoring was observed in 2000 for conservation-driven translocations and in 2015 for mitigation-driven translocations (see Figure 2B and Supplementary Document 3). The monitoring peak in 2015 for mitigation-driven translocations is consistent with the results of Julien et al. (2022a), showing that, in France, the number of derogation files (official requests made by the developers in the mitigation hierarchy) containing a mitigation translocation proposal was very high between 2012 and 2015. Mitigation translocations are quite a recent practice in France. There were few before 2005, but are increasing and now tend to outnumber conservation-driven translocations (Julien et al. 2022a). Germano et al. (2015) has made a similar observation for animal translocations worldwide. The peak in monitoring in 2000 for conservation-driven translocations has no apparent reason. One possibility is that some traditional stakeholders in

conservation-driven plant translocations (*e.g.*, the *Conservatoires Botaniques Nationaux* in France) are increasingly involved in mitigation-driven translocations alongside private consultants and at the request of environmental authorities. This diversion of attention and available time to mitigation-driven translocations could be detrimental to the establishment and monitoring of conservation-driven translocations. However, the discrepancy in timing between mitigation-driven and conservation-driven translocations did not affect the results of our model because the year of translocation was included as a random effect and because we considered the cessation of data in 2021.

#### **Weak monitoring and link with translocation failure.**

The percentage of TPUs monitored among those that could be monitored after 4 years (*i.e.*, TPUs at least 4 years old and non-extinct) is 37.9%. This percentage is 11.8% after 10 years. We do not know if the monitoring times are much less than expected at the outset of the translocation projects because we do not have this data. This data should be much more readily available for inclusion in the translocation databases and for comparison between what has been achieved and what was contractually planned.

Of the TPUs whose fate is known (persistent or extinct) after 10 years, 86% were extinct. However, this percentage should be treated with caution, as for TPUs whose monitoring was interrupted for no known reason, we do not know whether they are more or less likely to be extinct than those monitored. Of the extinct TPUs, most extinctions occurred within the first 4 years after translocation, which was also the case for animal translocations (Bubac et al. 2019). The documented causes of extinction, mainly poor recipient site selection, climatic conditions, species biology, inappropriate translocation period, low germination rate and poor recipient site management, were similar to those documented by Albrecht et al. (2011) and Godefroid et al. (2011).

Based on our results, most extinctions occur within the first 4 years after translocation or even earlier for seedlings. This length of monitoring would therefore be a minimum after translocation, but

more is needed to estimate the translocation success. A longer duration, more than 10 years, is often recommended (Drayton and Primack 2012; Hancock et al. 2014). In reality, it is difficult to apply a monitoring duration that allows for the estimation of success or failure that is valid for all species, as it depends on the ecological strategy and the life history of the species (Albrecht et al. 2011; Popoff et al. 2021).

Early extinction was observed in a rather large number of cases: 10.6% at  $t=0$  and 15.5% at  $t=1$ . These early extinctions may be related to an inappropriate translocation protocol but also to the biology of the species, some of which may be particularly unsuitable for translocation. For example, this may be the case of species whose translocation breaks an interaction with symbiotic fungi or with specific pollinators. Establishing a list of difficult-to-translocate species would improve both decision-making and translocation protocols. However, some TPUs may reach zero visible individuals without becoming extinct. This is the case for geophytic species that may remain in the soil for a bad season or even for several years (Bell 2021; Lavery et al. 2021) or for populations whose adult individuals have died but have had time to build up a diaspore bank, which may be expressed a few years later. In our dataset, we repeatedly observed TPUs reaching a number of individuals equal to 0 in year  $t$ , then having a non-zero number of individuals in year  $t+1$ . For TPUs that were observed only once with a zero number of individuals, it would be interesting to come back to monitor these TPUs to confirm their absence. As a result, our extinction percentages may have been overestimated. Similarly, for the other monitoring, an assessment of the status of TPUs after several years of interruption would provide further insight into their dynamics (see Drayton and Primack 2012).

### **Factors influencing monitoring time.**

The short monitoring times observed overall raises serious questions. According to Fahselt (2007), it is difficult for conservation-driven plant translocations to have long-term monitoring because of funding programs, which are often planned for short periods. It is, therefore, probably rare to have the opportunity to secure a funding source for more than 10 years. Mitigation-driven translocations

benefit from almost systematic monitoring shortly after translocation but are monitored during shorter times than conservation-driven translocations. This is consistent with our prediction that conservation-driven translocations are likely to generate an intrinsic motivation to observe the outcome of the initiated work. Still, the difference between both motivations of translocations is slight and the probability of having a monitoring 5 years after translocation is less than 50% for both.

However, contrarily to conservation-driven translocations, the post-translocation monitoring of mitigation-driven translocations in France is funded for longer times, the planned monitoring time is generally more than 10 years and sometimes up to 30 years, and the frequency and duration of monitoring are mentioned in the agreement given the authorities to the derogation requests. So, the short monitoring times observed for mitigation-driven translocations may be due to the lack of compliance to legal requirements or the difficulty in accessing monitoring data.

That translocations made with diaspores are monitored a lot in the first two years seems quite logical to us, since if one wants to observe the first results, *i.e.*, the emergence of seedlings from the seeds, one must return to the population quickly. The first results of transplants are survival rates of translocated individuals, which can be estimated longer after the translocation (especially for perennial plants) than seed emergence rates. Moreover, transplants generally require more effort since, on the one hand, it takes longer to plant a vegetative individual in the soil than to sow a seed, and, on the other hand, the plants have often been cultivated *ex situ* before being translocated. In contrast, seeds can be kept in cold storage which requires less attention and work. There is, therefore, also a certain logic to the fact that TPUs from plant translocations are monitored longer than TPUs from diaspore translocations because the investment in time and money has generally been greater. It is probably for the same reason that translocations made with many plants are monitored for much longer than those made with few plants.

### **Recommendations for translocations.**

Reliable projections of long-term population dynamics and viability require full integration of the intrinsic population properties and the environment (Sarrazin 2007; IUCN 2013; Robert et al. 2015; Armstrong et al. 2017). Such integration can be conducted once there is evidence of regulation, *e.g.*, by explicitly modelling the relationship between population density and demographic parameters in a population viability analysis framework (Acker et al. 2014; Zabel et al. 2006), and using all relevant available information on life history, habitat requirements, threats, and management options to estimate extinction risk. This process can take decades for a translocated population, especially if the species has a long generation time (Monks et al. 2012; Commander et al. 2018). However, requiring demographic monitoring over at least ten years (but not necessarily every year) for any translocation, with an estimate of numbers, is not insurmountable and would be very beneficial information for all: researchers, managers, and decision-makers. These results should, of course, be easily accessible and shared between stakeholders via translocation databases, which is essential for improving practices and making decisions based on good knowledge of the results of past translocations. For example, suppose it is observed that for some taxa the objectives of translocations are rarely achieved, and the investment required (in time or money) is high. In that case, it may be considered more reasonable and effective to base conservation policies on protecting and managing habitats and establishing ecological continuities.

Our results show that monitoring is generally far too short compared to this objective, even though the recommendation to improve monitoring has been repeated for over 10 years (*e.g.*, Godefroid et al. 2011, Dalrymple et al. 2012, Liu et al. 2015, Silcock et al. 2019). Post-translocation mitigation-driven monitoring could be greatly improved, especially as these operations can benefit from quite substantial funding (see Julien et al. 2022b). It would therefore be desirable for the environmental authorities to demand greater commitments in terms of monitoring from the promoters of translocations in the context of development projects or better compliance with the commitments made. These authorities could exercise a power of control and financial sanctions in the



event of non-compliance with commitments, which is not currently the case in France, where many of the translocations studied in this article were carried out.

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**Data availability.** The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

## **Declarations.**

**Competing interests.** The authors declare no competing interests. The authors have no relevant financial or nonfinancial interests.

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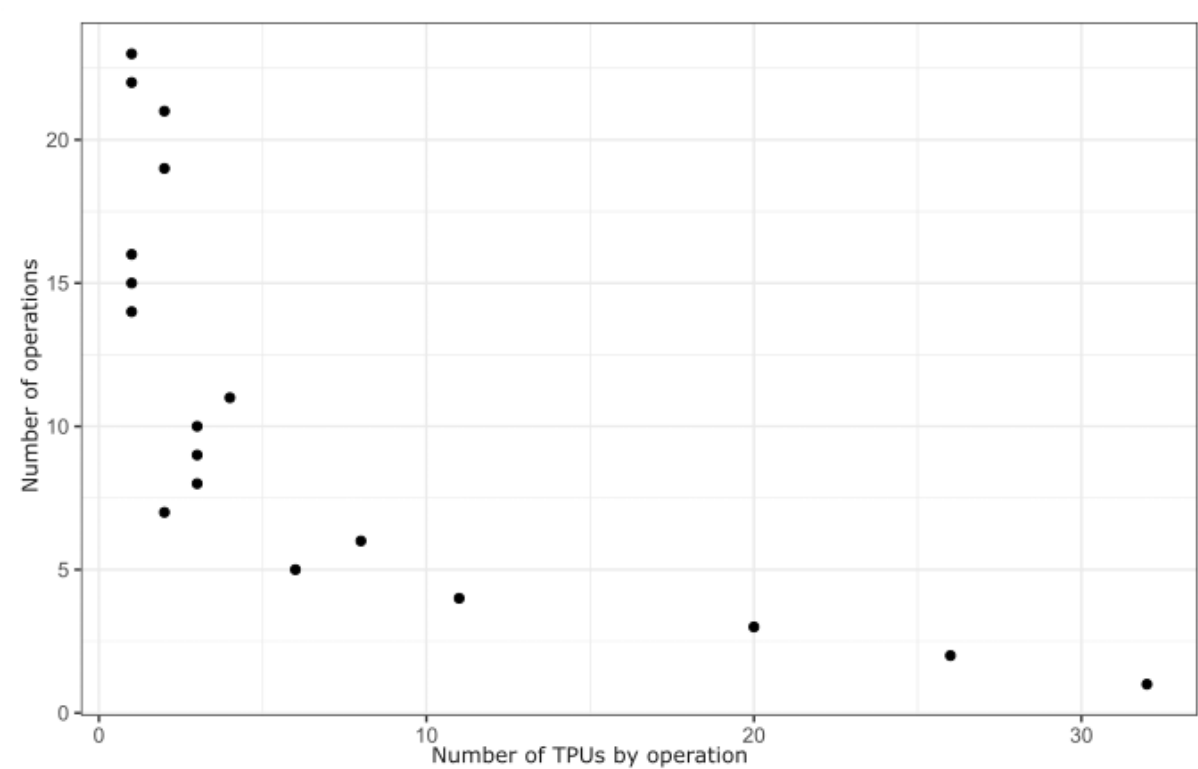
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SUPPLEMENTARY MATERIALS

Document 1:

The figure represents the number of operations by number of TPU by operation. The table corresponds to all TPU studied, and for each: the scientific name of the studied plant, the operation code, the number and type of biological materials.



Scientific name	O	Num- b e r	Bio-
Alcea biennis	C	1200	See

Scientific name	O	Num- b e r	Biolo- g i c a l m a t e r i a l s
Eryngium viviparum	C-	528	seed

<i>Alcea biennis</i>	C	1500	see
<i>Alcea biennis</i>	C	1200	see
<i>Aldrovanda vesiculosa</i>	C	42	plan
<i>Aldrovanda vesiculosa</i>	C	48	plan
<i>Aldrovanda vesiculosa</i>	C	42	plan
<i>Aldrovanda vesiculosa</i>	C	50	plan
<i>Aldrovanda vesiculosa</i>	C	39	plan
<i>Aldrovanda vesiculosa</i>	C	32	plan
<i>Aldrovanda vesiculosa</i>	C	50	plan
<i>Aldrovanda vesiculosa</i>	C	60	plan
<i>Aldrovanda vesiculosa</i>	C	30	plan
<i>Aldrovanda vesiculosa</i>	C	NA	plan
<i>Aldrovanda vesiculosa</i>	C	60	plan
<i>Alisma gramineum</i>	C	12	plan

<i>Eryngium viviparum</i>	C-	440	seed
<i>Eryngium viviparum</i>	C-	220	seed
<i>Eryngium viviparum</i>	C-	264	seed
<i>Eryngium viviparum</i>	C-	264	plant
<i>Eryngium viviparum</i>	C-	204	plant
<i>Filago gallica</i>	C-	10	plant
<i>Filago gallica</i>	C-	1000	seed
<i>Filago gallica</i>	C-	1000	seed
<i>Filago gallica</i>	C-	12	plant
<i>Fritillaria meleagris</i>	C-	260	plant
<i>Fritillaria meleagris</i>	C-	1920	seed
<i>Fritillaria meleagris</i>	C-	206	plant
<i>Gagea lutea</i>	C-	95	plant
<i>Gagea lutea</i>	C-	35	plant





<i>Allium roseum</i>	C	90	plan
<i>Allium roseum</i>	C	200	plan
<i>Allium roseum</i>	C	160	plan
<i>Allium roseum</i>	C	90	plan
<i>Allium roseum</i>	C	160	plan
<i>Allium roseum</i>	C	90	plan
<i>Allium roseum</i>	C	160	plan
<i>Allium roseum</i>	C	160	plan
<i>Allium scaberrimum</i>	C	100	plan
<i>Allium subhirsutum</i>	C	77	plan
<i>Allium vineale</i>	C	56	plan
<i>Anchusa crispa</i>	C	36	plan
<i>Anchusa crispa</i>	C	50	plan
<i>Anchusa crispa</i>	C	164	plan

<i>Honorius nutans</i>	C-	NA	plant
<i>Honorius nutans</i>	C-	NA	plant
<i>Honorius nutans</i>	C-	NA	plant
<i>Inula helvetica</i>	C-	252	plant
<i>Inula helvetica</i>	C-	350	plant
<i>Iris aphylla</i>	C-	5	plant
<i>Iris aphylla</i>	C-	5	plant
<i>Iris aphylla</i>	C-	5	plant
<i>Iris sibirica</i>	C-	5	plant
<i>Iris sibirica</i>	C-	5	plant
<i>Iris sibirica</i>	C-	10	plant
<i>Iris sibirica</i>	C-	5	plant
<i>Iris sibirica</i>	C-	25	plant
<i>Isoetes malinverniana</i>	C-	20	plant

<i>Anchusa crispa</i>	C	38	plan
<i>Anchusa crispa</i>	C	37	plan
<i>Anchusa crispa</i>	C	50	plan
<i>Anchusa crispa</i>	C	20	plan
<i>Anchusa crispa</i>	C	50	plan
<i>Anchusa crispa</i>	C	NA	see
<i>Anchusa crispa</i>	C	100	see
<i>Anchusa crispa</i>	C	127	plan
<i>Anchusa crispa</i>	C	100	see
<i>Anchusa crispa</i>	C	45	plan
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see

<i>Jurinea cya-noides</i>	C-	200	seed
<i>Jurinea cya-noides</i>	C-	200	seed
<i>Jurinea cya-noides</i>	C-	200	seed
<i>Jurinea cya-noides</i>	C-	200	seed
<i>Jurinea cya-noides</i>	C-	200	seed
<i>Jurinea cya-noides</i>	C-	200	seed
<i>Kickxia commu-tata</i>	C-	30	plant
<i>Kickxia commu-tata</i>	C-	146	plant
<i>Laphangium luteoalbum</i>	C-	NA	seed
<i>Limonium pseu-dominutum</i>	C-	60	plant
<i>Limonium pseu-dominutum</i>	C-	26	plant
<i>Linaria thymifo-lia</i>	C-	NA	seed
<i>Lotus angustissi-mus</i>	C-	NA	seed
<i>Lotus angustissi-mus</i>	C-	NA	seed

<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Androsace helvetica</i>	C	100	see
<i>Anemone coronaria</i>	C	166	plan
<i>Anemone ranunculoides</i>	C	53	plan
<i>Arenaria grandiflora</i>	C	450	plan
<i>Arenaria grandiflora</i>	C	450	plan
<i>Arenaria grandiflora</i>	C	450	plan
<i>Armeria belgencensis</i>	C	18	plan
<i>Armeria belgencensis</i>	C	57	plan

<i>Lotus hispidus</i>	C-	NA	seed
<i>Lythrum hyssopifolia</i>	C-	NA	seed
<i>Matthiola valesiaca</i>	C-	150	seed
<i>Matthiola valesiaca</i>	C-	150	seed
<i>Matthiola valesiaca</i>	C-	150	seed
<i>Matthiola valesiaca</i>	C-	150	seed
<i>Matthiola valesiaca</i>	C-	150	seed
<i>Medicago marina</i>	C-	NA	seed
<i>Medicago marina</i>	C-	NA	seed
<i>Muscari comosum</i>	C-	9	plant
<i>Neotinea lactea</i>	C-	7	plant
<i>Nigella nigellastrum</i>	C-	1000	seed
<i>Nigella nigellastrum</i>	C-	1000	seed
<i>Nigella nigellastrum</i>	C-	750	seed

<i>Armeria pungens</i>	C	50	plan
<i>Armeria pungens</i>	C	60	plan
<i>Asplenium scolopendrium</i>	C	59	plan
<i>Aster pyrenaeus</i>	C	16	plan
<i>Aster pyrenaeus</i>	C	26	plan
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus alopecurus</i>	C	50	see
<i>Astragalus glauc</i>	C	76	plan
<i>Atriplex glabriuscula</i>	C	15	plan
<i>Atriplex glabriuscula</i>	C	36	plan

<i>Nigella nigellastrum</i>	C-	1000	seed
<i>Oenanthe peucedanifolia</i>	C-	10	plant
<i>Ophioglossum vulgatum</i>	C-	125	plant
<i>Ophioglossum vulgatum</i>	C-	NA	plant
<i>Ophrys aurelia</i>	C-	8	plant
<i>Ophrys aurelia</i>	C-	12	plant
<i>Ophrys aurelia</i>	C-	5	plant
<i>Ophrys aurelia</i>	C-	30	plant
<i>Ophrys aurelia</i>	C-	18	plant
<i>Ophrys aurelia</i>	C-	18	plant
<i>Ophrys aurelia</i>	C-	15	plant
<i>Ophrys aurelia</i>	C-	20	plant
<i>Ophrys aurelia</i>	C-	12	plant
<i>Orchis militaris</i>	C-	12	plant

<i>Atriplex laciniata</i>	C	144	plan
<i>Atriplex laciniata</i>	C	31	plan
<i>Bassia laniflora</i>	C	84	plan
<i>Bassia laniflora</i>	C	3000	see
<i>Biscutella neus- triaca</i>	C	153	plan
<i>Brassica montana</i>	C	11	plan
<i>Brassica montana</i>	C	12	see
<i>Brassica montana</i>	C	20	plan
<i>Brassica montana</i>	C	20	plan
<i>Brassica montana</i>	C	20	plan
<i>Brassica montana</i>	C	48	see
<i>Brassica montana</i>	C	20	plan
<i>Brassica montana</i>	C	36	see
<i>Brassica montana</i>	C	20	plan

<i>Orchis militaris</i>	C-	120	plant
<i>Orchis militaris</i>	C-	111	plant
<i>Phalaris aquatica</i>	C-	90	plant
<i>Primula farinosa</i>	C-	50	plant
<i>Primula vulgaris</i>	C-	13	plant
<i>Quercus petraea</i>	C-	5760	plant
<i>Quercus petraea</i>	C-	5760	plant
<i>Quercus petraea</i>	C-	11520	plant
<i>Quercus petraea</i>	C-	5184	plant
<i>Quercus petraea</i>	C-	17520	plant
<i>Quercus petraea</i>	C-	11472	plant
<i>Quercus petraea</i>	C-	6696	plant
<i>Quercus petraea</i>	C-	16320	plant
<i>Quercus robur</i>	C-	2376	plant

<i>Brassica montana</i>	C	24	see
<i>Brassica montana</i>	C	50	plan
<i>Bupleurum falcatum</i> subsp. <i>Falcatum</i>	C	57	plan
<i>Centaurea corymbosa</i>	C	400	see
<i>Centaurea corymbosa</i>	C	1550	see
<i>Centranthus triner-vis</i>	C	50	see
<i>Centranthus triner-vis</i>	C	40	plan
<i>Cephalanthera rubra</i>	C	24	plan
<i>Cephalanthera rubra</i>	C	32	plan
<i>Cirsium tuberosum</i>	C	6	plan
<i>Coincya monensis</i>	C	385	plan
<i>Corrigiola litoralis</i>	C	10560	see
<i>Crambe maritima</i>	C	100	plan
<i>Cytisus lotoides</i>	C	6	plan

<i>Ranunculus ophioglossifolius</i>	C-	304	plant
<i>Ranunculus ophioglossifolius</i>	C-	155	plant
<i>Rhynchospora fusca</i>	C-	20	plant
<i>Rhynchospora fusca</i>	C-	20	plant
<i>Rhynchospora fusca</i>	C-	20	plant
<i>Rhynchospora fusca</i>	C-	20	plant
<i>Rhynchospora fusca</i>	C-	40	plant
<i>Rhynchospora fusca</i>	C-	12	plant
<i>Rhynchospora fusca</i>	C-	24	plant
<i>Rhynchospora fusca</i>	C-	24	plant
<i>Rhynchospora fusca</i>	C-	12	plant
<i>Rhynchospora fusca</i>	C-	24	plant
<i>Rhynchospora fusca</i>	C-	24	plant
<i>Rosa gallica</i>	C-	85	plant

<i>Cytisus lotoides</i>	C	14	plan
<i>Cytisus lotoides</i>	C	15	plan
<i>Cytisus lotoides</i>	C	20	plan
<i>Cytisus villosus</i>	C	6	plan
<i>Damasonium alisma</i>	C	10000	see
<i>Dianthus morisianus</i>	C	113	plan
<i>Dianthus morisianus</i>	C	25	plan
<i>Dianthus superbus</i>	C	17	plan
<i>Dianthus superbus</i>	C	5	plan
<i>Dianthus superbus</i>	C	15	plan
<i>Dianthus superbus</i>	C	28	plan
<i>Dianthus superbus</i>	C	15	plan
<i>Dianthus superbus</i>	C	33	plan
<i>Dianthus superbus</i>	C	27	plan

<i>Salix glaucosericea</i>	C-	NA	plant
<i>Salix lapponum</i>	C-	120	plant
<i>Scleranthus perennis prostratus</i>	C-	8	plant
<i>Scleranthus perennis prostratus</i>	C-	20	plant
<i>Scleranthus perennis prostratus</i>	C-	45	plant
<i>Scleranthus perennis prostratus</i>	C-	84	plant
<i>Scleranthus perennis prostratus</i>	C-	100	plant
<i>Scleranthus perennis prostratus</i>	C-	12	plant
<i>Scorzonera humilis</i>	C-	200	seed
<i>Serapias cordigera</i>	C-	22	plant
<i>Serapias lingua</i>	C-	29	plant
<i>Serapias neglecta</i>	C-	69	plant
<i>Serapias neglecta</i>	C-	47	plant
<i>Serapias parviflora</i>	C-	29	plant

<i>Dorycnopsis gerardii</i>	C	1152	see
<i>Dorycnopsis gerardii</i>	C	576	see
<i>Euphorbia terracina</i>	C	48	see
<i>Euphorbia terracina</i>	C	48	see
<i>Euphorbia terracina</i>	C	11	plan
<i>Euphorbia terracina</i>	C	48	see
<i>Euphorbia terracina</i>	C	48	see
<i>Euphorbia terracina</i>	C	11	plan
<i>Euphorbia terracina</i>	C	11	plan
<i>Euphorbia terracina</i>	C	48	see
<i>Euphorbia terracina</i>	C	10	plan
<i>Euphorbia terracina</i>	C	10	plan
<i>Euphorbia terracina</i>	C	10	plan
<i>Euphorbia terracina</i>	C	48	see

<i>Serapias parviflora</i>	C-	2	plant
<i>Spiranthes spiralis</i>	C-	300	plant
<i>Spiranthes spiralis</i>	C-	300	plant
<i>Teucrium scordium</i>	C-	43	plant
<i>Teucrium scordium</i>	C-	18	plant
<i>Teucrium scordium</i>	C-	41	plant
<i>Teucrium scordium</i>	C-	25	plant
<i>Teucrium scordium</i>	C-	50	plant
<i>Teucrium scordium</i>	C-	599	plant
<i>Teucrium scordium</i>	C-	323	plant
<i>Teucrium scordium</i>	C-	800	plant
<i>Tofieldia pusilla</i>	C-	50	plant
<i>Tulipa billietiana</i>	C-	250	plant
<i>Tulipa raddii</i>	C-	12	plant



<i>Euphorbia terracina</i>	C	23	plan
<i>Euphorbia terracina</i>	C	22	plan
<i>Euphorbia terracina</i>	C	24	plan
<i>Exaculum pusillum</i>	C	NA	see
<i>Festuca breistrofferi</i>	C	110	see
<i>Festuca breistrofferi</i>	C	100	see
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan
<i>Festuca breistrofferi</i>	C	25	plan

<i>Tulipa sylvestris subsp. Australis</i>	C-	661	plant
<i>Viola collina</i>	C-	913	seed
<i>Viola collina</i>	C-	121	plant
<i>Viola collina</i>	C-	122	plant
<i>Narcissus cavanillesii</i>	C-	1200	plant
<i>Naufraga balearica</i>	C-	100	plant
<i>Onosma arenaria</i>	C-	108	seed
<i>Onosma arenaria</i>	C-	210	seed
<i>Onosma arenaria</i>	C-	350	seed
<i>Onosma arenaria</i>	C-	19	plant
<i>Onosma arenaria</i>	C-	72	seed
<i>Onosma arenaria</i>	C-	106	seed
<i>Onosma arenaria</i>	C-	5	plant
<i>Onosma arenaria</i>	C-	17	plant



<i>Gladiolus imbricatus</i>	C	50	see
<i>Gladiolus palustris</i>	C	50	plan
<i>Gladiolus palustris</i>	C	101	plan
<i>Apium bermojoi</i>	C	95	plan
<i>Apium bermojoi</i>	C	111	plan
<i>Apium bermojoi</i>	C	16	plan
<i>Iris foetidissima</i>	C	125	plan
<i>Iris graminea</i>	C	84	plan
<i>Juniperus thurifera</i>	C	529	see
<i>Kosteletzkya pentacarpus</i>	C	15	plan
<i>Kosteletzkya pentacarpus</i>	C	196	plan
<i>Kosteletzkya pentacarpus</i>	C	12	plan
<i>Kosteletzkya pentacarpus</i>	C	15	plan
<i>Kosteletzkya pentacarpus</i>	C	30	plan

<i>Ophrys eleonora</i>	C-	34	plant
<i>Ornithogalum umbellatum</i>	C-	3	plant
<i>Orobancha picridis</i>	C-	NA	seed
<i>Orobancha picridis</i>	C-	NA	seed
<i>Phalaris aquatica</i>	C-	6000	seed
<i>Phalaris aquatica</i>	C-	220	plant
<i>Phyla nodiflora</i>	C-	30	plant
<i>Posidonia oceanica</i>	C-	5	plant
<i>Posidonia oceanica</i>	C-	28	plant
<i>Posidonia oceanica</i>	C-	7	plant
<i>Posidonia oceanica</i>	C-	6	plant
<i>Posidonia oceanica</i>	C-	37	plant
<i>Posidonia oceanica</i>	C-	60	plant
<i>Posidonia oceanica</i>	C-	80	plant

<i>Leucojum aestivum</i>	C	24	plan
<i>Leucojum aestivum</i>	C	12	plan
<i>Limonium mucronulatum</i>	C	50	plan
<i>Limonium perplezum</i>	C	72	plan
<i>Limonium perplezum</i>	C	56	plan
<i>Limonium perplezum</i>	C	166	plan
<i>Limonium perplezum</i>	C	406	plan
<i>Limonium perplezum</i>	C	44	plan
<i>Limonium perplezum</i>	C	1374	plan
<i>Limonium perplezum</i>	C	142	plan
<i>Limonium perplezum</i>	C	1308	plan
<i>Linaria flava</i>	C	200	see
<i>Linaria flava</i>	C	200	see
<i>Linaria supina</i>	C	NA	see

<i>Posidonia oceanica</i>	C-	12	plant
<i>Posidonia oceanica</i>	C-	52	plant
<i>Posidonia oceanica</i>	C-	46	plant
<i>Posidonia oceanica</i>	C-	65	plant
<i>Posidonia oceanica</i>	C-	52	plant
<i>Posidonia oceanica</i>	C-	205	plant
<i>Posidonia oceanica</i>	C-	10	plant
<i>Posidonia oceanica</i>	C-	10	plant
<i>Posidonia oceanica</i>	C-	4	plant
<i>Posidonia oceanica</i>	C-	7	plant
<i>Posidonia oceanica</i>	C-	20	plant
<i>Posidonia oceanica</i>	C-	107	plant
<i>Potentilla supina</i>	C-	NA	seed
<i>Primula pedemontana</i>	C-	1000	seed

<i>Linaria supina</i>	C	NA	see
<i>Linaria supina</i>	C	NA	see
<i>Marsilea quadrifolia</i>	C	10	plan
<i>Marsilea quadrifolia</i>	C	10	plan
<i>Melampyrum pratense</i>	C	288	plan
<i>Melampyrum pratense</i>	C	150	see
<i>Melampyrum pratense</i>	C	167	plan
<i>Melampyrum sylvaticum</i>	C	103	see
<i>Melampyrum sylvaticum</i>	C	91	see
<i>Melampyrum sylvaticum</i>	C	89	see
<i>Melampyrum sylvaticum</i>	C	500	see
<i>Melampyrum sylvaticum</i>	C	366	see
<i>Melampyrum sylvaticum</i>	C	99	see
<i>Melampyrum sylvaticum</i>	C	500	see

<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Primula pedemontana</i>	C-	6	plant
<i>Pulicaria vulgaris</i>	C-	1000	seed
<i>Pulicaria vulgaris</i>	C-	1000	seed
<i>Ranunculus sylviae</i>	C-	49	plant
<i>Rosa gallica</i>	C-	45	plant

<i>Melampyrum sylvaticum</i>	C	92	see
<i>Melampyrum sylvaticum</i>	C	500	see
<i>Melampyrum sylvaticum</i>	C	369	see
<i>Myosurus minimus</i>	C	NA	see
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	10	plan
<i>Aldrovanda vesiculosa</i>	C	10	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan
<i>Aldrovanda vesiculosa</i>	C	5	plan

<i>Rosa gallica</i>	C-	45	plant
<i>Rosa gallica</i>	C-	37	plant
<i>Rosa gallica</i>	C-	41	plant
<i>Rosa gallica</i>	C-	18	plant
<i>Rosa gallica</i>	C-	11	plant
<i>Rosa gallica</i>	C-	27	plant
<i>Rosa gallica</i>	C-	20	plant
<i>Rosa gallica</i>	C-	23	plant
<i>Rosa gallica</i>	C-	24	plant
<i>Rosa gallica</i>	C-	24	plant
<i>Rosa gallica</i>	C-	257	plant
<i>Sagina nodosa</i>	C-	NA	seed
<i>Saxifraga hirculus</i>	C-	303	plant
<i>Saxifraga hirculus</i>	C-	350	plant

<i>Allium ericetorum</i>	C	105	plan
<i>Allium polyanthum</i>	C	176	plan
<i>Anacamptis coriophora</i> subsp. <i>Fragrans</i>	C	9	plan
<i>Anacamptis coriophora</i> subsp. <i>Fragrans</i>	C	5	plan
<i>Anacamptis coriophora</i> subsp. <i>Fragrans</i>	C	60	plan
<i>Anthyllis barba-jovis</i>	C	12	plan
<i>Anthyllis barba-jovis</i>	C	34	plan
<i>Anthyllis barba-jovis</i>	C	46	plan
<i>Aristolochia pistolochia</i>	C	13	plan
<i>Aristolochia rotunda</i>	C	80	plan
<i>Aristolochia rotunda</i>	C	20	plan
<i>Aristolochia rotunda</i>	C	52	plan
<i>Aristolochia rotunda</i>	C	351	see
<i>Aristolochia rotunda</i>	C	128	plan

<i>Saxifraga hirculus</i>	C-	216	plant
<i>Saxifraga hirculus</i>	C-	83	seed
<i>Saxifraga hirculus</i>	C-	111	seed
<i>Saxifraga hirculus</i>	C-	165	seed
<i>Saxifraga hirculus</i>	C-	22	seed
<i>Saxifraga hirculus</i>	C-	52	seed
<i>Saxifraga hirculus</i>	C-	25	seed
<i>Saxifraga hirculus</i>	C-	84	seed
<i>Saxifraga hirculus</i>	C-	4	plant
<i>Saxifraga hirculus</i>	C-	2	plant
<i>Saxifraga hirculus</i>	C-	20	plant
<i>Saxifraga hirculus</i>	C-	14	plant
<i>Saxifraga hirculus</i>	C-	20	plant
<i>Saxifraga hirculus</i>	C-	126	seed

<i>Aristolochia rotunda</i>	C	536	see
<i>Armeria belgencensis</i>	C	56	plan
<i>Armeria pungens</i>	C	50	plan
<i>Armeria pungens</i>	C	50	plan
<i>Armeria pungens</i>	C	60	plan
<i>Armeria pungens</i>	C	160	plan
<i>Asparagus officinalis</i> subsp. <i>Prostratus</i>	C	NA	see
<i>Asparagus officinalis</i> subsp. <i>Prostratus</i>	C	NA	see
<i>Asphodelus macrocarpus</i>	C	1829	plan
<i>Berardia subacaulis</i>	C	NA	see
<i>Berardia subacaulis</i>	C	80	plan
<i>Berardia subacaulis</i>	C	80	plan
<i>Berardia subacaulis</i>	C	106	plan
<i>Carex bipartita</i>	C	50	plan

<i>Saxifraga hirculus</i>	C-	8	plant
<i>Saxifraga hirculus</i>	C-	13	plant
<i>Saxifraga hirculus</i>	C-	19	plant
<i>Saxifraga hirculus</i>	C-	6	plant
<i>Saxifraga hirculus</i>	C-	22	plant
<i>Saxifraga hirculus</i>	C-	15	plant
<i>Saxifraga hirculus</i>	C-	25	plant
<i>Saxifraga hirculus</i>	C-	15	plant
<i>Saxifraga hirculus</i>	C-	15	plant
<i>Saxifraga hirculus</i>	C-	8	plant
<i>Saxifraga hirculus</i>	C-	256	plant
<i>Saxifraga hirculus</i>	C-	275	plant
<i>Saxifraga hirculus</i>	C-	159	plant
<i>Saxifraga hirculus</i>	C-	607	plant



<i>Carex capillaris</i>	C	50	plan
<i>Cephalanthera rubra</i>	C	5	plan
<i>Cephalanthera rubra</i>	C	5	plan
<i>Cephalanthera rubra</i>	C	5	plan
<i>Crambe maritima</i>	C	7	plan
<i>Crambe maritima</i>	C	134	see
<i>Crambe maritima</i>	C	22	plan
<i>Crambe maritima</i>	C	66	see
<i>Cypripedium calceolus</i>	C	5	plan
<i>Cypripedium calceolus</i>	C	5	plan
<i>Cypripedium calceolus</i>	C	5	plan
<i>Cytisus sauzeanus</i>	C	5	plan
<i>Cytisus sauzeanus</i>	C	5	plan
<i>Cytisus sauzeanus</i>	C	5	plan

<i>Saxifraga hirculus</i>	C-	103	plant
<i>Saxifraga hirculus</i>	C-	NA	plant
<i>Silene velutina</i>	C-	4	plant
<i>Silene velutina</i>	C-	52	plant
<i>Silene velutina</i>	C-	300	seed
<i>Silene velutina</i>	C-	52	plant
<i>Silene velutina</i>	C-	53	plant
<i>Silene velutina</i>	C-	53	plant
<i>Silene velutina</i>	C-	54	plant
<i>Silene velutina</i>	C-	52	plant
<i>Silene velutina</i>	C-	90	plant
<i>Trifolium squamosum</i>	C-	2950	plant
<i>Tulipa agenensis</i>	C-	1400	plant
<i>Tulipa agenensis</i>	C-	1407	plant

<i>Cytisus sauzeanus</i>	C	20	plan
<i>Cytisus sauzeanus</i>	C	20	plan
<i>Cytisus sauzeanus</i>	C	20	plan
<i>Cytisus sauzeanus</i>	C	20	plan
<i>Cytisus sauzeanus</i>	C	50	plan
<i>Cytisus triflorus</i>	C	NA	plan
<i>Cytisus triflorus</i>	C	NA	plan
<i>Cytisus triflorus</i>	C	NA	plan
<i>Cytisus triflorus</i>	C	NA	plan
<i>Damasonium alisma</i>	C	NA	see
<i>Dianthus deltoides</i>	C	500	plan
<i>Dianthus deltoides</i>	C	500	plan
<i>Dianthus deltoides</i>	C	500	plan
<i>Dianthus deltoides</i>	C	500	plan
<i>Dianthus deltoides</i>	C	500	plan

<i>Tulipa agenensis</i>	C-	230	plant
<i>Tulipa agenensis</i>	C-	216	plant
<i>Tulipa aximensis</i>	C-	100	plant
<i>Tulipa sylvestris</i>	C-	250	plant
<i>Tulipa sylvestris</i>	C-	3200	plant
<i>Tulipa sylvestris</i>	C-	841	plant
<i>Tulipa sylvestris</i>	C-	445	plant
<i>Tulipa sylvestris</i>	C-	1000	plant
<i>Tulipa sylvestris</i>	C-	35	plant
<i>Tulipa sylvestris</i>	C-	35	plant
<i>Tulipa sylvestris</i>	C-	35	plant
<i>Typha minima</i>	C-	4	plant
<i>Typha minima</i>	C-	4	plant
<i>Viola hispida</i>	C-	560	seed



## Document 2:

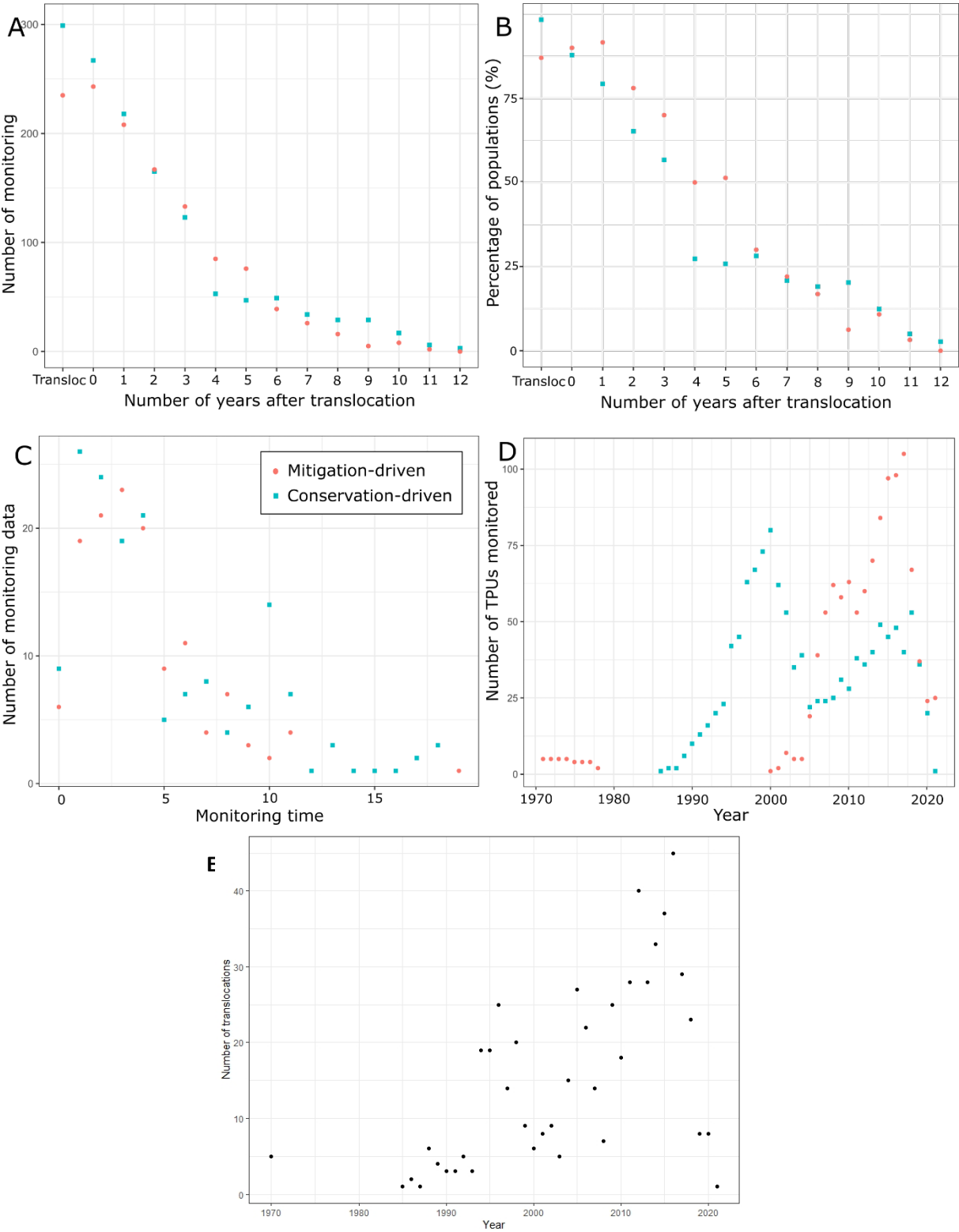
Model 1 and model 2 presented in Material & Methods are the first (model 1) and the last (model 2) models presented here.

- 1  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:BiolType} + \log(\text{NumberBiolMat}): \text{BiolMat} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + \text{PostMonityear:Organisation} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$  [Model 1]
- 2  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:BiolType} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + \text{PostMonityear:Organisation} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$
- 3  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + \text{PostMonityear:Organisation} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$
- 4  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:BiolType} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$
- 5  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$
- 6  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{Organisation} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:} \log(\text{NumberBiolMat}): \text{BiolMat} + \text{PostMonityear:Organisation} + (1 | \text{Operation}) + (1 | \text{Year}) + (1 | \text{Family})$

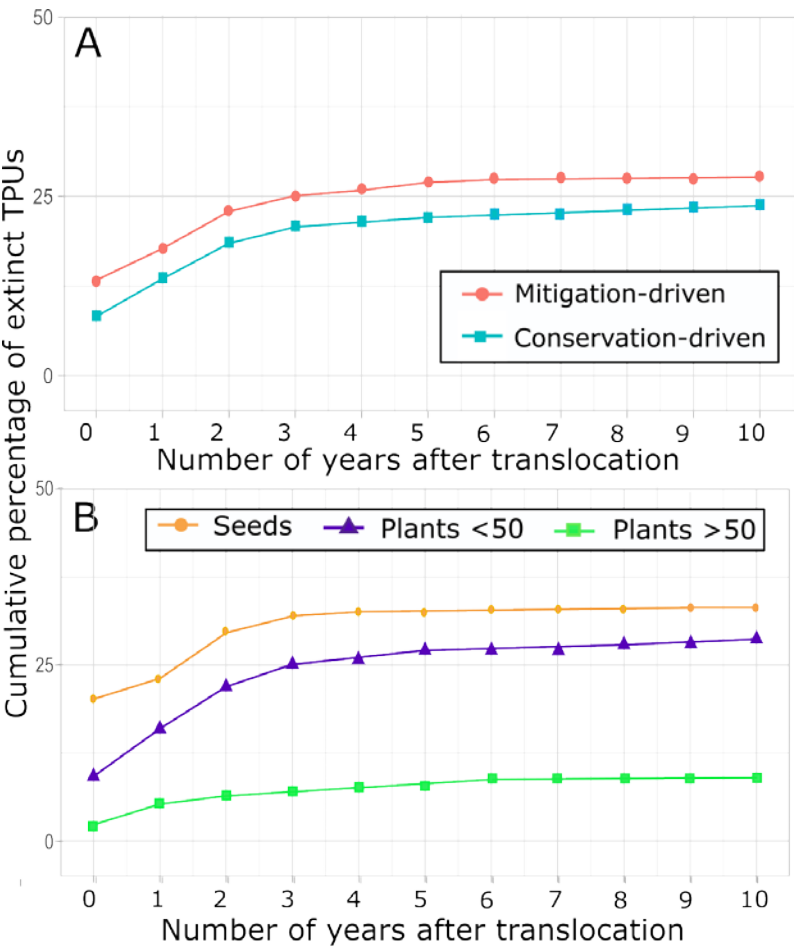
- 7  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \text{BiolType} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:BiolType} + \text{PostMonityear:log(NumberBiolMat):BiolMat} + (1|\text{Operation}) + (1|\text{Year}) + (1|\text{Family})$
- 8  $\text{Logit}(\text{Monitoring status}) = \text{PostMonityear} + \text{Motivation} + \log(\text{NumberBiolMat}) + \text{BiolMat} + \text{PostMonityear:Motivation} + \text{PostMonityear:log(NumberBiolMat):BiolMat} + (1|\text{Operation}) + (1|\text{Year}) + (1|\text{Family})$  [Model 2]

1	Convergence and collinearity problem; AIC = 2926
2	Collinearity problem; AIC = 2928
3	Collinearity problem; AIC = 2927
4	Collinearity problem; AIC = 2930
5	AIC = 2929
6	Collinearity problem; AIC = 2923
7	Collinearity problem; AIC = 2924
8	AIC = 2920

**Document 3:** Availability of monitoring data according to the translocation type. A: Number of available monitoring data in each post-translocation year. B: Percentage of monitoring relative to the number of expected monitoring. C: Monitoring time since translocation. D: Number of monitoring available per year. E: Number of translocations per year.



- 11
- Document 4: A. Cumulative percentage of extinct TPU according to the objective of the translocation.
- 12
- B. Cumulative percentage of extinct TPU according to the type and number of biological materials.



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